Welcome!
Texas Instruments New Product Update

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

New Product Update
Precision Amplifiers

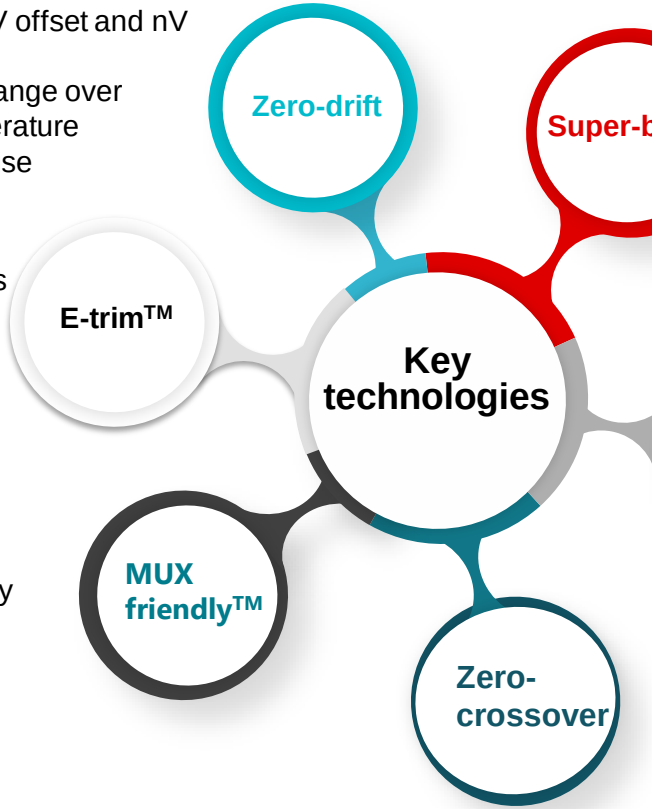
Soufiane Bendaoud

02/25/2021

Agenda

- Precision amplifiers products key market segments and top sectors
- Precision amplifiers technologies and key products
- Precision amplifiers use cases and application examples
  - Examples of product positioning with features and benefits

Precision amplifiers industry-leading technologies



- Enables µV offset and nV drift
- No Vos change over time/temperature
- No (1/f) noise

- Low IB
- Ultra low current noise
- Higher Zin

- Eliminates parameter shifts
- Sub 25µV offset without calibration
- Allows miniature package sizes

- Buried layer
- Low distortion
- High Zin
- Low 1/f corner

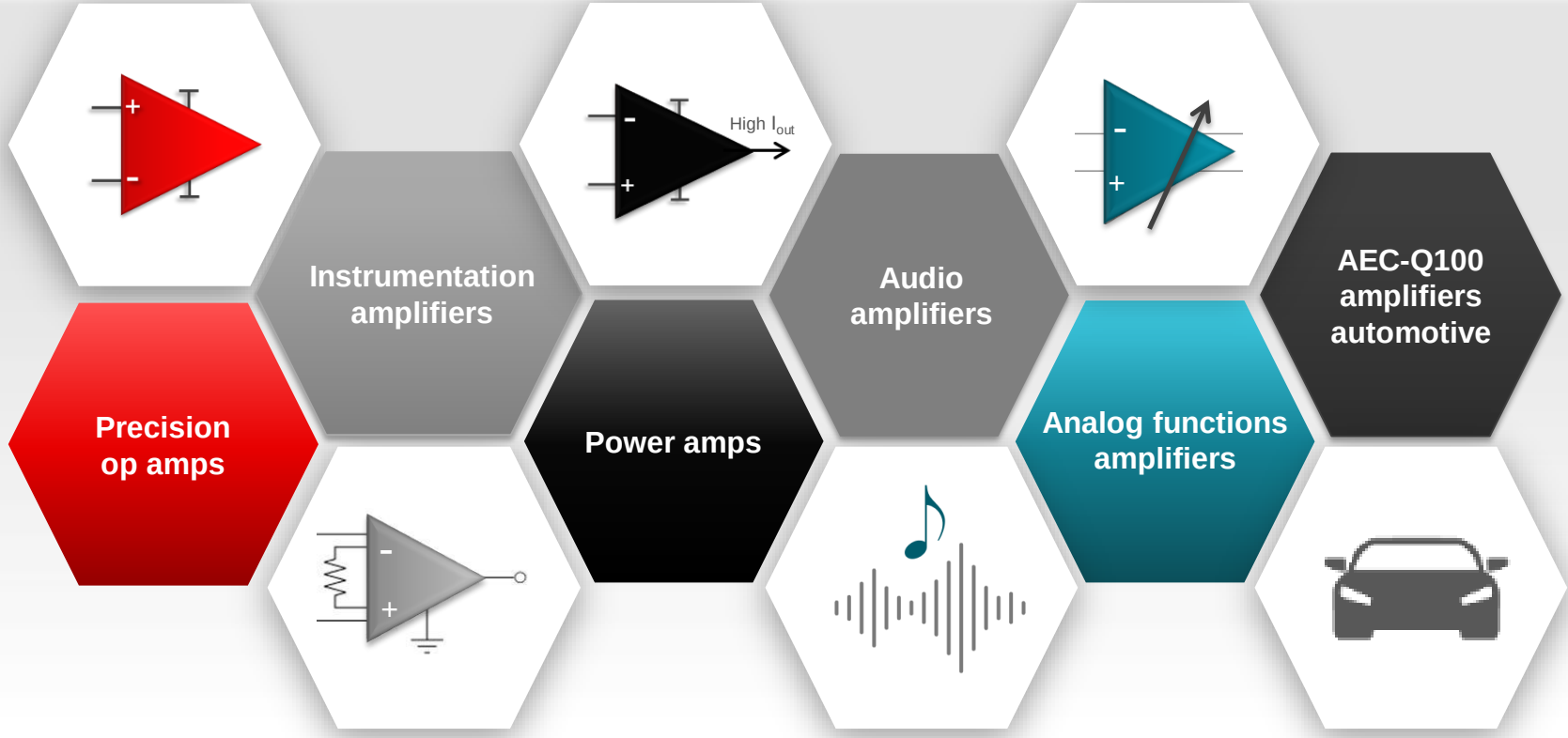
- True high-impedance differential input capability
- Fast-settling time
- No input diodes

- Ultra-high input linearity
- No input crossover distortion
- No dead band
- No transition

