# Demystifying Noise – KWIK Labs

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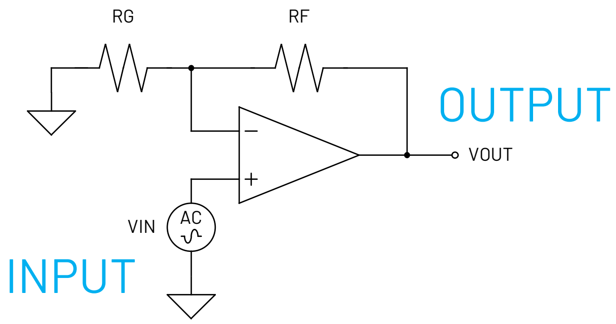
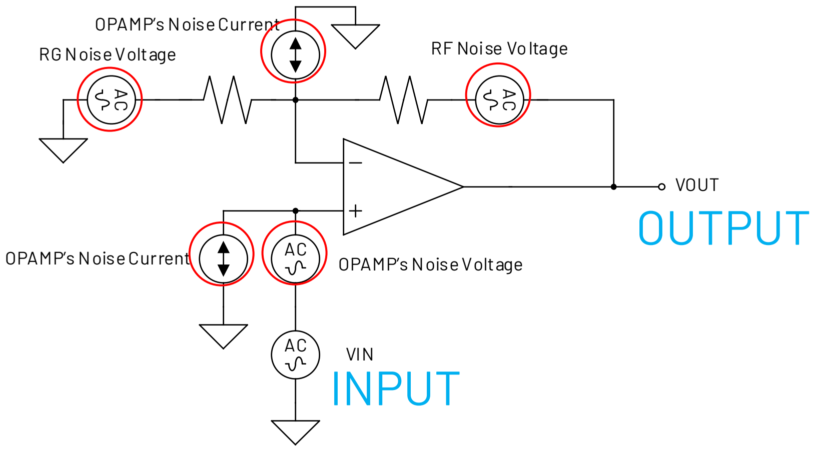
# Total Integrated Noise KWIK Lab Step-by-Step Guide

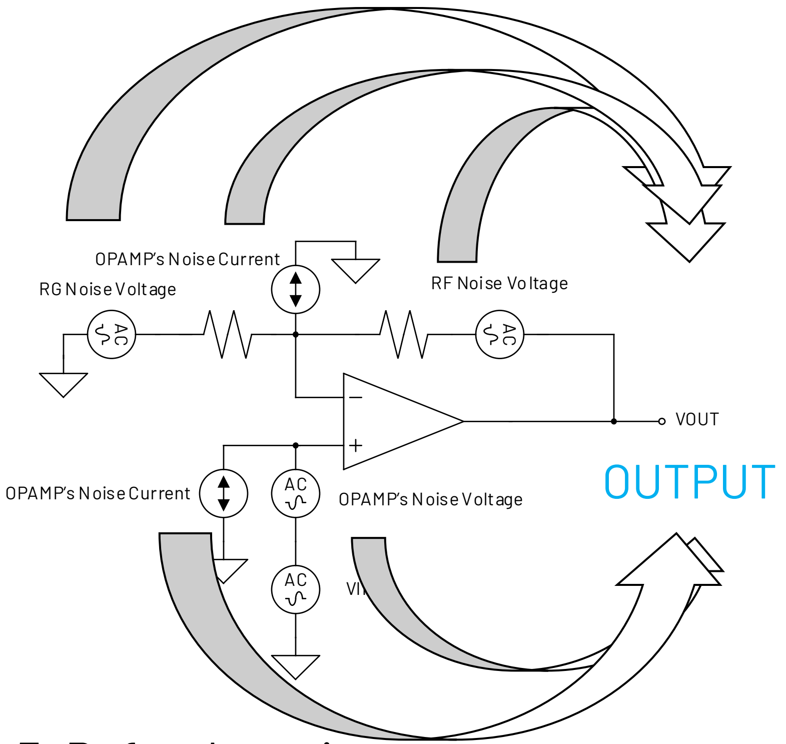
# Estimate the Noise




1. Start with your circuit



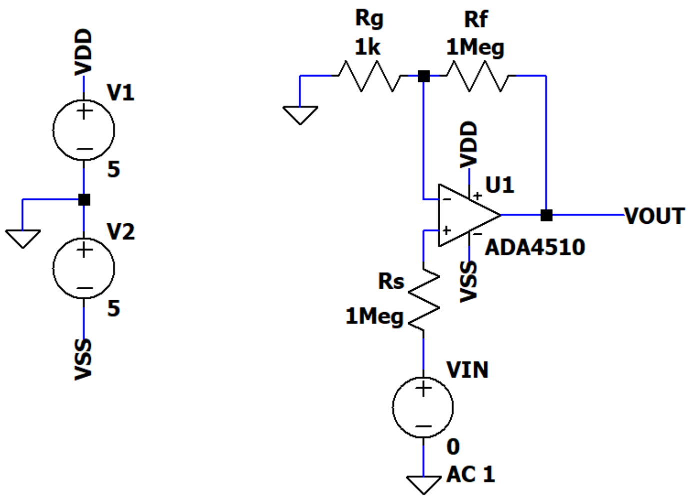

2. Add the noise sources




3. Refer the noise sources to the output

# Noise Bandwidth and Noise Sources

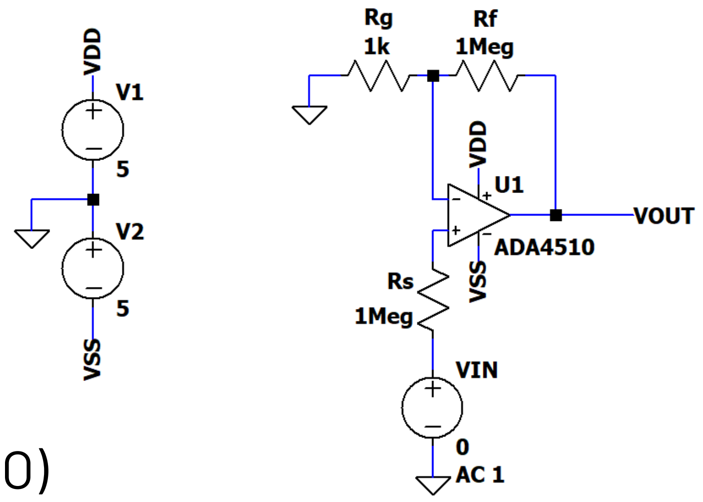
- Identify the noise Bandwidth
  - ADA4510 configured in G = 1001
    - Small-signal bandwidth = 10.4Mhz/1001 = 10.4kHz
    - Noise bandwidth = 10.4Khz * 1.57 = 16.3kHz




- Identify each noise source:
  - Rg = 1k ➔4nV/SQRT-Hz
  - Rf = 1M➔127nV/SQRT-Hz
  - Rs = 1M➔127nV/SQRT-Hz
  - ADA4510 ➔Vn = 5nV/SQRT-Hz (@16.3kHz)
  - ADA4510 ➔ In- = 200fA/SQRT-Hz (@16.3kHz)
  - ADA4510 ➔ In+ = 200fA/SQRT-Hz (@16.3kHz)

# Refer to the Output

- Refer each Noise Source to the Output:
  - Rg = 1k ➔4nV/SQRT-Hz*1000 = 4µV/SQRT-Hz (RTO)
  - Rf = 1M➔127nV/SQRT-Hz*1 = 127nV/SQRT-Hz (RTO)
  - Rs = 1M➔127nV/SQRT-Hz*1001 = 127µV/SQRT-Hz (RTO)
  - ADA4510 ➔Vn = 5nV/SQRT-Hz (@16.3kHz)*1001 = 5µV/SQRT-Hz (RTO)
  - ADA4510 ➔ In- = 200fA/SQRT-Hz (@16.3kHz) *1M= 200nV/SQRT-Hz (RTO)
  - ADA4510 ➔ In+ = 200fA/SQRT-Hz (@16.3kHz)*1M*1001 = 200µV/SQRT-Hz (RTO)



