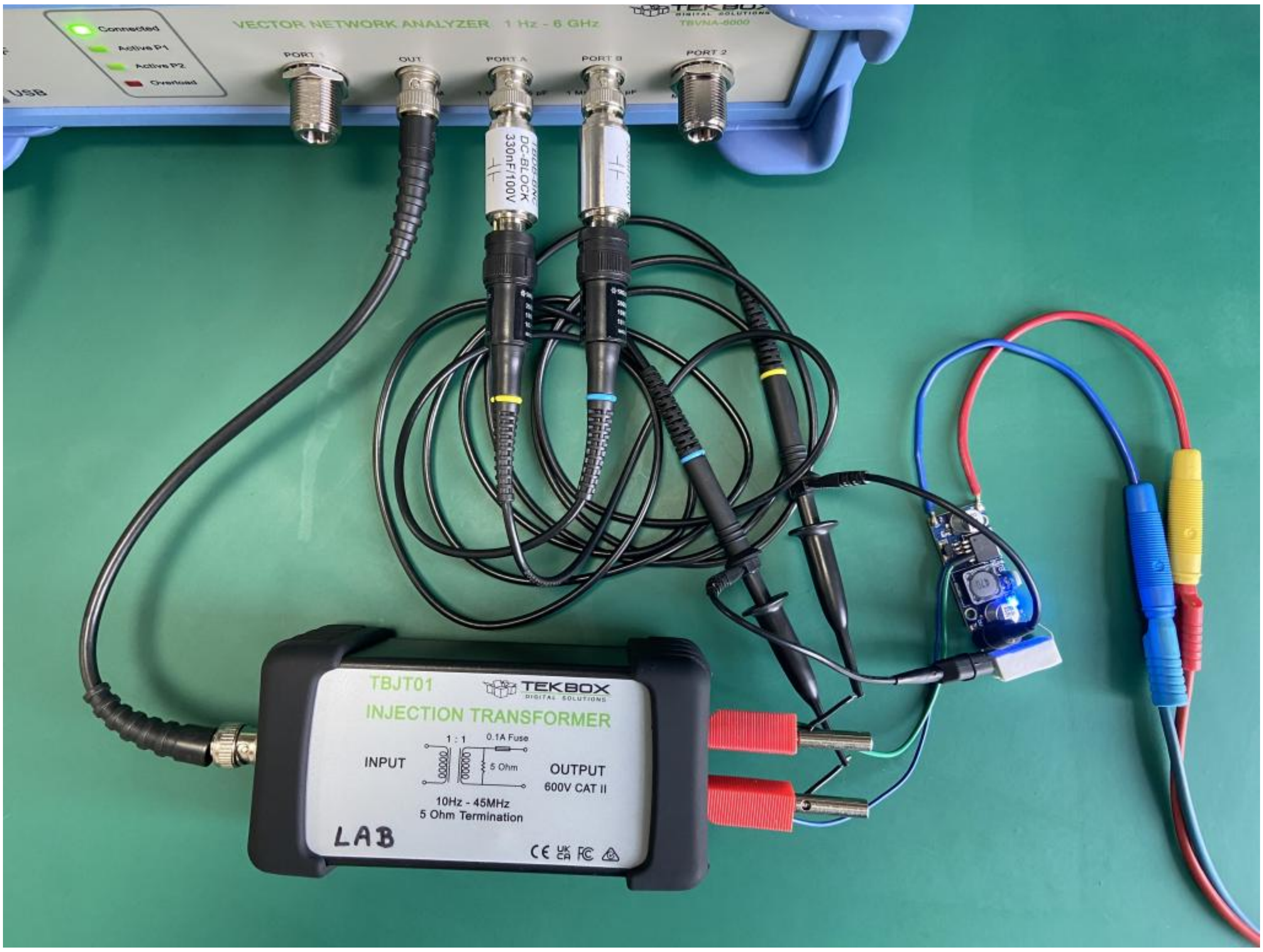

Connected
Active P1
Active P2
Overload
USB
VECTOR NETWORK ANALYZER 1 Hz - 6 GHz
PORT 1
OUT
PORT A
PORT B
PORT 2
DC-BLOCK
330nF/100V
TBJT01
TEKBOX
INJECTION TRANSFORMER
INPUT
1 : 1
0.1A Fuse
5 Ohm
OUTPUT
600V CAT II
10Hz - 45MHz
5 Ohm Termination
LAB

