Welcome!
Texas Instruments New Product Update

- This webinar will be recorded and available at www.ti.com/npu
- Phone lines are muted
- Please post questions in the chat or contact your TI sales contact or field applications engineer

FOUR-CHANNEL SYNCHRONOUS VIBRATION SENSOR INTERFACE FEATURING ADS127L11

New Product Update

Ahmed Noeman
- Systems Engineer

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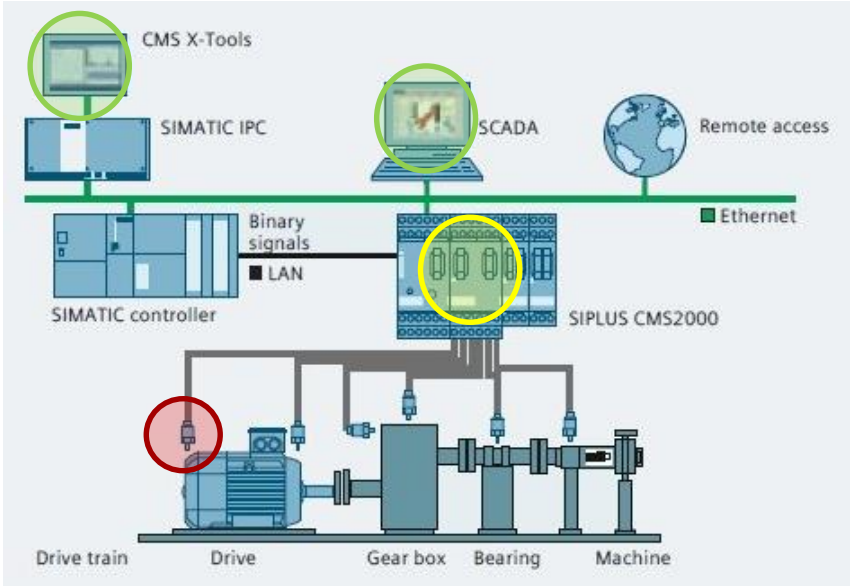
- Product Marketing Engineer

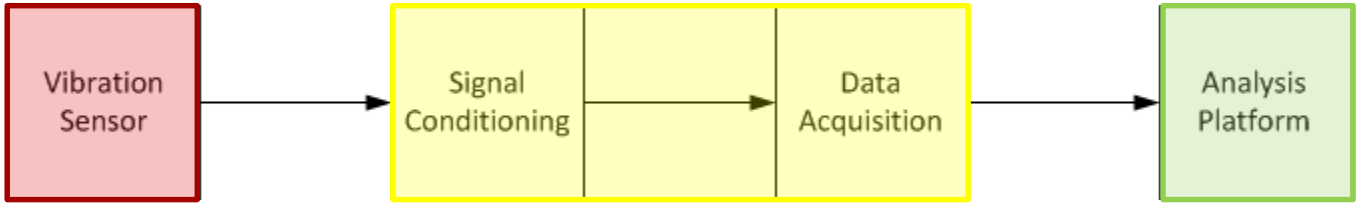
Agenda

- Introduction to vibration monitoring and vibration sensors
- IEPE sensors demystified
- Four-channel wideband interface design walk-through
- Introduction to ADS127L11
- Test setup and results of the IEPE sensor design

Please feel free to “chat” Michael Saul, Product Marketing Engineer, who is available to answer any questions you have throughout this presentation.

Vibration monitoring analysis system





Vibration sensors

Vibration sensor technology

	IEPE piezoelectric	Charge piezoelectric	Piezoresistive	Capacitive MEMS	Servo accelerometer
					
Frequency range	0.5 - 50 kHz	0.5 - 50 kHz	1 - 10 kHz	0 - 1 kHz	0 - 100 Hz
Sensitivity	5E-5 - 10 V/g	.01 - 100 pC/g	1E-7 - 1E-2 V/g	10 m - 1 V/g	1 - 10 V/g
Measure range	1E-6 - 1E5 g	1E-5 - 1E5 g	1E-3 - 1E5 g	1E-5 - 1E3 g	1E-6 - 1E3 g
Dynamic range	~120 dB	~110 dB	~80 dB	~90 dB	> 120 dB
Application	Industrial	High temp	Crash test	Airbag	Space navigation

***This table features typical ranges of such devices, but not necessarily the actual ranges/specs of the these products shown.**

Table source: Sensor Technology Handbook, Wilson, Jon. Elsevier 2005

Inside an IEPE sensor

IEPE sensor structure

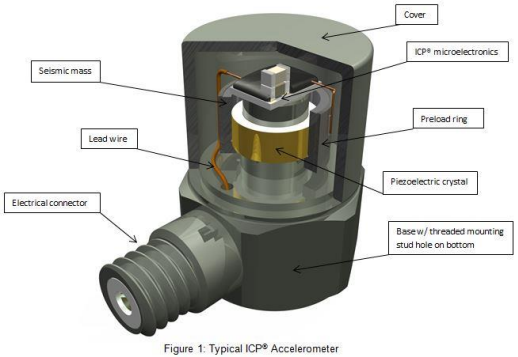
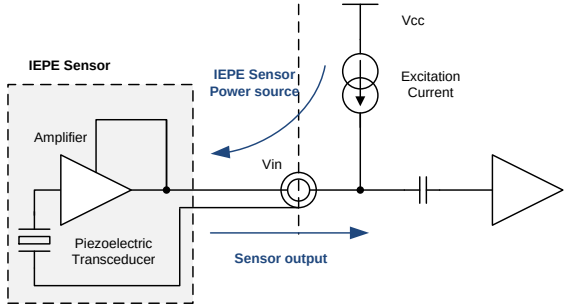


Figure 1: Typical ICP® Accelerometer

Image source: http://www.pcb.com

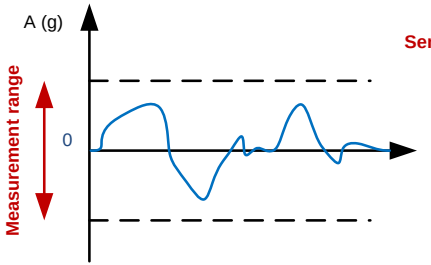
Sensor interface connection



Sensor specs

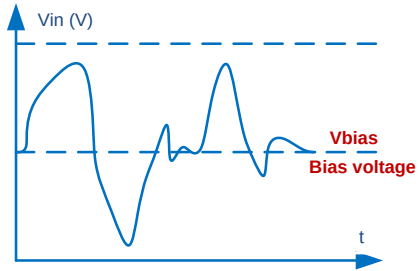
- Output range: ±10 V
- Bias voltage: 8-13 V
- Frequency range: 0.5 Hz - 20 kHz
- Noise: < 50 µVrms
- Excitation current: > 2 mA
- Dynamic range: 100 dB

