Amplifier Settling and Charge Bucket Filter Design

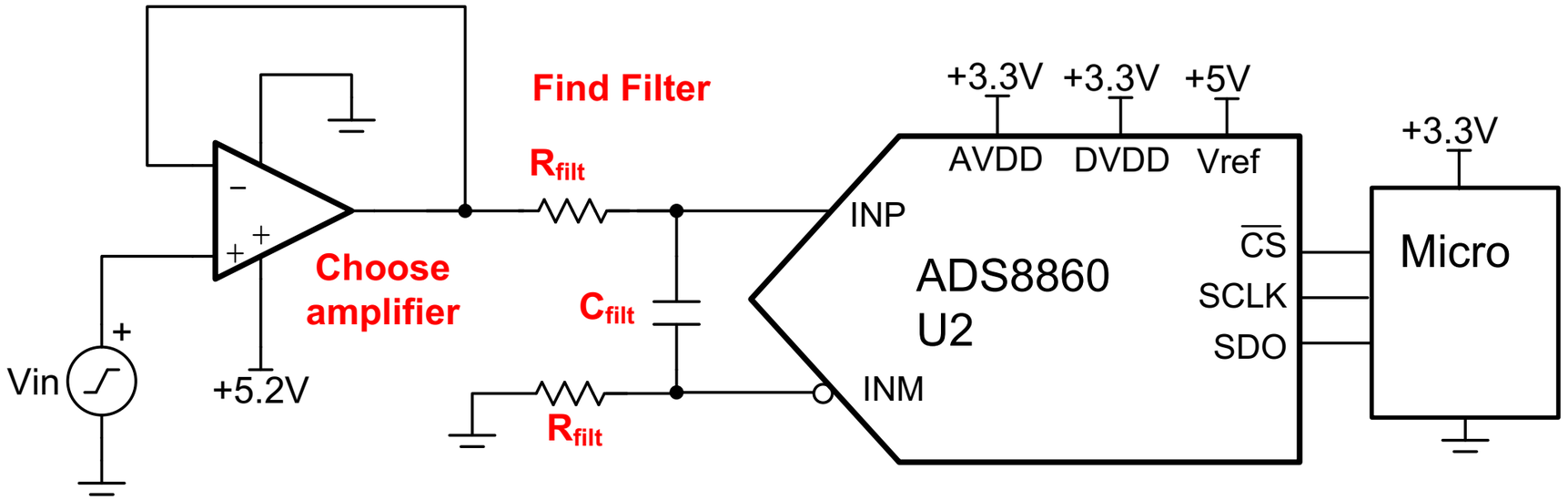
TIPL 4405-L
TI Precision Labs – ADCs

by Art Kay, Dale Li

Required/Recommended Equipment

- Calculation
  - Determine initial values for RC charge bucket circuit and bandwidth using Analog Engineer's Calculator
- Simulation
  - Optimize RC charge bucket circuit using TINA SPICE
  - Confirm final settling error is less than half of one LSB.
- Measurement
  - Verify THD and SNR for good and bad charge bucket filter design.
  - PLABS-SAR-EVM-PDK
  - http://www.ti.com/tool/plabs-sar-evm-pdk
  - Download EVM software and purchase EVM

Find amplifier and RC circuit



Amplifier:

- 5V, Rail-to-Rail I/O with Zero Crossover Distortion Required
- Find bandwidth using Analog Engineer's Calculator
- Use parametric search to find device.
- Verify model Open Loop Gain and Open Loop Output Impedance

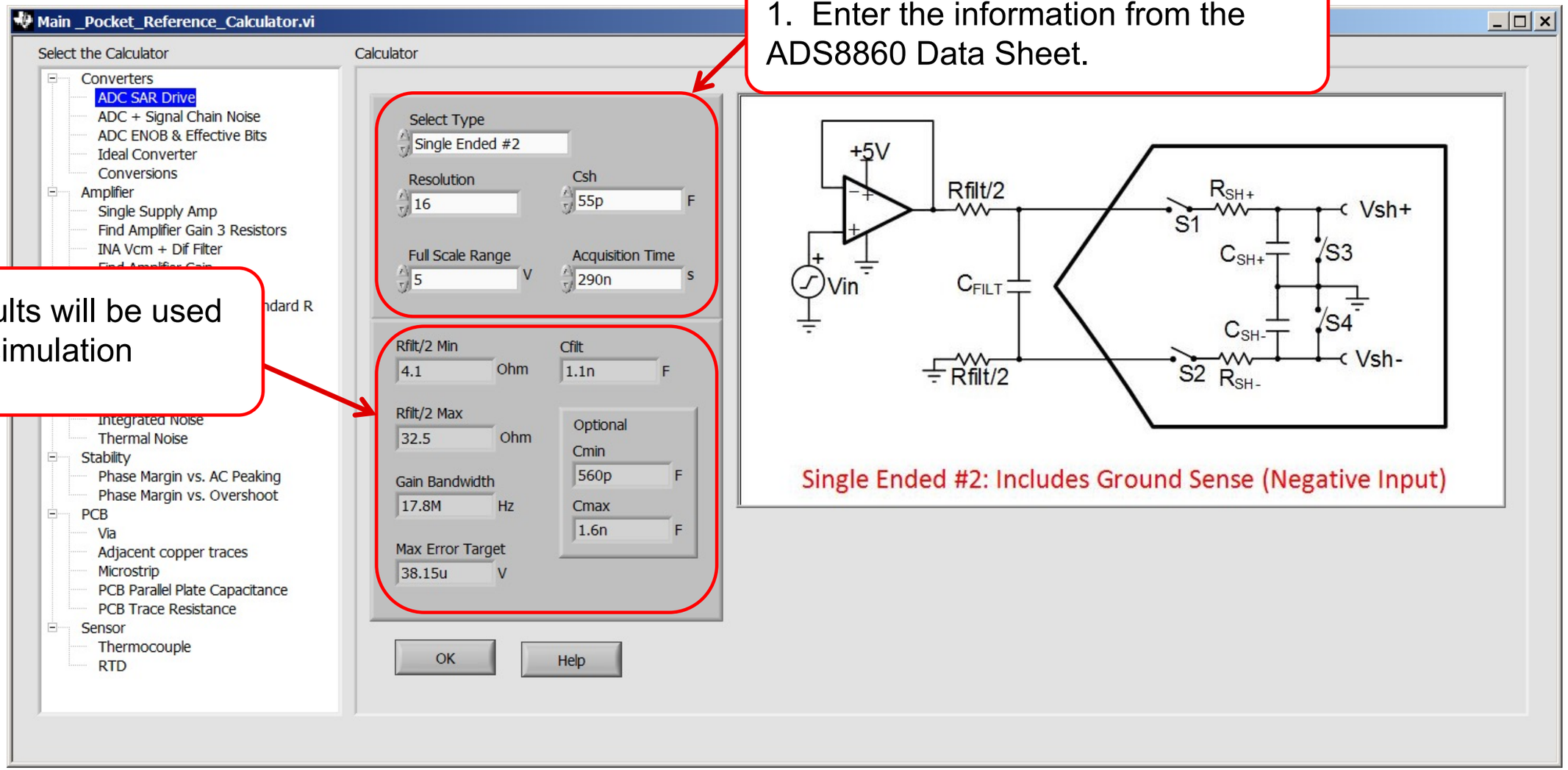
RC Charge Bucket Circuit:

- Use Analog Engineer's Calculator for initial values
- Use TINA Simulation to Optimize

Find the Op Amp Bandwidth and RC Charge Bucket

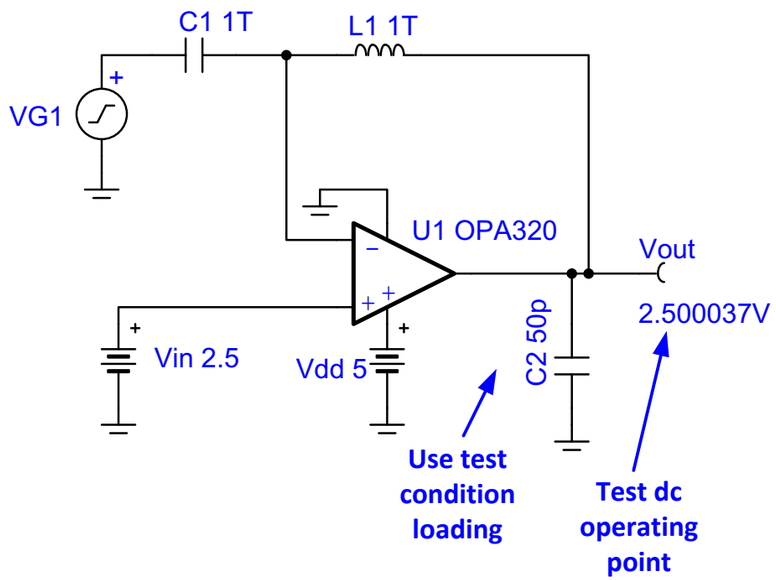
1. Enter the information from the ADS8860 Data Sheet.

2. Results will be used in the simulation

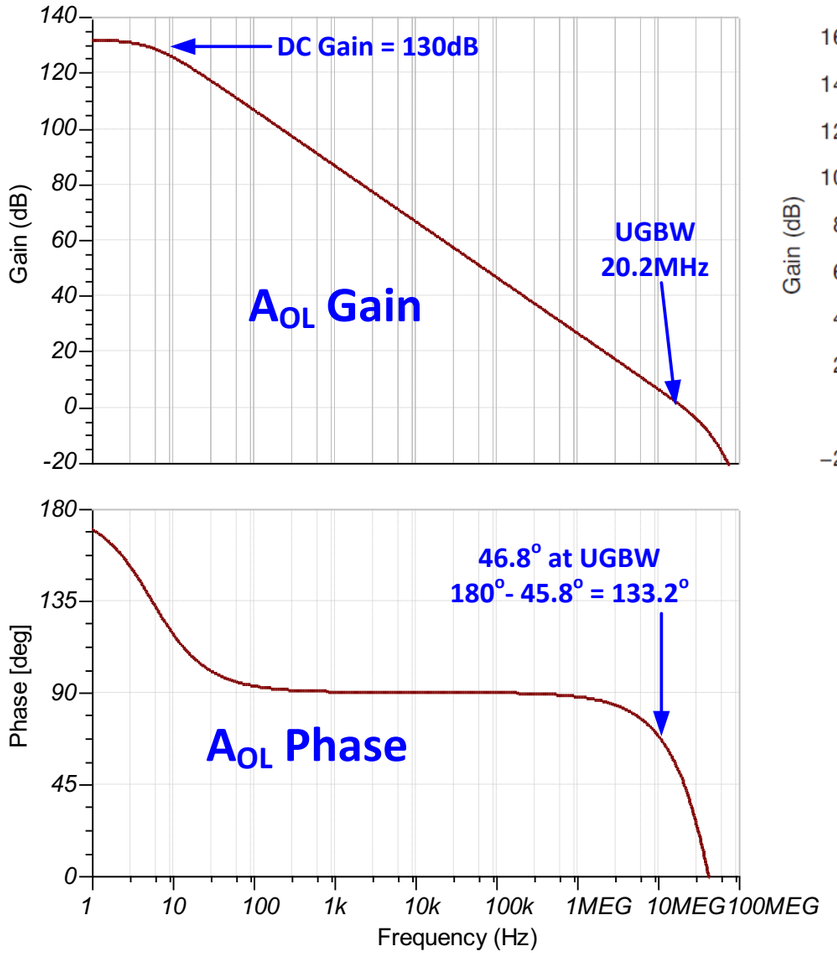


Op Amp Model: Open Loop Gain

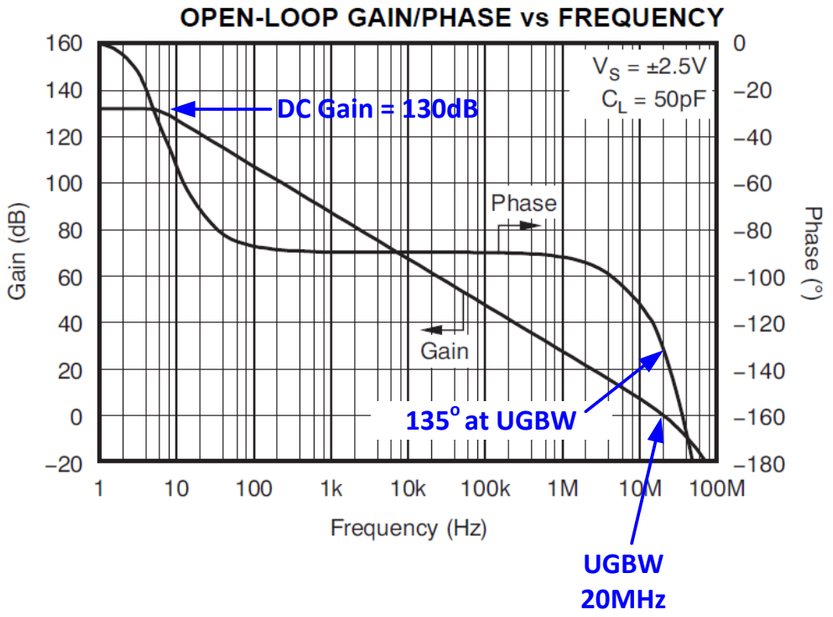
Test Circuit for Aol



Simulated results



Data Sheet Specification



1. Test dc operating point to assure that circuit is correctly wired
2. Run ac simulation for A_{OL} curve

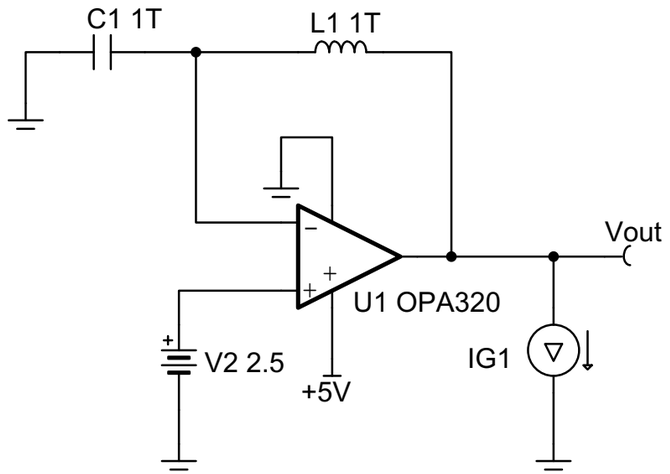
A_{OL} = Vout

Compare key points on simulation results to data sheet curve.

