

NanoRFE

User manual

VNA6000-A and VNA6000-B



For more documentation please go to:
<https://nanorfe.com/>

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Introduction

Safety information

The NanoRFE VNA6000 is designed for measuring and characterizing electronic devices in industrial and laboratory environments only. Always observe the following limits when using the VNA6000 to avoid possible damage to equipment.

Maximum input levels

DC input voltage	Both RF ports	5V
RF input power	Both RF ports	10dBm (10mW)
DC supply voltage	USB port	5.5V

Basic concepts

The VNA6000 allows you to perform a wide variety of measurements.

The parameters you can measure include:

- Impedance (of an antenna, capacitor, inductor, or any one or two port device)
- Return loss
- Frequency response and phase response (of a filter, amplifier, duplexer, or any two port device)
- Delay, velocity, or length (of a cable or other two port device)
- Characteristic impedance and material properties (using custom test jigs)
- And more...

S parameters describe the amount and phase of a reflection or transmission from the device under test (DUT) in response to a single frequency excitation signal at a port. The two most commonly used components of an S parameter are S11 (reflection coefficient) and S21 (transmission coefficient).

Impedance can be calculated from the reflection coefficient.

Frequency response/phase response is simply the transmission coefficient's magnitude and phase respectively.

Calibration refers to the procedure of measuring a few known loads (for example open, short, load, and thru) to establish a measurement plane of reference. Before any measurements are performed, the VNA6000 must be calibrated. See section [3.1.Calibration](#) for details.

First steps

What's in the box

The following items should be in the box:

- VNA6000 main unit
- USB cable
- Touch screen stylus
- 2 SMA connector savers
- 5 SMA calibration standards – Short, Open, and 2 Load standards
- (Optional) 2 SS405 or SS402 SMA male to male cables

SMA connector savers

Before using the VNA6000 for the first time, it is recommended to attach the two SMA connector savers to the two ports of the VNA and keep it attached. This will eliminate wear on the VNA main unit connectors and extend the service life of the VNA6000.

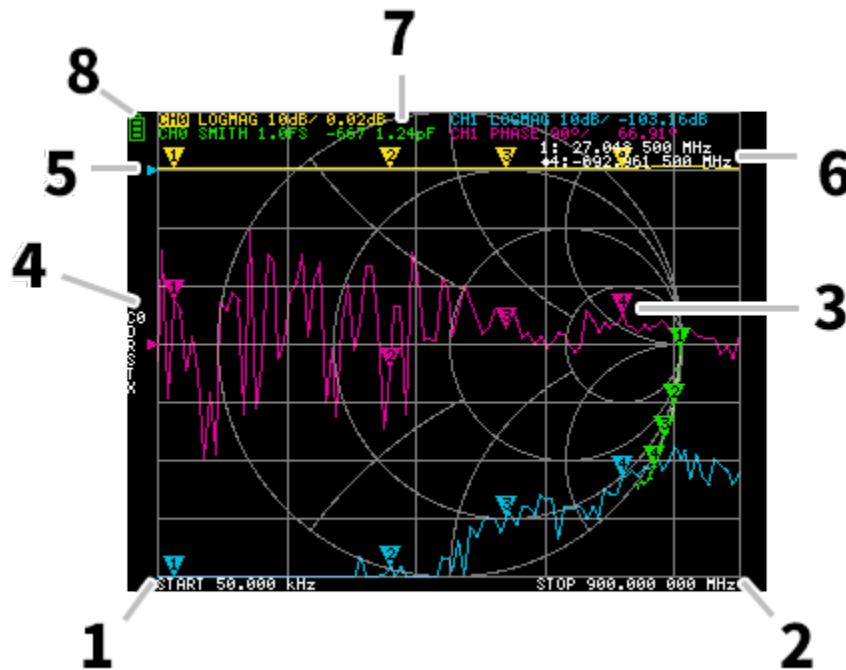
Battery

The VNA6000 includes battery management and protection circuitry. It can both charge and run from an internal lithium-ion battery.

If your VNA6000 did not come with the battery preinstalled due to shipping restrictions, you can insert a standard 18650 size flat-top unprotected lithium-ion cell. Running directly from USB power without a battery installed is also supported.

User interface

Main screen



1. START frequency

2. STOP frequency

The START frequency and STOP frequency are shown at the bottom of the display.

3. Marker

The marker position for each trace is displayed as a small numbered triangle. The selected marker can be moved to any of the measured points in the following ways:

- Drag a marker on the touch panel – best to use a stylus for this.
- Press and hold the ◀ or ▶ buttons.

4. Calibration status

Displays the saved slot number of the calibration being used and the error correction applied.

- C0 C1 C2 C3 C4 : Each indicates that the corresponding calibration data is loaded.
- E : Indicates that enhanced response calibration is enabled.
- S O L T : Each indicates that the corresponding (Short, Open, Load, and Thru) standards have been measured.

5. Reference position

Indicates the reference position of the corresponding trace. You can change the position with:

DISPLAY → SCALE → REFERENCE POSITION.

6. Marker status

The active marker that is selected and one marker that was previously active are displayed top right.

7. Trace status

The status of each trace format and the value corresponding to the active marker are displayed.

For example, if the display is showing: **CH0 LOGMAG 10dB/ 0.02dB** , read it as follows:

Channel CH0 (reflection)

Format LOGMAG

Scale is 10dB

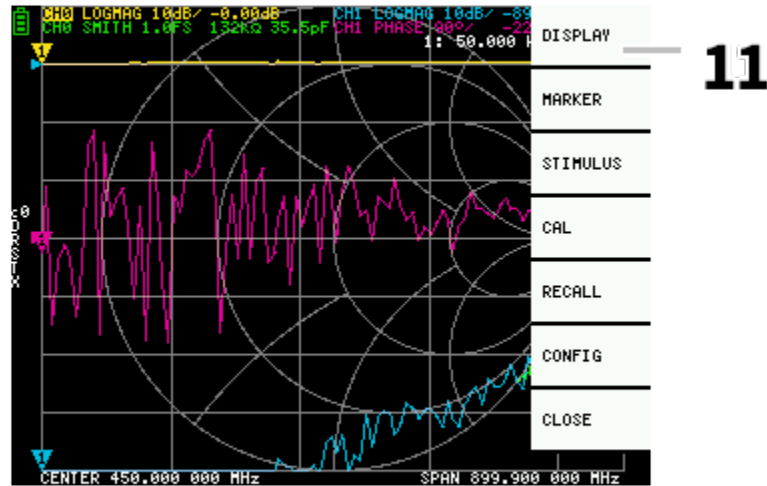
Current value is 0.02dB

For active traces, the channel name is highlighted.

