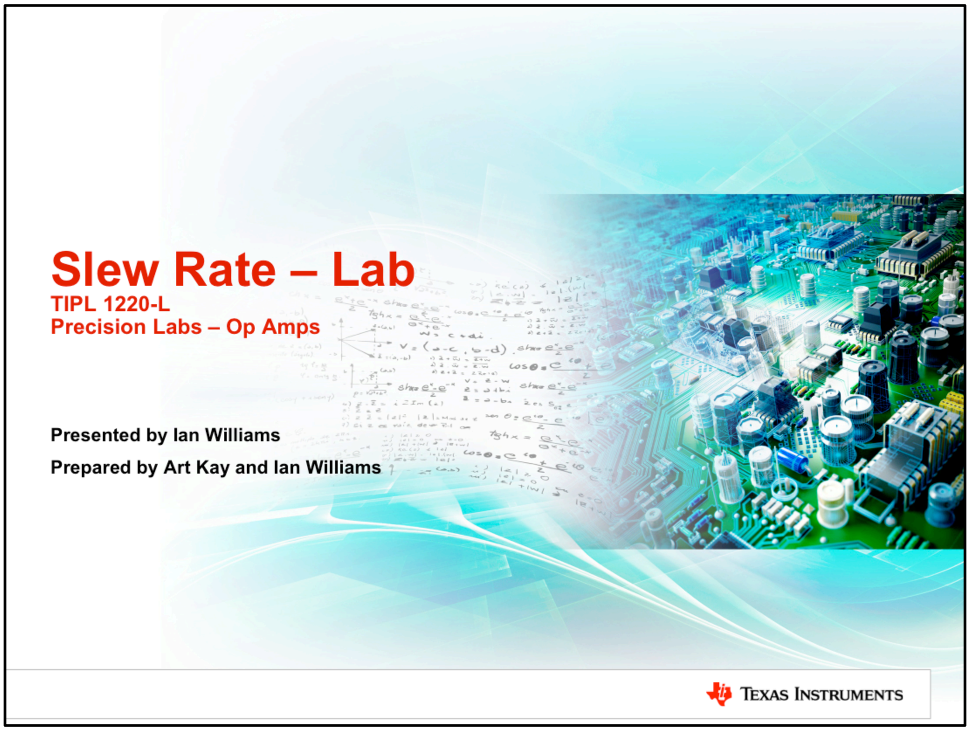
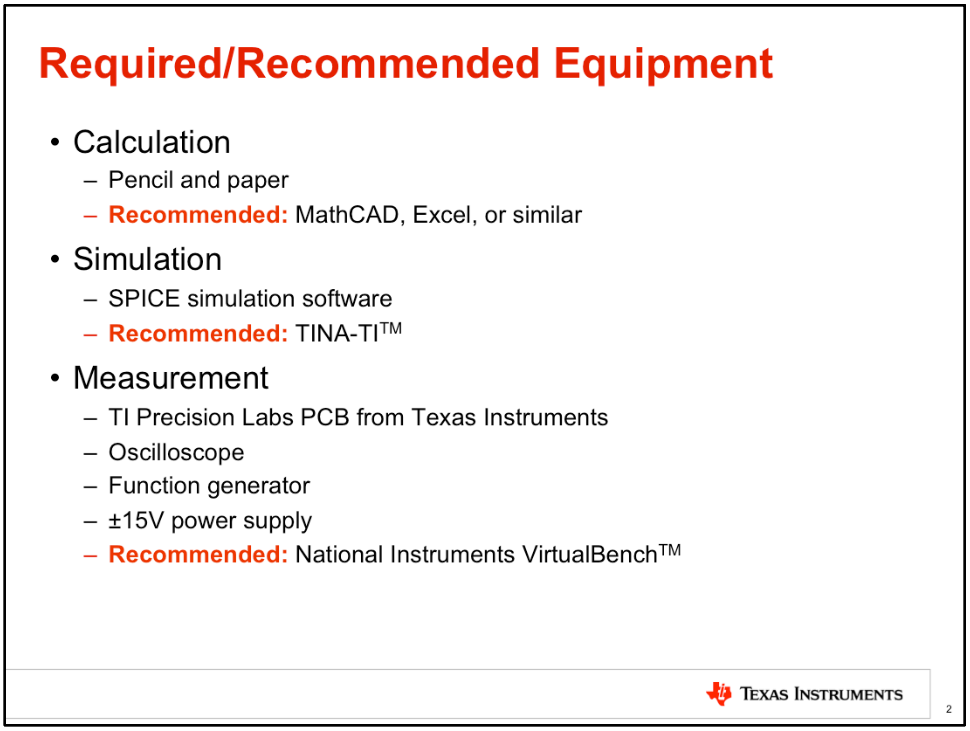