Index

1. Introduction

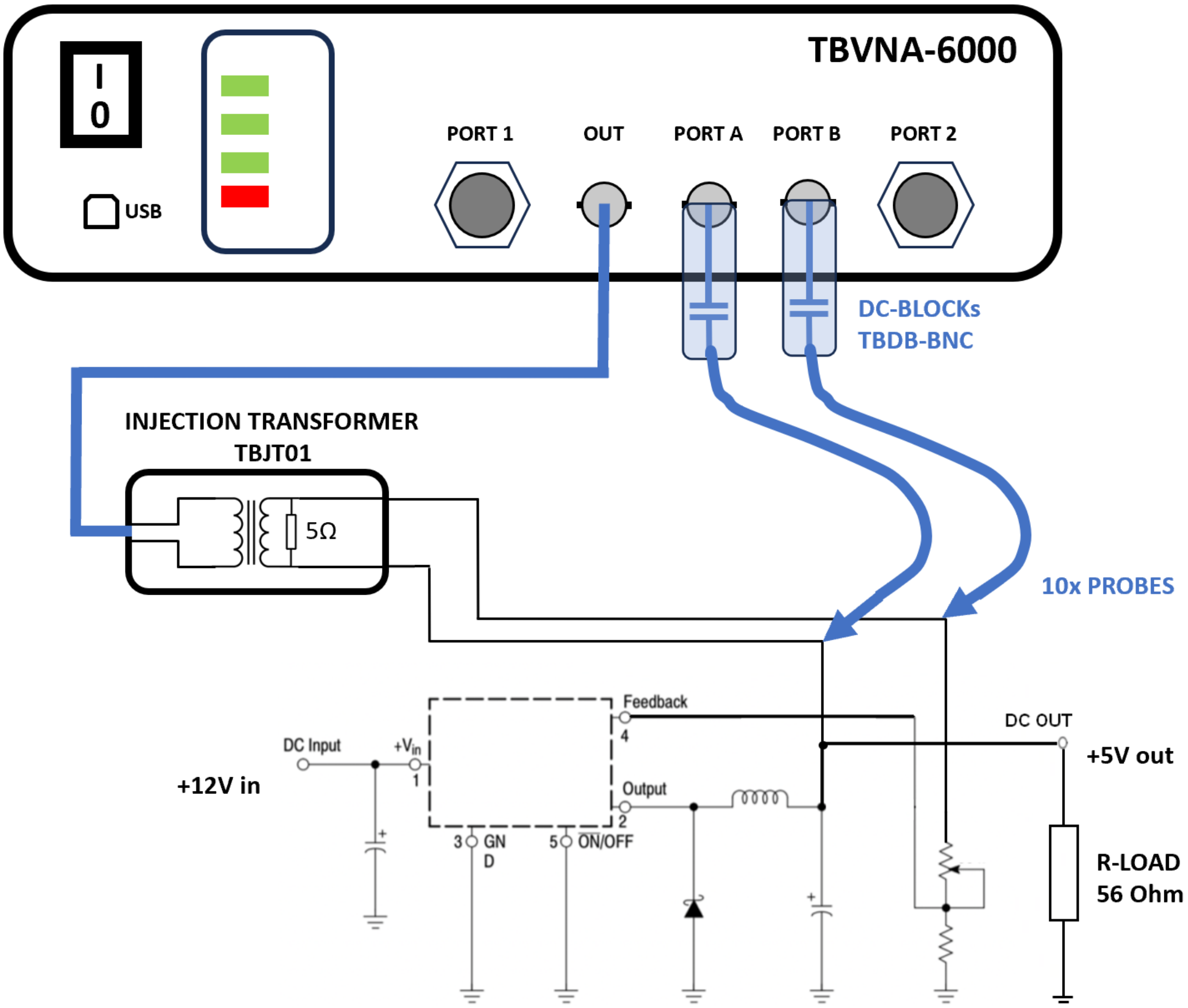
This application note explains how to measure control loop stability with a Tekbox Vector Network Analyzer TBVNA-6000 equipped with the TBVNA-6000-Bode option.

A TBJT01 injection transformer is inserted into the control loop of a simple DC/DC converter to measure open loop gain and phase in order to conduct a stability test.

Once the TBVNA-6000 is configured for loop stability analysis, the setup may be stored and reloaded for future measurements.

2. Setup

Open the feedback loop by separating the high side of the voltage adjustment potentiometer from the output path of the DC/DC converter. Connect the positive output of the DC/DC converter to one of the injection transformer´s output jacks. Connect the open end of the potentiometer to the second output jack of the transformer.

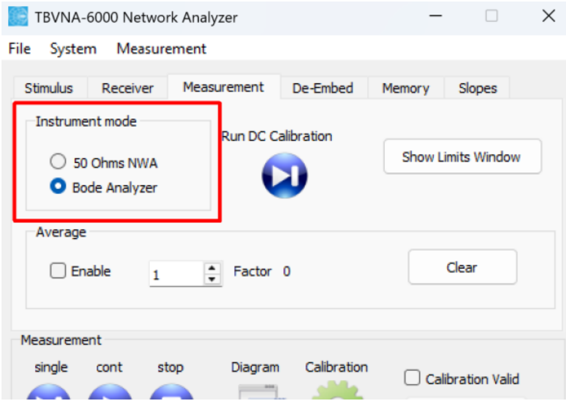


Picture 1, Bode measurement setup

Use a BNC cable to connect the input of the injection transformer to the OUT-port of the TBVNA-6000. Connect the DC-blocks supplied with the TBVNA-6000 to PORT A and PORT B to block the DC offset of the feedback loop. Connect two 10x oscilloscope probes to the DC-Blocks as depicted above.
Hook the probe tips to the DC/DC converter or output of the injection transformer as shown in Picture 1.