8. Battery status

This is not shown on the VNA6000. Battery percentage is indicated by the 4 red LEDs along the left side on the bottom of the device.

Menu screen

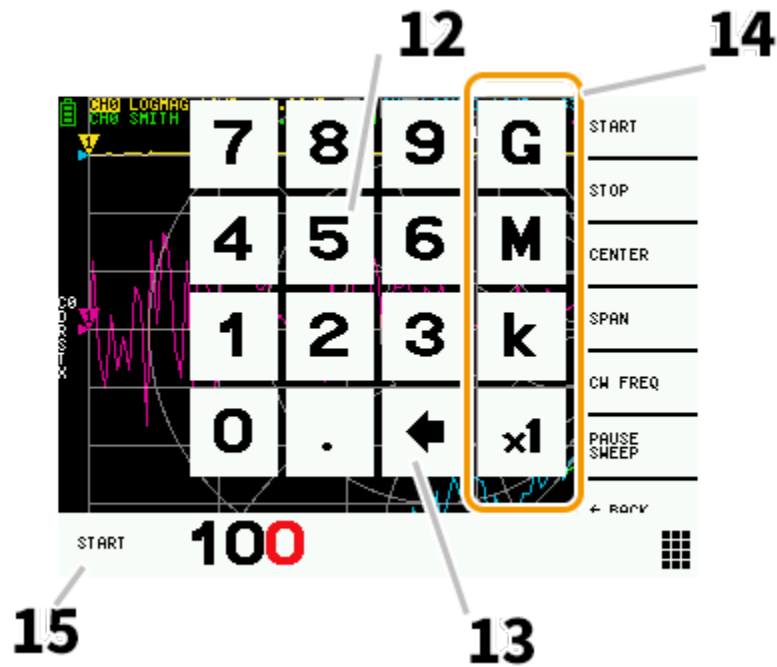


11. Menu List

The menu can be opened by the following operations:

- When a location other than a marker on the touch screen is tapped.
- When the ENTER button is pressed.

Keypad screen



12. Numeric keys

Tap a number to enter one character.

13. Back key

Delete one character. If no character is entered, the entry is canceled and the previous state is restored.

14. Unit key

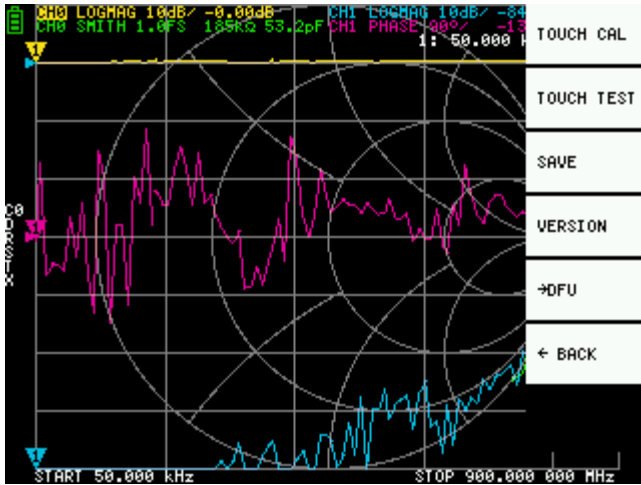
Multiplies the current input by the appropriate unit and terminates input immediately. In case of $\times 1$, the entered value is set as it is.

15. Input field

The name of the item to be entered and the entered number are displayed.

Device settings

The **CONFIG** menu contains general settings for the device:



Saving device settings

Select **CONFIG →SAVE** to save general instrument settings. General device settings are data that includes the following information:

- Touch screen calibration information
- Grid color
- Trace color

The **CONFIG →SAVE** command does not apply to calibration settings.

Display version info

Select **CONFIG →VERSION** to display device version information.

Firmware update mode

CONFIG →DFU and **ENTER DFU** mode. Select **RESET AND ENTER DFU** to reset the device and enter DFU (Device Firmware Update) mode. In this mode, firmware can be updated via USB.

DFU mode can also be entered by holding down the “left” push button while the device is powered off and on.

See section [5.5.Firmware Update](#) for how to update the device firmware using the VNA View PC software.

Touch panel calibration and testing

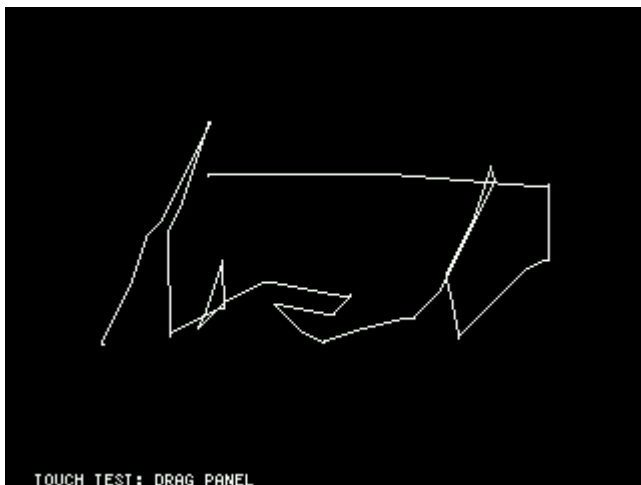
The LCD touch panel can be calibrated using **CONFIG → TOUCH CAL** if there is a large difference between the actual on-screen tap position and the recognized tap position.

NOTE: Be sure to save the settings with **CONFIG → SAVE**.



You can then test the LCD touch panel stylus tracking accuracy by selecting **CONFIG → TOUCH TEST**.

