
Hello, and welcome to the TI Precision Lab supplement for op amp bandwidth. This lab will walk through detailed calculations, SPICE simulations, and real-world measurements that greatly help to reinforce the concepts established in the op amp bandwidth video series.

## Required/Recommended Equipment

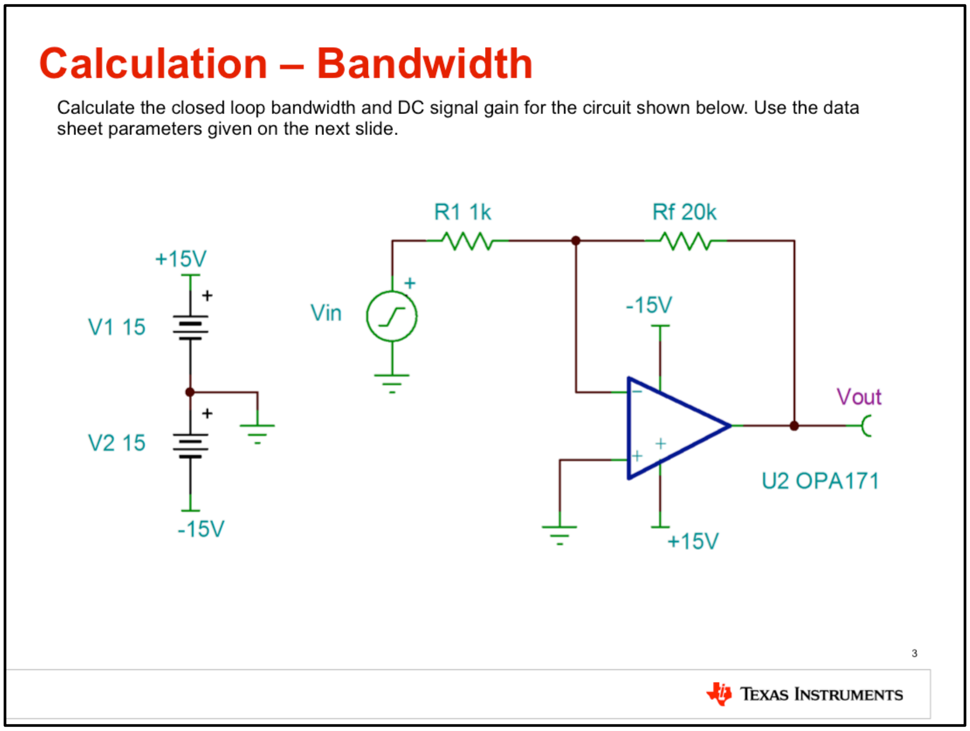
- Calculation
  - Pencil and paper
  - **Recommended:** MathCAD, Excel, or similar
- Simulation
  - SPICE simulation software
  - **Recommended:** TINA-TI™
- Measurement
  - TI Precision Labs PCB from Texas Instruments
  - Bode plotter
  - ±15V power supply
  - **Recommended:** National Instruments VirtualBench™

Texas Instruments 2

The detailed calculation portion of this lab can be done by hand, but calculation tools such as MathCAD or Excel can help greatly.

The simulation exercises can be performed in any SPICE simulator, since Texas Instruments provides generic SPICE models of the op amps used in this lab. However, the simulations are most conveniently done in TINA-TI, which is a free SPICE simulator available from the Texas Instruments website. TINA simulation schematics are embedded in the presentation.

Finally, the real-world measurements are made using a printed circuit board, or PCB, provided by Texas Instruments. If you have access to standard lab equipment, you can make the necessary measurements with any Bode plotter and ±15V power supply. However, we highly recommend the VirtualBench from National Instruments. The VirtualBench is an all-in-one test equipment solution which connects to a computer over USB or Wi-Fi and provides power supply rails, analog signal generator and oscilloscope channels, and a 5 ½ digit multimeter for convenient and accurate measurements. This lab is optimized for use with the VirtualBench.



