

Amplifier Settling and Charge Bucket Filter Design

TIPL 4405-L

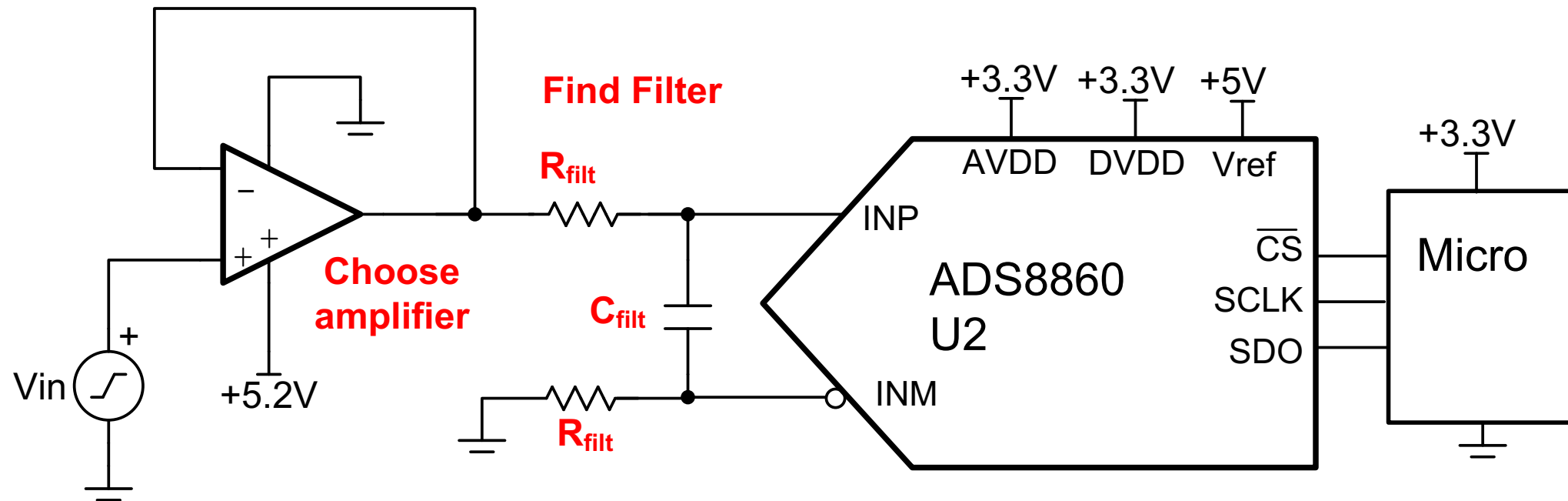
TI Precision Labs – ADCs

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

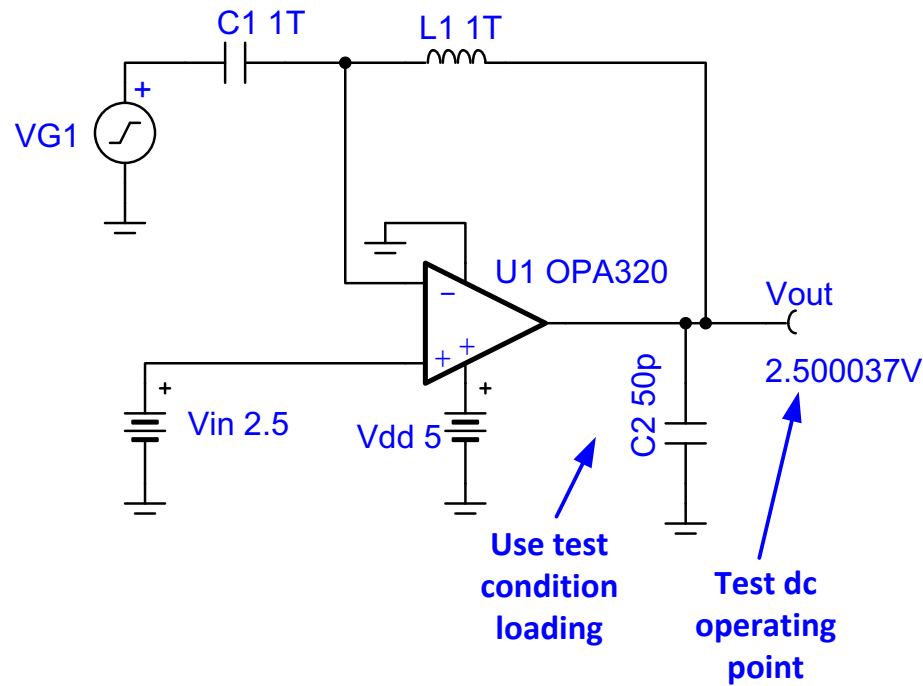
1. Enter the information from the ADS8860 Data Sheet.

2. Results will be used in the simulation

Single Ended #2: Includes Ground Sense (Negative Input)

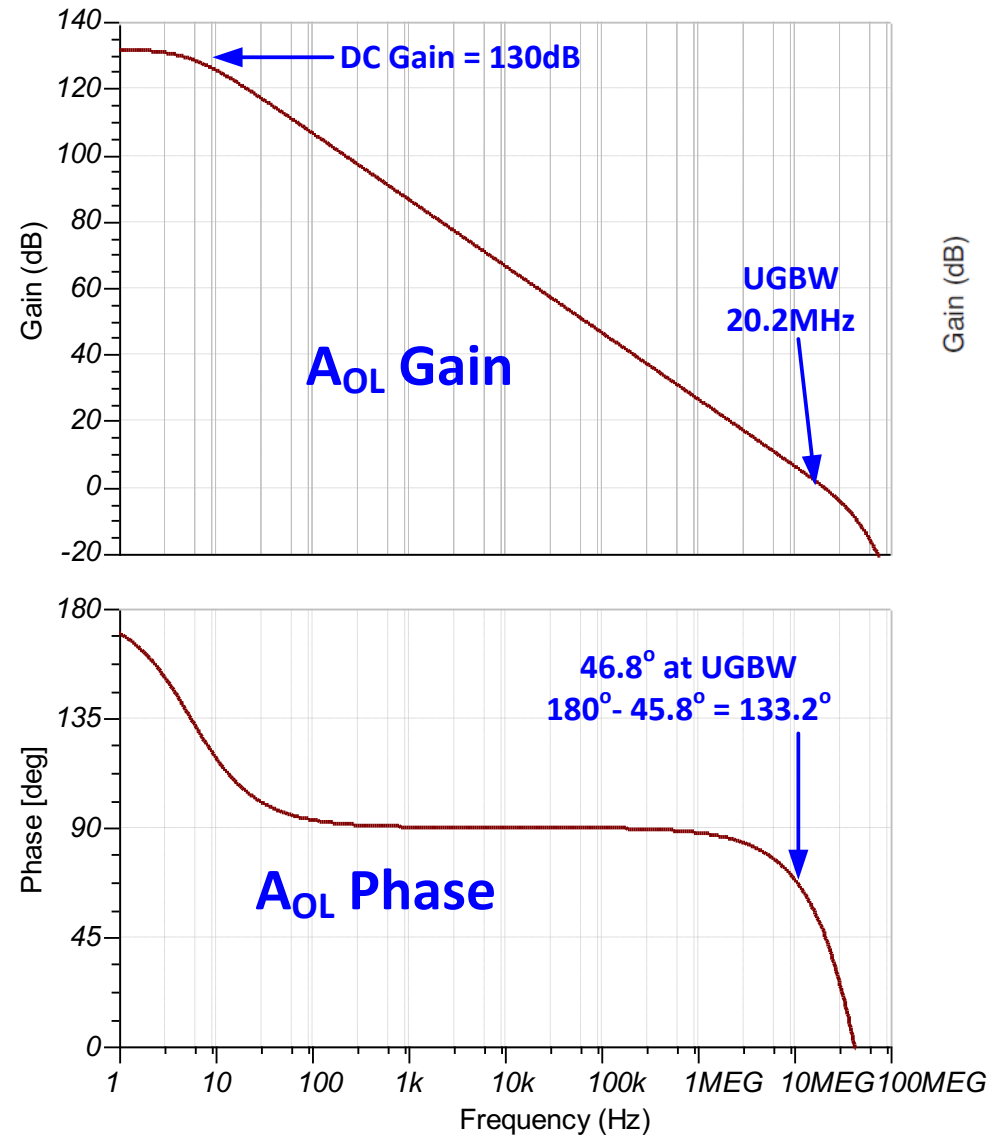
Op Amp Model: Open Loop Gain

Test Circuit for Aol

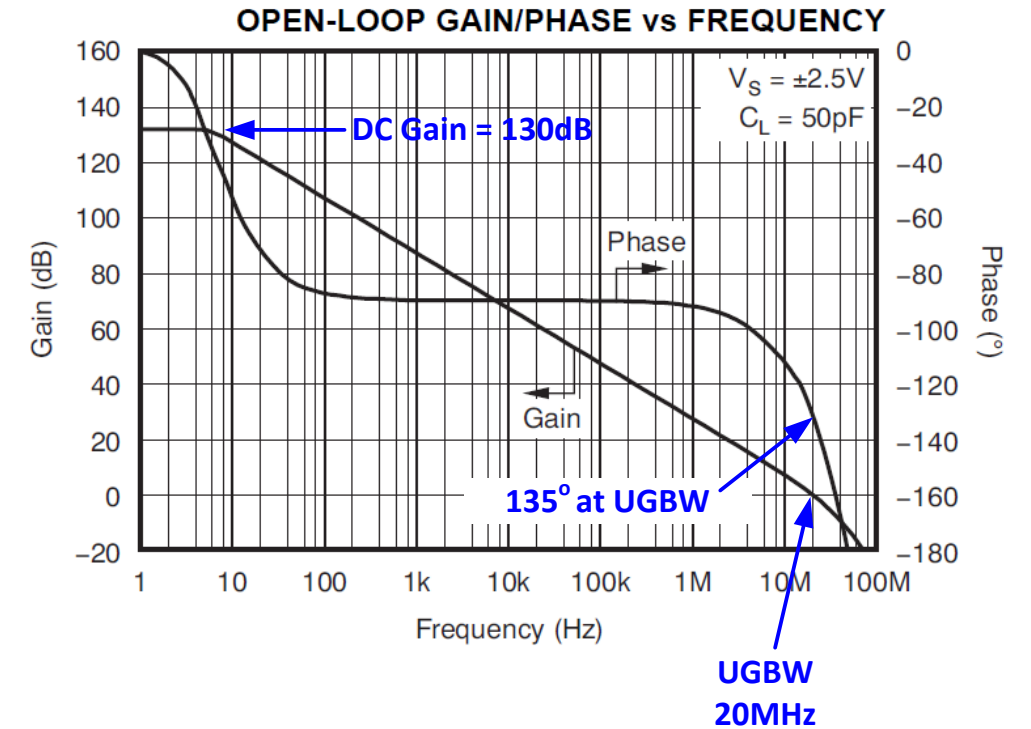


1. Test dc operating point to assure that circuit is correctly wired
 2. Run ac simulation for A_{OL} curve
- $A_{OL} = V_{out}$

Simulated results



Data Sheet Specification



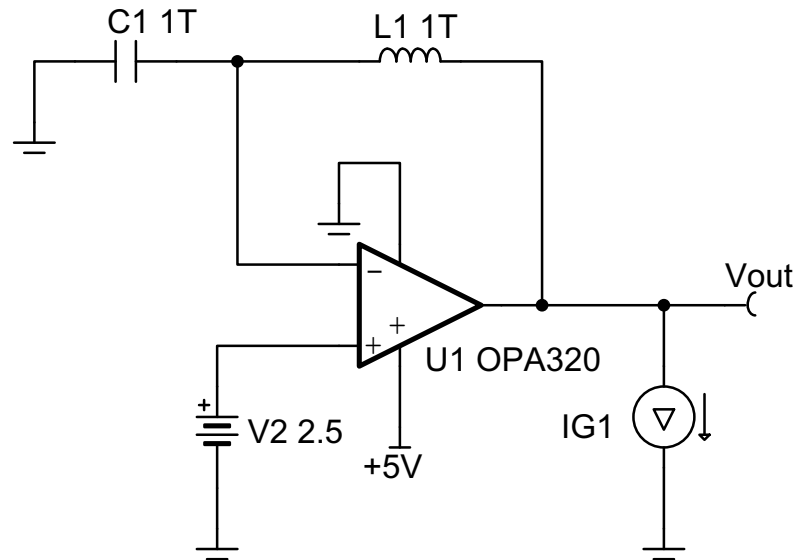
Compare key points on simulation results to data sheet curve.



