ANALOG DEVICES

High-Side, Bidirectional Current Shunt Monitor

Preliminary Technical Data

AD8210

FEATURES

- Precision bidirectional current sensing
- High common-mode voltage range
  - 2 V to +65 V operating
- Gain = 20
- CMRR = 100 dB
- Wide operating temperature range
  - Die: 40°C to +150°C
  - 8-lead SOIC: 40°C to +125°C
- Adjustable offset
- Available in SOIC and die form

EXCELLENT AC AND DC PERFORMANCE

- 5 μV/°C offset drift
- 30 ppm/°C gain drift
- 80 dB CMRR dc to 10 kHz

APPLICATIONS

- 42 V dc-to-dc converter current sensing
- High-side current sensing
- Motor controls
- Transmission controls
- Diesel injection controls
- Engine management
- Suspension controls
- Vehicle dynamic controls

TYPICAL OPERATING CIRCUIT

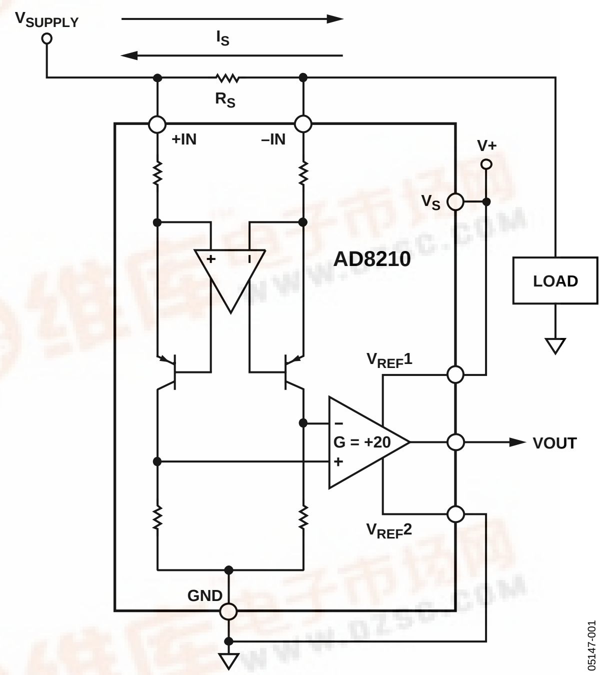


Figure 1.

GENERAL DESCRIPTION

The AD8210 is a high-side, single-supply, bidirectional current shunt monitor that features a wide input, common-mode voltage range of 2 V to +65 V, high bandwidth, a set gain of 20, and a typical 5 V supply voltage.

The AD8210 is offered in die and packaged form. The operating temperature range for the die is 25°C higher (up to 150°C) than that of the packaged part, which enables the user to apply the AD8210 in high temperature applications.

Excellent ac and dc performance over temperature keeps errors in the measurement loop to a minimum. Offset drift is typically below 5 μV/°C, and the gain drift is typically below 30 ppm/°C.

Bidirectional current measurement is achieved by offsetting the output between 0.05 V and 4.8 V with a 5 V supply. With the $V_{REF}2$ pin connected to the V+ pin, and the $V_{REF}1$ pin connected to the GND pin, the output is set at half scale. Attaching both V_{REF} pins to GND causes the output to be unipolar, starting near ground. Attaching both V_{REF} pins to V+ causes the output to be unipolar starting near V+. Other offsets can be obtained by applying an external voltage to $V_{REF}1$ and $V_{REF}2$ pins.

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 781.329.4700　www.analog.com
Fax: 781.326.8703

TABLE OF CONTENTS

REVISION HISTORY

1/05 Revision PrB: Preliminary Version

SPECIFICATIONS

T_A = operating temperature range, V_S = 5 V, unless otherwise noted.

Table 1.