Hello, and welcome to the TI Precision Lab supplement for op amp slew rate. This lab will walk through detailed calculations, SPICE simulations, and real-world measurements that greatly help to reinforce the concepts established in the op amp slew rate video series.




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

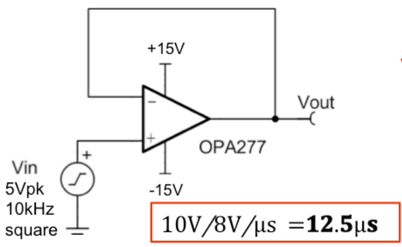
The simulation exercises can be performed in any SPICE simulator, since Texas Instruments provides generic SPICE models of the op amps used in this lab. However, the simulations are most conveniently done in TINA-TI, which is a free SPICE simulator available from the Texas Instruments website. TINA simulation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

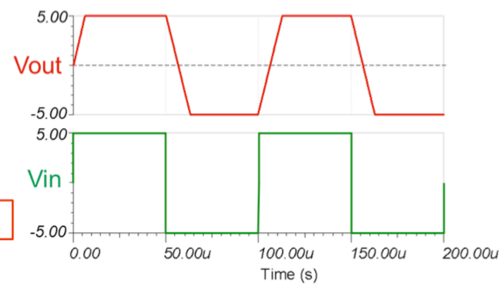
Finally, the real-world measurements are made using a printed circuit board, or PCB, provided by Texas Instruments. If you have access to standard lab equipment, you can make the necessary measurements with any oscilloscope, function generator, and ±15V power supply. However, we highly recommend the 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.

# Calculation – Slew Rate

Draw the output voltage waveform of the circuit shown below, based on the data sheet slew rate parameters given in the table.

| PARAMETER | | OPA735 | | | |
|---|---|---|---|---|---|
| | | MIN | TYP | MAX | UNIT |
| Gain-Bandwidth Product | GBW | | 1.0 | | MHz |
| Slew Rate | SR | | 0.8 | | V/µs |



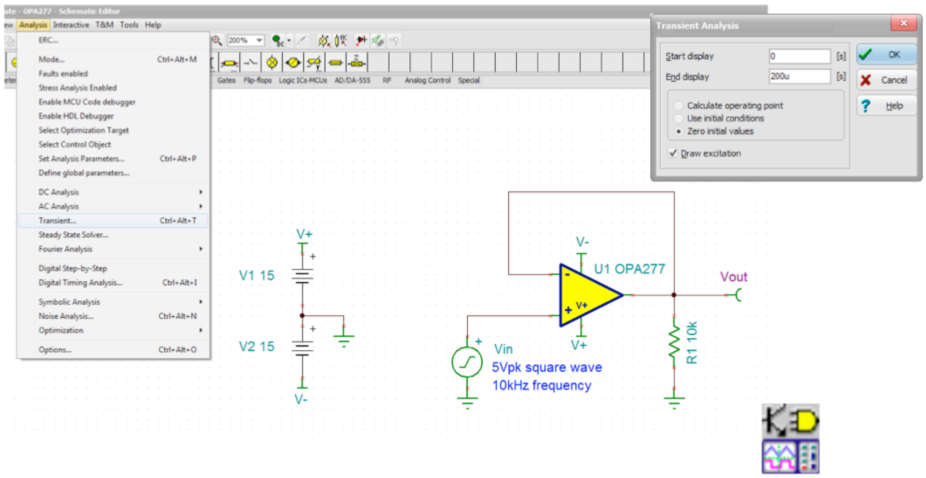






First, draw the output voltage waveform of the circuit shown below. Use the slew rate specifications given in the table and the techniques from the slew rate lecture. The answer is provided to allow you to check your work.

