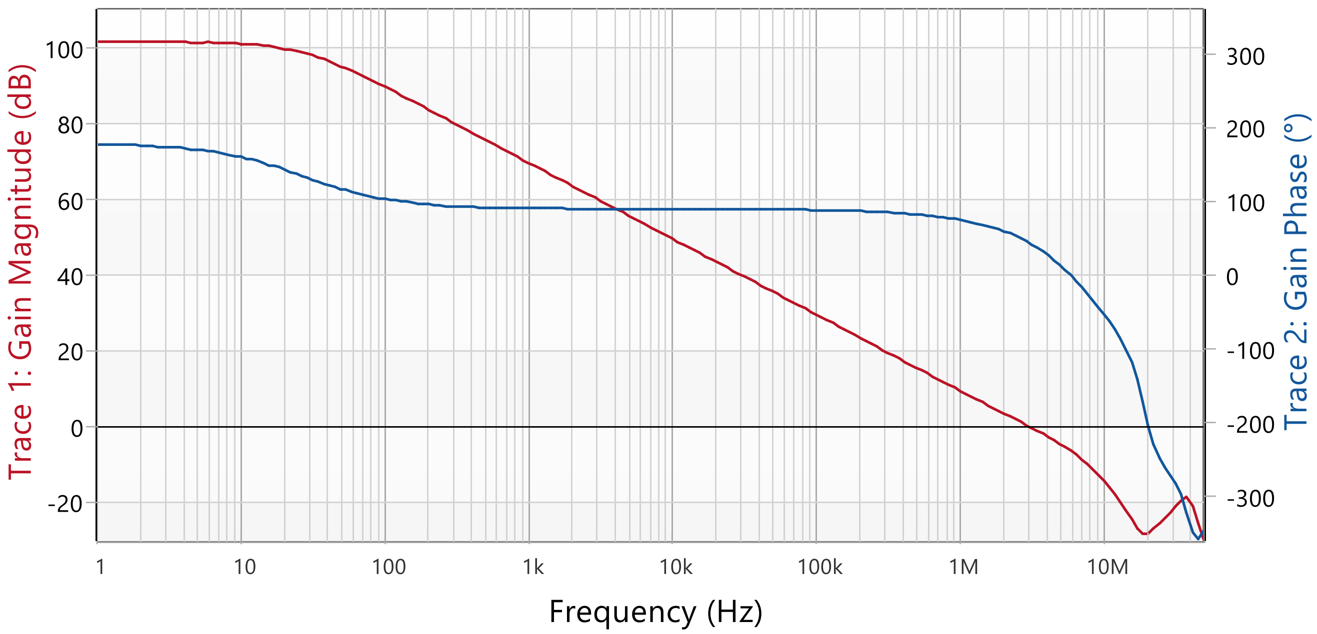
Bode 100 - Application Note

Operational Amplifier - Open Loop Gain Measurement



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Visit www.omicron-lab.com for more information.
Contact support@omicron-lab.com for technical support.

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Note: Basic procedures such as setting-up, adjusting and calibrating the Bode 100 are described in the Bode 100 user manual. You can download the Bode 100 user manual at www.omicron-lab.com/bode-100/downloads

Note: All measurements in this application note have been performed with the Bode Analyzer Suite V3.12. Use this version or a higher version to perform the measurements shown in this document. You can download the latest version at www.omicron-lab.com/bode-100/downloads

1 Executive Summary

When designing amplifier circuits, it is of advantage to know the location of the poles of the used operational amplifier. Also, the crossover frequency, gain-bandwidth product and phase margin are of interest.
This application note shows how the small-signal open loop gain of an operational amplifier can be measured using the *inverting node method*.

2 Measurement Tasks

In this application note we measure the open-loop gain of the operational amplifier TL072CP.
The op-amp is a part of an inverting circuit which is placed on a PCB with connectors for the power supply (Vcc+ and Vcc-), 2 BNC plugs for the input and output as well as a connector for the IN- pin of the op-amp.

