Current Shunt

Texas Instruments

Current Shunt Monitors

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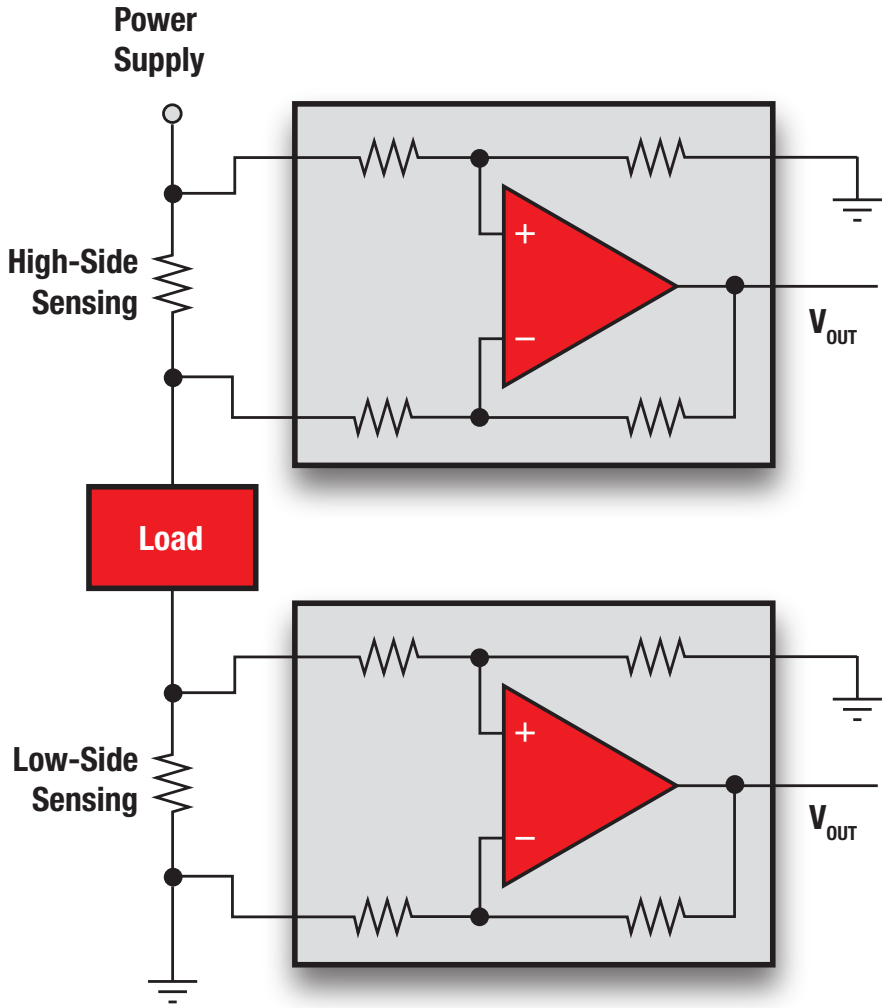
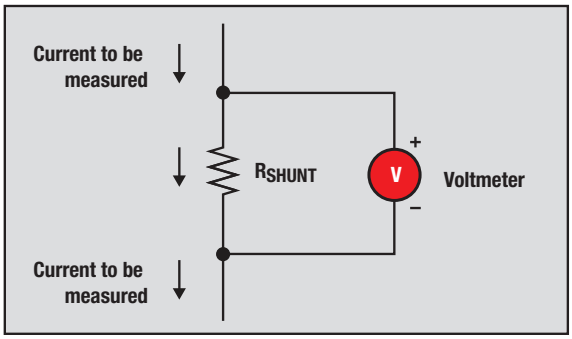


Current Shunt Monitors

What are Current Shunt Monitors?

- Current shunt monitors are designed to monitor the current flow by measuring the voltage drop across a resistor placed in the current path.
- Current shunt monitors tend to be easier to design, more precise, less prone to noise and lower cost than magnetic current sensors.