Acceleration input

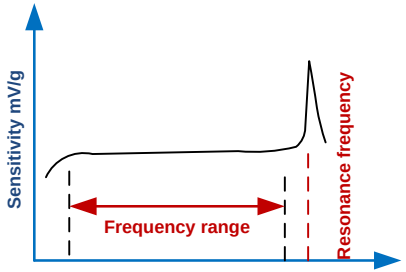


Sensitivity mV/g

Sensor output



Sensor frequency response



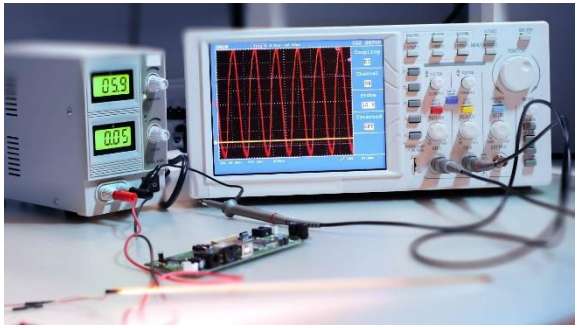
Condition monitoring applications

Automotive

Structural monitoring

Energy generation & transmission

Test and measurement



Industrial transportation

HVAC systems

4-ch synchronous vibration monitor front-end IEPE sensor interface

TIDA-010249

Design features

- 24-bits, 20 kHz BW IEPE sensor interface
- 4-channel simultaneous synchronized sampling
- Adjustable data rate 1 MSPS - 64 kSPS
  - Daisy-chain configuration up to 128 kSPS
  - Parallel configuration
    - 400 kSPS (wideband) 1 MSPS (sinc filter)
- Constant excitation current (~3.5 uA)
- ±10V AC input, 320 kΩ input impedance.
- Wire-break, and short-circuit detection

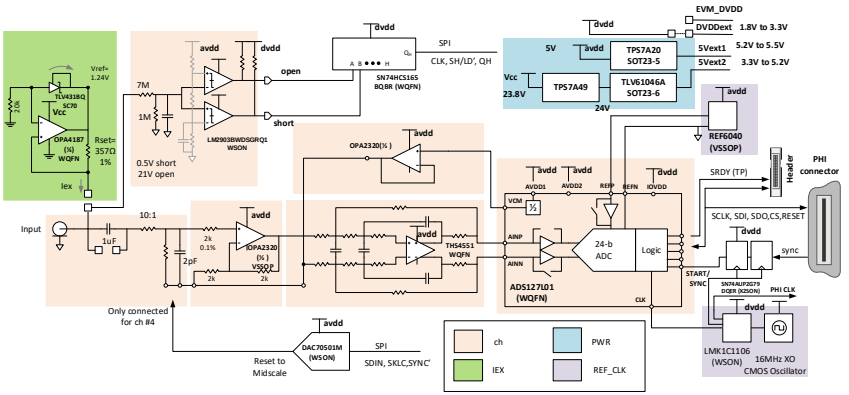
Tools and resources

Devices:

- ADS127L11
- THS4551
- OPA2320
- REF6040
- TLV431BQ
- DAC70501M

Design benefits

- High performance, low-cost IEPE interface
- On-board power solution, on-board variable current option
- On-board DC calibration path with 16b DAC
- Two board synchronization option
- DC coupling option for ch #4



ADS127L11

24-bit, 400-kSPS, low-power, wide-bandwidth delta-sigma ADC with input and ref buffers

Features

Resolution	24
# of Ch	1
Sample rate	400 kSPS (WB filter) 1.067 MSPS (LL filter)
Interface	SPI
AVDD	3 V (LP) to 5.5 V
IOVDD	1.65 V to 5.5 V
Input type	Differential
Temperature range	-40°C to +125°C
Package	3 mm x 3 mm QFN-20pin

High performance:
SNR: 109 dB @ 400 kSPS

Power scalable
High speed: 18.5 mW
Low speed: 3.3 mW

Integrated input buffers
Easy-drive inputs

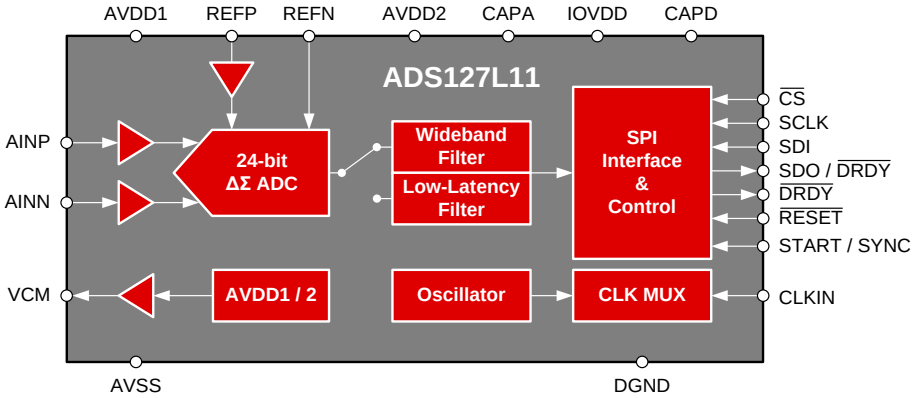
Daisy chain SPI
Multi-channel systems

Applications

- Vibration analysis
- Pressure sensors
- Ultrasonic sensors
- Acoustics / dynamic strain gauges
- Low power data acquisition
- High speed multi-channel PLC