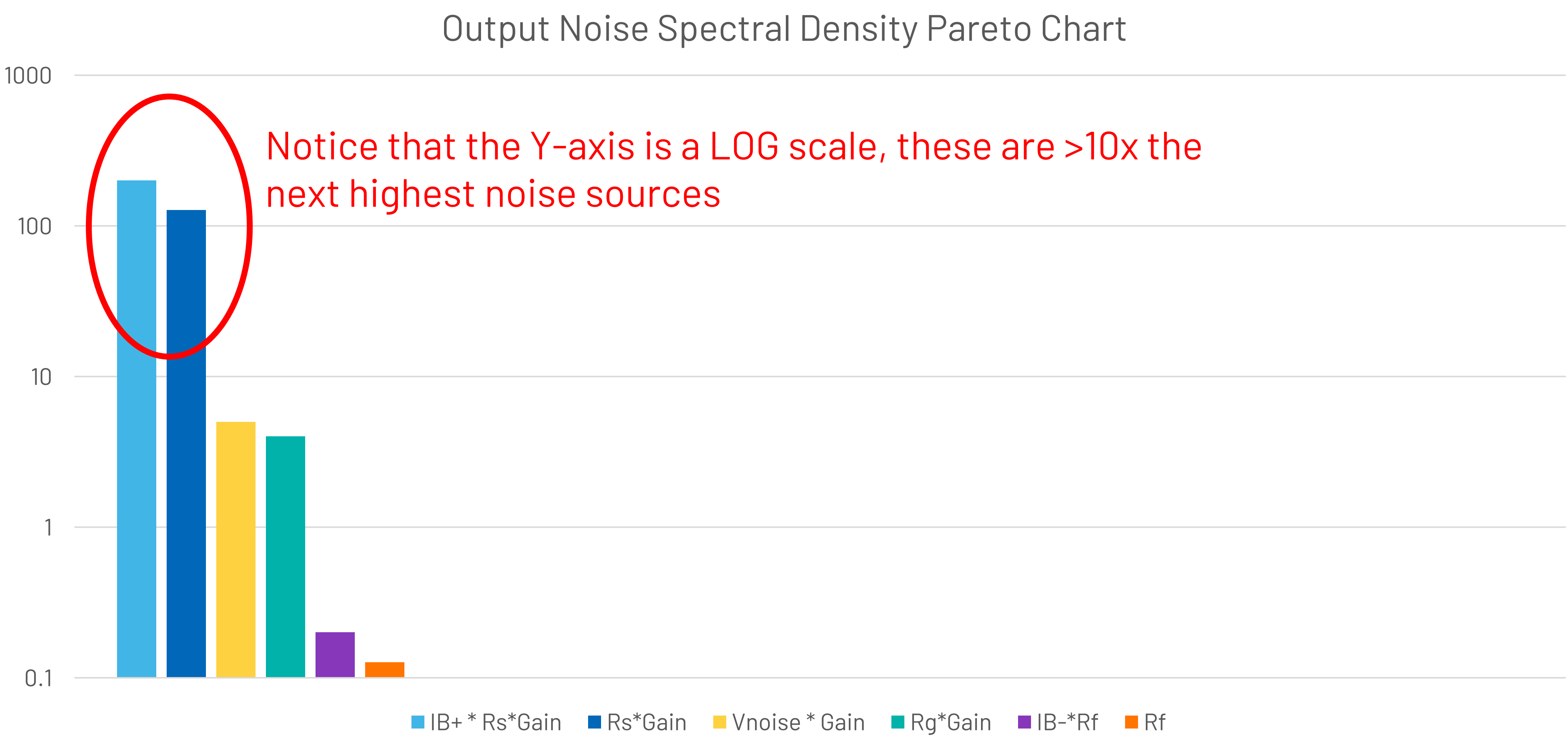

Sum the NSD at the output:

$$V_{OUT_{NSD@16.3kHz}} = \sqrt{\left(4\mu V/\sqrt{Hz}\right)^2 + \left(127nV/\sqrt{Hz}\right)^2 + \left(127\mu/\sqrt{Hz}V\right)^2 + \left(5\mu V/\sqrt{Hz}\right)^2 + \left(200nV/\sqrt{Hz}\right)^2 + \left(200\mu V/\sqrt{Hz}\right)^2} = 237\mu V/\sqrt{Hz}$$

Estimate the Total Noise:

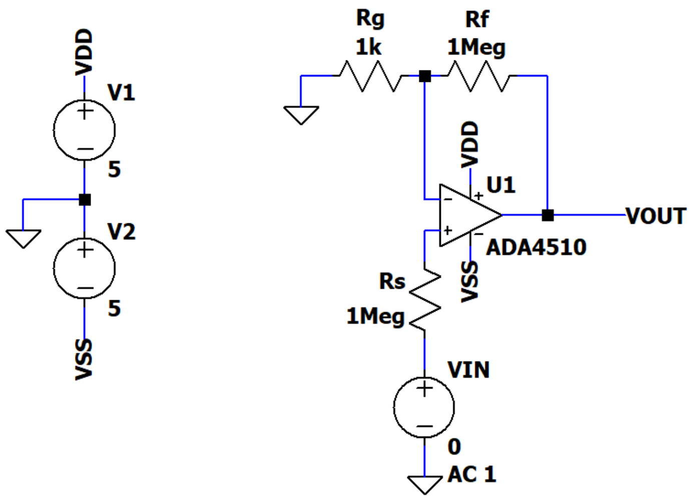
$$V_{OUT_{TOTALNOISE_{V_{PP}}}} = 6.6 \times 237\mu V/\sqrt{Hz} \times \sqrt{16.3kHz} = 200mV_{PP}$$