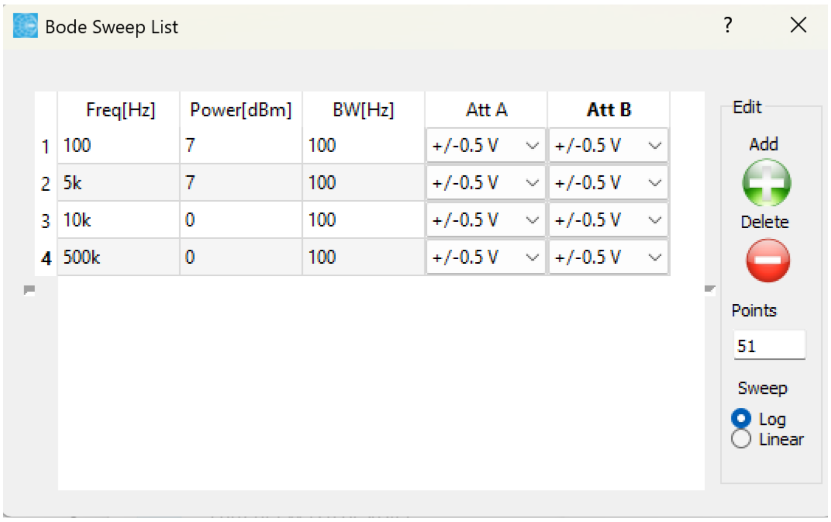
3. VNA setup and measurement

In the MEASUREMENT-tab, change the instrument mode to Bode Analyzer.



Picture 2, instrument mode setup

Upon entering the Bode-Analyzer mode. The Bode Sweep List will pop up. From 100 Hz to 5 kHz set the power of the OUT-port to +7 dBm, the measurement bandwidth to 100 Hz and the Port A and B input range to ±0.5V. From 5kHz to 10 kHz ramp the output power down to 0 dBm. From 10 kHz to 500 kHz keep the output power constant at 0 dBm. The initial settings may require some fine tuning, depending on the device under test. To speed up measurements while tuning the parameters, reduce the number of measurement points to 51.



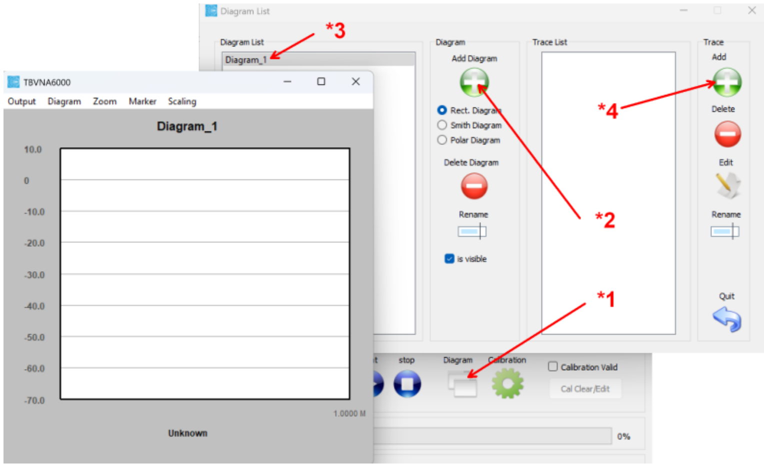
Picture 3, port parameter, sweep and measurement bandwidth setup

When performing loop stability measurements, the amplitude of the injected signal is a critical parameter. If the amplitude is chosen too high, the loop may be overdriven, resulting in a distorted measurement result. If the amplitude is chosen too low, the measurement result may become noisy.

Constant injected power versus frequency may not always give a satisfying result. The TBVNA-6000 software enables control of Port OUT power versus frequency in the Bode Sweep List.

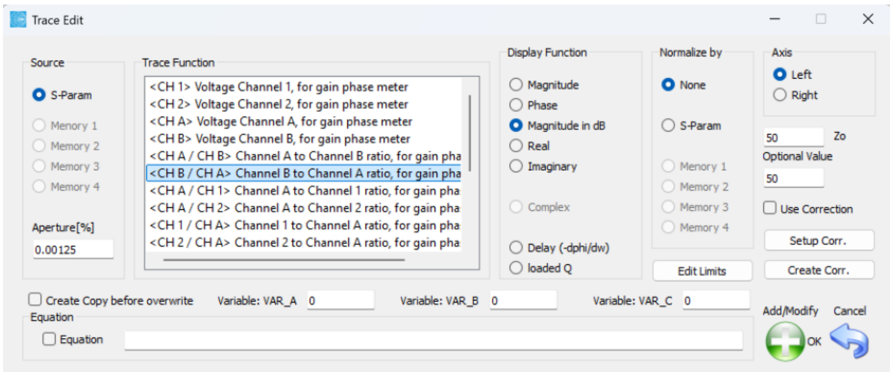
Especially at low frequencies, the measurement result may become noisy. The loop gain is high, consequently the feedback signal is low. To counteract, use the frequency dependent power shaping feature of the TBVNA-6000 to inject more power at low frequencies or start the sweep with high input power for lower frequencies and reduce the power towards higher frequencies.

