

Introduction to 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 10s of μA to 100s of A.
- Natively-support common-mode voltages from -16 to $+80$ V and with additional circuitry up to 100s of 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 INA240 is capable of supporting a common-mode voltage between -4 V to $+80$ V while running on a supply as low as 2.7 V.

Offset Voltage

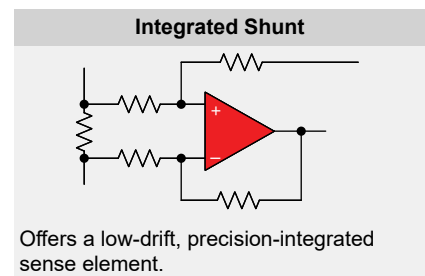
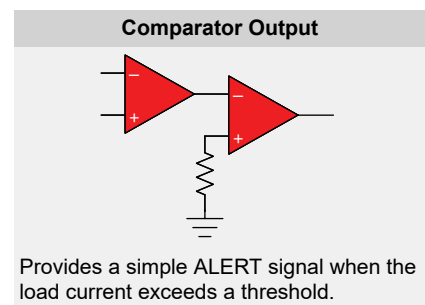
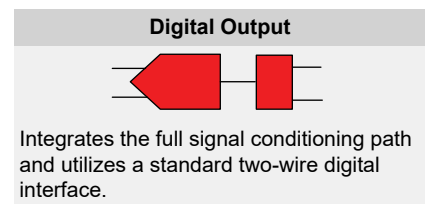
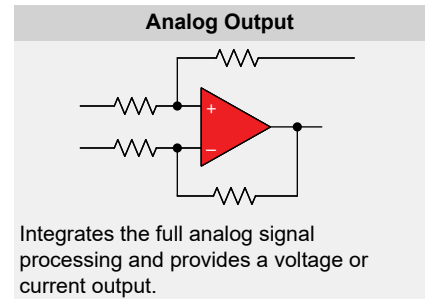
This is a differential DC error at the input of the amplifier. Historically, to reduce the impact of amplifiers with high offsets, larger value shunt resistors were used to increase the measured voltage drop. Today, TI is able to offer current sense amplifiers with offsets as low as $10 \mu\text{V}$, 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 0.125 V/V to 1000 V/V with gain errors as low as 0.01%.

Temperature Stability

Current sense amplifiers integrate the amplifier along with all the gain-setting resistors which enables small and unified temperature drift. This allows for robust current measurements across the whole specified temperature range. The achieved temperature stability is one of the key advantages current sense amplifiers have over discrete implementations.



Key Design Considerations

High-Side Measurements

Sensing between supply bus and load.

System Advantages:

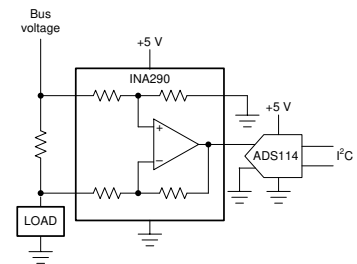
- Able to detect load short to ground
- Current is monitored directly from the source
- High immunity to ground disturbance

System Challenges:

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

Advantages Over Discrete Current Sense Circuit:

- Integrated gain resistors provide excellent matching to enable higher performance
- Reduction in board space requirements
- Unique input architecture allows for the common-mode voltage to greatly exceed the device supply voltage



Low-Side Measurements

Sensing between the load and ground.

System Advantages:

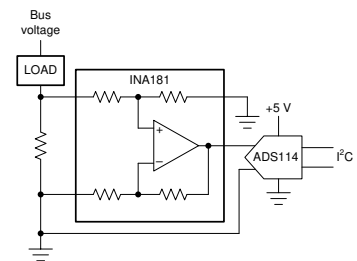
- Simple to implement and low-cost solution
- Wide range of available options

System Challenges:

- Difficult to detect load short to ground
- System ground disturbance by the shunt resistor

Advantages Over Discrete Current Sense Circuit:

- Integrated gain resistors provide excellent matching enable higher performance
- Reduction in board space requirements
- Sense a 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



In-line Measurements

Sense current in-line to the load.

System Advantages:

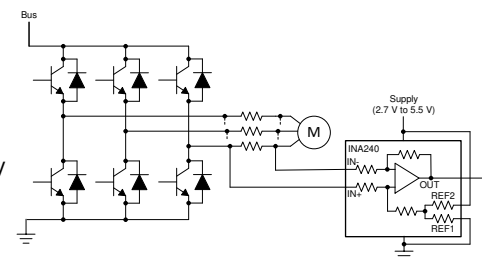
- True phase current at all times reduces phase-to-phase errors
- Best current feedback for greatest accuracy

System Challenges:

- PWM common-mode voltage seen by amplifier
- High common-mode voltage combined with high dV/dT poses steep challenge to many amplifiers

INA240 Advantages Over Discrete Current-Sense Circuit:

- Enhanced PWM rejection provides high levels of suppression for large common-mode transients (dV/dT) in systems that use PWM signals



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