Amplifiers for any system

From ultra-high performance to cost-optimized

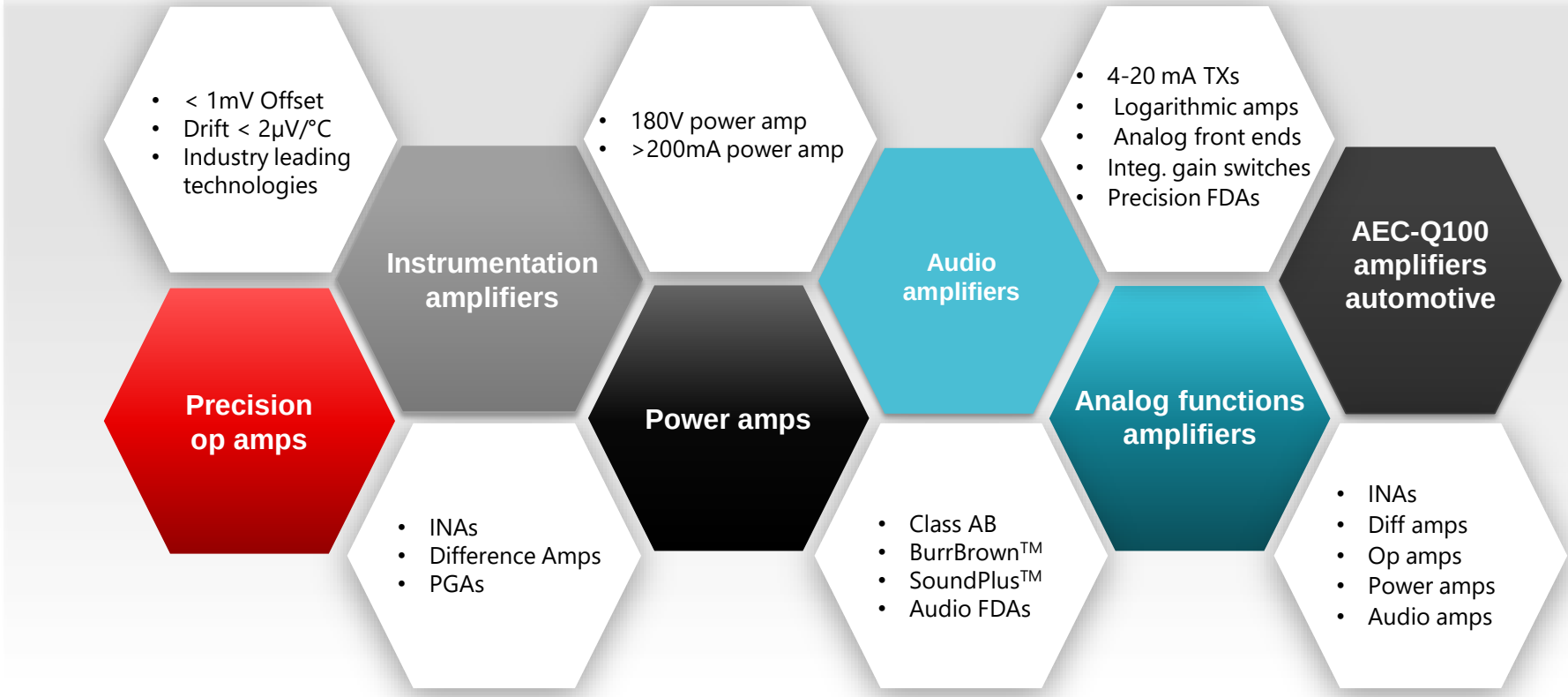
Options for industrial & auto



Amplifiers for any system

From ultra-high performance to cost-optimized

Options for industrial & auto



Precision amplifiers key markets

Industrial and automotive are top key markets for precision amplifiers

- Industrial
- Automotive
- Personal electronics
- Communications equipment
- Enterprise systems

Industrial

Automotive

Precision amplifiers delivers

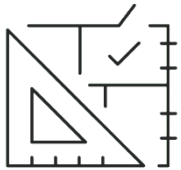
Broad and diverse product portfolio with **1,500+ products**

Industrial solutions, including high precision (low offset & long-term stability) and high voltage

Automotive-qualified products, enabling the future of automotive design

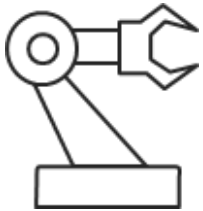
Precision amplifiers applications focus

Test & measurement



- Battery Test Equipment
- DAQ
- Weigh Scales
- Memory and Semiconductor Test Equipment
- Lab Instrumentation

Factory automation

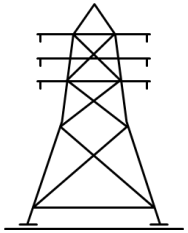


- Analog Input Modules
- Analog Output Modules
- Pressure Transmitters
- Flow Transmitter
- Position Sensor

Medical

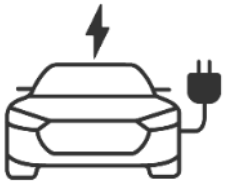
- Patient Monitoring
- ECG / EKG
- Ultrasound Scanners
- Surgical Equipment
- Infusion Pumps

Grid infrastructure



- Ckt Breakers
- String Inverters
- E-meters
- Analog I/O Modules
- Substation Automations

HEV/EV & PT



- Inverter and Motor Control
- DC-DC
- OBC
- BMS
- EPS
- Powertrain Sensors

New products update, technologies & end equipment use cases

Zero-drift technology overview

Differentiation

- Best in class DC performance
- No 1/f noise
- First in industry
  - Wide BW zero-drift op amps (OPA388/OPA189)
  - Zero Drift INA (INA188)

System benefits

- Eliminates calibration
- Very low p-p noise for higher resolution
- Allows for very high gain circuits
- Reduces errors due to Aol, CMRR and PSRR

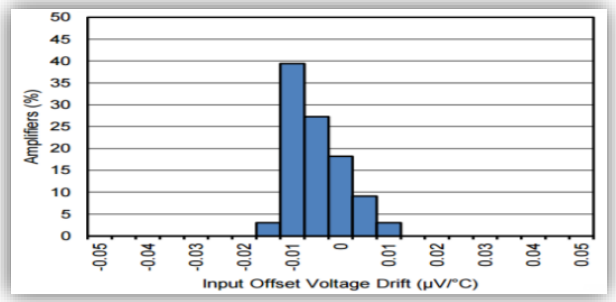
Product examples

Specifications	Zero drift OPA189	E-trim OPA192
Input Offset (µV) (Typ, Max)	3	25
Input Offset Drift (µV/°C) (Max)	0.02	0.5

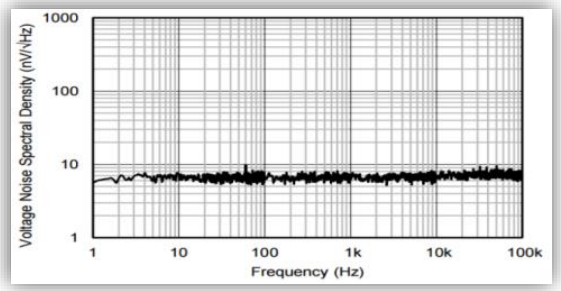
Specifications	Zero drift OPA388	E-trim OPA376
Input Offset (µV) (Typ, Max)	5	25
Input Offset Drift (µV/°C) (Max)	0.05	0.5

DC and AC performance for precision measurements

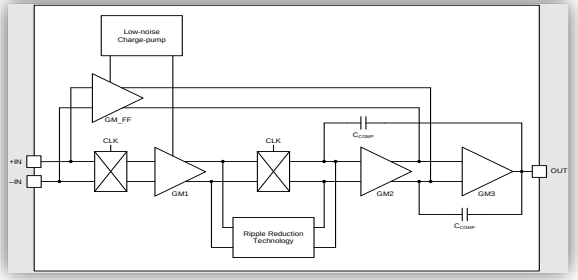
Vos distribution



No 1/f



Simplified topology



TI's high voltage zero-drift op amps family

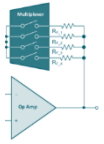
Features

- **Industry's lowest offset drift op amps**
  - OPAx182: **45%** lower drift vs competition
- **24 V Zero-drift amp with RRIO**
  - TLVx186: only one in its class with RRIO

- **Wide gain-bandwidth options:** 0.55 – **14MHz**
  - Wideband operation enables fast settling and increased throughput in multiplexed / multi-channel systems

- **Low power options for portable applications**
  - Reduce system power without compromising performance: TLVx186 (**90µA**) & OPAx187 (**100µA**)

- **p2p package family options**
  - **Single**: SOIC-8, VSSOP-8, SOT-23-5
  - **Dual**: SOIC-8, VSSOP-8
  - **Quad**: SOIC-14, TSSOP-14, WQFN-16



- **MUX-Friendly Inputs**
  - OPAx189, OPAx182, TLV2186

Device	Supply voltage (V)	Bandwidth (MHz)	Vos (µV)(max)	Vdrift (µV/°C) (max)	Iq (mA) (typ)
OPAx189	4.5-36	14	3	0.050	1.3
OPAx182 NEW!	4.0-36	5	4	0.012	0.85
OPAx188	4.0-36	2	25	0.085	0.385
OPAx180	4.0-36	2	75	0.350	0.45
TLVx186 NEW!!	4.5-24	0.75	250	0.100	0.09
OPAx187	4.5-36	0.55	10	0.015	0.10

Applications

- Weigh scales
- Test equipment
- Medical instrumentation
- Precision multichannel systems
- Field transmitters
- Sensor interfaces (infrared, bridge, thermopile)