A line is drawn while dragging the stylus along the touch panel. When released from the touch panel, it returns to its original state. Repeat & save the touch screen calibration if tracking is incorrect.

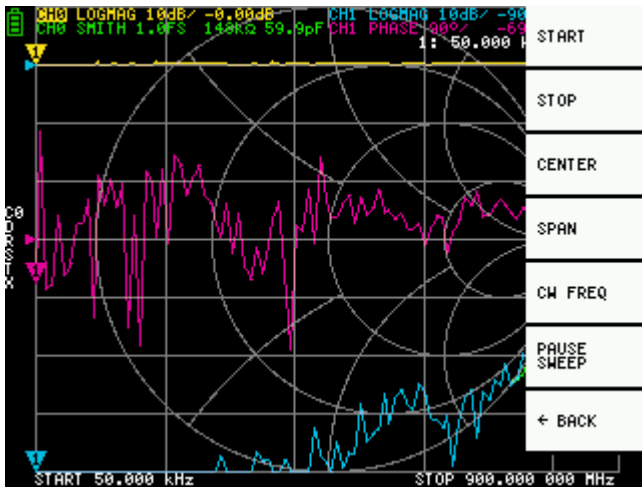


Performing measurements

The basic measurement sequence is:

1. Set the frequency range to be measured.
Use **STIMILUS** → **START/STOP** or **STIMILUS** → **SPAN/CENTER**
2. Perform calibration (and save!)
3. Connect the Device Under Test (DUT) and measure.

Setting the measurement frequency range



There are three types of measurement range settings.

- Setting the start frequency and stop frequency
- Setting the center frequency and span
- Zero span

Setting the start frequency and stop frequency

Select and set **STIMULUS** → **START** and **STIMULUS** → **STOP**, respectively.

Setting the center frequency and span

Select and set **STIMULUS** → **CENTER** and **STIMULUS** → **SPAN**, respectively.

Zero span

Zero span is a mode in which one frequency is sent continuously without frequency sweep.

Select and set **STIMULUS** → **CW FREQ**.

Temporarily stop measurement

When menu item **PAUSE SWEEP** is active, measurement is temporarily stopped.

Calibration

When calibration is activated, the left side of the screen should show "Cx".

Changing the frequency sweep range will cause the current calibration to be interpolated for the new frequency range, which may degrade accuracy. It is recommended to re-calibrate after changing frequency sweep parameters.

Two common calibration scenerios are described here.

SOL/SOLT calibration at instrument port

This will establish the measurement reference plane at the instrument port. Any cable you connect afterwards are not included in the calibration and will add a phase shift to the measurement.

The calibration procedure is as follows:

1. Reset current calibration state. Select menu item **CAL→RESET** and then **→CALIBRATE**.
2. Attach a LOAD standard to port 2.
3. Connect OPEN standard to port 1 and click **→OPEN**. Wait for menu item highlight.
4. Connect SHORT standard to port 1 and click **→SHORT**. Wait for menu item highlight.
5. Connect the second LOAD standard to port 1 and click **→LOAD**. Wait for menu item highlight.
6. (Optional) Connect a coaxial cable between port 1 and 2, and click **→THRU**. Disconnect the port 1 end of the cable.
7. Click **→DONE**.
8. (Optional) Specify which calibration slot (0 to 6) to save to. e.g. **→SAVE 0**.

SOL/SOLT calibration with cable

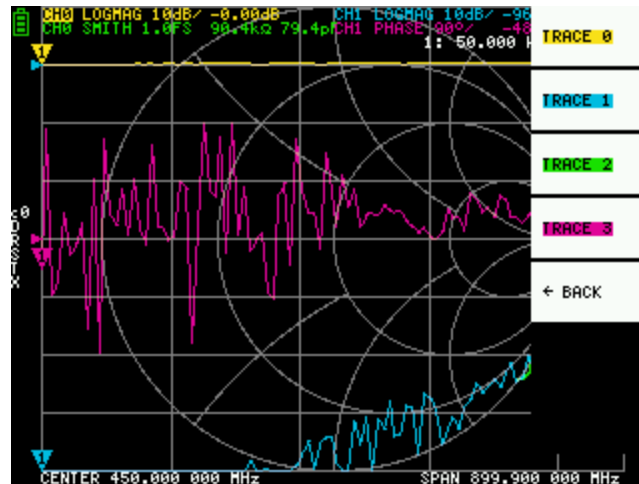
This will establish the measurement reference plane at the end of the coaxial cable and will eliminate any effects of the cable, provided the cable's characteristics are stable.

The calibration procedure is as follows:

1. Reset current calibration state. Select menu item **CAL→RESET** and then **→CALIBRATE**.
2. Attach a SMA coaxial cable to port 1.
3. Attach a LOAD standard to port 2.
4. Connect OPEN standard to port 1 cable end and click **→OPEN**. Wait for menu item highlight.
5. Connect SHORT standard to port 1 cable end and click **→SHORT**. Wait for menu item highlight.
6. Connect the second LOAD standard to port 1 cable end and click **→LOAD**. Wait for menu item highlight.
7. (Optional) Connect the second coaxial cable to port 2.
8. (Optional) Connect the THRU standard between the port 1 and port 2 cable ends, and click **→THRU**.
9. Click **→DONE**.
10. (Optional) Specify which calibration slot (0 to 6) to save to. e.g. **→SAVE 0**.

Note that there is no need to wait for the plots to fully update before clicking the menu item associated with a calibration standard. Clicking any of the OPEN, SHORT, LOAD, THRU calibration menu items will perform a full sweep with higher averaging than the currently configured averaging factor. Once the sweep is complete, the corresponding menu item will become highlighted, and you may proceed to the next calibration standard.

Trace display



Up to four traces can be displayed, one of which is the active trace.

You can turn on/off traces as needed. The menu items **DISPLAY → TRACE → TRACE n** allow you to activate as well as turn on/off traces.

When a trace is active, its channel name at the top of the screen is highlighted. In the image above, TRACE 0 is the active trace.