# Simulation Setup – Slew Rate

Click **Analysis → Transient** to show the slew rate limitations for the OPA277.
Run the analysis from 0µs to 200µs. The input is a 5Vpk, 10kHz square wave.

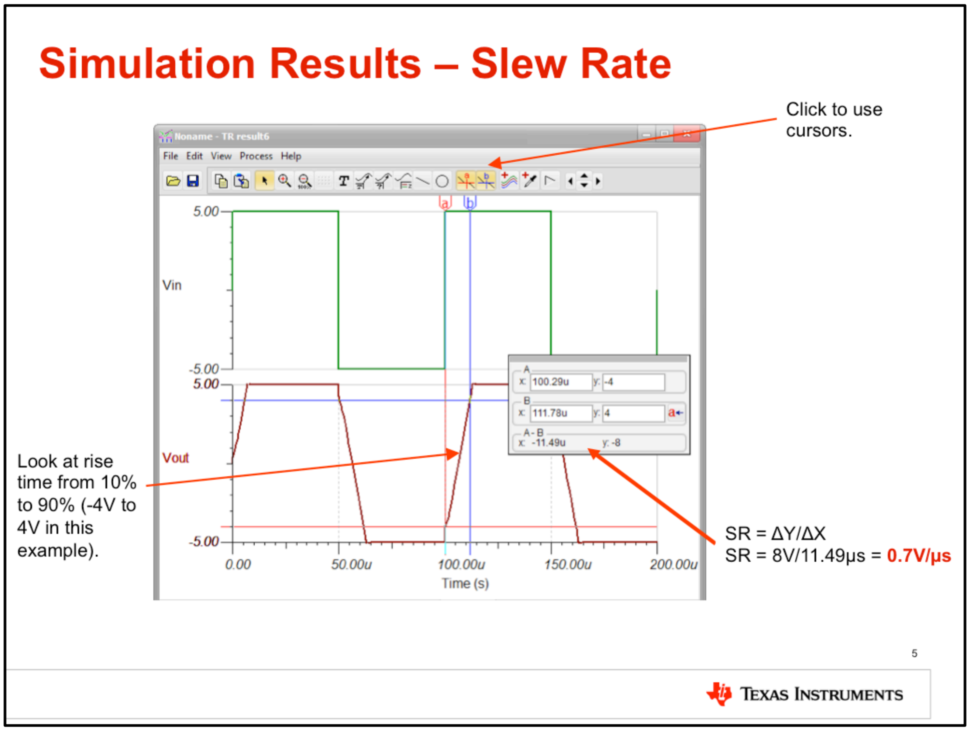



1220-L - Slew Rate - OPA277.TSC

TEXAS INSTRUMENTS

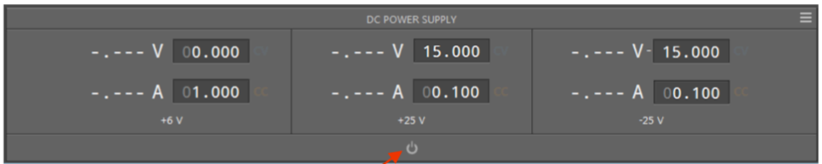
The next step is to run a SPICE simulation analysis for the transient output voltage behavior. This will allow us to see the op amp's output voltage response for a specified input signal, which in this case is a 5Vp, 10kHz square wave.

The necessary TINA-TI simulation schematic is embedded in this slide set – simply double-click the icon to open it. To simulate the transient output behavior, click Analysis → Transient. Run the analysis from 0µs to 200µs.