Aol opa320.TSC

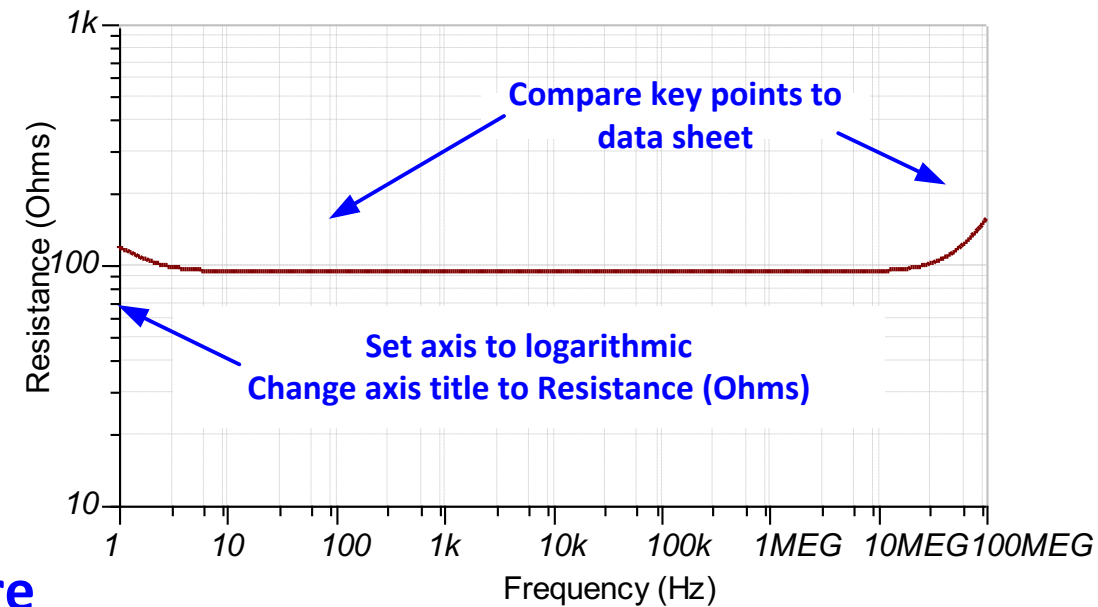
Op Amp Model: Open Loop Output Impedance

Test Circuit for Aol

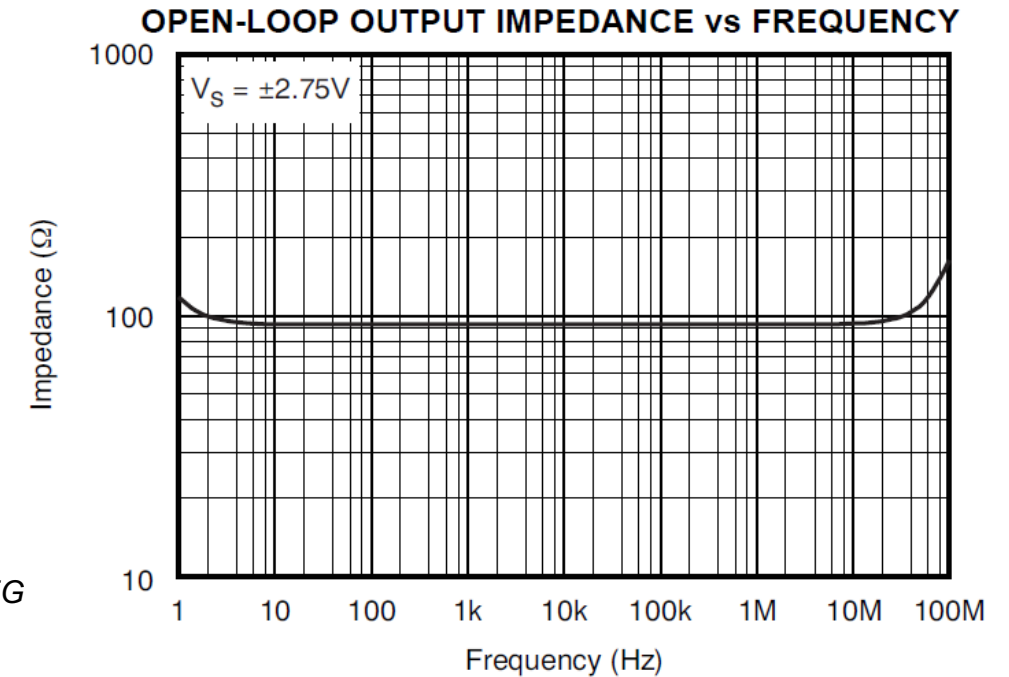


1. Test dc operating point to assure that circuit is correctly wired
2. Run ac simulation for Z_o curve.
 $Z_o = V_{out}$.

Simulated results

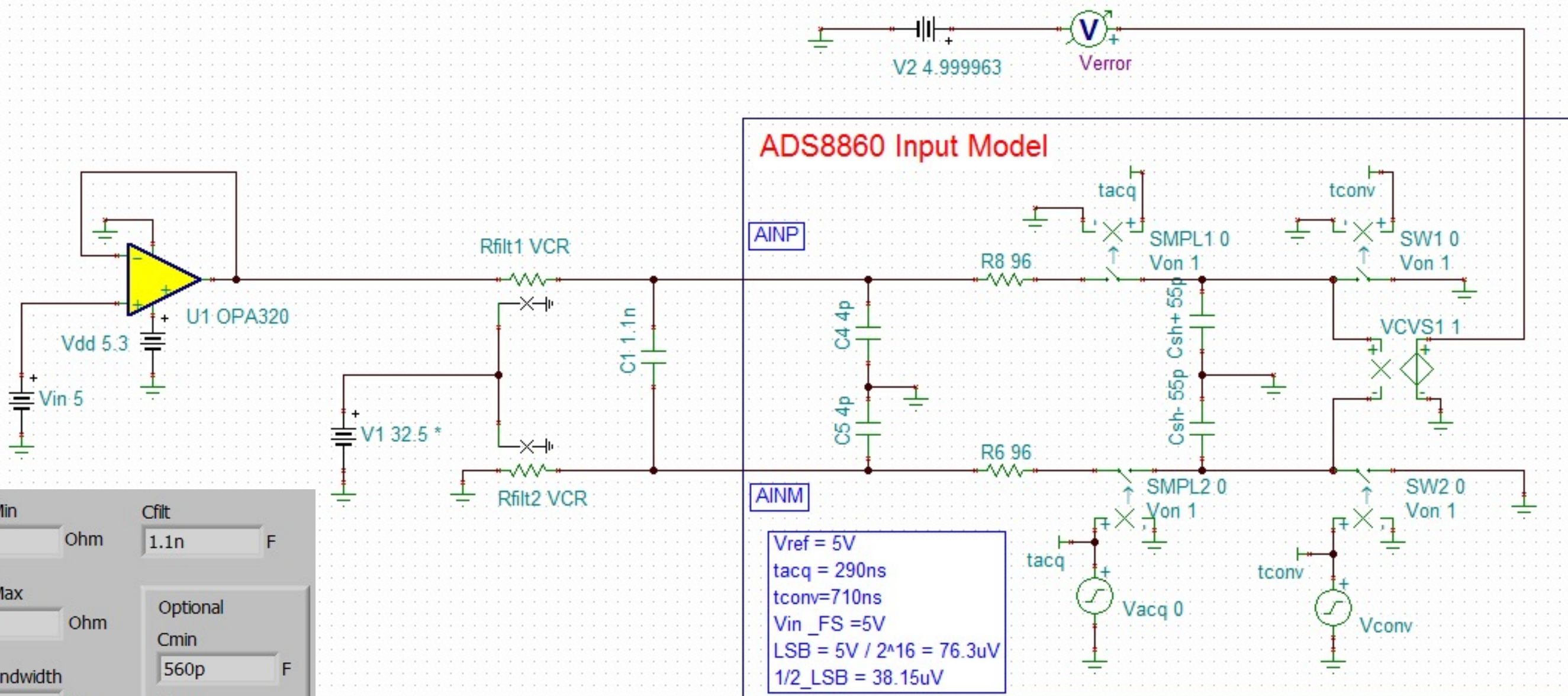


Data Sheet Specification



Zo opa320.TSC

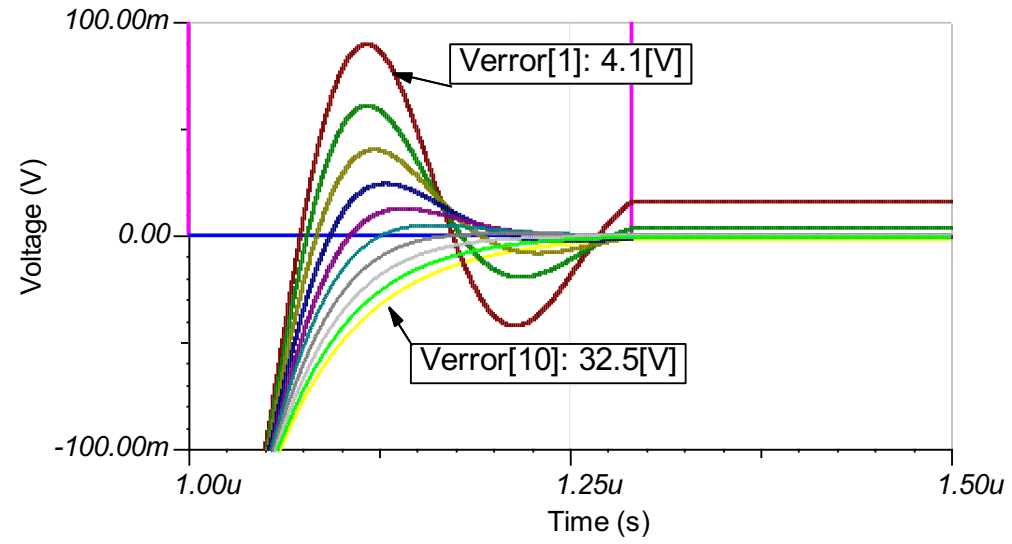
Find the Op Amp Bandwidth and RC Charge Bucket



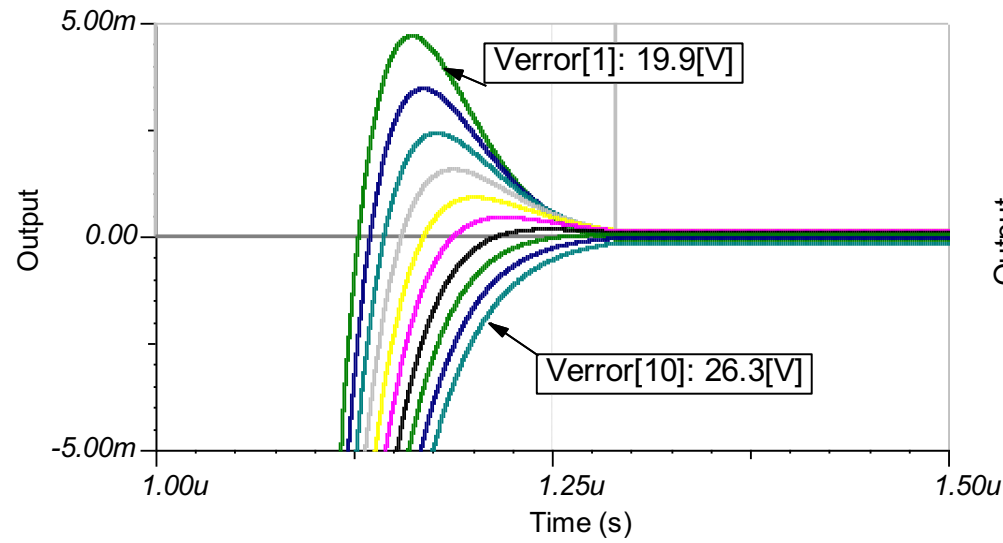
ADS8860 Input Model

Vref = 5V
 tacq = 290ns
 tconv = 710ns
 Vin_FS = 5V
 LSB = $5V / 2^{16} = 76.3\mu V$
 1/2_LSB = 38.15uV