Clicking **DISPLAY → TRACE → TRACE n** on the current active trace will turn it off. Clicking any other trace activates it.

Trace format

Although each trace can have its own displayed format, you can only change the format of the active trace.

To assign a format, set the trace to active (see above) then select: **DISPLAY →FORMAT**

The description and unit of measurement of each format is as follows:

- **LOGMAG** : Logarithm of absolute value of measured value (dB per div)
- **PHASE** : Phase in the range of -180 ° to + 180 ° (90 degree default)
- **DELAY** : Delay (pico or nano seconds)
- **SMITH** : Smith Chart (Impedance scale is normalized during calibration)
- **SWR** : Standing Wave Ratio (can be scaled to show 1, 0.1 or 0.01 per div)
- **POLAR** : Polar coordinate format (Impedance scale is normalized during calibration)
- **LINEAR** : Absolute value of the measured value
- **REAL** : Real part of measured S parameter
- **IMAG** : Imaginary part of measured S parameter
- **RESISTANCE** : Resistance component of the measured impedance (ohms per div)
- **REACTANCE** : Reactance component of the measured impedance (ohms per div)

Trace channel

The VNA6000 has two channels, **CH0** and **CH1**, corresponding to ports 1 and 2.

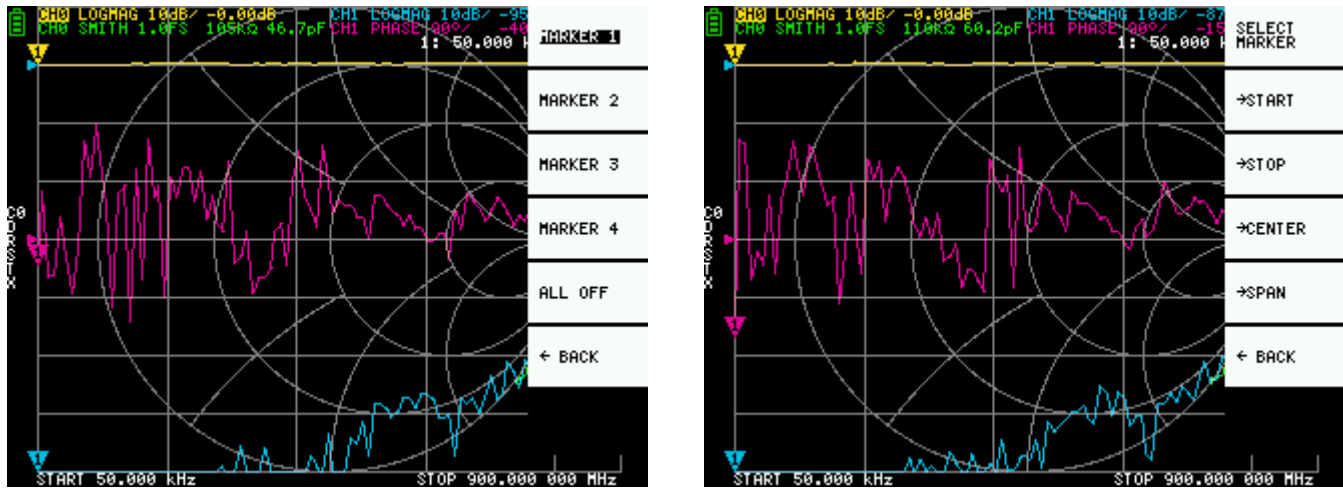
CH0 is the S parameter **S11**, while **CH1** is the S parameter **S21**.

Each trace can be set to display data from either channel.

To change the channel used by the currently active trace, select

DISPLAY →CHANNEL →CH0 REFLECT or **DISPLAY →CHANNEL →CH1 THROUGH**.

Markers



Up to 4 markers can be displayed.

Markers are selected by the menu items **MARKER →SELECT MARKER →MARKER n**.

Clicking on a disabled marker menu item enables it and makes it active. Clicking on an enabled but non-active marker activates it. Clicking on the currently active marker disables it.

Setting frequencies from marker(s)

You can set the frequency range from the **MARKER →OPERATIONS** menu as follows:

- **OPERATIONS →START** - Sets the start frequency to the active marker's frequency.
- **OPERATIONS →STOP** - Sets the stop frequency to the active marker's frequency.
- **OPERATIONS →CENTER** - Sets the frequency of the active marker to be the center frequency.
- **OPERATIONS →SPAN** - Sets the absolute frequency span to the last two active markers. You need to have any two markers (M1-M4) enabled for the Span button to work. If only one marker is displayed, nothing happens.

Time domain operation

The VNA6000 can simulate time domain reflectometry by transforming frequency domain data.

Select **DISPLAY → TRANSFORM → TRANSFORM ON** to convert measured data to the time domain.

If **TRANSFORM ON** is enabled (Inverted white text on black background), the measurement data is immediately converted to the time domain and displayed. The relationship between the time domain and the frequency domain is as follows.

- Increasing the maximum frequency increases the time resolution
- The shorter the measurement frequency interval (ie, the lower the maximum frequency), the longer the maximum time length

For this reason, the maximum time length and time resolution are in a trade-off relationship. In other words, the time length is the distance.

- If you want to increase the maximum measurement distance, you need to lower the frequency spacing (frequency span / sweep points).
- If you want to measure the distance accurately, you need to increase the frequency span.

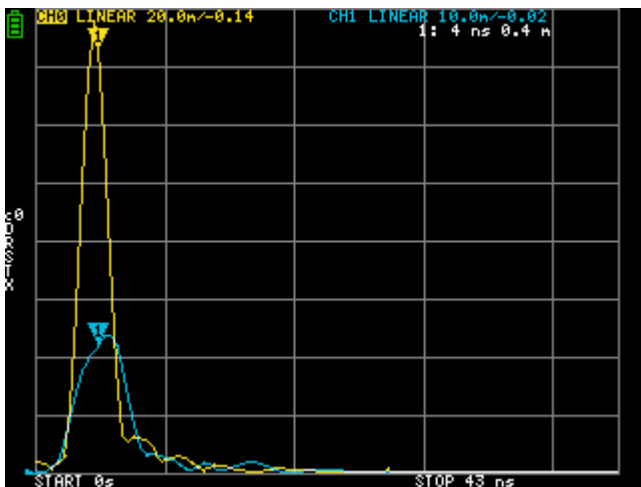
HINT – Use a lower frequency to measure a longer length and a higher frequency to measure a shorter length and adjust accordingly for accurate results.