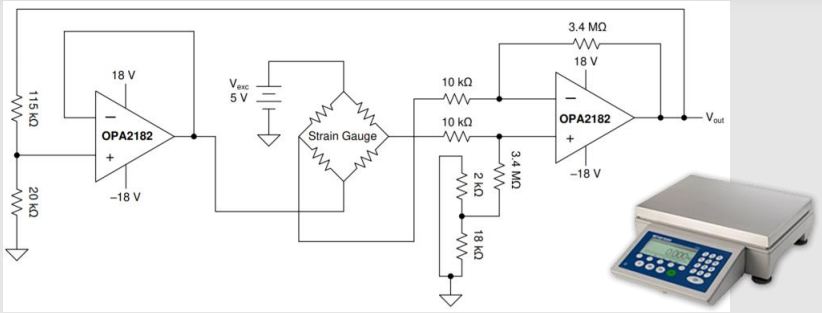
OPA2182 Overview

Industry's highest precision, high voltage zero-drift amplifier

EE - TI.com subsystem

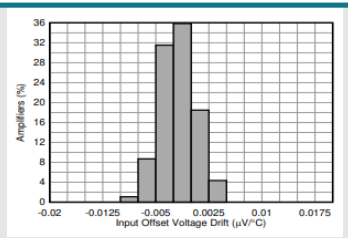
- **Weight scale** – voltage reference buffer & difference amplification of the voltage across the bridge (i.e. pressure)
- **Battery test** - Voltage measurement for DUT driver & calibration ref buffer
- **DC power supply** - Precision DAC gain and output voltage sensing
- **Analog input module** - Input buffer/ADC driver, reference driver
- **Mixed module** - Input buffer/ADC driver, reference driver
- **Semiconductor test** - Voltage measurement for DUT driver and ref driver

EE example: Weigh scale
Subsystem: Voltage reference buffer & difference amp

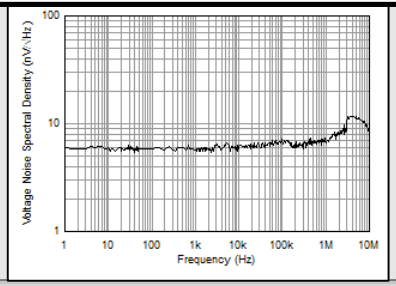


Problems solved

Lowest offset drift in the industry increases accuracy across operating temperature range and relaxes calibration



Flat voltage noise at DC and through a wide frequency range enables higher system SNR



Top competitors

Specifications	OPA2182	ADA4522-2	MAX44246
GBW (MHz)	5	2.7	5
Slew Rate (V/us)	10	1.7	3.8
Vos max (uV)	4	5	5
Drift max (uV/C)	0.012	0.022	0.02
Iq typ (mA)	0.81	0.83	0.55
Vn (nV/rtHz)	5.7	5.8	9
Ibias max (pA)	350	300	600

OPAx182- Industry's lowest offset drift op amp

CMOS, ultra-high precision, fast settling, low noise, RRO

Features

- Input stage offset voltage: **3.5 µV** (max)
- Offset voltage drift: **0.02 µV/°C** (max)
- Gain bandwidth: **5 MHz**
- Slew rate: **10 V/µs**
- Fast settling **10-V 0.01% in 1.7 µs**
- Input stage voltage noise: **5.7 nV/√Hz** at 1kHz
- 0.1-Hz to 10-Hz noise: **0.12 µVpp**
- Quiescent current: **0.85 mA** (typ,/ch)
- Supply range: **4.5V to 36V**
- **MUX-Friendly and RFI/EMI filtered Inputs**

Packages**: (Released / Sampling / Preview) :**

OPA2182 (SOIC-8, VSSOP-8)

OPA182 (SOIC-8, SOT23-5, VSSOP-8) | OPA4182 (TSSOP-14, SOIC-14)

Applications

- Battery test
- DC power supply
- Analog input module
- Weight scale
- Semiconductor test
- Mixed modules

Benefits

- **Zero-drift** architecture provides ultra-low input offset voltage and near-zero input offset voltage drift over the entire industrial temperature range avoiding the need of calibration
- **Low broadband noise** and **zero flicker noise** enable maximum signal integrity through the signal chain
- **Rail-to-rail output** enables sensing of signals close to supply/ground and maximizes the dynamic range and improved SNR of the signal chain
- **Wide supply range** allows maximum versatility of industrial rails
- **MUX-friendly input** prevents inrush current when applying large input differential voltages which improves settling performance

Specifications	OPA2182	ADA4522-2	MAX44246
GBW (MHz)	5	2.7	5
Slew rate (V/us)	10	1.7	3.8
Vos max (uV)	4	5	5
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Iq typ (mA)	0.81	0.83	0.55
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Ibias max (pA)	350	300	600

45% lower drift vs competition !!

TI's low voltage zero-drift op amps family

Features

OPA388: First and only zero-drift and zero-crossover op amp & now Q-100 Qualified!

- Ultra **low offset and drift**
  - Removes need for calibration and increases DC precision

- **Wide-bandwidth operation: up to 10MHz**
  - Enables high gain configurations
  - Ability to support equipment from precision weigh scales to heart-rate monitors

- **Low power options for portable applications**
  - LPV821 (**650nA**)
  - TLVx333 (**17µA**)

- **p2p package family options***
  - **Single**: SOIC-8, VSSOP-8, SOT-23-5, SC70-5
  - **Dual**: SOIC-8, VSSOP-8, SON-8, WSON-8
  - **Quad**: SOIC-14, TSSOP-14, RUM-16, VQFN-14

Device	Supply Voltage (V)	Bandwidth (MHz)	Vos (µV) (max)	Vdrift (µV/°C) (typ)	Iq (mA) (typ)	Ibias (pA) (max)
OPA2387 NEW!!	1.7	5.7	2	0.003	0.57	135
OPAx388	2.5-5.5	10	5	0.005	1.7	350
OPAx333	1.8-5.5	0.35	10	0.02	0.017	200
OPAx330	1.8-5.5	0.35	50	0.02	0.021	500
LPV821	1.7-3.6	0.008	10	0.02	0.00065	--
OPAx335	2.7-5.5	2	5	0.02	0.285	200
LMP2021	2.2-5.5	5	5	0.004	0.95	100
OPA2333P	1.8-5.5	0.35	10	0.02	0.017	200

Applications

- IR sensors
- Medical instrumentation
- Temperature measurements
- Precision sensor applications
- Battery-powered instruments
- Current sensing

*Not all devices listed have all of the package options, refer to the device ds for specific package types

Precision amplifiers in IR thermometers

Key amplifier care specs & key devices

- **Low Offset & Zero drift:** minimize temperature detection errors
- **Fast settling time:** help minimize the number of samples required to achieve a specific temperature resolution ***(faster measurement)***
- **Low voltage operation & low power:** handheld/battery power

Key Devices

Higher precision, faster settling time, lower noise: **OPAx388, OPAx387**

Lower cost, lower power option: **TLVx333**

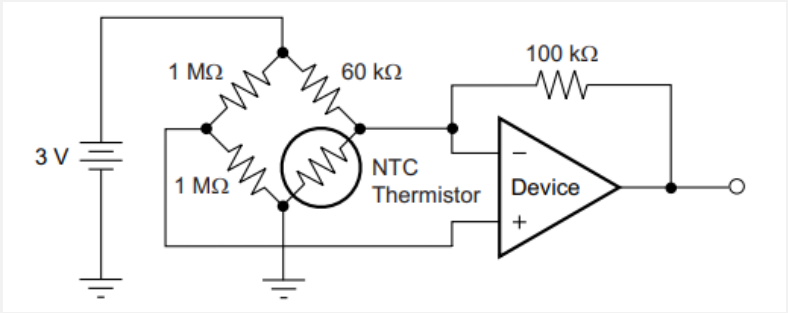
How to WIN collateral, tools & PL contacts

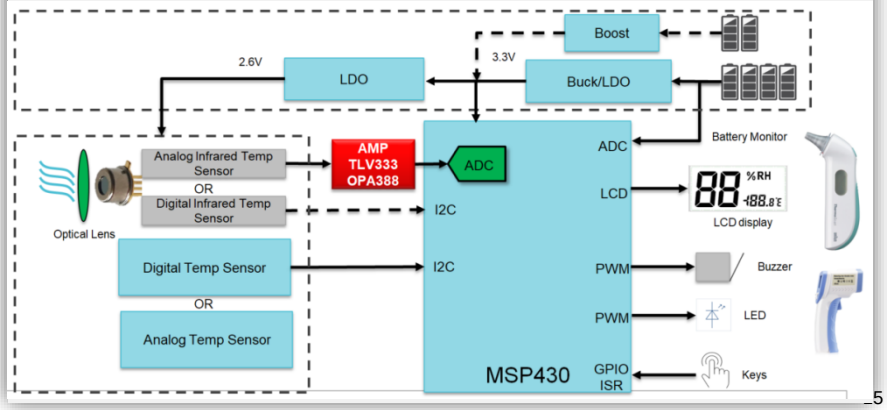
- **Blog:** How to design and infrared thermometer quickly
- **OPA388 product folder**
- **TLV333 product folder**

NEW!