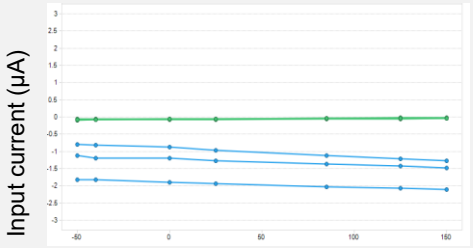
Benefits

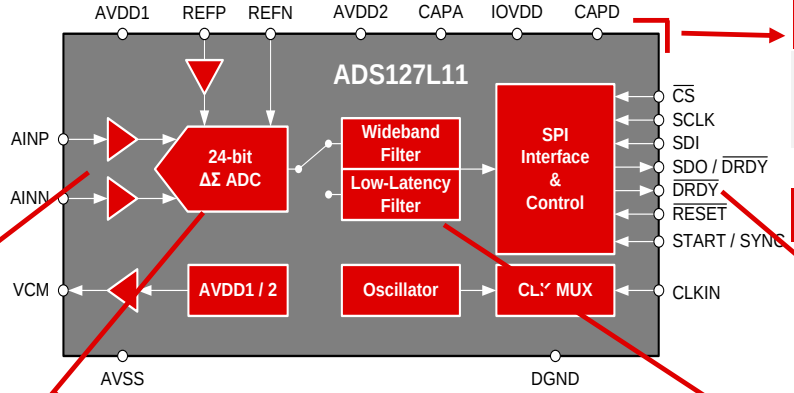
- Improved **dc and ac** performance increase system accuracy
- Optimized for **wide bandwidth or fast settling** with multiple filter options in the same ADC
- Design the ADS127L11 into **low power**, battery-operated systems without sacrificing resolution or accuracy
- Enable **input and reference pre-charge buffers** to reduce driver requirements and simplify design
- **Power scalable speed modes** optimize bandwidth and power



ADS127L11 | AC precision + DC accuracy

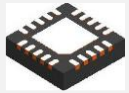
Easy-drive inputs



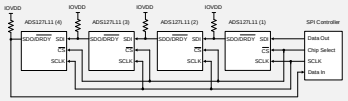


Ultra-small package

3 mm x 3 mm

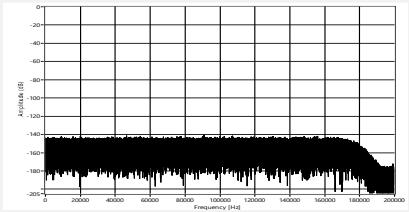


Daisy-chain SPI



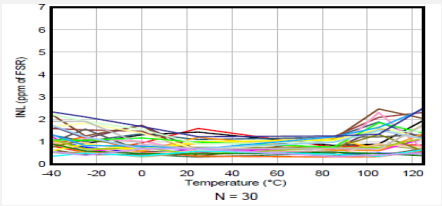
AC precision

111.5 dB dynamic range @ 200 kSPS
120 dB spurious-free dynamic range
-125 dB total harmonic distortion

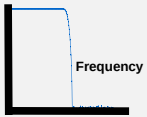


DC accuracy

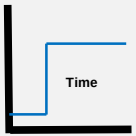
0.9 ppm INL
50 nV/°C offset drift
0.6 ppm/°C gain drift



Filter options



Wideband filter
165 kHz bandwidth



Low-latency filter
4.38 µs step response

ADS117L11

16-bit, 400-kSPS, low-power, wide-bandwidth delta-sigma ADC with input and ref buffers

Features

Resolution	16
# of Ch	1
Sample rate	400 kSPS (WB filter) 1 MSPS (LL filter)
Interface	SPI
AVDD	3 V (LP) to 5.5 V
IOVDD	1.65 V to 5.5 V
Input type	Differential
Temperature range	-40°C to +125°C
Package	3 mm x 3 mm QFN-20pin