Parameter	Conditions	AD8210 SOIC			AD8210 Die			Unit
		Min	Typ	Max	Min	Typ	Max	
GAIN								
Gain			20			20		V/V
Accuracy	V_O 0.1 V dc		–0.5	–1		–0.5	–1.5	%
Accuracy Over Temperature	Specified temperature range			–1.5			–2.5	%
Gain vs. Temperature			–20			–30		ppm/°C
VOLTAGE OFFSET								
Offset Voltage (RTI)	25°C			–1			–2	mV
Over Temperature (RTI)	Specified temperature range			–2			–4	mV
Offset Drift			5			10		µV/°C
INPUT								
Input Impedance								
Differential			2			2		k
Common Mode	V common-mode > 5 V		5			5		M
Common Mode	V common-mode < 5 V		3.5			3.5		k
Input Voltage Range	Common-mode, continuous	2		+65	2		+65	V
Input Voltage Range	Differential, unconditional		250			250		mV
Input Voltage Range	Differential		–125			–125		mV
Common-Mode Rejection	f = 1 kHz	100						dB
Common-Mode Rejection	f = 10 kHz	100			90			dB
OUTPUT								
Output Voltage Range		0.05		4.8	0.05		4.8	V
DYNAMIC RESPONSE								
Small Signal 3 dB Bandwidth			500			500		kHz
Slew Rate			3			3		V/µs
NOISE								
0.1 Hz to 10 Hz, RTI			TBD			TBD		µV p-p
Spectral Density, 1 kHz, RTI			TBD			TBD		µV/ Hz
OFFSET ADJUSTMENT								
Offset Adjustment Range	V_S = 5 V	0.05		4.8	0.05		4.8	V
POWER SUPPLY								
Operating Range	For specified performance	4.5		5.5	4.5		5.5	V
Quiescent Current Over Temperature	V_O = 0.1 V dc		0.5	1		0.5	1	mA
Power-Supply Rejection Ratio		80			80			dB
TEMPERATURE RANGE								
For Specified Performance	Operating temperature range	40		+125	40		+150	°C

ABSOLUTE MAXIMUM RATINGS

Table 2.

Parameter	Rating
Supply Voltage	12 V
Continuous Input Voltage	65 V
Transient Input Voltage	72 V
Reverse Supply Voltage	0.3 V
Negative Common-Mode Range	2.3 V
Operating Temperature Range	40°C to +125°C
Storage Temperature	65°C to +150°C
Lead Temperature Range	300°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or any other conditions above those indicated in the operational section of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ESD CAUTION

ESD (electrostatic discharge) sensitive device. Electrostatic charges as high as 4000 V readily accumulate on the human body and test equipment and can discharge without detection. Although this product features proprietary ESD protection circuitry, permanent damage may occur on devices subjected to high energy electrostatic discharges. Therefore, proper ESD precautions are recommended to avoid performance degradation or loss of functionality.

PIN CONFIGURATION AND FUNCTION DESCRIPTIONS

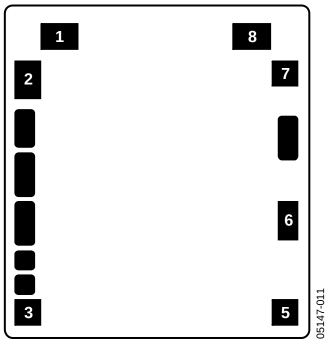


Figure 2. Metallization Diagram

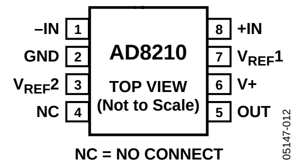


Figure 3. Pin Configuration

Table 3. Pin Function Descriptions

Pin No.	Mnemonic	X	Y
1	IN		
2	GND		
3	$V_{REF}2$		
4	NC		
5	OUT		
6	V+		
7	$V_{REF}1$		
8	+IN		