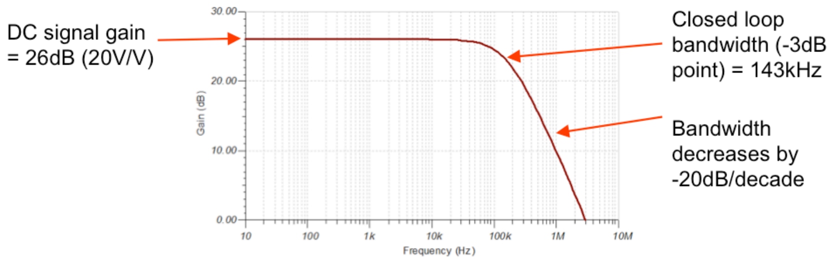

First, calculate the closed loop bandwidth and DC signal gain for the circuit shown here, using the techniques and equations given in the bandwidth lecture. Use the data sheet parameters given on the next slide.

# Calculation – Bandwidth

1. Use excerpt from data sheet below to fill in the table and AC transfer function:

| PARAMETER | | OPA171 | | | |
|---|---|---|---|---|---|
| | | MIN | TYP | MAX | UNIT |
| Gain bandwidth product | GBP | | 3.0 | | MHz |
| Slew rate | SR | | 1.5 | | V/µs |

| | |
|---|---|
| **Closed Loop Bandwidth:** | $GBP/G_n$ = 3MHz/21= 143kHz. |
| **Signal Gain at DC** | $G_{CL}$ = -(Rf/R1) = -(20k/1k) = -20V/V |

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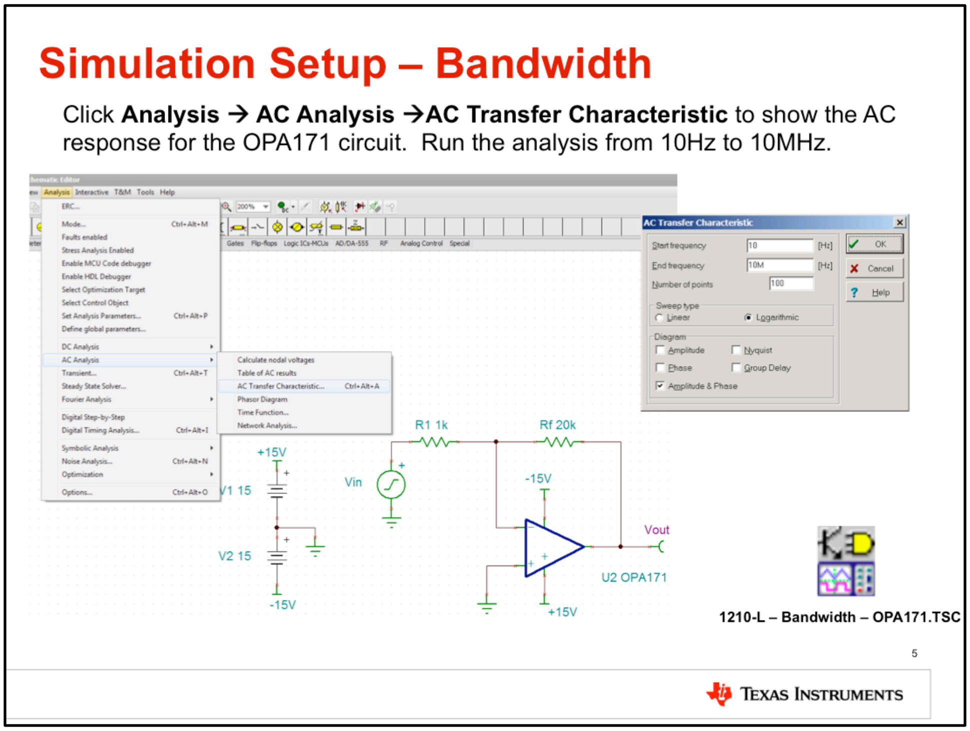
This circuit uses the OPA171. In order to perform the calculations, you need to know the gain bandwidth product and for that device. That value is given here.

