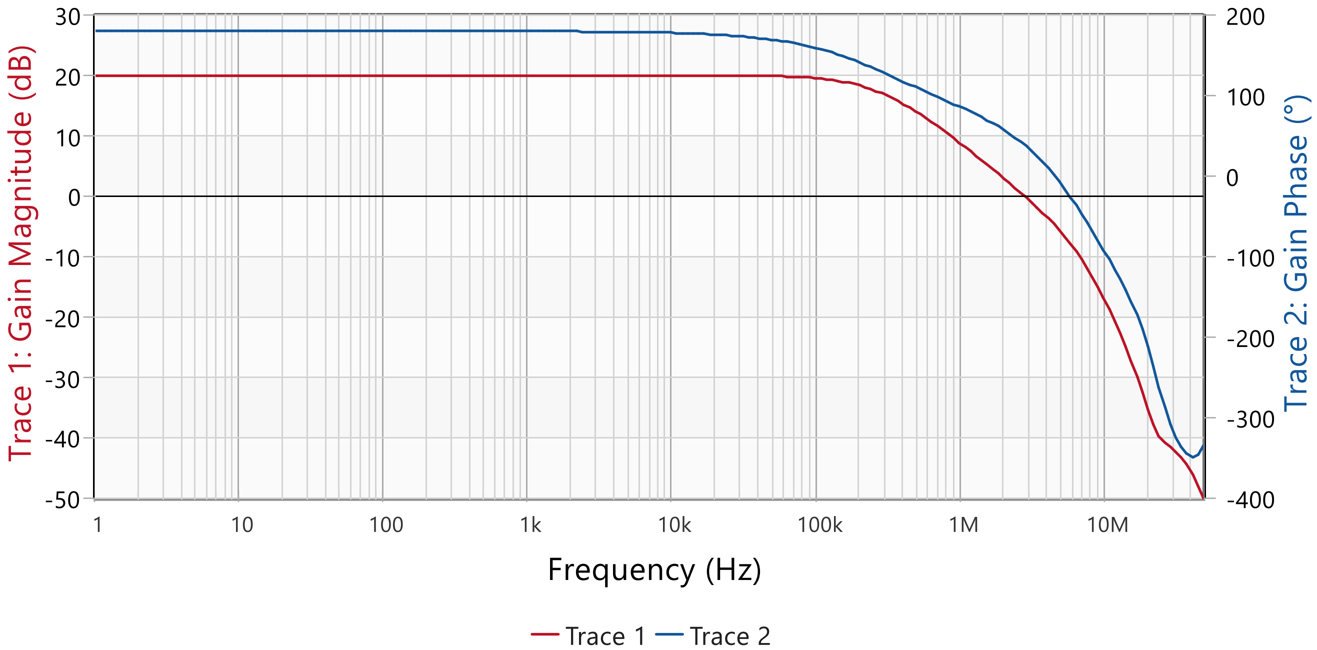
## Bode 100 - Application Note

# Operational Amplifier - Closed Loop Gain Measurement




By Tobias Schuster

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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 verify the calculated open and closed loop gain by measuring them. Also, the gain-bandwidth product and phase are of interest.

This application note shows how the small-signal closed loop gain of an operational amplifier can be measured using the Bode 100.

# 2 Measurement Tasks

In this application note we measure the closed-loop gain of an inverting op-amp circuit featuring the operational amplifier TL072CP.
The inverting circuit is designed to have a Gain of -10 and 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.

