

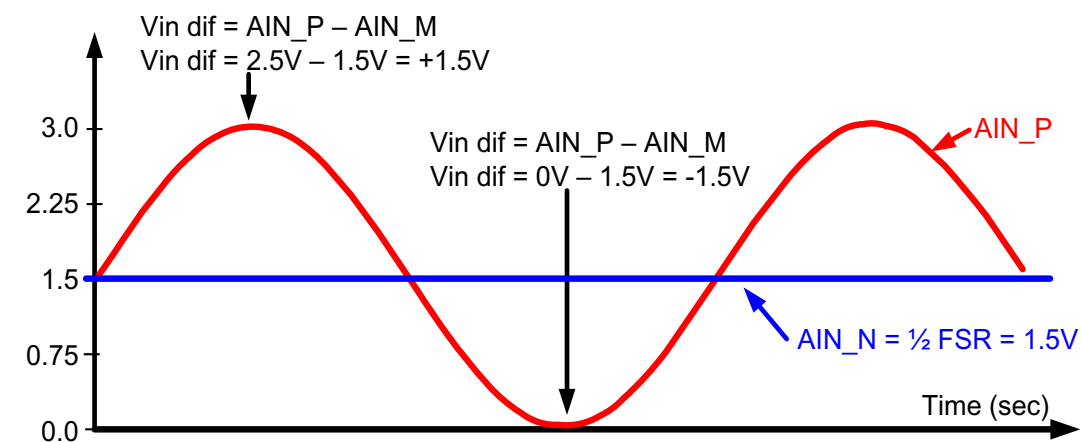
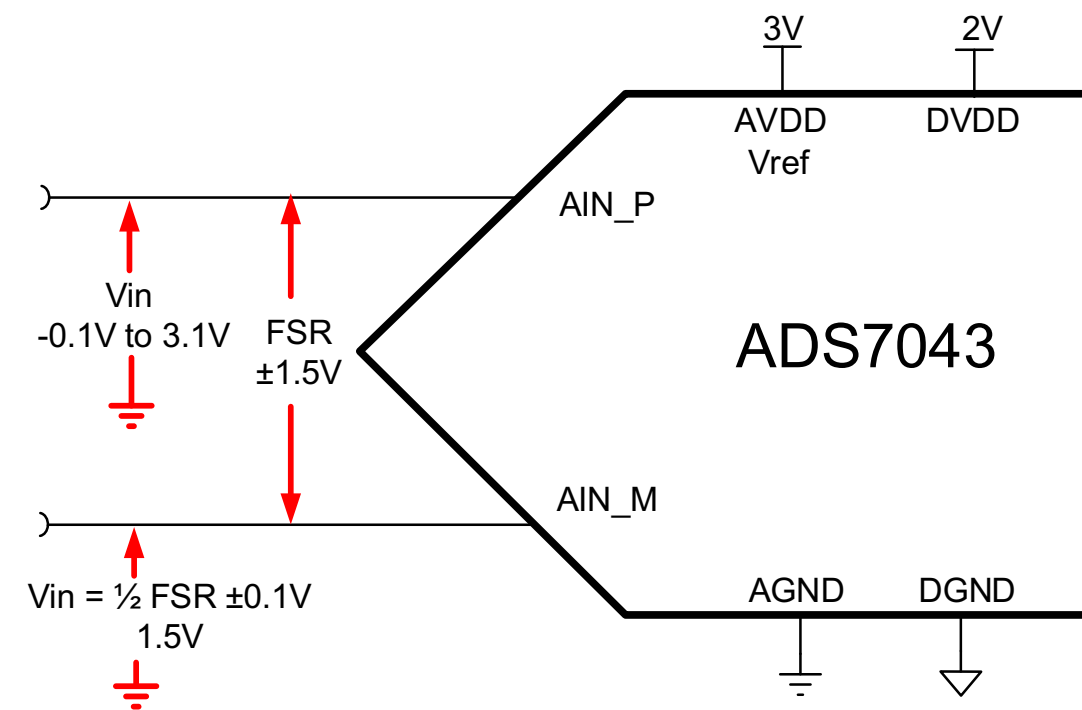
# Introduction to Precision Labs-Pro Webinar Series

TI Precision Labs – ADC

by Art Kay

# What is Precision Labs (PLABS)?

- Logical sequence – like a college curriculum
- Questions and solutions to reinforce learning
- Covers a wide range of expertise
- Hands-on aspect (EVM)
- Teaching with pictures and heavily animated
- Teaching with practical real world examples
- Less math more practical
- Short length to each video (10 to 15min)



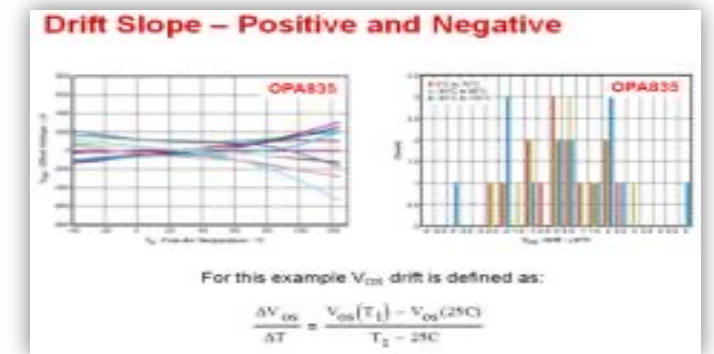
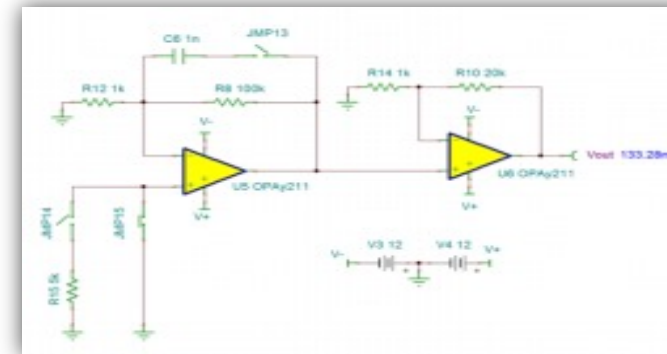


# TI Precision Labs Now including ADCs, MUXs, and Comparators!!!

## [ti.com/PrecisionLabsADCs](http://ti.com/PrecisionLabsADCs)



- Created for both new and experienced engineers
- 80+ Lectures with quizzes & Labs with experiments
- < 15 minutes per video, 16 hrs of total content



### Op Amps

#### Input Offset Voltage ( $V_{OS}$ ) & Input Bias Current ( $I_B$ )

TIPL 1100  
TI Precision Labs – Op Amps

Presented by Ian Williams  
Prepared by Art Kay and Ian Williams

### Comparators

#### Comparator Applications 3

TIPL 2103  
TI Precision Labs – Op Amps

Presented by Ian Williams  
Prepared by Thomas Kuehl and Ian Williams

### MUXes

#### Basics of Analog Multiplexers 2

TIPL 2602  
TI Precision Labs – Op Amps

Created by Abhijeet Godbole, Art Kay  
Presented by Peggy Liska

### ADCs

#### DC Specifications:

input capacitance, leakage current, input impedance, reference voltage range, INL, and DNL