High performance:
SNR: 98 dB @ 400 kSPS

Power scalable
High speed: 18.6 mW
Low speed: 3.3 mW

Integrated input buffers
Easy-drive inputs

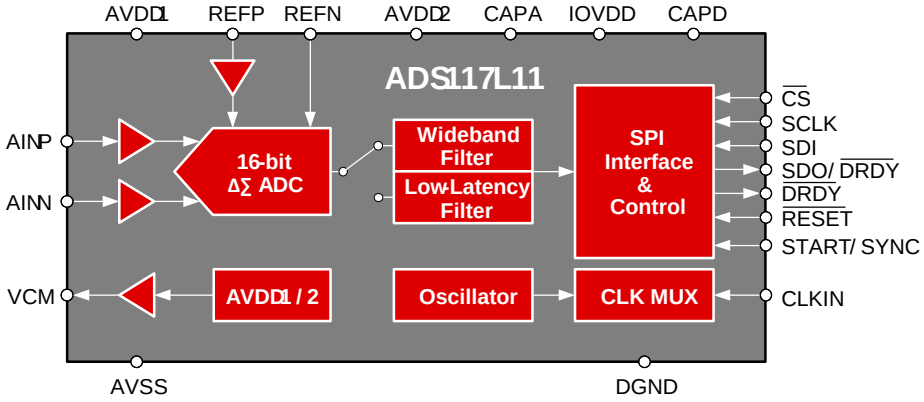
Daisy chain SPI
Multi-channel systems

Applications

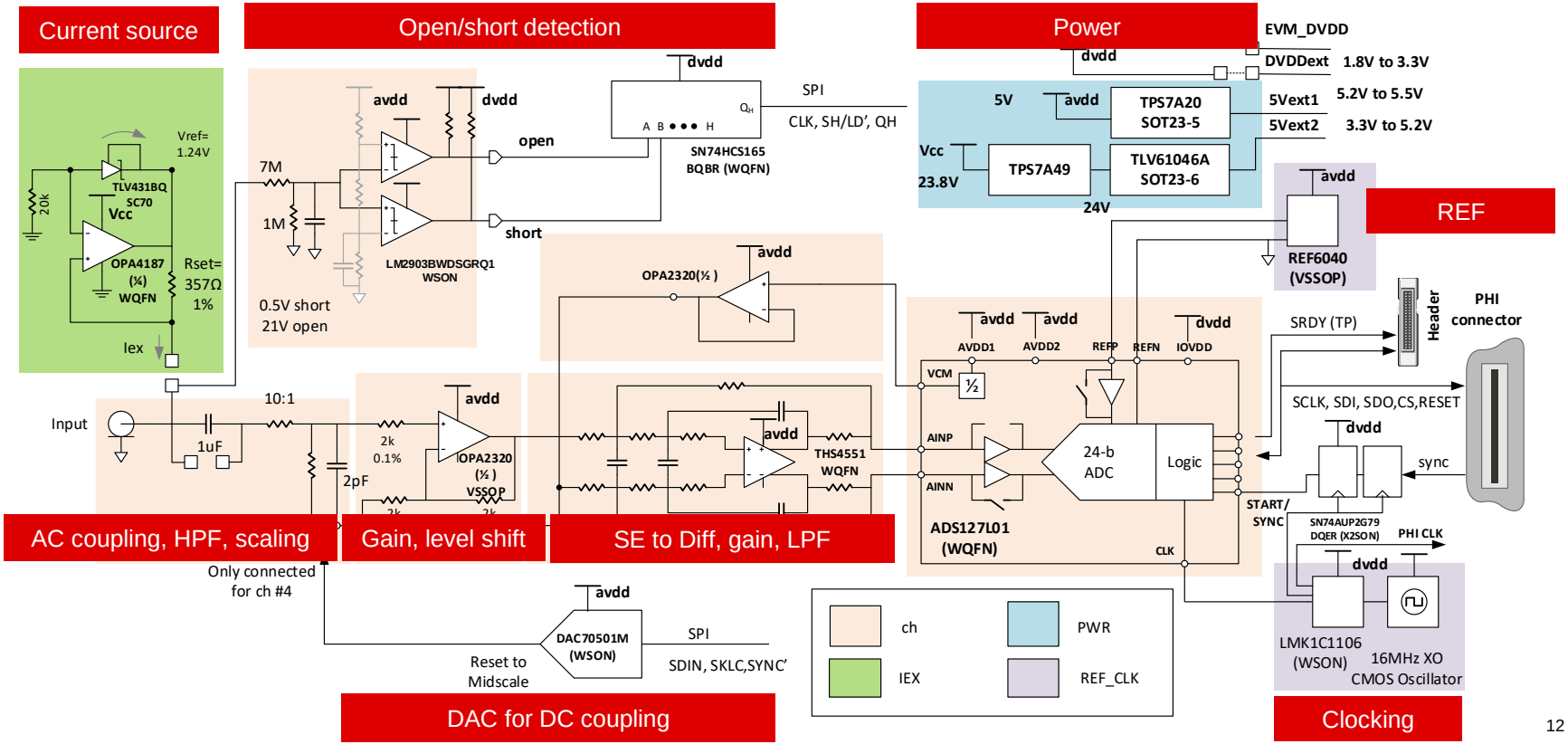
- Vibration analysis
- Pressure sensors
- Acoustics / dynamic strain gauges
- Low power data acquisition
- Analog input modules
- Pulse oximetry

Benefits

- Improved **dc and ac** performance increase system accuracy
- Optimized for **wide bandwidth or fast settling** with multiple filter options in the same ADC
- Design the ADS117L11 into **low power**, battery-operated systems without sacrificing resolution or accuracy
- Enable **input and reference pre-charge buffers** to reduce driver requirements and simplify design
- **Power scalable speed modes** optimize bandwidth and power

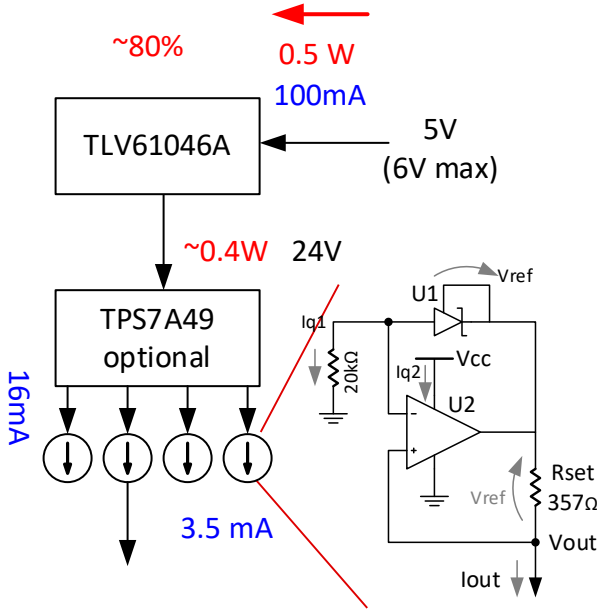


IEPE sensor block diagram

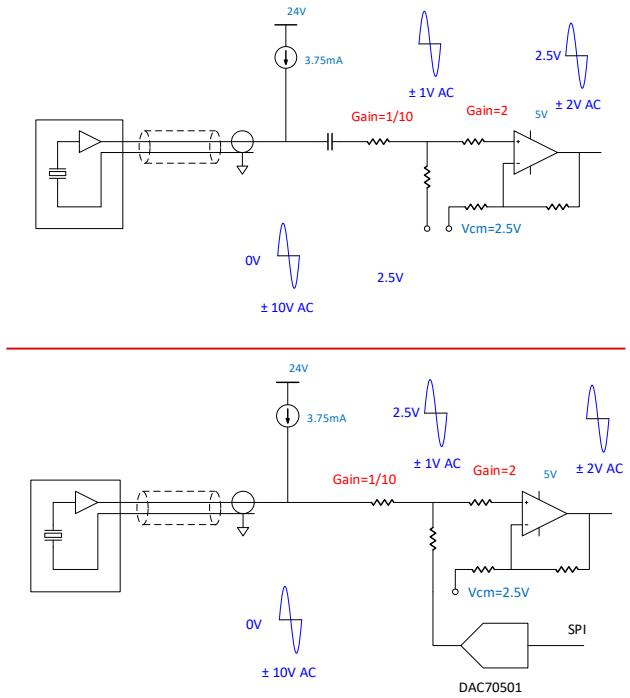


IEPE sensor design choices

High-side current source large compliance, low cost, high PSRR, low load regulation

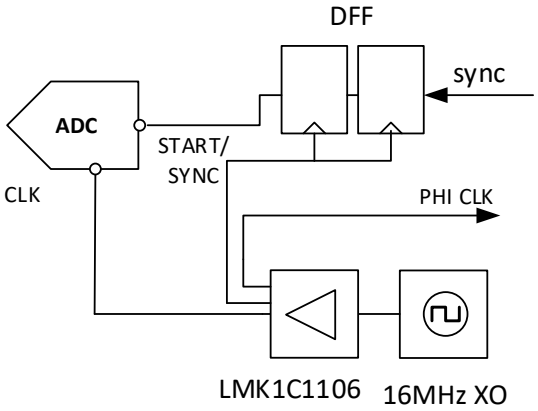


DC coupling, DC elimination



Ensure synchronization of 4-ch

- SPI is not based on CLK, gating of the sync/start signal with 16 M clock
- Buffering each ADC clock