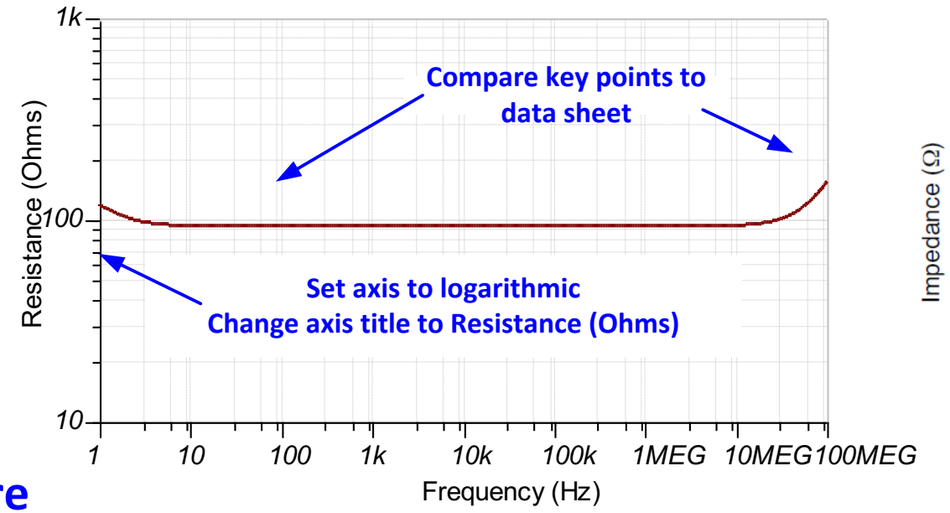
Aol opa320.TSC

Op Amp Model: Open Loop Output Impedance

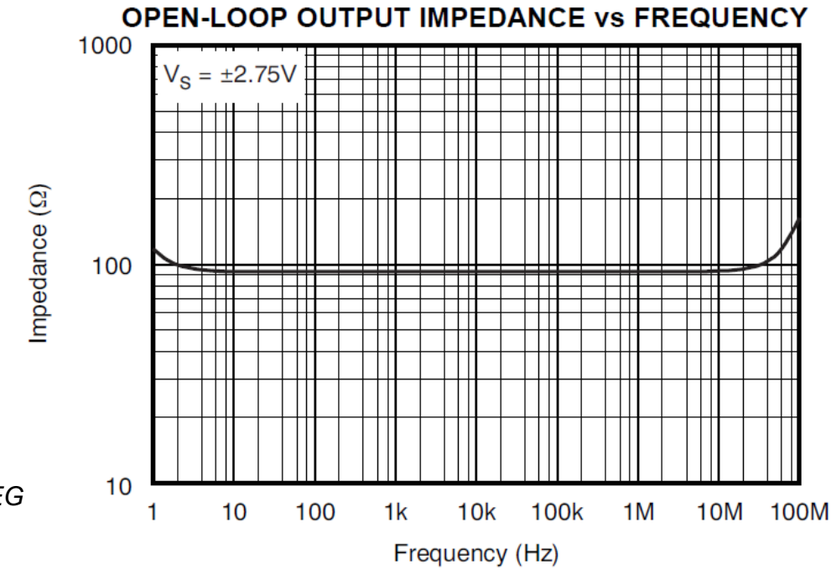
Test Circuit for Aol



Simulated results



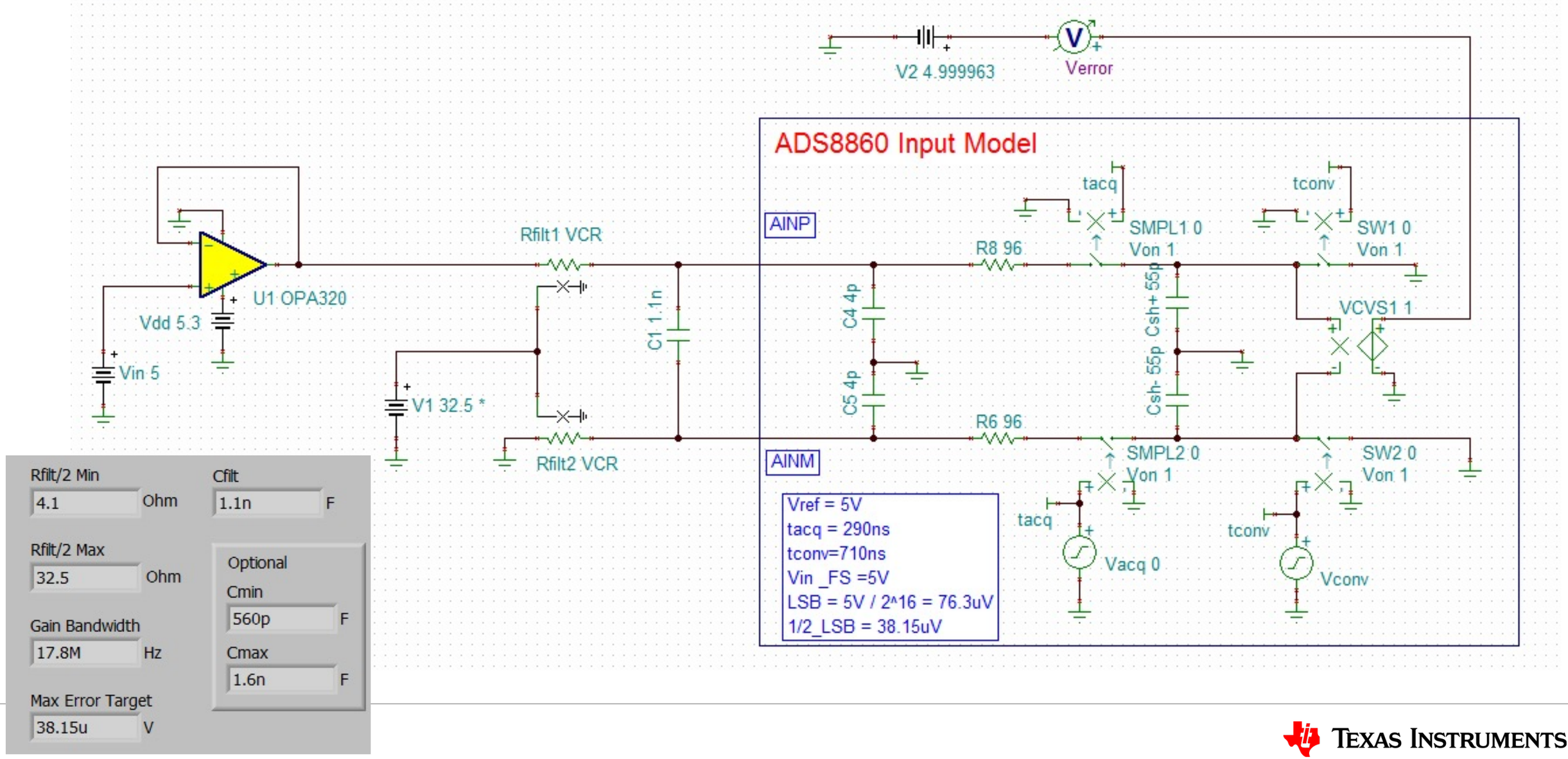
Data Sheet Specification



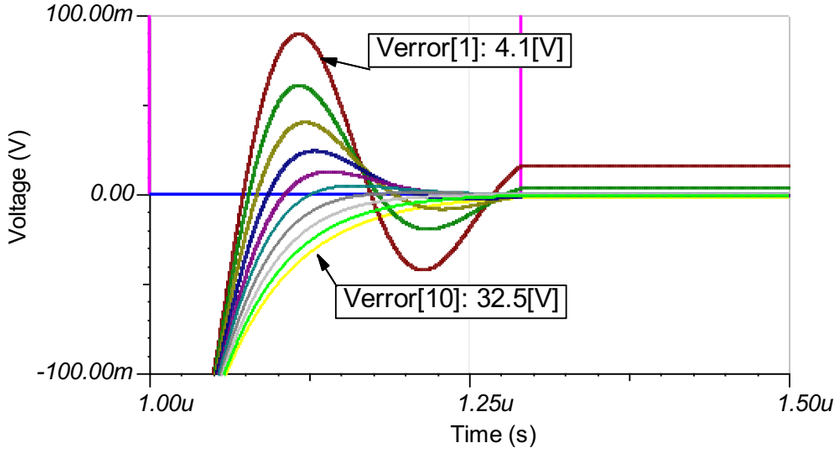
1. Test dc operating point to assure that circuit is correctly wired
2. Run ac simulation for Z_o curve. Z_o = Vout.

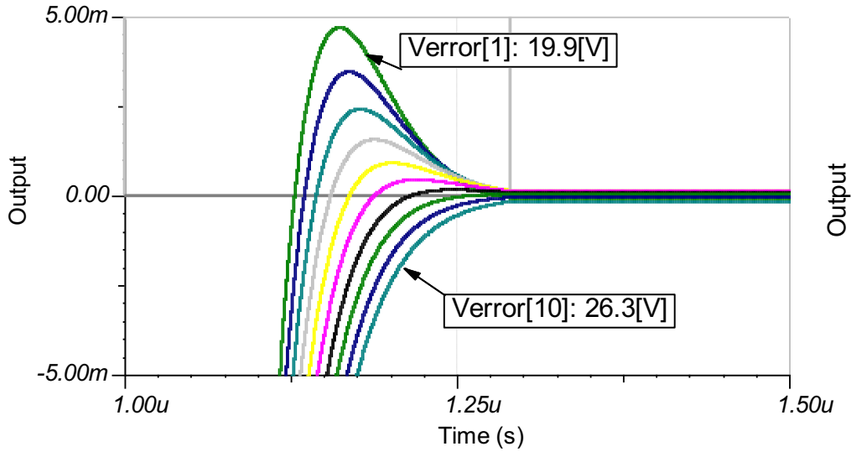
Zo opa320.TSC

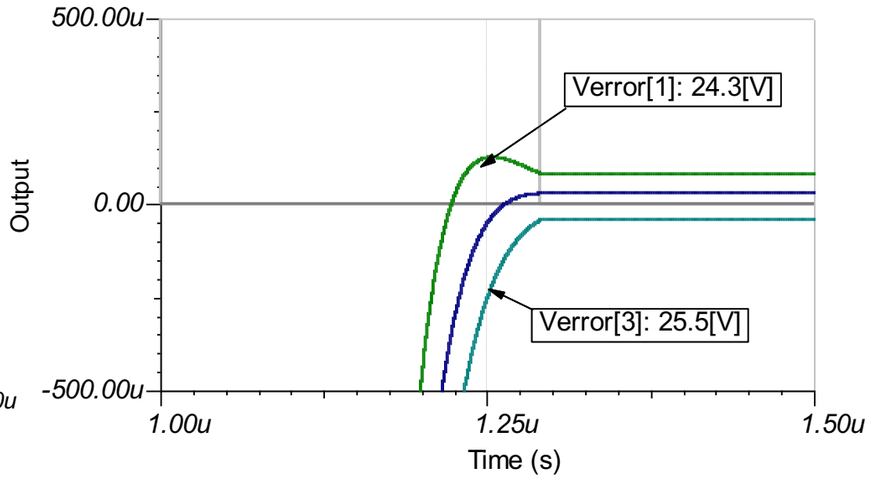
Find the Op Amp Bandwidth and RC Charge Bucket