- **OPA387 product folder**

Subsystem: Thermistor measurement





e-Trim™ technology overview

Differentiation

- Post assembly trim
- No Vos shift due to packaging stress
- No Vos, TCVos shift
- Low offset without self-calibration

System benefits

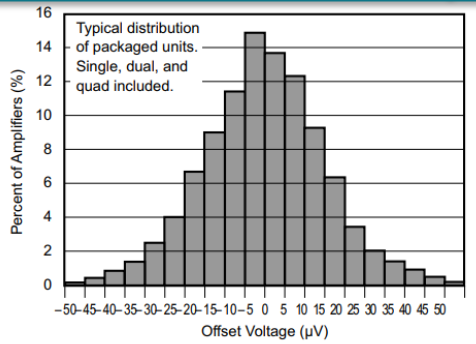
- Stable Vos over CM
- Allows miniature package size
- Better long-term stability
- Versatile application use cases

Product examples

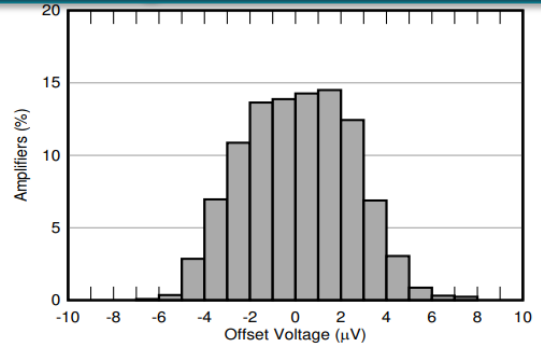
Specifications	E-Trim OPA392	Laser trim OPA320
Input Offset (µV) (Typ, Max)	7, 25	40, 150
Input Offset Drift (µV/°C) (Typ, Max)	0.1, 0.6	1.5, 5

Specifications	E-Trim OPA2205	Laser trim OPA2277A
Input Offset (µV) (Typ, Max)	5, 25	35, 100
Input Offset Drift (µV/°C) (Typ, Max)	0.1, 0.3	0.15, 1

Input offset digital trimming



OPA2277 Laser-trimmed operational amplifier offset voltage distribution

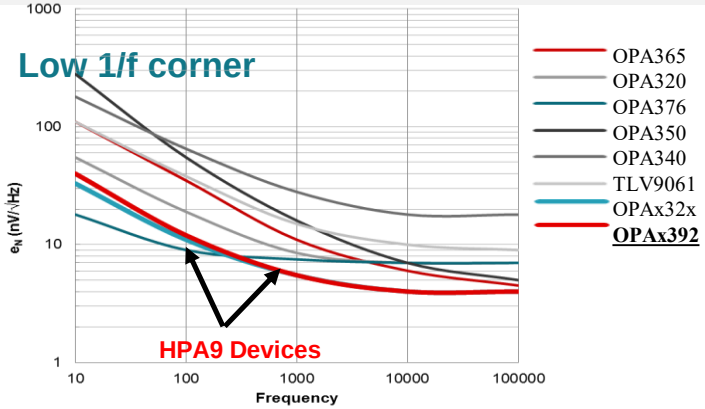


OPA2205 e-trim™ operational amplifier offset voltage distribution

OPAx39x: TI's low voltage e-trim™ op amps family

Features

- **True-RRIO** allows for use of the full dynamic range
- **Lowest offset linear amp:** 25uV of max offset (OPAx392)
- **Low input bias current** provide low noise with high impedance sensor interface
- **e-Trim™** - no parameter shifts due to packaging stress
- **Highest speed to power ratio** in its class



	Low Iq: 30uA	Low Bias: 0.8pA
Specifications	OPA391	OPA392
Vos (max)	45 µV	10 µV
Vos Drift (typ)	1 µV/°C	0.1 µV/°C
Ibias (max)	0.8 pA	0.8 pA
Voltage noise (1kHz)	60 nV/√Hz	6 nV/√Hz
1/f Noise	0.9 µVp-p	1.7 µVp-p
GBW (G=1)	1 MHz	13 MHz
I_Q (max)	30 µA	1.4 mA
Price (1K) (Single)	$0.83	$0.92

OPA391 applications

- Blood Glucose Monitors
- Portable electronics
- Flow transmitters
- Process automation
- Process control
- Medical Instrumentation

OPA392 applications

- ECG
- Multiparameter Patient Monitor
- Optical Modules
- Pulse Oximeter
- Medical Instrumentation
- Low Power Instrumentation
- Analog Input Modules

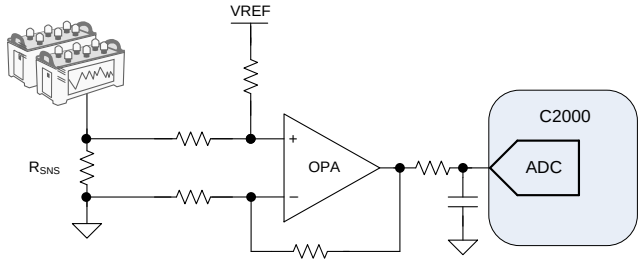
TI TechNotes *Offset Correction Methods: Laser Trim, e-Trim ™, and Chopper*

OPAx392- 5.5V e-Trim op-amp (0.8pA max)

High precision, low power, low IB, RRIO, WCSP (small packages)

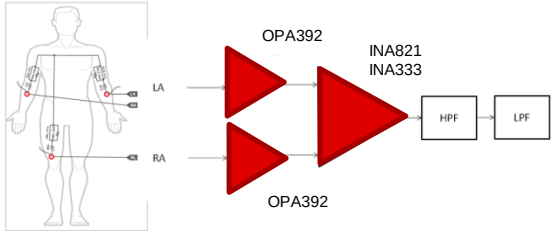
EEs: Merchant DC/DC & server PSU

Precision, Bi-directional current measurement



EEs: Patient monitoring

Pace detection circuit



	Low Bias: 0.8pA
Specifications	OPA392
Vos (max)	10 µV
Vos Drift (typ)	0.1 µV/°C
Ibias (max)	0.8 pA
Voltage noise	6 nV/√Hz
1/f Noise	1.7 µVp-p
GBW (G=1)	13 MHz
I_Q (max)	1.4 mA
Price (1K) (Single)	$0.92

OPA392 applications

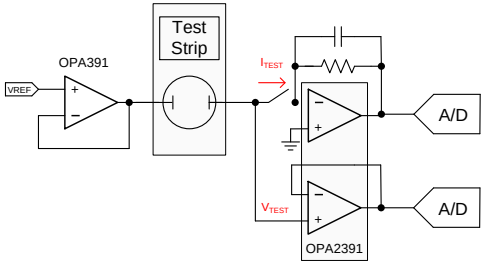
- ECG
- Multiparameter patient monitor
- Optical modules
- Pulse oximeter
- Medical instrumentation
- Low power instrumentation
- Analog input modules

OPAx391- 5.5V e-trim op-amp (22µA max)

High precision, low power, low IB, RRIO

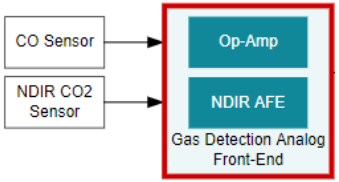
EE: Blood glucose

Transimpedance Amplifier (TIA)