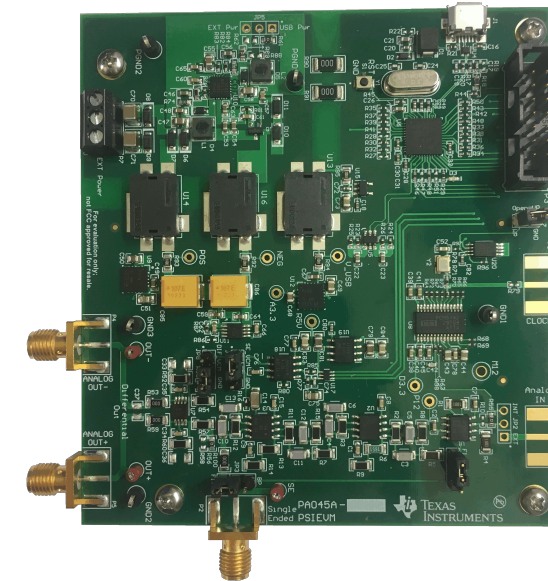
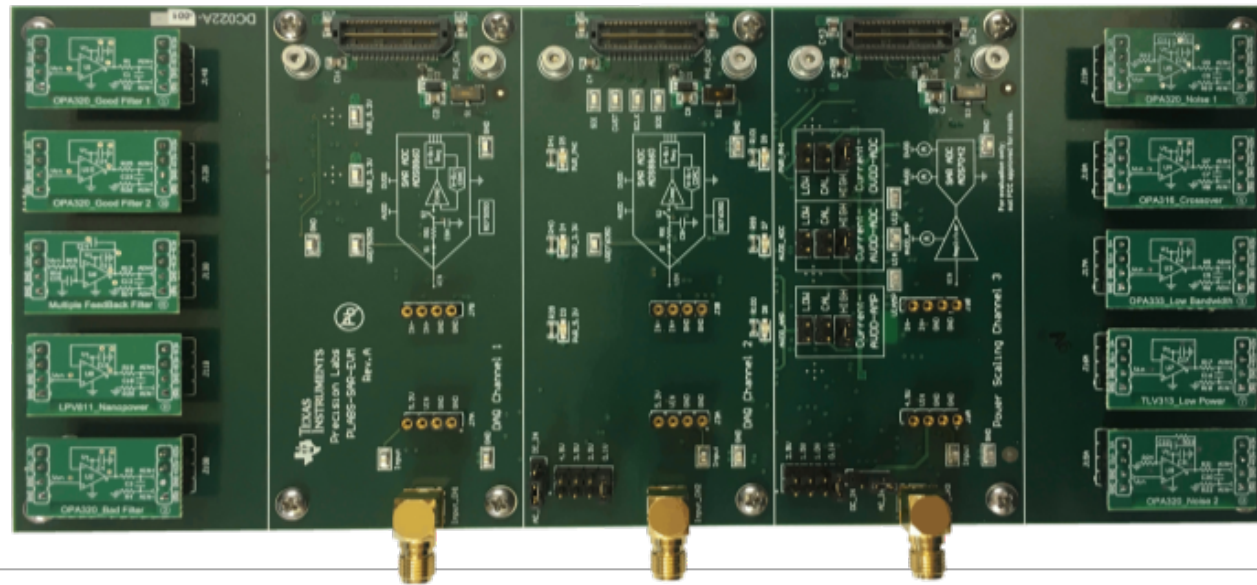
TIPL 4001  
TI Precision Labs – ADCs

Created by Art Kay  
Presented by Peggy Liska

**More than 80+ videos!!!**

# How is PLABS Pro Webinar Different?

- Opportunity to ask questions and get immediate feedback.
- Five 90 min Live Sessions
  - 60 min theory + 15 min hands-on experiments + 15 min Q & A
- Webinar material is a subset of on-line content
  - Webinar focuses on key concepts that relate to hands-on experiments
  - Webinar is a “readers digest” version of the on-line content





# Sessions Cover

1. ADC Amplifier Drive Configurations and Swing Limitations
  - Hands-on: Crossover distortion measurement
2. ADC Error Sources (Offset, Gain Error, Noise)
  - Hands-on: Noise calculation, simulation, and measurement
3. Understanding the frequency domain (FFT, Windowing, Aliasing)
  - Hands-on: Aliasing and anti-aliasing filters
4. Selecting Components in SAR ADC Drive (amplifier bandwidth and RC filter)
  - Hands-on: Comparison of properly designed input to improperly designed
5. Low Power SAR Design (ADC Power Scaling and low power amplifiers)
  - Hands-on: Power measurement vs sampling rate with different amplifiers.

# Suggested Pre-work: Watch ADC and Op Amp PLABS

**ADC PLABS: DC Specifications:** Input Capacitance, Leakage Current, Input Impedance, Reference Voltage Range, INL, and DNL

<https://training.ti.com/ti-precision-labs-adcs-dc-specifications?cu=1128375>

**ADC PLABS: AC & DC Specifications:** Offset Error, Gain Error, CMRR, PSRR, SNR, and THD

<https://training.ti.com/ti-precision-labs-adcs-ac-dc-specifications?cu=1128375>

**Op Amp Plabs: Input and Output Limitations 1**

<https://training.ti.com/ti-precision-labs-op-amps-input-and-output-limitations-1?cu=14685>



# Install PLABS-SAR-EVM-PDK Setup Toolkit

- Purchase hardware and download at: <http://www.ti.com/tool/plabs-sar-evm-pdk>
- You will need to fill out forms and accept license agreements.
- It will take a few minutes to download and install (275MByte file).

## US Government Approval

U.S. Government export approval:  
All fields are Required. Incomplete information will be DENIED.

First name: Arthur  
Last name: Kay  
Your email address: [Redacted]  
Your full company/university name: Texas Instruments  
Country this file will be used in: United States  
What end-equipment/application will you use this file for:  
 Military  
 Civil

I certify that the following is true:

(a) I understand that this Software/Tool/Document is subject to export controls under the U.S. Commerce Department's Export Administration Regulations ("EAR").

(b) I am NOT located in Cuba, Iran, North Korea, Sudan or Syria. I understand these are prohibited destination countries under the EAR or U.S. sanctions regulations.

(c) I am NOT listed on the Commerce Department's Denied Persons List, the Commerce Department's Entity List, the Commerce Department's General Order No. 3 (in Supp. 1 to EAR Part 736), or the Treasury Department's Lists of Specialty Designated Nationals.

(d) I WILL NOT EXPORT, re-EXPORT or TRANSFER this Software/Tool/Document to any prohibited destination, entity, or individual without the necessary export license(s) or authorization(s) from the U.S. Government.

(e) I will NOT USE or TRANSFER this Software/Tool/Document for use in any sensitive NUCLEAR, CHEMICAL or BIOLOGICAL WEAPONS, or MISSILE TECHNOLOGY end-users unless authorized by the U.S. Government by regulation or specific license.

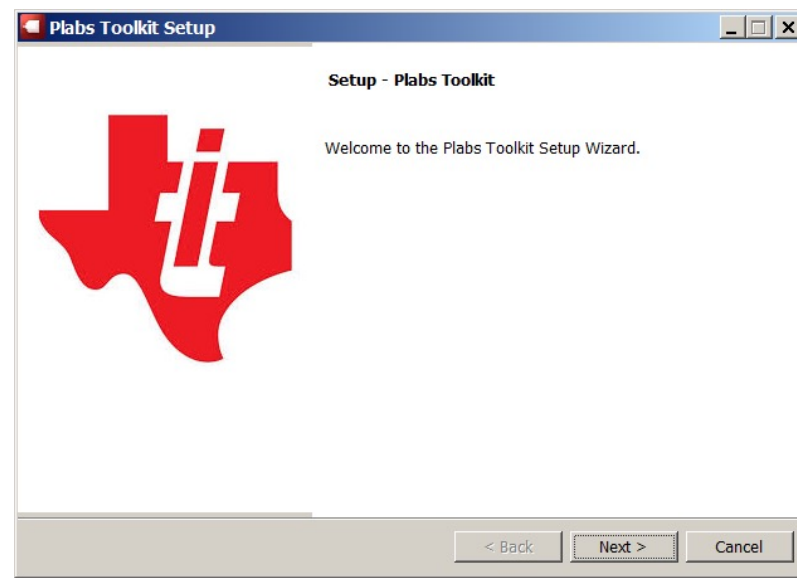
(f) I understand that countries other than the United States may restrict the import, use, or export of the Subject Product. I agree that we shall be solely responsible for compliance with any such import, use, or export restrictions.

- I / We hereby certify that we will adhere to the conditions above.  
- I / We do not know of any additional facts different from the above.  
- I / We take responsibility to comply with these terms.  
- I / We understand we are responsible to abide by the most current versions of the Export Administration Regulations and other U.S. export and sanctions laws.