Key Parameters

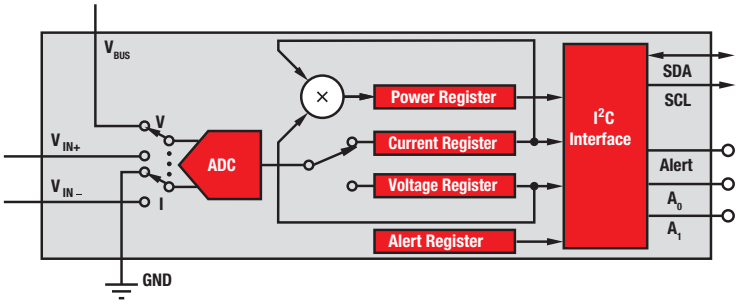
Common Mode Range: This specification defines the DC voltage range at the input of an amplifier with respect to ground. Current shunt monitors are typically designed to accept common mode voltages well beyond the chip supply voltage. For example, the INA282 is capable of accepting a common mode voltage from -14V to +80V while running on a supply as low as 2.7V.

Offset Voltage: The differential DC error at the input of the amplifier. Historically, to reduce the impact of amplifiers with high offsets, larger shunt resistors are used to increase the measured voltage drop. Today, TI is able to offer current sensing solutions with offsets as low as 10µV, enabling higher precision measurements at low currents and the use of smaller shunt resistances for improved system efficiency.

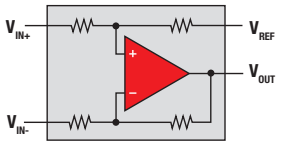
CMRR (Common Mode Rejection Ratio): CMRR is the ability of the amplifier to reject signals common to the differential inputs. This is important in the ability to measure small signals superimposed upon a large voltage. TI's portfolio offers solutions with CMRR as high as 140dB.

Current Shunt Output Types

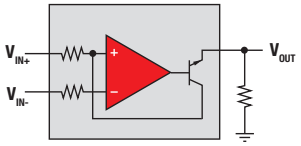
Digital Output: Simple all-in-one solution integrating the ADC / MUX with programmable switching. Provides measurements in amps, volts and watts across the I²C interface for a complete power monitoring solution.



Voltage Output: High precision, lowest power and industry's smallest form factors. Fixed gain options ranging from 14V/V to 1000V/V. Variable gain may be set through an external resistor.



Current Output: Variable gain set through external resistor. Highest bandwidth options.



Current Shunt Monitors

Low-Side Measurements

Advantages:

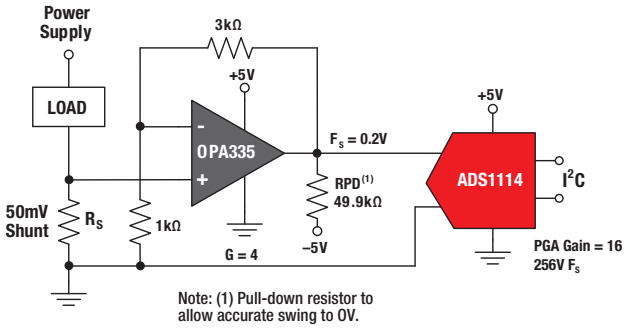
- Typically only requires an op amp such as OPA335
  - Straightforward, easy
  - Inexpensive

Disadvantages:

- Undesirable resistance in the load's ground path
- Cannot detect fault conditions (short/open circuits)
- Requires precision external components to achieve and maintain high accuracy

Low-side current sensing techniques connect the current sensor element between the load and ground.

When to choose low-side sensing: Always choose low-side sensing if the system can tolerate disturbances on the ground path.



High-Side Measurements

Advantages:

- Eliminates ground disturbances associated with low-side sensing
- Able to detect fault conditions

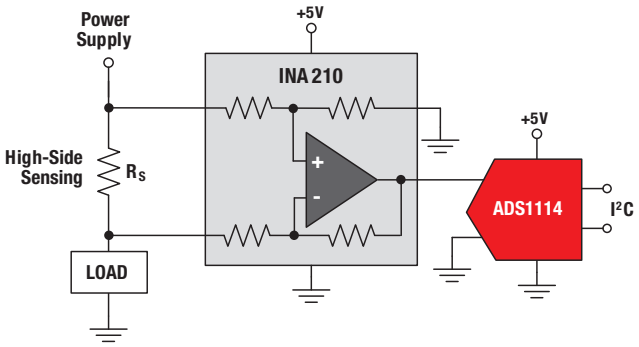
Disadvantages:

- Difficult to use standard op amp. Resistors must be precisely matched to obtain acceptable common mode rejection ratios (CMRR)
  - A 0.01% deviation in resistor value lowers the CMRR to 86dB approach
  - A 0.1% deviation in resistor value lowers the CMRR to 66dB
  - A 1% deviation in resistor value lowers the CMRR to 46dB
- Must withstand very high, dynamic changes in common mode voltage

High-side current sensing techniques connect the current sensor element between the supply and the load.

