

Crossover Distortion Hands-on Experiment

TIPL 4101-L

TI Precision Labs – ADCs

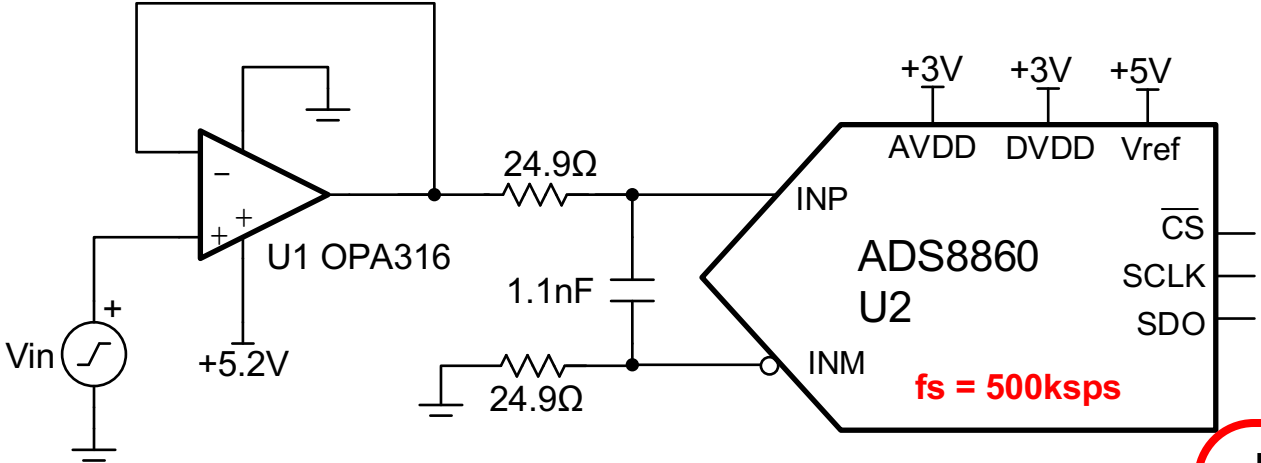
by Art Kay and Dale Li



Required/Recommended Equipment

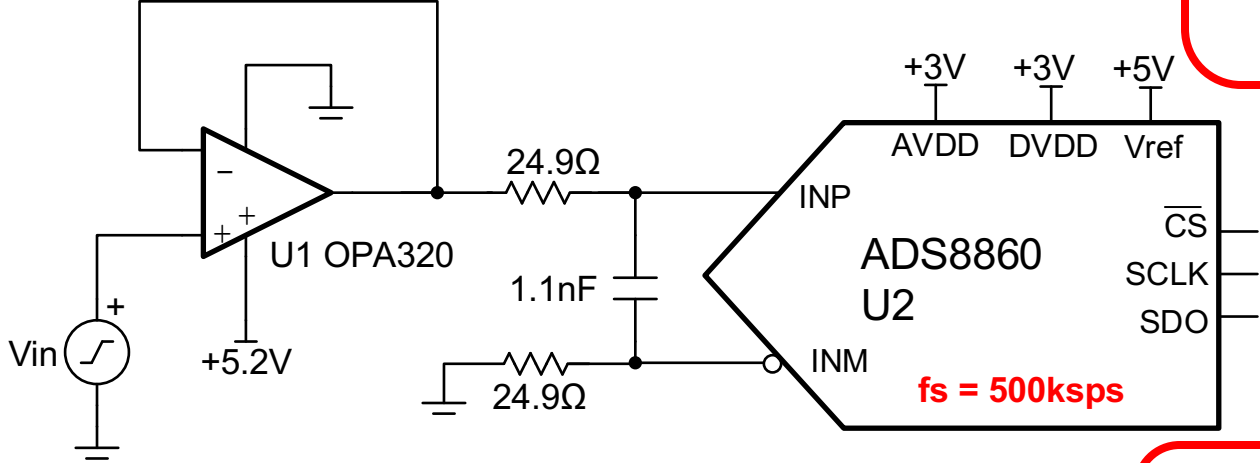
- Calculation
 - Simple calculation using OPA320 and OPA316 Data Sheet
- Simulation
 - No simulation in this experiment.
- Measurement
 - PLABS-SAR-EVM-PDK
 - <http://www.ti.com/tool/plabs-sar-evm-pdk>
 - Download EVM software and purchase EVM

Op Amp with and without input Crossover distortion



PARAMETER:	MIN	TYP	MAX	UNIT
OPA316 – Has Crossover				
V_{CM}				
Common Mode Voltage	(V-)-0.2		(V+)+0.2	V
CMRR	(V-)-0.2 < V_{cm} < (V+)-1.4V	76	90	dB
	(V-)-0.2 < V_{cm} < (V+)+0.2V	65	80	