TYPICAL PERFORMANCE CHARACTERISTICS

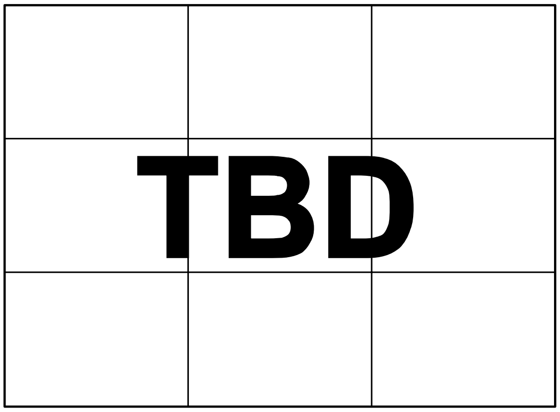


Figure 4. Typical Offset Drift

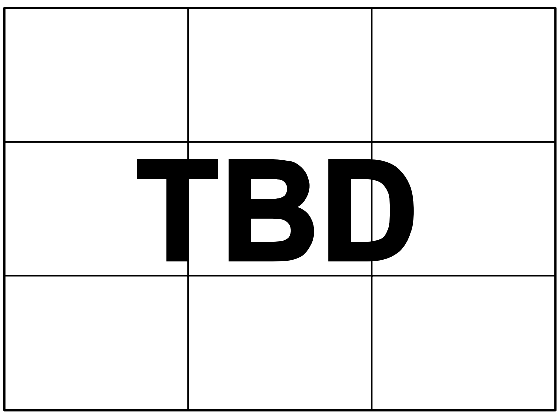


Figure 5. CMR vs. Frequency

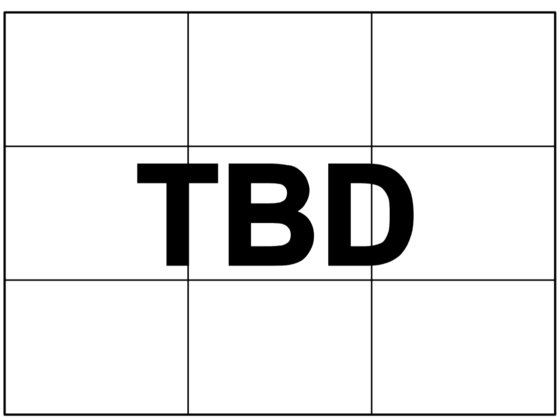


Figure 6. Gain Drift

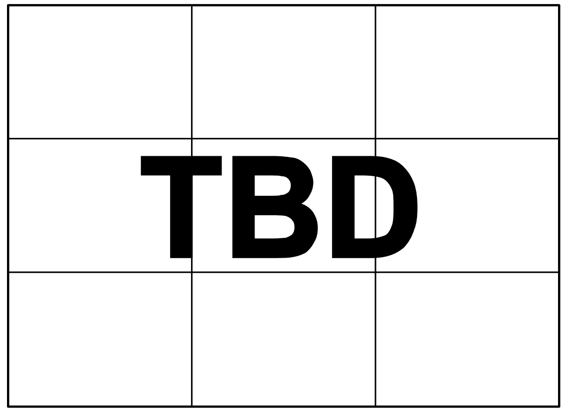


Figure 7. Typical Small Signal Bandwidth (V_{OUT} = 200 mV p-p)

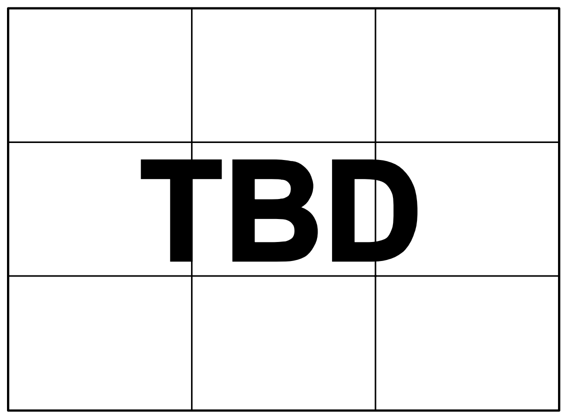


Figure 8. Quiescent Current vs. Common-Mode Voltage

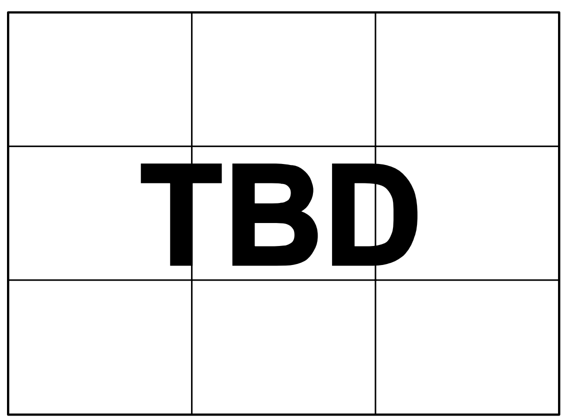


Figure 9. Differential Overload Recovery (Falling)