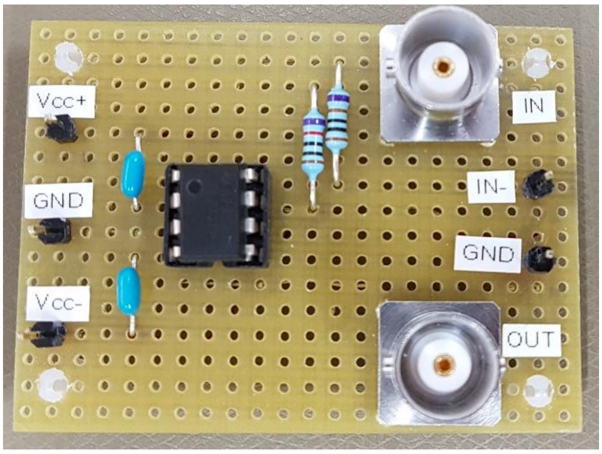


Figure 1: inverting op-amp on a PCB

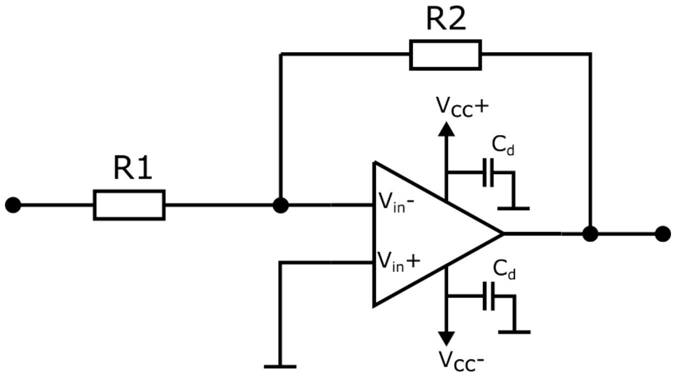


Figure 2: inverting op-amp circuit diagram

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

The closed-loop gain $A_{CL}$ of this op-amp circuit is 10 (20 dB) with a 180° phase shift.

# 3 Measurement Setup & Result

## 3.1 Measurement Setup

As mentioned before we measure the closed loop gain of the op-amp in an inverting configuration.

To do so, the Bode 100 is connected to the circuit as shown in the following figure:

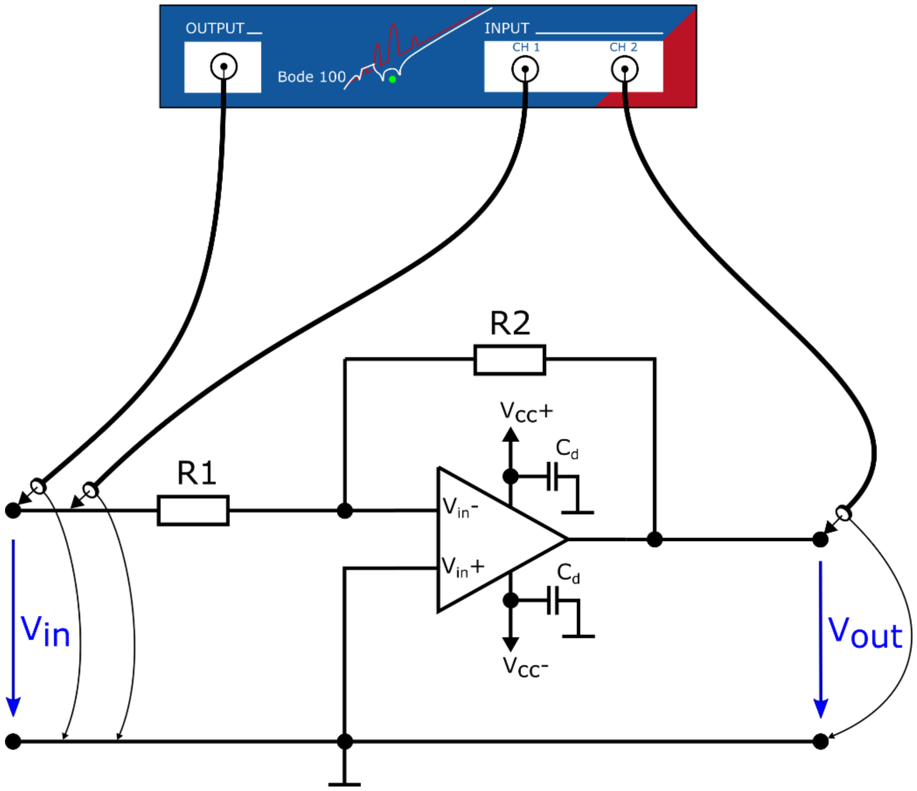


Figure 3: Schematic of measurement setup

Connect the Bode 100 output as well as the Channel 1 to the input of the inverting op-amp circuit. To measure the closed loop gain, Channel 2 must be connected to the output of the op-amp circuit.