EE: Gas meters

Sensor signal conditioning



	Low Iq: 30uA
Specifications	OPA391
Vos (max)	45 µV
Vos Drift (typ)	1 µV/°C
Ibias (max)	0.8 pA
Voltage noise	60 nV/√Hz
1/f Noise	0.9 µVp-p
GBW (G=1)	1 MHz
I_Q (max)	30 µA
Price (1K) (Single)	$0.83

OPA391 applications

- Blood glucose monitors
- Portable electronics
- Flow transmitters
- Process automation
- Process control
- Medical instrumentation

Super beta technology overview

Differentiation

- Lower Ib
  - Lower current noise
  - Higher Zin
- Better transistor matching
  - Lower Vos

System benefits

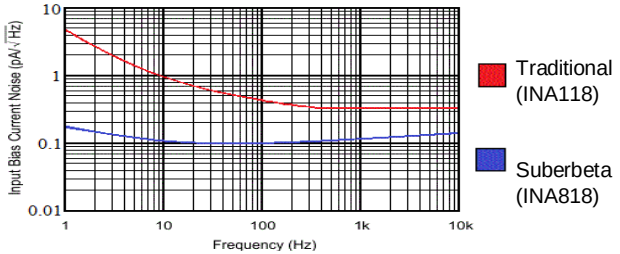
- Enables higher system accuracy
- Versatile use cases
  - Ideal for interfacing with high source impedances
- Maintains signal integrity

Product examples

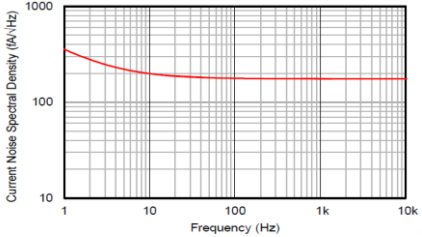
	Device		I_B (nA)	V_{os} (µV)	V_{os} Drift (µV/°C)
Op Amps	OPA2210 Superbeta	max	±2	35	0.6
	OPA2209 Traditional	max	±4.5	150	3
INAs	INA818 Superbeta	max	±0.5	35	0.5
	INA118 Traditional	max	±5	50	1

Improving industry standard

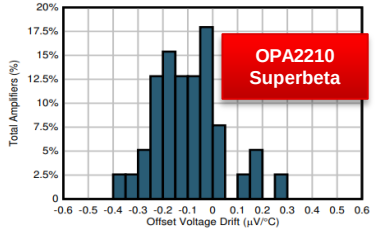
Superbeta vs. Traditional BJT
Ib Comparison

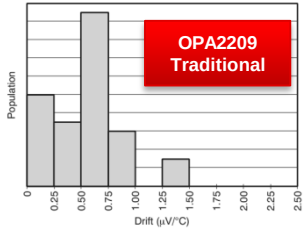


Lower current noise



Superbeta vs. Traditional BJT
Offset Voltage Drift Production Distribution





Precision instrumentation amplifiers
with super beta Inputs

Specifications	INA818/ INA819	INA821	INA828	INA848	INA849
Vos (µV) (max)	35	35	50	35	35
Vos Drift (µV/ºC) (max)	0.4	0.4	0.5	0.4	0.4
Ibias (nA) (max)	0.5	0.5	0.6	50	20
Input current noise (fA/√Hz) (typ)	130	130	170	1850	1600
Voltage noise (nV/√Hz)	8	7	7	1.5	1
GBW (MHz) (typ)	2	4.7	2	2.8 (G=2,000)	28
Iq (mA) (typ)	0.35	0.6	0.6	6.2	6.2
Overvoltage protection	± 60V	± 40V	± 40V	-	-

- Biopotential measurements
- Bridge sensing elements
- Current leakage detection
- Field transmitters
- Battery test equipment

INA819 and INA821
QFN offerings !!

WSON (8Pin) Package

Overvoltage protection overview

Differentiation

- Reduced leakage from diodes when compared to external solution
- Low series impedance during normal operation with higher series impedance during overvoltage condition to limit current

System benefits

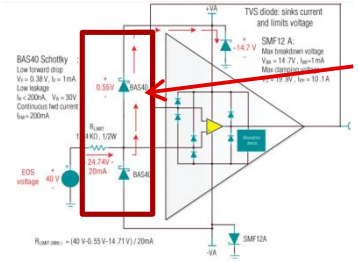
- Reduces system errors with lower leakage diodes enabling higher accuracy
- Reduces cost of external solution
- Smaller footprint with reliable protection

Product examples

Device	Overvoltage protection
INA818	± 60 V
INA821	± 40 V
INA819	± 60 V
OPA2206	± 40 V

Improving industry standard

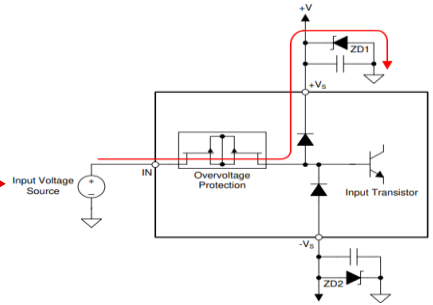
Typical protection scheme



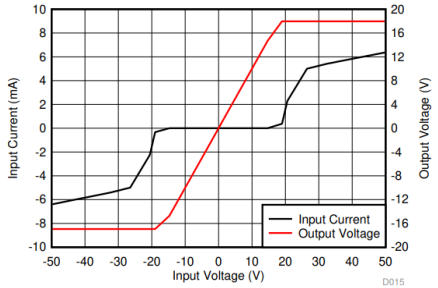
Typical protection scheme with high power current limit resistor and low leakage Schottky diodes

Integrated solution offers smaller footprint, less design work, and reliable protection

Input current path during EOS



Input current vs. input overvoltage



INA849 36V industry's lowest noise instrumentation amplifier

Ultra-low noise, high bandwidth, high precision

Features

- Voltage noise: **1 nV/√Hz** at 1kHz
- Gain bandwidth: **28 MHz**
- Slew rate: **35 V/µs**
- Voltage offset: **35 µV** (max)
- Offset voltage drift: **0.4 µV/ºC** (max)
- CMRR (high gain): **120 dB** (min)
- Bias current **20 nA** (max)
- Gain error: **0.025 %** (max)
- Supply current: **6.2 mA** (typ)
- Wide Supply Range: **8V to 36V**

Released| Sampling| Preview

SOIC|8, DGK

Applications

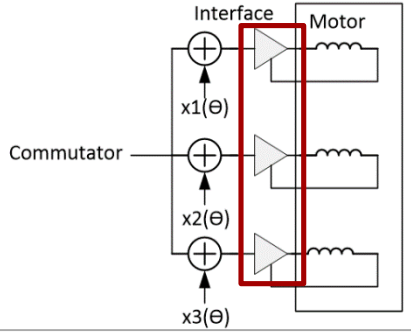
- Optical networking
- Ultrasound scanners
- Gas detectors
- Battery testers
- Oscilloscopes
- Bearing failure detection

Benefits

- **Industry's lowest noise** instrumentation amplifier with low distortion enables the highest resolution for data acquisition systems such as ultrasound scanners and vibration analysis
- **Industry's highest bandwidth** instrumentation amplifier with better quiescent current to bandwidth ratio than competitors
- **Low input offset and drift** enable extremely accurate measurements for battery testers and oscilloscopes
- Device variant with fixed gain (G=2,000) available: **INA848**

Example EE: Torque sensor

Low noise and ***low distortion*** to allow high resolution data acquisition



INA849 Available!
INA848 Available!