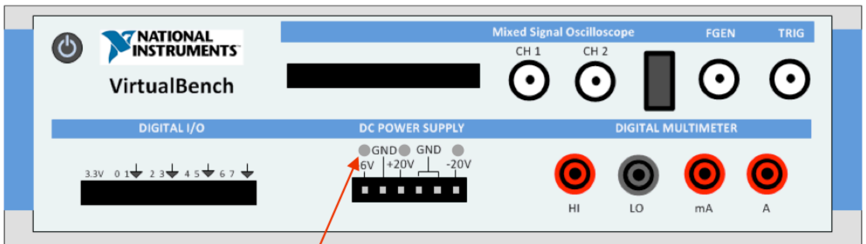



You should see a result similar to this. Vin is a square wave, as expected, but Vout must obey the slew rate limitations of the OPA277. You can see this effect in the rise time from 10% to 90% of the output, or -4V to 4V. Use the cursors to measure the time required to slew from -4V to 4V, and use the equation that slew rate = delta y over delta x to calculate the simulated slew rate of 0.7V/µs.

# Disable DC Power Supply




Power button GRAY = DC power supply OFF




LEDs OFF = DC power supply OFF

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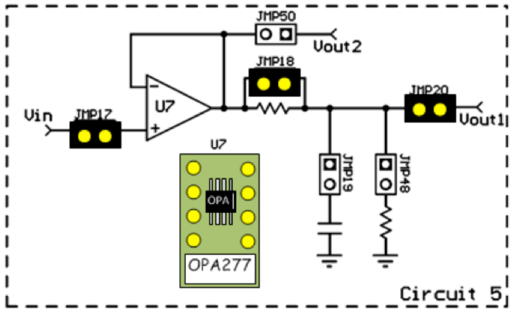
Make sure to disable the DC power supply before setting up the test PCB! In the VirtualBench software, click the power button in the DC Power Supply area to turn off the power. Check the front panel of the VirtualBench unit to make sure the LEDs are OFF! Also make sure that the function generator is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

# Test Board Setup – Jumpers




| Jumper, Device | Description |
|---|---|
| **JMP17** | Connect input to signal source. |
| **JMP18** | Short output resistance |
| **JMP20** | Connect Circuit 5 output to Vout1 |
| **U7** | Install OPA277 |