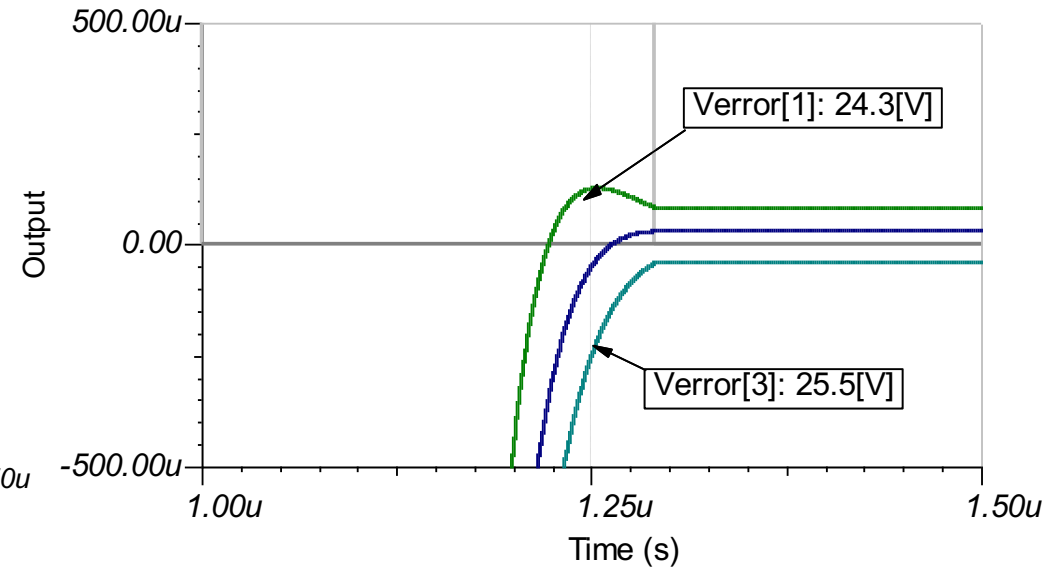
Parameter Step R_{filt}



ADS8860_OPA320 - 1st - iteration.TSC

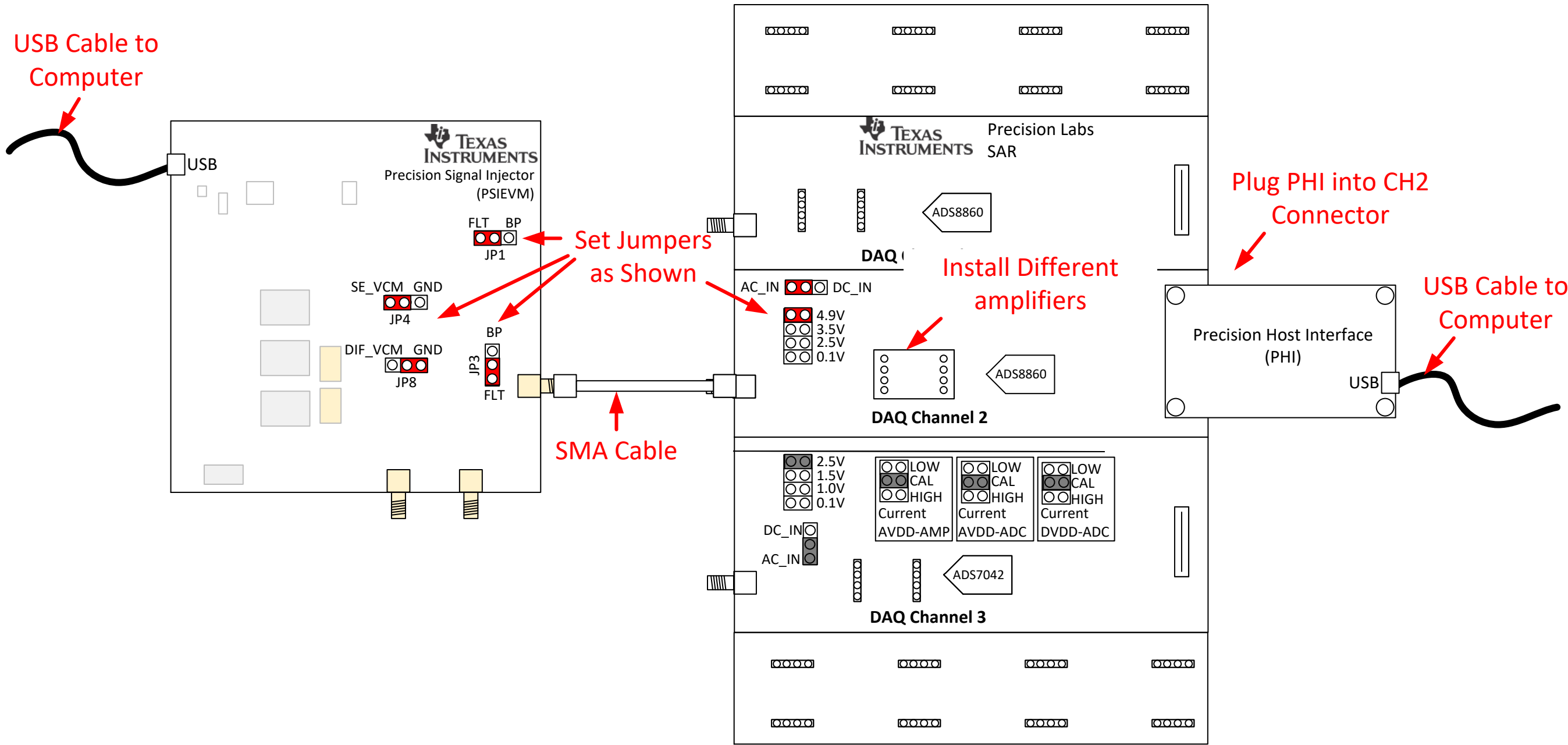


ADS8860_OPA320 - 2nd - iteration.TSC



ADS8860_OPA320 - 3rd - iteration.TSC

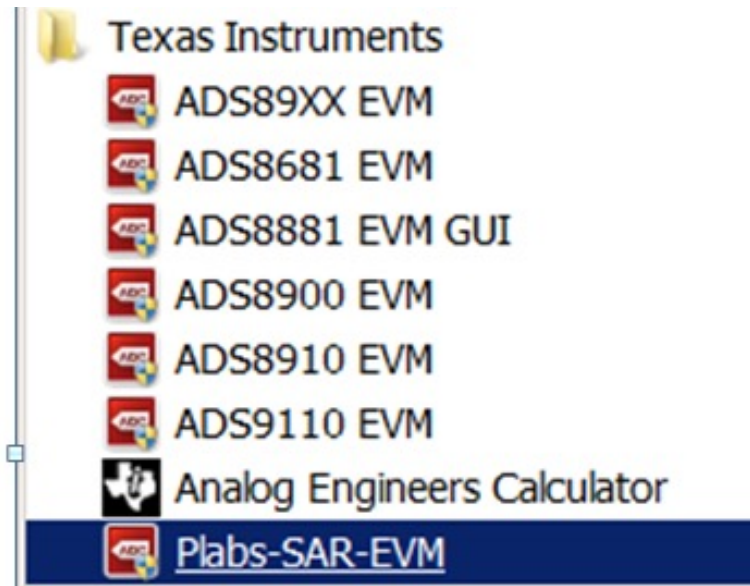
Connect the hardware



Record results as we progress through Experiment

Device					Simulated Settling Error $\frac{1}{2}\text{LSB}=38\mu\text{V}$	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	28 μV	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	47 μV	90.3	-102.4		

Start & Setup the Plabs-Power Scaling EVM Software



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

Plabs-SAR-EVM

File Debug Capture Help

Channel Connected: DAQ Channel 2 External Reference : REF6050 Connect to Hardware

Pages

- ◆ Time Domain Display
- ◇ Spectral Analysis
- ◇ Histogram Analysis
- ◇ Linearity Analysis
- ◇ Reference Settling Analysis

Interface Configuration

Device Modes

SPI-3-Wire-WithBusy

Protocol Selected

SPI_3_Wire_WithBusy

SCLK Frequency(Hz)

Target Achievable

66M 66.00M

Sampling Rate(sps)

Target Achievable

1.00M 1.00M

Time Domain Display

Y Scale fit Auto mode

Codes

64246

64245

64244

64243

64242

64241

64240

64239

64238

64237

64236

64235

64234

64233

64232

64231

0 20000 40000 60000 80000 100000 120000 140000 160000 180000 200000 220000 240000 262143

Samples

Voltage (V)

-4.902

-4.901

-4.9

Min and Max Values

Max_Code Max_Volt

0 0.000

Min_Code Min_Volt

0 0.000

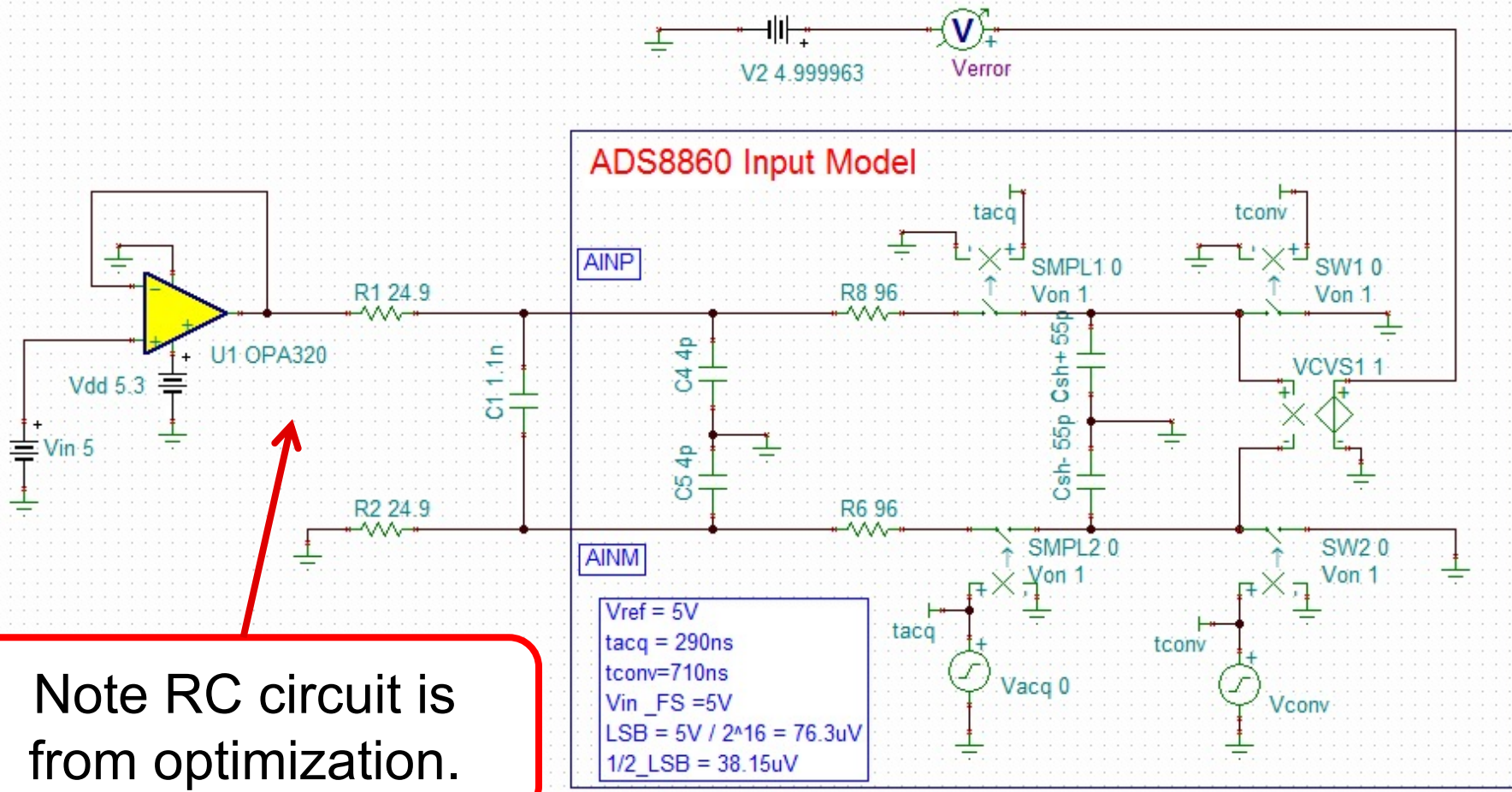
PSI Controls

HW CONNECTED

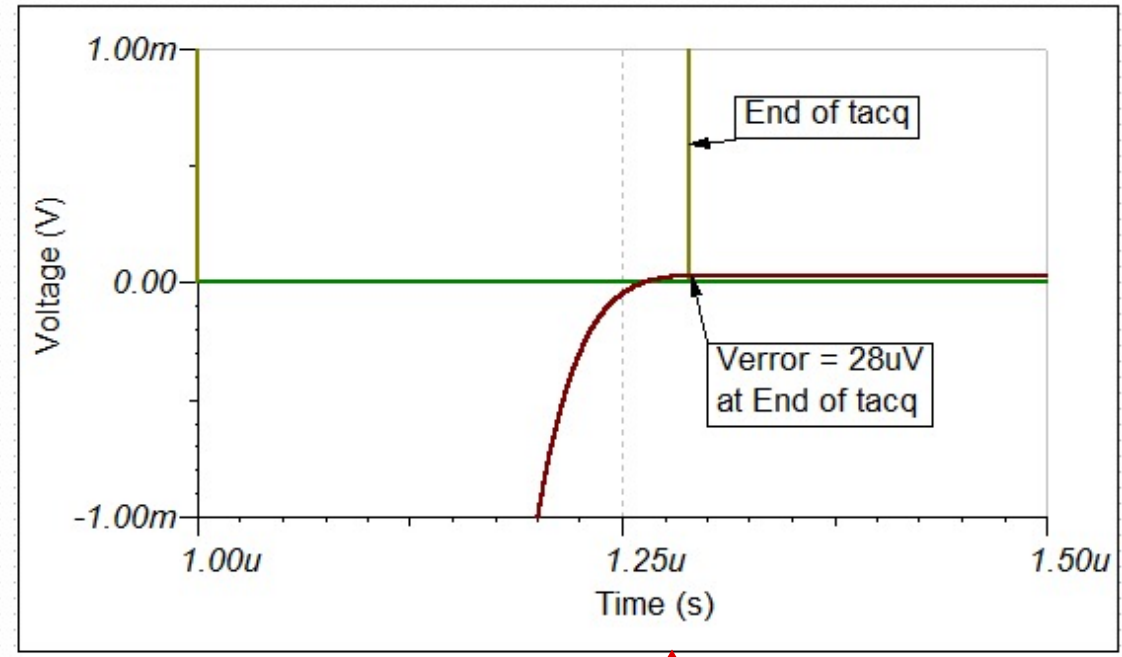
TEXAS INSTRUMENTS

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

1: OPA320_Good Filter1



Note RC circuit is from optimization.