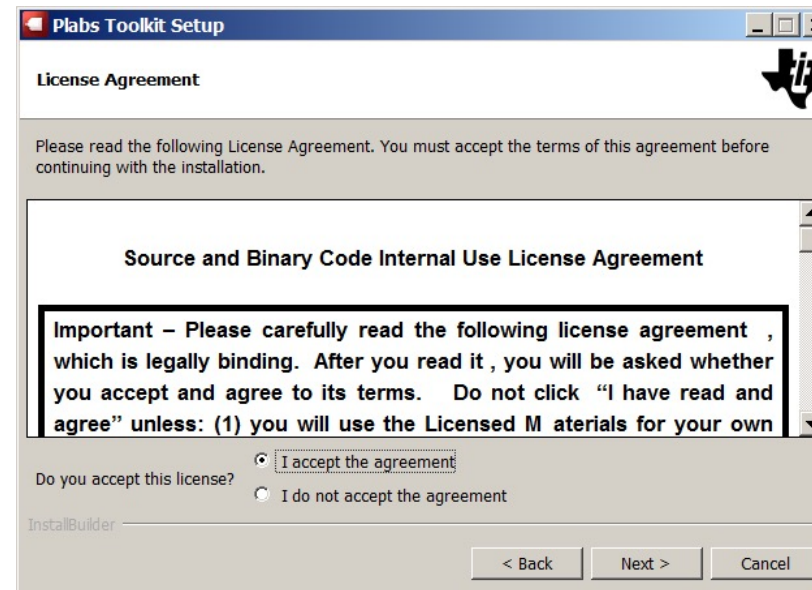
I CERTIFY ALL THE ABOVE IS TRUE: Yes  No

Submit

## Start software installation



## Accept license agreements.



## Finish the installation



# Install “Analog Engineer’s Calculator” Free Tool

<http://www.ti.com/tool/analog-engineer-calc>

The screenshot displays the 'Analog Engineer's Calculator' software interface. On the left, a tree view under 'Select the Calculator' shows 'ADC SAR Drive' selected. The main 'Calculator' area is configured for 'Single Ended #2' with the following parameters:

- Resolution: 16
- Csh: 60p F
- Full Scale Range: 5 V
- Acquisition Time: 300n s
- Rfilt/2 Min: 3.9 Ohm
- Cfilt: 1.2n F
- Rfilt/2 Max: 30.8 Ohm
- Optional Cmin: 620p F
- Optional Cmax: 1.8n F
- Gain Bandwidth: 17.2M Hz
- Max Error Target: 38.15u V

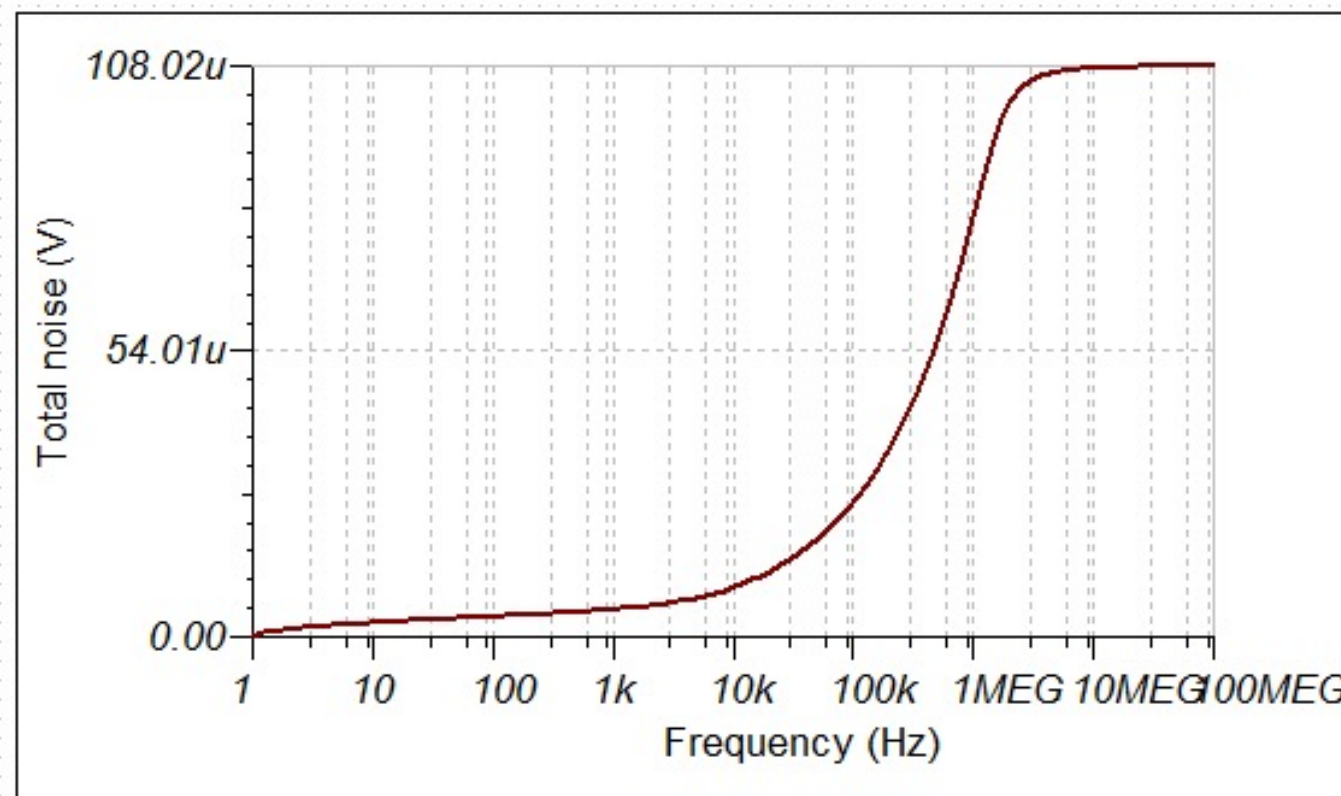
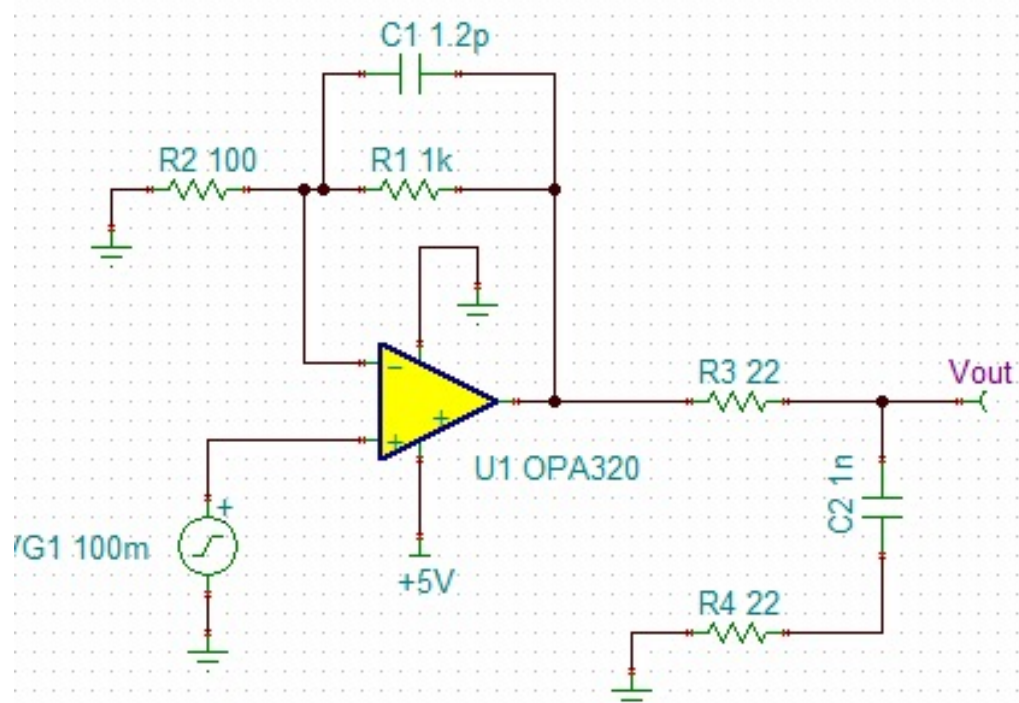
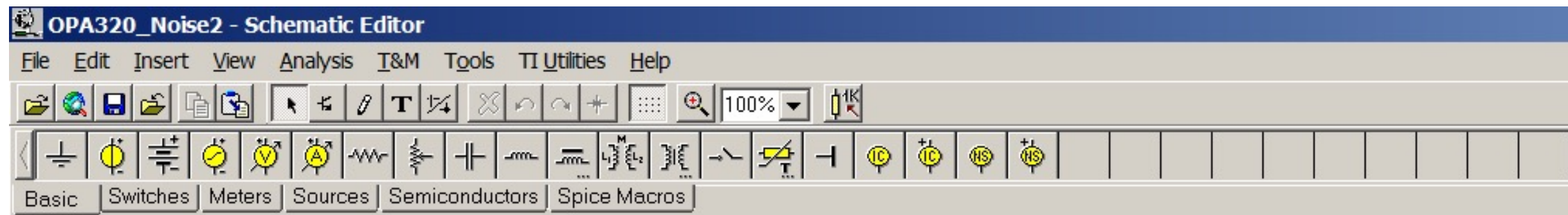
At the bottom of the calculator are 'OK' and 'Help' buttons. To the right of the calculator is a circuit diagram for a single-ended ADC SAR drive. The diagram shows an op-amp with a +5V supply and a Vin input. The op-amp output is connected to a network of resistors (Rfilt/2), capacitors (CFILT, CSH+, CSH-), and switches (S1, S2, S3, S4) leading to Vsh+ and Vsh- nodes.