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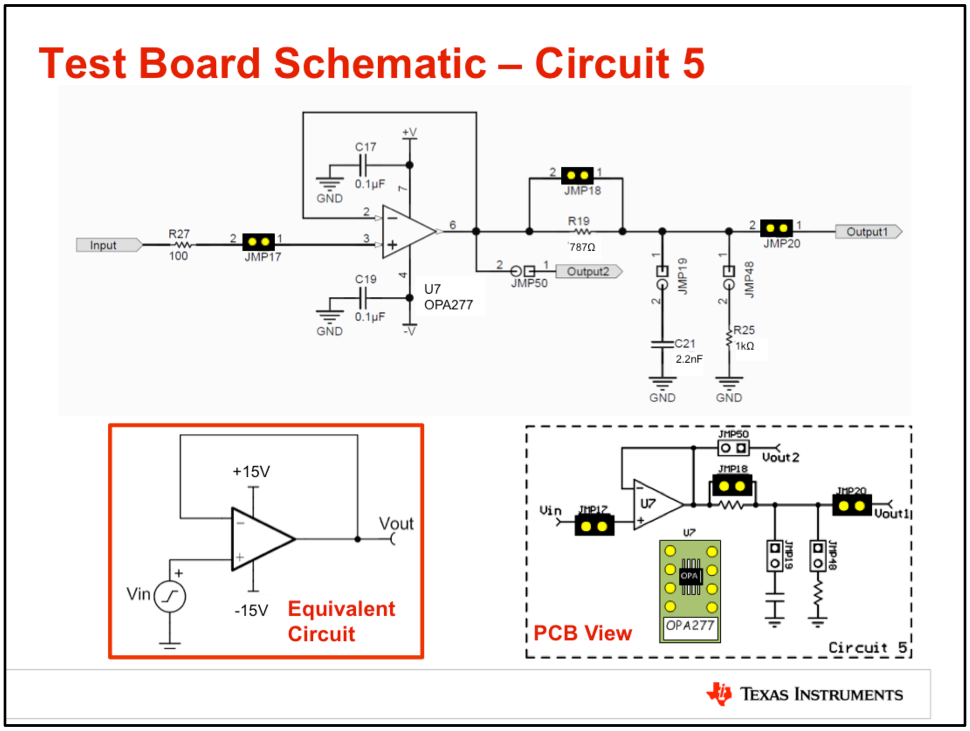
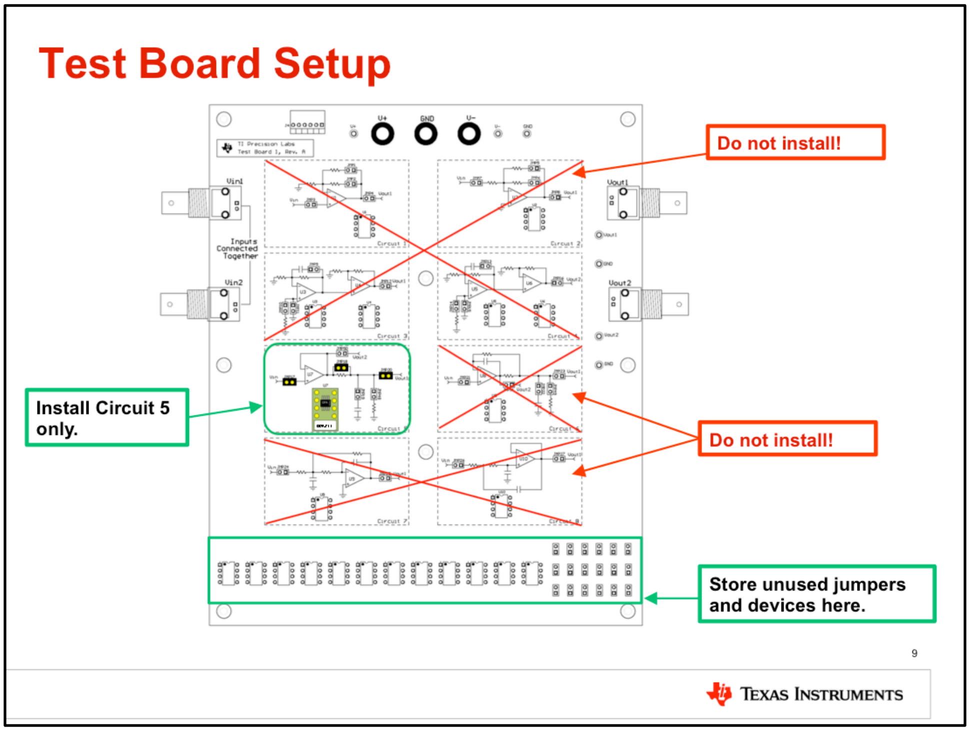
TEXAS INSTRUMENTS

To prepare the test board for the measurement, install the jumpers and devices on circuit 5 as shown here.

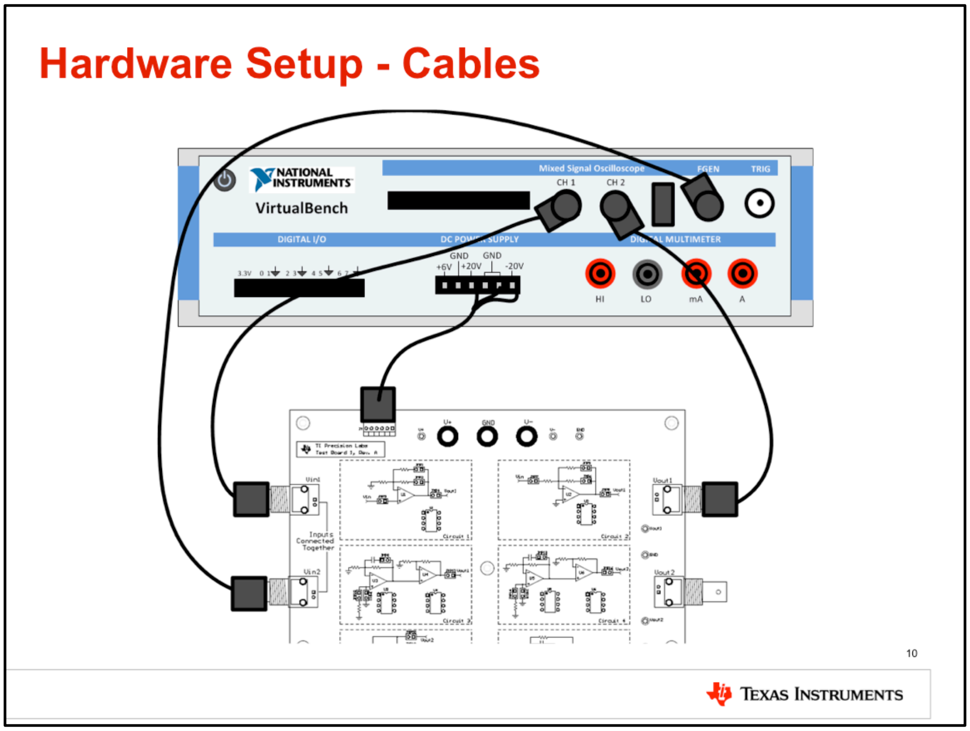
Install JMP17, JMP18, and JMP20, as well as the OPA277 in socket U7.