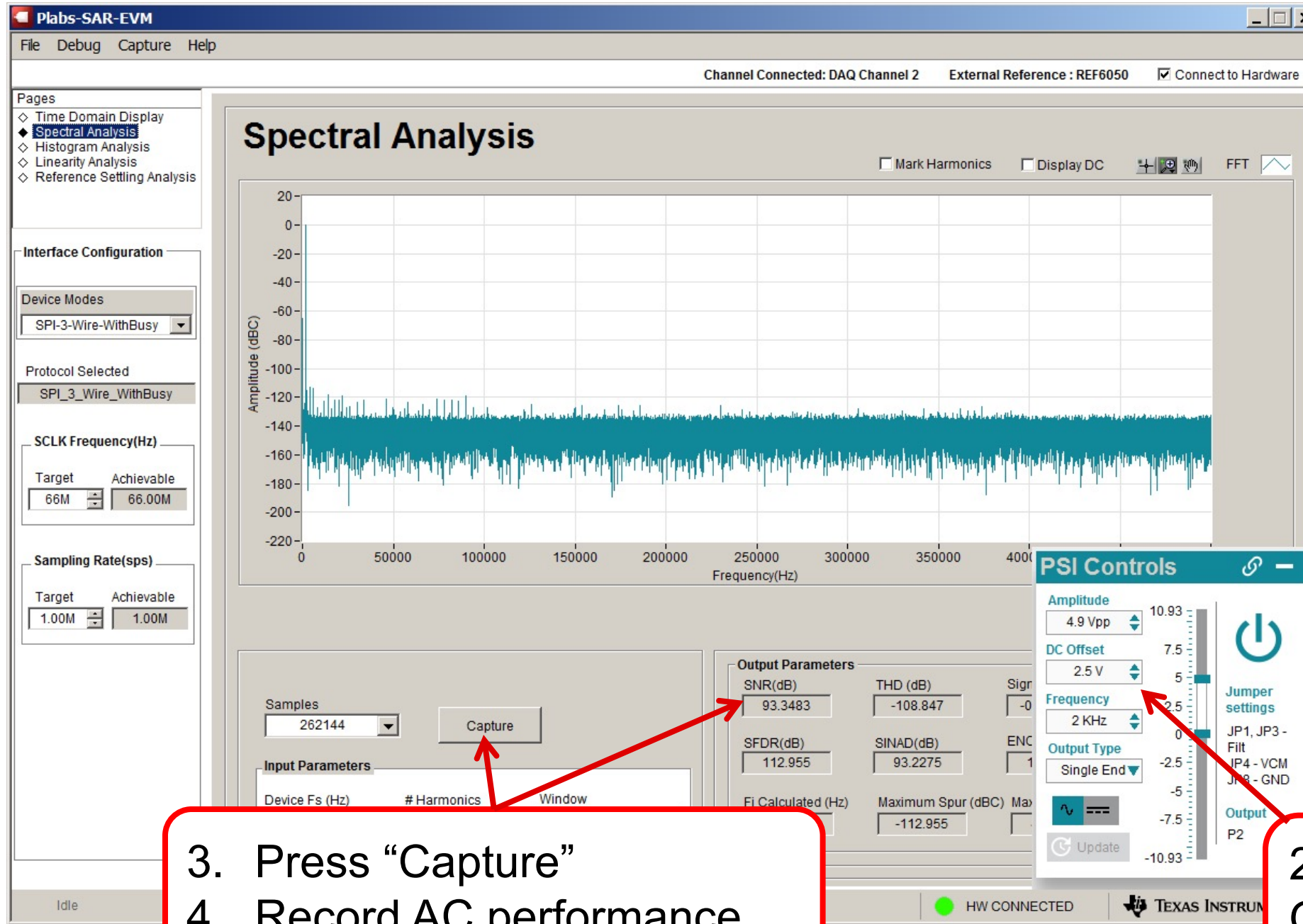


Error Target = 38μV
Simulate Error = 28μV

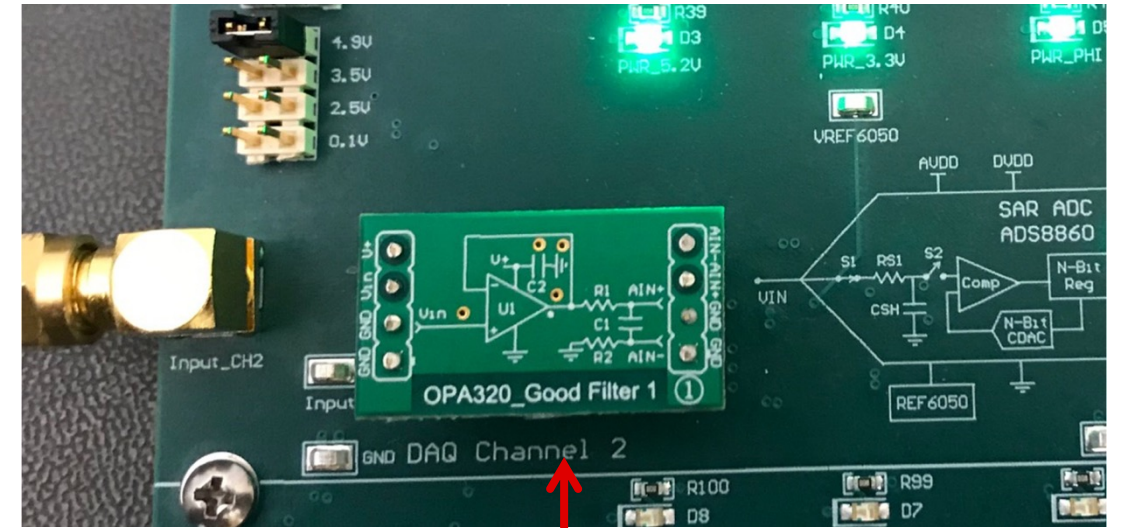


ADS8860_OPA320 - good filter.TSC

1: OPA320_Good Filter1



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

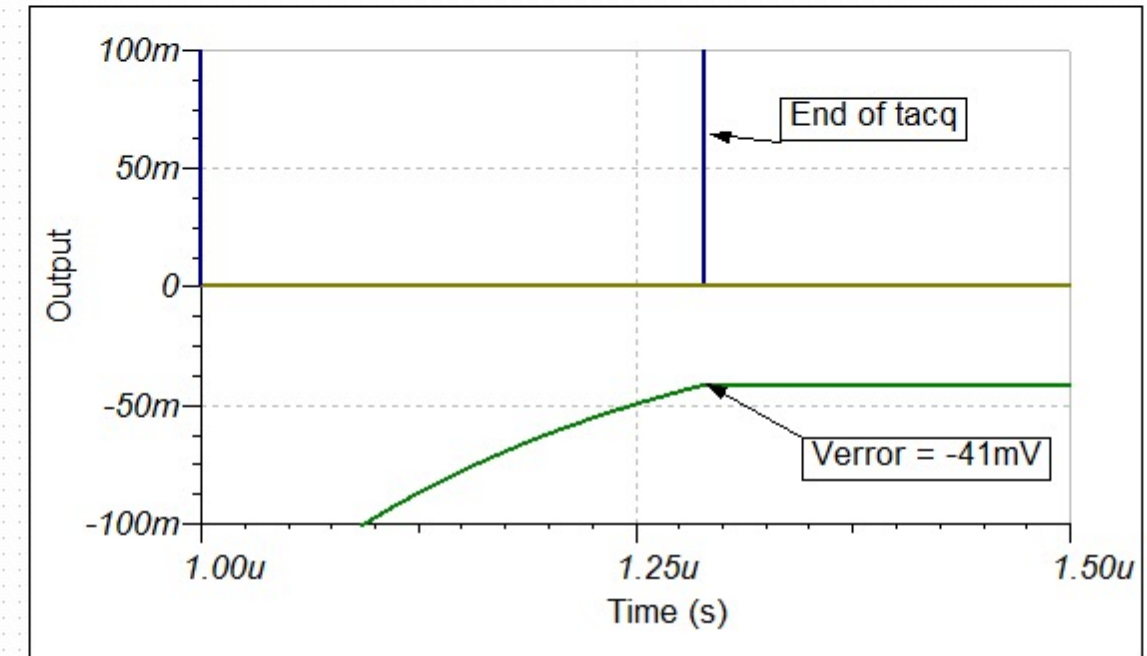
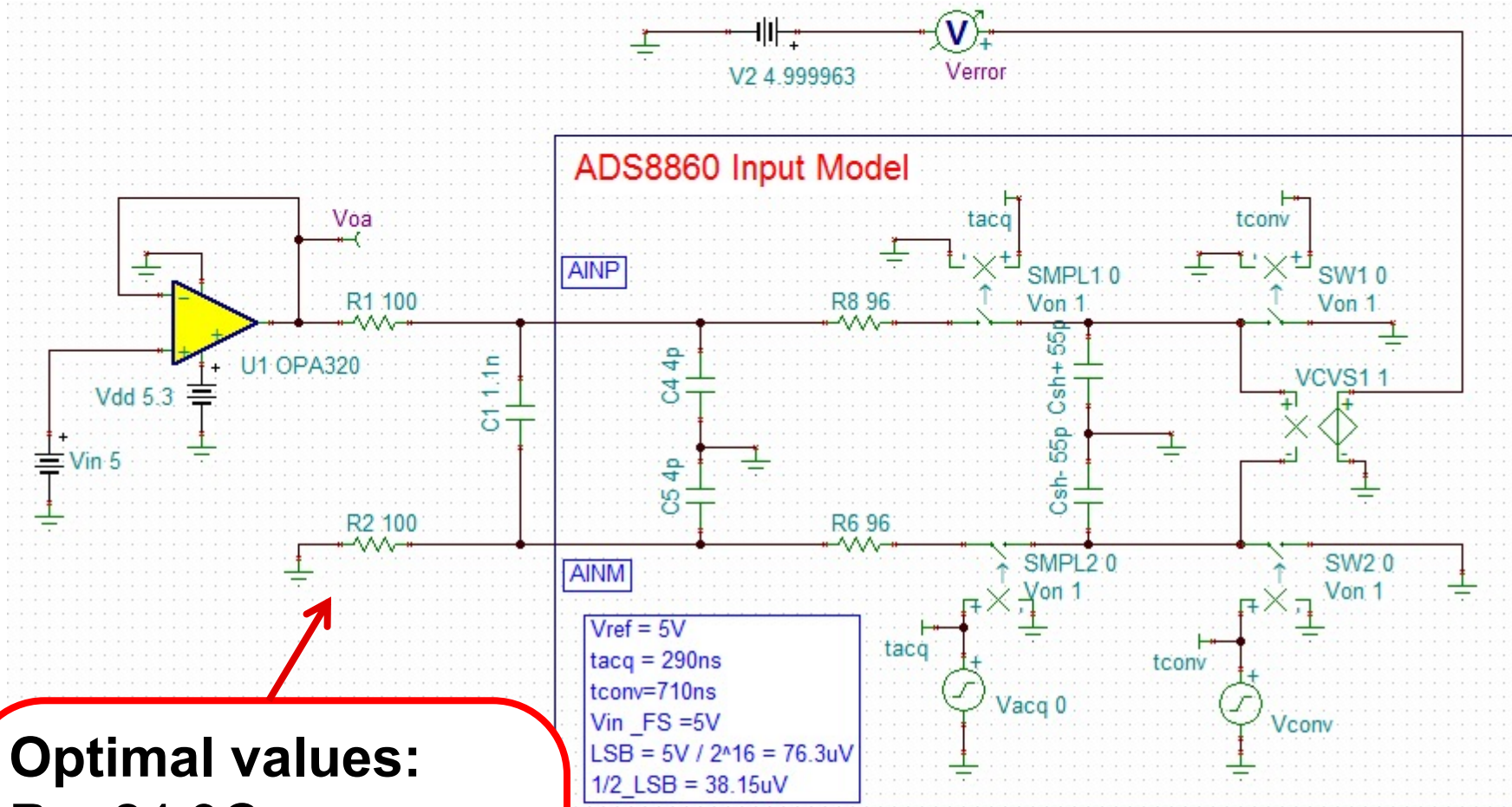


