

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: High-precision multi-decade current sensing

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Agenda

- TI's Current Sensing Portfolio
- TI's new digital power monitors solve the multi-decade challenge
 - New family of digital power monitors
 - The five decade challenge
 - How the INA228 & INA229 solve the challenge
- Additional resources

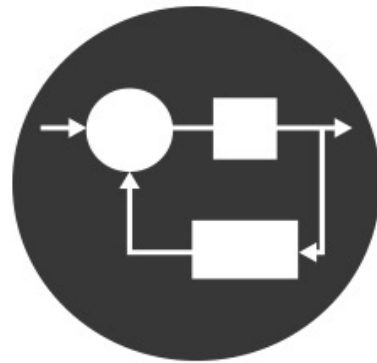
Current & power measurement use cases



**Real-time
overcurrent
protection (OCP)**



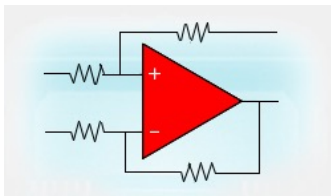
**Current and power
monitoring for
system optimization**



**Current
measurement for
closed loop circuits**

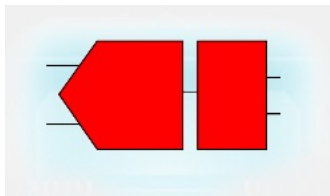
Current measurement portfolio

Analog Sense Amplifiers



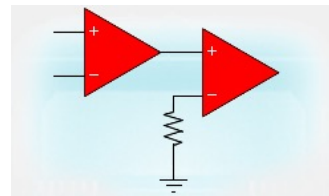
Integrate the full analog signal processing and provide a voltage or current output

Digital Power Monitors



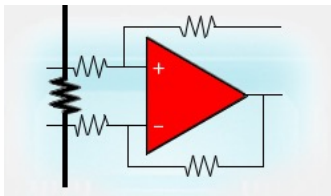
Integrate the full signal conditioning path and utilize a standard 2-wire digital interface

Analog Output with Integrated Comparators



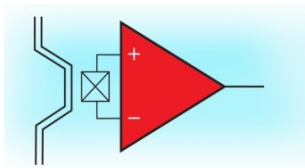
Provides an ALERT signal(s) when the load current exceeds a threshold along with the analog voltage output

In-package Shunt Solutions



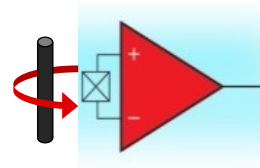
Offers a low-drift, precision shunt resistor element in-package with either analog or digital out

In-Package Hall-effect Current Sensors



Offers precision isolated Hall through-package current measurement

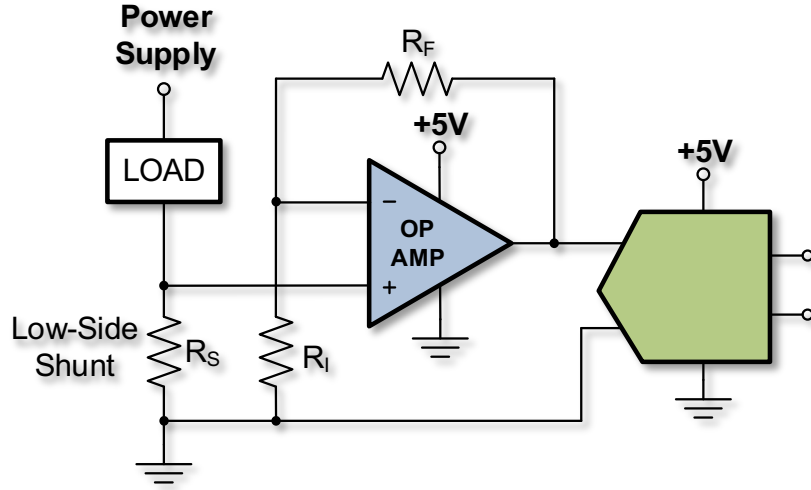
Ambient Field Magnetic Current Sensors



On-chip sensors measures the magnetic field flux density and generates a voltage output proportional to the current

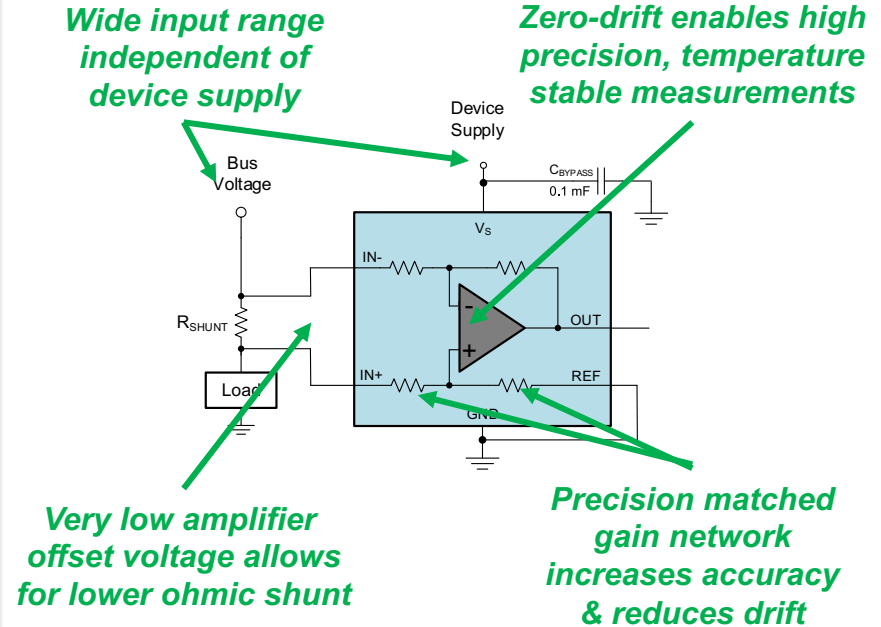
Benefits of designing with a dedicated current sense device