When to choose high-side sensing:

- System cannot tolerate ground disturbance of low side sensing
- System needs to be able to identify shorts to ground



Low-Side Measurements With a High-Side Monitor

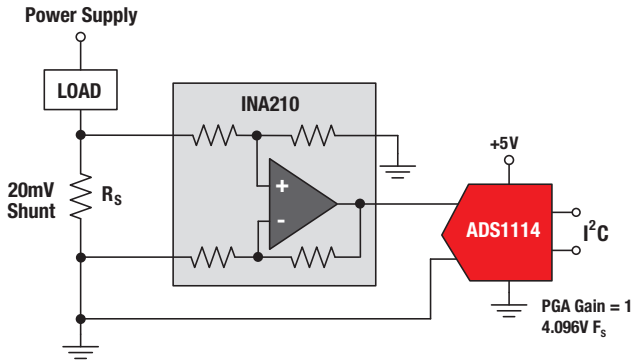
Advantages over op amps as a low-side monitor:

- Integrated gain resistors
  - Excellent matching that requires more expensive external precision resistors with an op amp approach
  - Integrated resistors approach reduces board space requirements

Disadvantages over op amps:

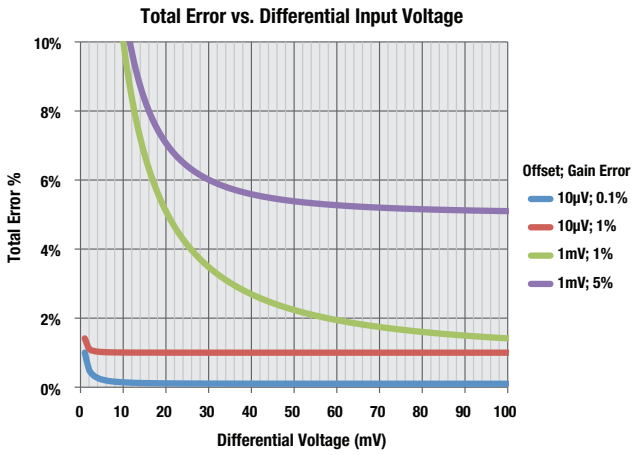
- Fixed gain settings reduce flexibility in maximizing the full-scale range of the following ADC stage

High-side monitors are designed to accommodate input voltages that exceed the power supply voltage. However, many of our current shunt monitors have common-mode ranges that include or even go below ground. This makes them excellent low-side current shunt monitors as well.



Total Error

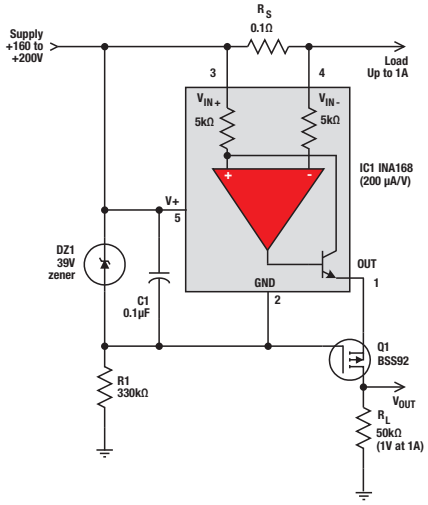
- For small differential signals at the input, the error is dominated by the amplifier's offset voltage. Low input offsets are critical to achieving accurate measurements at the low end of the dynamic range.
- For large differential signals at the input, the error is dominated by the amplifier's gain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



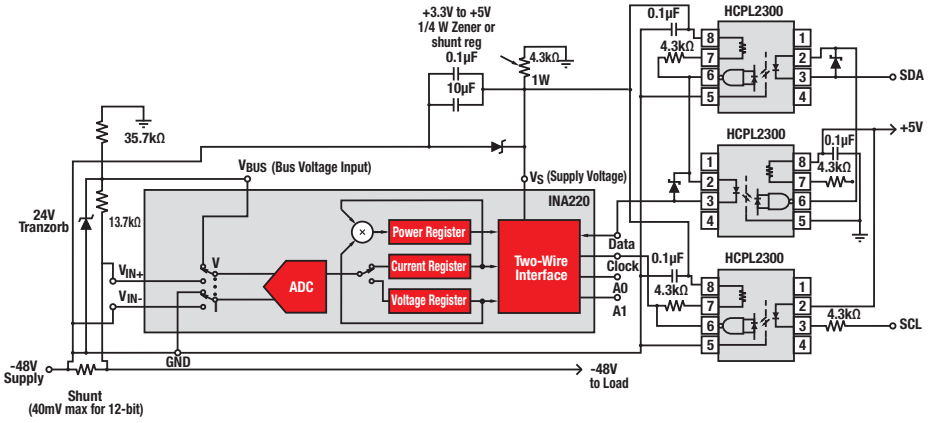
Extending the Common Mode Range

With additional circuitry, current shunts can be configured to operate beyond the specified common mode range by using one of the following techniques.

