

Current Sense Amplifiers



TEXAS INSTRUMENTS



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Current Sense Amplifiers

Introduction

What are Current Sense Amplifiers?

Current sense amplifiers, also called current shunt monitors, are specialized differential amplifiers with a precisely matched resistive gain network with the following characteristics:

- Designed to monitor the current flow by measuring the voltage drop across a sense element, typically a shunt resistor
- Tend to be easier to use, more precise and less prone to noise
- Support currents from mAs to 100s A
- Natively support common-mode voltages from -16 to +80V and with additional circuitry up to 100s volts

System benefits addressed by using current sense amplifiers:

- Real-time overcurrent protection
- Current and power monitoring for system optimization
- Current measurement for closed-loop feedback

Key Parameters

Common Mode Range:

This specification defines the DC voltage range at the input of an amplifier with respect to ground. Current sense amplifiers are typically designed to support common-mode voltages well beyond the chip supply voltage. For example, the INA282 is capable of supporting a common-mode voltages between -14V to +80V while running on a supply as low as 2.7V.

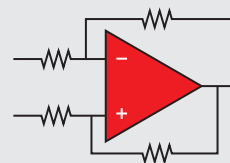
Offset Voltage:

This is a differential DC error at the input of the amplifier. Historically, to reduce the impact of amplifiers with high offsets, larger value shunt resistors were used to increase the measured voltage drop. Today, TI is able to offer current sense amplifiers with offsets as low as 10 μ V, enabling higher precision measurements at low currents and allowing the use of smaller value shunt resistors for improved system efficiency.

Gain:

Current sense amplifiers come with various gain options that have robust performance over temperature and process variations by integrating a precisely matched resistive gain network. The gain options for fixed gain amplifiers vary from 0.125V/V to 1000V/V with gain errors as low as 0.01%.

Analog Output



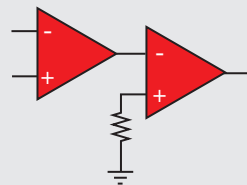
Integrates the full analog signal processing and provides a voltage or current output.

Digital Output



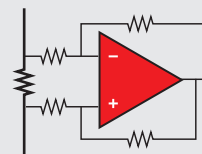
Integrates the full signal conditioning path and utilizes a standard 2-wire digital interface.

Comparator Output



Provides a simple ALERT signal when the load current exceeds a threshold.

Integrated Shunt



Offers a low-drift, precision integrated sense element.

Current Sense Amplifiers

Key Design Considerations

High-Side Measurements

Current sensing techniques connect the current sense element between the supply bus and the load.

System Advantages:

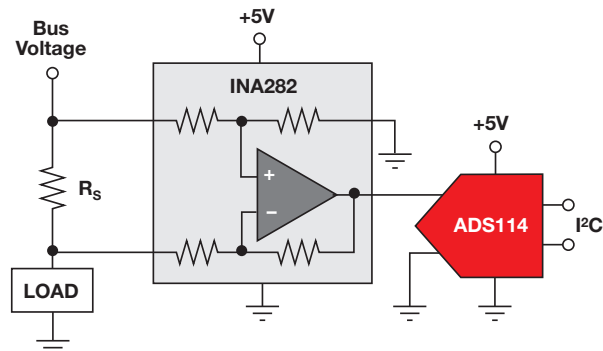
- Load shorted to ground (fault condition) can be easily detected
- Current is monitored directly from the source
- High immunity to ground disturbance

System Challenges:

- High bus voltage limits the availability of high Input common-mode voltage devices

Advantages over Standard Op Amps:

- Integrated gain resistors:
 - Provides excellent matching that requires more expensive external precision resistors with an op amp approach
 - Reduces board space requirements
- High dynamic changes in the common-mode voltage is difficult to achieve with standard op amps
- Unique input architecture allows for the common-mode voltage to greatly exceed the device supply voltage



Low-Side Measurements

Current sensing techniques connect the current sense element between the load and ground.

System Advantages:

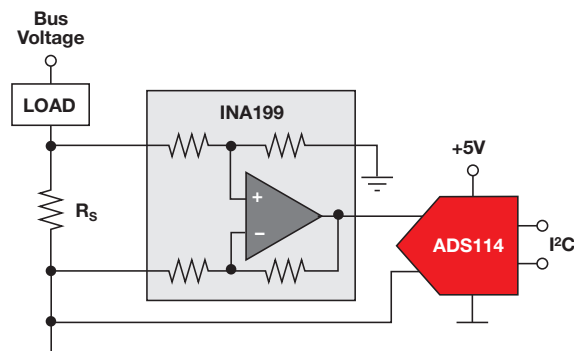
- Simple to implement and low-cost solution
- Wide range of available options

System Challenges:

- Load shorted to ground (fault condition) is hard to detect
- System ground disturbance by the shunt resistor

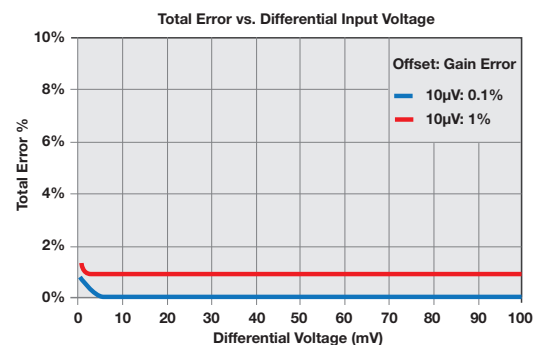
Advantages over Standard Op Amps:

- Integrated gain resistors:
 - Provides excellent matching that requires more expensive external precision resistors with an op amp approach
 - Reduces board space requirements
- True differential measurement across the shunt resistor
- Lower V_{OFFSET} saves system power by enabling the use of smaller value shunt resistors to achieve the same error level



Total Error

- For small differential signals at the input, the error is dominated by the amplifier's offset voltage. Low input offsets are critical to achieving accurate measurements at the low end of the dynamic range.
- For large differential signals at the input, the error is dominated by the amplifier's gain error.