Parameter Step R_{filt}





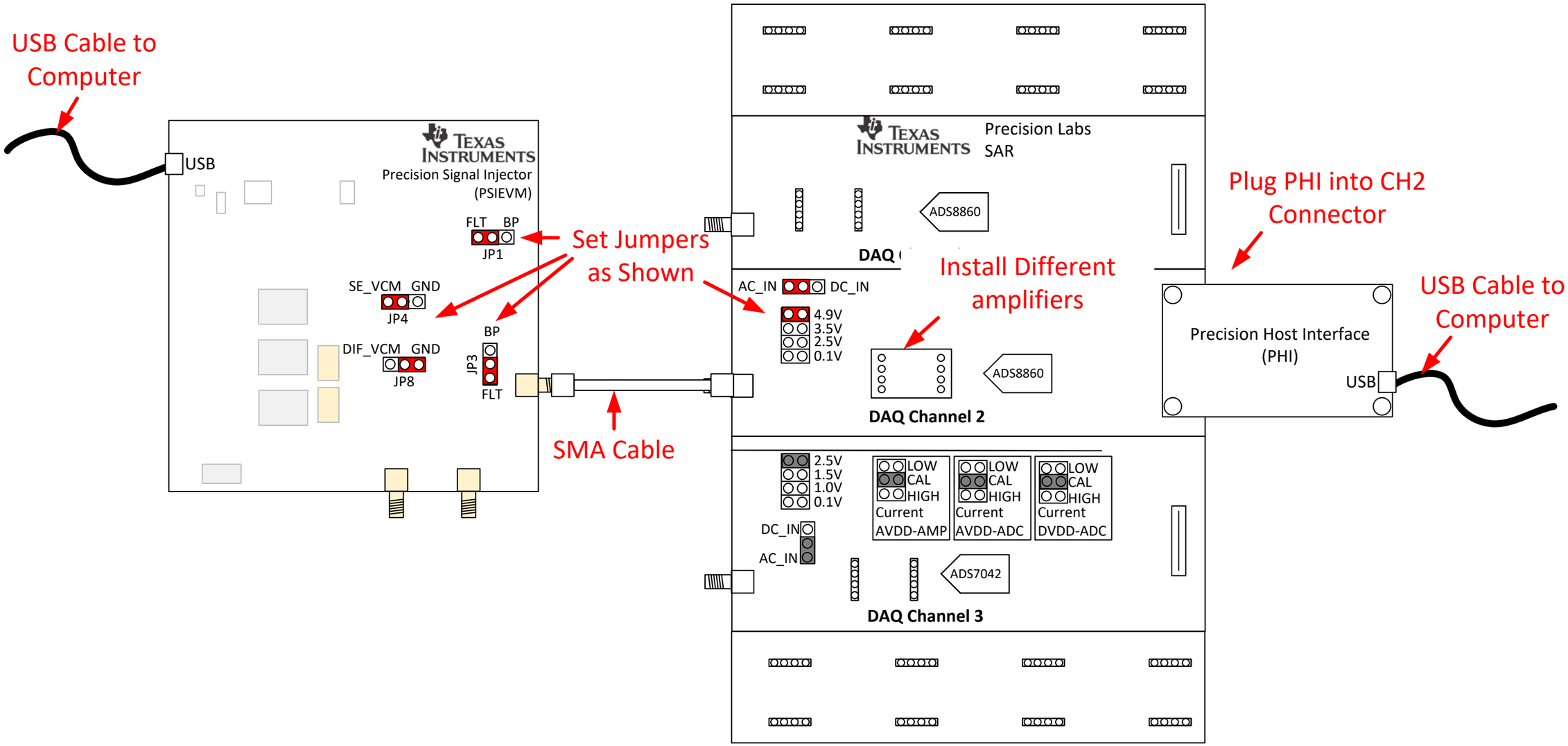


ADS8860_OPA320 - 1st - iteration.TSC

ADS8860_OPA320 - 2nd - iteration.TSC

ADS8860_OPA320 - 3rd - iteration.TSC

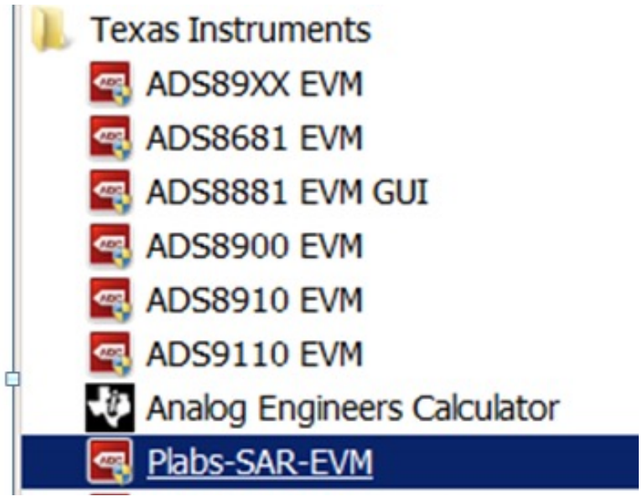
Connect the hardware



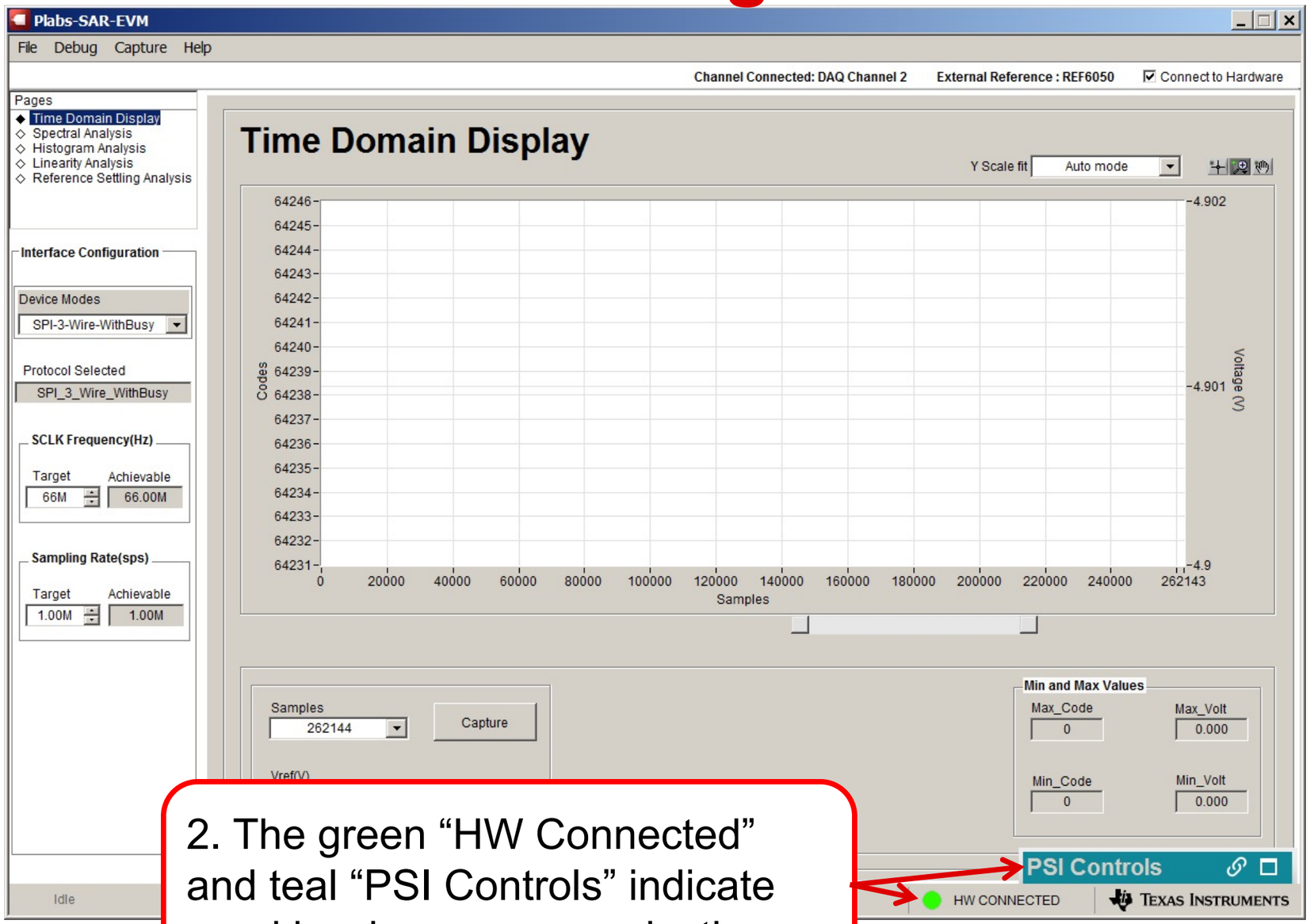
Record results as we progress through Experiment

Device					Simulated Settling Error ½LSB=38uV	Example Measurements		Your Measurements	
	Device	Samp. Rate	V_{offset} (V)	V_{in} (V)	V_{error} (V)	SNR (dB)	THD (dB)	SNR (dB)	THD (dB)
	ADS8860 Data Sheet					93	-108		
1	OPA320 Good filter1	1M	2.5	4.9	28uV	93.3	-108.8		
2	OPA320 Bad filter	1M	2.5	4.9	-41mV	82.5	-73.4		
3	OPA333 Low Bandwidth	1M	2.5	4.9	-91mV	54.1	-55.9		
4	OPA316 Crossover	1M	1.8	3.6	36.7mV	86.1	-85.0		
5	OPA316 Crossover	500k	1.8	3.6	47uV	90.3	-102.4		

Start & Setup the Plabs-Power Scaling EVM Software

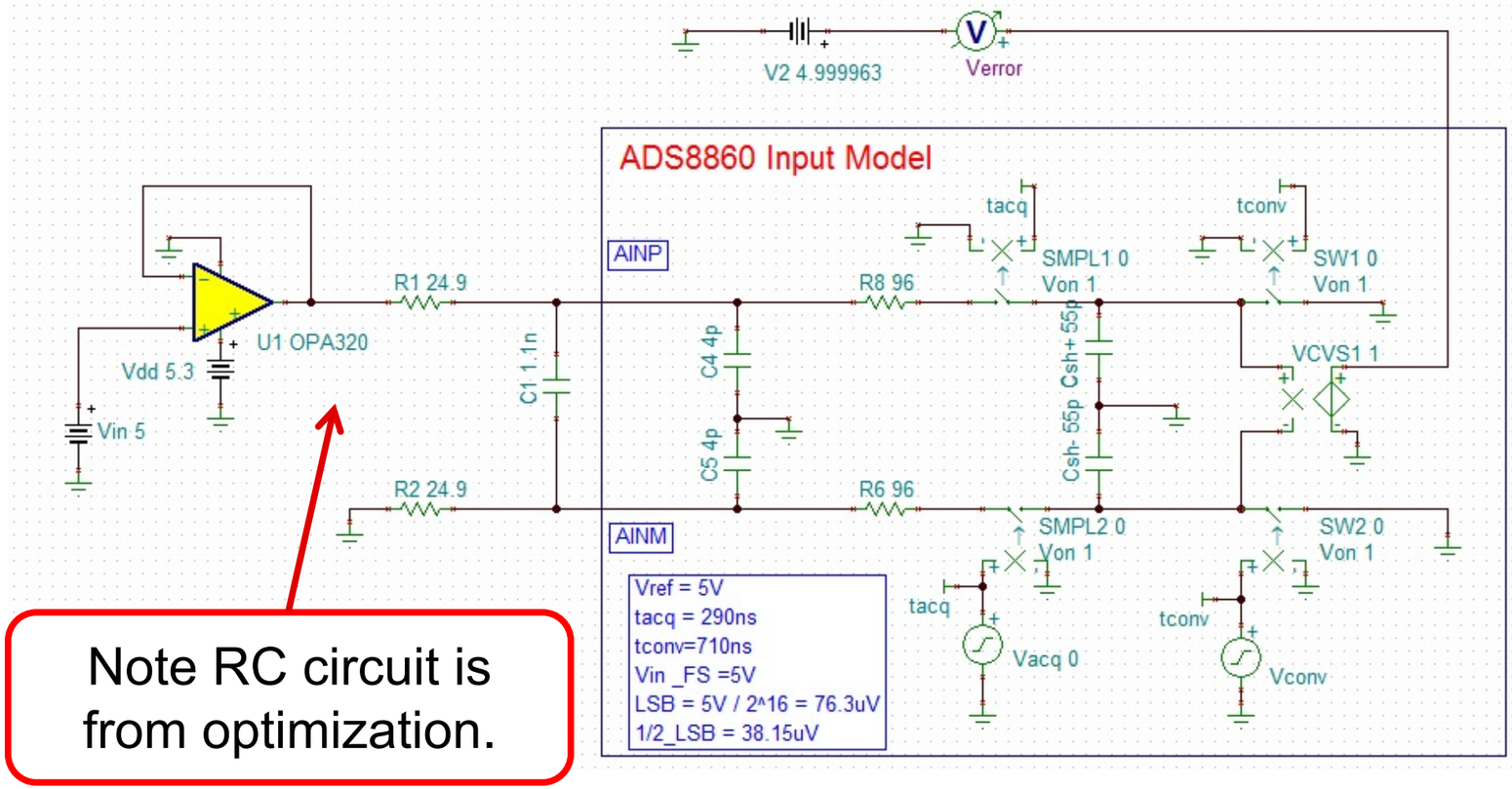


1. Select “Plabs-SAR-EVM” from “start>All Programs”

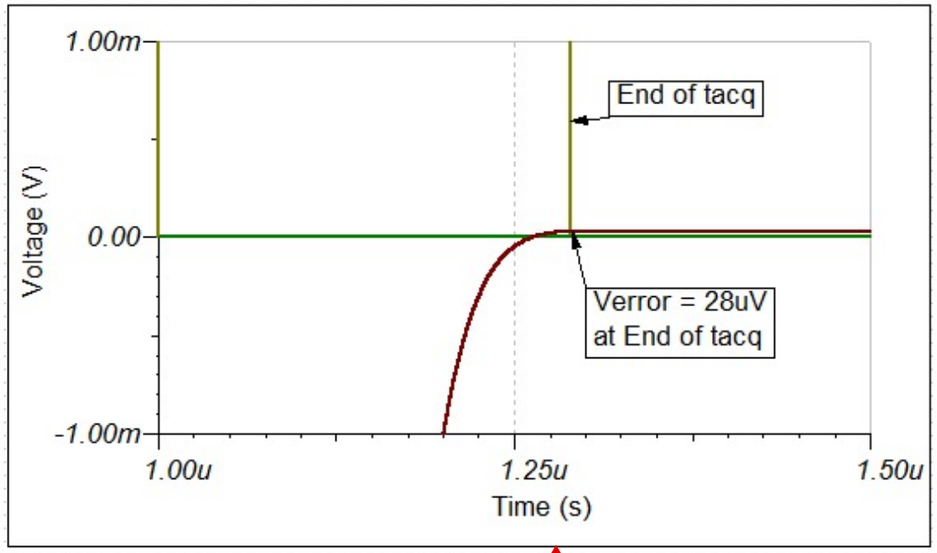


2. The green “HW Connected” and teal “PSI Controls” indicate good hardware communication.

1: OPA320_Good Filter1



Note RC circuit is from optimization.