Precision instrumentation amplifiers for test & measurement

Application: Battery test

Key amplifier care specs & key devices

Function:

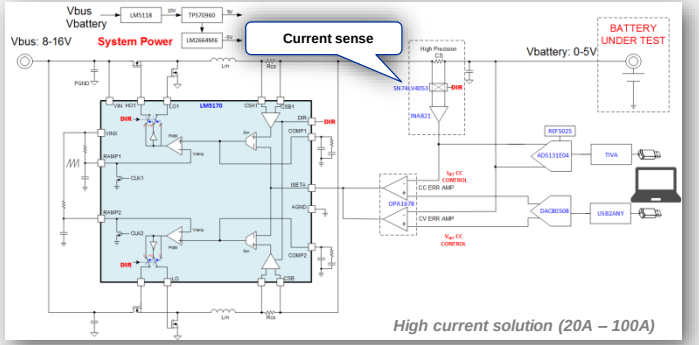
- **Current sensing** INA used for bi-directional current measurement of the battery during the charging and discharging cycle. 2 Cycles: CV= Constant Voltage, CC = Constant Current

Requirements:

- High-input impedance, low drift, wide VCM range

Hero product: **INA821: High precision instrumentation amp**

Subsystem: Current sensing



How INA821 boost system performance

- Low offset **< 35 µV,** offset drift **< 0.4 µV/°C** and gain error **< 0.025%** and low noise **7 nV/√Hz:** smallest error impact in current measurement!
- **Input overvoltage protection**: robustness for surges on Vbus up to ±40 V beyond supply
- CMRR **>90dB** for all gains: accuracy of current measurement does not depend on the battery voltage

TI.COM collateral & tools

- Product folder – INA821
- SBOA341 – Comprehensive error calculation for INAs
- SBOA236 - Simplify V & I measurement in battery test
- TIDA-01040 - Batter tester for high current applications
- [FAQ] INA stickie: How do INAs fit into my design?

Precision instrumentation amplifiers for factory automation

Application: Field transmitters

Key amplifier care specs & key devices

- **High CMRR**: to reduce the need for continuous calibration
- **High Input Impedance:** required as the output impedance of the sensor could be as high as GΩ range
- **High voltage input** allows for faulty conditions and provides safety

INA821: High precision instrumentation amp

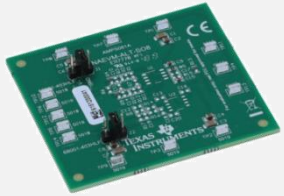
- V_{IO}=35uV(max), Offset drift: 0.4 µV/°C (max)
- CMRR= 140dB
- Input impedance ~ 100 GΩ

INA821
WSON (8Pin) Package
3 mm x 3 mm

TI.COM content & tools

- **INA821 product folder**

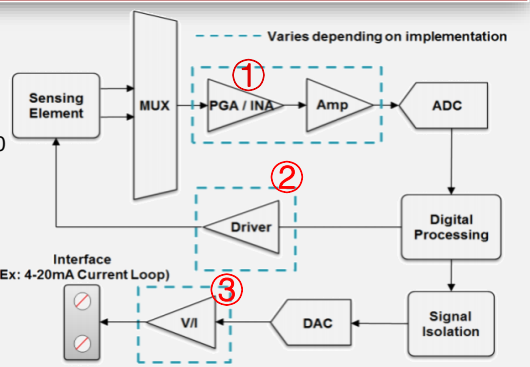
TIDesigns TIDA-00834
High accuracy analog front end using 16-Bit SAR ADC with 10 V measurement range



EVM and SPICE models
INA821 evaluation board | INA821 SPICE model

Application: Field transmitters

1. **PGA/INA**: INA821/333, PGA280
2. **Driver**: TLVx333, OPAx18x, TLV2186
3. **V/I**: XTRs, TLVx333, TLV2186



Adjacent applications

Factory automation

- Torque sensor
- Position sensor
- Condition monitoring sensor
- PLC circuit breaker

Alternative products:

- PGA280 – Zero-drift programmable amplifier

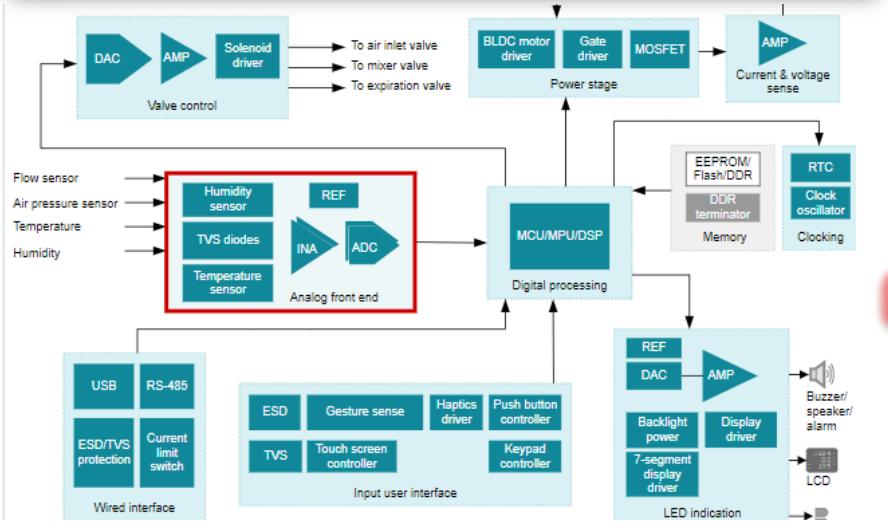
PGA280

TSSOP (8Pin) Package
5 mm x 4 mm

Precision instrumentation amplifiers for medical

Application: Ventilators

Analog front end, pressure-sensing bridge



Key amplifier care specs & key devices

- **Precise pressure measurements** and oxygenation levels are required to provide the desirable ratios (oxygen/air).
- **Low power consumption** is needed to maximize battery life when the ventilator machine is used away from hospital or during power outage.

NEW!

INA819/8: High precision, low power INA

- Low offset: 35-µV
- Low drift: 0.4 µV/ºC
- Low power: 350-µA

- Alternate products: INA826, INA826S

Precision op amps with super beta inputs

Specifications	OPAx202	OPA2205 (NEW!)	OPA2206 (NEW!)	OPAx210
Vos (µV) (max)	200	25	25	35
Vos Drift (µV/°C) (typ)	0.5	0.1	0.1	0.1
Ibias (nA) (max)	2	0.75	0.75	2
Input current noise (fA/$\sqrt{\text{Hz}}$) (typ)	76	200	200	400
Voltage noise (nV/$\sqrt{\text{Hz}}$) (typ)	9	7.2	8	2.2
1/f Noise (μV_{pp}) (typ)	0.2	0.15	0.15	0.09
Overvoltage protection	No	No	± 40V	No

Op amp applications examples

- Semiconductor test
- DAQ
- High-end medical instrumentation
- Ultrasound equipment
- Analog input modules

Precision amplifiers for medical
Application: Ultrasound

Key amplifier care specs & key devices

Low Noise, High Voltage Amplifiers

- **Low Noise:** Ultra-low noise required to maintain extremely high SNR for image quality
- **High Voltage:** Transducer drive can require ±100 V supply rail voltages; Time-Gain Compensation Circuit requires ±15 V rail capability.
- **Wide Bandwidth:** Fast transient response requires > 10 MHz amplifier Bandwidth.

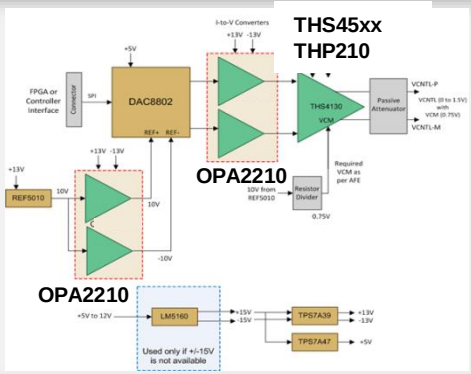
TI.COM content & tools

OPA2210 product folder

EE Collateral:

- Ultrasound block diagram
- Time gain control (compensation) in ultrasound applications

Subsystem: Time gain compensation (TGC)