1. Install OPA320_Good filter 1 coupon card in socket.

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

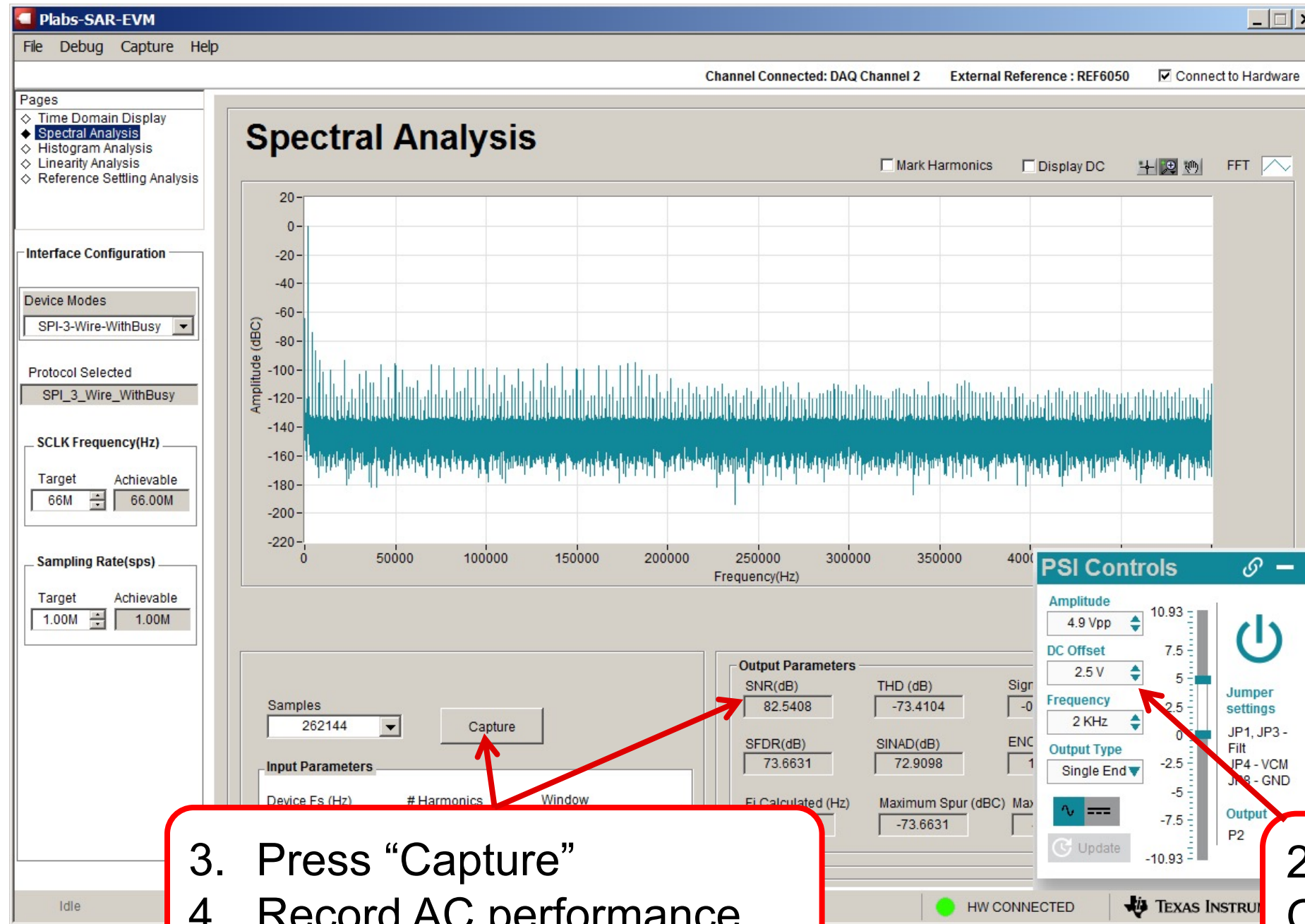
C = 1.1nF



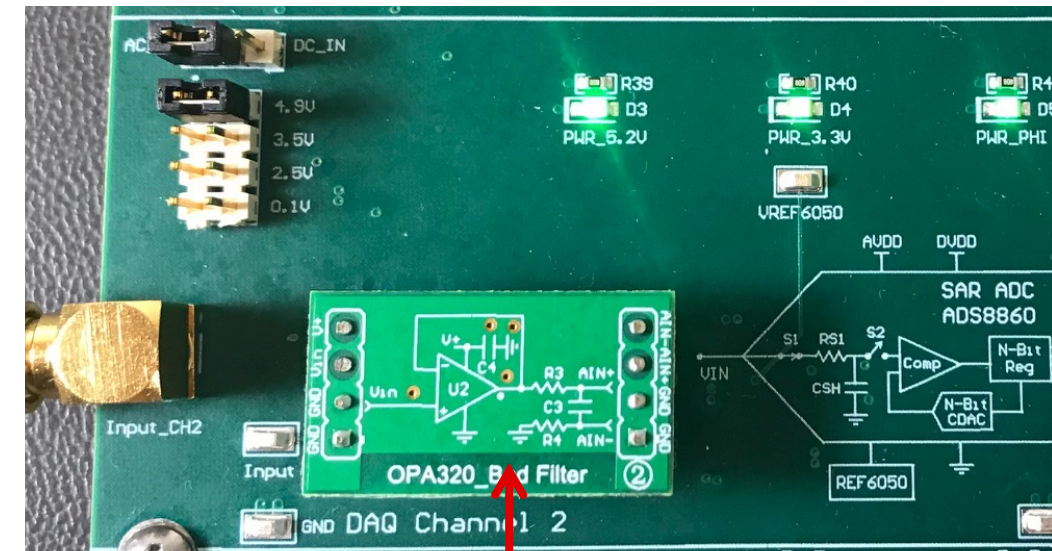
ADS8860_OPA320 - bad filter.TSC

Error Target = 38μV
Simulate Error = -41mV

2: OPA320 Bad Filter



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

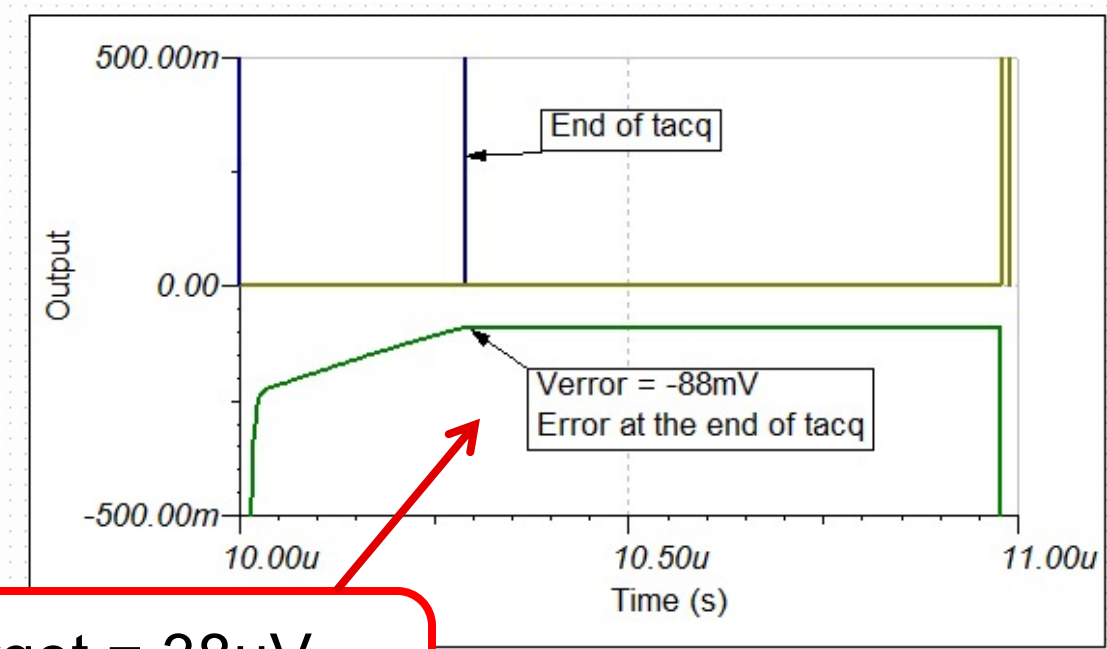
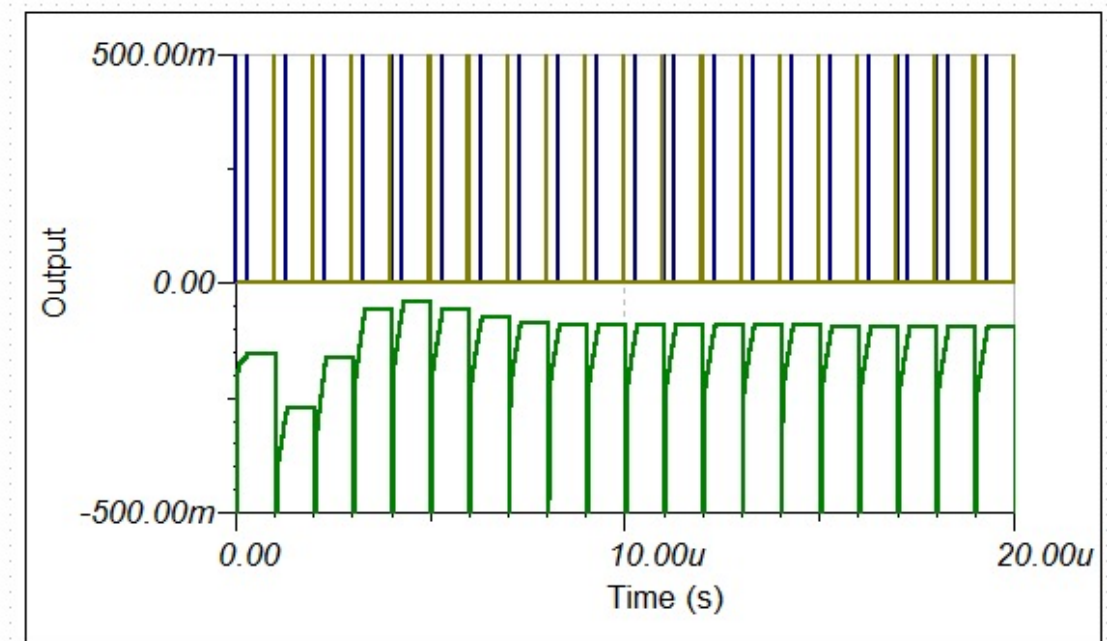
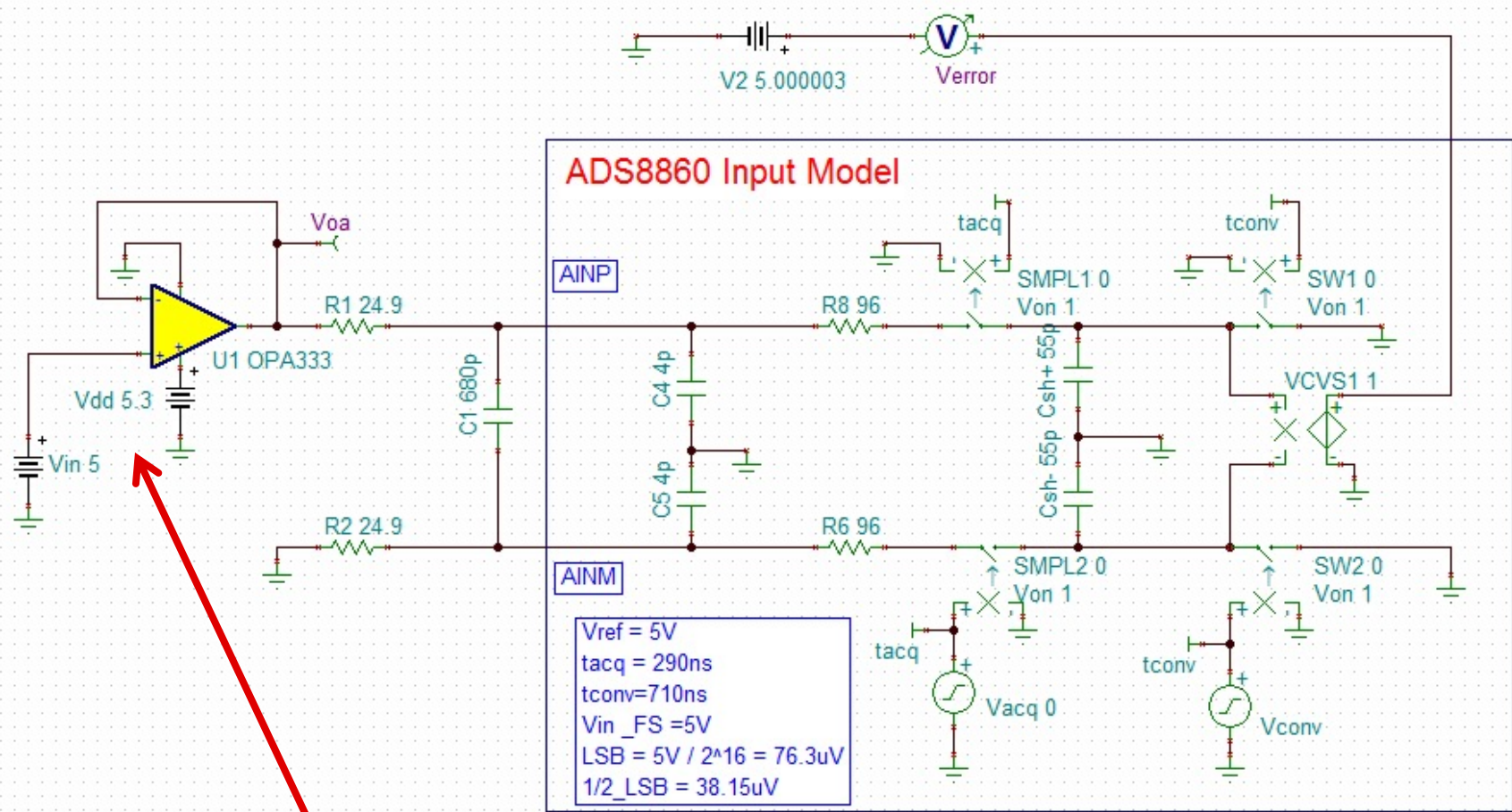


1. Install OPA320_Bad Filter coupon card in socket.

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

3. Press "Capture"
4. Record AC performance

3: OPA333 Low Bandwidth

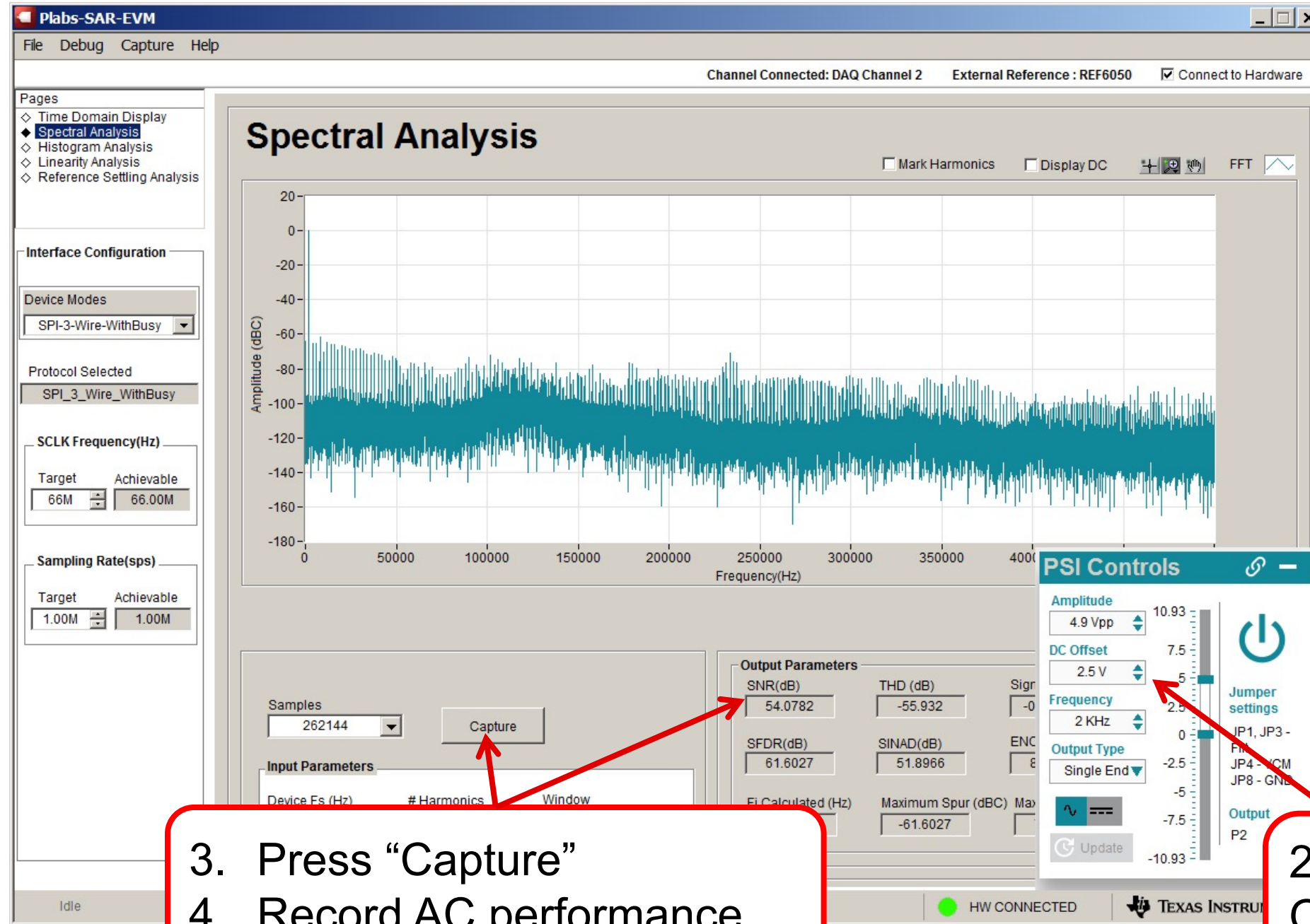


Bandwidth Required:
 Gain Bandwidth= 17.8MHz
OPA333 Bandwidth:
 Gain Bandwidth= 350kHz