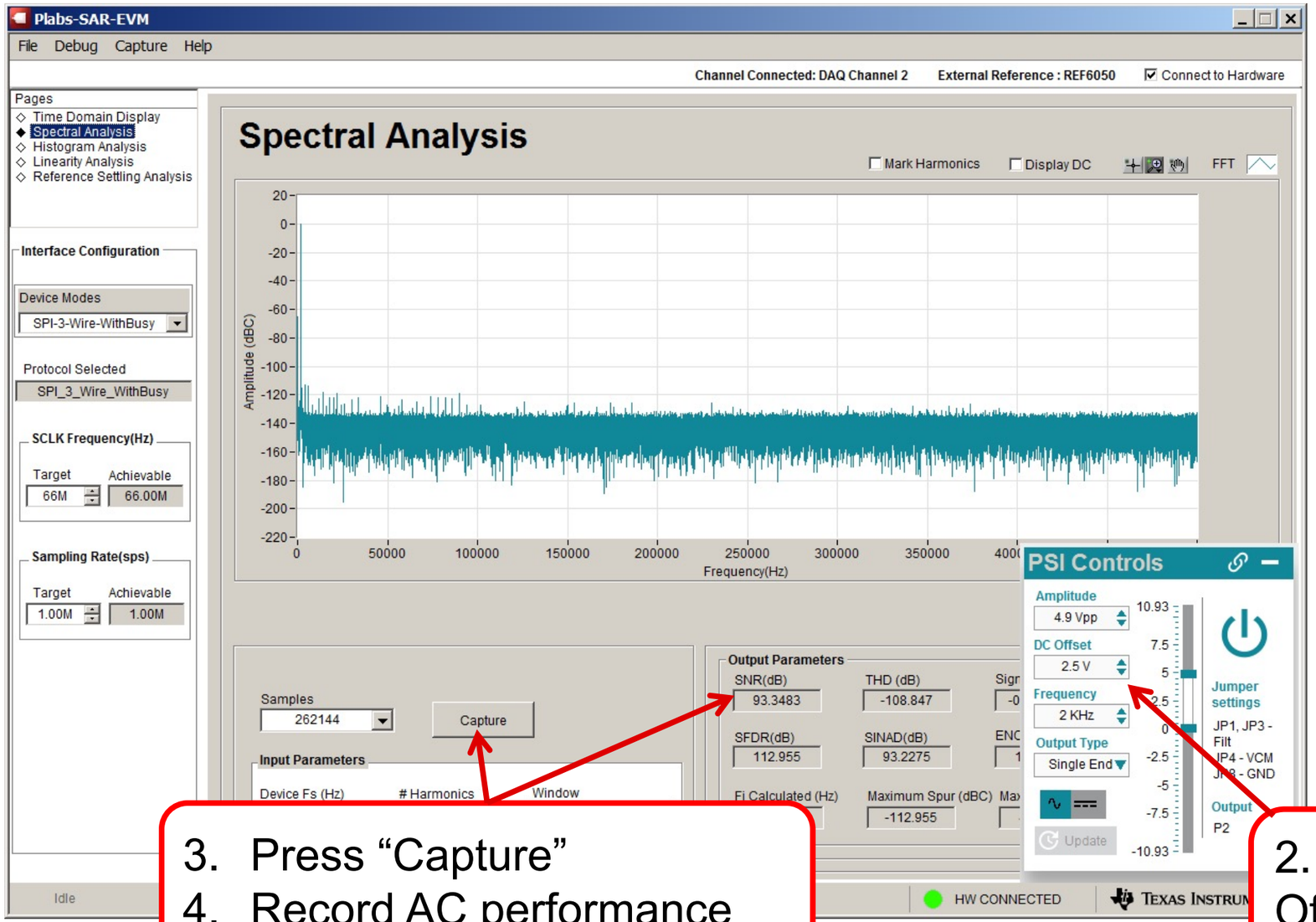


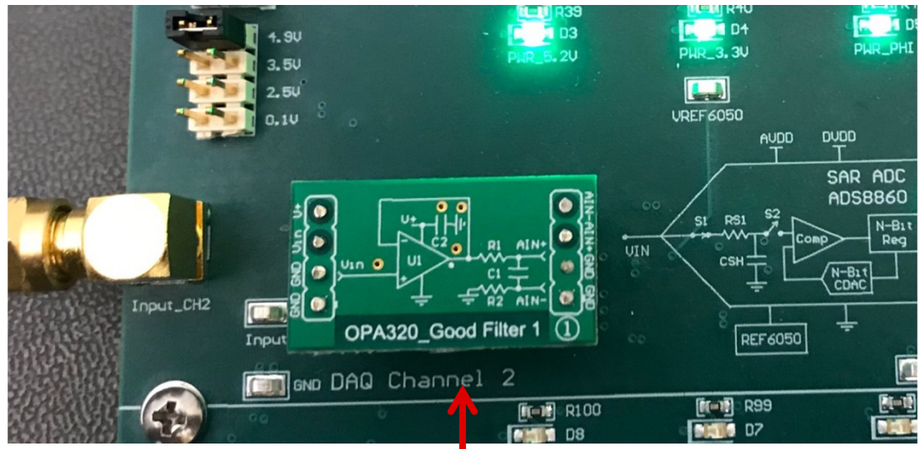
Error Target = 38µV
Simulate Error = 28µV

ADS8860_OPA320 - good filter.TSC

1: OPA320_Good Filter1

	SNR (dB)	THD (dB)
ADS8860 Spec.	93	-108
Good Filter 1	93.3	-108.8



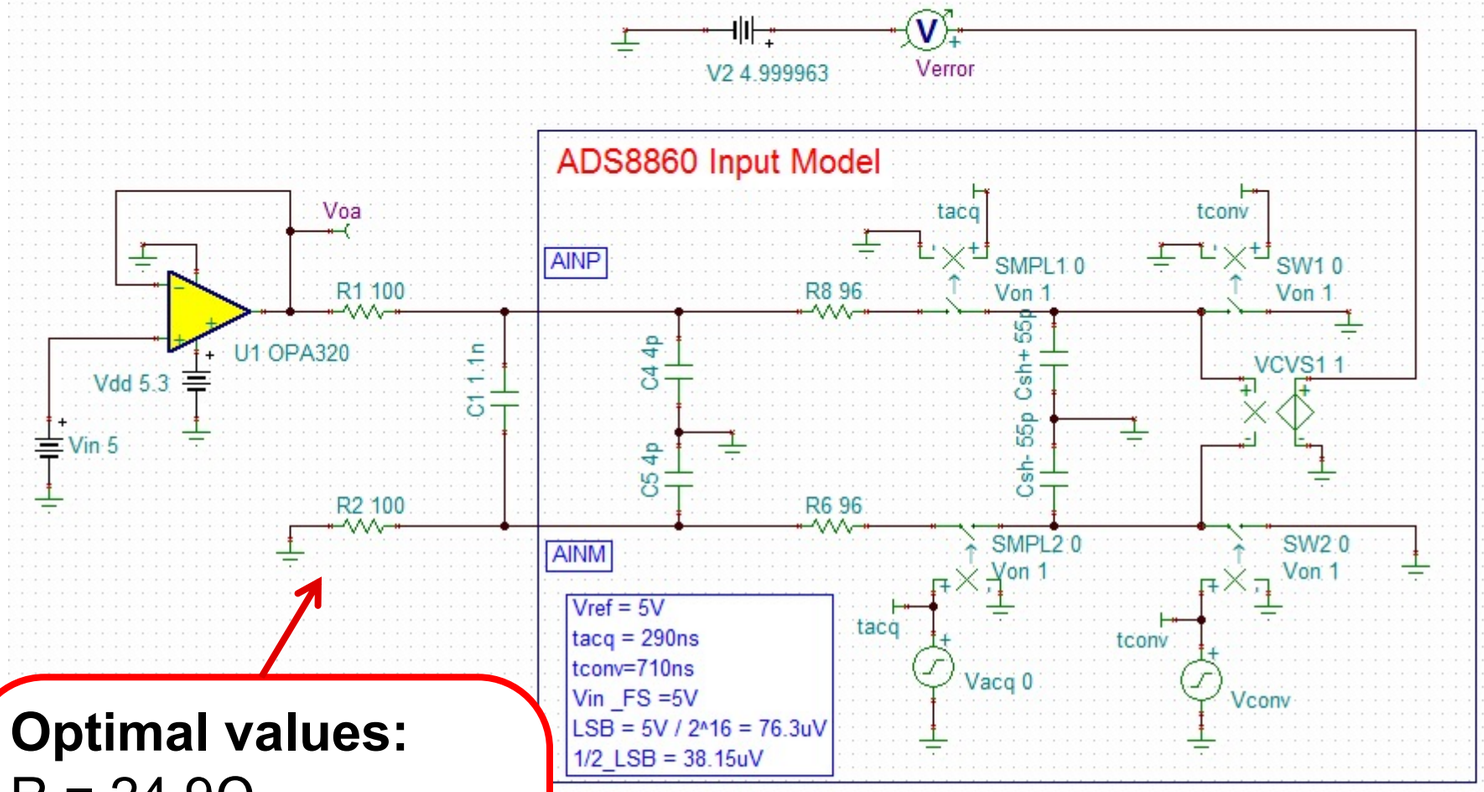


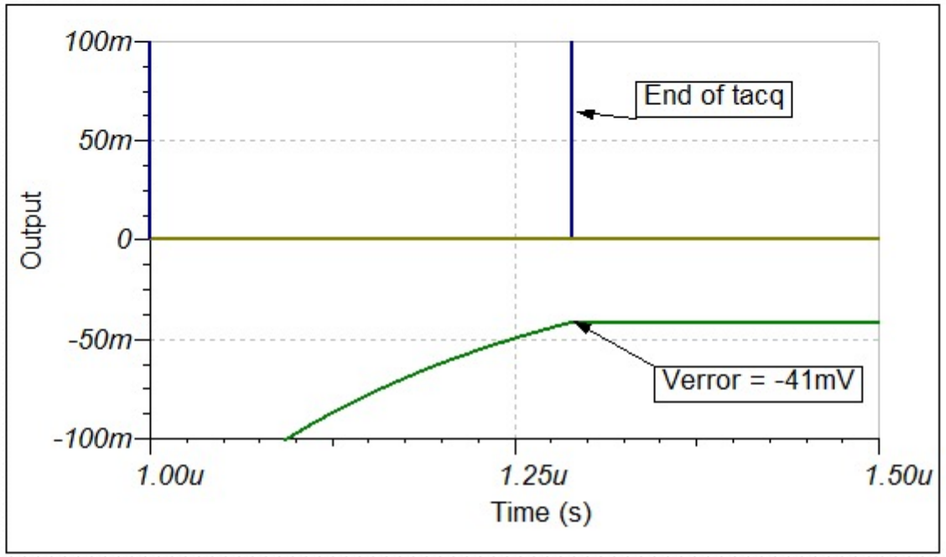
1. Install OPA320_Good filter 1 coupon card in socket.

2. Amplitude = 4.9V
Offset = 2.5V
Frequency = 2kHz

3. Press “Capture”
4. Record AC performance

2: OPA320 Bad Filter





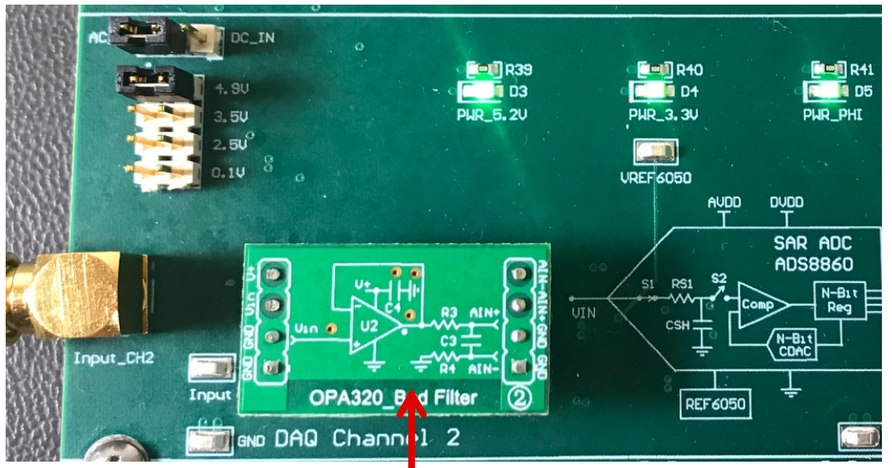
Optimal values:
R = 24.9Ω
C = 1.1nF
Bad Filter Values:
R = 100Ω
C = 1.1nF

ADS8860_OPA320 - bad filter.TSC

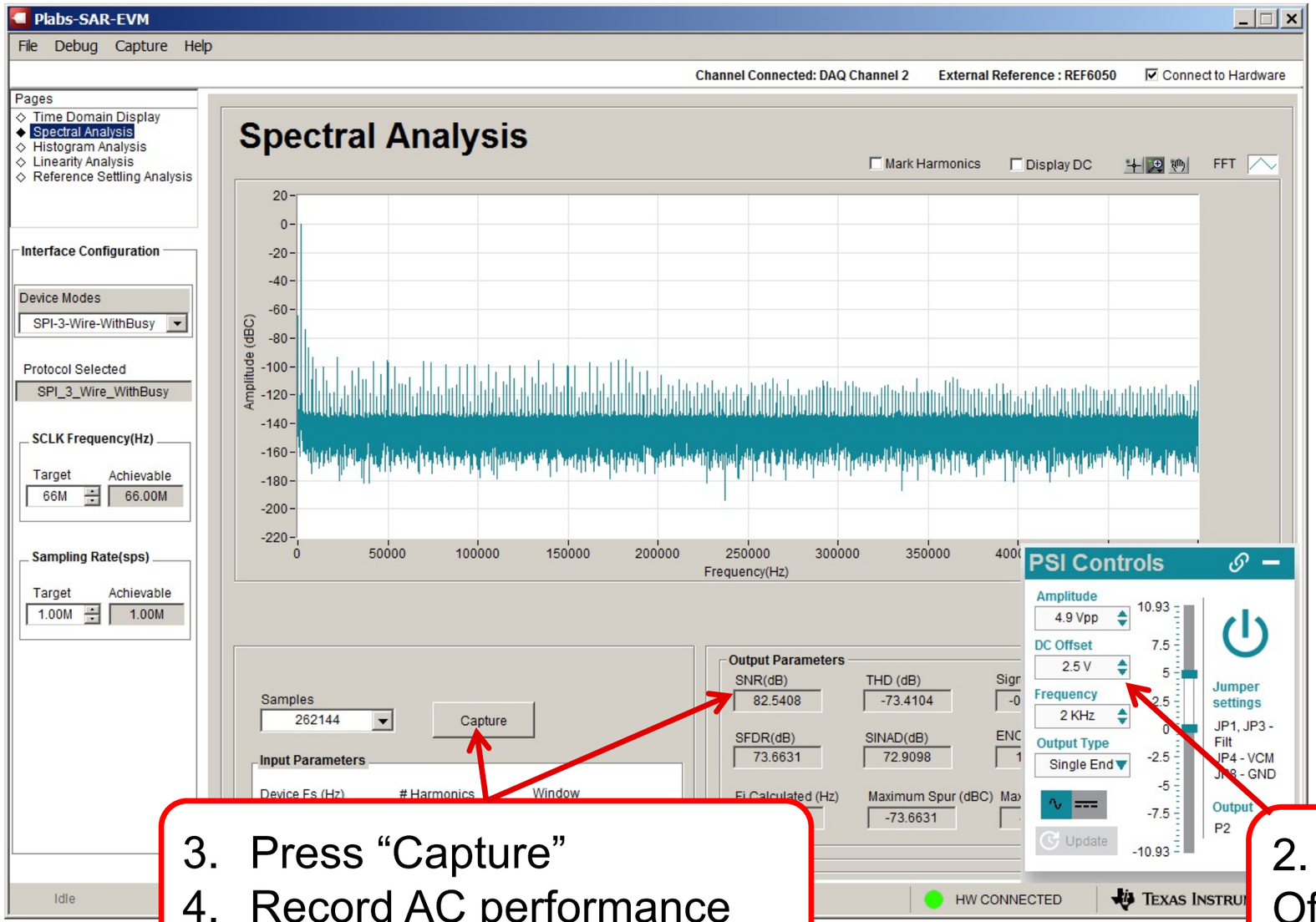
Error Target = 38µV
Simulate Error = -41mV