Discrete current sense circuit



- External gain resistors are primary error and temperature drift contributors
- Input range limited by supply voltage

Dedicated current sense device



TI's new family of digital power monitors

Features

- -0.3 V to 85 V common mode voltage
- ADC specifications
 - Full scale range (± 160 mV or ± 40 mV)
 - 20-bit and 16-bit options
- High accuracy
 - High common mode rejection ratio
 - Low offset and drift
 - Low gain error and drift
 - Low bias current
 - Internal 1% oscillator (20-bit only)
- Telemetry capabilities
 - 16-bit: voltage, current, power, & internal temperature
 - 20-bit: above plus time, energy, & charge

Benefits

- Wide common mode range supports low-side, and high-side applications for 24 V, 48 V, 60 V systems.
- ADC allows for up to 120dB of dynamic range measurements
- High accuracy enables:
 - Low ohmic shunts ($\mu\Omega$) to minimize measurement power dissipation
 - Minimize/eliminate calibration
- Optimized monitoring and feedback control for system optimization and increased efficiency

TI's new family of digital power monitors

	20-Bit Options		16-bit Options		
Measure: <ul style="list-style-type: none"> • Current • Bus Voltage • Internal Temp. 					
Parameter	INA228	INA229	INA238	INA239	INA237
Interface	I ² C	SPI	I ² C	SPI	I ² C
Gain error	0.05% max at 25°C with 20 ppm/°C drift		0.1% max at 25°C with 25 ppm/°C drift		0.3% (25°C) w/ 50 ppm/°C
Input offset	1 μV max at 25°C with 10 nV/°C drift		5 μV max at 25°C with 20 nV/°C drift		50 μV (25°C) w/ 20 nV/°C
CMRR	154 dB minimum		140 dB minimum		120 dB minimum
Calculations	Power, Energy, & Charge Accumulation		Power		

The five decade challenge

I need to measure five decades (± 1 mA to ± 10 A) of current across a single shunt with a single device?

1. Maximum current will determine the shunt value

Analog out:
$$R_{MAX} = \frac{(V_S - V_{SWING} - V_{REF}) / GAIN}{I_{MAX}}$$

Digital Out:
$$R_{MAX} = \frac{V_{Full-scale\ Input}}{I_{MAX}}$$

2. Root-sum square method is typically used to calculate error in current measurement

$$e_{RSS} = \sqrt{(e_{V_{OS}} + e_{CMRR} + e_{PSRR})^2 + e_{I_{BIAS}}^2 + e_{GAIN}^2 + e_{SHUNT}^2}$$

3. Offset will determine the minimum current that can be accurately measured

Error due to offset:
$$e_{V_{OS}} = \frac{V_{OFFSET}}{R_{SHUNT} \times I_{IN}}$$

The five decade challenge

Step 1: Calculate Shunt

Device option	INA190A1	INA190A5	INA229
V_S	5 V		
Swing to supply	40 mV		
V_{REF}	2.5 V		
Max output voltage	2.46 V		
Nominal gain option	25 V/V	500 V/V	Unity
Max input voltage	98.4 mV	4.92 mV	163.84 mV
Maximum current	10 A		
Maximum shunt value	9.8 m Ω	0.5 m Ω	16.4 m Ω

Step 3: What is the lowest current I can accurately measure due to offset?

Device option	INA190A1	INA190A5	INA229	INA229
Shunt value	9.5 m Ω	470 $\mu\Omega$	15 m Ω	7.5 m Ω
V_{OFFSET} at 25°C	15 μ V		1 μ V	
Offset Error at:				
10 A	0.02%	0.32%	0.00%	0.00%
1 A	0.16%	3.19%	0.01%	0.01%
100 mA	1.58%	31.9%	0.07%	0.13%
10 mA	15.8%	319.1%	0.67%	1.33%
1 mA	157.9%	3191.5%	6.67%	13.3%

The five decade challenge – SOLVED!

To measure five decades of current with a single device and a single shunt is a challenge that requires:

1. A full scale input range that allows for a “large” shunt value at max current value **$\pm 164 \text{ mV}$**
2. An offset voltage that allows for measuring low currents across the low ohmic shunt required to measure the max current **$\pm 1 \text{ }\mu\text{V}$**
3. High common mode rejection to minimize the additional offset error seen over a wide common mode voltage range. **154 dB**
4. Low bias current is required when the minimum current level drops below 1 mA **2.5 nA**

Additional resources

- [TI Precision Labs – Current Sense Amplifiers](#)
- [Current Sense Amplifier Comparison and Error Tool](#) (Excel-based tool)

- [Getting Started with Digital Power Monitors Application Report](#)
- [Shunt-Based Current-Sensing Solutions for BMS Applications in HEVs and Evs Application Brief](#)
- [Digital Interfaces for Current Sensing Devices Application Brief](#)
- [Integrated, Current Sensing Analog-to-Digital Converter Application Brief](#)

- [TI E2E™ support forums](#)

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