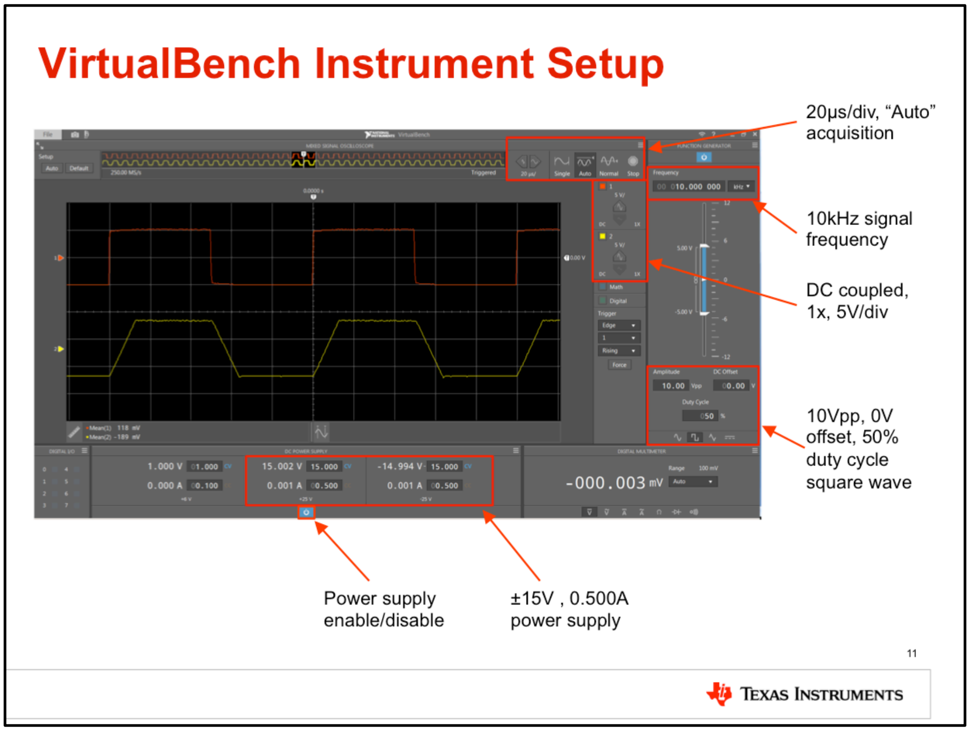

This slide shows the full schematic for Circuit 5 on the TI Precision Labs test board. You will use this circuit to measure the effect of slew rate limitations on the OPA277.




For the test board to function properly, it is important that you only install jumpers and devices in circuit 5. 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.