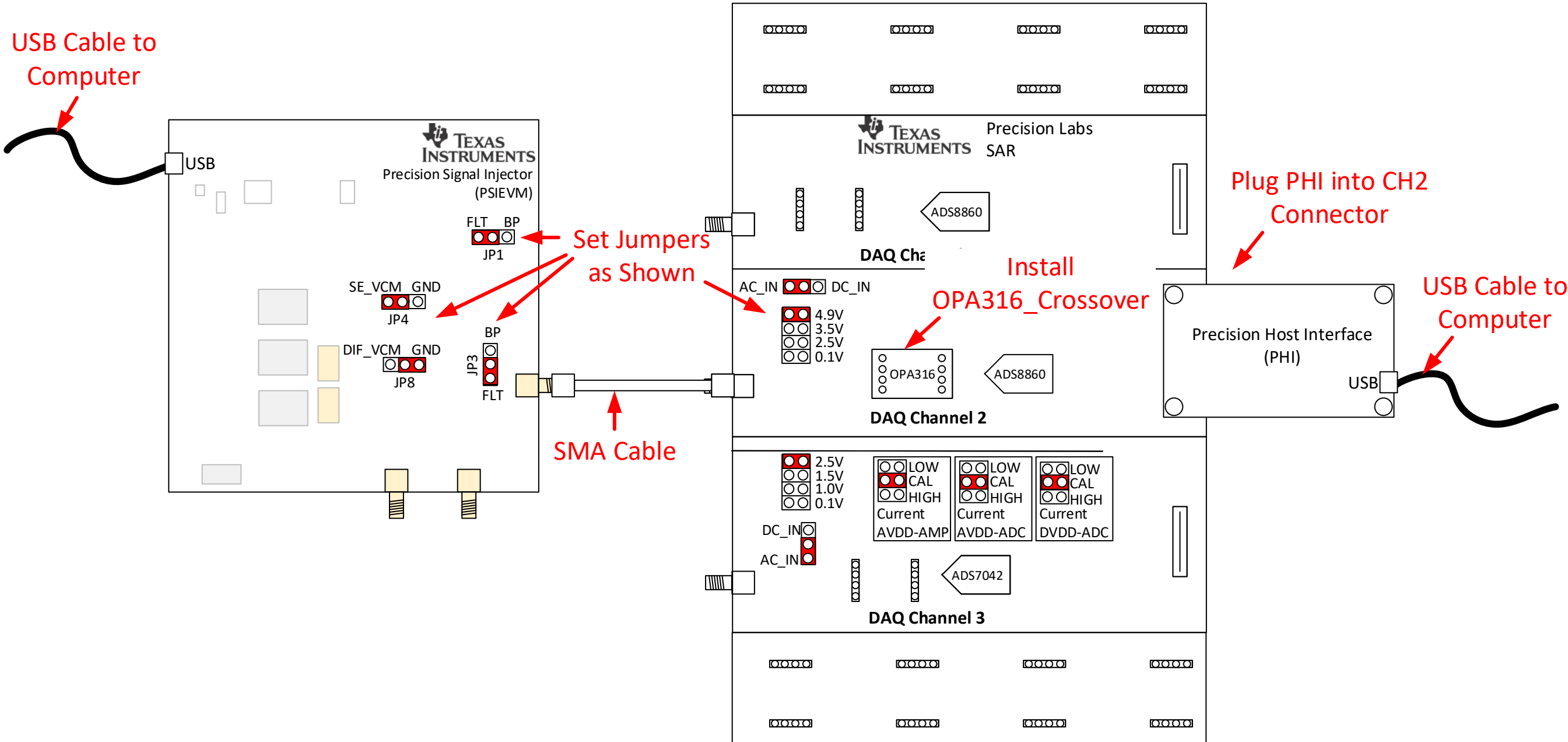
Much better CMRR 1.4V below positive rail. For 5.2V supply, crossover happens at 3.8V ($5.2V - 1.4V = 3.8V$)



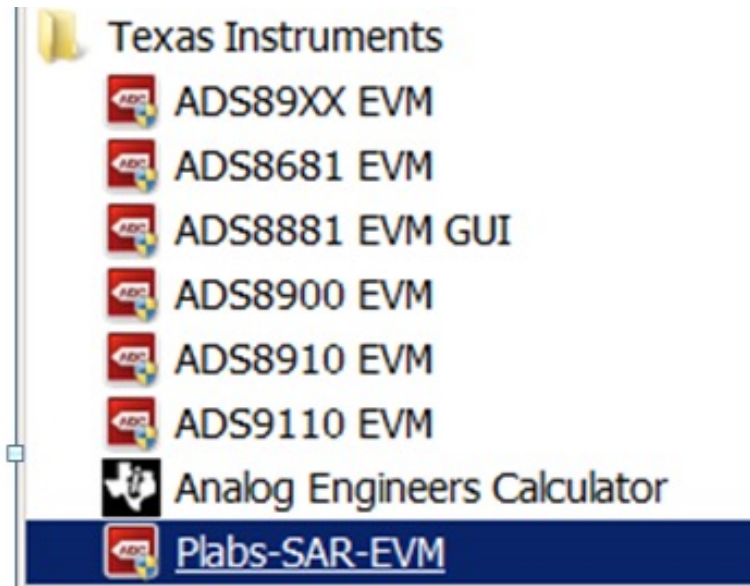
PARAMETER:	MIN	TYP	MAX	UNIT
OPA320 – No Crossover				
V_{CM}				
Common Mode Voltage	(V-)-0.1		(V+)+0.1	V
CMRR	(V-)-0.1 < V_{cm} < (V+)+0.1V	100	114	dB

Much better CMRR across entire common mode range.