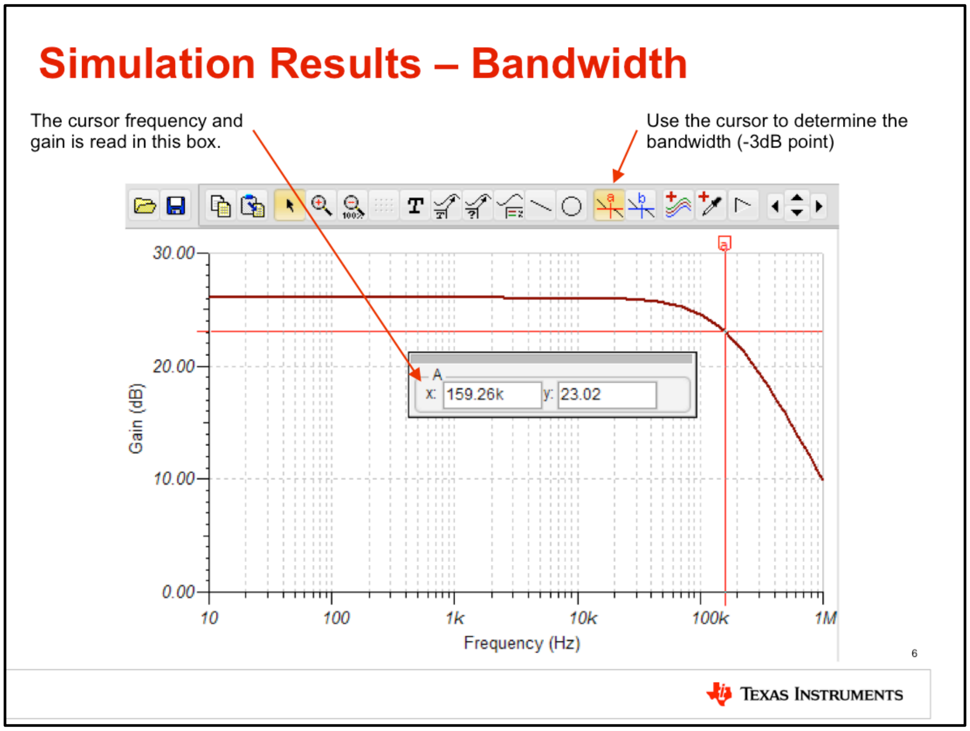
Enter your answers in the table in the middle of the slide. The solutions are already provided to allow you to check your work.

Also complete the AC transfer function for this circuit. Again, the solution is already provided.

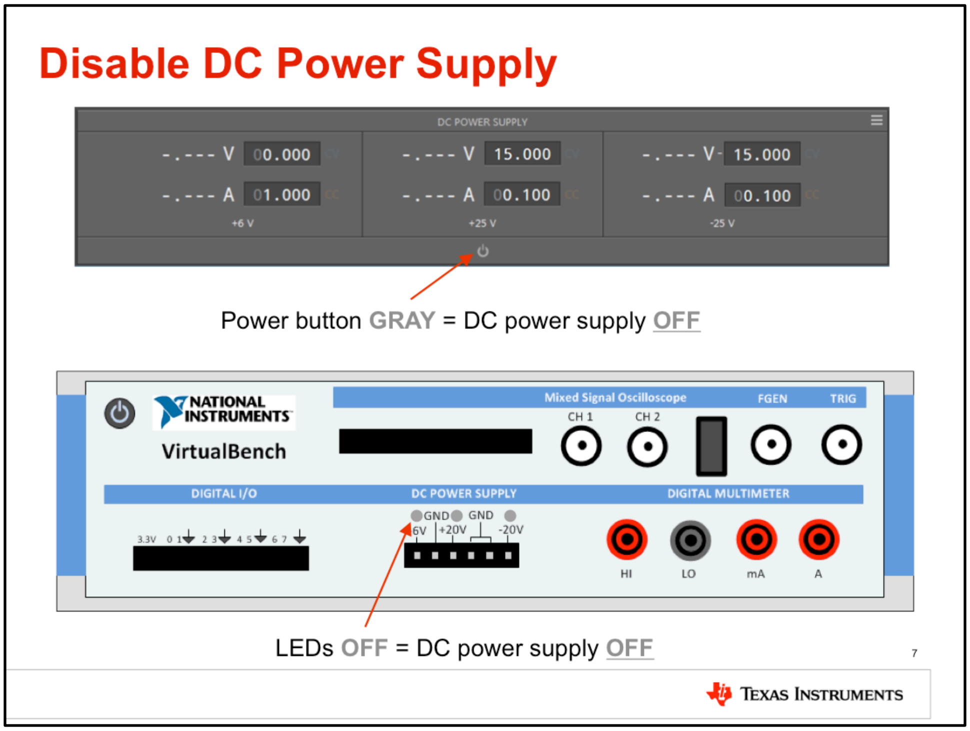



The next step is to run a SPICE simulation analysis for the AC transfer characteristic. This will allow us to see the op amp's closed loop bandwidth and DC gain in this configuration.