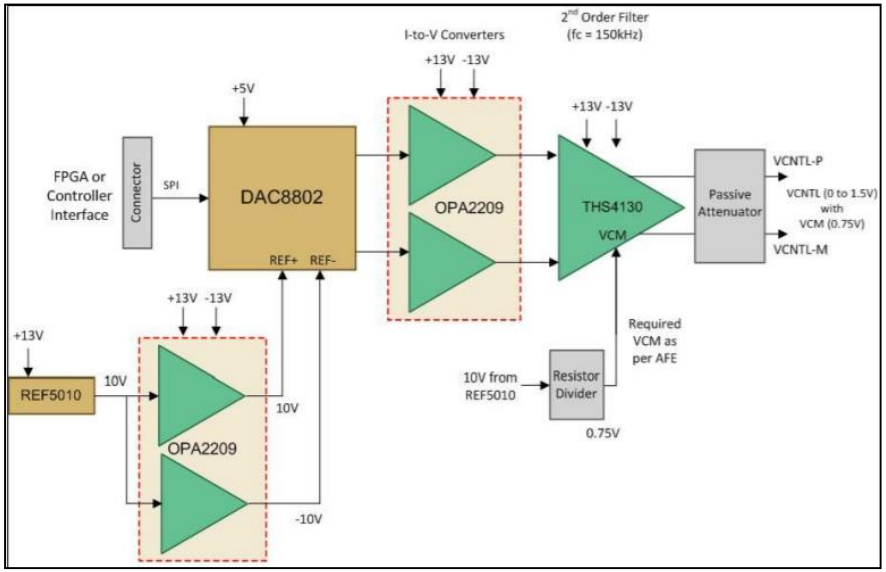
Subsystems & recommended products

Ultrasound

- TGC amplifier
  - OPA2210
  - THP210, THS45xx
- Transducer supply (PHV)
  - INA819
  - OPA2210

Application: Ultrasound
OPA2210: improved version of OPA2209

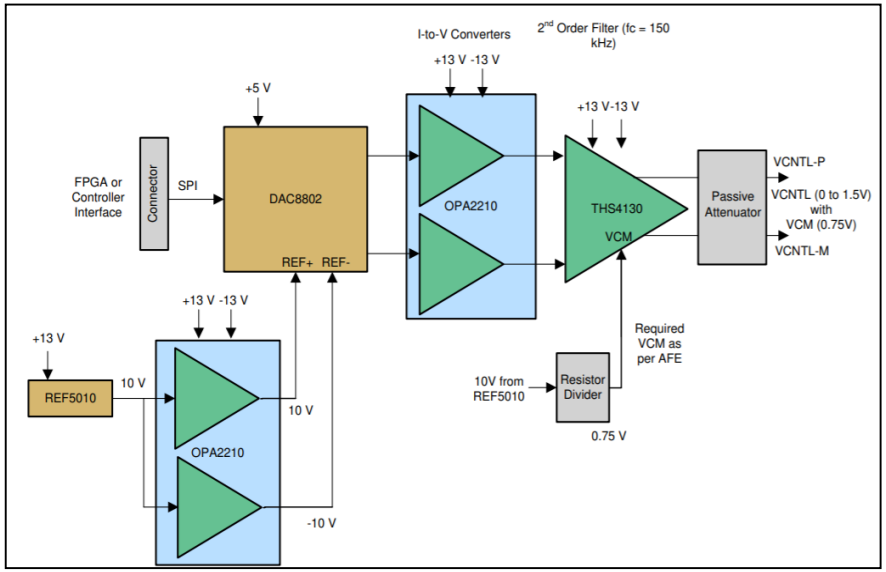
- TGC circuit with **OPA2209**



Output noise : 2.3nV at 1kHz

TIDesigns https://www.ti.com/tool/TIDA-01427

- TGC circuit with **OPA2210**



Output noise : 1.87nV at 1kHz
= **19% lower output noise**

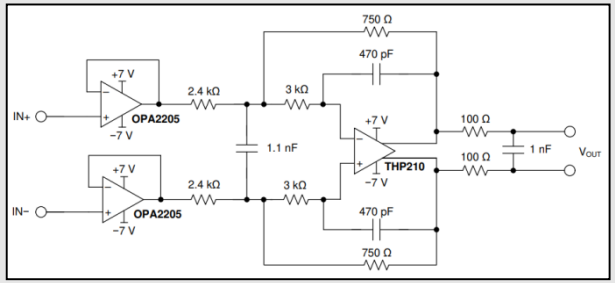
OPA2205 Overview

First high voltage amplifier with e-trim and super beta inputs

Sector / EE - TI.com Subsystem

- FAC / Analog Input Module - Input signal buffer and ADC driver
- T&M / Battery Test - Output voltage feedback/error amplification
- Grid Infrastructure / Single Phase String Inverter - Input voltage monitoring
- Grid Infrastructure / Data Acquisition (DAQ) - Input signal buffer and ADC driver
- FAC / Process Analytics - ADC driver and DAC buffer
- Motor Drives / AC-Input BLDC Motor Drive - Voltage and current monitoring

Typical application



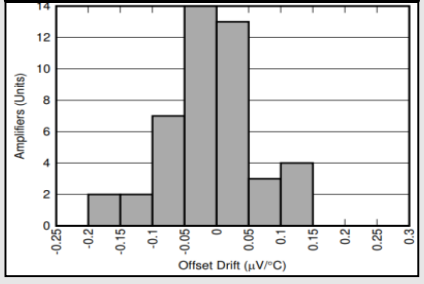
- **Input buffer**
- **Filtering**
- **Voltage monitoring**
- **Current monitoring**
- **ADC driver**

Problems solved

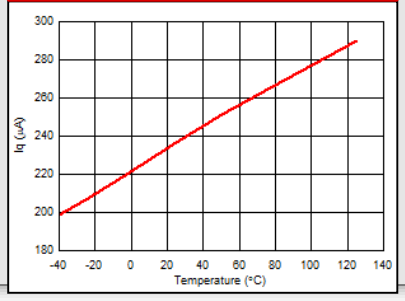
Best combination of noise/power

Device	1/f noise (µV)	Quiescent current (mA)
OPAx205/6	0.2	0.22
OPAx191	1.4	0.14
OP2177	0.4	0.4
ADA4077-2A (MSOP)	0.25	0.4

Low offset drift ensures long term stability



Low power consumption enhances system efficiency



OPA2206 overvoltage protection feature

EE: Analog input module

EE design challenges

Background: The analog input modules design trends are moving to *channel-to-channel isolation*. Resulting in e-fuse/OPTOMOS's not being used which requires a TVS diode on each channel for OVP.

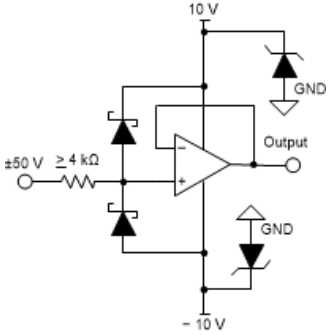
Problems:

- Leakage through the diodes, causing systemic offset errors and degraded precision
- Increase BOM costs
- Thermal noise

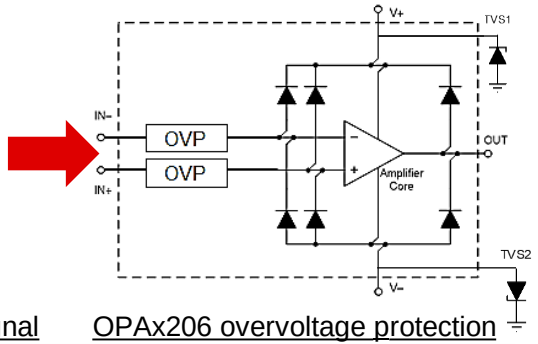
Solution:

- OPA2206 inputs feature integrated protection against voltages to 40V beyond either rail while eliminating the external current-limit resistor and external Schottky diodes on the inputs.
- The OPA2206 enables engineers to achieve high system accuracy while optimizing their BOM, shrinking the solution size and increasing robustness!