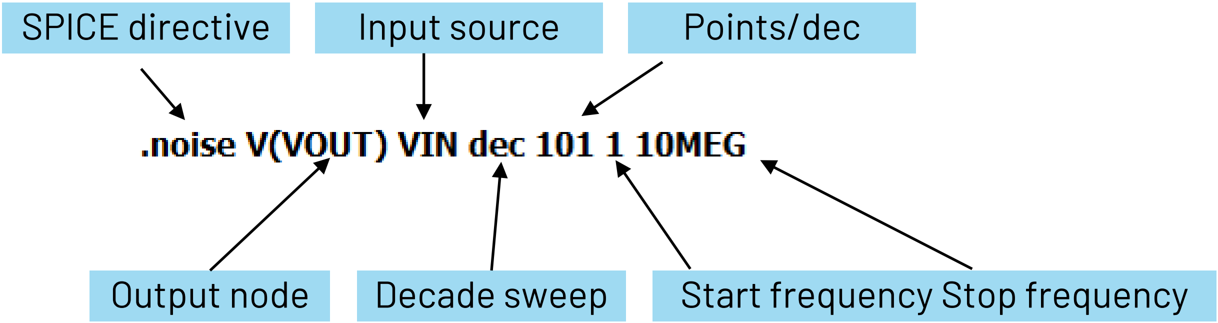
# Identify Dominant Noise Sources



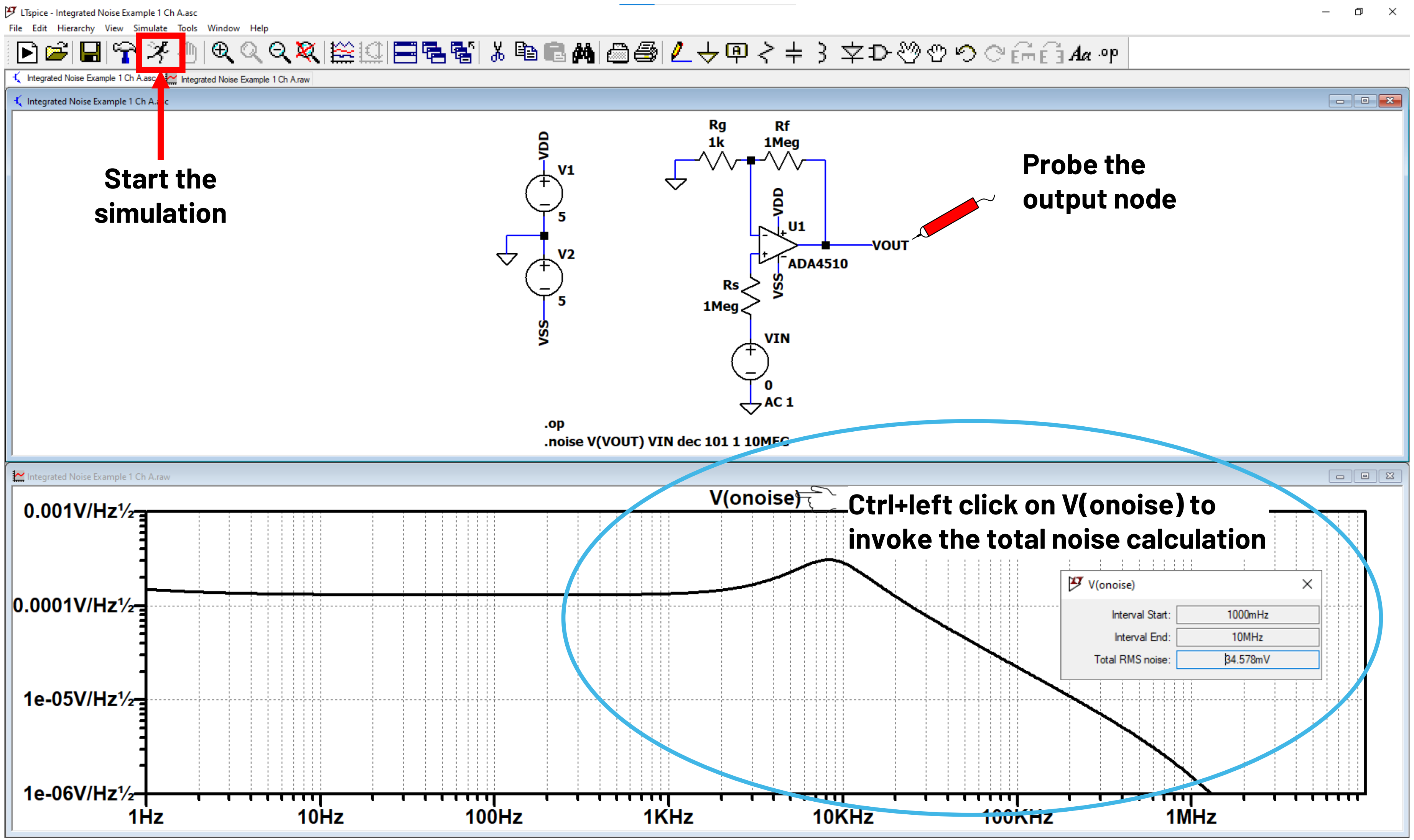
# Simulating Noise in LTSpice

- Add the .noise command as a SPICE directive with the listed arguments:
  - <u>Output</u>: The <u>**node**</u> where you want to examine the ***output referred noise***
  - <u>Input</u>: The <u>**source**</u> where you want to examine the ***input referred noise***
  - <u>Type of sweep</u>: octave, decade, linear or list
  - <u>Number of points</u>: per octave, per decade, etc
  - <u>Start Frequency</u>: Lowest frequency in the sweep in Hz
  - <u>Stop Frequency</u>: Highest frequency in the sweep in Hz