Press the DIAGRAM-button (*1) to set up a measurement. Press the ADD DIAGRAM-button (2*) to create a rectangular graph.



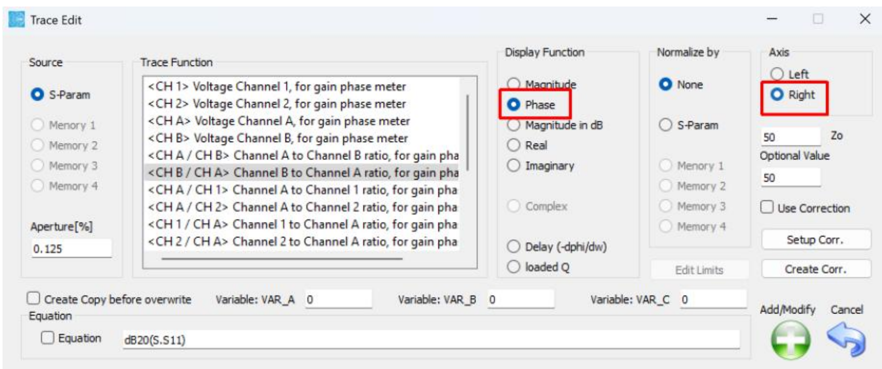
Picture 4, diagram utility

Highlight *DIAGRAM_1 (*3)* and press the ADD TRACE-button (*4) to assign measurements to the graph. In the Trace dialog, select *CH B / CH A* to calculate the transfer function (loop gain) and press the ADD-button.



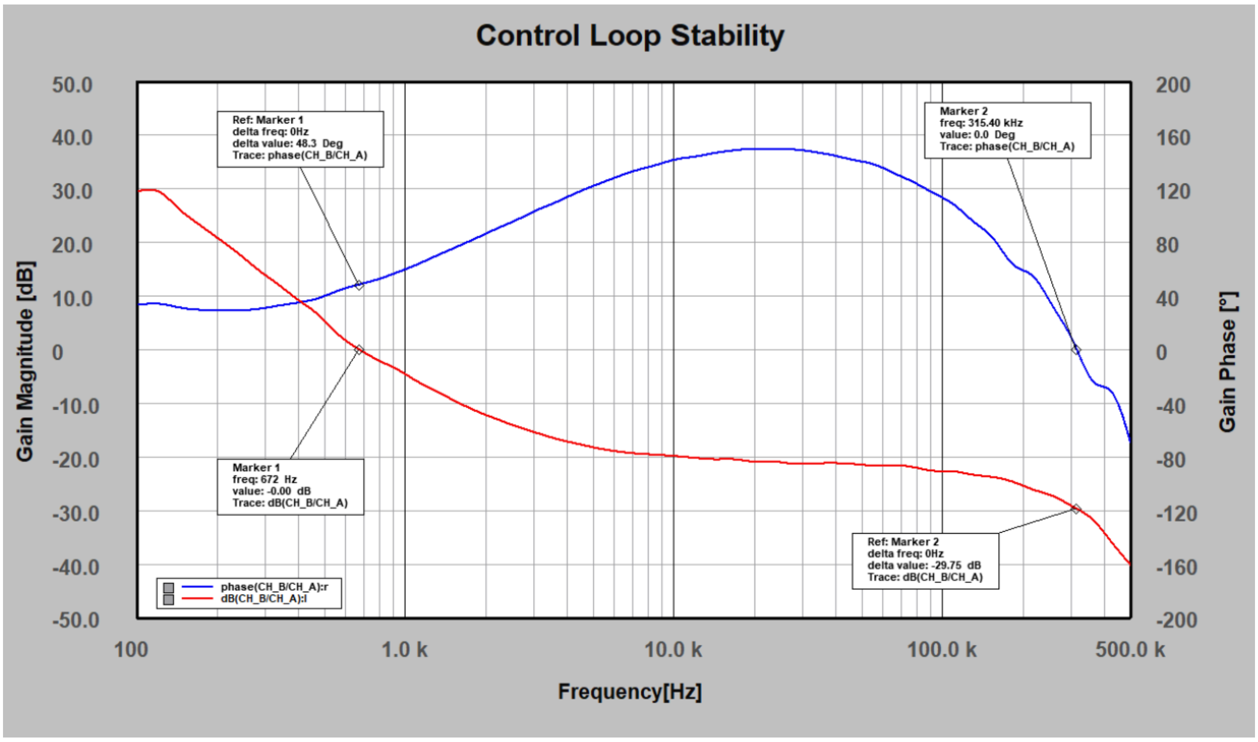
Picture 5, Trace dialog, magnitude of Channel B to Channel A ratio selected

Click the ADD TRACE-button (*4) again to add a second graph. Again, select *CH B / CH A,* but select PHASE and assign the graph scale to the right axis. Press the ADD-button.