2: OPA320 Bad Filter

	SNR (dB)	THD (dB)
ADS8860	93	-108
Bad Filter	82.5	-73.4



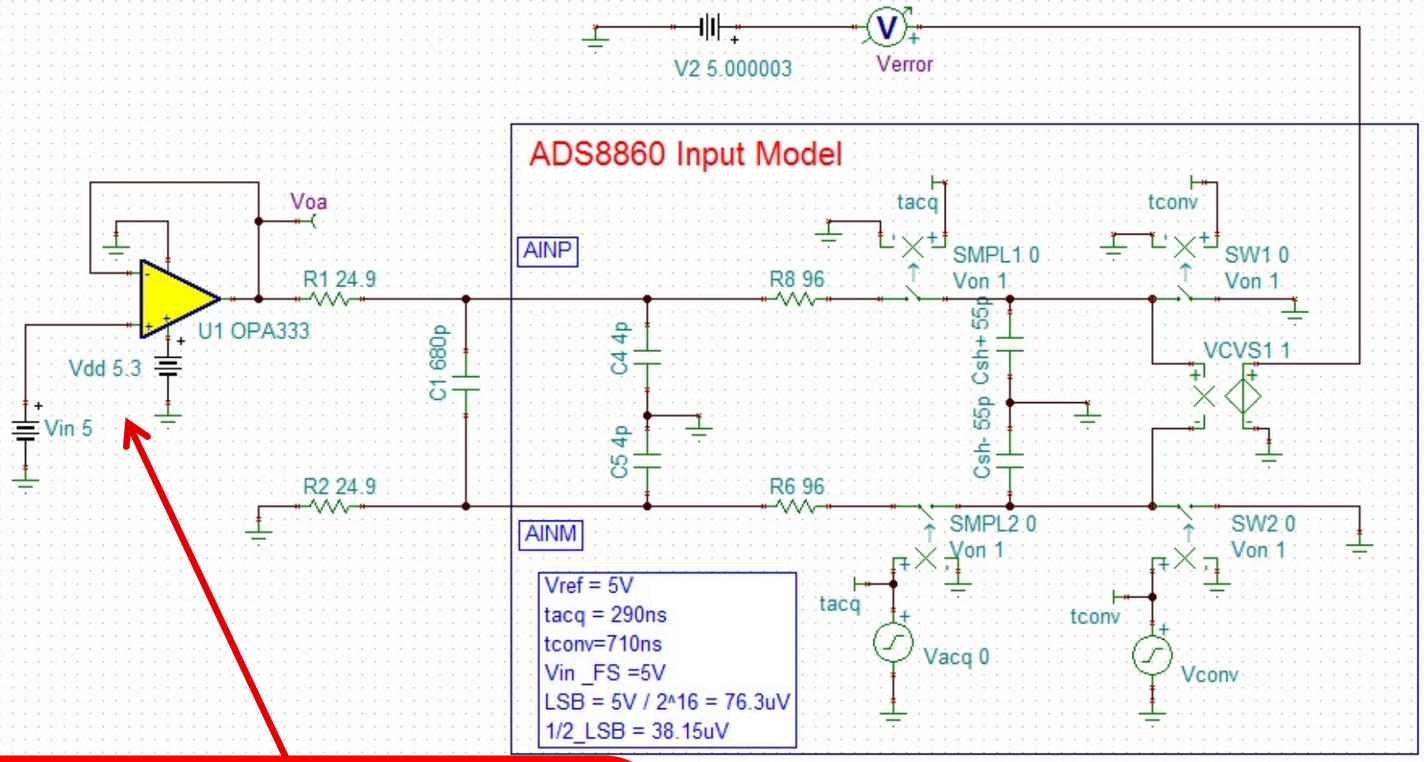
1. Install OPA320_Bad Filter coupon card in socket.

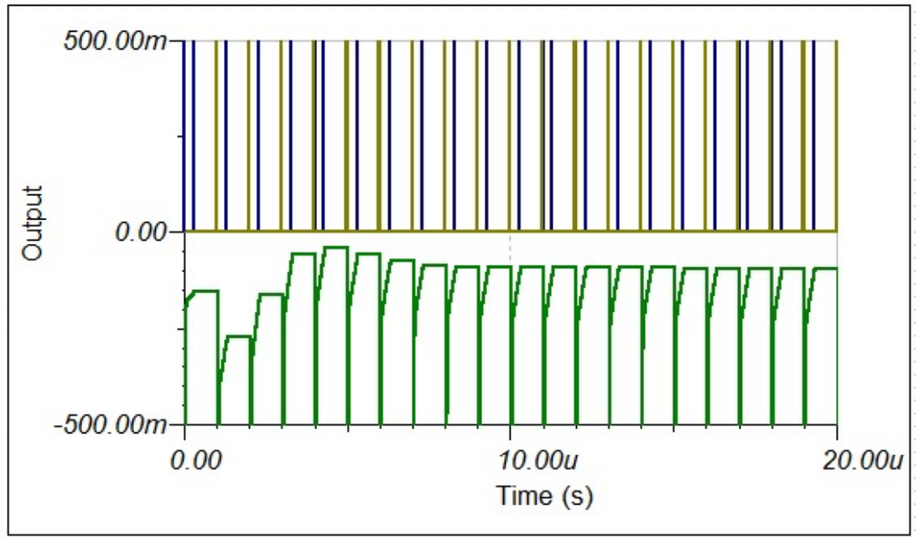


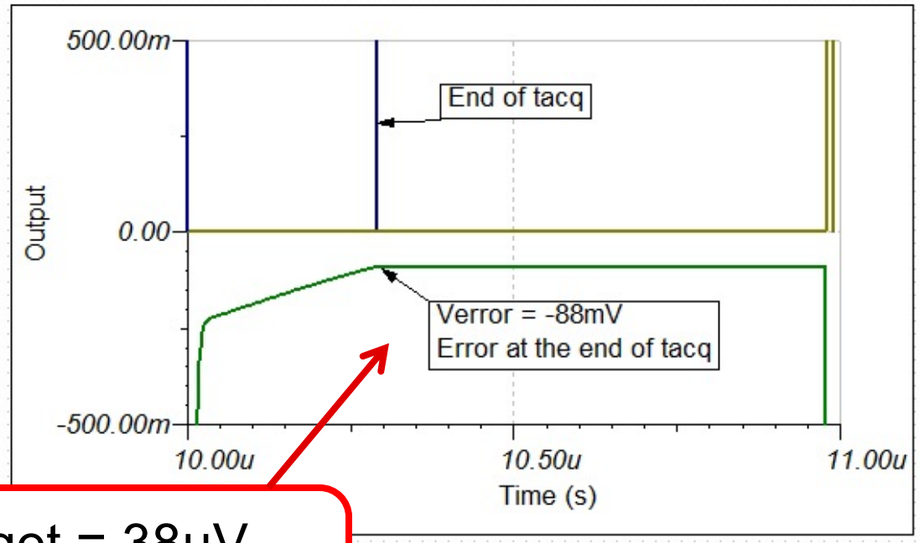
3. Press “Capture”
4. Record AC performance

2. Amplitude = 4.9V
Offset = 2.5V
Frequency = 2kHz

3: OPA333 Low Bandwidth







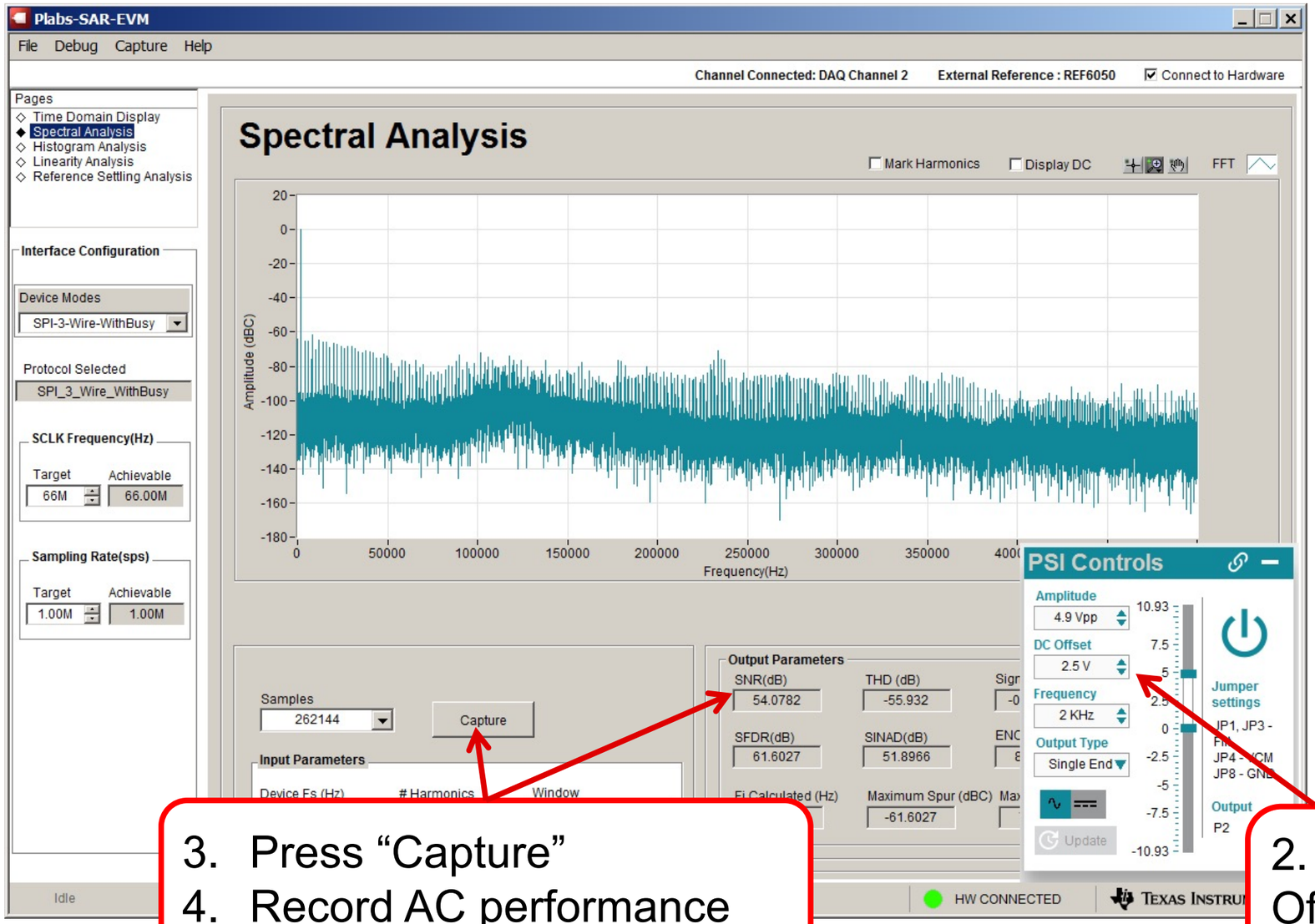
Bandwidth Required:
Gain Bandwidth= 17.8MHz
OPA333 Bandwidth:
Gain Bandwidth= 350kHz