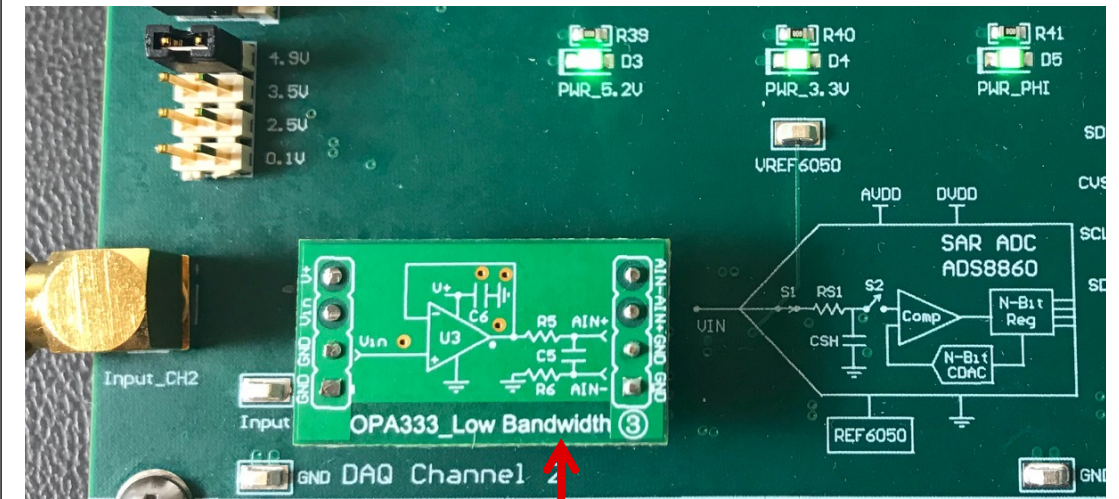
ADS8860_OPA333 - Low Bandwidth.TSC

Error Target = 38μV
Simulate Error = -88mV

3: OPA333 Low Bandwidth



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

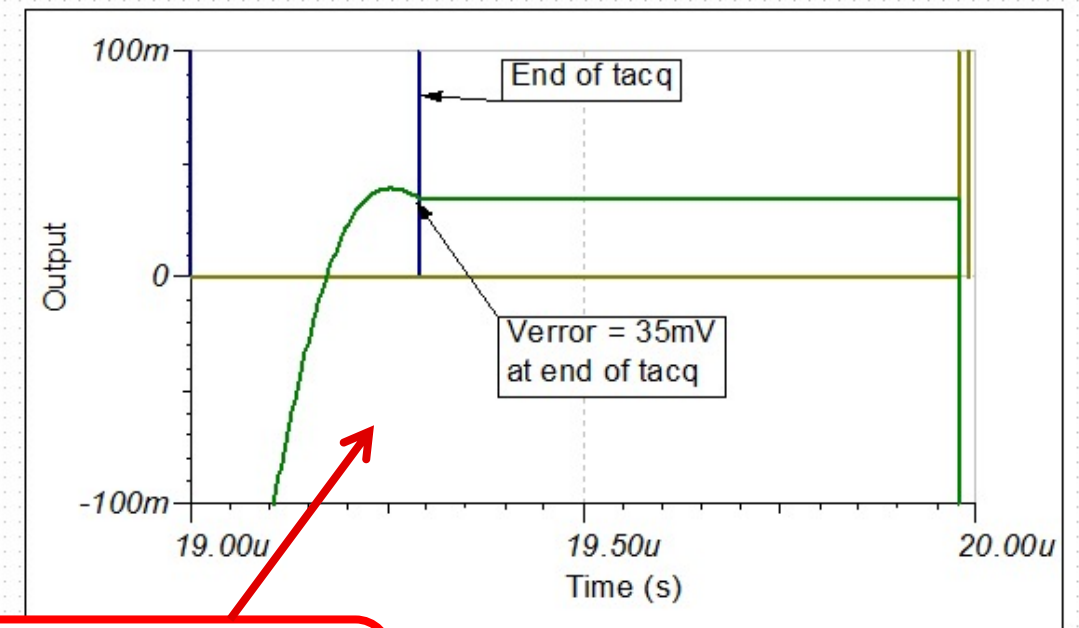
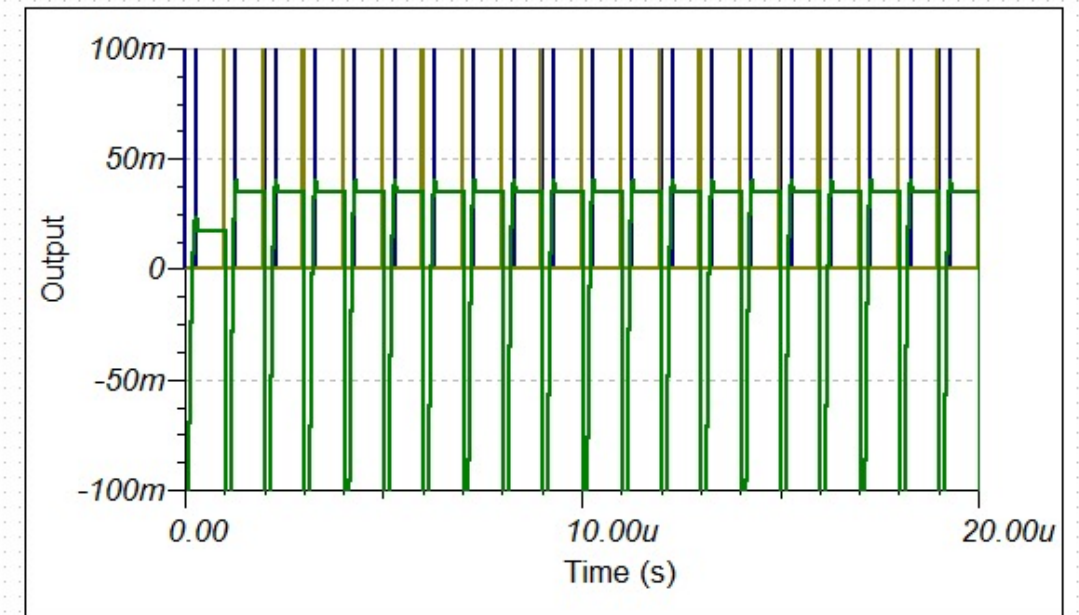
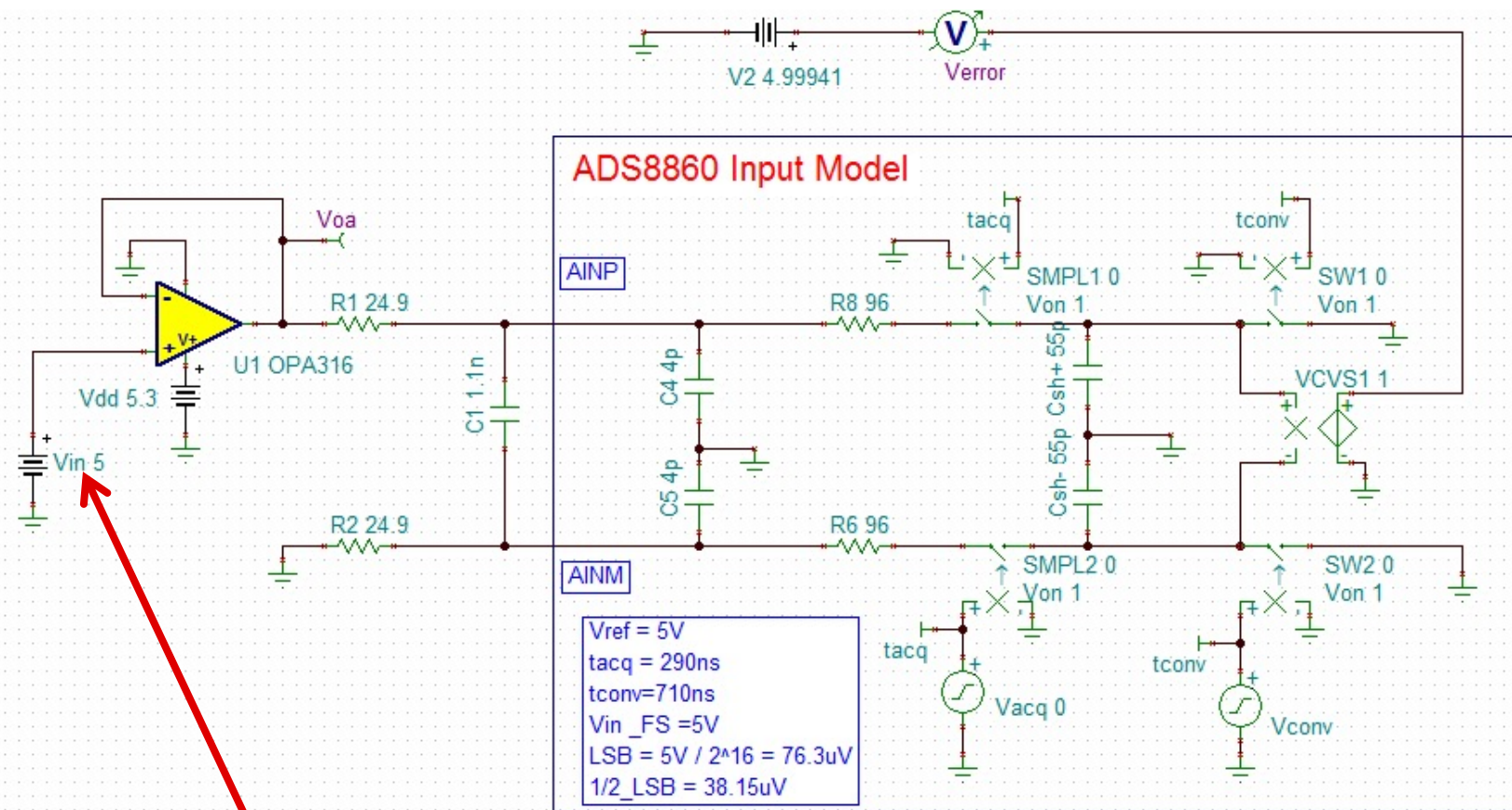


1. Install OPA333_Low Bandwidth coupon card in socket.

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

3. Press "Capture"
4. Record AC performance

4: OPA316 Crossover, $f_s = 1\text{Mps}$



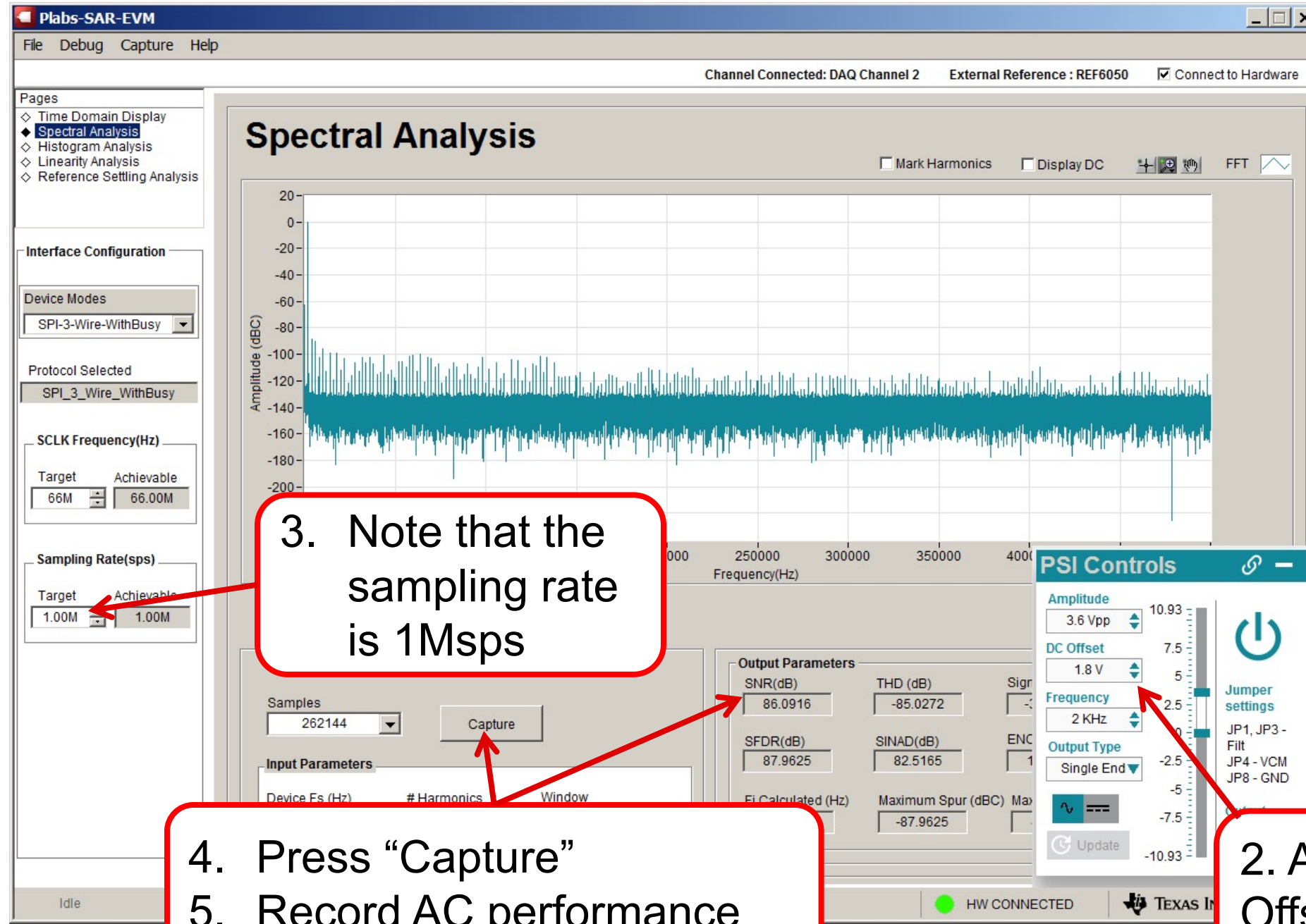
Bandwidth Required:
Gain Bandwidth= 17.8MHz
OPA316 Bandwidth:
Gain Bandwidth= 10MHz