The necessary TINA-TI simulation schematic is embedded in this slide set – simply double-click the icon to open it. To run the analysis, click Analysis → AC Analysis → AC Transfer Characteristic. Run the analysis from 10Hz to 10MHz.

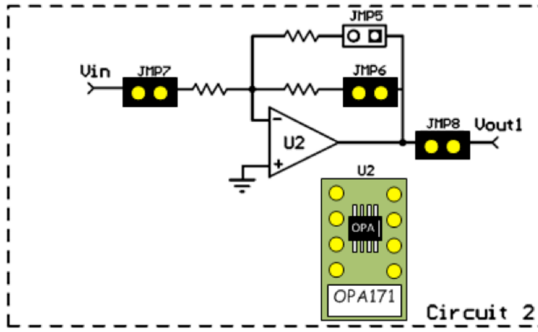



You should see a result similar to this. Enable the cursor, then check the DC gain, or gain at minimum frequency. The result will be 26dB, or 20V/V. Next, find the -3dB point, or the frequency where gain drops to 23dB. This occurs at 159kHz.




Make sure to disable the DC power supply before setting up the test PCB! In the VirtualBench software, click the power button in the DC Power Supply area to turn off the power. Check the front panel of the VirtualBench unit to make sure the LEDs are OFF! Also make sure that the Function Generator is OFF.

## Test Board Setup - Jumpers




| Jumper, Device | Description |
|---|---|
| **JMP6** | Select Rf = 20kΩ for gain = -20V/V |
| **JMP7** | Connect input to signal source |
| **JMP8** | Connect Circuit 2 output to Vout1 |
| **U2** | Install OPA171 |

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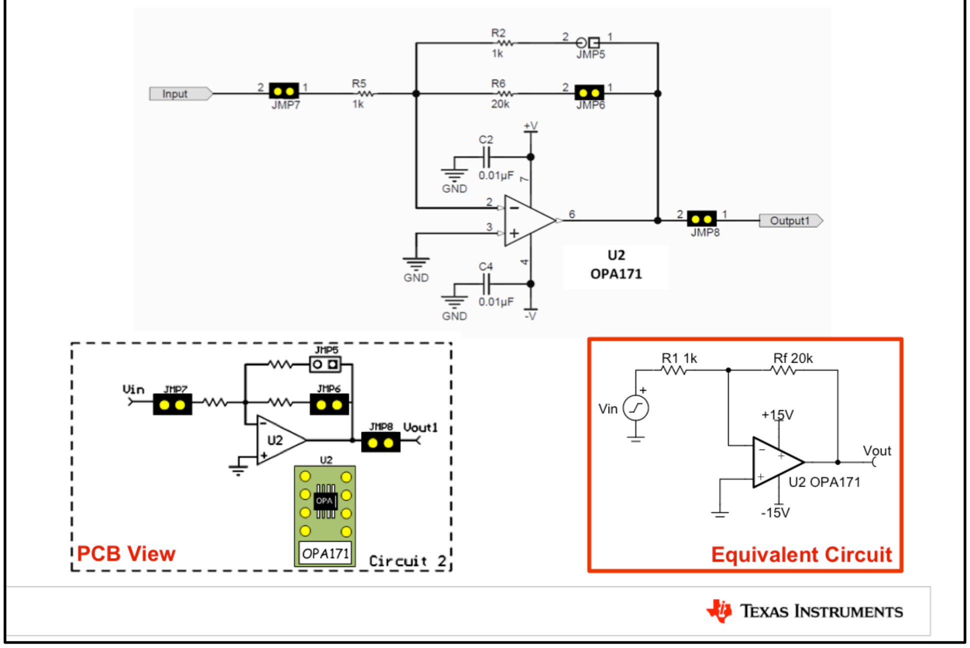
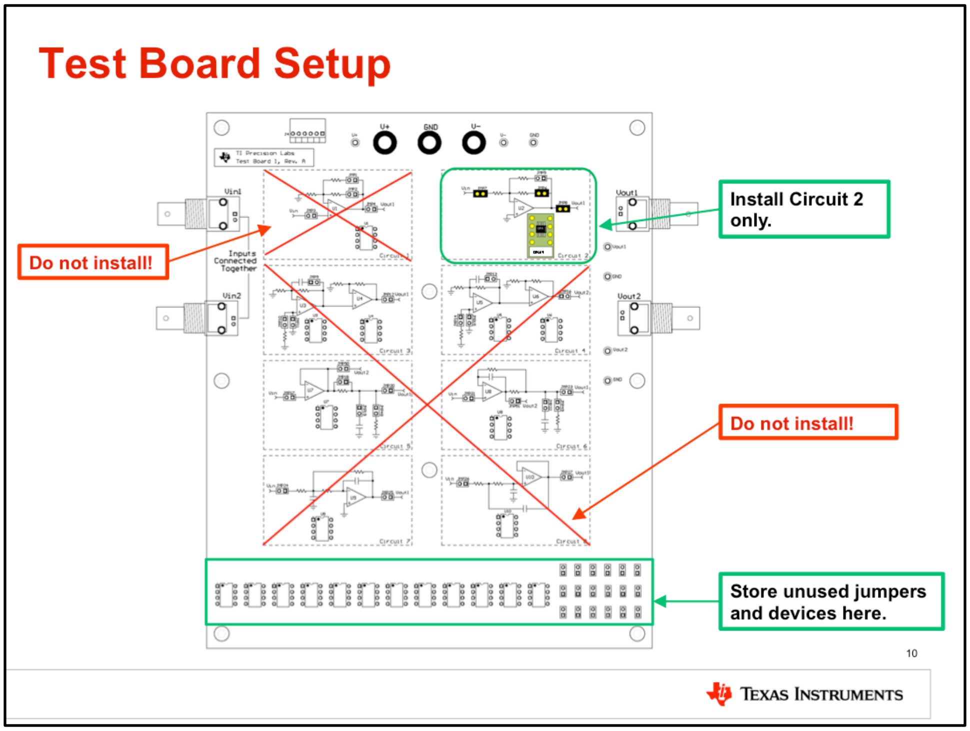
To prepare the test board for the measurement, install the jumpers and devices on circuit 2 as shown here.