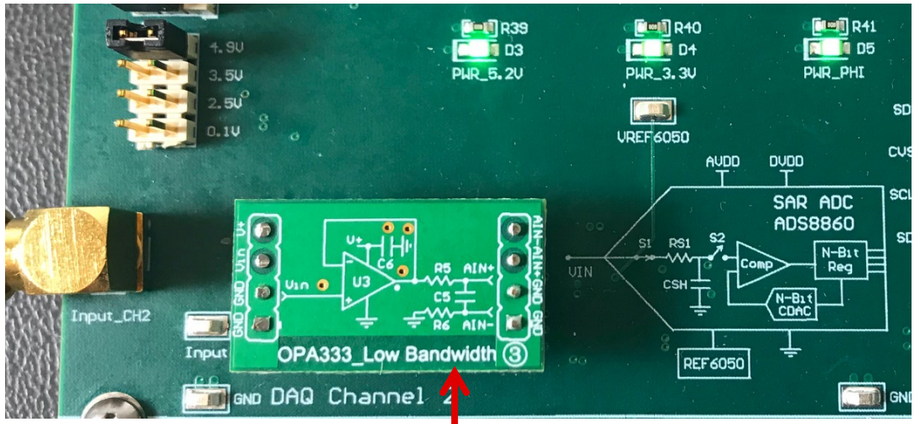
ADS8860_OPA333 - Low Bandwidth.TSC

Error Target = 38µV
Simulate Error = -88mV

3: OPA333 Low Bandwidth

	SNR (dB)	THD (dB)
ADS8860	93	-108
Low Bandwidth	54.1	-55.9



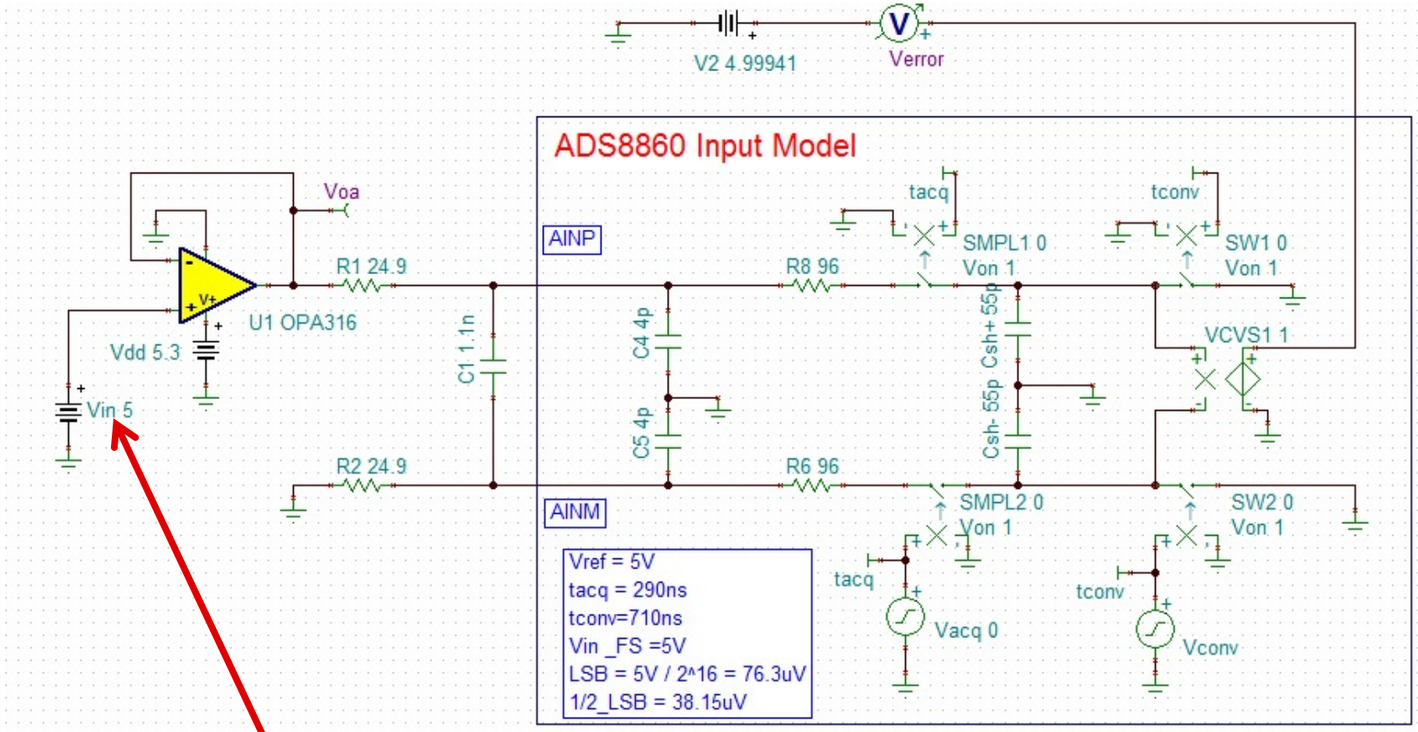


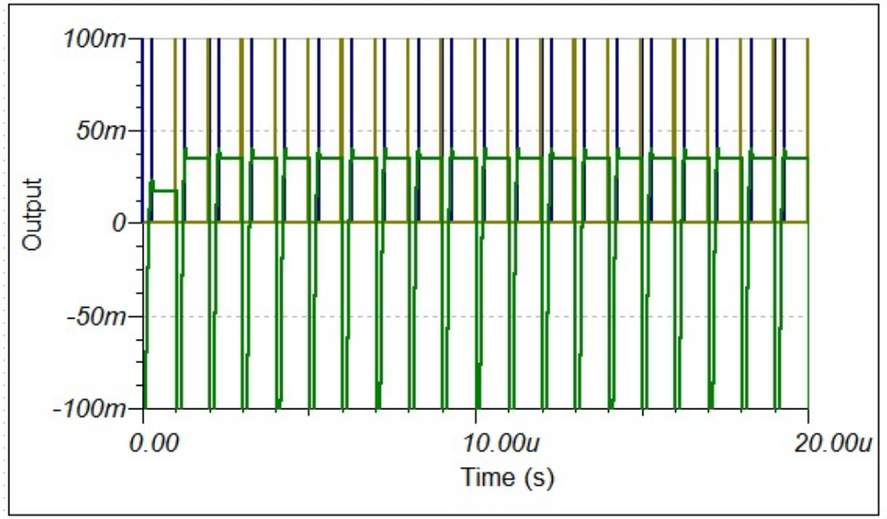
1. Install OPA333_Low Bandwidth coupon card in socket.

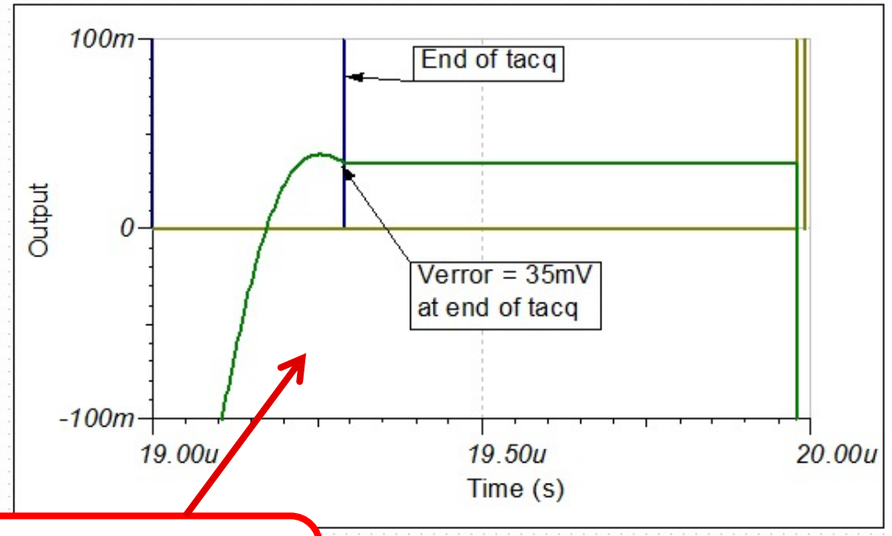
2. Amplitude = 4.9V
Offset = 2.5V
Frequency = 2kHz

3. Press “Capture”
4. Record AC performance

4: OPA316 Crossover, fs = 1Msps







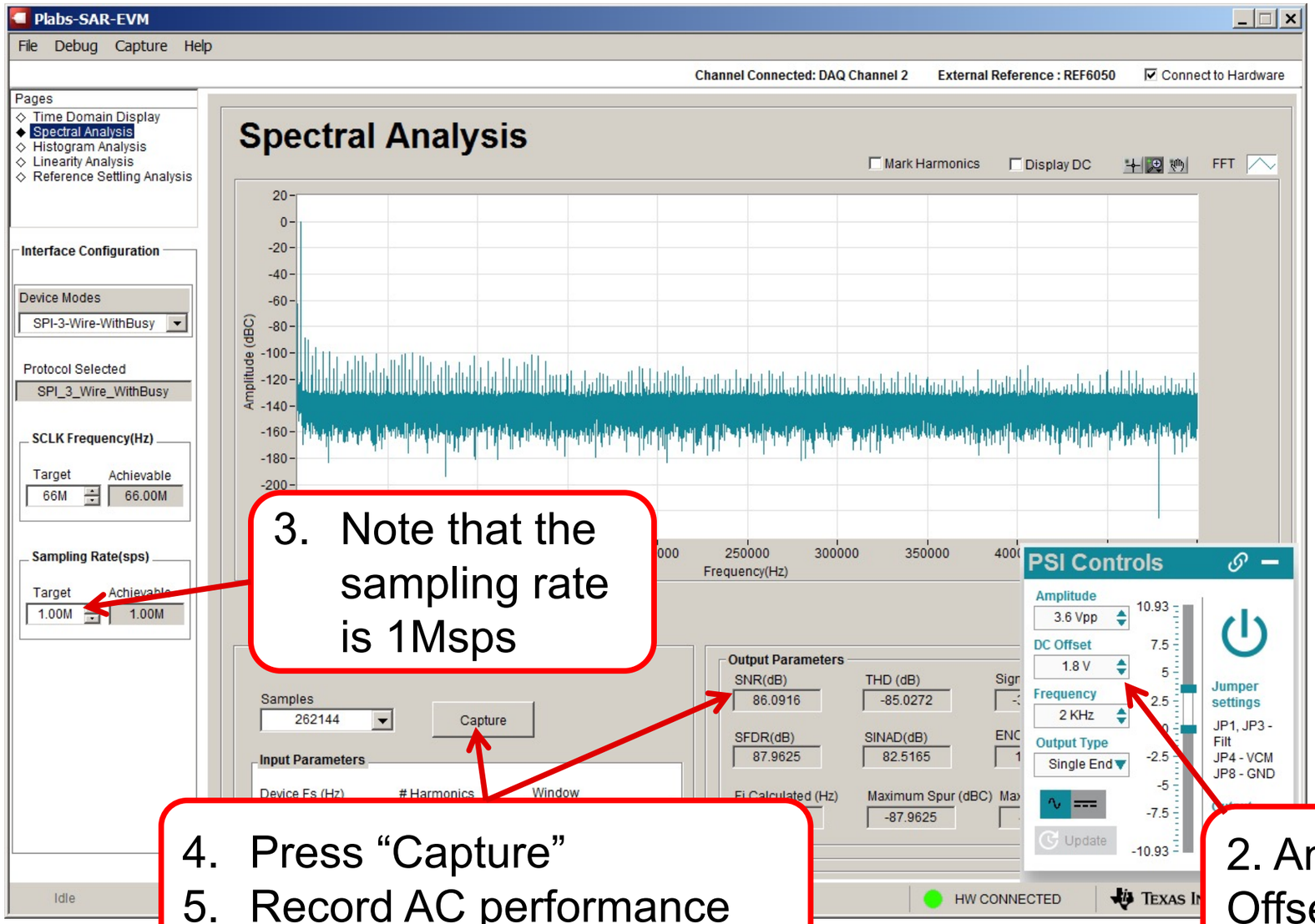
Bandwidth Required:
Gain Bandwidth= 17.8MHz
OPA316 Bandwidth:
Gain Bandwidth= 10MHz

ADS8860_OPA316 - Crossover-1Msps.TSC

Error Target = 38µV
Simulate Error = 35mV

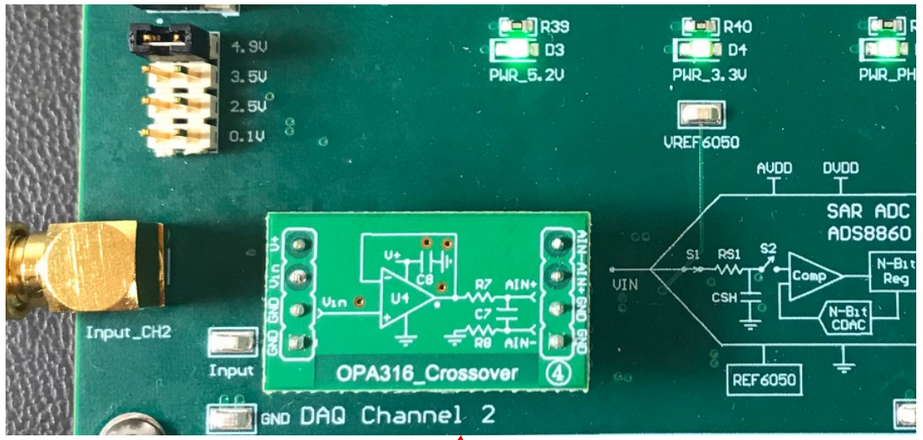
4: OPA316 Crossover, fs = 1Msps

	SNR (dB)	THD (dB)
ADS8860	93	-108
Crossover 1Msps	86.1	-85.0



3. Note that the sampling rate is 1Msps

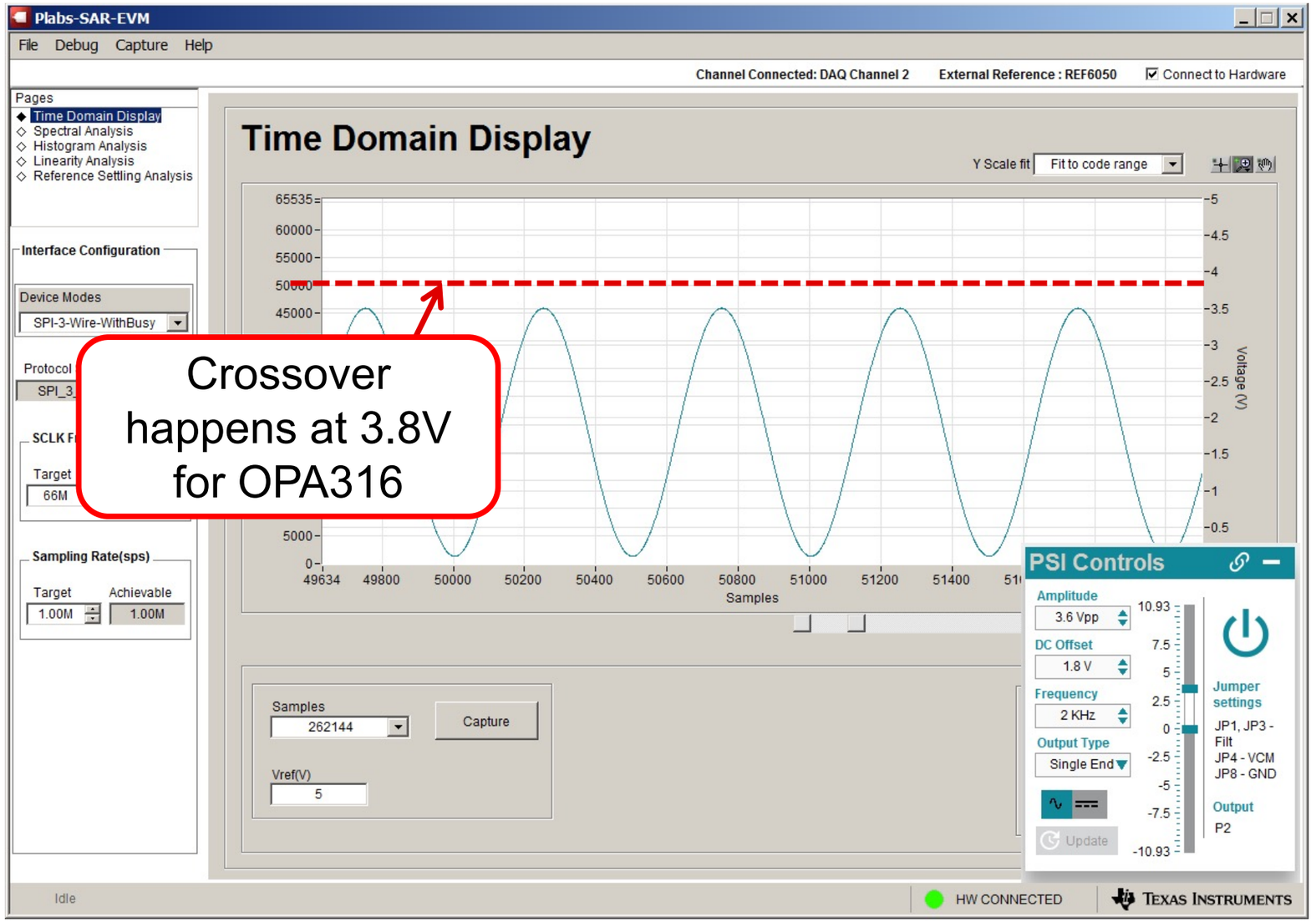
4. Press “Capture”
5. Record AC performance