ADS8860_OPA316 - Crossover-1Mps.TSC

Error Target = $38\mu\text{V}$
Simulate Error = 35mV

4: OPA316 Crossover, $f_s = 1\text{Mps}$

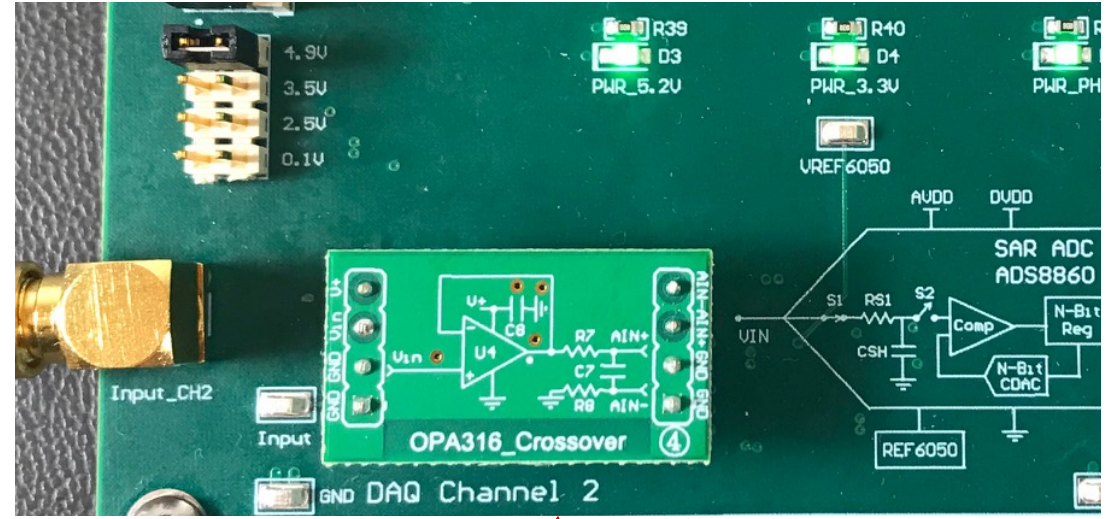


3. Note that the sampling rate is 1Mps

4. Press "Capture"

5. Record AC performance

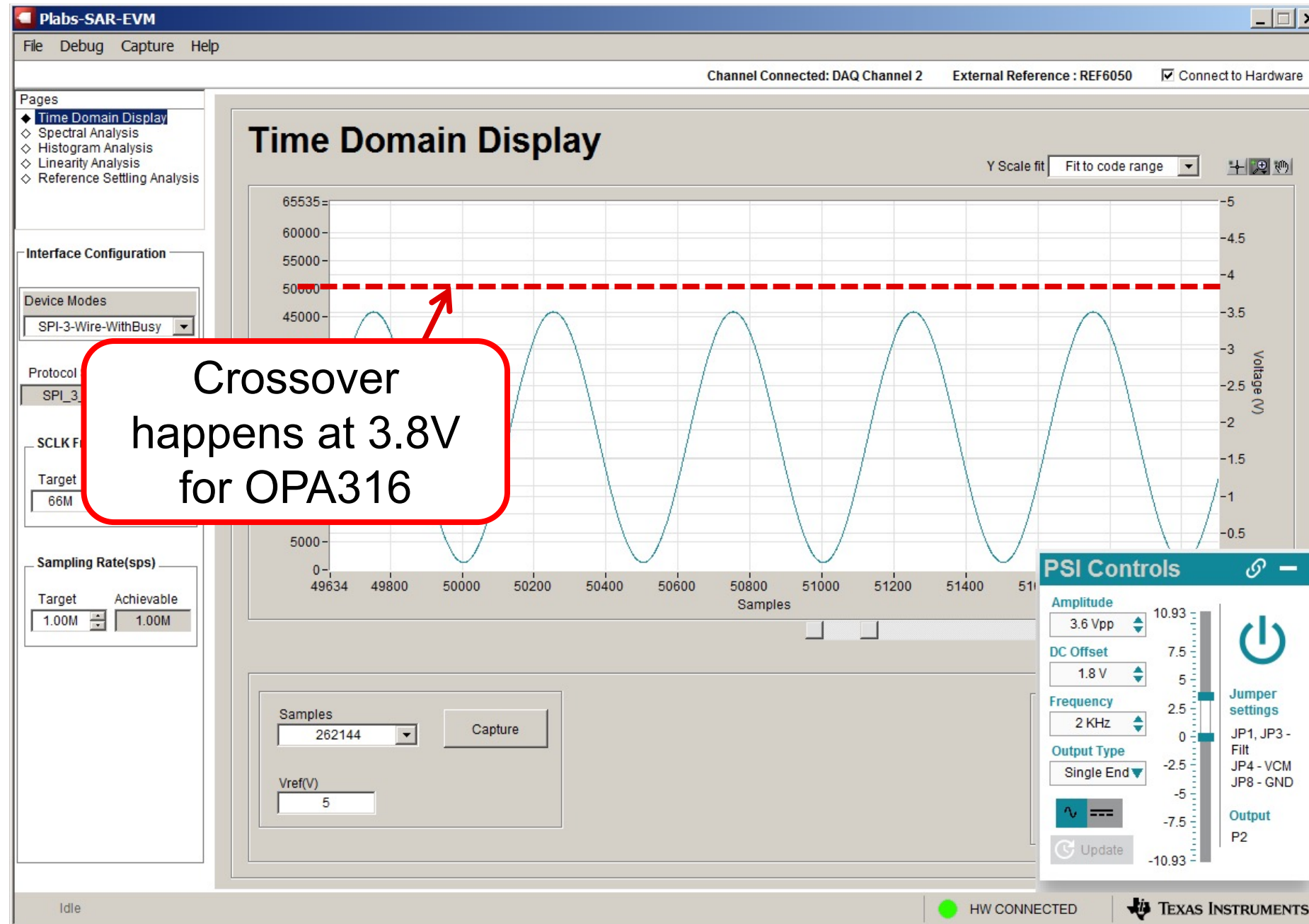
	SNR (dB)	THD (dB)
ADS8860	93	-108
Crossover 1Mps	86.1	-85.0



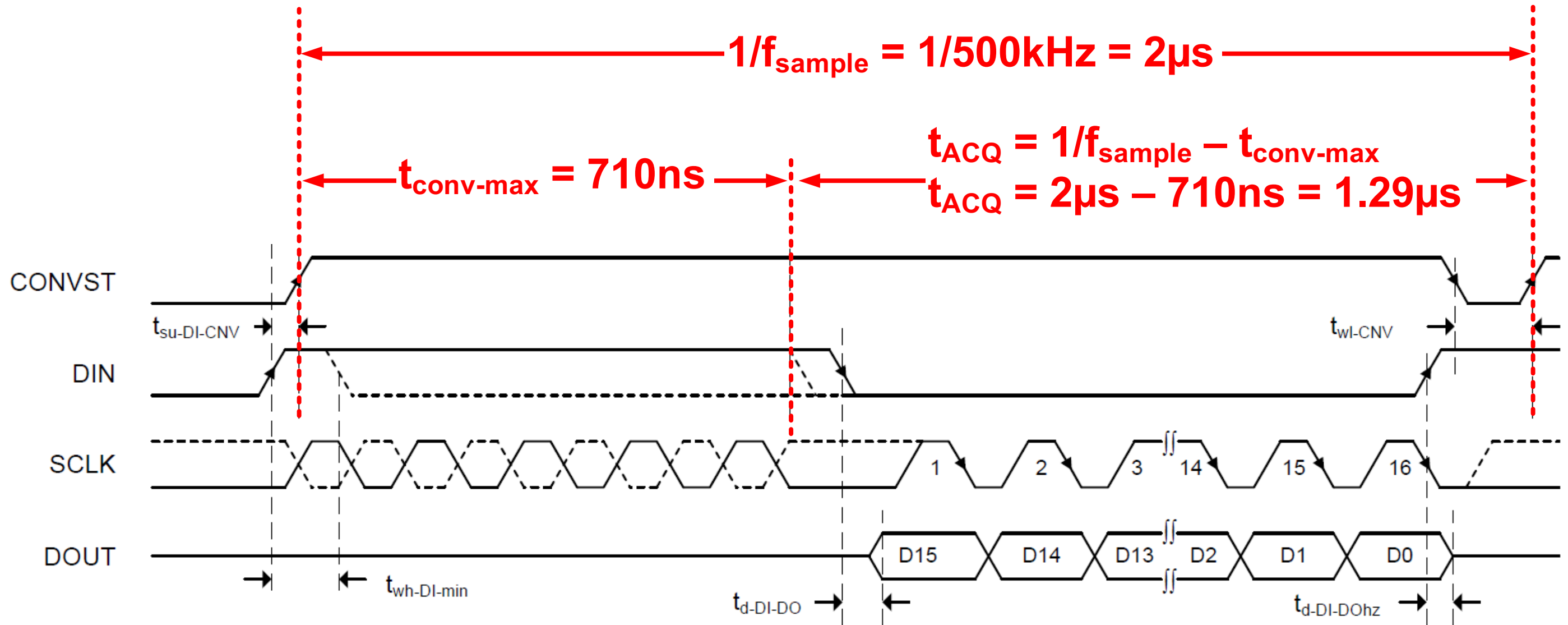
1. Install OPA316_Crossover coupon card in socket.

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

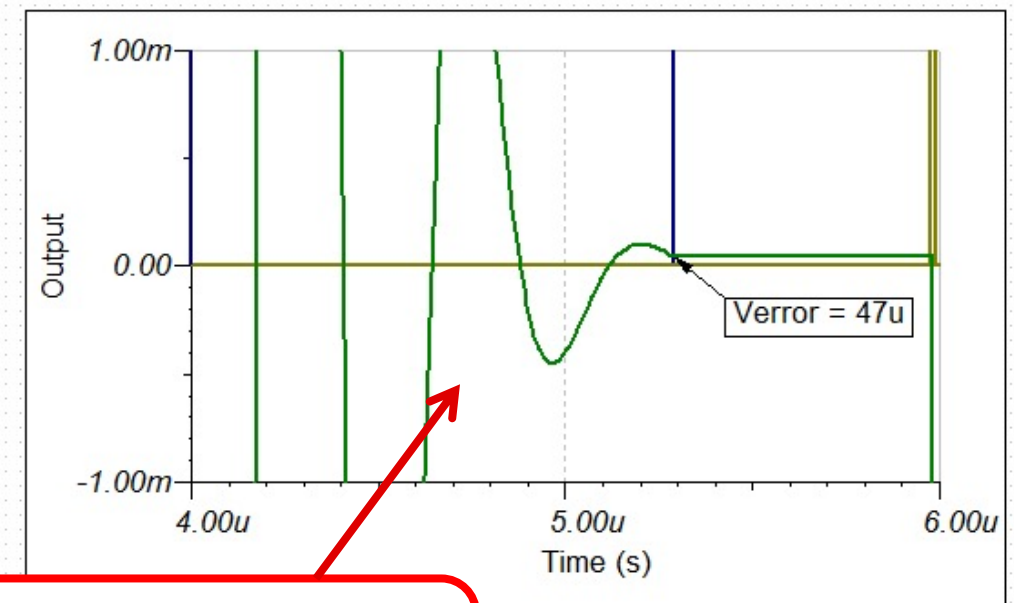
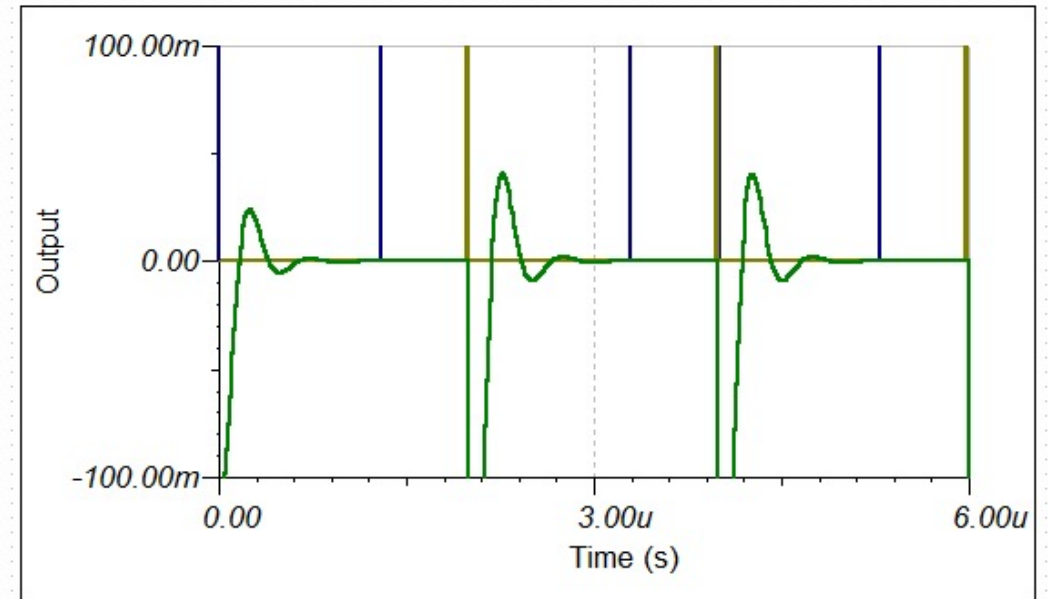
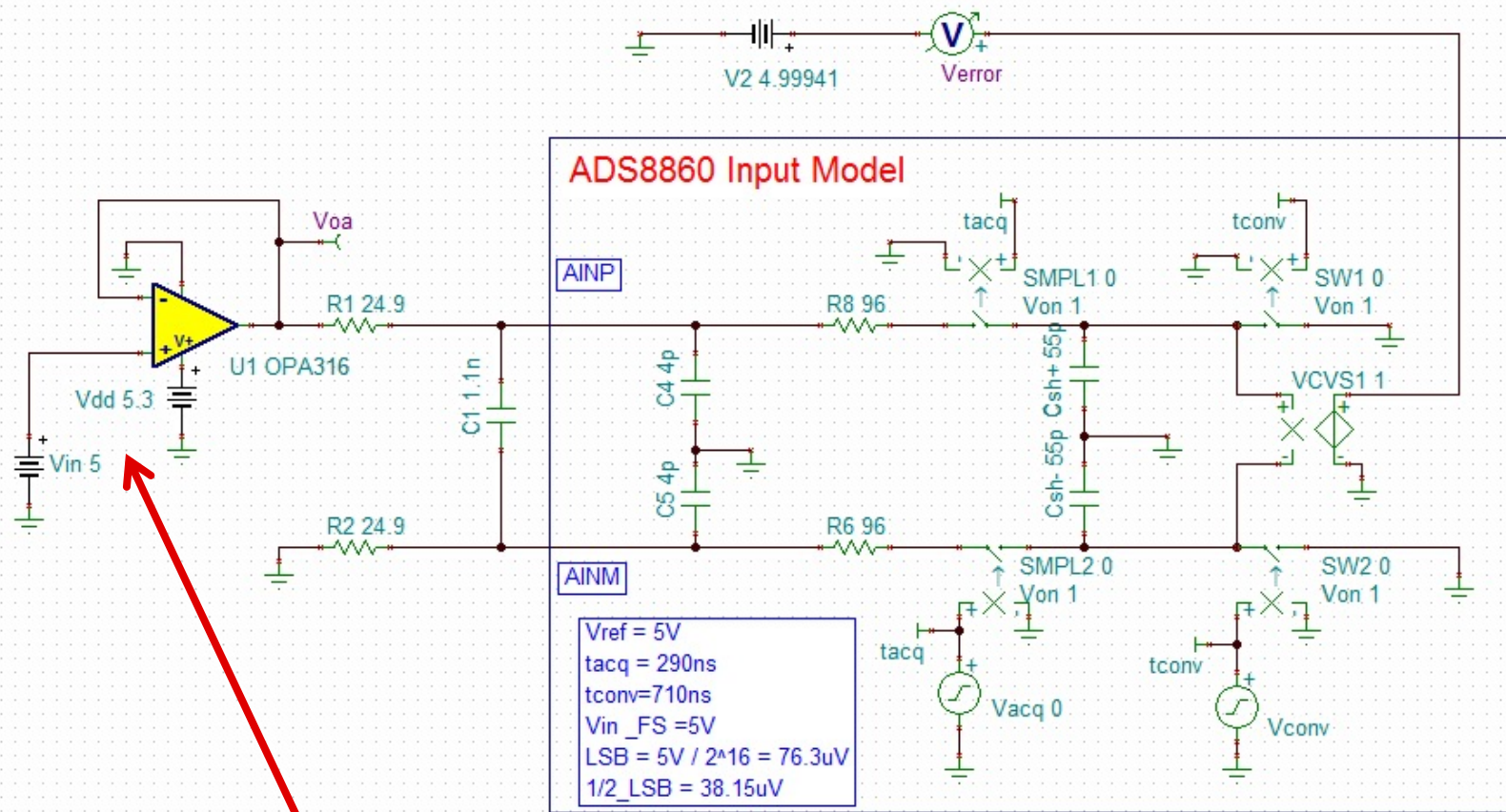
Acquisition time (t_{acq}) from last slide.

Single Ended #2: Includes Ground Sense (Negative Input)

Note: the values of R_{filt} , and C_{filt} are intended as a starting point for TINA SPICE parameter step sweep. See the help file for details.