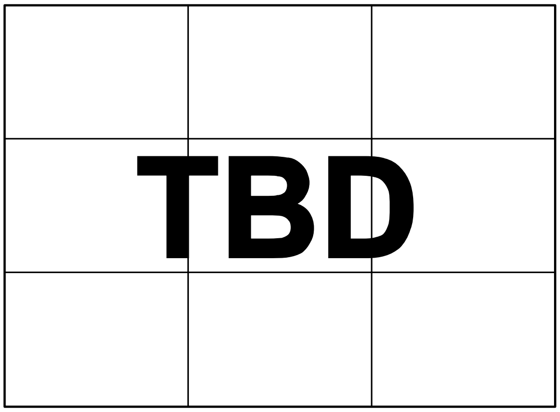


Figure 10. Gain Drift

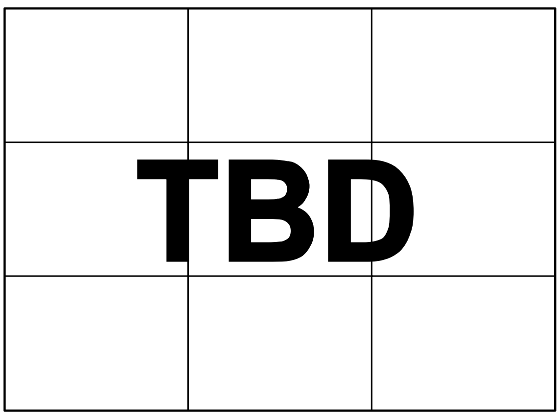


Figure 11. Settling Time

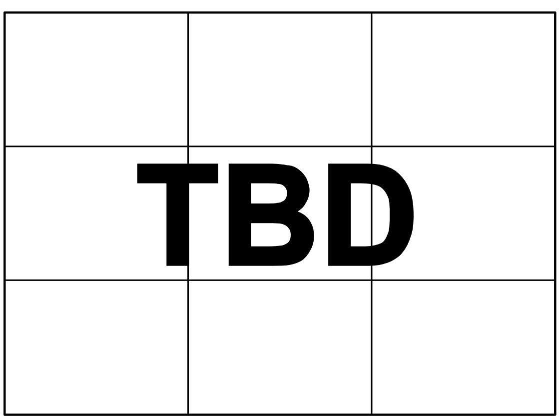


Figure 12. Quiescent Current vs. Output Voltage

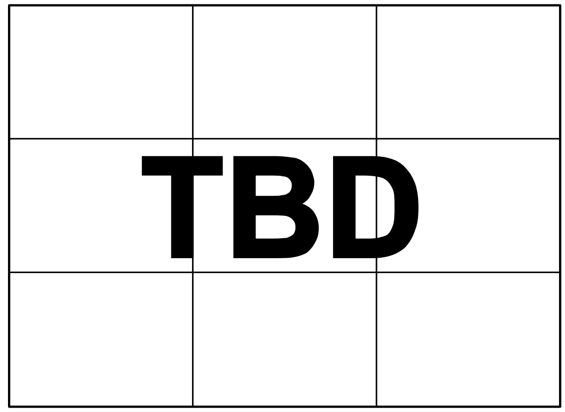


Figure 13. Common-Mode Response

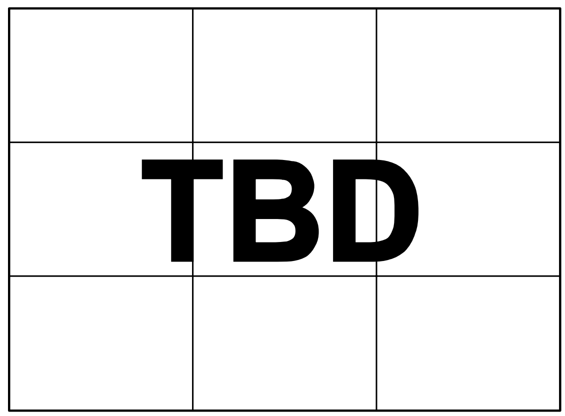


Figure 14. Rise/Fall Time

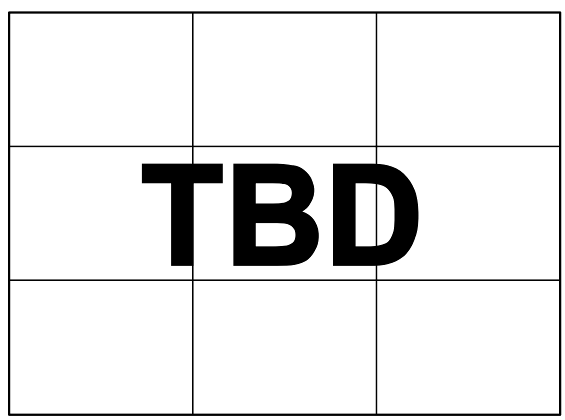


Figure 15. Input Common-Mode Range vs. Supply

THEORY OF OPERATION

The AD8210 is a single-supply current shunt amplifier that uses a unique architecture to accurately amplify small differential current shunt voltages in the presence of rapidly changing common-mode voltages. It is offered in both packaged and die form.

In typical applications, the AD8210 is used to measure current by amplifying the voltage across a current shunt placed across the inputs.

The gain of the AD8210 is 20 V/V, with an accuracy of 1.5%. This accuracy is guaranteed over the operating temperature range of 40°C to +125°C. The die temperature range is 40°C to +150°C with a guaranteed gain accuracy of 2.5%.

The AD8210 operates with a single supply from 4.5 V to 5.5V (absolute maximum = 12.5 V). The supply current is typically less than 1 mA.

The AD8210 is comprised of two main blocks, a differential and an instrumentation amplifier. A load current flowing through the external shunt resistor produces a voltage at the input terminals of the AD8210. The input terminals are connected to the differential amplifier (A1) by Resistors R1 and R2. A1 nulls the voltage appearing across its own