Picture 6, Trace dialog, Phase of Channel B to Channel A ratio selected

Now, the Bode measurement is set up and all that is left is to press the Single or Continuous Measurement button. Drag the windows to fit your monitor.

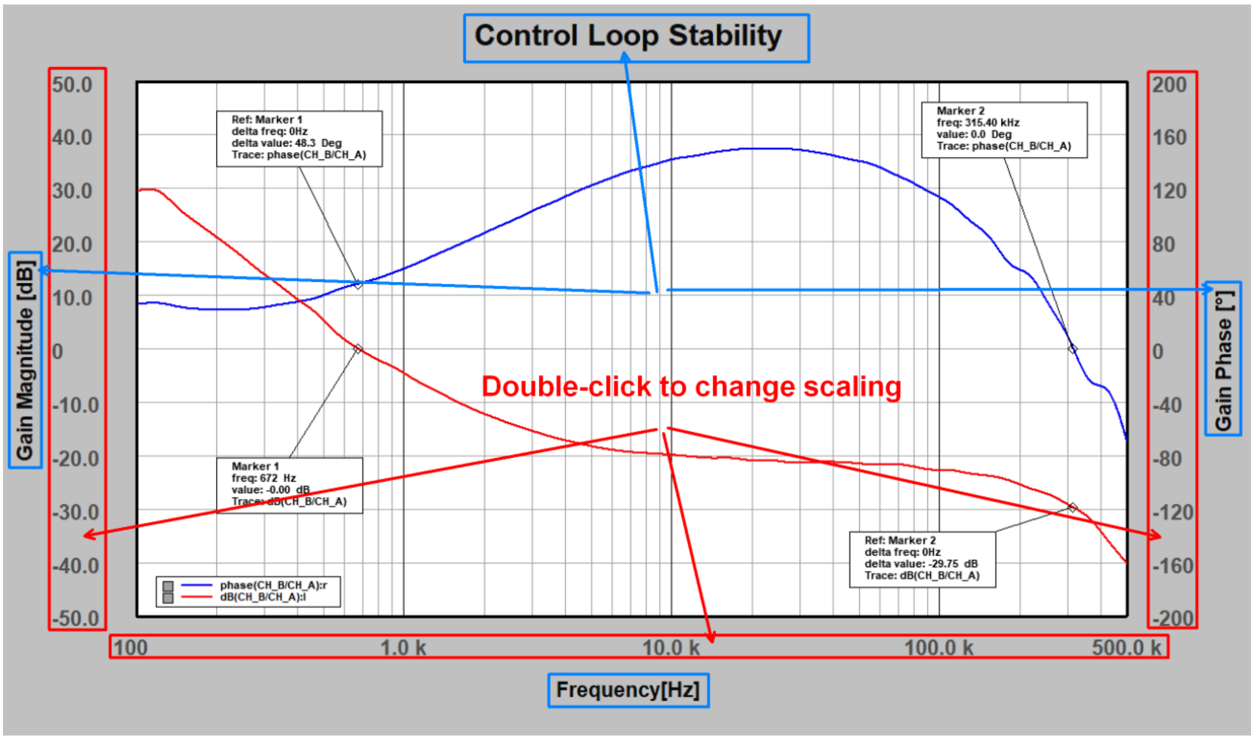


Picture 7, measurement result, 48.3° phase margin, 29.75 dB gain margin

Scale and label the axis. Set markers and delta markers to obtain gain and phase margin following the instructions in the next chapters.

4. Formatting

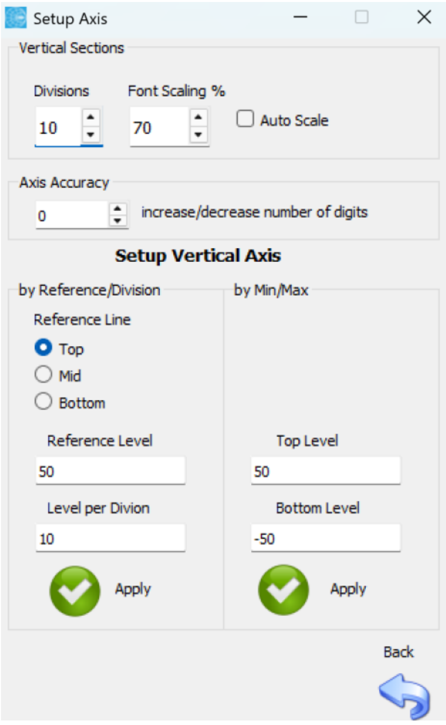
In order to format the text or scaling, click anywhere into the areas marked below:



Picture 8, formatting areas

Add a legend by pressing (CTRL+L) or in the Add Legend in the diagram menu.

Change the scale of the gain axis by double clicking the gain scale, select 10 divisions, set the top level to 50 dB and the bottom level to -50 dB. It is necessary to press the APPLY-button before closing the Axis Setup utility.