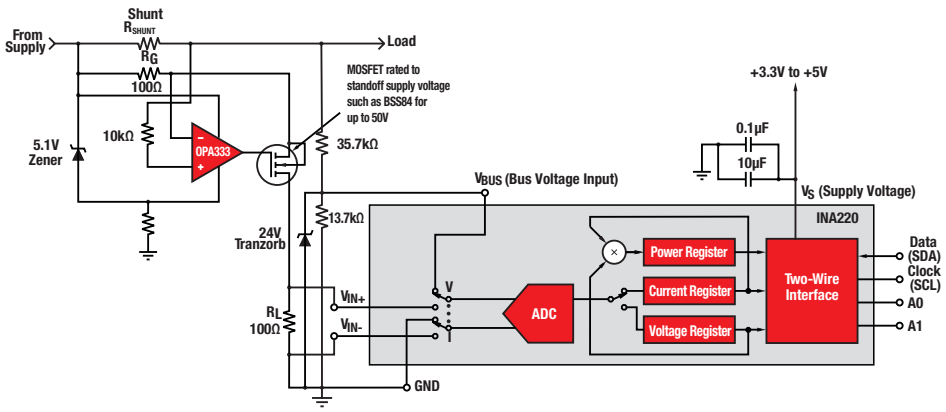
Example 1: MOSFET and Zener



Example 2: Digital isolation



Example 3: Current follower



Current Shunt Monitors

Hero Products

INA226: Highest precision solution on the market

- Integrated ADC and MUX with programmable sampling
- Common mode range = 0V to 36V
- Offset (max) = 10µV
- Gain error (max) = 0.1%
- CMRR (typ) = 140dB
- Lower cost alternative => INA219, INA230

INA210: Precision voltage output

- Gain options: 50V/V, 100V/V , 200V/V, 500V/V, 1000V/V
- Common mode range: –0.3V to 26V
- Offset (max) = 35µV
- Gain error (max) = 1%
- CMRR (typ) = 140dB
- Lower cost alternative => INA199

INA216: Designed for portable battery powered applications

- Gain options: 25V/V, 50V/V, 100V/V , 200V/V
- Common mode range = 1.8V to 5.5V
- Offset (max) = 75µV
- Gain error (max) = 0.2%
- Quiescent current = 25µA
- CMRR (typ) = 108dB
- 0.76 x 0.76mm WCSP or QFN package available

INA3221: Triple-channel digital shunt and bus voltage monitor

- Integrated ADC and MUX with programmable sampling
- Common mode range = 0V to 26V
- Offset error (max) = 80µV
- Gain error (max): 0.5%
- Quiescent current = 450µA

INA282: Widest common mode range + precision

- Common mode range = -14V to 80V
- Offset (max) = 70µV
- Offset drift (max) = 1.5µV/ºC
- Gain error (max) = 1.4%
- CMRR (typ) = 140dB
- Lower cost alternative: INA193, LMP8601

LMP8640: High bandwidth and high voltage

- Bandwidth = 950kHz
- Common mode range: -2V to 76V
- Offset (max) = 900µV
- Gain error = 0.25%
- CMRR (min) = 103dB
- Lower cost alternative: LMP8645

AMC1200: 4kV isolated amplifier

- Offset (max) =1.5mV
- Offset drift (max) = 10µV/K
- Gain error (max) = 1%
- CMRR (typ) = 108dB

LMP8481: High voltage

- Bandwidth = 270kHz
- Common mode range = 4.0V to 76V
- Offset (max) = 400µV
- Gain error (max) = 1.2%
- CMRR (typ) = 124dB
- Lower cost alternative => LMP8480

Applications:

- Battery gauge: (Coulomb Counting)
- Power supplies
- Inductive charging
- Graphics cards
- Desktops / laptops / servers
- Tablets / E-books
- Smartphones & feature phones
- Basestations
- Networking
- Industrial automation
- Automotive
- Medical
- Motor control
- Battery backups
- Inverters
- Solar

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