input terminals by adjusting the current through R1 and R2 with Transistors Q1 and Q2. When the input signal to the AD8210 is 0, the currents in R1 and R2 are equal. When the differential signal is nonzero, the current increases through one of the resistors and decreases in the other. The current difference is proportional to the size and polarity of the input signal. Since the differential input voltage is converted into a current, common-mode rejection is no longer reliant on resistor matching, and high accuracy and performance is provided throughout the wide common-mode voltage range.

The differential currents through QI and Q2 are converted into a differential voltage due to R3 and R4. A2 is configured as an instrumentation amplifier, and this differential input signal is converted into a single-ended output voltage by A2. The gain is internally set with thin-film resistors to 20V/V.

The output reference voltage is easily programmed by the $V_{REF}1$ and $V_{REF}2$ pins. In a typical configuration, $V_{REF}1$ is connected to V_{CC} while $V_{REF}2$ to GND. In this case, the output is centered at $V_{CC}/2$ when the input signal is 0.

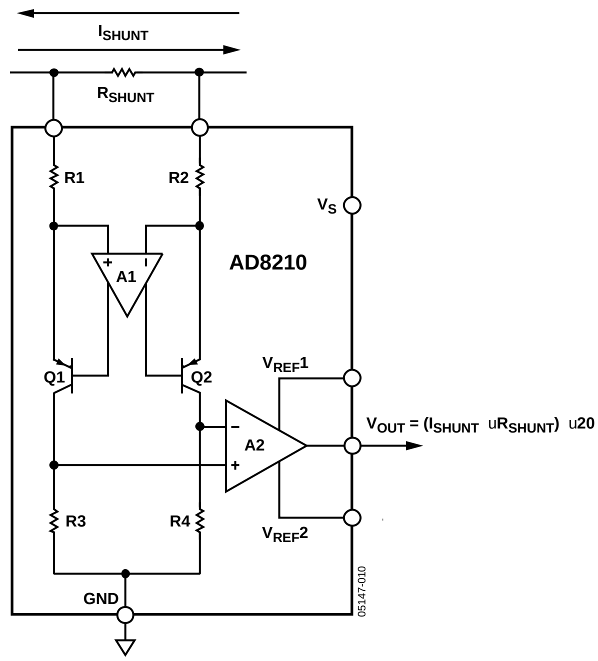


Figure 16. Simplified Schematic

OUTPUT OFFSET ADJUSTMENT

The output of the AD8210 can be adjusted for unidirectional or bidirectional operation.

UNIDIRECTIONAL OPERATION

Unidirectional operation allows the AD8210 to measure currents through a resistive shunt in one direction. The basic modes for unidirectional operation are ground-referenced output mode and V+ referenced output mode.