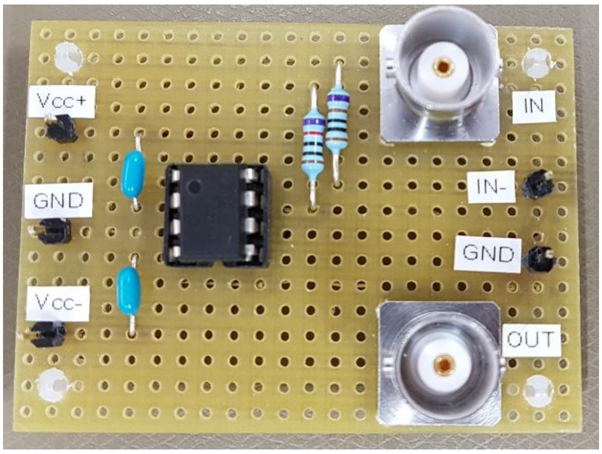

Figure 1: inverting op-amp on a PCB

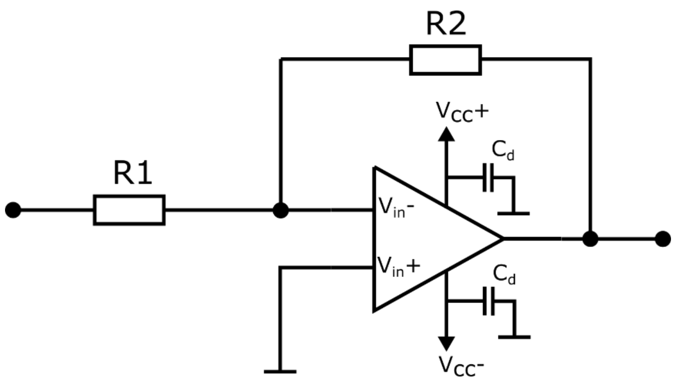

Figure 2: inverting op-amp circuit diagram

$$A_{CL} = -\frac{R2}{R1} = -\frac{10k\Omega}{1k\Omega} = -10$$

Therefore, the closed-loop gain A_{CL} of this op-amp is 10 (20 dB) with a 180° phase shift.
he typical open loop gain of an op-amp is A_{OL} = 100 000 (100 dB) or even higher.

3 Measurement Setup & Result

3.1 Measurement Setup

As mentioned before we measure the open loop gain of the op-amp in an inverting configuration. The advantage of this measurement setup is the following:

The circuit has a gain of 10, leading to a big signal at Channel 2. This forces us to choose a high input attenuator at Channel 2 which leads to an increased dynamic range of this test-setup.

The connections are done as shown in the figure below:

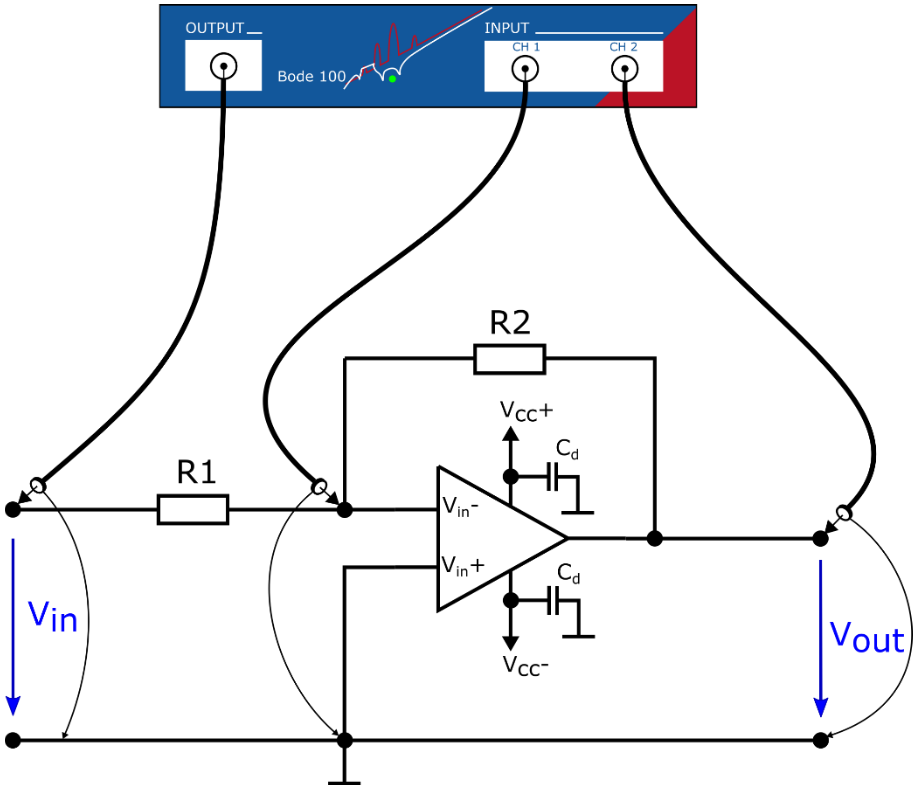

Figure 3: Schematic of measurement setup

Connect the Bode 100 output to the input of the inverting op-amp circuit. Channel 1 is connected to the inverting input of the op-amp and channel 2 to the output of the op-amp circuit to measure the open loop gain. Theoretically the inverting input does not change but the finite open loop gain causes a small change of voltage at the inverting input of the op-amp.