Time domain bandpass

In bandpass mode, you can simulate the DUT response to an impulse signal.

NOTE: The trace format can be set to **LINEAR**, **LOGMAG** or **SWR**.

The following is an example of the impulse response of a bandpass filter.



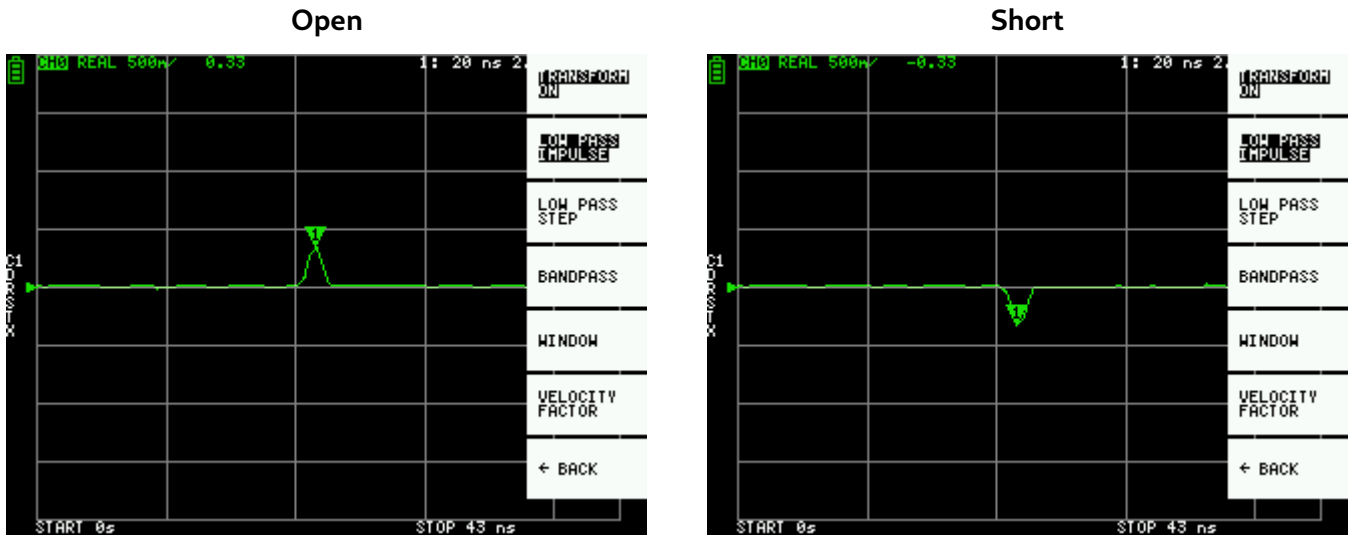
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Time domain low pass impulse

In low-pass mode, you can simulate TDR. In low-pass mode, the start frequency must be set to 50 kHz, and the stop frequency must be set according to the distance to be measured.

The trace format can be set to **REAL**.

Examples of Impulse response in open state and impulse response in short state are shown below.



Time domain low pass step

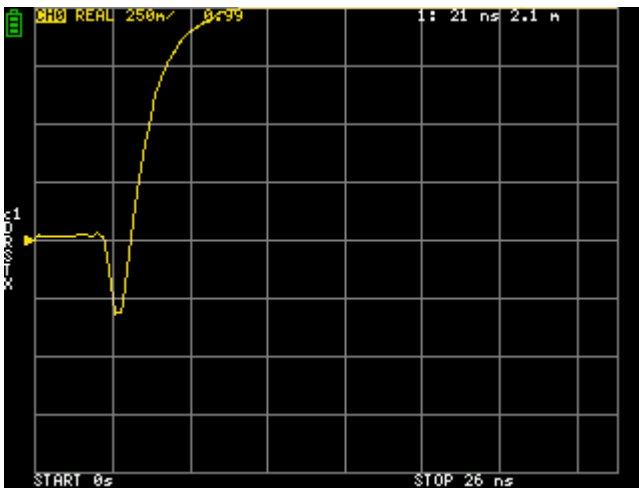
The trace format can be set to **REAL**.

Example measurements of Step response are shown below.

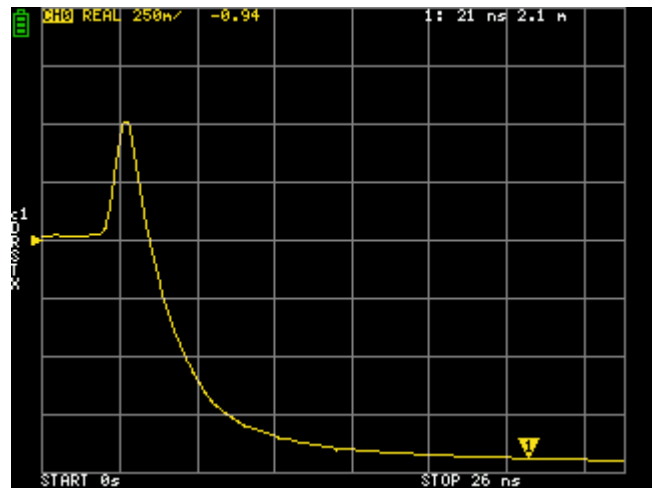


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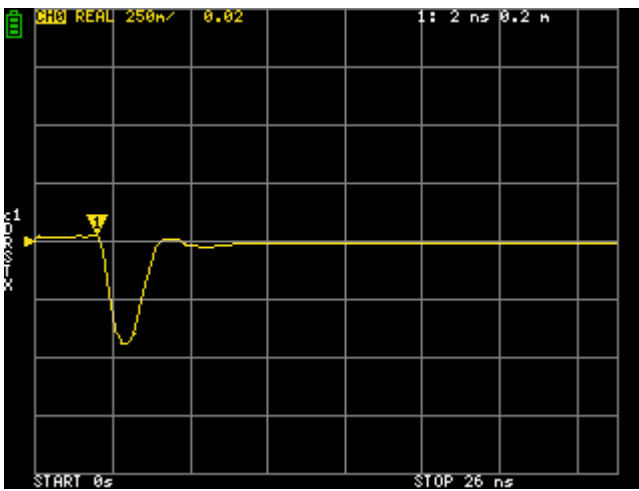
Capacitive short