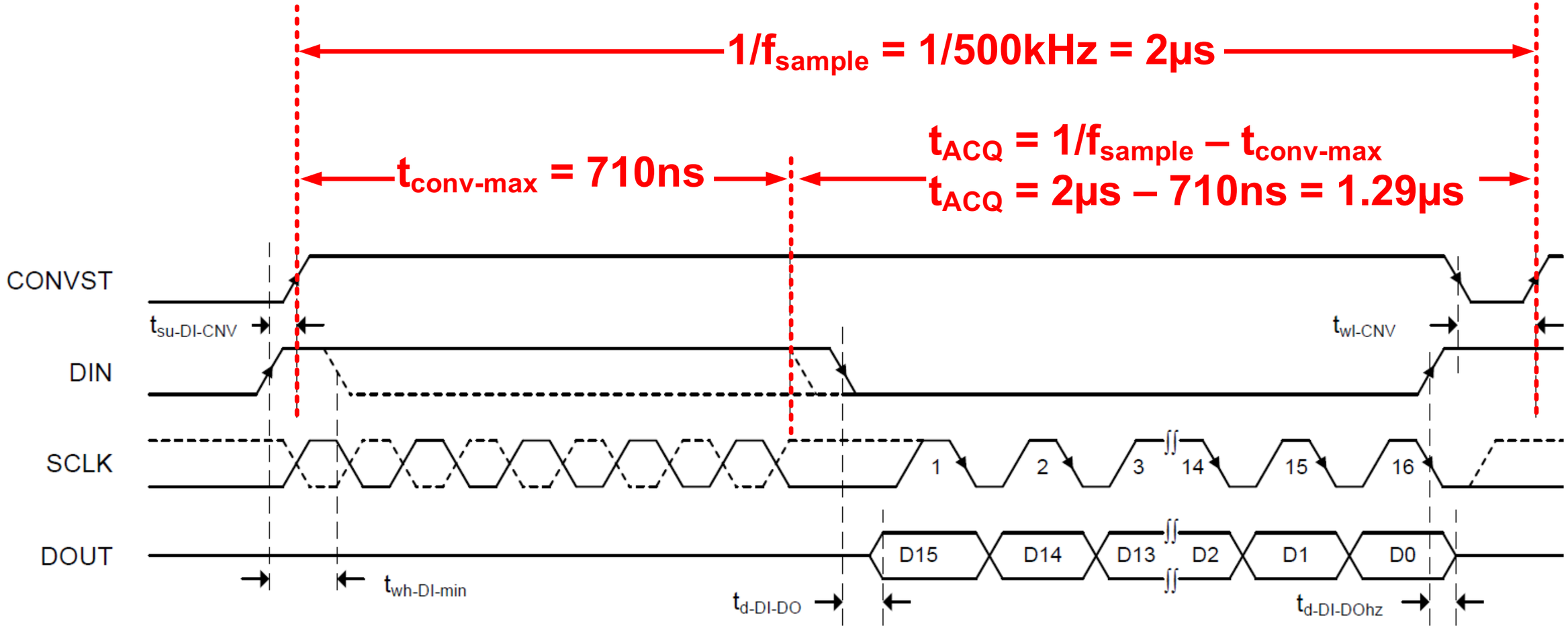
1. Install OPA316_Crossover coupon card in socket.

2. Amplitude = 3.6V
Offset = 1.8V
Frequency = 2kHz

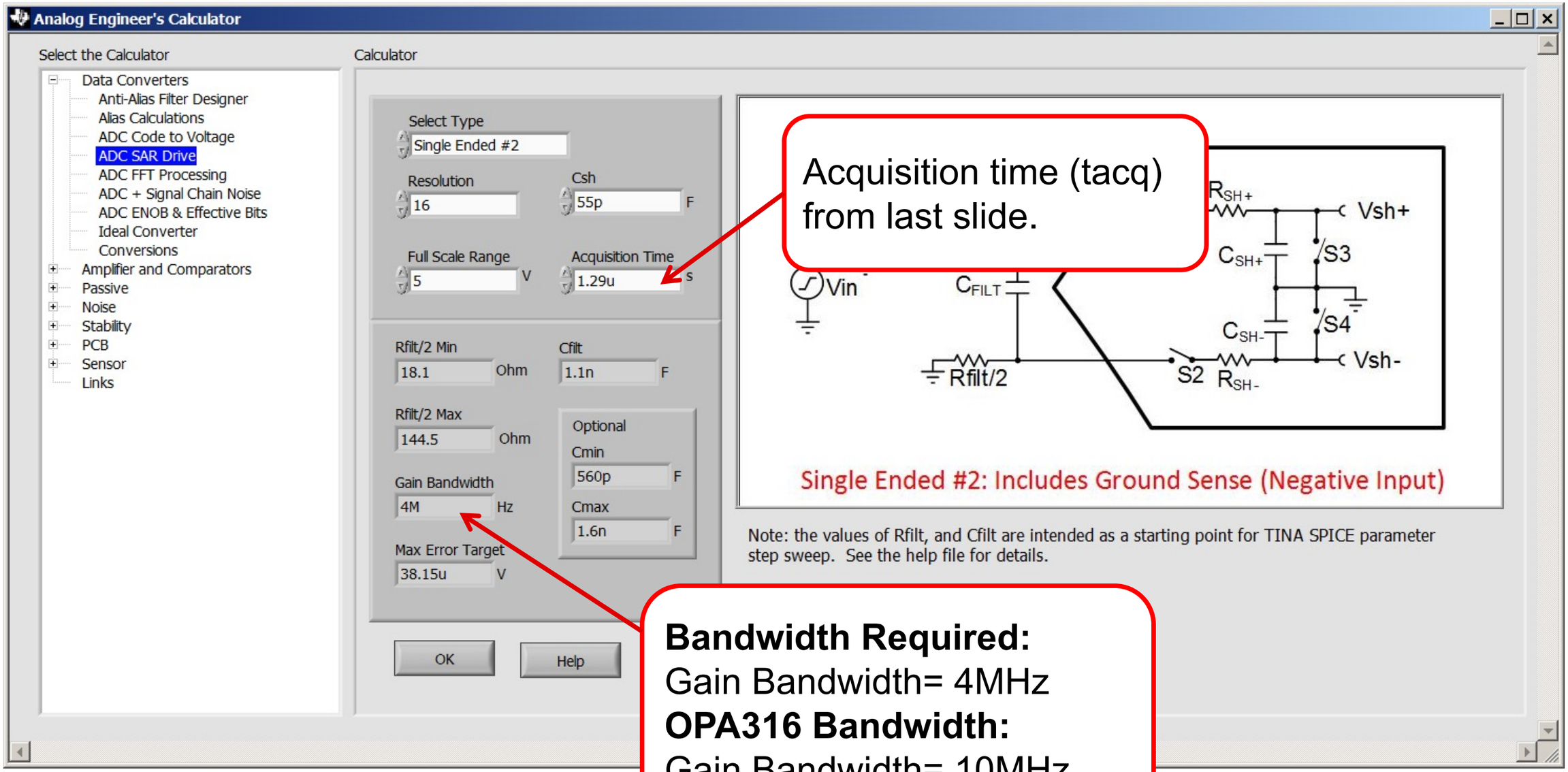
Input signal range to avoid crossover distortion



Changing the Sampling Rate to 500kHz



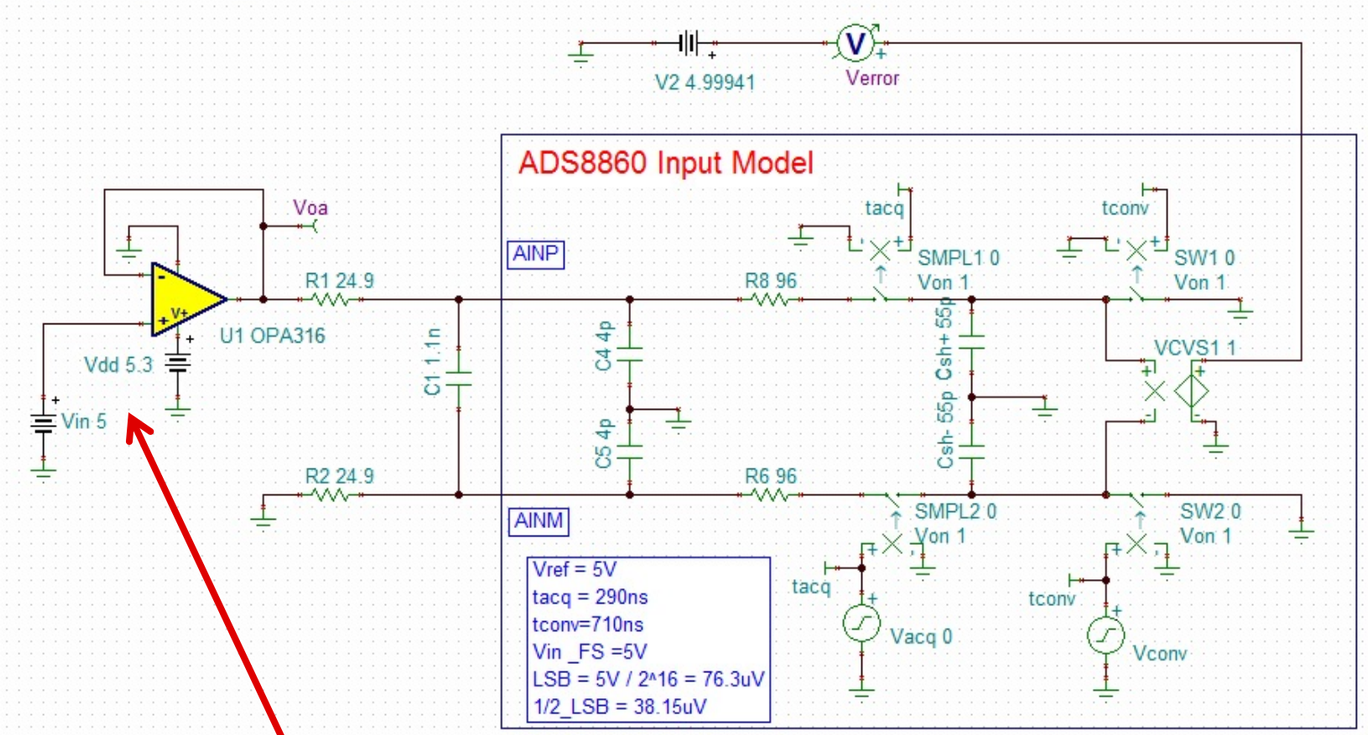
Changing the Sampling Rate to 500kHz

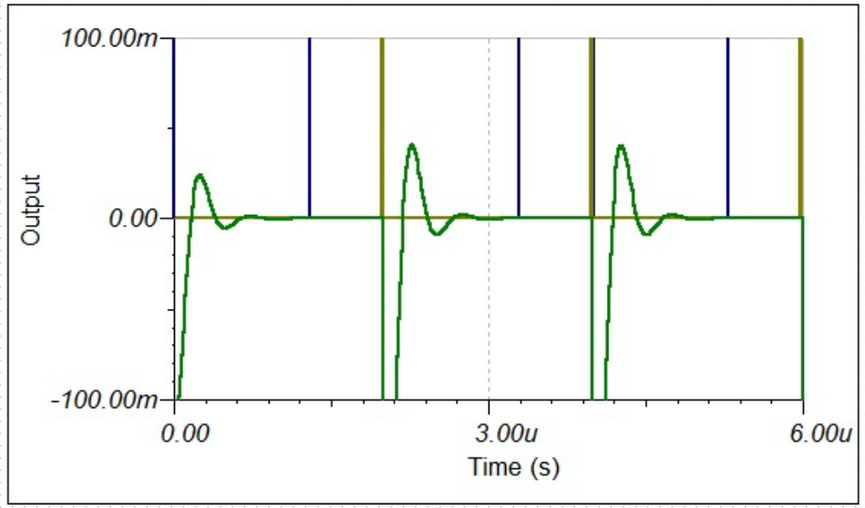


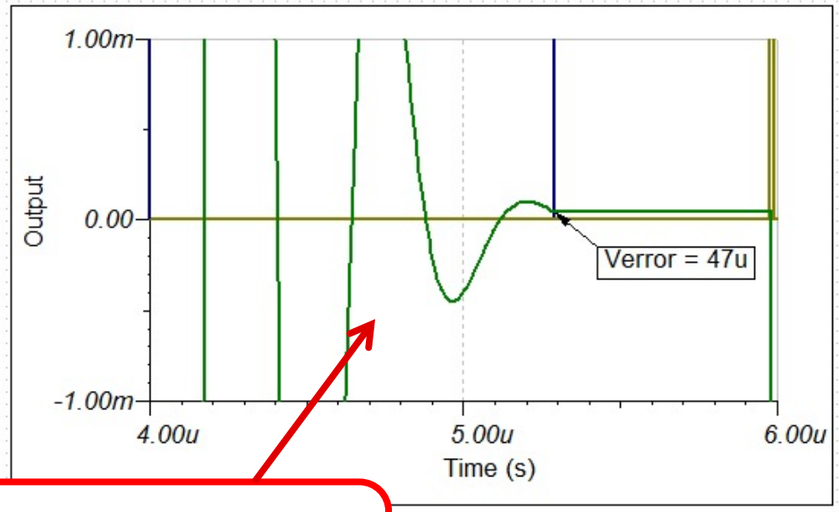
Acquisition time (tacq) from last slide.