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



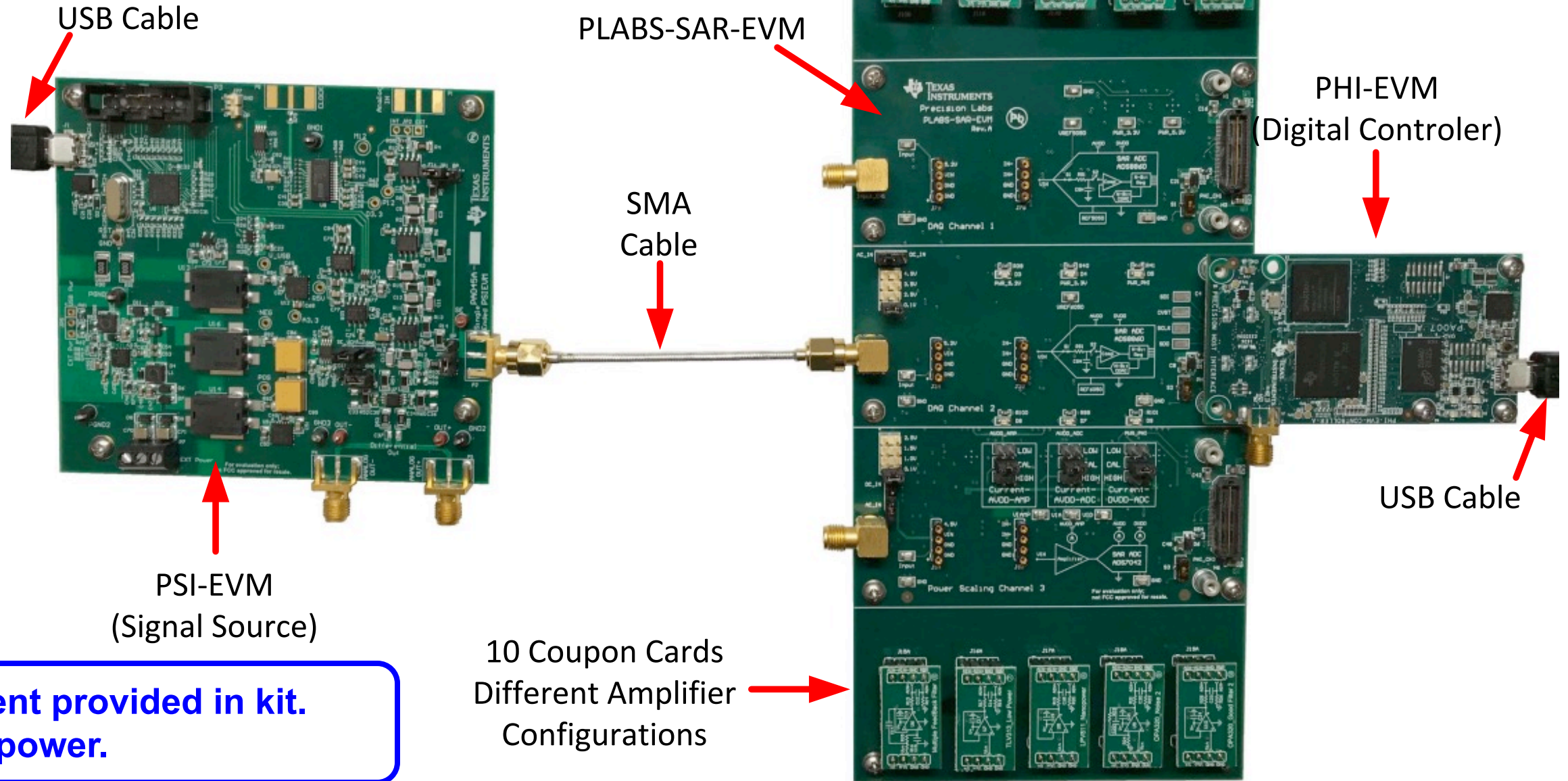
# Install "TINA-TI™" Free SPICE Software