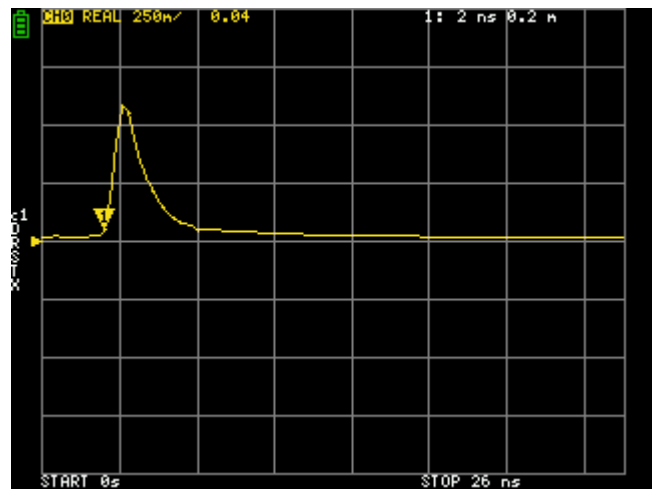
Inductive short



Capacitive discontinuity (C in parallel)



Inductive discontinuity (L in series)



Time domain window

The range that can be measured is a finite number, and there is a minimum frequency and a maximum frequency. A window can be used to smooth out this discontinuous measurement data and reduce ringing.

There are three levels of windowing.

- **MINIMUM** (no window, ie: same as rectangular window)
- **NORMAL** (equivalent to Kaiser window $\beta = 6$)
- **MAXIMUM** (equivalent to Kaiser window $\beta = 13$)

MINIMUM provides the highest resolution and **MAXIMUM** provides the highest dynamic range. **NORMAL** is in the middle.

Setting the velocity factor in the time domain

The transmission speed of electromagnetic waves in the cable varies depending on the material. The ratio to the transmission speed of electromagnetic waves in vacuum is called the Velocity Factor. This is always stated in the cable specifications.

In the time domain, the displayed time can be converted into distance. The wavelength shortening ratio used for distance display can be set with **DISPLAY → TRANSFORM → VELOCITY FACTOR** .

For example, if you measure the TDR of a cable with a wavelength reduction rate of 67%, specify **67** for the **VELOCITY FACTOR**. (Do not use the decimal point).

Recall calibration and settings

Up to 5 calibration datasets can be saved.

Calibration data includes the following information:

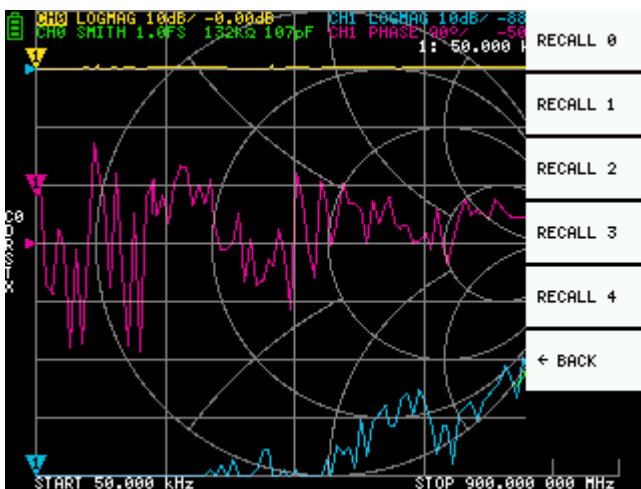
- Frequency range setting
- Error correction at each measurement point
- Trace settings
- Marker settings
- Domain mode settings
- Electrical delay

You can save the current settings by selecting **CAL → SAVE → SAVE n**.

Current calibration data can be reset by selecting **CAL → RESET**.

CAL → CORRECTION indicates whether error correction is currently enabled. You can deselect this to temporarily disable error correction. (Inverted text=ON, Normal text=OFF)

RECALL the saved settings by selecting **CAL → RECALL → RECALL n**.