Connect the hardware



Start & Setup the PLABS-SAR 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
500.00k 500.00k

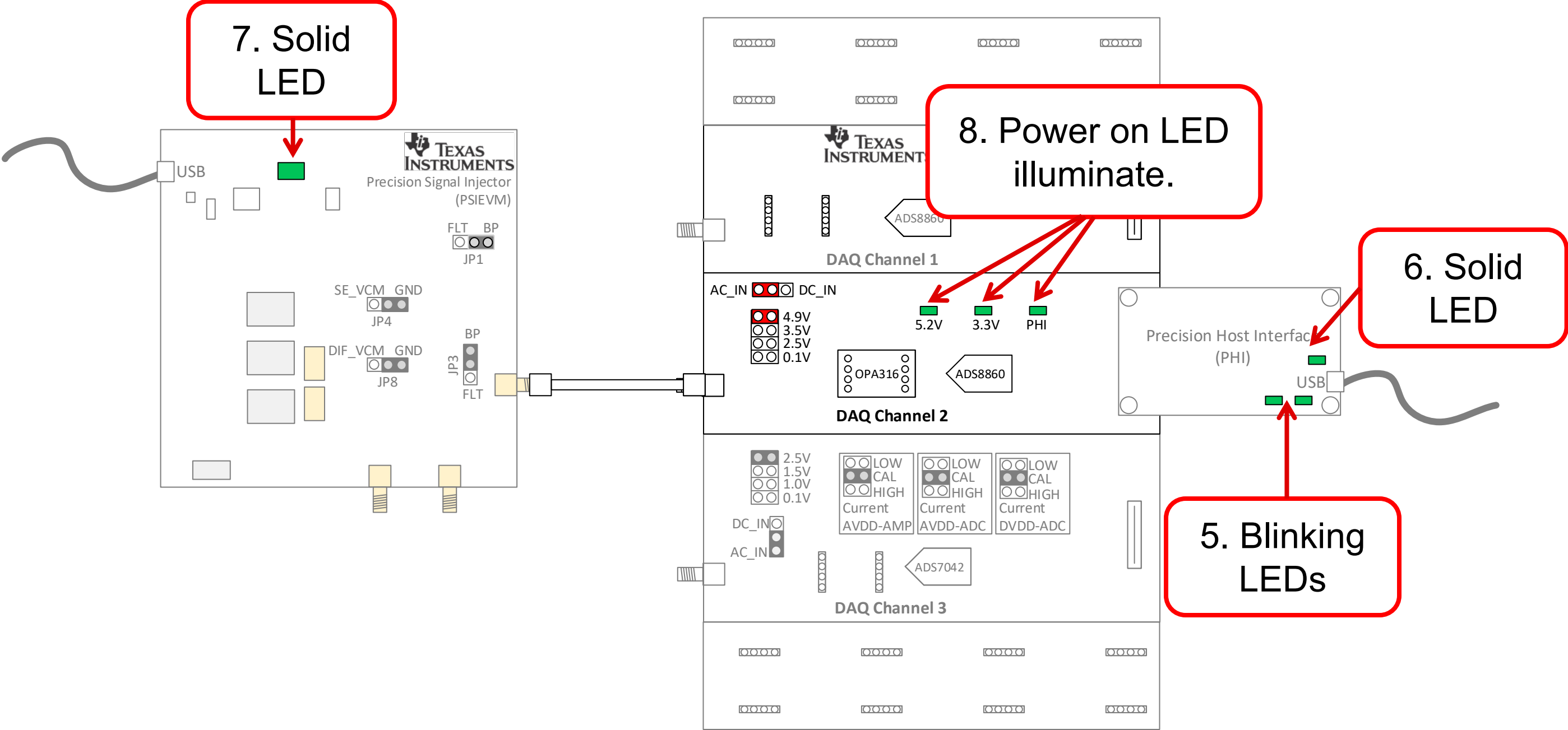
Time Domain Display
Y Scale fit Auto mode
Codes
Voltage (V)
Samples
HW CONNECTED
PSI Controls
Min_Code 0 Min_Volt 0.000
TEXAS INSTRUMENTS

3. Set the sampling rate to 500ksps

2. If the EVM is operating correctly, "HW Connected" will be displayed.

4. Press here to expand PSI controls

Power-on LEDs illuminate



Setup the PSI

The screenshot shows the Plabs-SAR-EVM software interface. The main window is titled "Time Domain Display" and shows a grid with "Codes" on the y-axis (ranging from -3 to 3) and sample numbers on the x-axis (ranging from 0 to 200,000). The "PSI Controls" panel is open, showing the following settings:

- Amplitude: 2 Vpp
- DC Offset: 1.5 V
- Frequency: 2 KHz
- Output Type: Single End
- Update button: [Update]
- Power button: [Power]
- Jumper settings: JP1, JP3 - Filt; JP4 - VCM; JP8 - GND
- Output: P2

Red callout boxes provide instructions:

- 9. Enter the amplitude, and DC offset
- 10. Press Update.
- 11. Click to Turn on output.

The interface also includes a "Pages" menu on the left with options like "Time Domain Display", "Spectral Analysis", "Histogram Analysis", "Linearity Analysis", and "Reference Settling Analysis". The "Interface Configuration" section shows "Device Modes" set to "SPI-3-Wire-WithBusy", "Protocol Selected" as "SPI_3_Wire_WithBusy", "SCLK Frequency(Hz)" with a target of 66M and achievable of 66.00M, and "Sampling Rate(sps)" with a target of 500.00k and achievable of 500.00k. The "Samples" field is set to 262144 and "Vref(V)" is set to 5. The status bar at the bottom indicates "HW CONNECTED" and "TEXAS INSTRUMENTS".