<http://www.ti.com/tool/tina-ti>



# Overview of the PLABS Kit

<http://www.ti.com/tool/plabs-sar-evm-pdk>

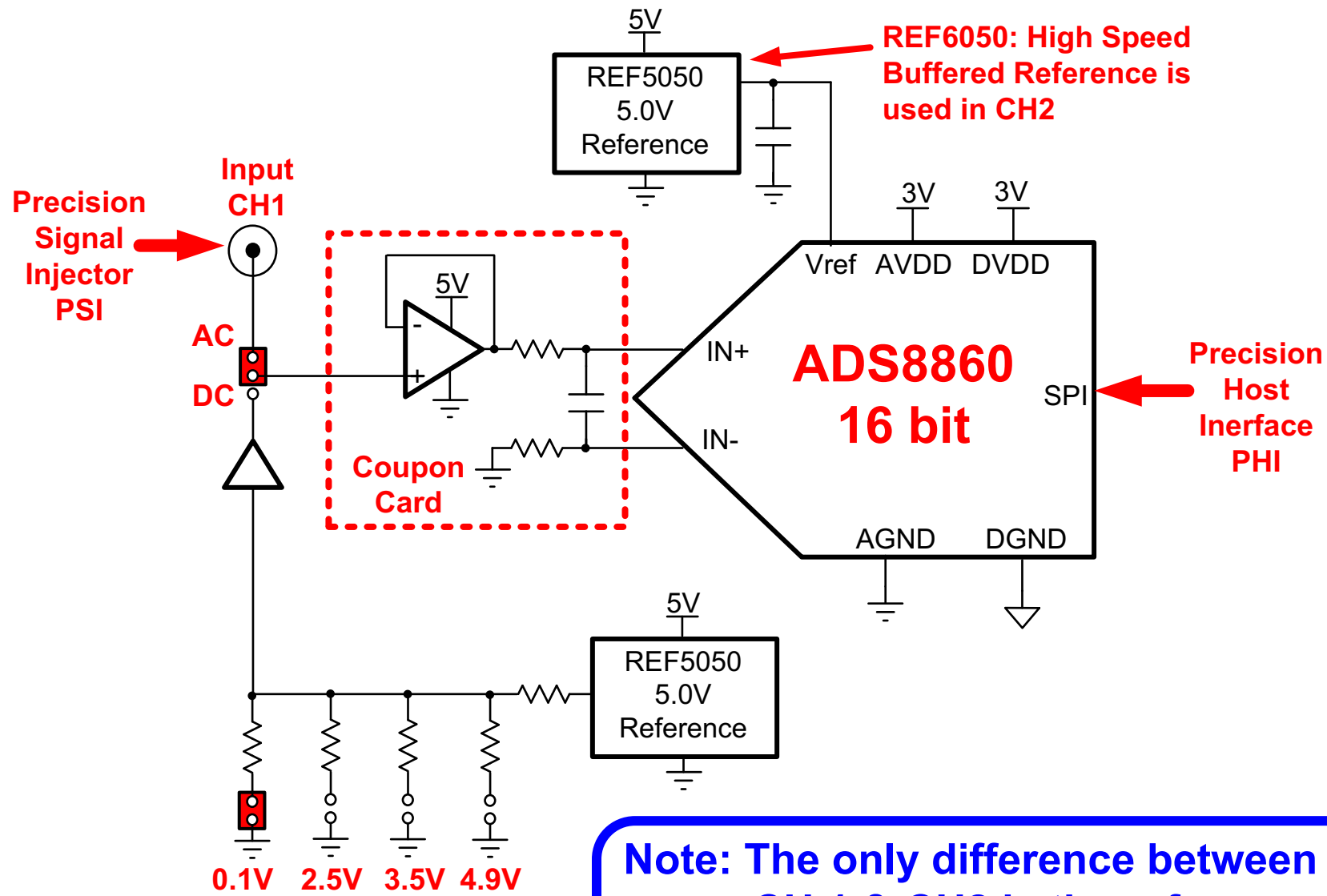


**Note: All equipment provided in kit.  
USB supplies all power.**



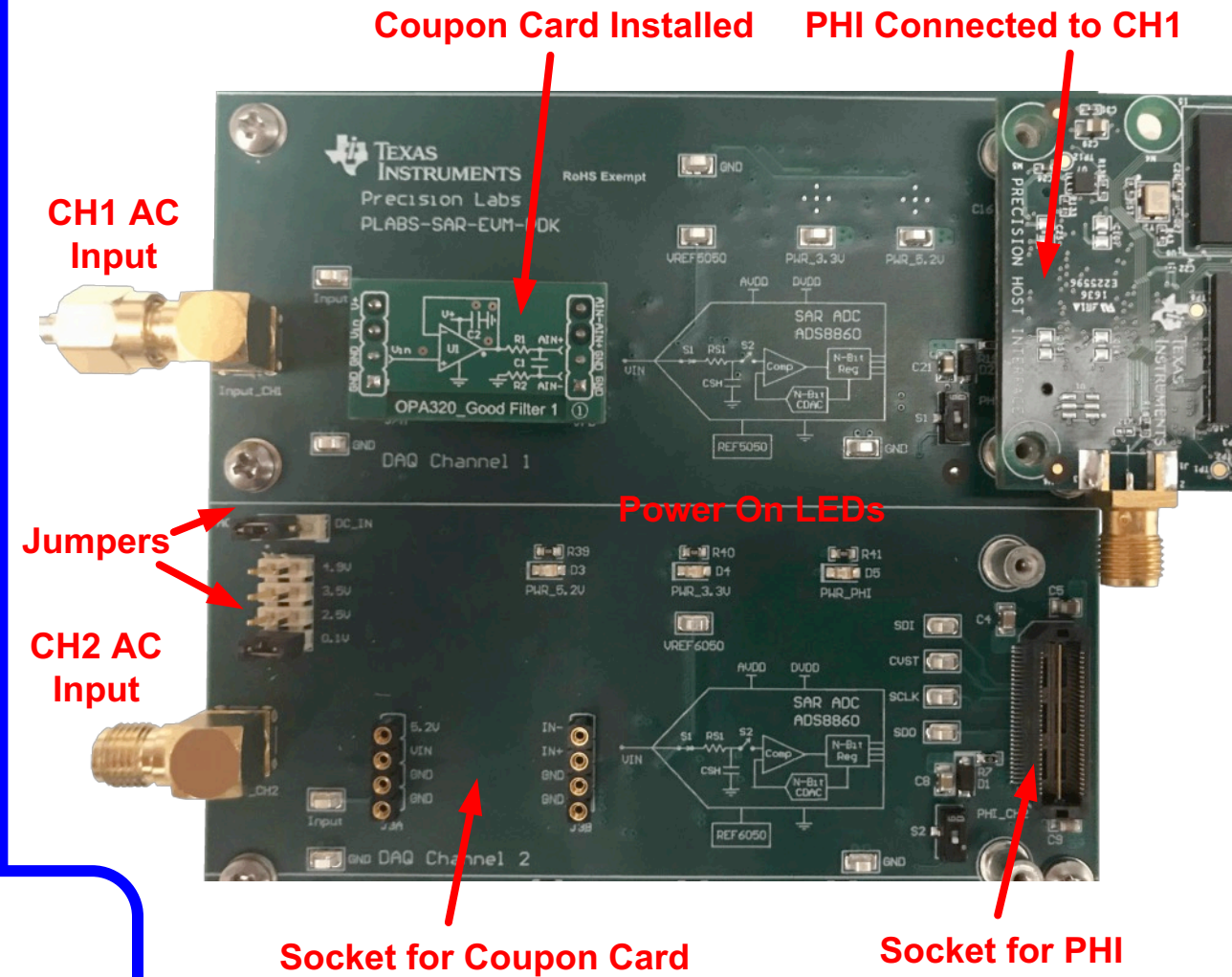
# Overview: CH1 & CH2 PLABS-SAR-EVM

## Schematic CH1 Shown



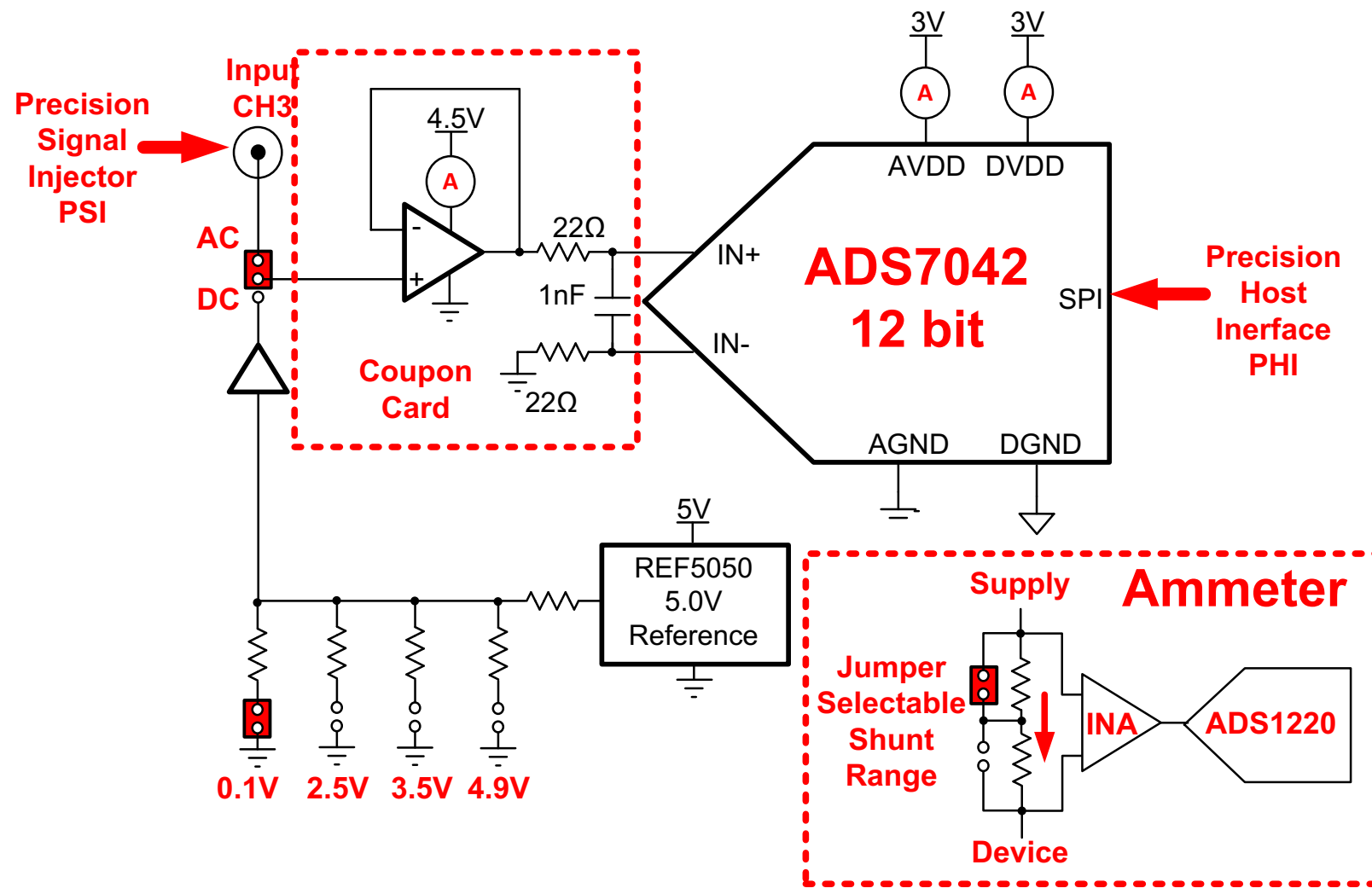
**Note: The only difference between CH 1 & CH2 is the reference.  
 CH1 = REF5050 (No high speed buffer)  
 CH2 = REF6050 (high speed buffer)**