IEPE sensor design choices

Supporting three modes:
Daisy-chain, parallel SDO, parallel SDO/SDI

- Assembly options with minimal changes

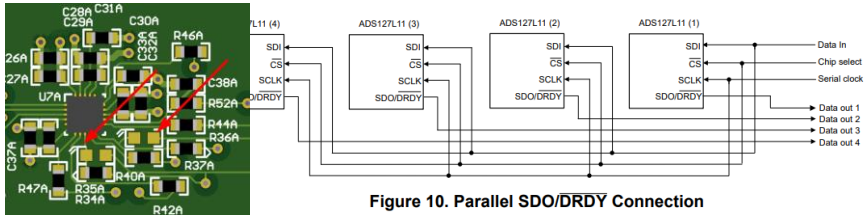
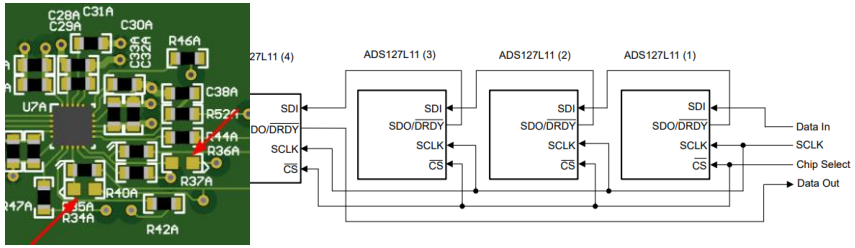
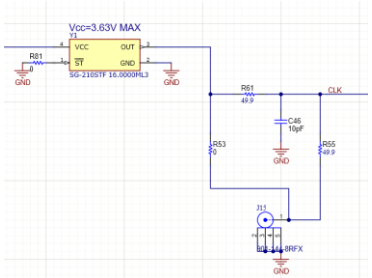


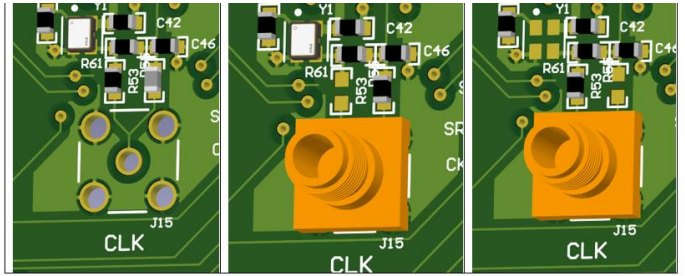
Figure 10. Parallel SDO/DRDY Connection



Supporting synchronization between two boards
(8 channels)

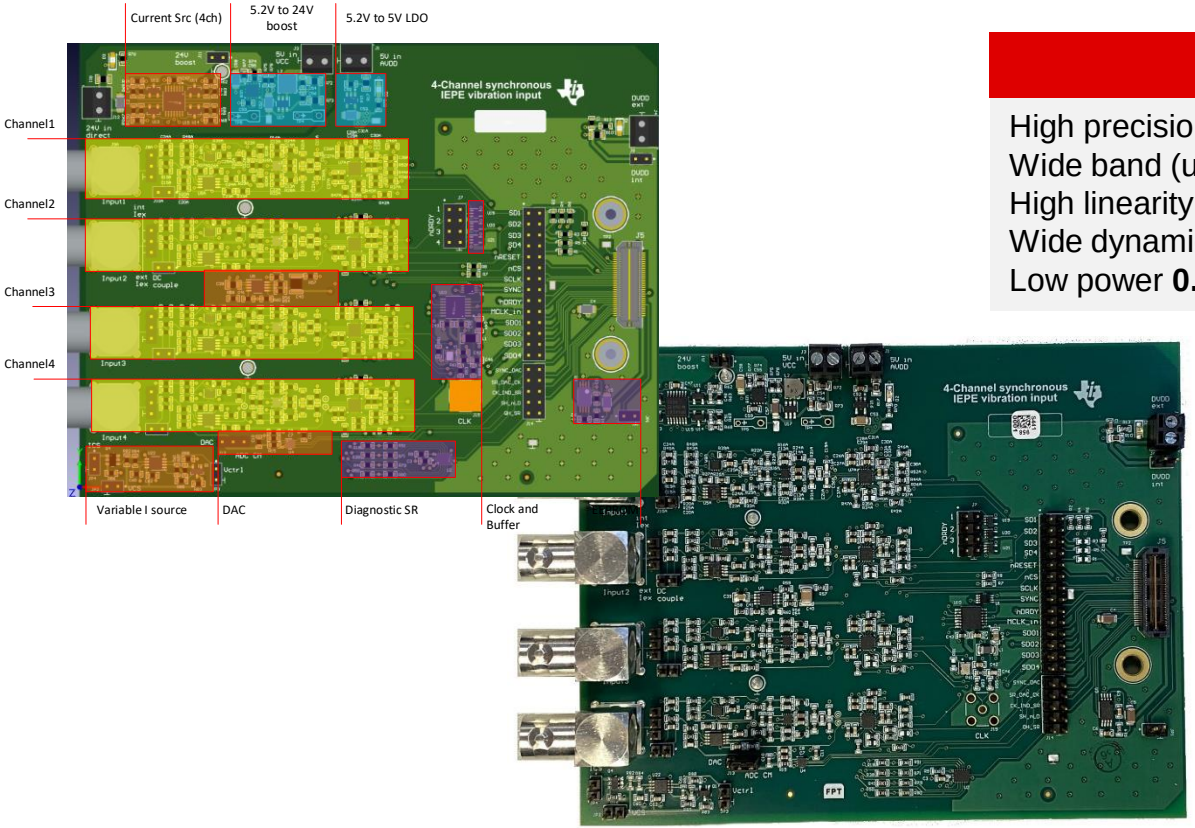
- Enabling clock in/out on SMA using assembly





On-board Output Input

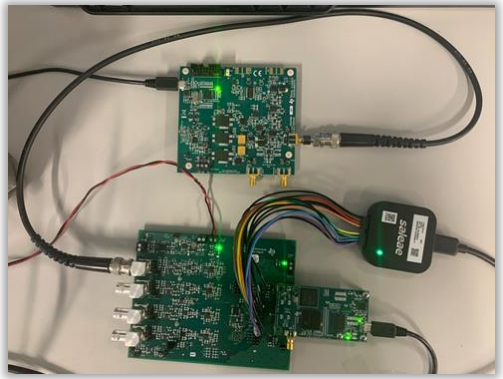
IEPE sensor PCB image



Performance

High precision **17 ENOBs**
Wide band (up to **200 kHz**)
High linearity **-97 dB**
Wide dynamic range **103 dB**
Low power **0.65 W**