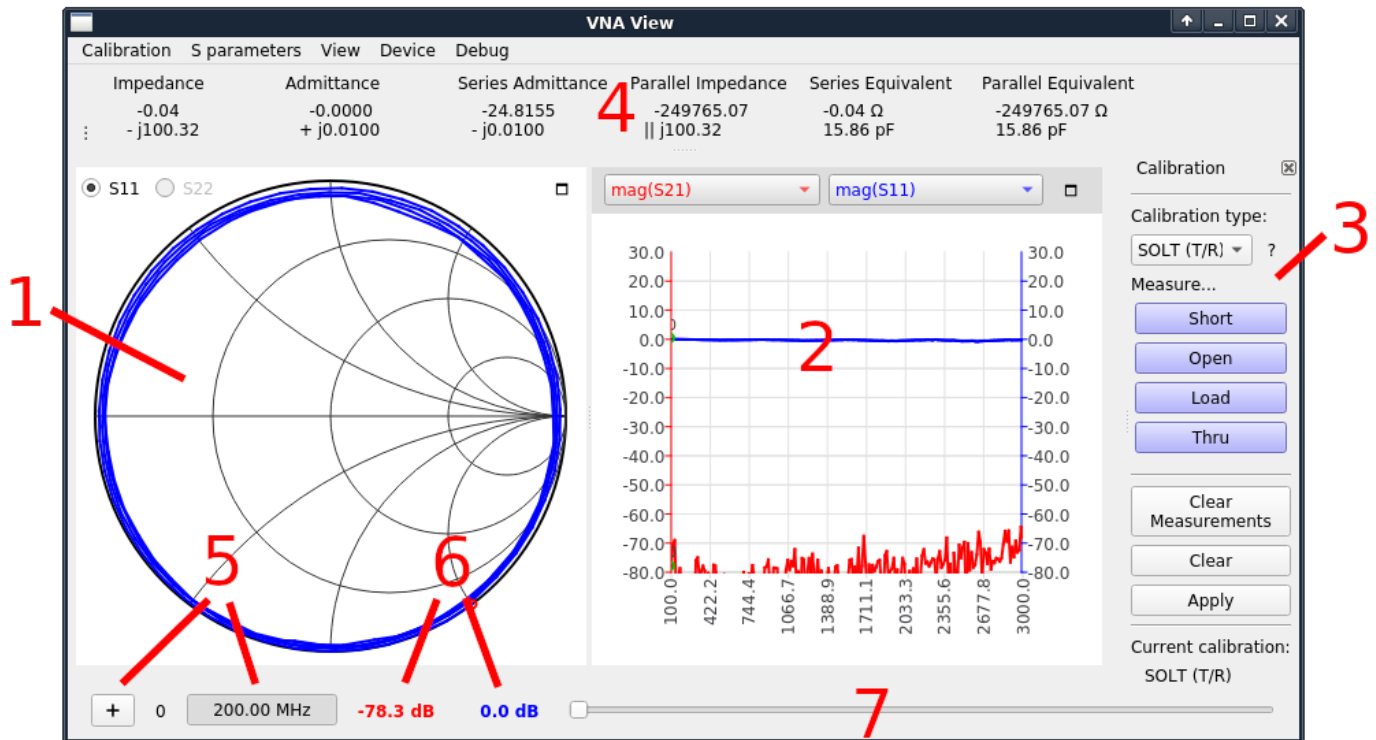
VNA View Software

VNA View software allows you to control the VNA6000 from a PC, view plots in real time, export S parameters, and use custom calibration kit parameters.

VNA View supports Linux, Windows (7+), and Mac OS (10.11+)

For software downloads please go to <https://nanorfe.com/nanovna-v2-software.html>

User interface



1 – Smith chart display

Shows a smith chart of S11 or S22 depending on the radiobutton selected.

2 – Line graph display

Shows a line graph plot of two user selected traces. The two dropdown lists above the graph select the data source displayed. The color of the trace corresponds to the color of the dropdown.

3 – Calibration pane

Allows you to measure calibration standards and enable/disable calibration.

4 – Impedance display

Shows impedance values and series/parallel equivalent circuits calculated from S11.

5 – Marker control

6 – Marker values

The “+” button adds a new marker. Clicking on the frequency indicator will show/hide the marker dot. Labels show the numeric value of each line graph trace at the current marker frequency.

7 – Marker slider

Adjust this slider to control marker position.

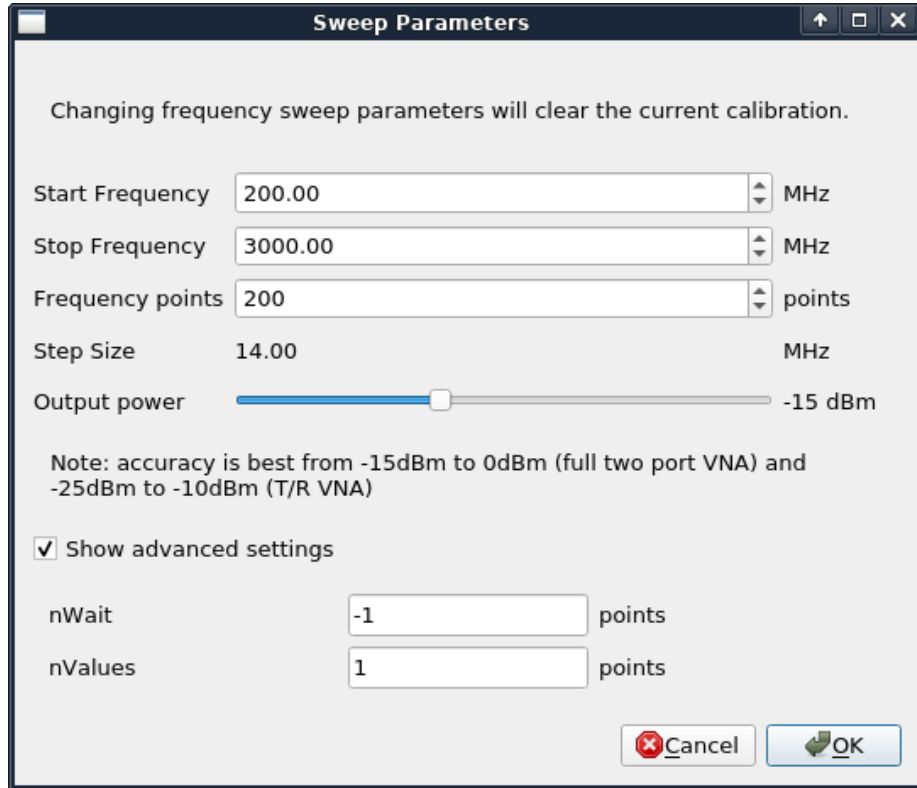
Connecting to the device

After connecting the device to the PC using a USB cable, a new serial port device should show under the **Device** menu in VNA View. If no device shows up, you may need to install the Cypress USB Serial driver (can be found on VNA View binary release downloads). The device uses the USB CDC class, which does not require dedicated drivers on Linux and Mac OS.

Select the device under the **Device** menu to connect to it. Continuous sweep will start immediately and you should see continuously updating data on the smith chart and line plots.

Setting sweep range and parameters

Click **Device > Sweep parameters...** from the main menu to bring up the Sweep Parameters dialog.



Settings:

- **Start frequency/Stop Frequency** control the sweep frequency range.
- **Frequency points** is the number of discrete frequency points.
- **Output power** is not applicable to the VNA6000 and the setting is ignored.

Under **Show advanced settings**:

- **nWait** is not applicable to the VNA6000 and the setting is ignored.
- **nValues** controls the number of data points per sweep point to average over. Setting a higher averaging factor will result in proportionally lower noise and higher sweep times.