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

5: OPA316 Crossover, $f_s = 500\text{kps}$



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

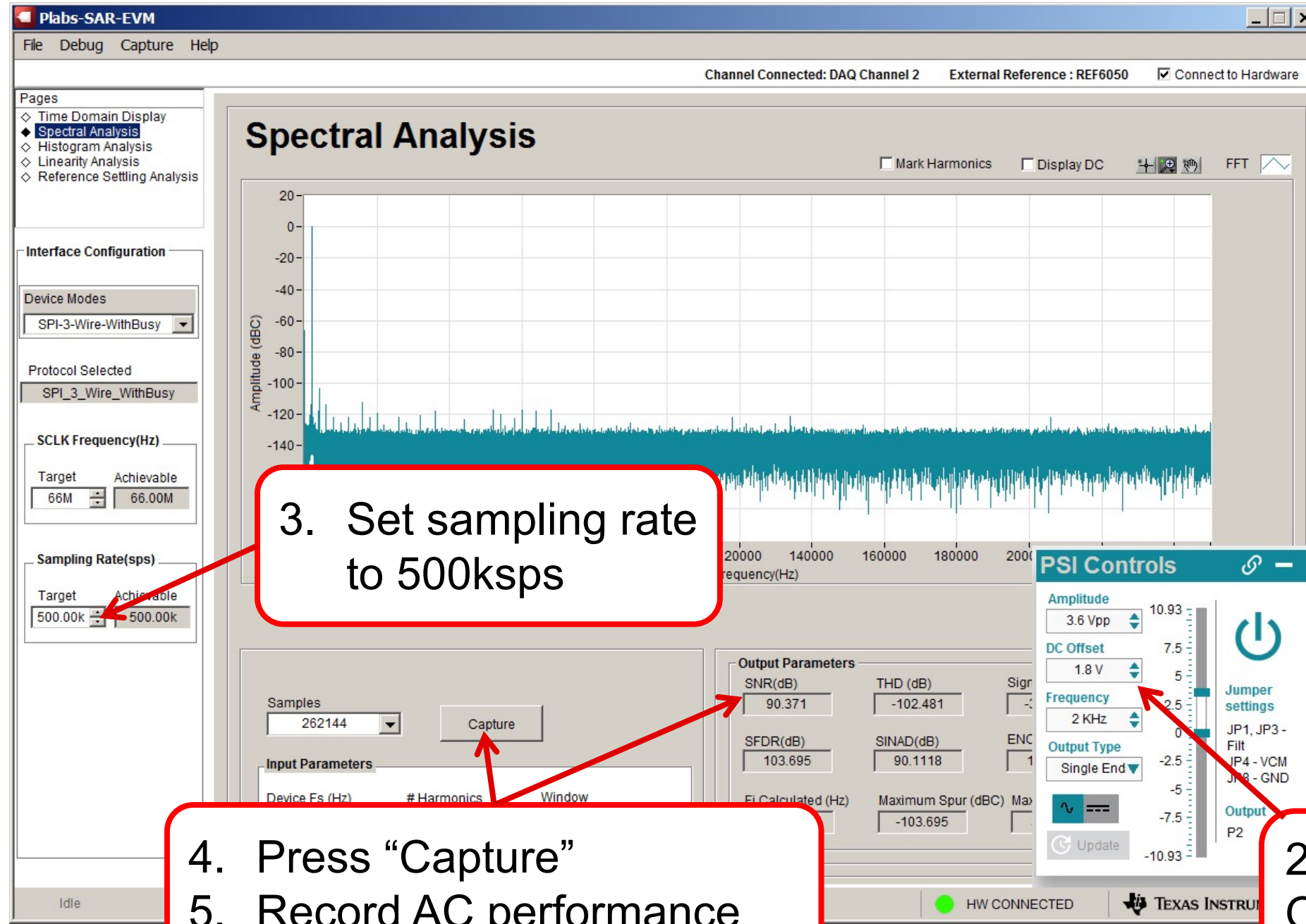


ADS8860_OPA316 - Crossover-500kps.TSC

Error Target = $38\mu\text{V}$
Simulate Error = $47\mu\text{V}$

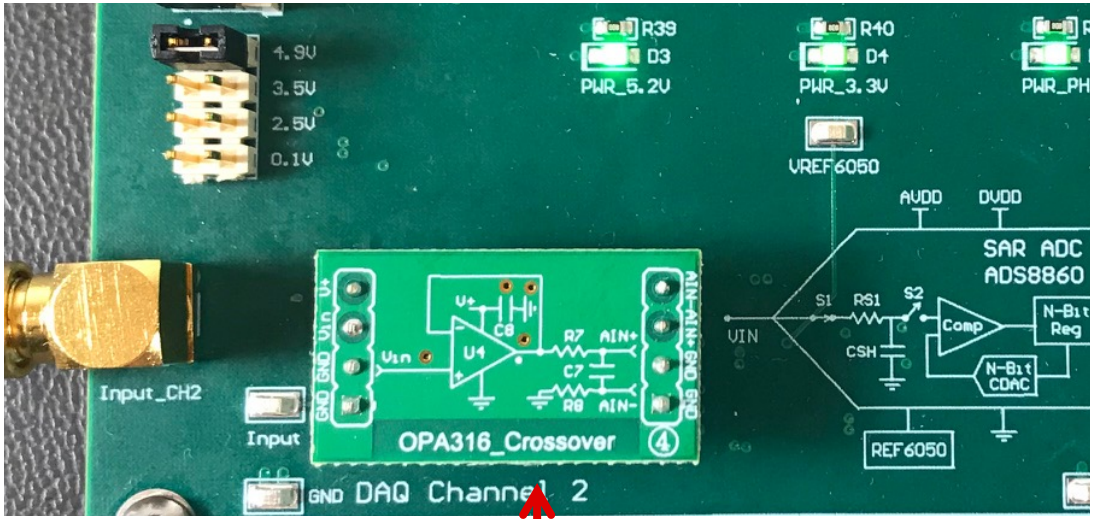
OPA316 Crossover, $f_s = 500\text{kps}$

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



3. Set sampling rate to 500kpsps

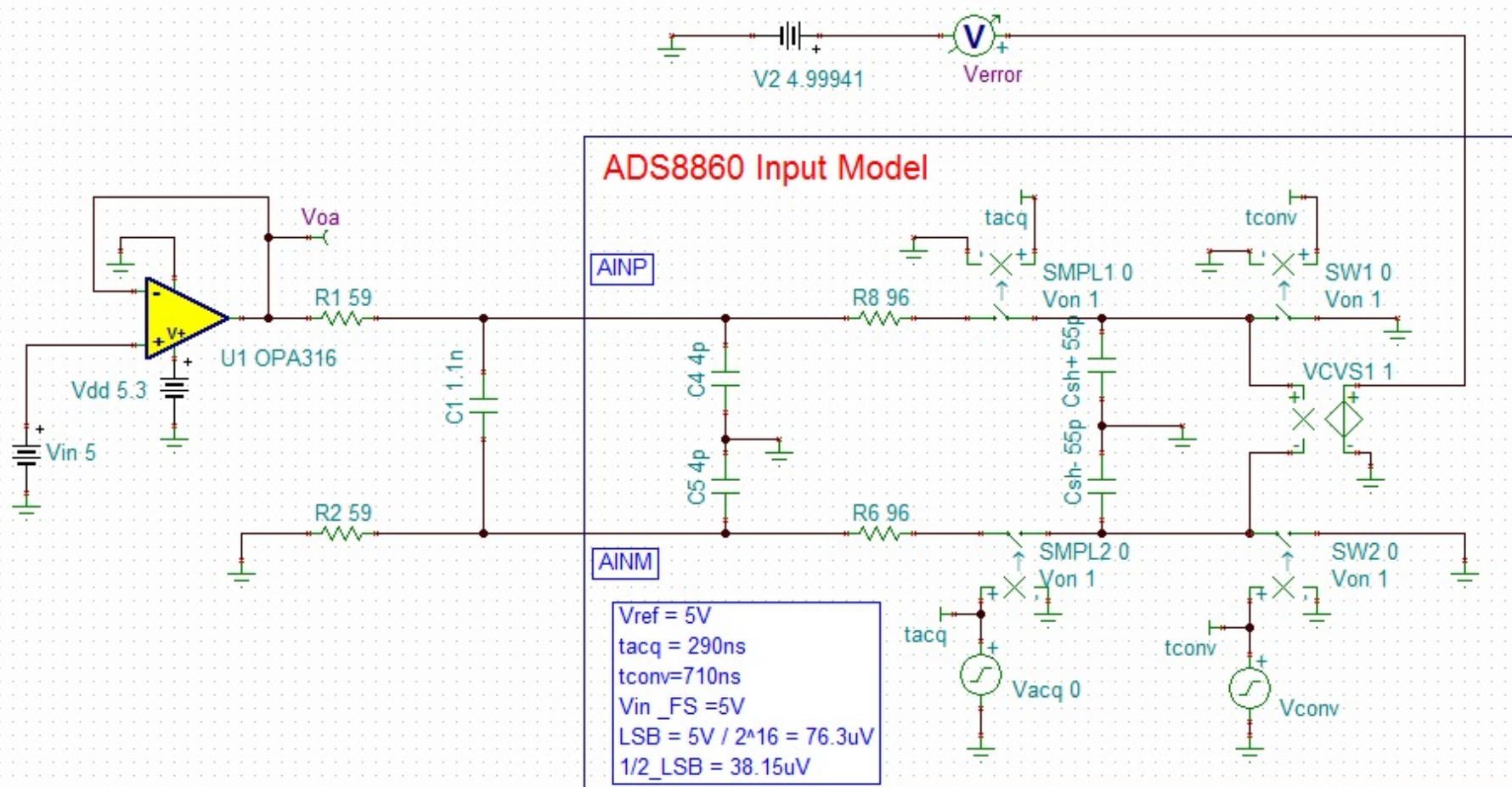
4. Press "Capture"
5. Record AC performance



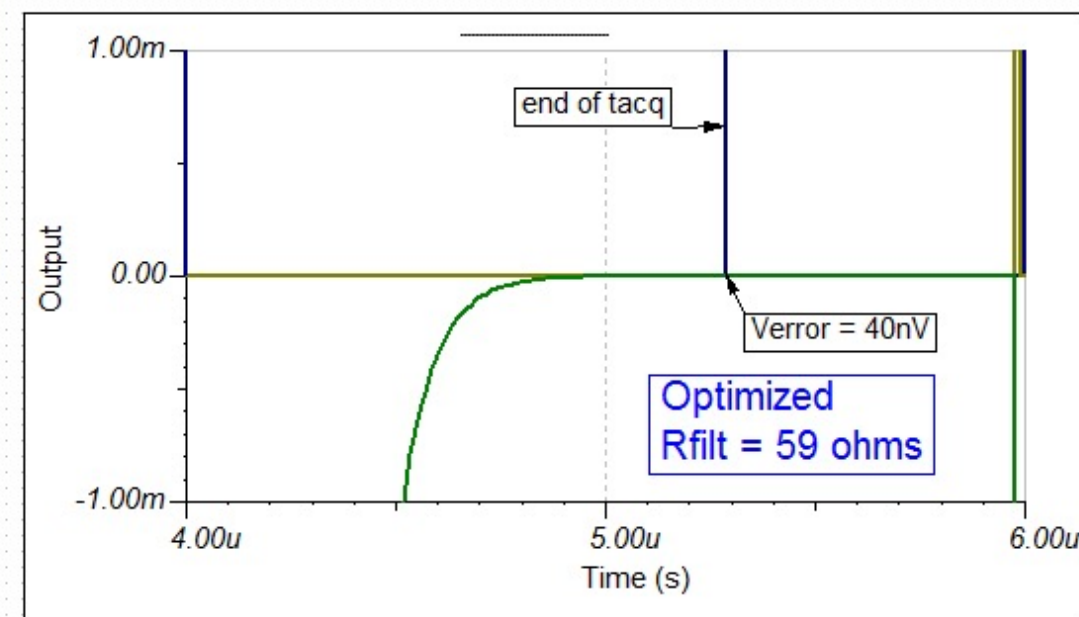
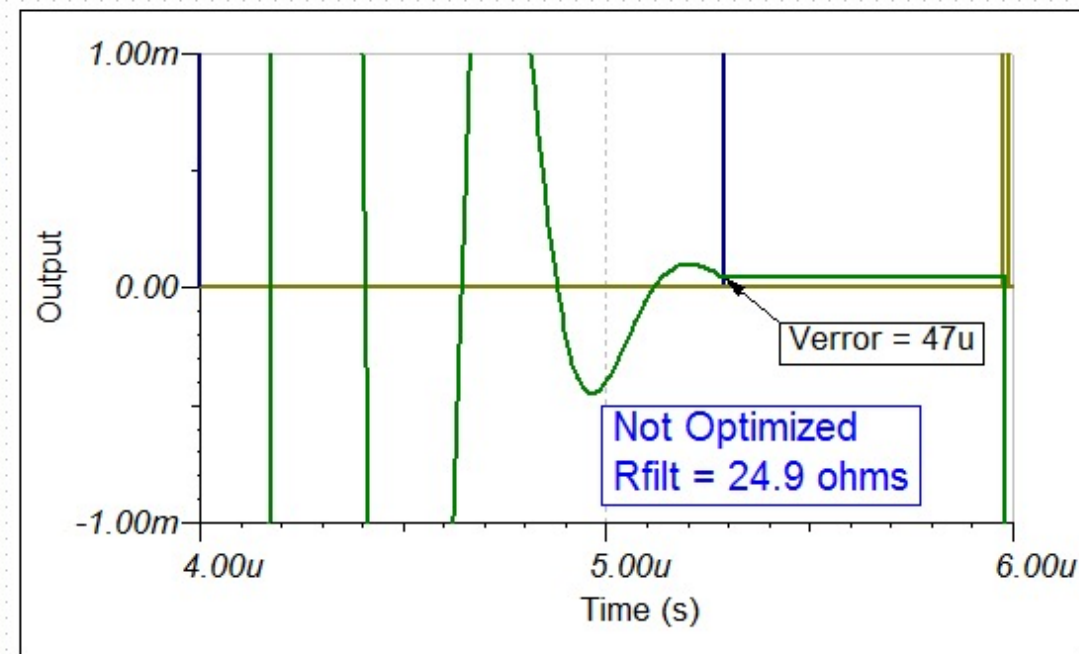
1. No device change needed.

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 $\frac{1}{2}\text{LSB}=38\mu\text{V}$	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	28 μV	93.3	-108.8		
2	OPA320 Bad filter	1M	2.5	4.9	-41mV	82.5	-73.4		
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4	OPA316 Crossover	1M	1.8	3.6	36.7mV	86.1	-85.0		
5	OPA316 Crossover	500k	1.8	3.6	47 μV	90.3	-102.4		

Thanks for your time!