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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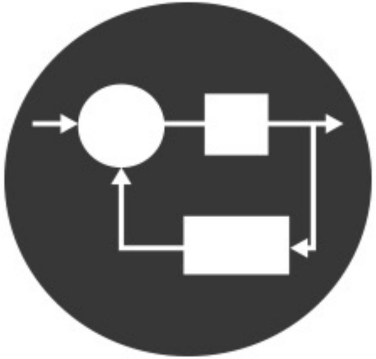
Agenda

- 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)

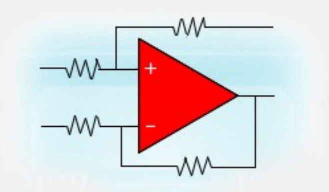
Current and power monitoring for system optimization



Current measurement for closed loop circuits

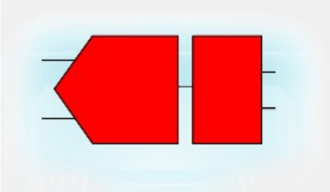
Current measurement portfolio

Analog Sense Amplifiers



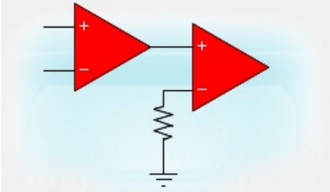
Integrate the full analog signal processing and provide a voltage or current output

Digital Power Monitors



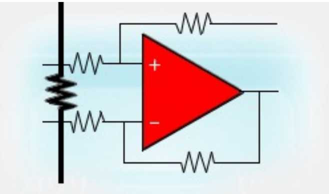
Integrate the full signal conditioning path and utilize a standard 2-wire digital interface

Analog Output with Integarted Comparators



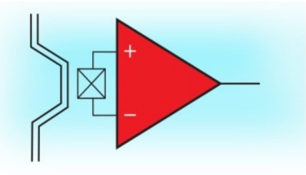
Provides an ALERT signal(s) when the load current exceeds a threshold along with the analog voltage output

In-package Shunt Solutions



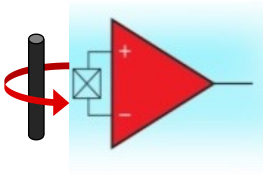
Offers a low-drift, precision shunt resistor element in-package with either analog or digital out

In-Package Hall-effect Current Sensors



Offers precision isolated Hall through-package current measurement

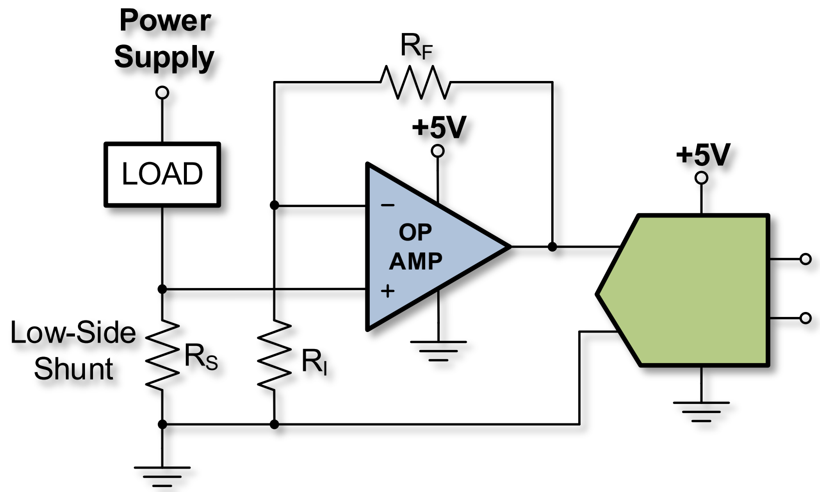
Ambient Field Magnetic Current Sensors



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

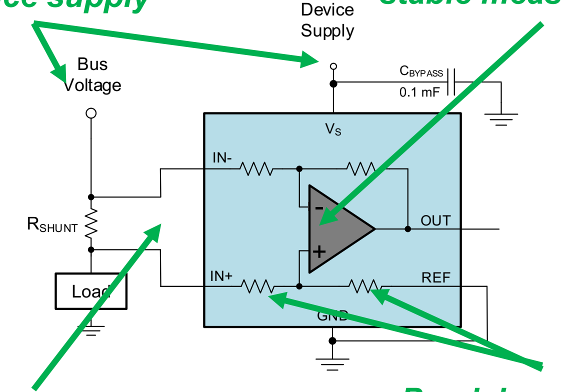


- **External gain resistors are primary error and temperature drift contributors**
- **Input range limited by supply voltage**

Dedicated current sense device

Wide input range independent of device supply

Zero-drift enables high precision, temperature stable measurements



Very low amplifier offset voltage allows for lower ohmic shunt

Precision matched gain network increases accuracy & reduces drift

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

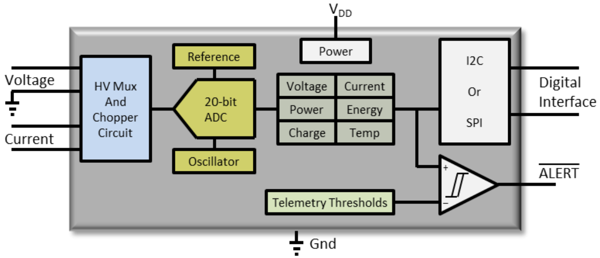
- Wide common mode range supports low-side, and high-side applications for 24 V, 48 V, 60 V systems.
- ADC allows for up to 120dB of dynamic range measurements
- High accuracy enables:
  - Low ohmic shunts (μΩ) to minimize measurement power dissipation
  - Minimize/eliminate calibration
- Optimized monitoring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

TI's new family of digital power monitors

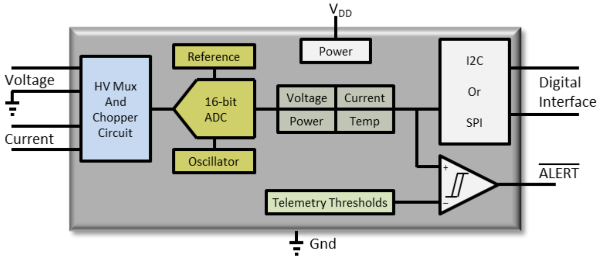
Measure:

- **Current**
- **Bus Voltage**
- **Internal Temp.**

20–Bit Options



16–bit Options



Parameter	INA228	INA229	INA238	INA239	INA237
Interface	I²C	SPI	I²C	SPI	I²C
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 mΩ	0.5 mΩ	16.4 mΩ

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

Device option	INA190A1	INA190A5	INA229	INA229
Sh[illegible]ue	9.5 mΩ	470 µΩ	15 mΩ	7.5 mΩ
V_{OFFSET} at 25°C	15 µV		1 µV	
Oiffset 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 — **±164 mV**
2. An offset voltage that allows for measuring low currents across the low ohmic shunt required to measure the max current — **±1 µV**
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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