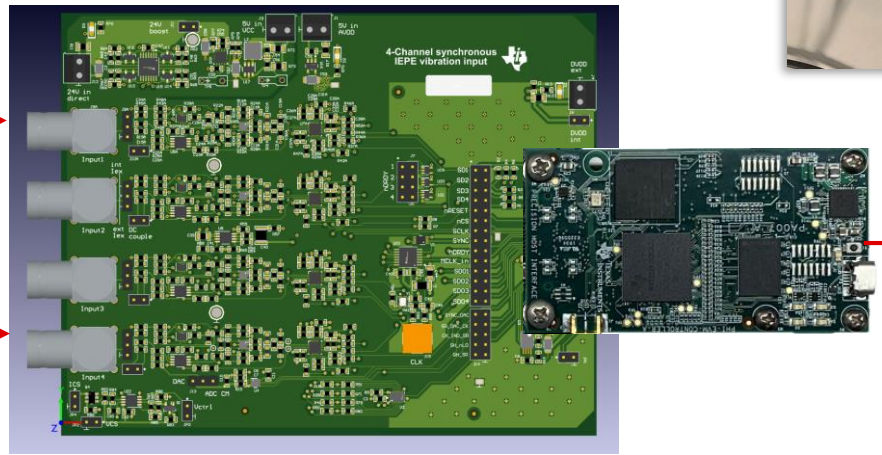
IEPE sensor test setup



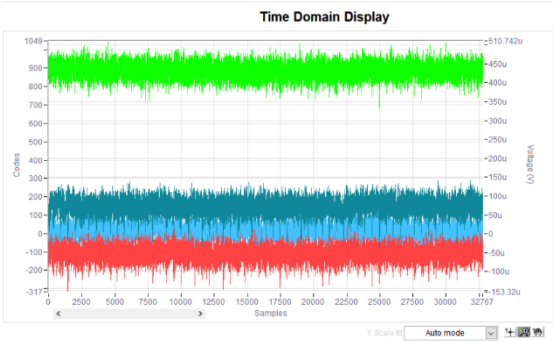
PSI

Agilent 33522A

IEPE simulator

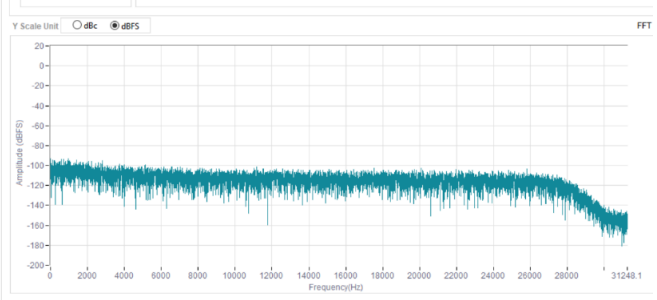


IEPE sensor performance plots (AFE+ADC) shorted input



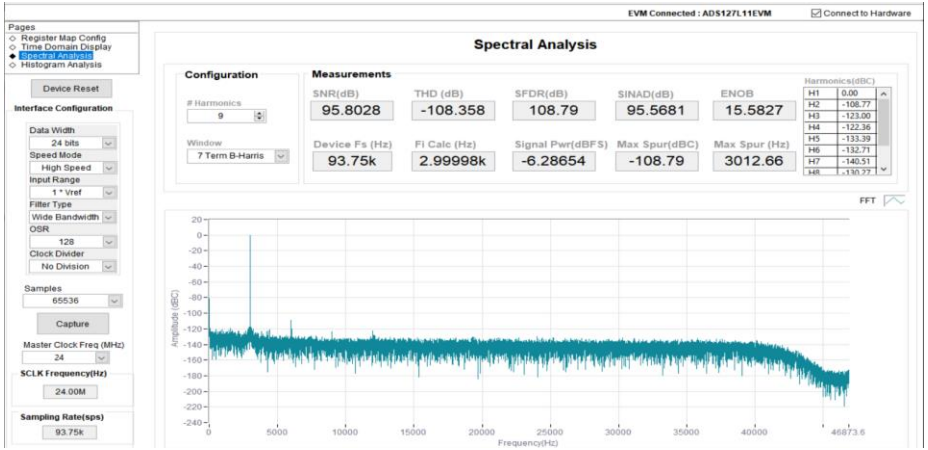
Measurements

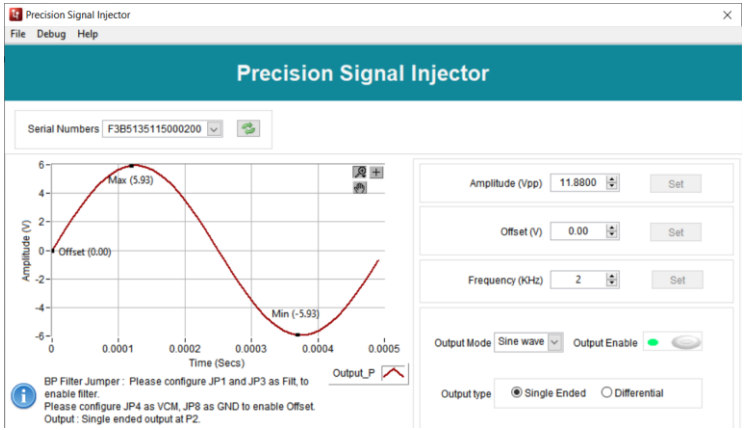
	Min (V)	Max (V)	Sigma (Vrms)	Mean (V)
CH 1	-40.039063u	142.089844u	18.553436u	72.74504u
CH 2	-153.320313u	22.949219u	18.123325u	-53.365558u
CH 3	333.496094u	510.742188u	18.269361u	433.396041u
CH 4	-83.496094u	79.589844u	18.292443u	5.964071u