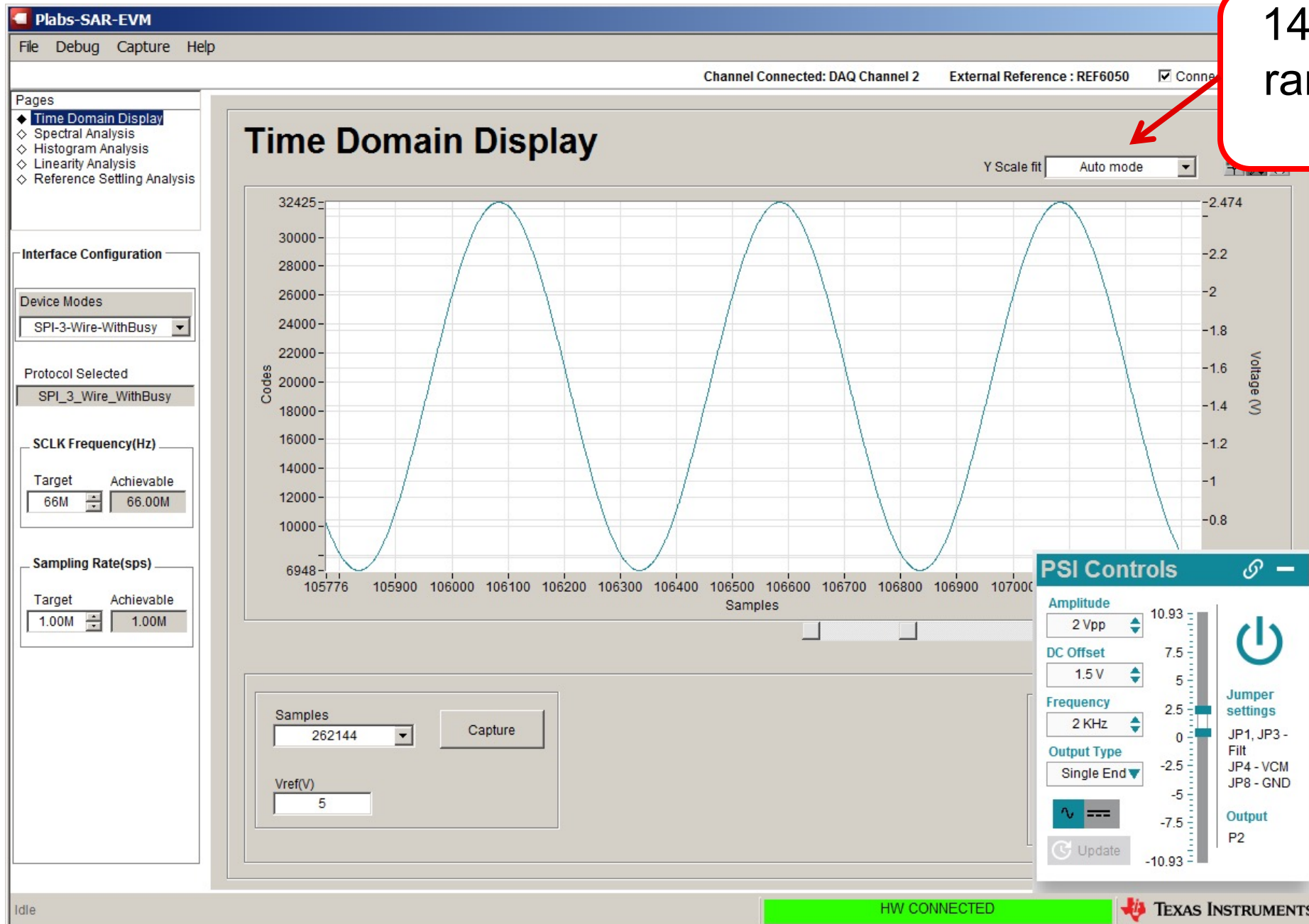
Capture the waveform and zoom in.

The screenshot shows the Plabs-SAR-EVM software interface. The main window is titled "Time Domain Display" and shows a plot of Codes (Y-axis, ranging from 6954 to 32431) versus Samples (X-axis, ranging from 0 to 200,000). The plot area is currently blank, indicating that the waveform has not been captured or zoomed in. The interface includes a menu bar (File, Debug, Capture, Help) and a status bar (Channel Connected: DAQ Channel 2, External Reference: REF6050, Connect to Hardware checked). On the left, there is a "Pages" panel with options like Time Domain Display, Spectral Analysis, Histogram Analysis, Linearity Analysis, and Reference Settling Analysis. Below that is the "Interface Configuration" panel, which includes settings for Device Modes (SPI-3-Wire-WithBusy), Protocol Selected (SPI_3_Wire_WithBusy), SCLK Frequency (Hz) (Target: 66M, Achievable: 66.00M), and Sampling Rate (sps) (Target: 500.00k, Achievable: 500.00k). At the bottom left, there is a "Samples" field set to 262144 and a "Vref(V)" field set to 5, with a "Capture" button next to the Samples field. On the right, there is a "PSI Controls" panel with sliders for Amplitude (2 Vpp), DC Offset (1.5 V), and Frequency (2 KHz), and a dropdown for Output Type (Single End). The status bar at the bottom indicates "Idle" and "HW CONNECTED" with the Texas Instruments logo.