## Picture of Hardware

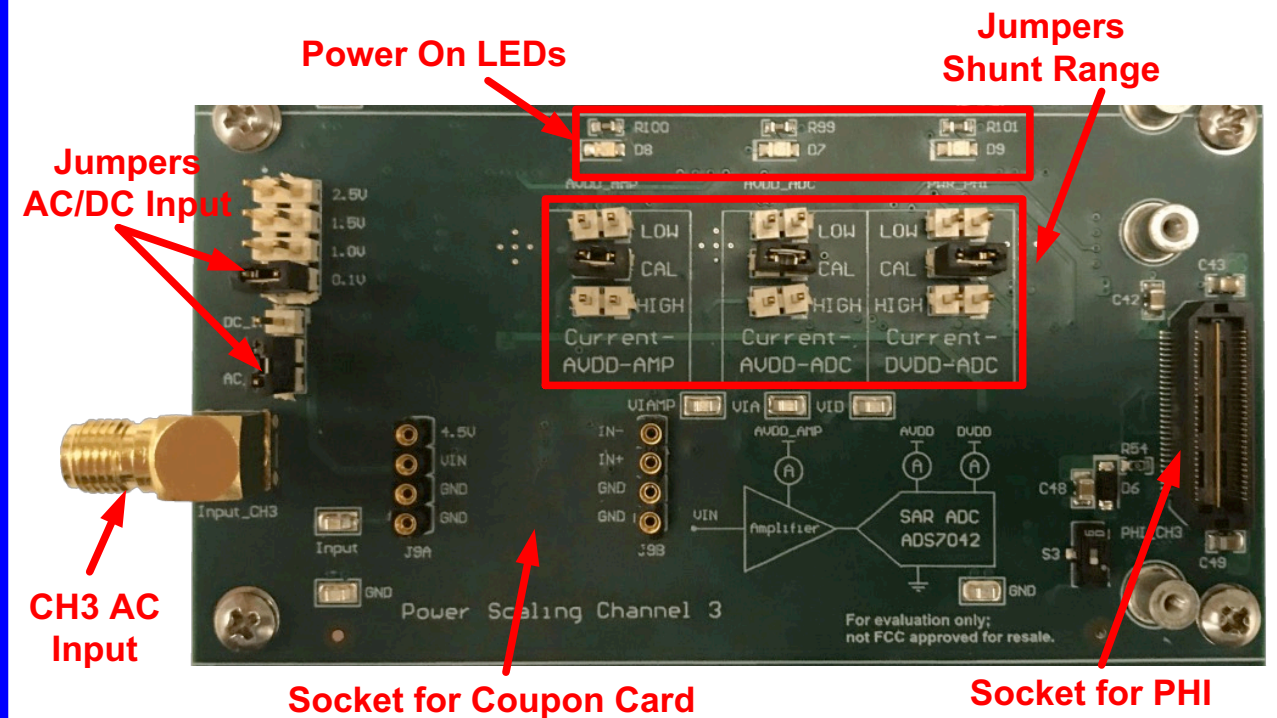


# Overview: CH3 PLABS-SAR-EVM

## Schematic



## Picture of Hardware





# Overview: Precision Signal Injector (PSI)

## PSI Spec.

THD 125dB  
SNR 100dB  
Vout = 12Vpp  
Voffset =  $\pm 5V$

**High Res mode**  
f<sub>out</sub> = 2kHz

**Bypass Mode**  
f<sub>out</sub> = 20 to 20kHz

Note: A commercial signal generator with comparable performance is very costly!

USB  
Control and  
Power

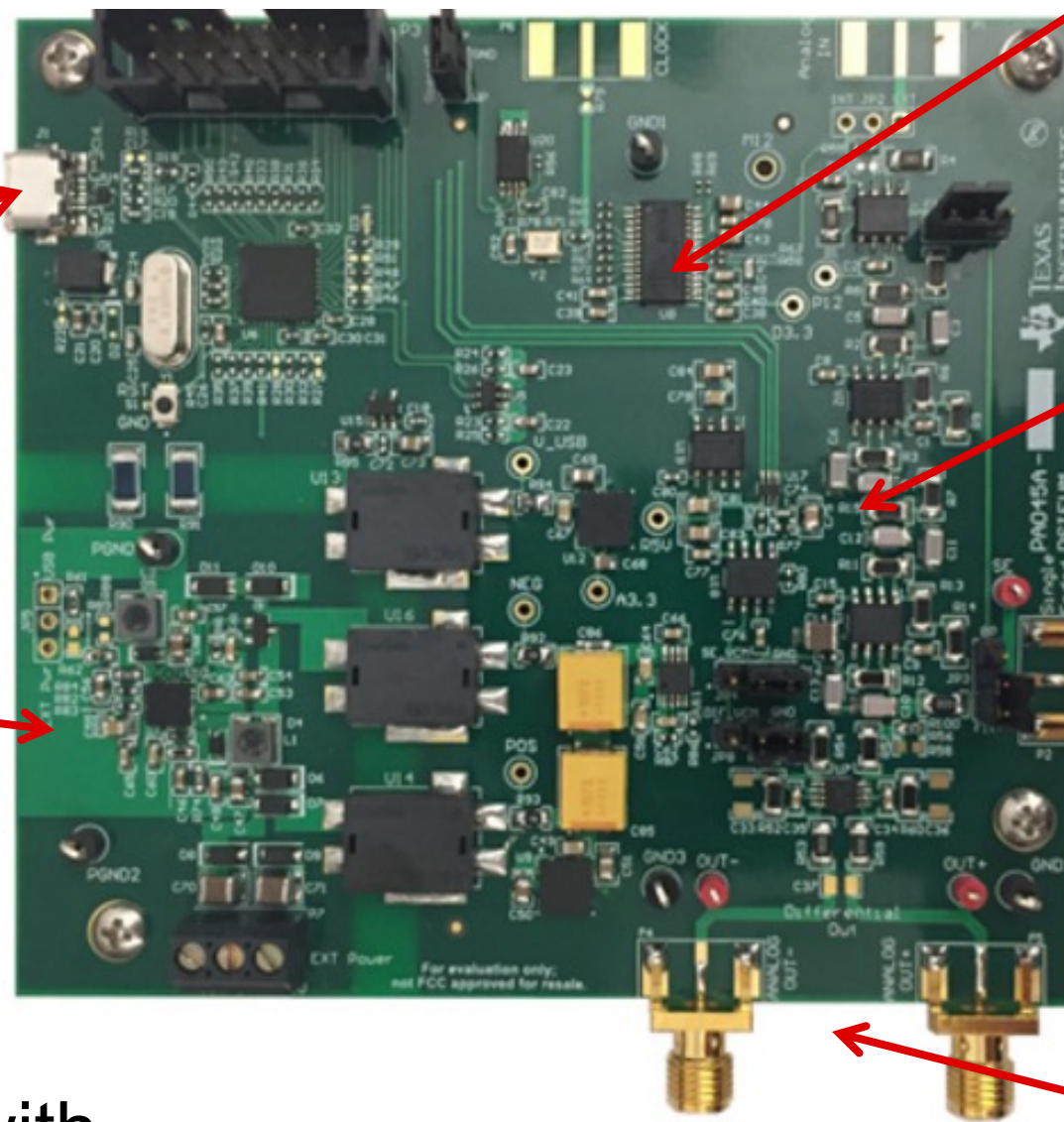
DC-to-DC  
converts 5V  
USB Power  
to  $\pm 12V$