- **Result: Increased system level performance with decreased size and cost!**



Schottky diodes clamp input signal

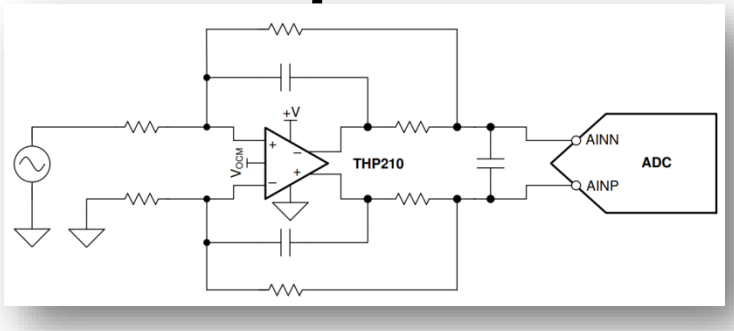


OPAx206 overvoltage protection

Specifications	OPAx206	ADA4177	ADA4096
Protection range (V)	(V-) - 40V < Vcm < (V+) + 40V	(V-) - 32V < Vcm < (V+) + 32V	(V-) - 32V < Vcm < (V+) + 32V
Fault current (max, mA)	±3	-8 / +10	-0.2 / +1
GBW (typ, MHz)	3.6	3.5	0.786
Slew rate (typ, V/µs)	4	1.5	0.4
Input offset (max, µV)	25	60	300
Input offset drift (max, µV/°C)	0.3	1	1 (typ)
Input bias current (max, nA)	0.75	1	25
Noise @ 1kHz (typ, nV/rtHz)	8	8	27
Noise (0.1 to 10Hz, nVpp)	200	175	700
Iq per channel (max, mA)	0.25	0.58	0.055

36V Precision FDAs with super beta inputs

THP210: Industry's highest precision FDA
OPA1637: High-fidelity, low power, Burr-Brown™ Audio



Features

- **High-voltage supply capability** allows for supply voltages up to 36V
- **Very-low voltage and current noise** enables the devices to be used in high-gain configurations with minimal impact to the signal fidelity
- **Wide bandwidth and high speed** allows the device to be used with high resolution 24-bit Delta-Sigma ADCs
- **High Efficiency:** Lower power at higher speeds
- **Low THD** reduce front end error contribution and provide extremely accurate analog-to-digital conversions
- **Versatility:** Ability to drive single-ended and differential outputs

THP210 Applications

- High resolution ADC driver
- Medical ultrasounds
- Power quality measurements
- Analog input module
- Semiconductor test

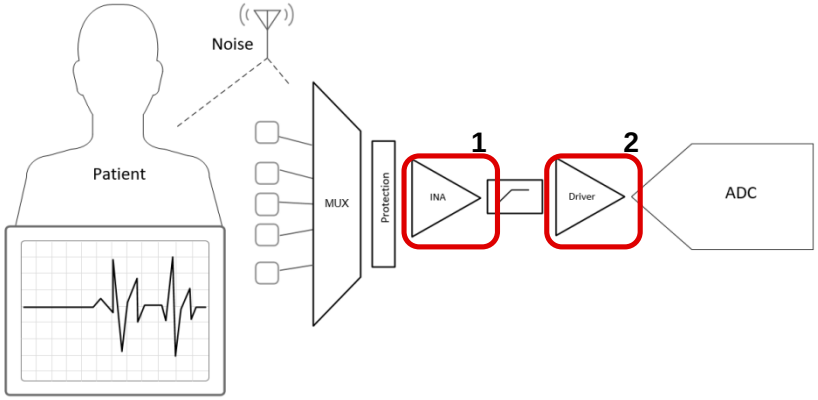
OPA1637 Applications

- High fidelity audio
- Microphone preamplifiers
- Digital audio interfaces
- Mixing consoles
- Class D amplifier front-end

Specifications	THP210	OPA1637
Supply voltage (V)	3-36	3-36
Vos (µV) (max)	40	200
Vos drift (µV/°C) (max)	0.35	1
Iq (mA) (max)	1.05	1.2
PSRR (dB) (min)	-132	-126
Ibias (nA) (max)	2	2
Input current noise (fA/$\sqrt{\text{Hz}}$) (typ)	300	300
Voltage noise (nV/$\sqrt{\text{Hz}}$)	3.7	3.7
GBW (MHz) (typ)	9.2	9.2
THD + N (dB) @ 1kHz	-120	-120

Precision amplifiers in medical equipment

Subsystem: Biopotential front end



Key amplifier care specs & key devices

- **Low noise:** Ultra-low noise is needed to maintain extremely high SNR for accuracy
- **High gain:** Biopotential signals are low amplitude and high gain is needed to extract useful information
- **High common-mode rejection:** Signals of interest are often coupled with common-mode noise that needs to be removed
- **Low temperature drift:** Very low temperature drift is needed to minimize the voltage drop on electrodes and skin impedances.
- **Overvoltage protection:** Overvoltage protection is needed to protect the front-end electrode of occasional surges from peripheral devices

1) Differential amplifier

Monolithic instrumentation amplifiers

	Device	Noise (nv/√Hz)	GBW (MHz)	CMRR (dB, typ)	Offset drift (µV/°C, max)	Power (mA)	Package	Feature
High voltage	INA849	1	28	127	0.4	6.2	SOIC, SSOP	Super-beta
	INA848	1.5	2.8 (G=2000)	150	0.45	6.2	SOIC	Fixed-gain
	INA821	7	4.7	150	0.4	0.6	SOIC, SSOP, QFN (3x3 mm)	Over-voltage protection
	INA819	8	2	150	0.4	0.35	SOIC, SSOP, QFN (3x3 mm)	Over-voltage protection
	INA188	12	2	130	0.2	1.4	SOIC, QFN (4x4mm)	Zero-drift
Low voltage	INA333	50	0.15	115	0.1	0.05	SSOP, QFN (3x3mm)	Zero-drift
	INA331	46	2	94	5 (typ)	0.00001 (shutdown)	SSOP	Shutdown

Build your own

	Device	Noise (nv/√Hz)	GBW (MHz)	CMRR (dB, typ)	Offset drift (µV/°C, max)	Power (mA)	Package	Feature
High voltage	OPA2182	5.7	5	168	0.012	0.85	SOIC, SSOP	Zero-drift
	OPA2205	7.2	3.6	140	0.3	0.22	SSOP	Super-beta
	OPA2206	7.2	3.6	140	0.3	0.22	SSOP	Over-voltage protection
Low voltage	OPA391	60	1	121	0.5	0.024	SC70	e-Trim
	OPA2333	55	0.35	130	0.05	0.017	SSOP, SOIC, SON (2x2mm)	Zero-drift

2) Drivers

	Noise (nv/√Hz)	GBW (MHz)	CMRR (dB, typ)	Offset drift (µV/°C, max)	Power (mA)	Package	Feature
THP210	3.7	9.2	140	0.35	0.95	SOIC, SSOP	36V Fully-differential
OPA210	2.2	18	140	0.5	2.2	SOIC, SSOP, QFN	Super-beta
OPA320	7	20	114	5	1.5	SOT23	Zero-crossover

Test these parts today

Universal OPA EVM Universal INA EVM THP210EVM

Precision amplifiers for test & measurement

Application: Lab & field instrumentation

Key amplifier care specs & key devices

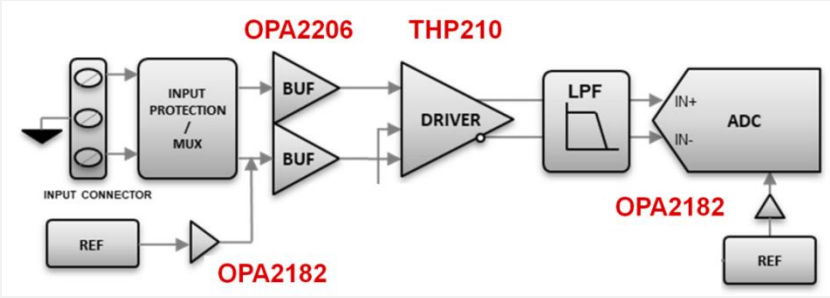
Input protection, low noise, high DC precision

- **Input protection:** The **OPA2206** has integrated protection when the input voltage exceeds the supplies by up to 40V, while maintaining high precision under normal operation
- **Low noise:** Low voltage and current noise increase system SNR, resolution and accuracy.
- **High DC precision:** High DC precision, especially low offset drift, simplify calibration needs and increase system accuracy both in the ADC driver (**THP210**) and calibration loop (**OPA2182/7**)

Reference designs

- Analog input module for industrial outputs and temperature sensors
- 20-bit 1MSPS DAQ reference design optimizing power supply efficiency

Subsystem: ADC signal chain



Alternate products

Alternate products

- ADC Driver: OPA2140, OPA2145, OPA2392, OPA2210
- Calibration/reference driver: OPA2333, OPA2187

Visit www.ti.com/npu

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

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