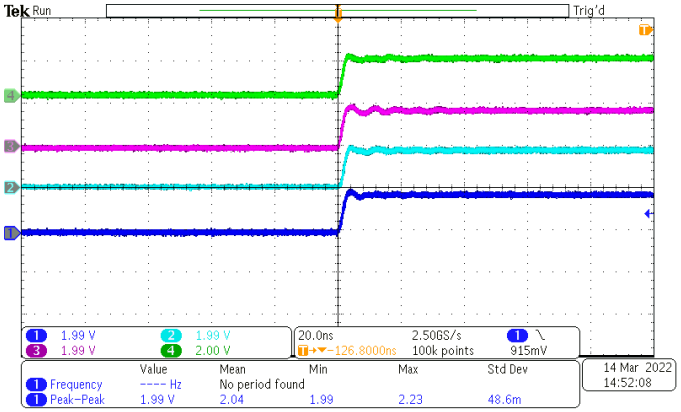
IEPE sensor THD, synch

- Signal source: TI's precision signal injector
  - 11.88 V @ 2 kHz
- Result:
  - THD= -105.9 dB @ -4.8 dB FS





ADC synchronization



IEPE sensor results summary

Parameter	Target Value	Unit
Number of Channels	4	
Input signal	Voltage	
Input terminals	Single-ended	
Coupling	AC (DC option)	
Input impedance	320	kΩ
Input Range	1.7V to 22.2V (+/-10V + 12V)	V
Abs max	23.8V	V
Input DC bias	12V nominal	V
Bandwidth	0.6-20000	Hz
Gain	0.4	V/V
Sampling Clock ferq.	16	MHz
SPI Cock frequency	16	MHz
Data rate	124 (wide, daisy), 400 (wide, parallel), 1000 (sinc, paralle)	kSPS/ch
Resolution	24	Bits
Noise	18.5 (only AFE+ADC) 19.8 (AFE+ADC+Simulator+CS)	uV
DR	103 (only AFE+ADC)	dB
Excitation current	3.45	mA
Excitation voltage	23.8	V
Excitation current load regulation	Max [@ 10V] 9.25 (0.26 %)	uA/V
Digital Supply	1.8-3.3	V
Diagnostic error level	Open (>20.1V), short (<0.5V), 1.5ms	
Current consumption	5.2V analog: 85 5.2V for 24V booster: 100 1.8V : 14	mA mA mA
THD	-97	dB
Cross-talk	-90	dB
Clock image rejection	-100	dB

Highlights

- 103 dB dynamic range
- 0.96 W power off 5.2 V (analog)
- 0.25 W power off 1.8 V (digital)
- 17b ENOBs over 20kHz (64 kSPS)
- 1.7 V - 22.2 V compliance range

Moving vibration data from edge to cloud

Vibration monitoring with edge AI processing

Features

4-channel IEPE vibration analog input module (TIDA-010249)

- 4x ΔΣ ADCs in parallel or daisy-chain configuration
- Max data rate: 124 kSPS (daisy chain) to 1 MSPS (parallel)
- SPI interface

Sensor board

- MCU: 4x R5F cores (@800 MHz) + 12x real-time cores (@333 MHz)
- SPE PHY w/ PoDL supporting cable reach beyond 2000 meters

Gateway

- MPU: 2x Cortex-A53 (@1 GHz) + 4x Cortex-R5F (@800 MHz)
- 5x Gb industrial Ethernet ports
- Linux or RTOS

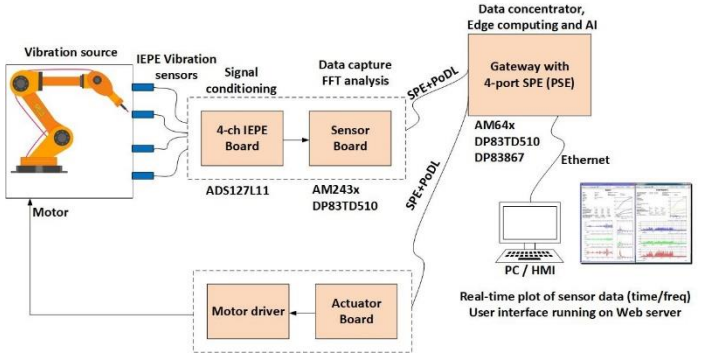
Tools and resources

- ADS127L11 (ΔΣ ADC)
- AM2434 (MCU)
- AM6422 (MPU)
- DP83TD510E (SPE PHY)
- AM243x RTOS + AM64x Linux SDK
- TIDA-010249

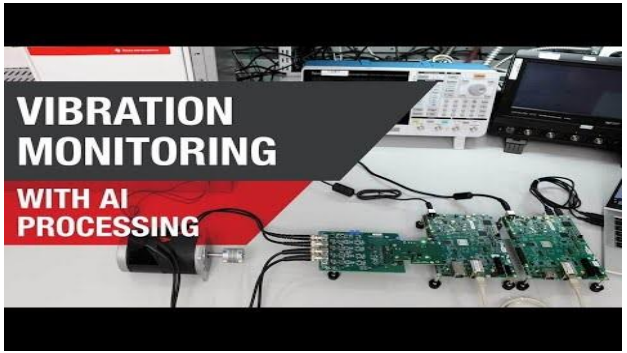
Applications

- PLC, DCS analog, and mixed input module
- Analog signal conditioner/transmitter
- Data acquisition and measurement systems

Simplified block diagram



Demo video Demo blog post



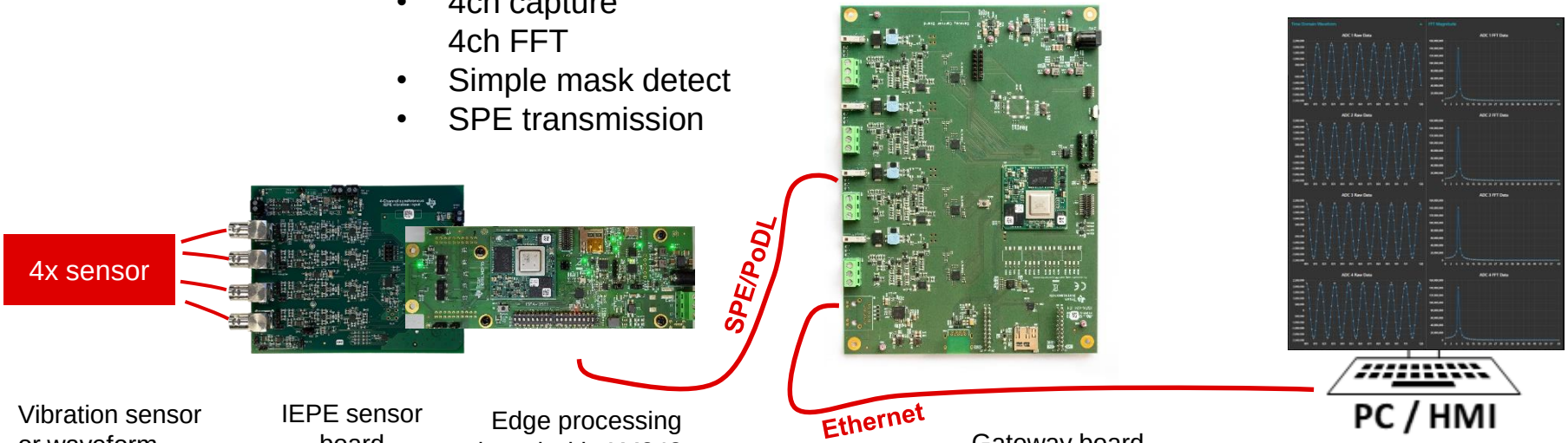
Vibration monitoring with edge AI processing system demo