Bandwidth Required:
Gain Bandwidth= 4MHz
OPA316 Bandwidth:
Gain Bandwidth= 10MHz

5: OPA316 Crossover, fs = 500ksps







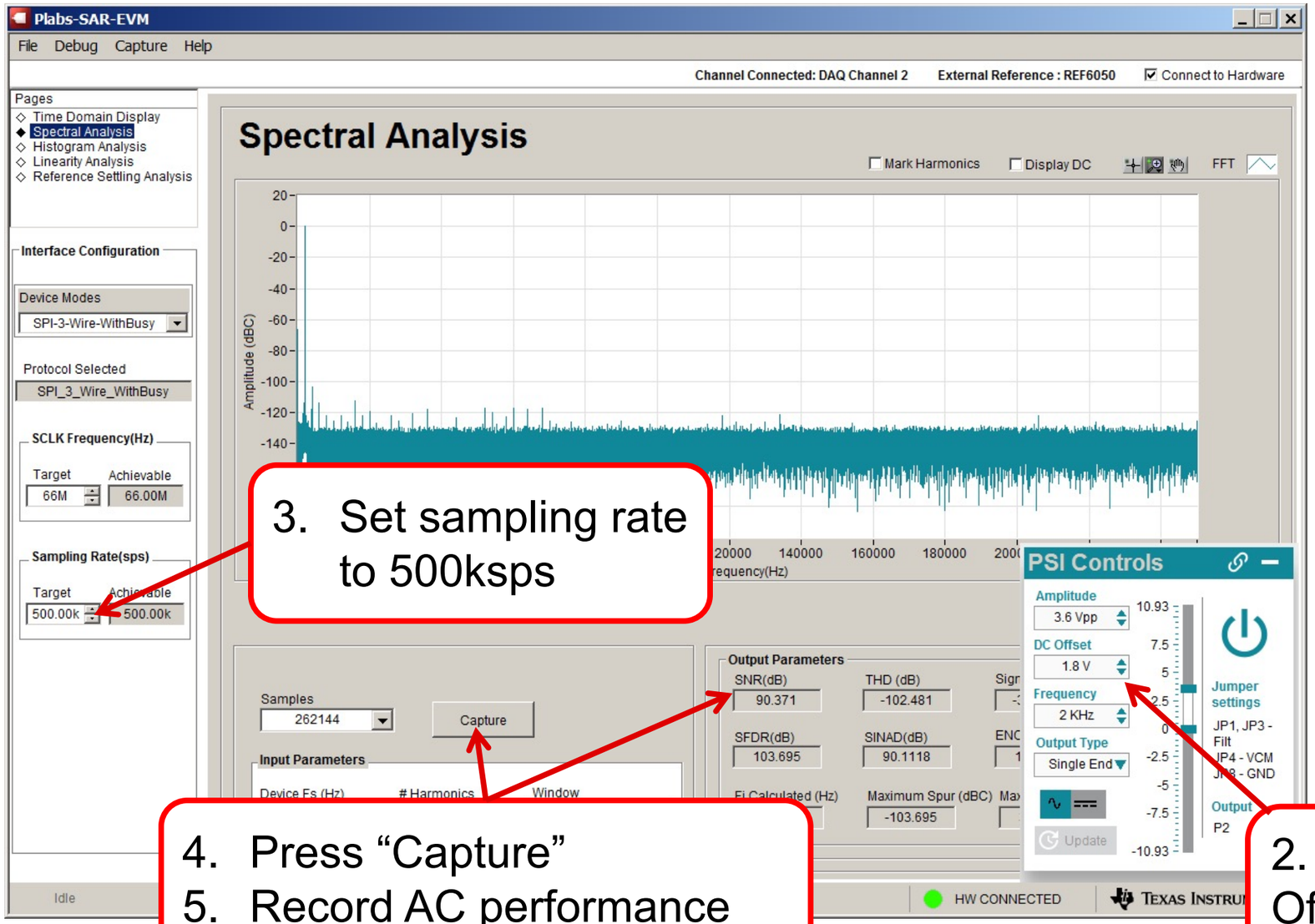
Bandwidth Required:
Gain Bandwidth= 4MHz
OPA316 Bandwidth:
Gain Bandwidth= 10MHz

ADS8860_OPA316 - Crossover-500ksps.TSC

Error Target = 38µV
Simulate Error = 47µV

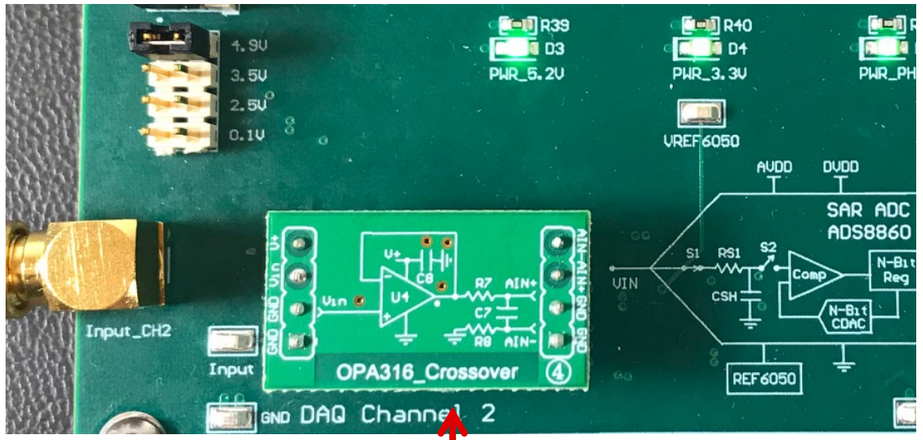
OPA316 Crossover, fs = 500ksps

	SNR (dB)	THD (dB)
ADS8860	93	-108
Crossover 1Msps	86.1	-85.0
Crossover 500ksps	90.3	-102



3. Set sampling rate to 500ksps

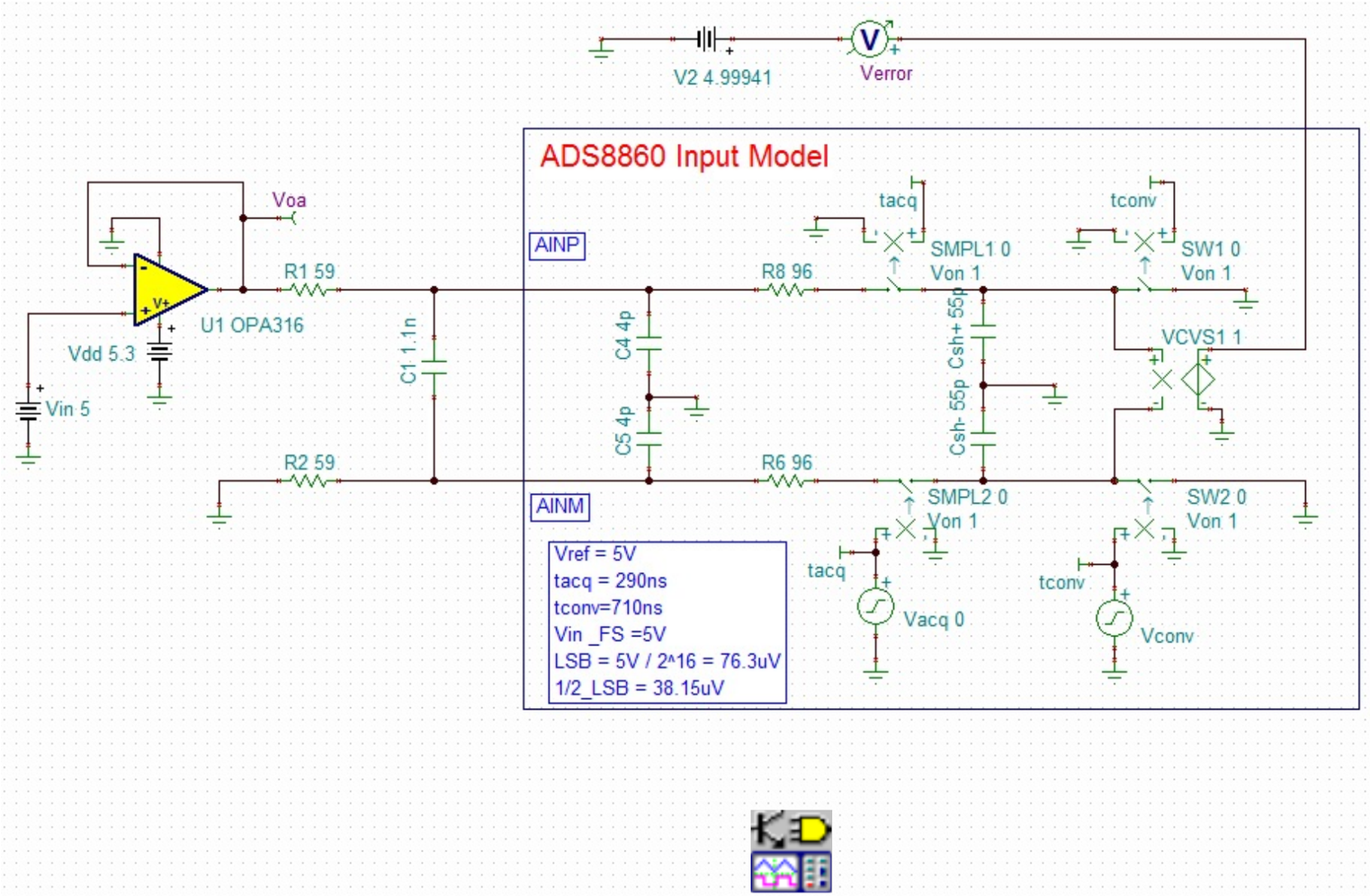
4. Press “Capture”
5. Record AC performance



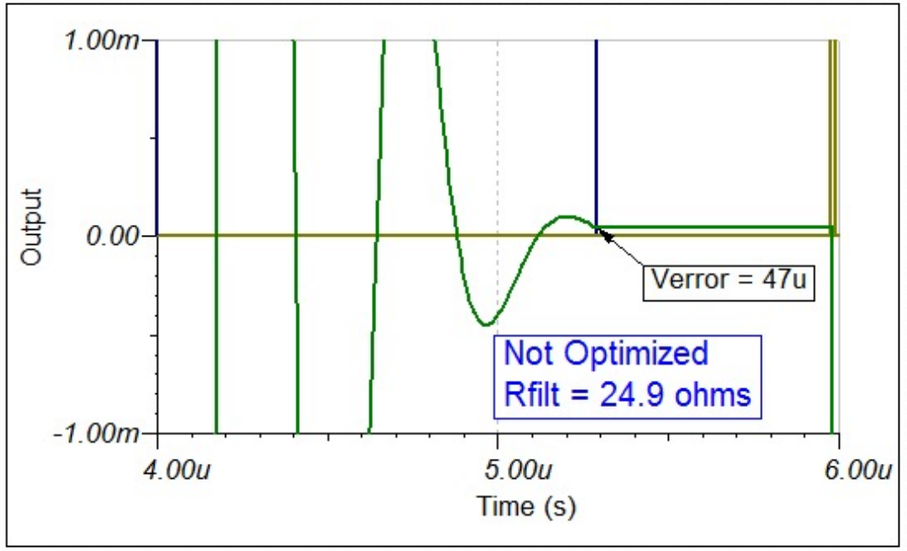
1. No device change needed.

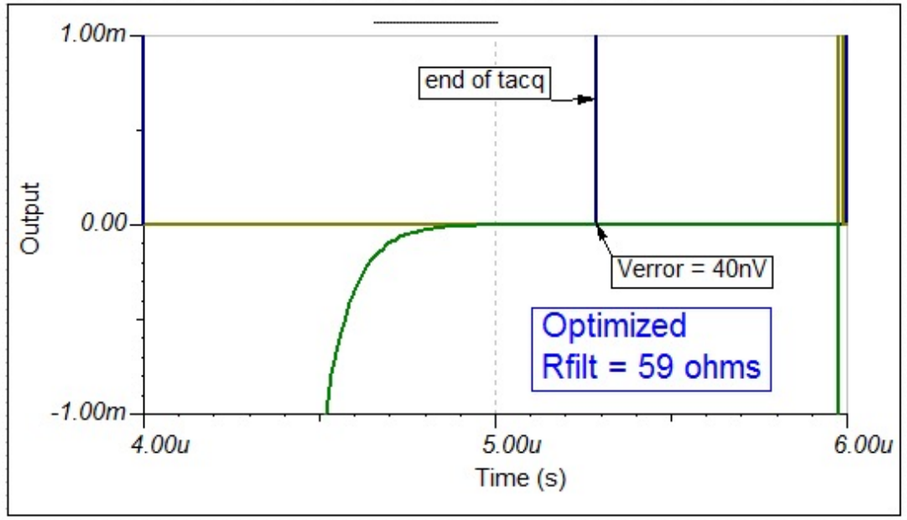
2. Amplitude = 3.6V
Offset = 1.8V
Frequency = 2kHz

Settling can be improved



ADS8860_OPA316 - Crossover-500ksps-optimized.TSC





Measured vs Expected Results

Your results should show the same trend as the expected result but the specific values will differ.

Device					Simulated Settling Error ½LSB=38uV	Example Measurements		Your Measurements	
	Device	Samp. Rate	V_{offset} (V)	V_{in} (V)	V_{error} (V)	SNR (dB)	THD (dB)	SNR (dB)	THD (dB)
	ADS8860 Data Sheet					93	-108		
1	OPA320 Good filter1	1M	2.5	4.9	28uV	93.3	-108.8		
2	OPA320 Bad filter	1M	2.5	4.9	-41mV	82.5	-73.4		
3	OPA333 Low Bandwidth	1M	2.5	4.9	-91mV	54.1	-55.9		
4	OPA316 Crossover	1M	1.8	3.6	36.7mV	86.1	-85.0		
5	OPA316 Crossover	500k	1.8	3.6	47uV	90.3	-102.4		

Thanks for your time!