We recommend using BNC cables 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 our case this is ±15 V.

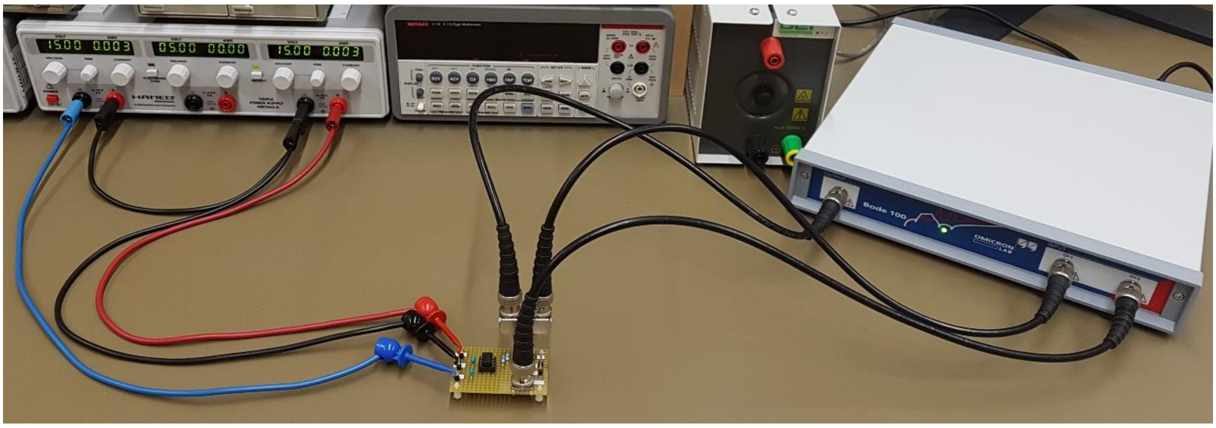

Figure 4: Measurement connection setup

## 3.2 Bode Analyzer Suite Setup

To setup the Bode 100 for the measurement, select the measurement type “Gain / Phase” and set the measurement settings as follows:

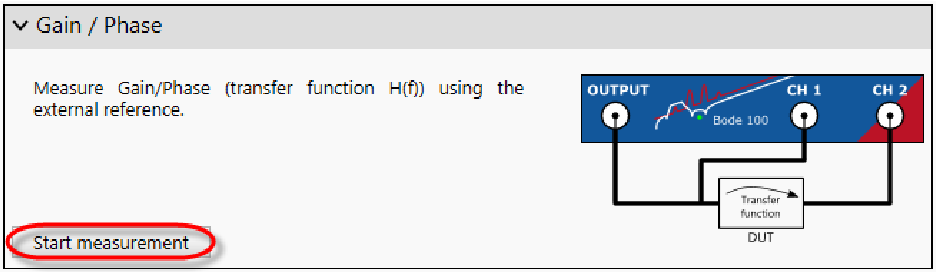


Figure 5: measurement mode

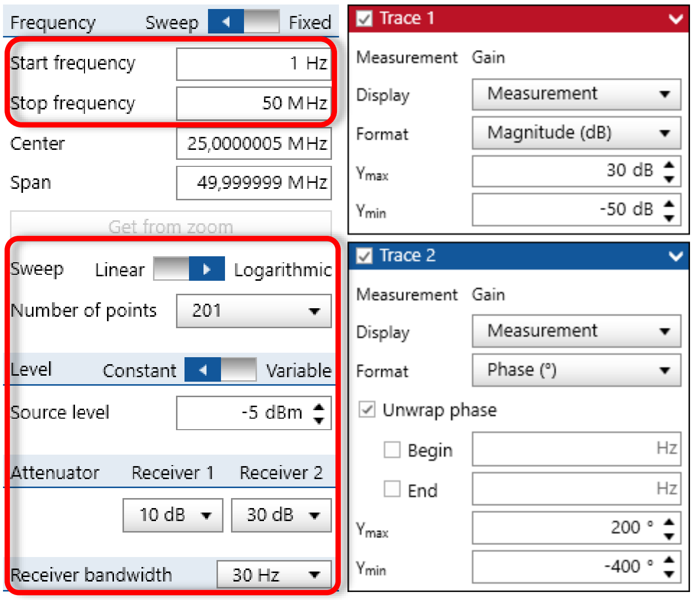


Figure 6: measurement & trace settings

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 in our case).
In addition, we recommend to use the “Unwrap phase” function of the Bode 100 for better visibility of the phase curve due to the high phase changes.

## 3.3 Calibration

First, a full-range THRU calibration is performed to eliminate the influence of the cables and probes. To do so, channel 1 as well as channel 2 are connected to the output of the Bode 100 using the BNC T adapter which is delivered with the Bode 100.

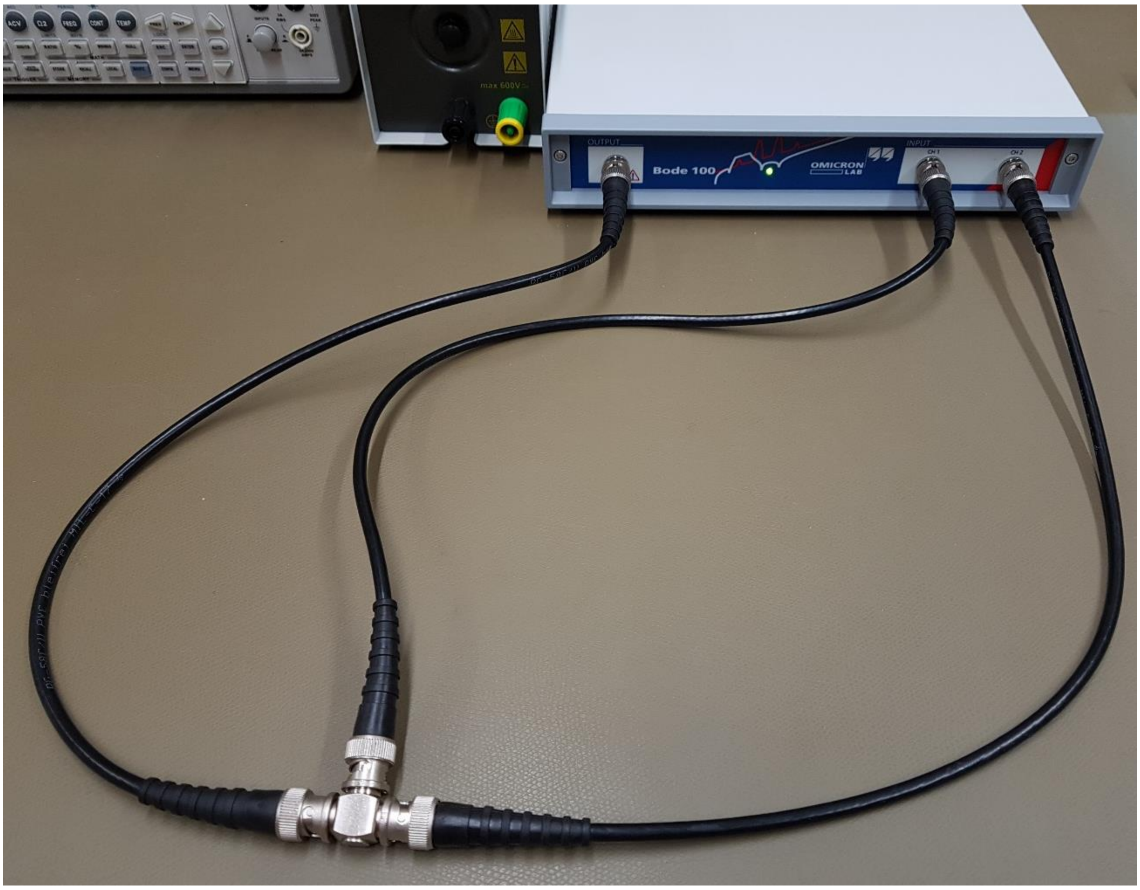


Figure 7: THRU calibration setup

## 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 curve shows the op-amp clipping which was caused by excessive output signal of the Bode 100 (10 dBm)
- the red curve shows the correct measurement of the op-amp without any noise and no clipping error (-5 dBm output of Bode 100)