PCM5142  
Audio DAC  
generates  
sine wave

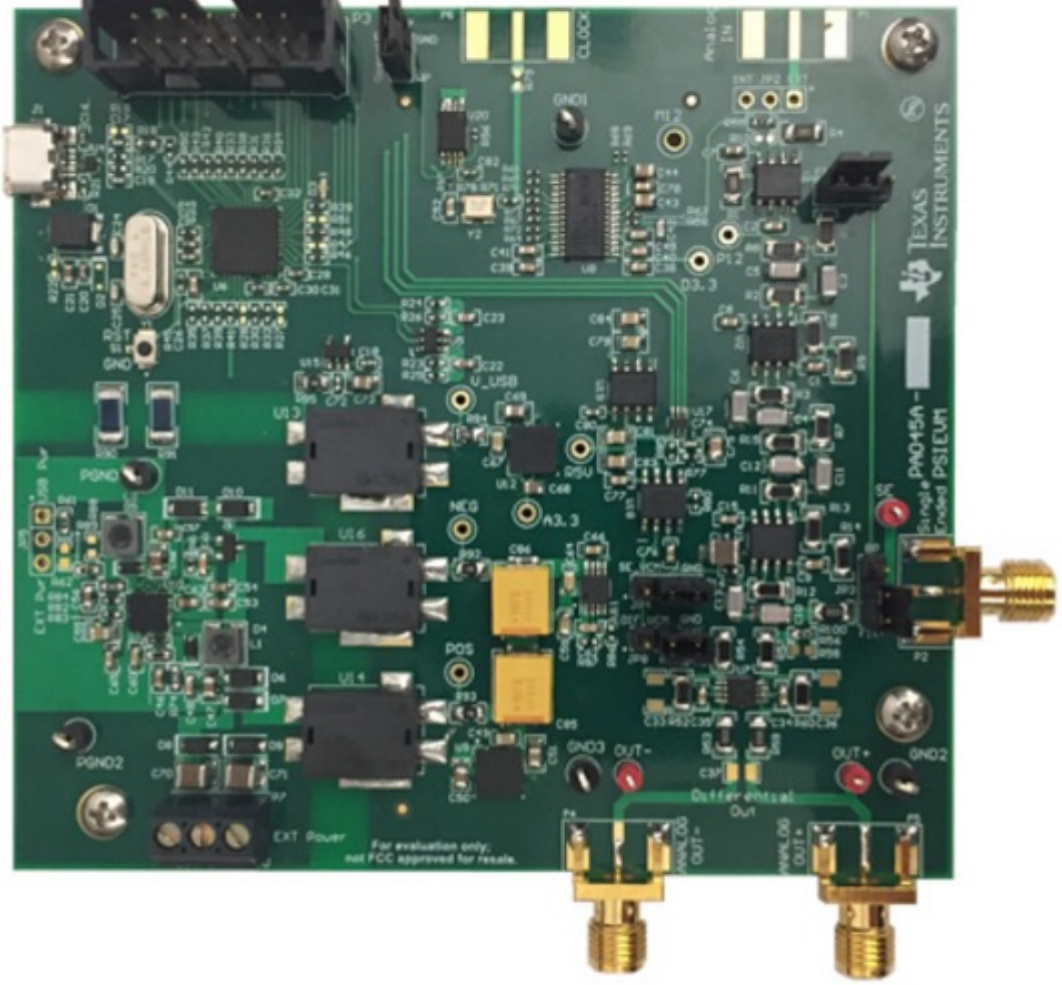
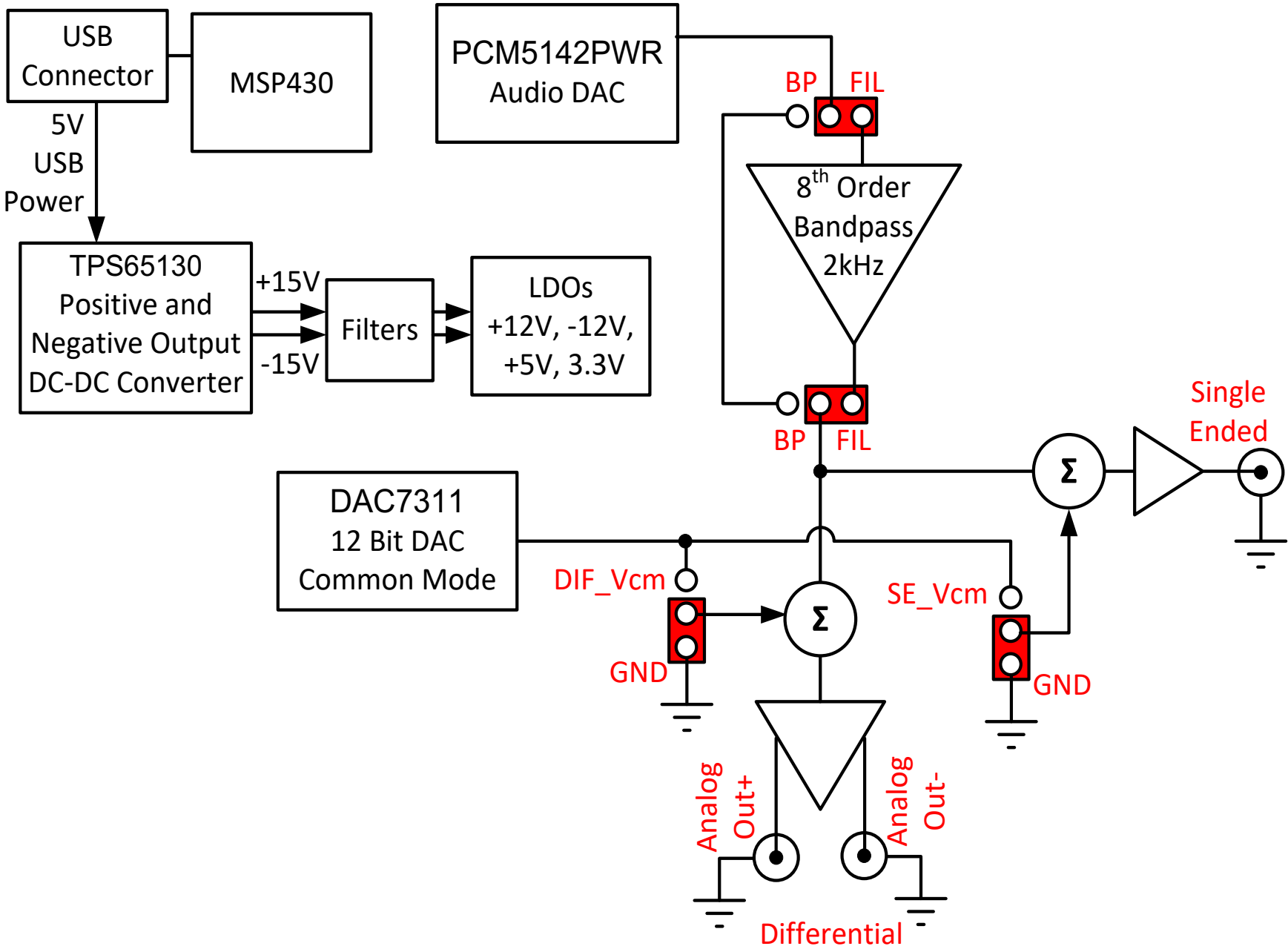
8<sup>th</sup> order  
BPF

Single  
Ended  
Output

Differential  
Output



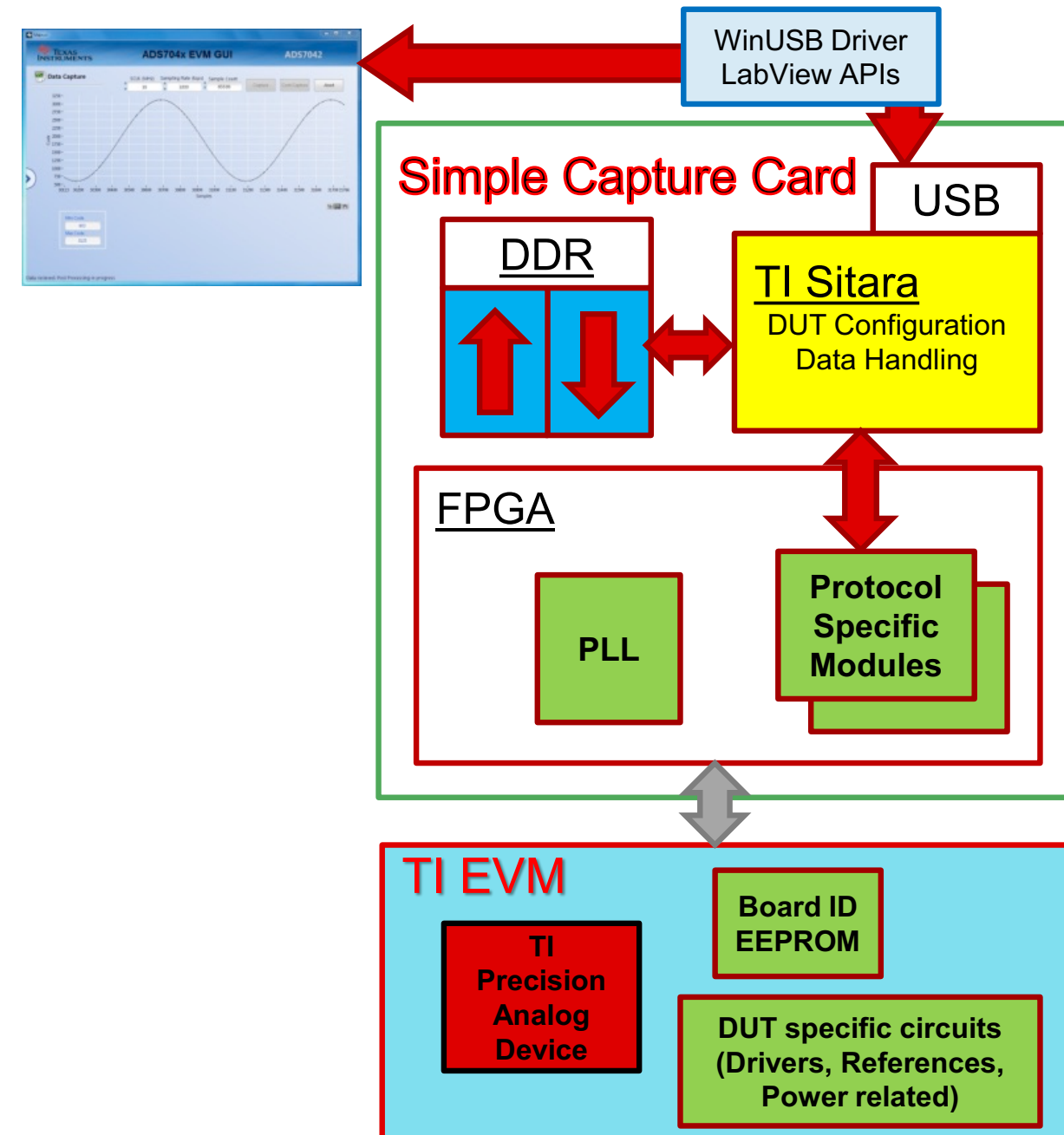
# Hardware Overview: Precision Signal Injector (PSI)