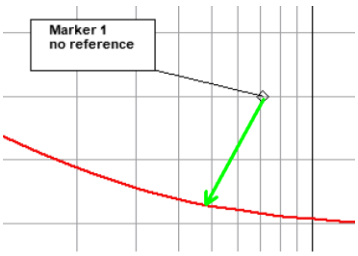
Picture 9, axis setup utility

Similarly, configure the top level of the phase axis to 200° and the bottom level to -200°.

5. Measurement analysis, markers and delta markers

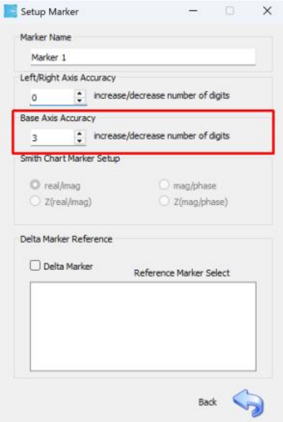
The stability of a control loop is analyzed by measuring the phase margin at the gain crossover point, where the gain crosses the 0 dB line. Furthermore we have to determine the gain margin at the phase crossover point, where phase crosses the 0° line.
This may sound contradicting to the literature, which refers to positive feedback happening at -180° phase shift. However, in our setup we measure open loop gain in a closed system, as the 5 Ohm resistor inside the injection transformer closes the feedback loop. Consequently, positive feedback would happen at 0° and we have to measure phase margin relative to the 0° line.

In order to set markers and delta markers for gain and phase margin, press (CTRL+M) or click ADD MARKER in the MARKER-menu of the Diagram utility. Drag the tiny rectangle over the gain graph and let it snap.



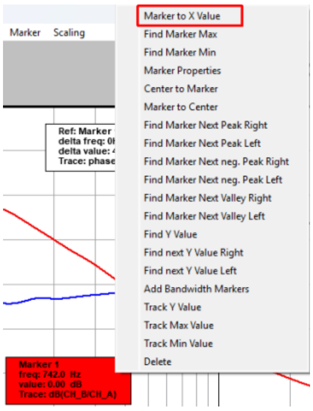
Picture 10, adding a marker

Now drag the rectangle to the point, where the gain graph crosses the 0 dB line. Double-click the marker box and increase the Base Axis Accuracy to 3 digits in order to display the frequency with higher resolution.



Picture 11, marker setup

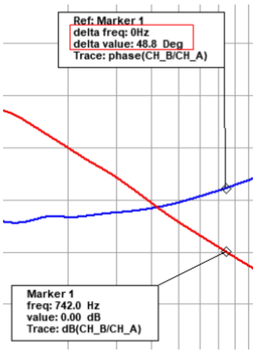
Single-click the marker box to highlight it. Right-click it to open the marker context menu. Press MARKER TO X VALUE and fine tune the marker position until it is exactly at 0 dB.



Picture 12, marker context menu

In order to setup a Delta Marker, press (CTRL-D) or or click ADD MARKER DELTA in the MARKER-menu of the Diagram utility. Drag the tiny rectangle over the phase graph and let it snap.

Highlight the delta marker, right click the box and select MARKER TO X VALUE in the context menu. Enter 0 to set the frequency offset with respect to the gain marker to 0.



Picture 13, delta marker, phase margin

The delta marker will now show the phase margin of the control loop. Proceed similarly to set up markers for the gain margin.

