

High Voltage, High Precision Current Sensing with Output Level Shifting Using the **AD8210** Current Sense Amplifier and the **AD8274** Difference Amplifier

CIRCUIT FUNCTION AND BENEFITS

Current monitoring is a critical function in a variety of applications, such as power management, solenoid control, and motor control. Accurate current sensing and diagnostic protection from shorts to GND are achieved by monitoring current on the high-side of the load.

An integrated device such as the **AD8210** simplifies high-side current monitoring by providing a high voltage interface and bidirectional current monitoring capability across the shunt resistor. The **AD8210** offers high common-mode rejection ratio (CMRR) and excellent temperature performance, for optimal accuracy in the application. The **AD8210** amplifies the current

flowing through a shunt resistor to a load and provides a ground referenced output voltage that is proportional to the load current.

In applications where dual supplies are used, the output of the **AD8210** can drive a precision, low distortion difference amplifier, such as **AD8274**, as shown in Figure 1. The **AD8274** provides additional gain and level shifts the **AD8210** output to a desired output common-mode voltage, which facilitates interfacing to other circuit components that use dual supplies. The precision **AD780** provides a 2.5 V reference voltage that enables bidirectional current monitoring by the **AD8210** and provides a reference voltage for the **AD8274** level shifting function.

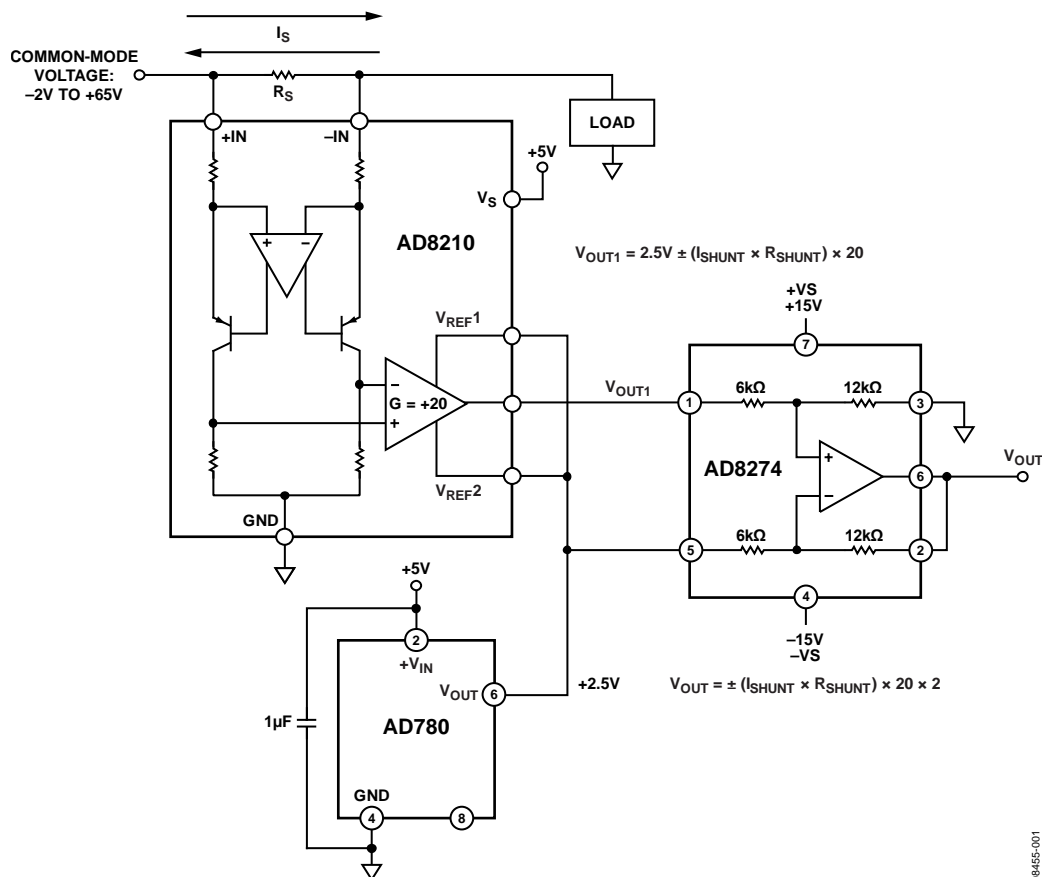


Figure 1. Current Sensing and Level Shifting Around GND Using the **AD8210**, **AD8274**, and **AD780** (Simplified Schematic, All Connections Not Shown)