Gateway:

- Data concentration
  Webserver
- Ethernet or WiFi comm.

Edge processing:

- 4ch capture
  4ch FFT
- Simple mask detect
- SPE transmission



Vibration sensor or waveform generator

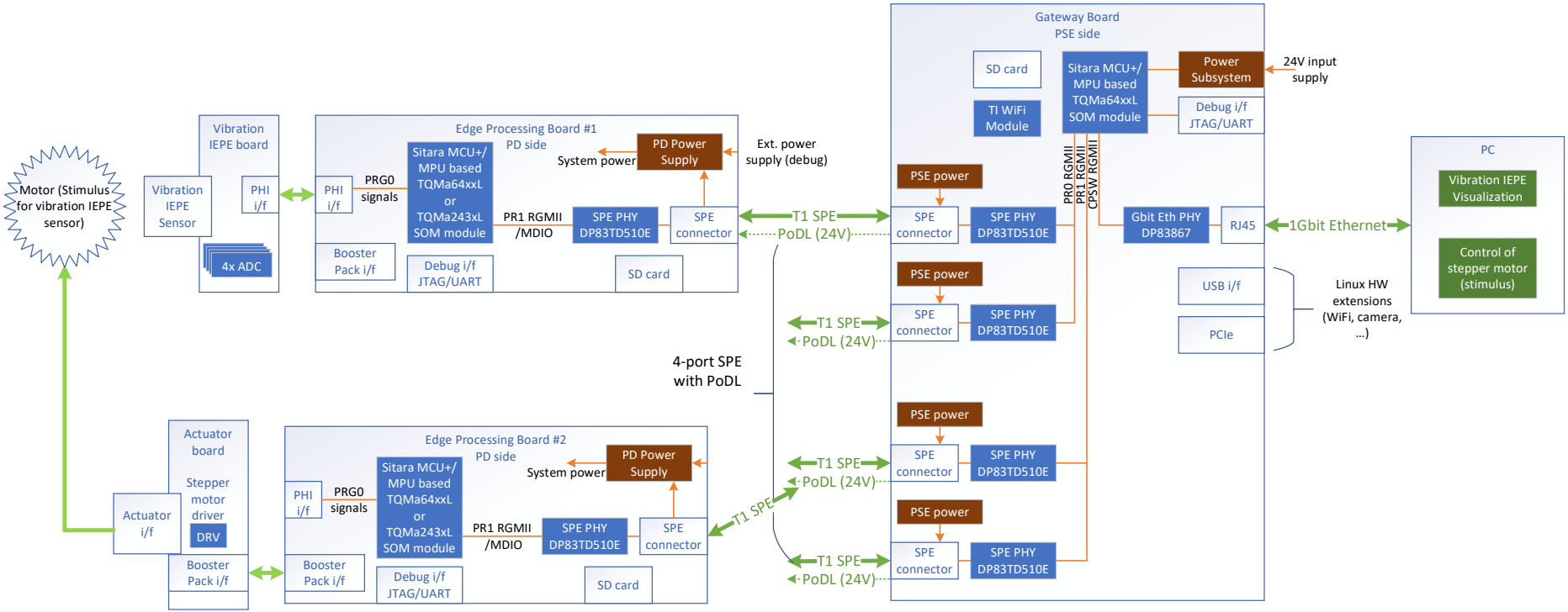
IEPE sensor board TIDA-010249

Edge processing board with AM243x

Gateway board with AM64x

Laptop

Vibration monitoring with edge AI processing demonstrator (detailed)



Gateway board and edge processing board

24V board power supply

AM64xx SOM from TQ

LP i/f for WiFi

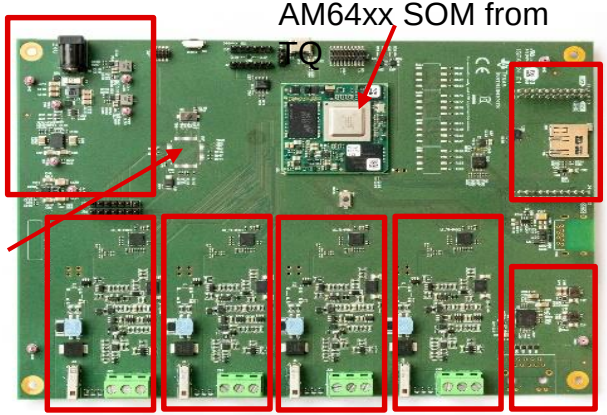
SD card i/f

MSPM0 PoDL PSE controller

USB3

1Gbit Ethernet

4x 10Mbit T1 + PoDL PSE ports



AM64xx SOM from TQ

SD card

Isolated debug UART

ADC-PHI-PRU-EVM
PHI connector on bottom

10BASE-T1L SPE with Power over Datalines (PoDL)

10BASE-T1L Phy DP83TD510E

Getting started

You can start evaluating this device leveraging the following:

Content type	Content title	Link to content or more details
Reference design	Four-channel synchronous vibration sensor interface reference design	https://www.ti.com/tool/TIDA-010249
Design Guide	Four-channel vibration sensor design guide	http://www.ti.com/lit/pdf/tiduf13
Product Folder	ADS127L11	https://www.ti.com/product/ADS127L11
Evaluation Module	Precision signal injector (PSI) evaluation module	https://www.ti.com/tool/PSIEVM

Visit www.ti.com/npu

For more information on the New Product Update series, calendar and archived recordings

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