6. Save Setup

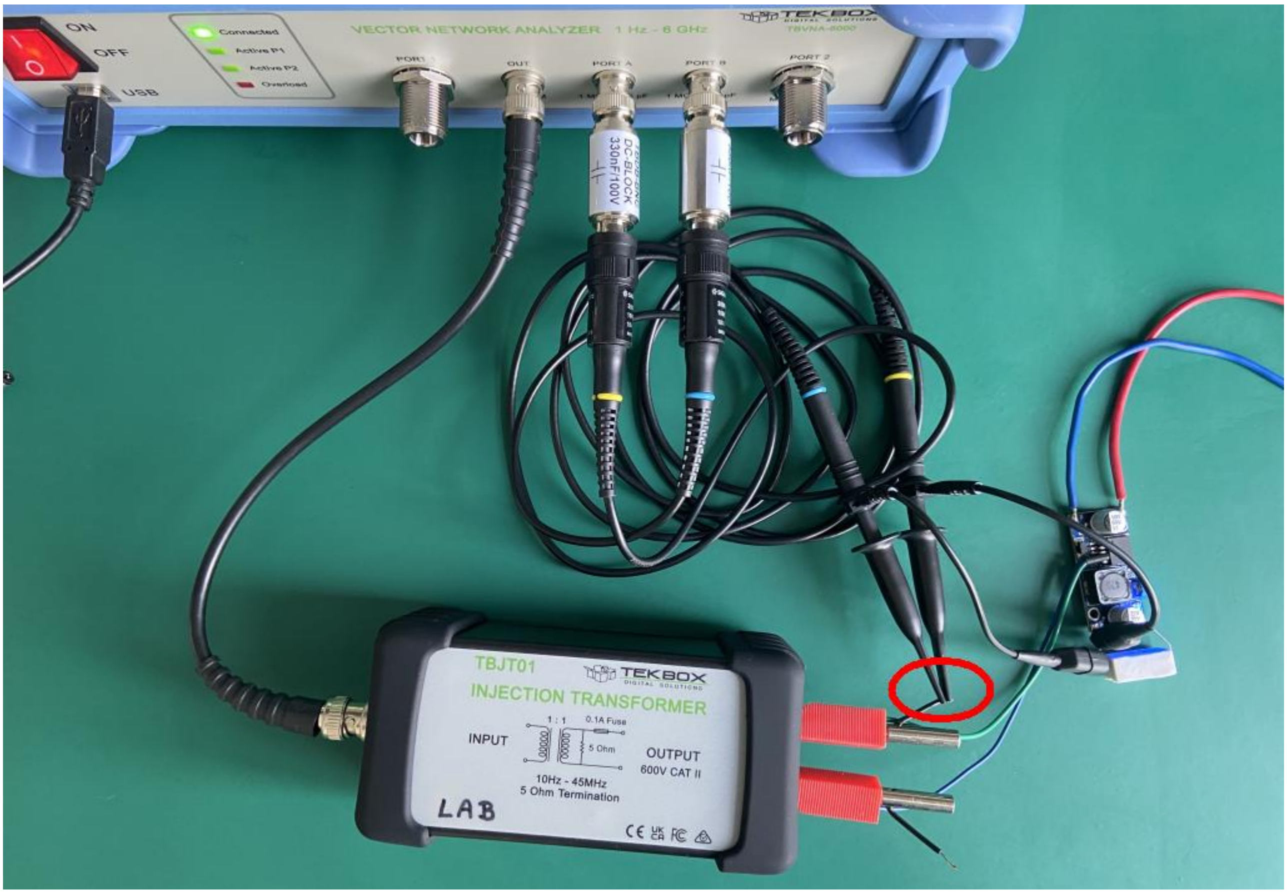
In order to avoid the setup procedure for future measurements, enter the FILE-menu of the main window and click SAVE SETUP. Chose a file name for the setup and click the SAVE button.
Setup files are saved in *C:\user\user name\TekBox\TBVNA-6000\Setups*.suf*

In order to load a setup at a later point of time, simply enter the FILE-Menu, LOAD SETUP and select the desired setup file from your list of setups.

7. Hints

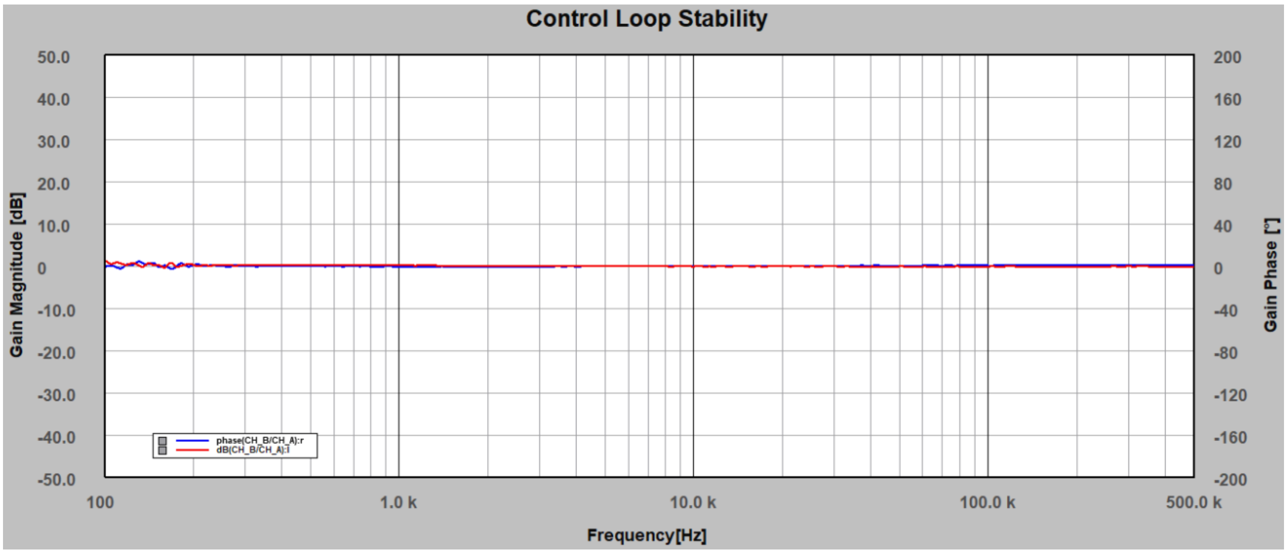
7.1 Calibration

Normally, no calibration of the setup should be required. In case of doubts, connect both probe tips directly to the OUT Port of the TBVNA-6000 using a BNC-T adapter or connect it at the same output port of the injection transformer.