12. Press Capture

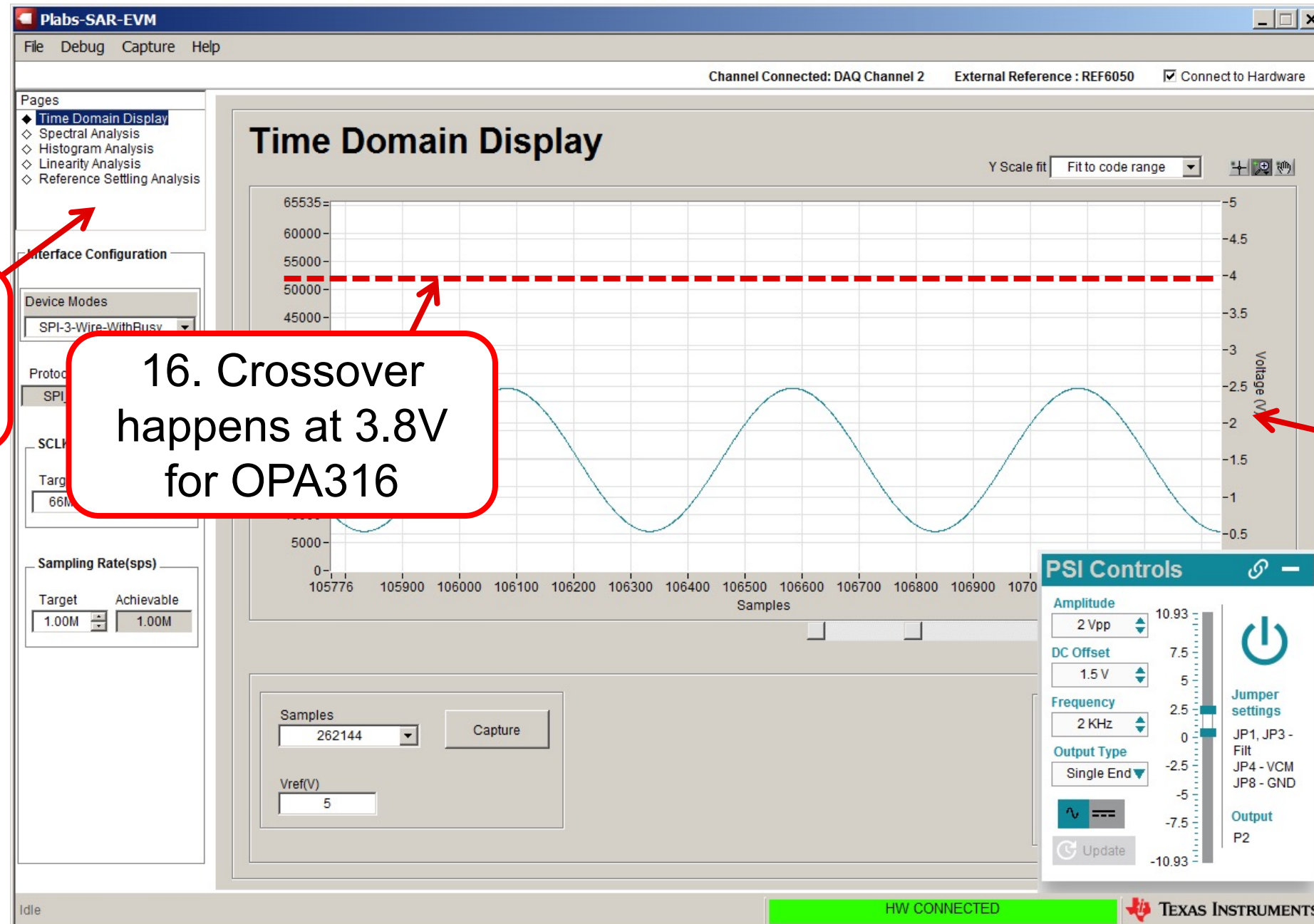
13. This is a sine wave output, but the time scale doesn't let you see the wave. Right click an drag to zoom in.

Capture the waveform and zoom in.



14. Select "Fit Code to range" to show the full scale range.

Capture the waveform and zoom in.