Install JMP6, JMP7, and JMP8, as well as the OPA171 in socket U2.

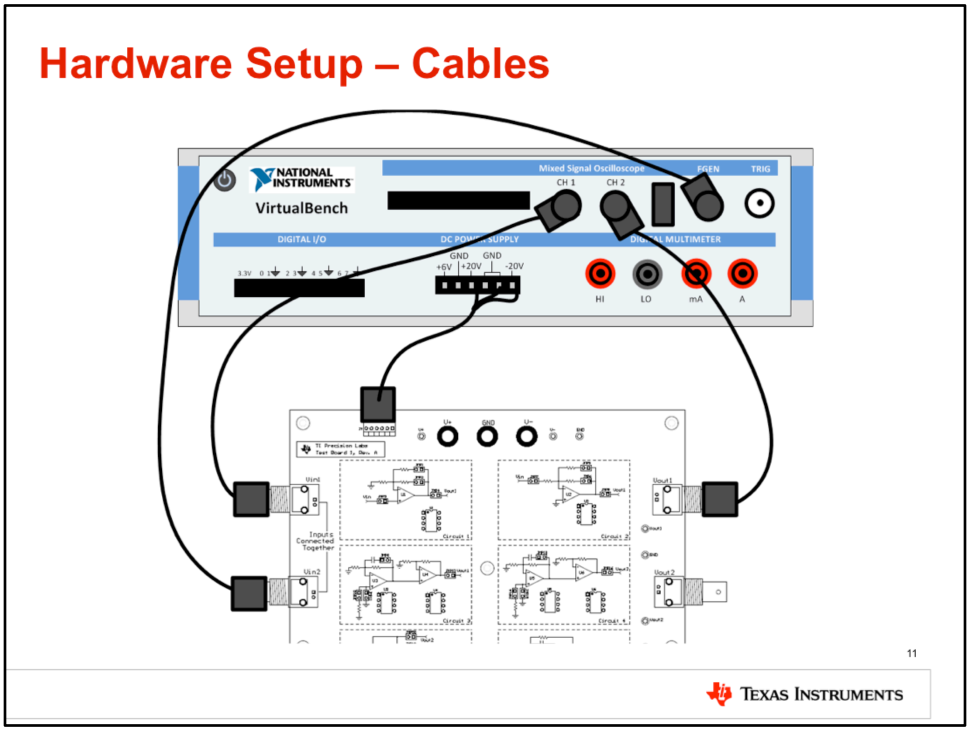
# Test Board Schematic – Circuit 2




It's now time to verify our calculations and simulations with real-world measurements. This slide shows the schematic for Circuit 2 on the TI Precision Labs test board. You will use this circuit to measure the bandwidth of the OPA171.