Current sensing reference designs from the TI Designs library. See more designs online at ti.com/tidesigns.

Design Number	Description	
TIDA-00795	Automotive Precision eFuse One of the keys to preventing damage in automotive electronic systems is the ability to detect and react to potentially damaging conditions as rapidly as possible. This INA300-Q1 eFuse reference design is focused on providing high accuracy and fast response over current protection at current levels as high as 30A and scalable to > 100A.	
TIDA-00528	40V to 400V Unidirectional Current/Voltage/Power Monitoring This TI Design demonstrates a simple, non-isolated technique using a precision opamp and a high voltage P-FET to extend the common-mode voltage of a current sense amplifier up to 400 V. With minor component changes, this design can be optimized for any voltage ranging from 40 to 400 Volts.	
TIDA-00753	Three-phase Current Measurements for Motor Maximizing motor control requires accurate current measurement. This reference design featuring the INA199 demonstrates a method for enhancing the signal chain on the output of a current transformer. In addition, this circuits offers significant power savings by lowering the burden resistor value.	

Current Sense Amplifiers

Featured Products

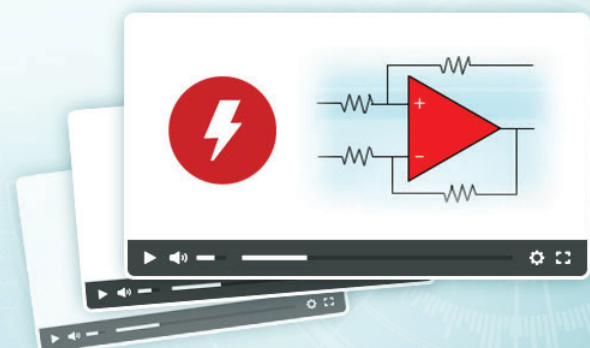
Part Number	AEC-Q100 Available	Bi-directional	Low-Side	Description	Common Mode Voltage Range	Input Offset +/- μ V Max	Input Offset Drift +/- μ V/ $^{\circ}$ C Typ	Gain Error % Typ	Package(s)
INA210 Family	✓	✓	✓	High performance, Zero-Drift Current Sense Amplifier	-0.3 to 26	35	0.1	0.02	10 UQFN, 6 SC70
INA282 Family	✓	✓	✓	High Performance, High Common Mode Current Sense Amplifier	-14 to 80	70	0.3	0.4	8 VSSOP, 8 SOIC
INA240 Family	✓		✓	High AC CMRR High Common Mode Current Sense Amplifier for Motor & Solenoid Control	-4 to 80	100	0.1	0.05	8 TSSOP
INA216 Family				Ultra-small, 5V Current Sense Amplifier	1.8 to 5.5	100	0.06	0.01	10 UQFN, 4 WSCP
INA199 Family	✓	✓	✓	Value line, Zero-Drift Current Sense Amplifier	-0.3 to 26	150	0.1	0.03	10 UQFN, 6 SC70
INA225	✓	✓	✓	Programmable-Gain, Zero-Drift, High Accuracy Current Sense Amplifier	0 to 36	150	0.1	0.1	8 VSSOP
LMP8481 Family	✓	✓		High Common Mode, High-Speed Current Sense Amplifier	4 to 76	265	6	0.6	8 VSSOP
LMP8640 Family	✓		✓	High-Speed Current Sense Amplifier	-2 to 42	900	1.2	0.25	6 SOT
INA193 Family	✓		✓	High Common Mode, High-Speed Current Sense Amplifier	-16 to 80	2000	2.5	0.2	5 SOT-23
INA301 Family	✓		✓	Overcurrent protection high-speed, precision current sense amplifier with integrated comparator	0 to 36	100	0.1	0.15	8 VSSOP
INA300	✓		✓	Overcurrent Protection Comparator	0 to 36	650	0.1		10 WSON, 10 VSSOP
INA226	✓	✓	✓	Ultra-High Accuracy, Current, Voltage, & Power Monitor with Alert	0 to 36	10	0.02	0.02	10 VSSOP
INA231		✓	✓	Current, Voltage & Power Monitor with Alert in Ultra-small WCSP	0 to 28	50	0.1	0.2	12 WCSP
INA3221	✓	✓	✓	Triple-channel, Current & Voltage Monitor with Alert	0 to 26	80	0.1	0.1	16 VQFN
INA250 Family	✓	✓	✓	High Accuracy, Zero-Drift Current Sense Amplifier with 0.1%, 15 PPM 2m Ω Integrated Shunt	0 to 36	50mA	25 μ A/ $^{\circ}$ C	0.3	16 TSSOP

Preview devices are listed in **bold teal**.

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