We recommend using BNC cables with and without additional leads or the PML-111O 10:1 probes from OMICRON Lab to achieve highest signal/noise ratio.

In addition, the supply voltage for the op-amp must be connected. In this case $\pm$15 V.

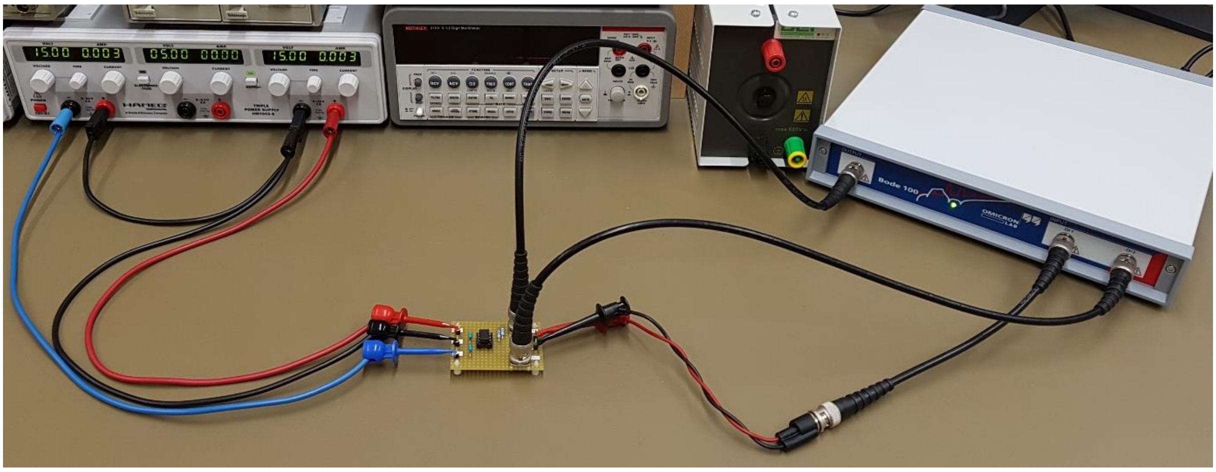

Figure 4: Measurement connection setup

3.2 Bode Analyzer Suite Setup

To setup the Bode 100 for the open loop gain measurement, select the measurement type "Gain / Phase" and set the measurement settings as follows:

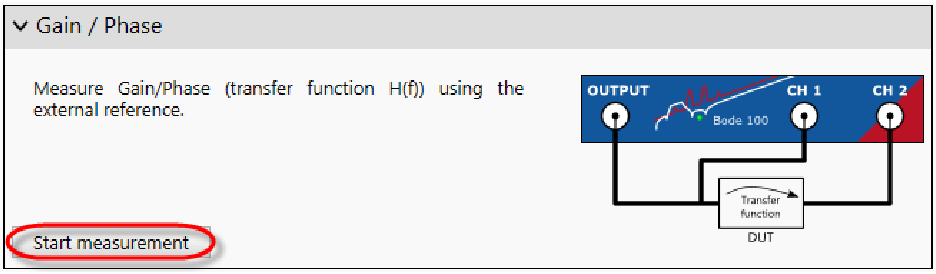

Figure 5: measurement mode

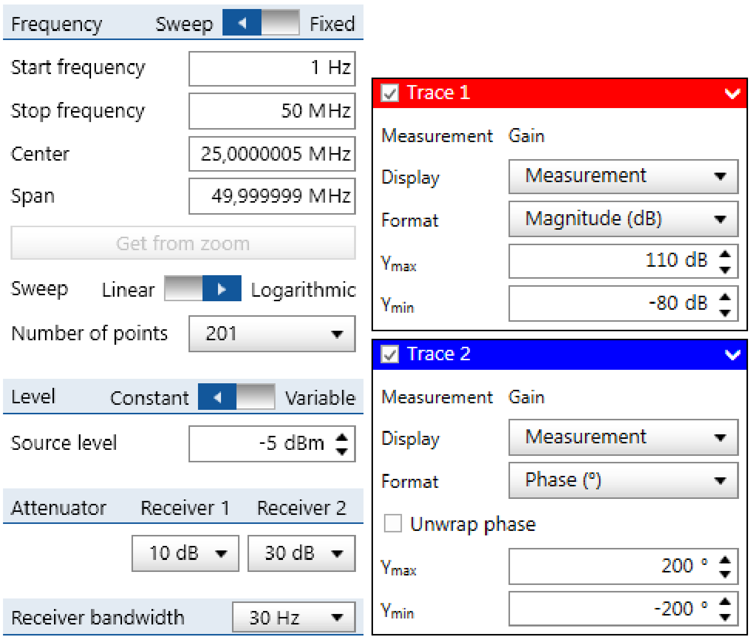

Figure 6: measurement & trace settings

Since the injected signal is amplified from the input to the output of the test circuit, the output level of the Bode 100 must be set to a small value and the CH2 attenuator to a high attenuation (30 dB for this op-amp).

3.3 Calibration

First, a full-range THRU calibration is performed to eliminate the influence of the BNC cables and leads. To do so, channel 1 and channel 2 are connected to the output of the Bode 100. The same BNC connector that is used in the test setup as well as an BNC adapter is used to connect all the cables together.

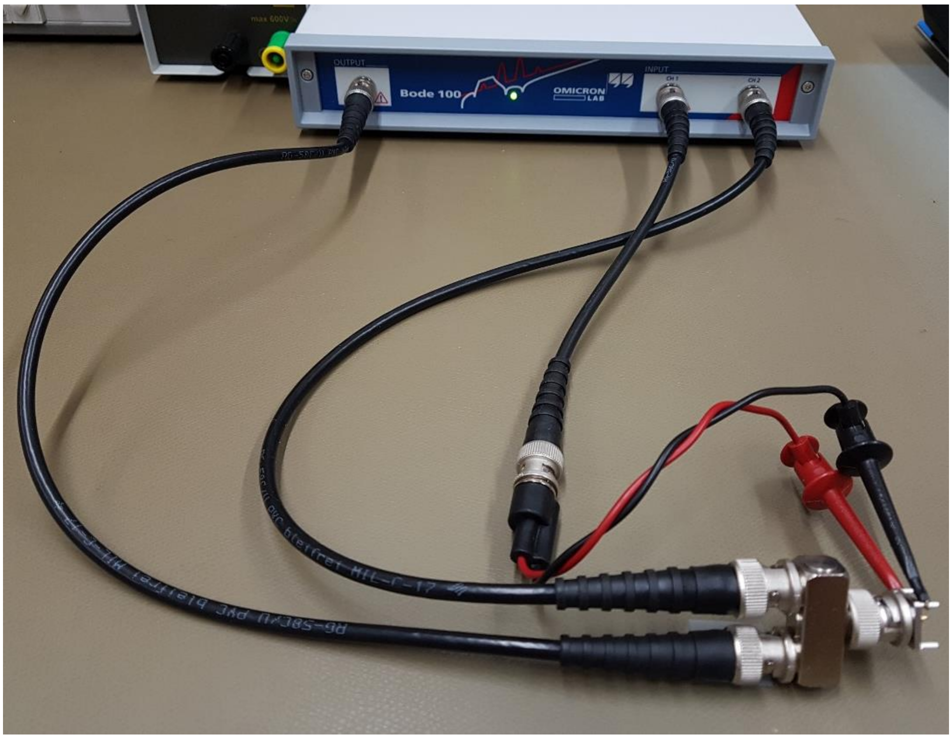

Figure 7: THRU calibration setup


Figure 8: close-up of the connection for the THRU calibration

3.4 Measurement Result

Attention: It is very important that the circuit is not overdriven by the Bode 100 output level. The following pictures show the tremendous influence of excessive signal.

- the blue curves show the op-amp clipping “rail to rail” which was caused by excessive output signal of the Bode 100 (8 dBm)
- the red curves show the correct measurement of the op-amp without any noise and no clipping error (-5 dBm output of Bode 100)