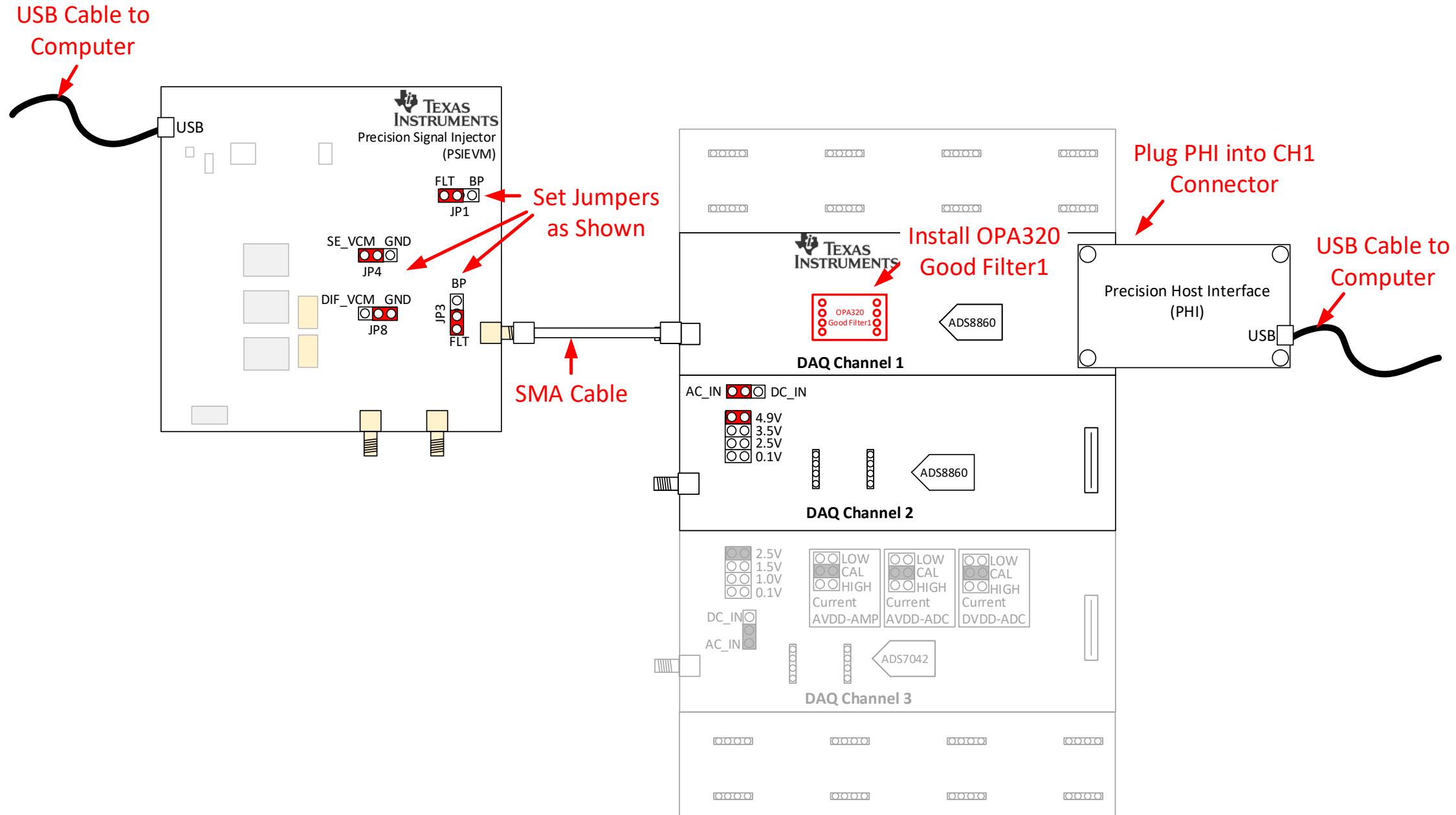


# Precision Host Interface (PHI)

- Supports USB2.0 to Serial or Parallel-bus interfaces
- Powered by and communicates using of a single USB2.0 supply
- TI AM3352 Sitara Processor & FPGA configurable data capture and pattern generator
- High speed data communications (80MHz SCLK)
- PHI can work with a wide range of TI-EVMs using a common firmware (no reprogramming required)
- EEPROM based board identification scheme
- Auto boot up when paired with the right GUI
- In-field/in-system programmability/upgradability



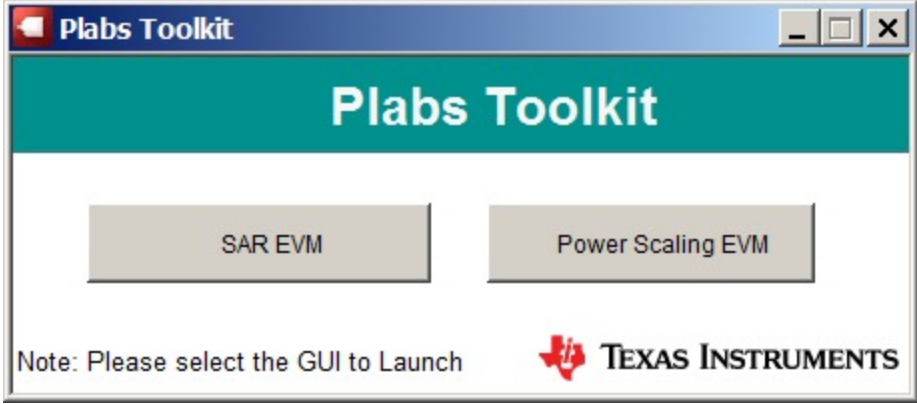
# Connecting the hardware





# Connecting the hardware: Avoiding common problems

# Running the software.



The screenshot displays the 'Plabs-SAR-EVM' software interface. The main window is titled 'Spectral Analysis' and shows a plot of Amplitude (dBC) versus Frequency (Hz). The plot displays a series of peaks labeled [H1] through [H10], representing harmonics. The y-axis ranges from -220 to 20 dBC, and the x-axis ranges from 0 to 21989 Hz. The [H1] peak is the most prominent, reaching approximately 10 dBC. Other peaks are significantly lower, with [H2] at about -95 dBC and [H10] at about -125 dBC.

The interface includes several configuration panels:

- Pages:** Time Domain Display, Spectral Analysis (selected), 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 66M, Achievable 66.00M
  - Sampling Rate(sps): Target 1.00M, Achievable 1.00M
- Input Parameters:**
  - Samples: 262144
  - Device Fs (Hz): 1.00M
  - # Harmonics: 9
  - Window: 7 Term B-Harris
- Output Parameters:**
  - SNR(dB): 92.3937
  - THD(dB): -93.5317
  - Signal power(dBFS): -0.425489
  - SFDR(dB): 94.7456
  - SINAD(dB): 89.9152
  - ENOB: 14.6437
  - Fi Calculated (Hz): 1.999986k
  - Maximum Spur (dBC): -94.7456
  - Maximum Spur (Hz): 4001.62
- Harmonics(dBC) Table:**

Harmonic	Amplitude (dBC)
H1	0.00
H2	-94.74
H3	-99.83
H4	-117.6
H5	-119.1
H6	-124.8
H7	-124.4

The status bar at the bottom indicates 'Idle' and 'HW CONNECTED'.



**Thanks for your time!  
I hope you find the  
webinar useful.**