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REVISION HISTORY

9/2018—Rev. 0 to Rev. A

Document Title Changed From CN0116 to AN-1579 Universal
Changes to Figure 1 1
Changes to Circuit Description Section 3

8/2009—Revision 0: Initial Version

CIRCUIT DESCRIPTION

The current to the load flows through the resistor, R_S . The voltage across the R_S resistor is amplified by the [AD8210](#) by an initial gain of 20 V/V. The [AD8210](#) can withstand an input common-mode voltage that varies from -2 V to $+65$ V. The high CMRR of the [AD8210](#) makes it possible to monitor current even in the presence of a pulse width modulator (PWM) common-mode signal, as in the case of monitoring phase current for motors driven in an H-bridge configuration. Figure 2 shows typical waveforms when monitoring a PWM motor current, and Figure 3 shows the circuit overload characteristic.

The output (V_{OUT1}) of the [AD8210](#) is proportional to the current (I_S) across the shunt resistor, as shown in the following equation:

$$V_{OUT1} = 2.5 \text{ V} \pm (R_S \times I_S \times 20)$$

where R_S is the impedance of the shunt resistor.

The [AD8210](#) output is biased at 2.5 V. This is achieved by connecting the V_{REF1} and V_{REF2} pins to the [AD780](#) precision 2.5 V reference, which allows the [AD8210](#) to monitor current flowing in both directions through the shunt resistor. When the current flows from the positive input side to the negative input side, the output goes positive above 2.5 V. When the current flows from the negative input side to the positive input side, the output goes negative below 2.5 V. The [AD780](#) output is also connected to the [AD8274](#) negative input, which ensures that the [AD8274](#) input has the same common-mode voltage as the [AD8210](#). The positive input of the [AD8274](#) is connected directly to the output of the [AD8210](#). The [AD8274](#) is powered from ± 15 V supplies and is configured in a noninverting, gain of two configuration.

The [AD8274](#) takes the difference between its two inputs, V_{IN+} and V_{IN-} , and applies a gain of 2, as shown in the following equation:

$$V_{OUT(AD8274)} = (V_{IN+} - V_{IN-}) \times 2.$$

where $V_{OUT(AD8274)}$ is the output voltage of the [AD8274](#).

Because both inputs are centered around 2.5 V, the [AD8274](#) amplifies only the difference, which results in an input-to-output transfer function for this system that is shown in the following equation:

$$V_{OUT} = \pm(R_S \times I_S \times 20) \times 2.$$

where V_{OUT} is the output voltage of the circuit.

The output common-mode voltage of the [AD8274](#) is set to 0 V by connecting Pin 3 to GND. The output voltage is then positive or negative, depending on the direction of the load current across the shunt resistor.

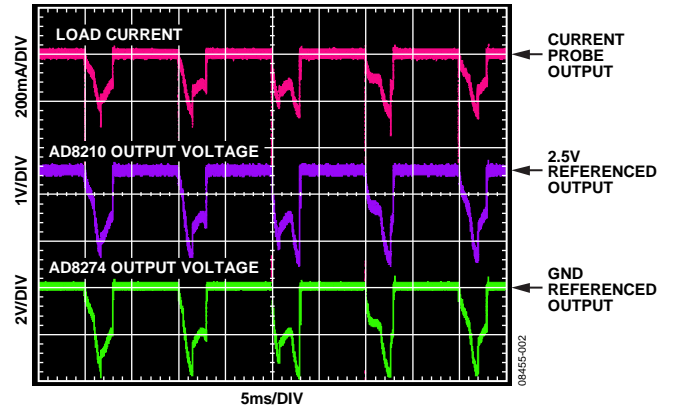


Figure 2. [AD8210](#) Output Voltage Proportional to the Load Current, [AD8274](#) Level Shifts [AD8210](#) Output