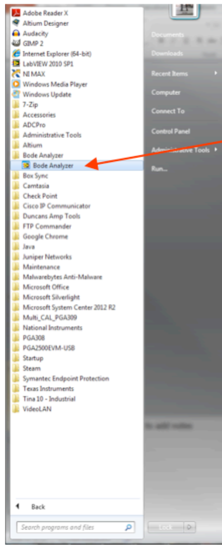



For this measurement, only circuit 2 is used. Do not install any jumpers or devices in any other circuits on the PCB! Remove any jumpers or devices from the unused circuits and store them in the storage area at the bottom of the test board.




This slide gives the connection diagram between the TI Precision Labs test board and the National Instruments VirtualBench. Connect the provided power cable to the DC power supply of the Virtual Bench and power connector J4 on the test board. Connect Vin2 on the test board to VirtualBench channel FGEN, or function generator. Then connect Vin1 on the test board to VirtualBench oscilloscope channel 1, and Vout1 on the test board to VirtualBench oscilloscope channel 2.

# VirtualBench Bode Analyzer



Install the Bode Analyzer software. Run the software by clicking **Start → All Programs → Bode Analyzer → Bode Analyzer**.

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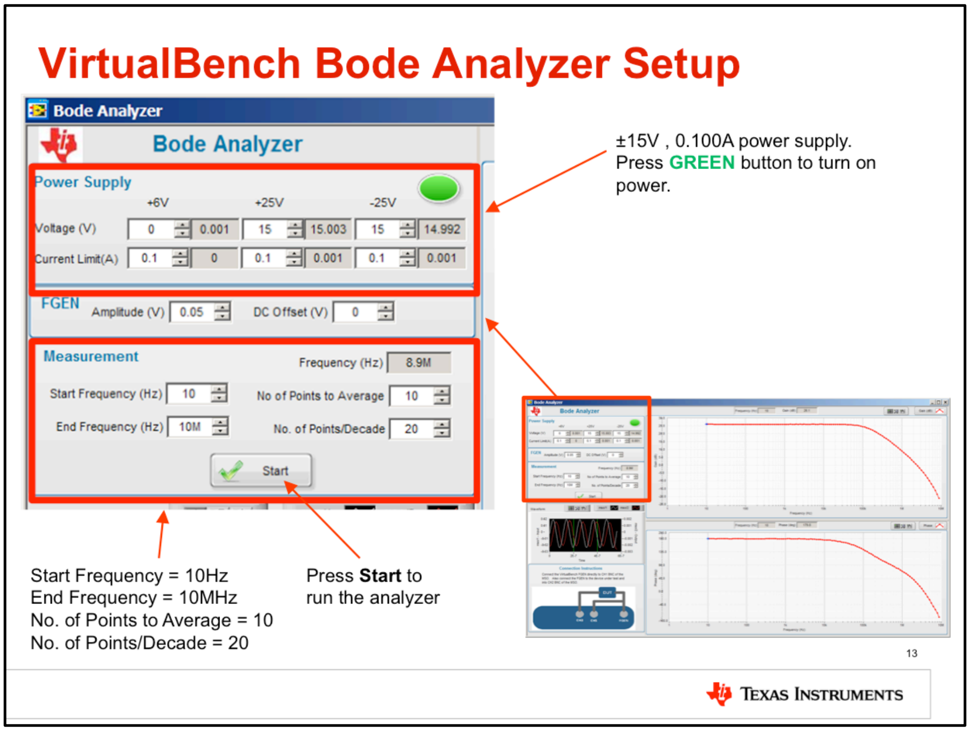
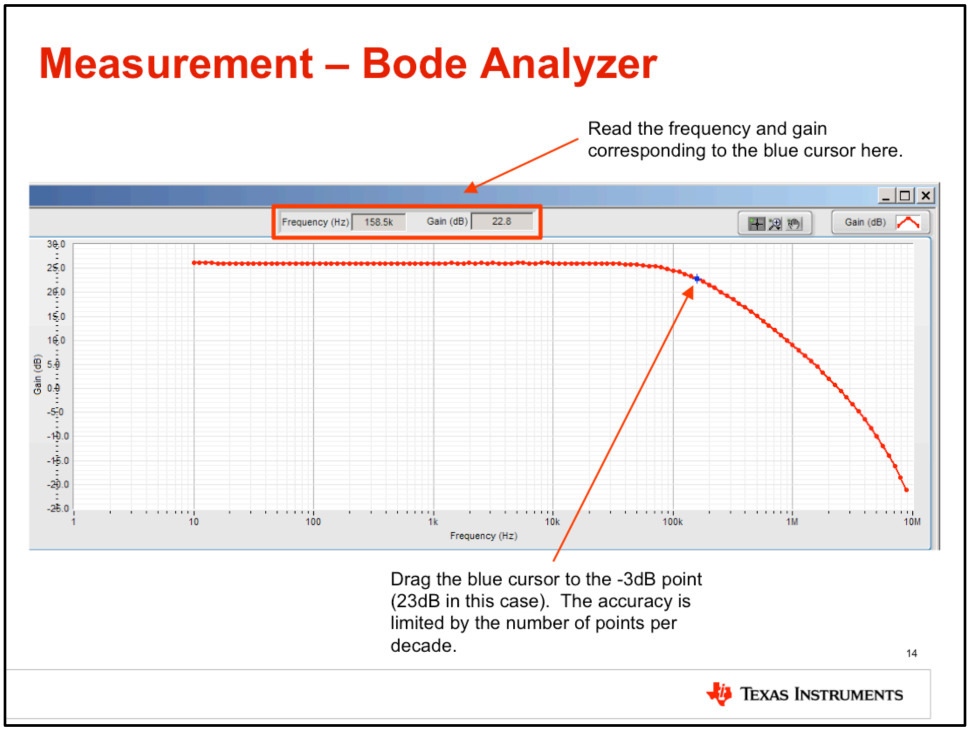
This lab requires additional Bode analyzer software. Install the software, then run it by clicking Start → All Programs → Bode Analyzer → Bode Analyzer.