Calibration

Calibration in the VNA View UI is similar to the on-device UI.

Calibration must be performed whenever the frequency range to be measured is changed. When calibration is activated, the label under “Current calibration” in **3 – Calibration pane** will indicate the current calibration type. “None” indicates no calibration is active.

Changing the frequency sweep range always clears the active calibration, if any.

The calibration procedure is as follows:

1. Reset current calibration. Click **Clear** and **Clear Measurements** under **3 – Calibration pane**.
2. Select **Calibration type**. Use **SOL (1 port)** to correct for S11 only, and use **SOLT (T/R)** to correct for S11 and S21 response. Other calibration types in the dropdown list apply to full two port VNAs only and are not applicable to the VNA6000 which is a T/R VNA.
3. Attach a SMA coaxial cable to port 1.
4. (SOLT only) Attach a SMA coaxial cable to port 2.
5. Connect OPEN standard to port 1 cable and click **Open**. Wait for button highlight.
6. Connect SHORT standard to port 1 cable and click **Short**. Wait for button highlight.
7. Connect LOAD standard to port 1 cable and click **Load**. Wait for button highlight.
8. (SOLT only) Connect the THRU standard between the port 1 and port 2 cable ends, and click **Thru**. Wait for button highlight.
9. Click **Apply**.

Refer to the figures in section [3.1.Calibration](#) for how to connect the calibration standards.

Note that there is no need to wait for the plots to fully update after connecting a calibration standard. Clicking any of the **Open**, **Short**, **Load**, **Thru** buttons will perform a full sweep with 2x averaging. Once the sweep is complete the button will become highlighted, and you may proceed to the next calibration standard.

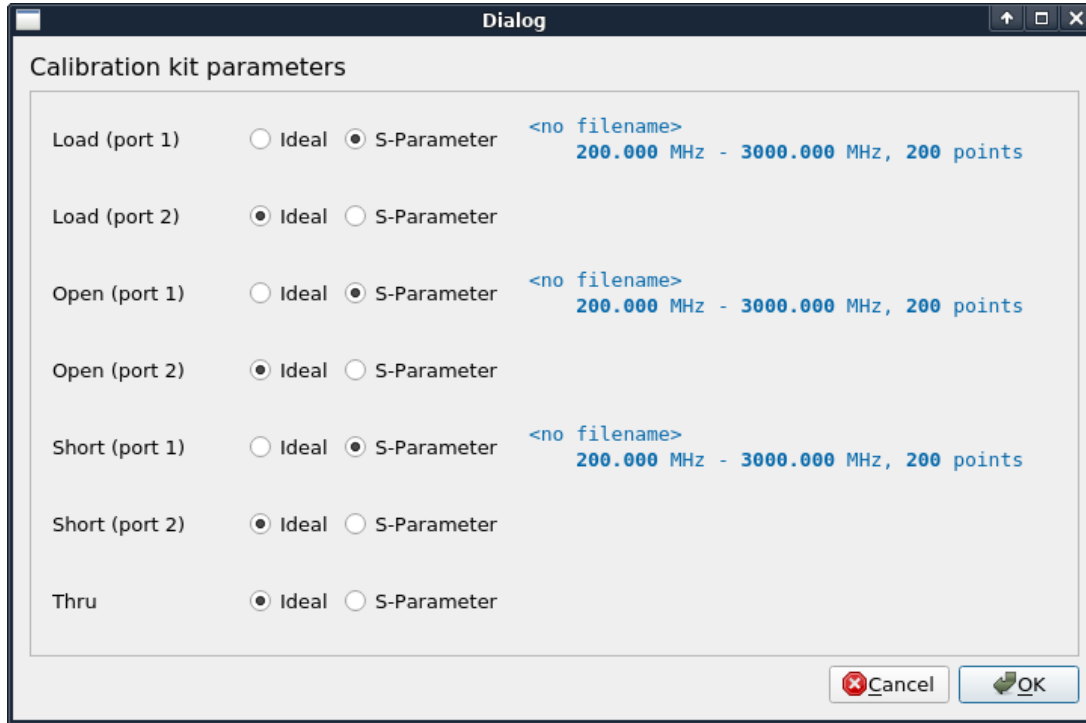
To save the current calibration click **Calibration > Save as...** in the main menu.

To recall a saved calibration click **Calibration > Load...** in the main menu. Recently saved or recalled calibrations will also be listed under the **Calibration** menu and can be selected directly.

Saved calibration files contain the measurements for each calibration standard. Recalling a saved calibration file will calculate a new calibration using the old (saved) measurements and the currently configured calibration kit parameters.

Calibration kit parameters

VNA View supports user calibration kit parameters. Click Calibration > Kit settings under main menu to open the **Calibration kit parameters** dialog.



Each calibration kit type can be associated with an S parameter model, or an ideal model can be used. Clicking on the S-Parameter radio button will bring up a file chooser dialog to select the S parameter file.

Note: these kit parameters are global and are not associated with a calibration save file. If you modify kit parameters and proceed to recall an older calibration file, the old calibration will be re-calculated using the newly configured kit parameters!

Firmware Update

The VNA View software has built in support for updating the firmware on the VNA6000.

To perform a firmware update:

1. Switch off the VNA6000.
2. Connect the VNA6000 to your PC through a USB cable.
3. Hold down ◀ and switch on the VNA6000. Once white screen appears, release ◀.
4. The device should appear under the **Device** menu in VNA View.
5. Click the device under the **Device** menu, for example **/dev/ttyACM0**.
6. You will be prompted to update the device firmware. Answer "yes" or "update firmware".
7. You will be prompted to select a firmware raw binary file. Select the file you wish to flash.
8. Firmware update will begin and progress is shown in VNA View.
9. The firmware update typically takes 5 - 10 seconds, and the VNA6000 will automatically reboot into the new firmware.
10. If the update process appears to be stuck, you can restart the update by repeating the steps above. Interrupting a firmware update will not brick your device, but you will need to flash the firmware again before the device will boot.