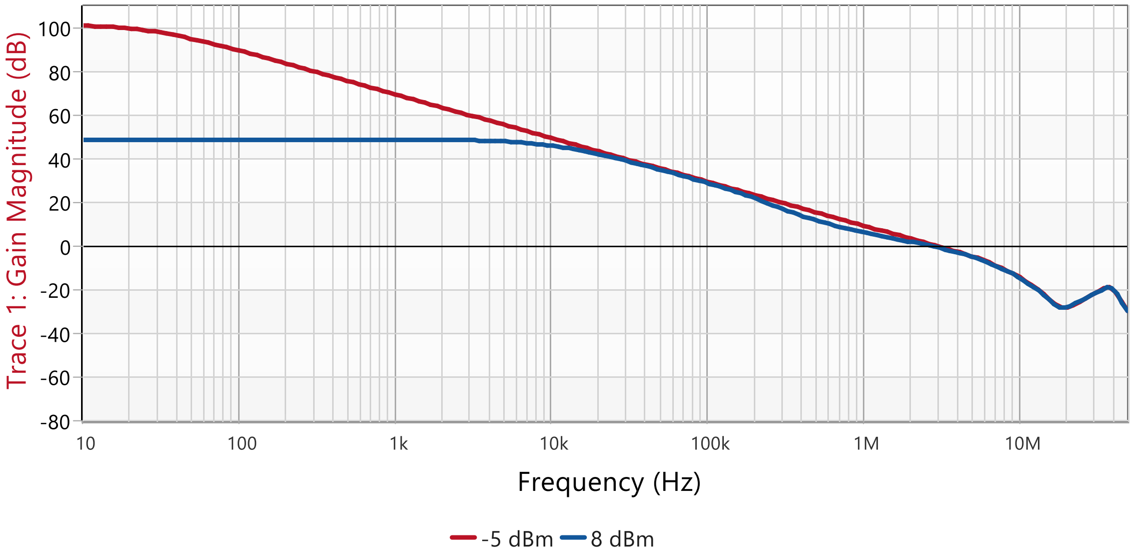

Figure 9: Measurement result - Gain

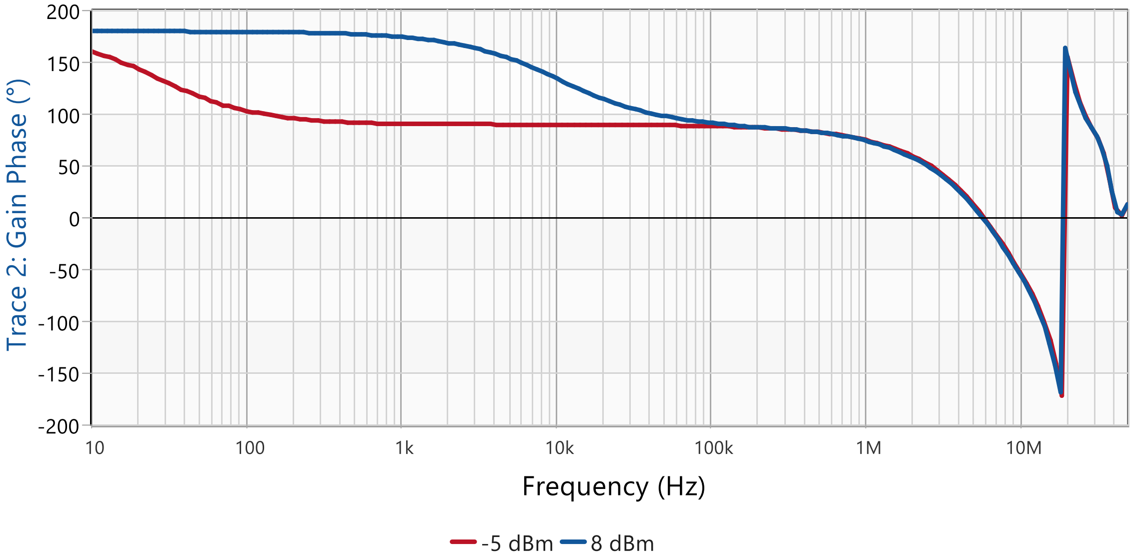

Figure 10: Measurement result - Phase

To be sure that the measurement result is correct, the output level of the Bode 100 must be decreased until the gain/phase plot does not change anymore. Decrease by another 6 dBm for safety reason. The output of the Bode 100 should be as high as possible, to get a good signal to noise ratio but not too high, avoiding clipping of the op-amp.

4 Conclusion

The Bode 100 is the perfect tool to measure open-loop gain of operational amplifiers in the frequency range from 1 Hz to 50 MHz.

With the adjustable input attenuators of Bode 100 and the chosen test-setup, very high gains can be measured easily. The measurement shown in this document ranges from +100 dB to -30dB, demonstrating 130 dB noise-free dynamic range.

Note: An alternative test-setup using an ultra-low high-pass filter can be used to measure the open-loop gain of an operational amplifier. This measurement is shown in a second Bode 100 application note. However, the measurement shown in this document is easier to perform and provides excellent results. Only the phase result is shifted by 180° compared to the common notation.

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