In the configuration panel, set the power supply to ±15V, 0.1A. Press the green button to turn on the power.

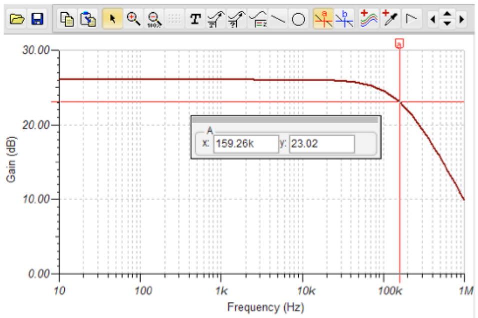
Set the start frequency to 10Hz and the end frequency to 10MHz. Set the number of points to average to 10, and the number of points per decade to 20. Press “Start” to run the Bode analyzer.

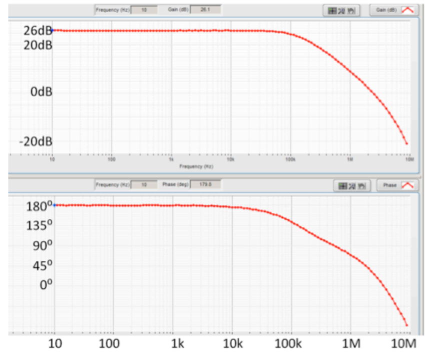



You should see a result similar to this. Enable the cursor, then drag the cursor to the -3dB point, or 23dB in this case. Take note of the frequency – in this case the result is 159kHz, although your results may vary slightly.

# Measurement Results – Bandwidth

1. Compare TINA-TI™ simulation results to measured results.




2. Compare the calculated, simulated, and measured bandwidth for the OPA171.

| Device | Calculated | Simulated | Measured |
|---|---|---|---|
| **OPA171** | 143kHz | 159kHz | 159kHz |

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Compare the bandwidth measurement of the VirtualBench to the simulated results from TINA-TI. Compare this to your calculated results. You should see very good correlation between all three values, although your numbers may vary slightly.


That concludes this lab – thank you for your time!