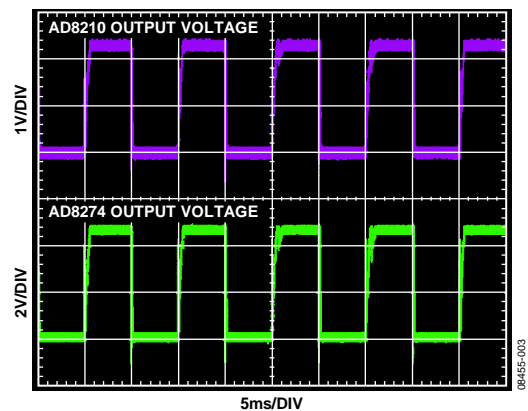


Figure 3. [AD8210](#) and [AD8274](#) Output Voltage for an Overload Condition

This circuit provides a simple and precise solution for current monitoring. The [AD8210](#) removes the high common-mode voltage and amplifies only the small voltage drop across the shunt resistor, which provides an output voltage centered around the 2.5 V applied reference. The [AD8274](#) simplifies interfacing with other components in the circuit that are powered by dual supplies by removing the 2.5 V common-mode offset of the [AD8210](#) and level shifting the output of the [AD8210](#) with respect to GND.

The 1 μ F capacitor decouples the [AD780](#) reference between its input and output pins. Connect a low inductance, 0.1 μ F ceramic decoupling capacitor (not shown in Figure 1) to the V_S pin, close to the two ICs. A typical decoupling network consists of a 1 μ F to 10 μ F electrolytic capacitor in parallel with a 0.1 μ F low inductance, multilayer ceramic capacitor (MLCC) type.

Excellent layout, grounding, and decoupling techniques must be used to achieve the desired performance from the circuits discussed in this application note (see the [MT-031 Tutorial](#) and the [MT-101 Tutorial](#)). As a minimum, use a 4-layer printed circuit board (PCB) with one ground plane layer, one power plane layer, and two signal layers.

COMMON VARIATIONS

The [AD8274](#) has a wide supply voltage range and can be powered from a lower dual supply of ± 5 V. A gain of 2 was chosen to provide the widest dynamic range in the application, but the [AD8274](#) can also be configured as a gain of $\frac{1}{2}$ difference amplifier, depending on the needs of the user. Other difference amplifiers, such as the [AD8271](#) and [AD8276](#), can provide precision level shifting with unity gain.

A 2.5 V reference can also be derived by creating a resistor voltage divider based on the 5 V supply to the [AD8210](#). A buffer must be used to drive the reference pins of the [AD8210](#) and [AD8274](#) because a low impedance source is necessary to maintain the gain and offset ratings (see the [AD8274](#) data sheet for details).

The [AD780](#) is an ultrahigh precision reference with superior output stability over temperature, load, and line conditions. Other lower cost references, such as the [ADR421](#) or [ADR03](#), can be substituted in applications with slightly higher error budgets.

REFERENCE

- [MT-031 Tutorial. *Grounding Data Converters and Solving the Mystery of "AGND" and "DGND."* Analog Devices.](#)
- [MT-032 Tutorial. *Ideal Voltage Feedback \(VFB\) Op Amp.* Analog Devices.](#)
- [MT-061 Tutorial. *Instrumentation Amplifier \(In-Amp\) Basics.* Analog Devices.](#)
- [MT-068 Tutorial. *Difference and Current Sense Amplifiers.* Analog Devices.](#)
- [MT-087 Tutorial. *Voltage References.* Analog Devices.](#)
- [MT-095 Tutorial. *EMI, RFI, and Shielding Concepts.* Analog Devices.](#)
- [MT-101 Tutorial. *Decoupling Techniques.* Analog Devices.](#)