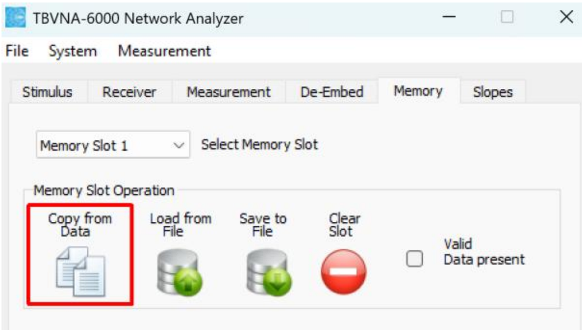
Picture 14, calibration setup

Reduce the power of the OUT Port to -10dBm or lower and press the MEASUREMENT – Button.
If the measurement plot shows the gain as a flat line at 0 dB and phase at 0°, no calibration is required.



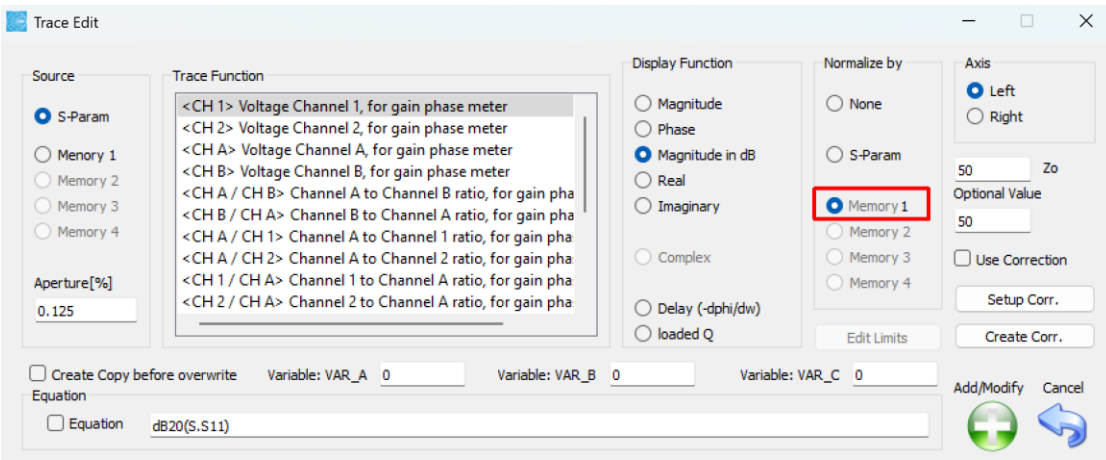
Picture 15, calibration check, gain at 0 dB and phase at 0°

If the measurement result is different, a normalisation needs to be done. Open the MEMORY-tab of the main window and press COPY FROM DATA.



Picture 16, memory-tab

Next, click the Diagram-button and edit the gain – trace. Activate Normalize by Memory 1 and the gain measurement will be corrected.



Picture 17, trace normalization

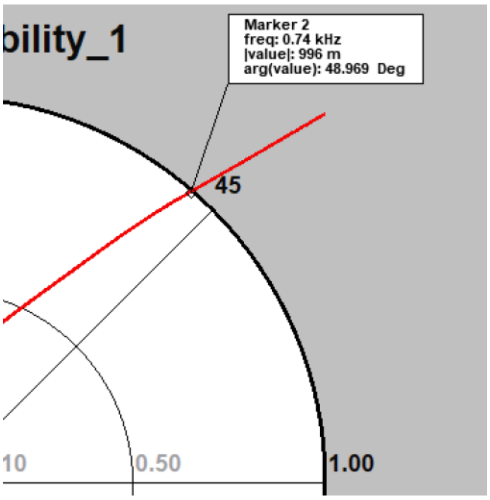
Open the trace utility to edit the phase trace and proceed the same way.

7.2 Measurement speed, bandwidth settings

Measurement speed depends on the number of measurement points and on the measurement bandwidth. In order to speed up the measurement, reduce the number of measurement points in the STIMULUS-tab of the main window.
The measurement bandwidth has to be matched with the start frequency of the sweep. The bandwidth set up in the RECEIVER-tab should not be higher than the start frequency. However, this can lead to excessive measurement time, especially when starting the sweep at very low frequencies. Setting the measurement bandwidth too high can cause higher noise.
This can be avoided, by using the frequency dependent bandwidth setting feature in the Bode Sweep List.

7.3 Polar Plots

Some users may find it convenient to use polar plots instead or in addition to rectangular gain/phase diagrams. Use the DIAGRAM-Feature to add a Polar diagram and then add the desired measurement.
In order to assign phase, place a marker and in Marker Properties select *mag/phase.*



Picture 18, setting up a marker to display phase margin in a polar plot

8. Summary

The TBVNA-6000 Vector Network Analyzer, with its TBVNA-6000-BODE option, is a useful instrument for setting up and customizing control loop and power supply measurements, contributing to an efficient design process.

Version	Date	Author	Changes
V 1.0	5.03.2025	Mayerhofer	Creation of the document
V 1.1	11.03.2025	Mayerhofer	Chapter 3 updated