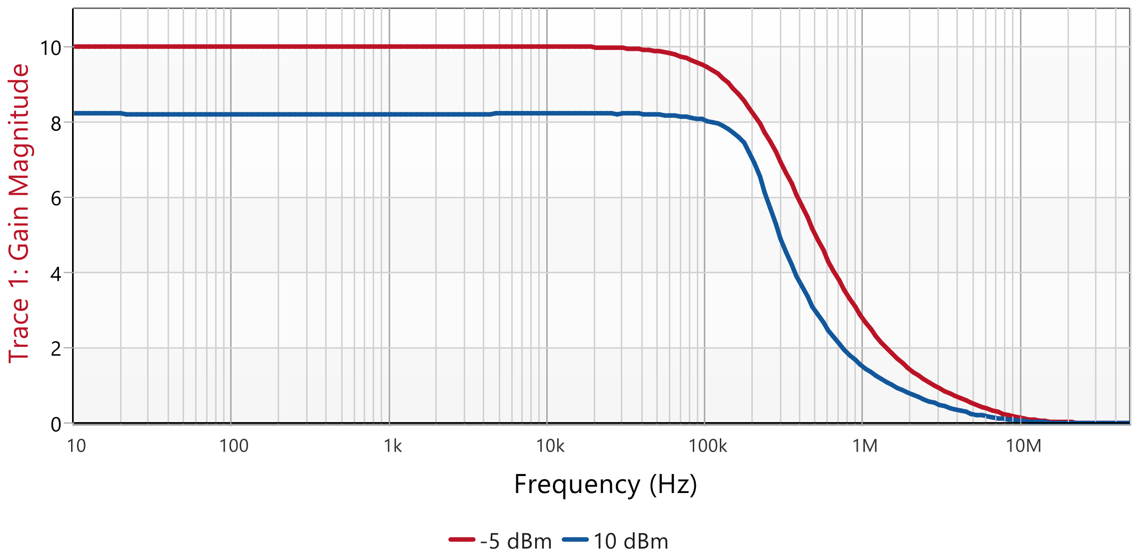


Figure 8: Measurement result - Gain

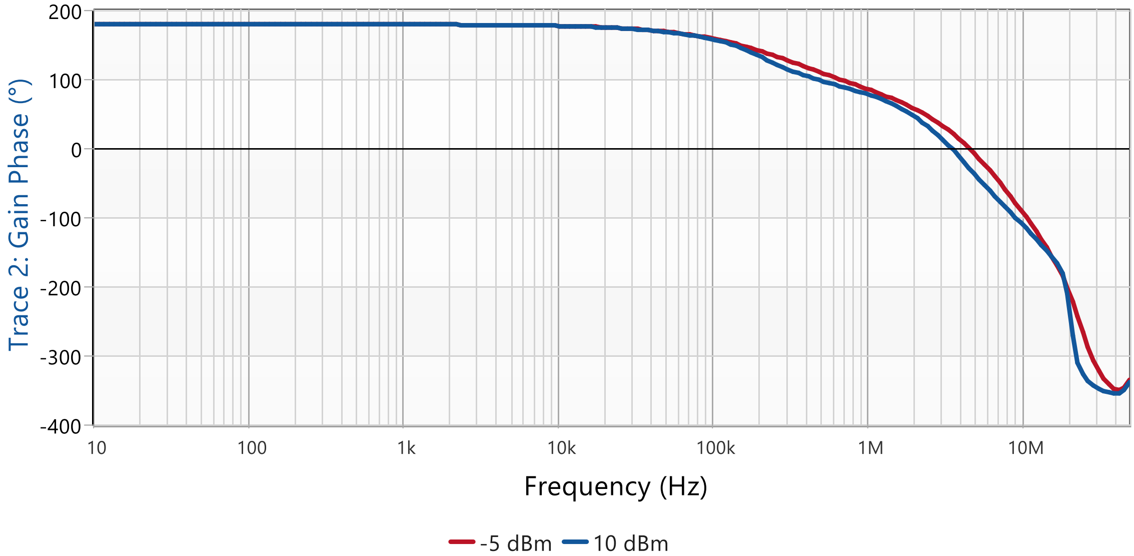


Figure 9: Measurement result - Phase

To be sure that the measurement result is displaying the small signal response, the output level of the Bode 100 must be decreased until the gain and phase plot does not change anymore. Decrease by another 3 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.

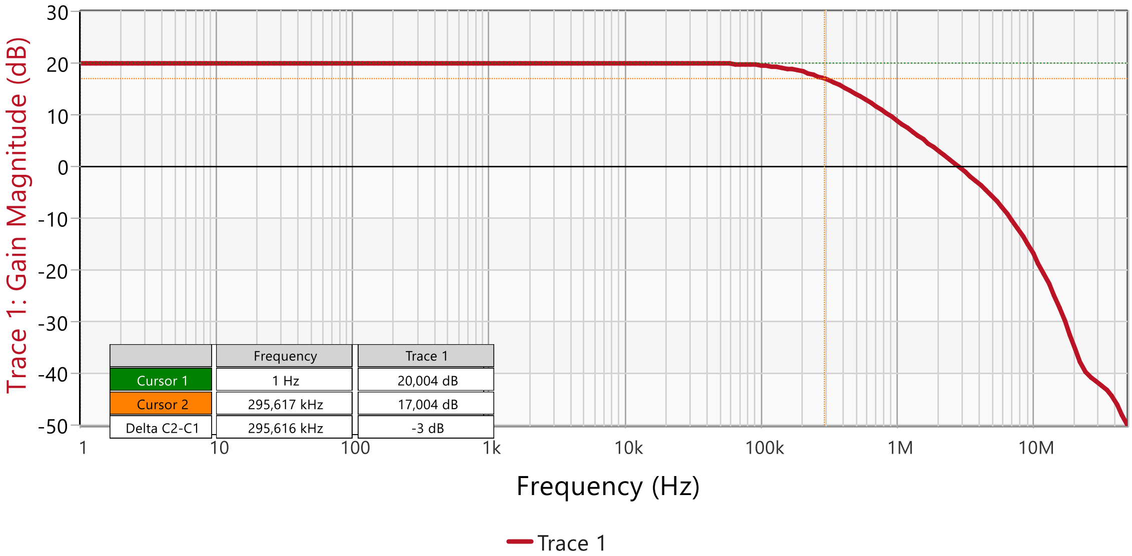


Figure 10: measurement result - 3 dB gain-bandwidth product

Measuring the -3 dB bandwidth can be easily done with the cursor function of the Bode 100. Place cursor 1 to the start frequency and then, type -3 dB into the *Delta C2-C1* field. This will force the cursor 2 to jump to the -3 dB frequency.
Now, the -3 dB bandwidth product can be read: **≈300 kHz** in our case.

# 4 Conclusion

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

With the cursor functions of the Bode Analyzer Suite, the bandwidth of the amplifier circuit can be measured fast and easy. Also, the adjustable input attenuators of the Bode 100 help to measure very high gains. The unwrap phase function also helps for better visibility of the phase curve.

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**Europe, Middle East, Africa**
OMICRON electronics GmbH
Phone: +43 59495
Fax: +43 59495 9999

**Asia Pacific**
OMICRON electronics Asia Limited
Phone: +852 3767 5500
Fax: +852 3767 5400

**Americas**
OMICRON electronics Corp. USA
Phone: +1 713 830-4660
Fax: +1 713 830-4661

**info@omicron-lab.com • www.omicron-lab.com**