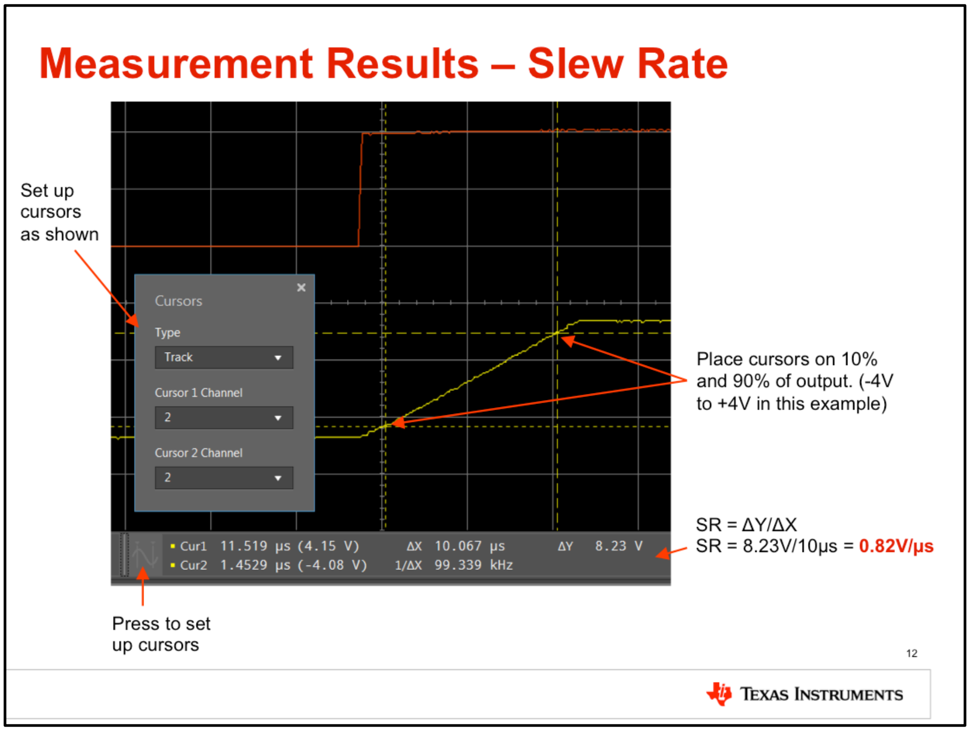



Next apply power to the National Instruments VirtualBench and connect it to your computer with a USB cable. The hardware should be detected as a virtual CD drive, and you can run the VirtualBench software directly from the drive. Once the software opens, configure the software as follows:

Set the time scale to 20us per division, with the acquisition mode set to "Auto." Enable channels 1 and 2 on the oscilloscope, and set them to 1x, DC-coupled mode, 5V/div. Enable the function generator and setup the signal as follows:

10kHz frequency, 10Vpp, 0V offset, 50% duty cycle square wave.

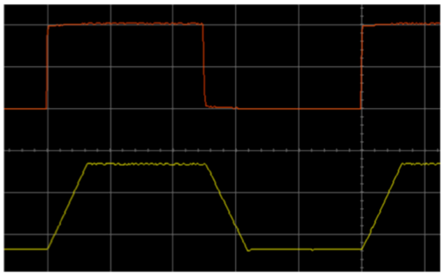
Set the +25V power supply to +15V, 0.500A. Set the -25V power supply to -15V, 0.500A. Press the power button to turn on the power supply rails.

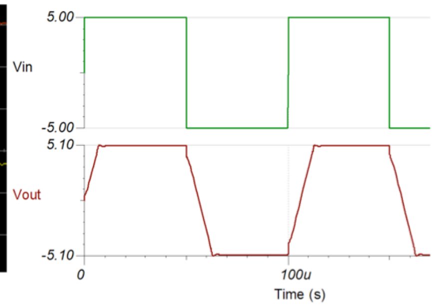



Let's now determine the measured slew rate. Enable cursors, set them up as shown, then place the cursors on 10% and 90% of the output signal. Take note of the time and voltage difference, and then calculate the slew rate using the equation given. In this example, a slew rate of 0.82V/us was measured. You may have different results in your experiment.

# Measurement Results – Slew Rate

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






| | |
|---|---|
| **Slew Rate (data sheet):** | 0.8V/µs |
| **Slew Rate (simulation):** | 8V / 11.49µs= 0.7V/µs |
| **Slew Rate (measurement):** | 8.23V / 10µs = 0.82V/µs |

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Compare the oscilloscope display of the VirtualBench to the simulation results from TINA-TI. Also compare the slew rate values from the data sheet, simulation, and measurement. They should all be similar, although you may get slightly different results.


That concludes this lab – thank you for your time!