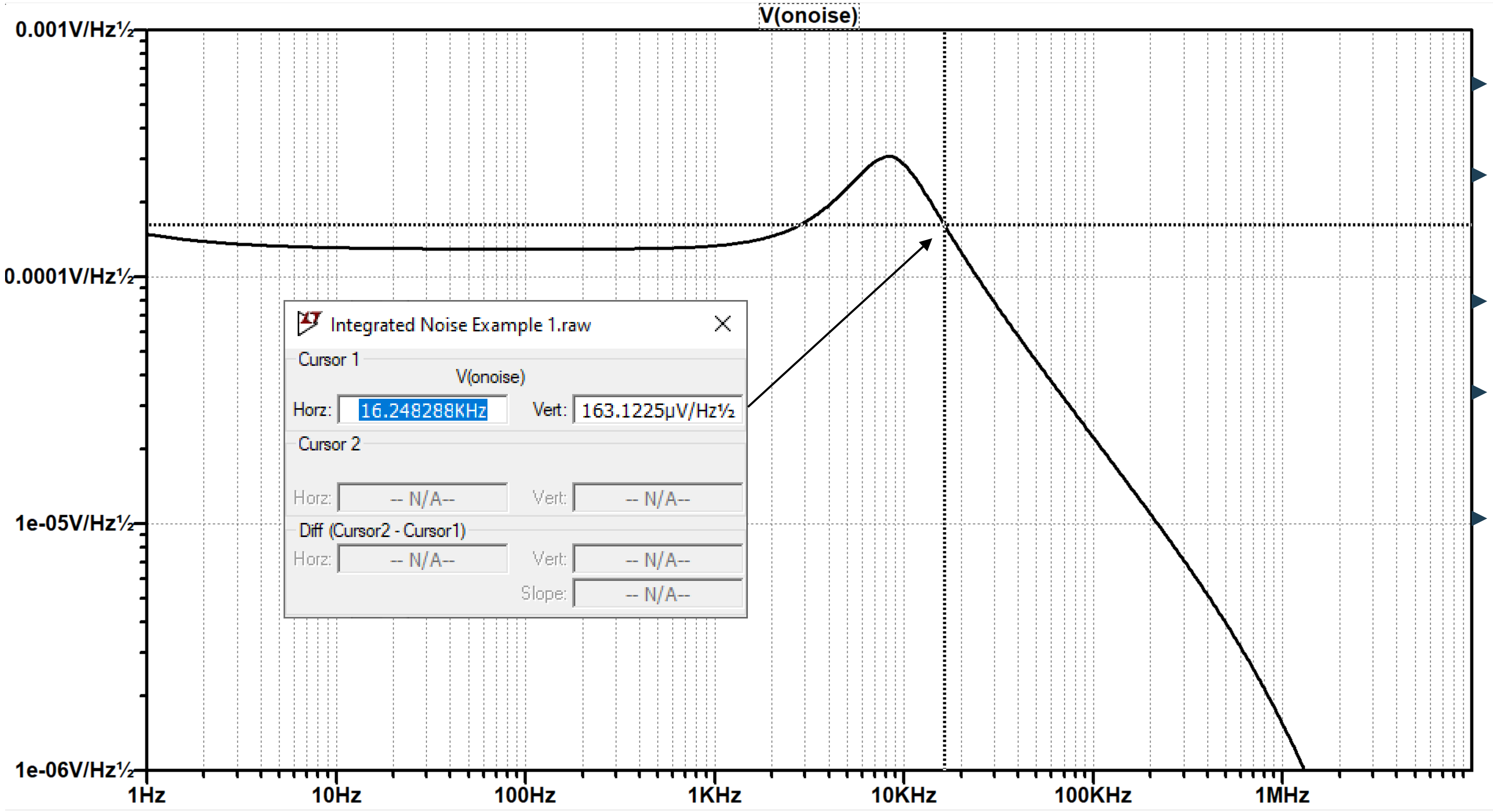


# Simulating Noise in LTSpice

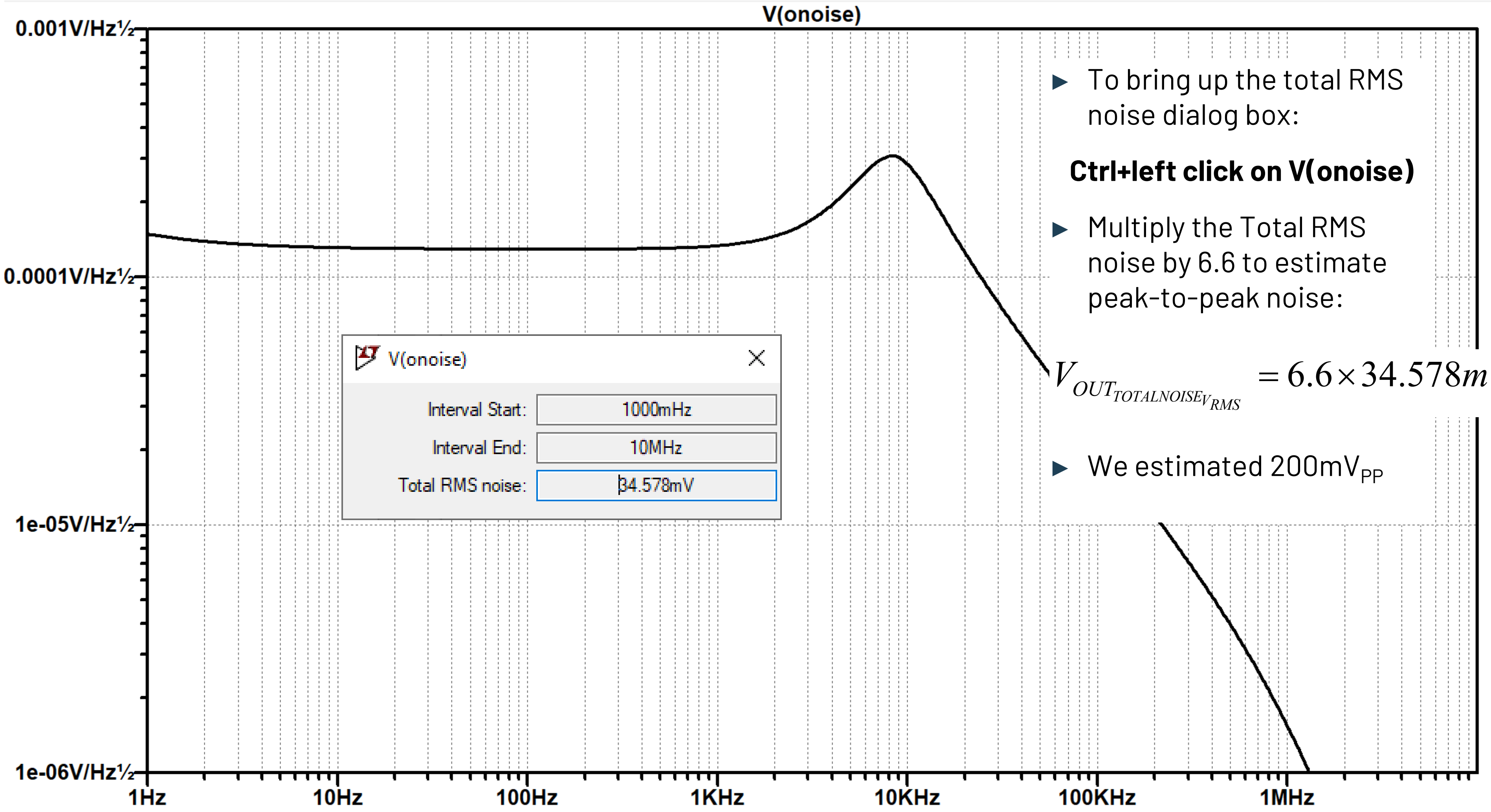


# Output Referred Noise Spectral Density




- Place the cursor at the noise bandwidth of 16.3kHz
- We estimated 237 µV/√Hz at the noise bandwidth of 16.3 kHz
- This is slightly past the -3dB point
- Calculating ~3dB down from our estimate we would expect 167 µV/√Hz
- The simulation shows 163 µV/√Hz

# Total Noise




- To bring up the total RMS noise dialog box:

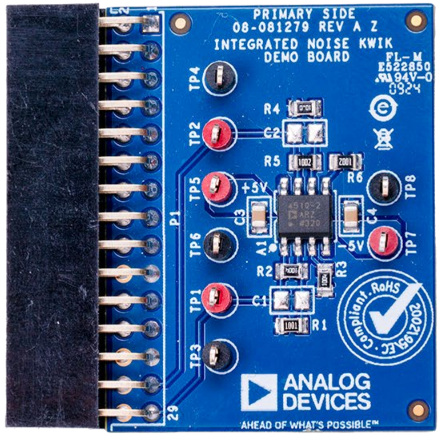
**Ctrl+left click on V(onoise)**

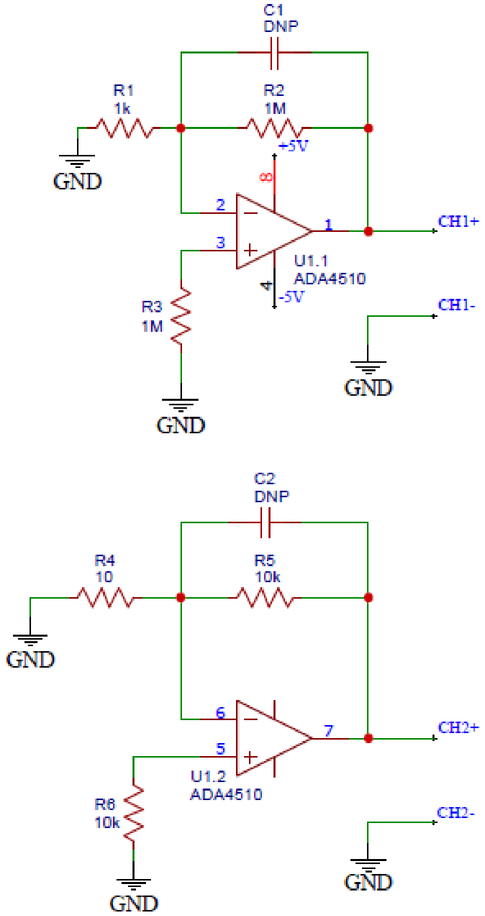
- Multiply the Total RMS noise by 6.6 to estimate peak-to-peak noise:

$$V_{OUT_{TOTALNOISE_{V_{RMS}}}} = 6.6 \times 34.578mV = 228mV_{PP}$$

- We estimated $200mV_{PP}$

# Integrated Noise Demo Board Schematic



# Physically Connect PCB to ADALM2k


ADALM2000

EVAL-KW4501Z

Using EVAL-KW4501Z

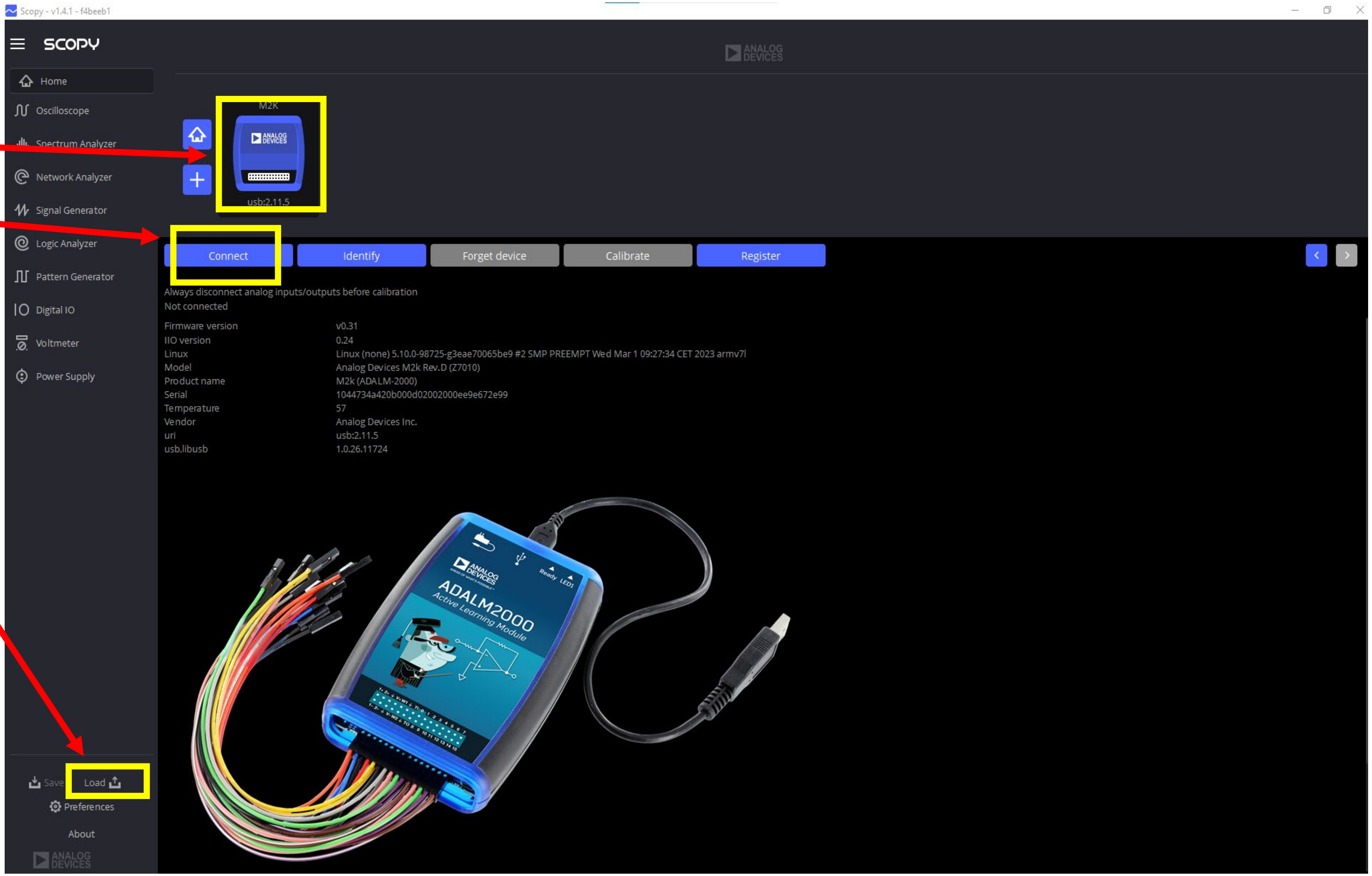
Carefully align pins and insert firmly

ADALM2000 should be powered off when connecting or disconnecting the PCB

# Launch Scopy and Load Config File

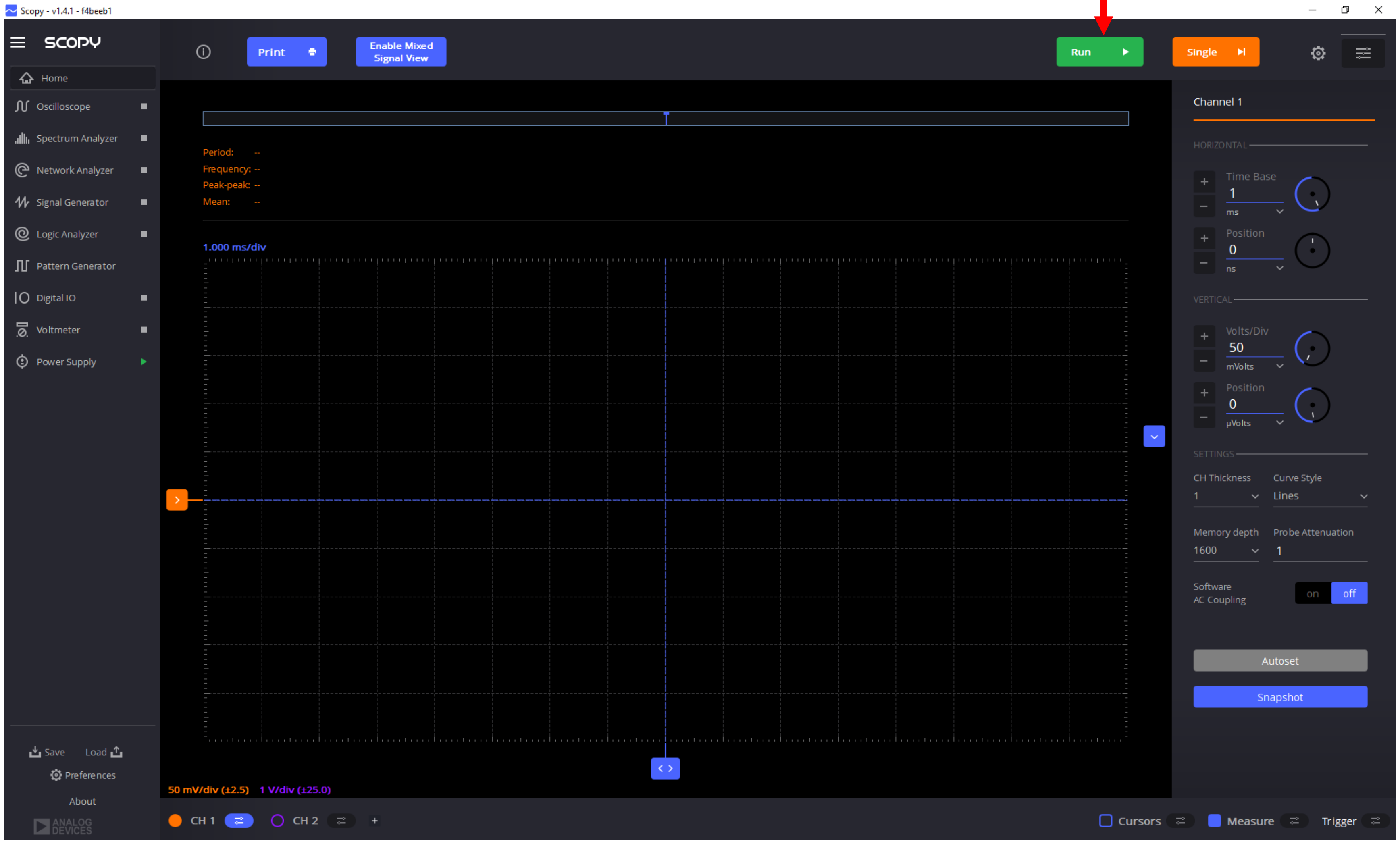
- Connect the ADALM2000 to your laptop and launch Scopy
- Click on the M2K icon
- Click connect
- Once connected click on load and load the file named:

**"Integrated Noise Scopy Config Ch A.ini"**



# Let's Have a Look at the Total Noise

- Click "Run" to start the oscilloscope

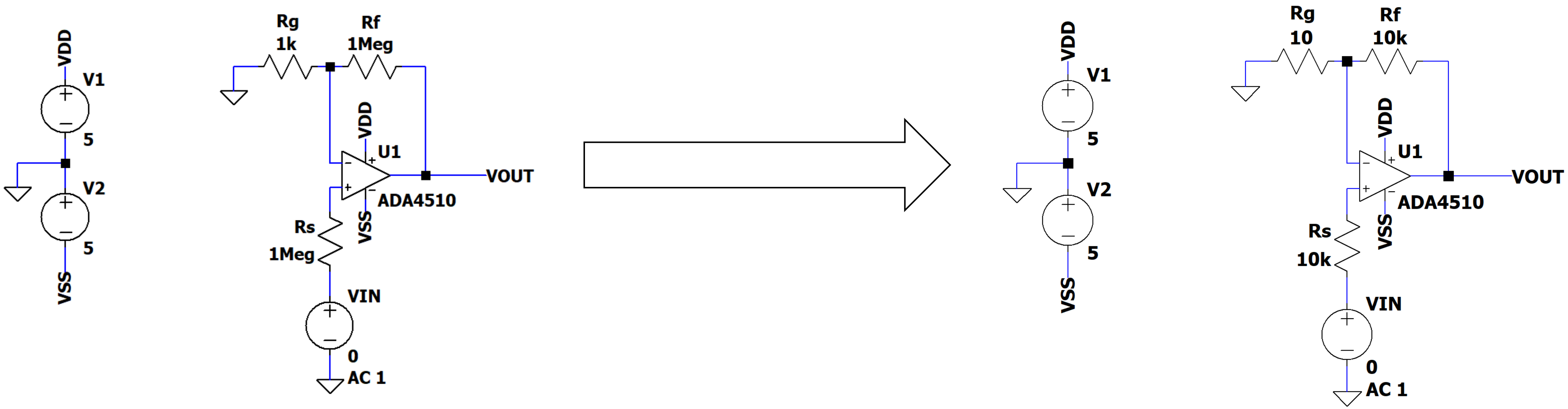


# Review the Result…is it about what you expected?


- You can click the stop button and look at the peak-to-peak measurement
- Try running and stopping a few times…you will notice some variation in the result…this is the nature of noise
- *If your result seems too high, you might be picking up external noise (the circuit has very high impedances and is in a high gain) try moving the board or rotating it to reduce any external interference ☺*

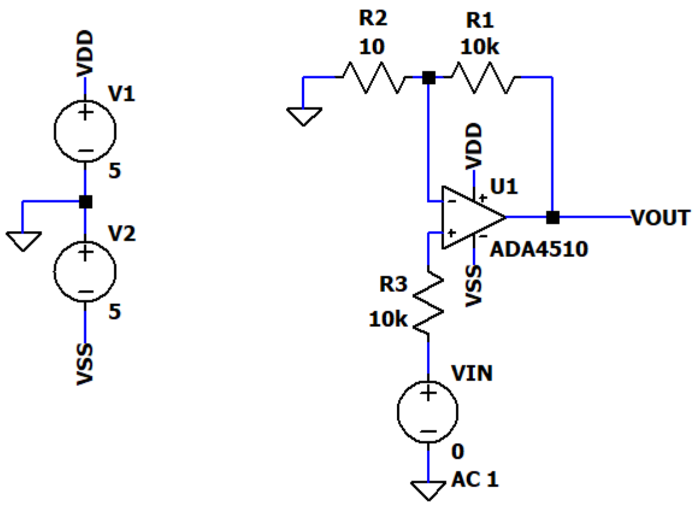
# Reducing the Noise

- In the previous example we saw that the dominant sources of noise were the IB+ noise current multiplied by the source impedance multiplied by the gain and the voltage noise of the source resistance multiplied by the gain
- Let's reduce all the impedance values by 100, keeping the same gain, but with less noise contribution from IB+ and Rs



# Example for a Simple Non-Inverting Amplifier

- Identify the noise Bandwidth
  - ADA4510 configured in G = 1001
    - Small-signal bandwidth = 10.4Mhz/1001 = 10.4kHz
    - Noise bandwidth = 10.4Khz * 1.57 = 16.3kHz




- Identify each noise source:
  - Rg = 10 ➔0.4nV/SQRT-Hz
  - Rf = 10k➔12.7nV/SQRT-Hz
  - Rs = 1k➔12.7nV/SQRT-Hz
  - ADA4510 ➔Vn = 5nV/SQRT-Hz (@16.3kHz)
  - ADA4510 ➔ In- = 200fA/SQRT-Hz (@16.3kHz)
  - ADA4510 ➔ In+ = 200fA/SQRT-Hz (@16.3kHz)

# Example for a Simple Non-Inverting Amplifier

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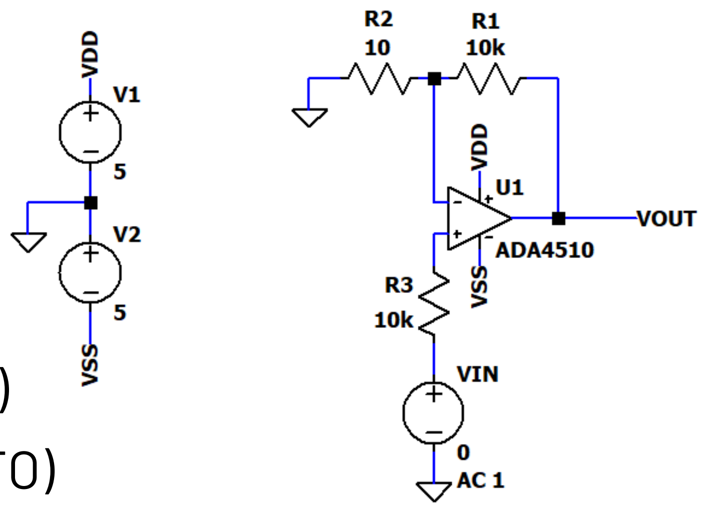
- Refer each Noise Source to the Output:
  - Rg = 10 ➔0.4nV/SQRT-Hz*1000 = 0.4μV/SQRT-Hz (RTO)
  - Rf = 10k➔12.7nV/SQRT-Hz*1 = 12.7nV/SQRT-Hz (RTO)
  - Rs = 10k➔12.7nV/SQRT-Hz*1001 = 12.7μV/SQRT-Hz (RTO)
  - ADA4510 ➔Vn = 5nV/SQRT-Hz (@16.3kHz)*1001 = 5μV/SQRT-Hz (RTO)
  - ADA4510 ➔ In- = 200fA/SQRT-Hz (@16.3kHz) *10k= 2nV/SQRT-Hz (RTO)
  - ADA4510 ➔ In+ = 200fA/SQRT-Hz (@16.3kHz)*10k*1001 = 2μV/SQRT-Hz (RTO)




Sum the NSD at the output:

$$V_{OUT_{NSD@16.3kHz}} = \sqrt{\left(0.4\mu V/\sqrt{Hz}\right)^2 + \left(12.7nV/\sqrt{Hz}\right)^2 + \left(12.7\mu/\sqrt{Hz}V\right)^2 + \left(5\mu V/\sqrt{Hz}\right)^2 + \left(2nV/\sqrt{Hz}\right)^2 + \left(2\mu V/\sqrt{Hz}\right)^2} = 14\mu V/\sqrt{Hz}$$