17. Change to
“Spectral
Analysis”

16. Crossover
happens at 3.8V
for OPA316

15. Now you can
see that the full
scale range is
displayed (5V) in
this example.

Frequency Domain Results

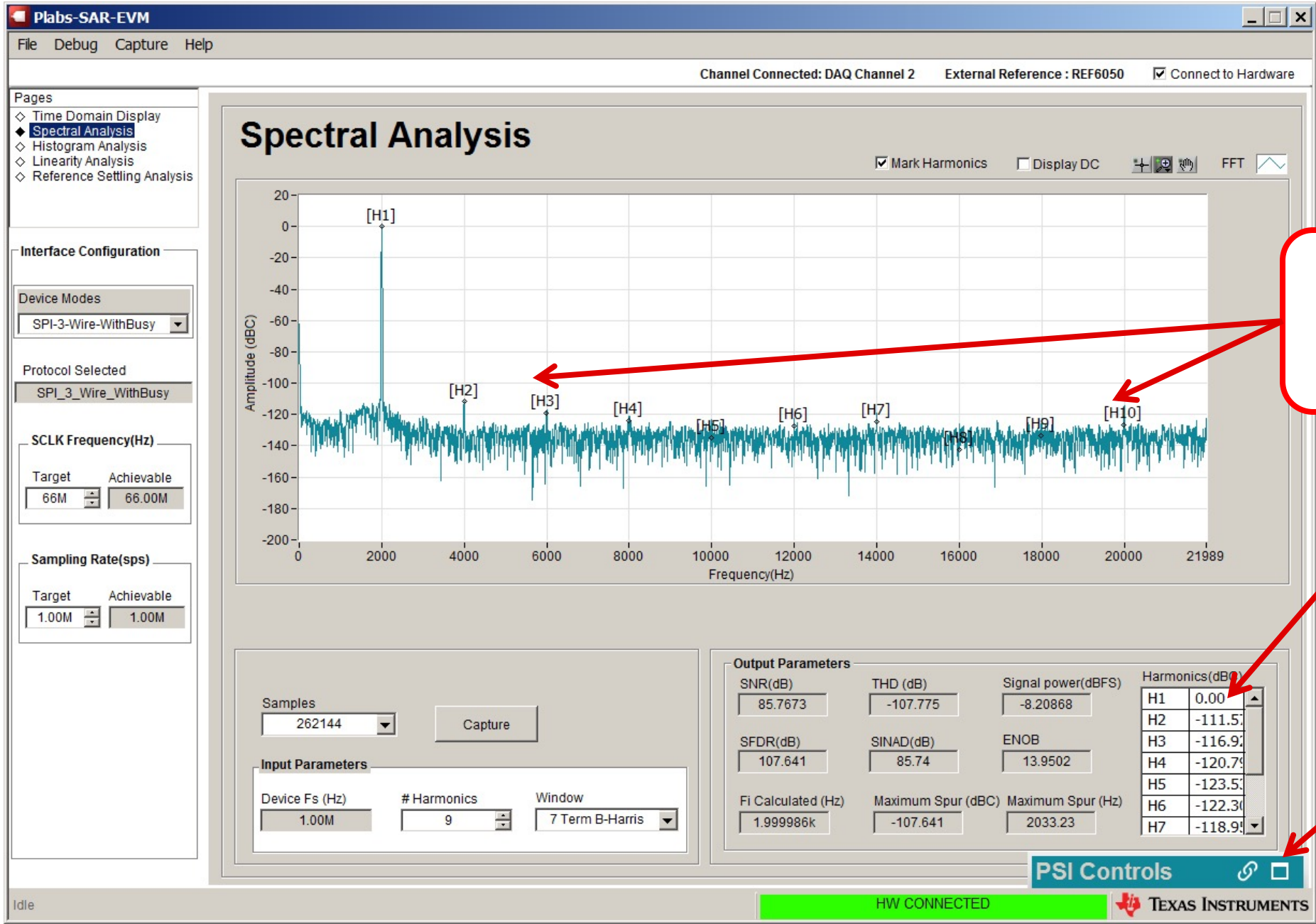
20. Press "Mark Harmonics" to zoom in on harmonics.

19. Frequency domain display

18. Important AC measured results. Note that better SNR could be achieved with full scale signal.

Output Parameters	
SNR(dB)	85.7673
THD (dB)	-107.775
SFDR(dB)	107.641
SINAD(dB)	85.74
Fi Calculated (Hz)	1.999986k
Maximum Spur (dBC)	-107.641

Mark Harmonics



21. Zoom in on harmonics marked H2 ...H10

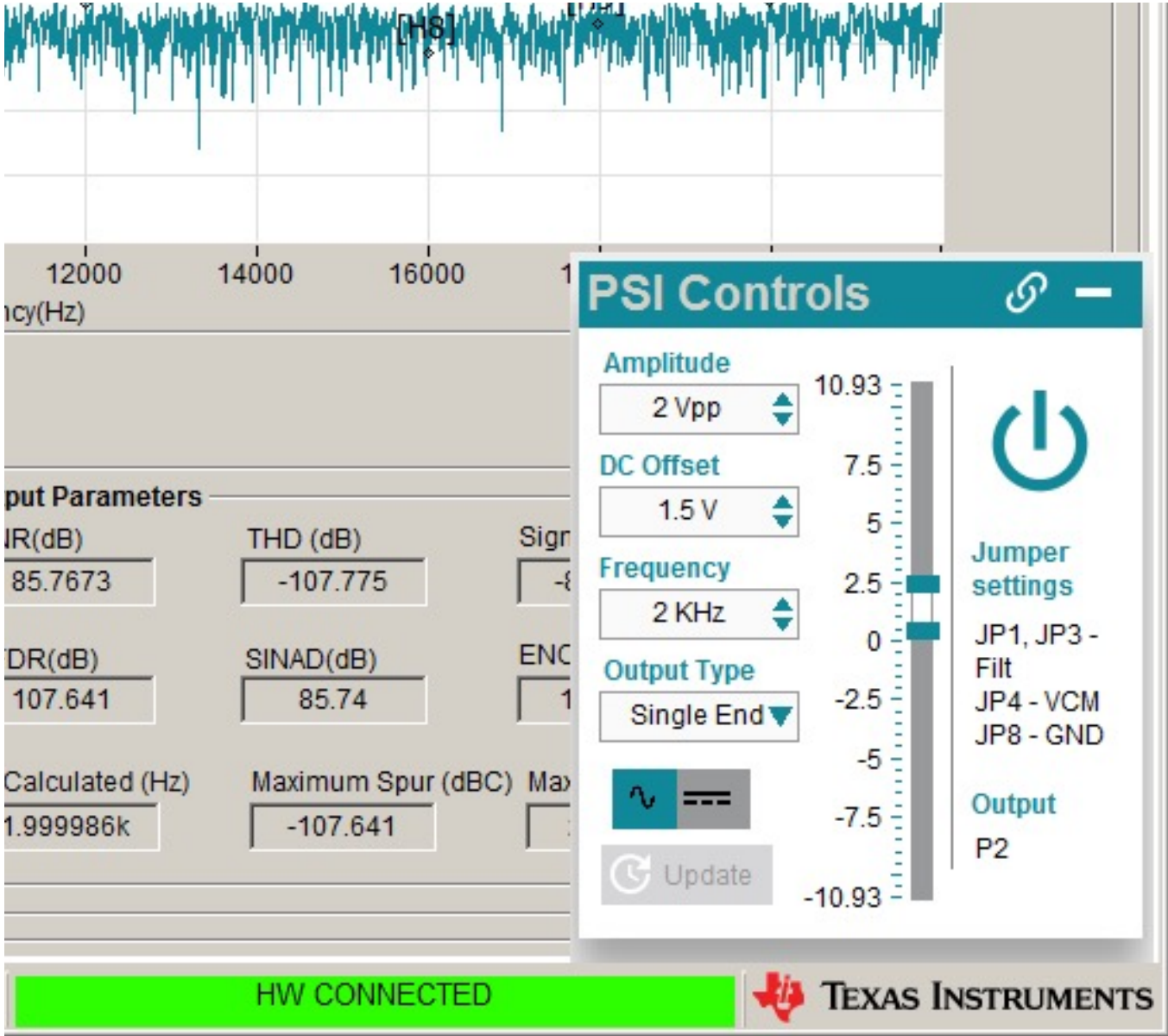
22. Amplitude of harmonics in table form.

23. Minimize or maximize PSI controls as needed.

Enter Vin, Vcm to compare OPA316 and OPA320

fin = 2kHz, fsamp = 500kHz
Crossover region at 3.8V on OPA316

PSI Signal Settings		Calculated PSI Min and Max Output		OPA316 Expected	
Vin (Vpp)	Vcm (V)	Vmin (V)	Vmax (V)	SNR (dB)	THD (dB)
2	1.5	0.5	2.5	85.3	-104.4
2	2	1	3	85.3	-102.9
2	3	2	4	85.2	-98.8
2	3.2	2.2	4.2	85.2	-83.8
2	3.5	2.5	4.5	85.1	-76.1
2	3.8	2.8	4.8	85.0	-77.2



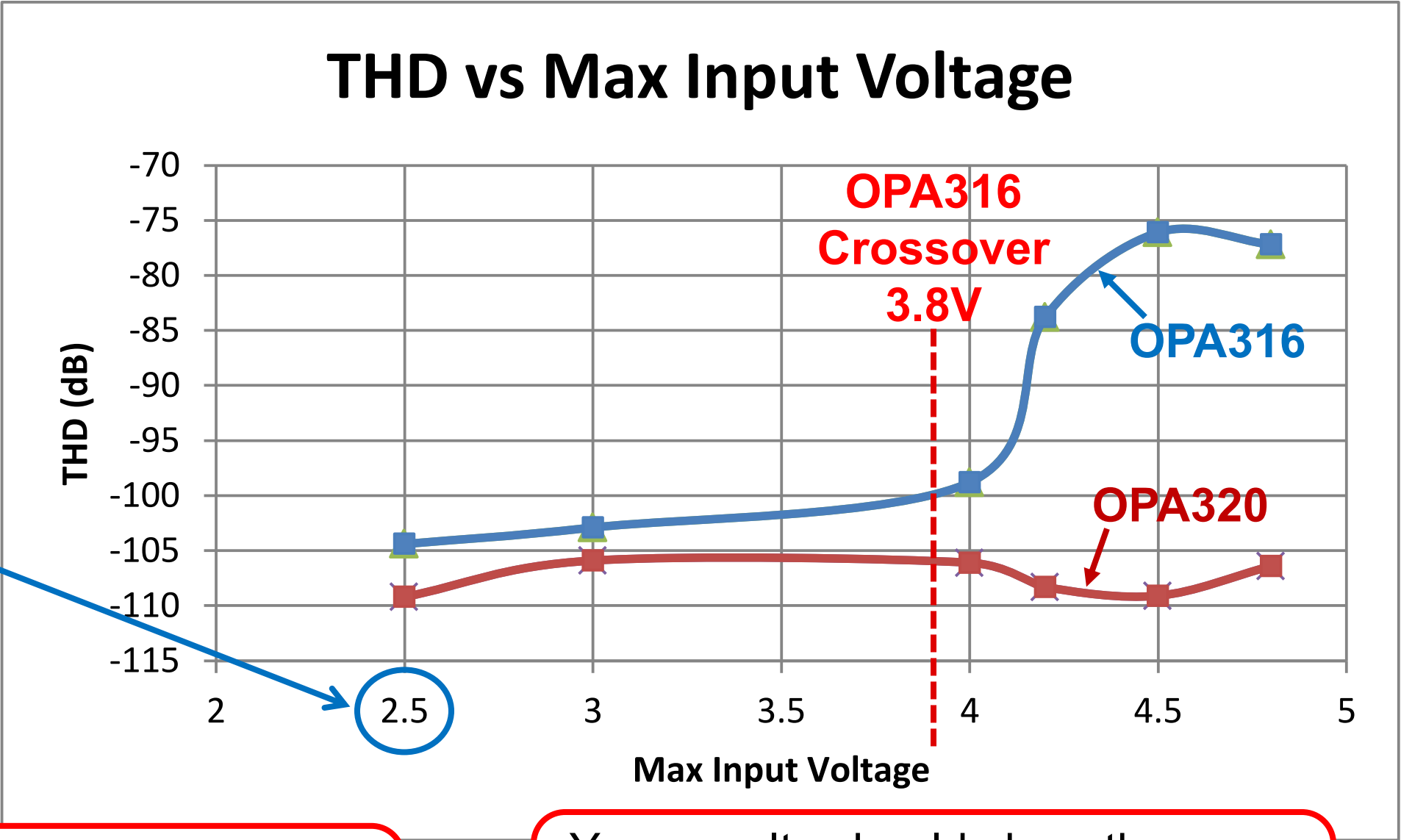
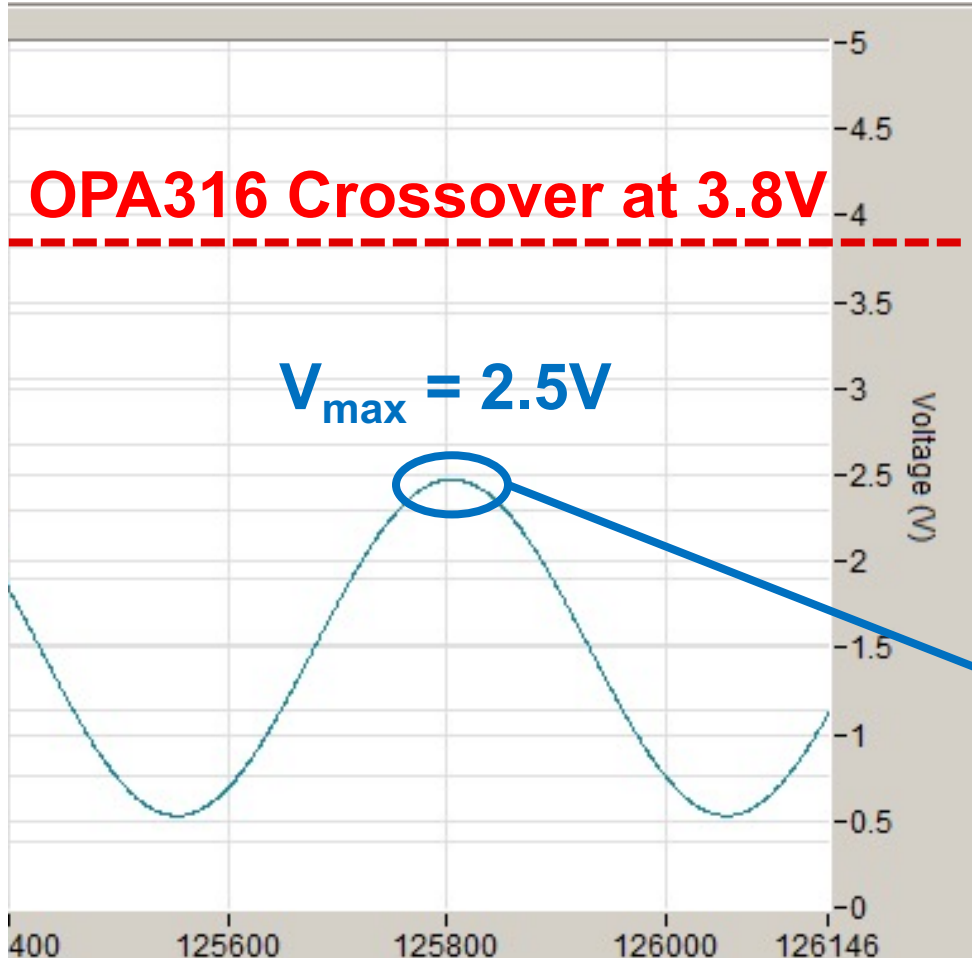
Measured vs Expected Results

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

$f_{in} = 2\text{kHz}$, $f_{samp} = 500\text{kHz}$
Crossover region at 3.8V on OPA316

PSI Signal Settings		Calculated PSI Min and Max Output		OPA316 Expected		OPA316 Measured		OPA320 Expected		OPA320 Measured	
V_{in} (Vpp)	V_{cm} (V)	V_{min} (V)	V_{max} (V)	SNR (dB)	THD (dB)	SNR (dB)	THD (dB)	SNR (dB)	THD (dB)	SNR (dB)	THD (dB)
2	1.5	0.5	2.5	85.3	-104.4			85.7	-109.2		
2	2	1	3	85.3	-102.9			85.6	-105.9		
2	3	2	4	85.2	-98.8			85.7	-106.1		
2	3.2	2.2	4.2	85.2	-83.8			85.6	-108.3		
2	3.5	2.5	4.5	85.1	-76.1			85.6	-109.1		
2	3.8	2.8	4.8	85.0	-77.2			85.7	-106.4		

Graph of results



Microsoft Excel
Worksheet

Click here to access Excel Spreadsheet for data collection.

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

Thanks for your time!