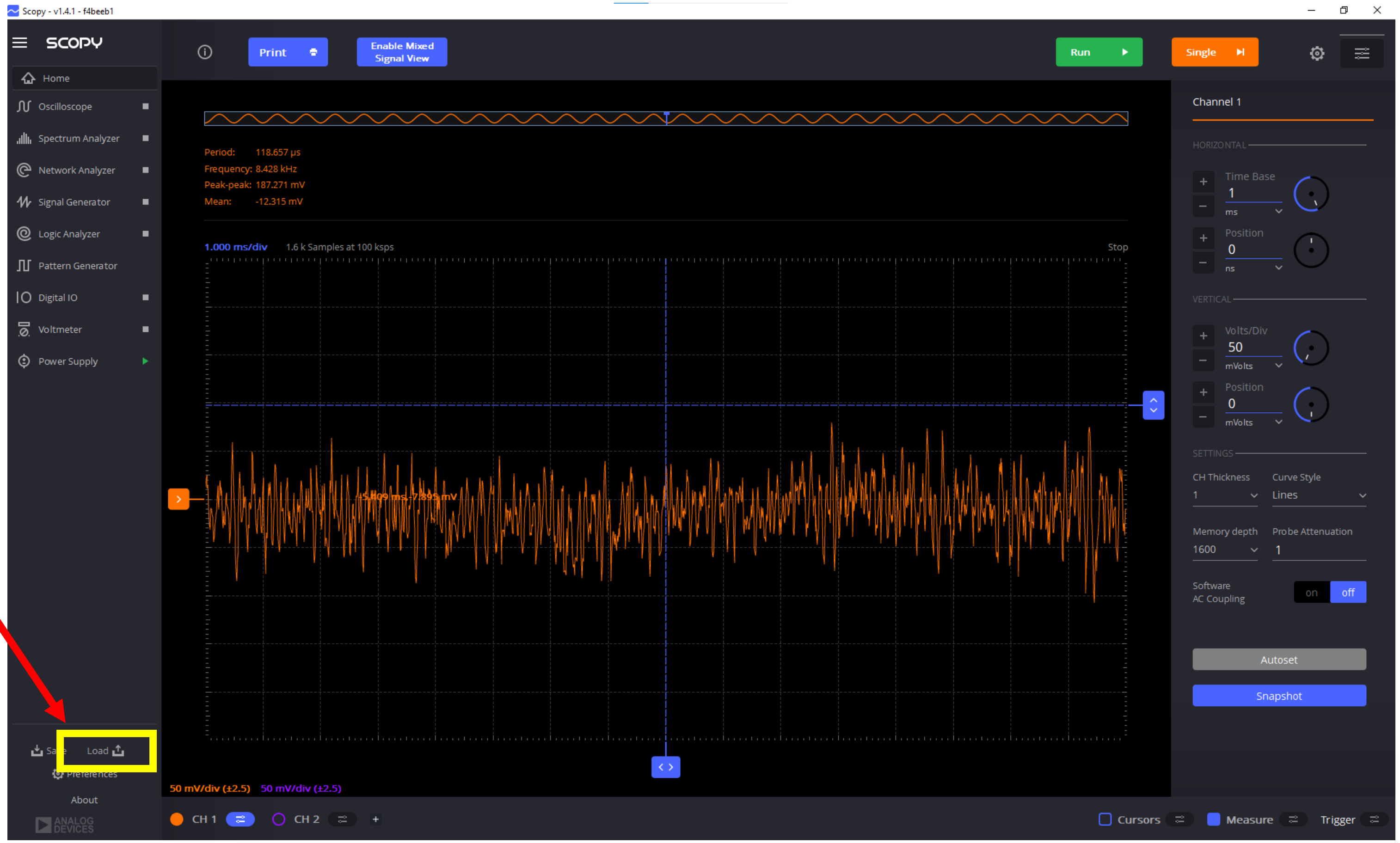
Estimate the Total Noise:

$$V_{OUT_{TOTALNOISE_{V_{PP}}}} = 6.6 \times 14\mu V/\sqrt{Hz} \times \sqrt{16.3kHz} = 12mV_{PP}$$

# Load Config File

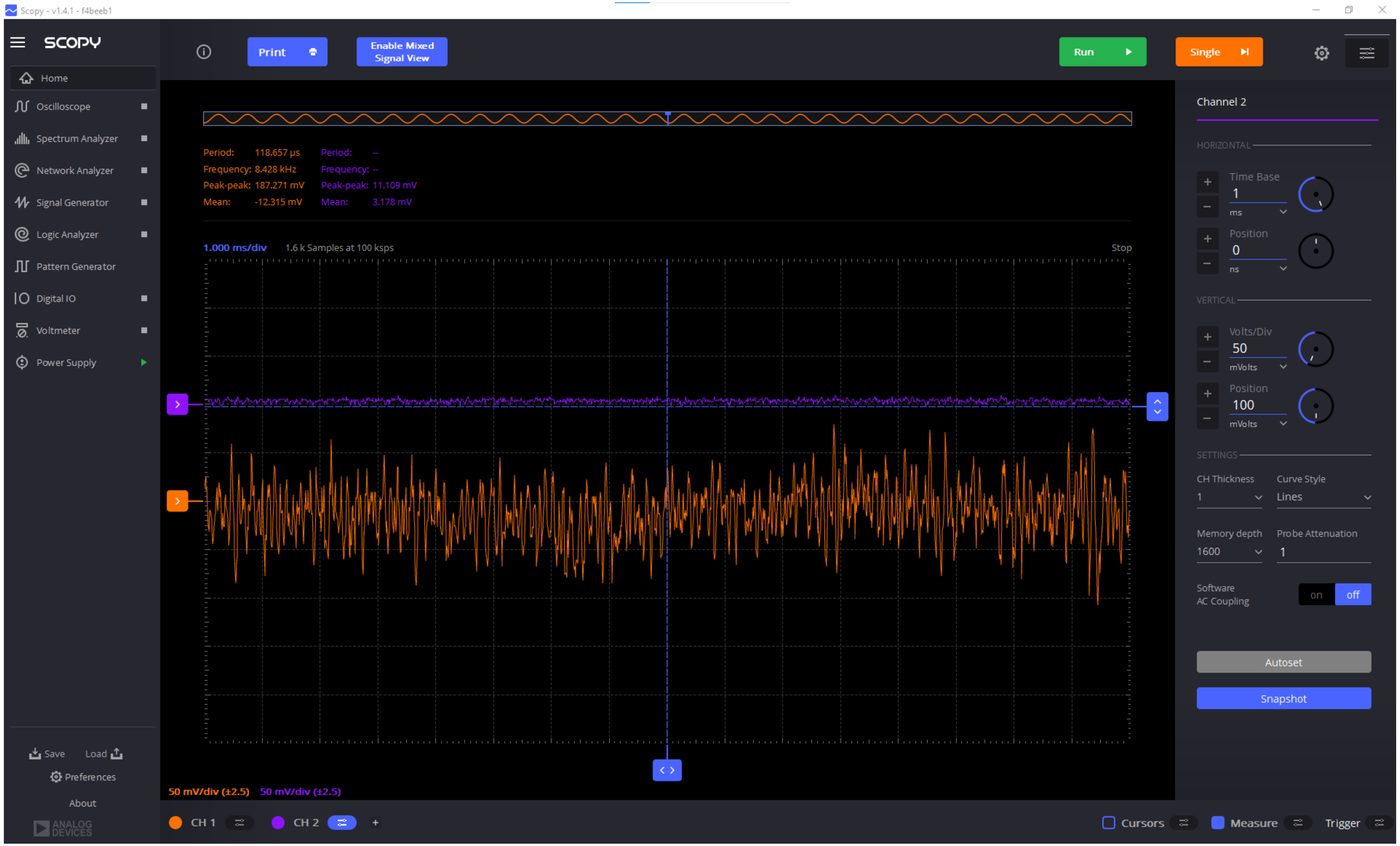
- Load the file named:

**"Integrated Noise Scopy Config Ch B.ini"**



# Let’s Have a Look at the Total Noise

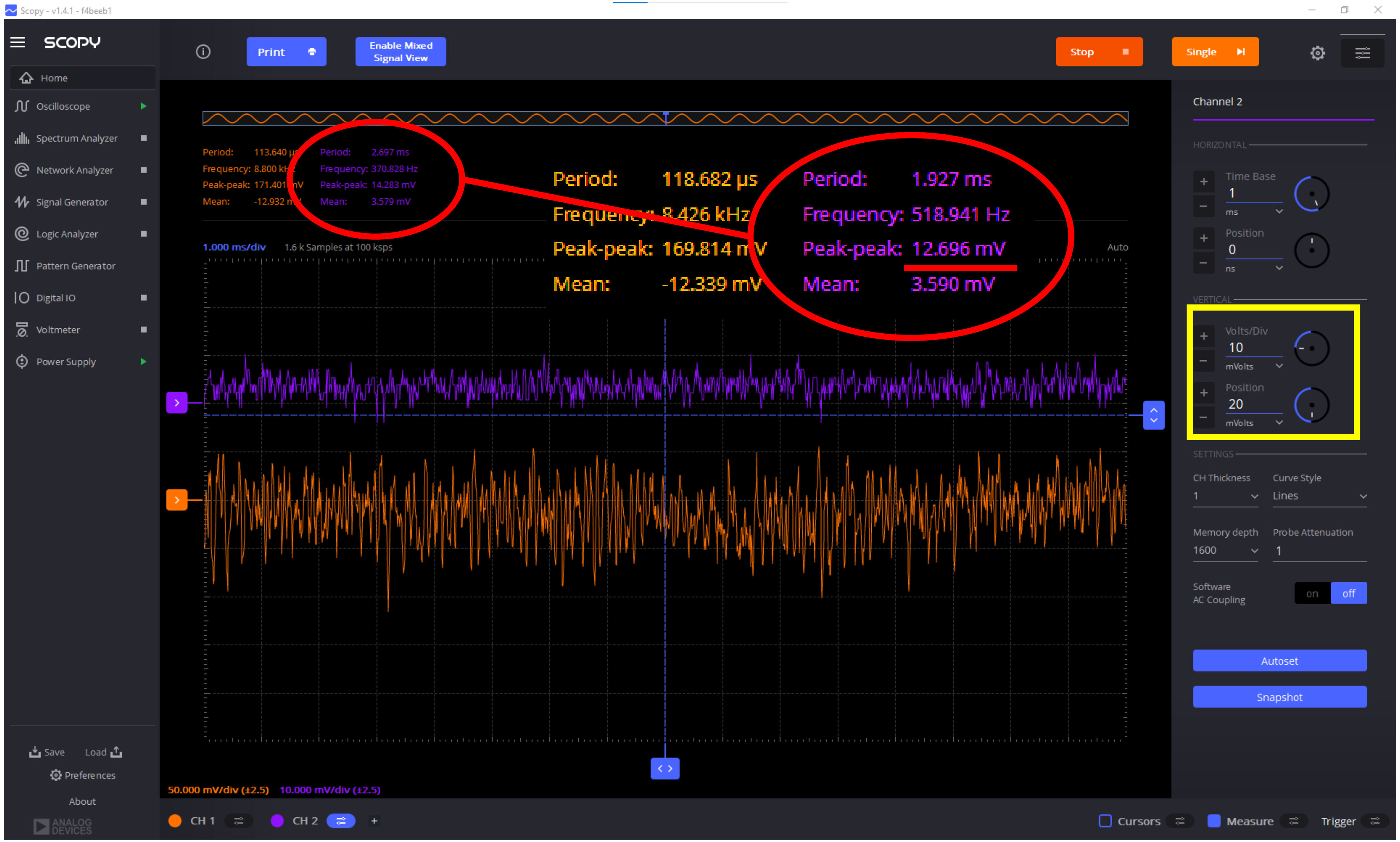
- Click “Run” to start the oscilloscope




- Click “Run” to start the oscilloscope
- Notice both Ch1 and Ch2 are on the same scale
- You see how much the noise is reduced

# Let’s Zoom In and Measure

- Click “Run” to start the oscilloscope




- Change Ch 2 to 10mV/Div
- Change Ch2 Position to 20mV
- Measure the peak-to-peak noise

# Shutting Down

# Shutting Down

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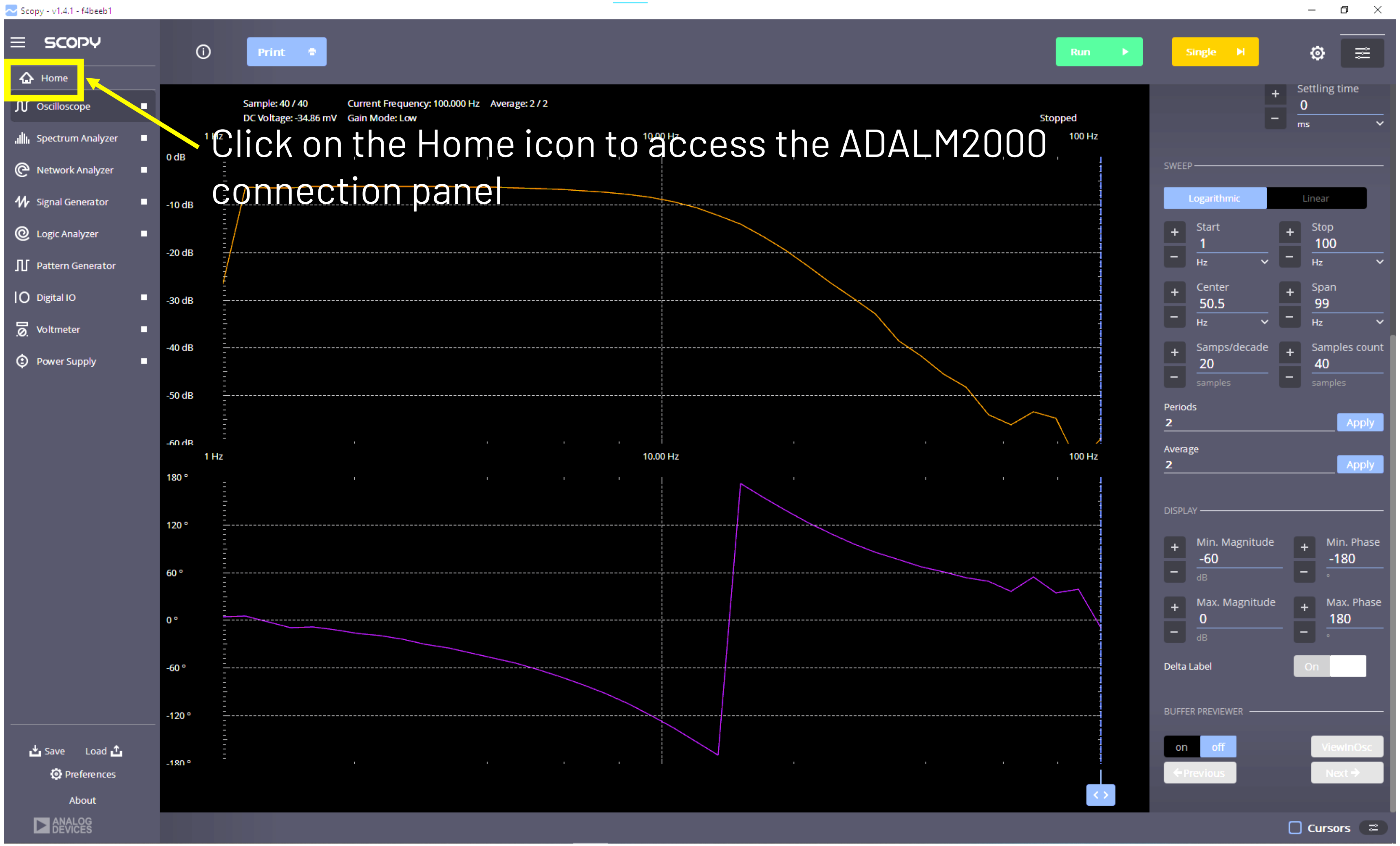
# Shutting Down



# Click on the Disconnect Button


You may first need to click on this icon if the option to disconnect does not automatically appear

Click on the Disconnect button. It is now safe to disconnect the ADALM2000 from your laptop

# Thank You!