With unidirectional operation, the output can be set at the negative rail (near ground) or at positive rail (near V+) when the differential input is 0 V. The output moves to the opposite rail when a correct polarity differential input voltage is applied. In this case, full scale is approximately 250 mV. The required polarity of the differential input depends on the output voltage setting. If the output is set at the positive rail, the input polarity needs to be negative to move the output down. If the output is set at ground, the polarity is positive to move the output up.

GROUND REFERENCED OUTPUT

When using the AD8210 in this mode, both reference inputs are tied to ground, which causes the output to sit at the negative rail when there are zero differential volts at the input (see Figure 17).

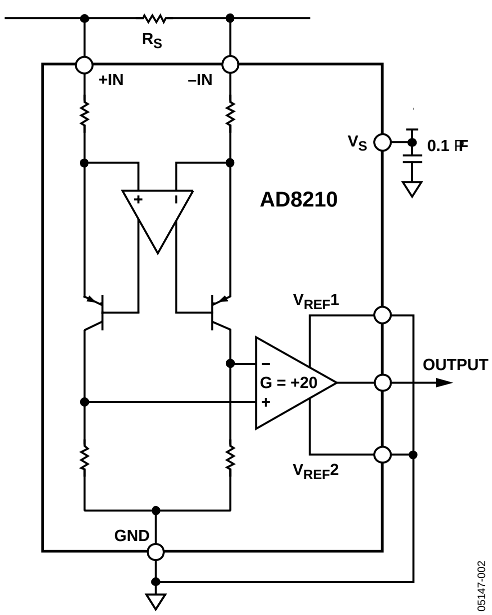


Figure 17. Ground Referenced Output

Table 4. V+ =5 V

VIN (Referred to IN)	VO
0 V	0.05 V
250 mV	4.8 V

V+ REFERENCED OUTPUT

This mode is set when both reference pins are tied to the positive supply. It is typically used when the diagnostic scheme requires detection of the amplifier and the wiring before power is applied to the load (see Figure 18).

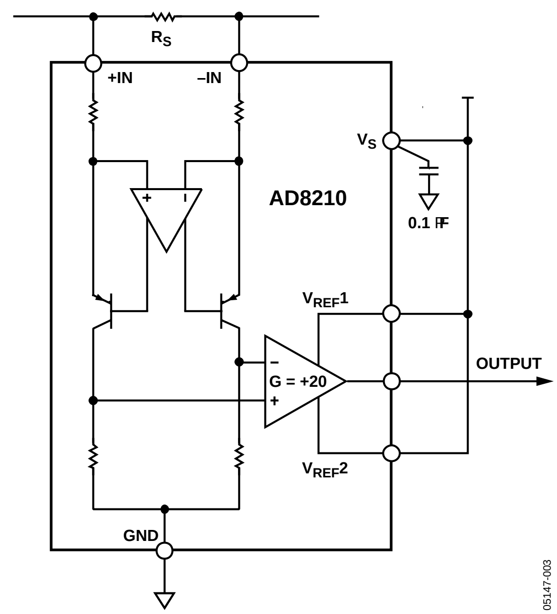


Figure 18. V+ Referenced Output

Table 5. V+ =5 V

VIN (Referred to IN)	VO
0 V	4.8 V
250 mV	0.05 V

BIDIRECTIONAL OPERATION

Bidirectional operation allows the AD8210 to measure currents through a resistive shunt in two directions.

In this case, the output is set anywhere within the output range. Typically, it is set at half-scale for equal range in both directions. In some cases, however, it is set at a voltage other than half-scale when the bidirectional current is nonsymmetrical.

Table 6. V+ =5 V, V_O = 25 with V_{IN} = 0V

VIN (Referred to IN)	VO
+100 mV	4.5 V
100 mV	0.5 V

Adjusting the output is accomplished by applying voltage(s) to the reference inputs.

Pins $V_{REF}1$ and $V_{REF}2$ are tied to internal resistors that connect to an internal offset node. There is no operational difference between the pins.

EXTERNAL REFERENCE OUTPUT

Tying both pins together and to a reference produces an output at the reference voltage when there is no differential input (see Figure 19). The output moves down from the reference voltage when the input is negative relative to the IN pin and up when the input is positive relative to the IN pin.

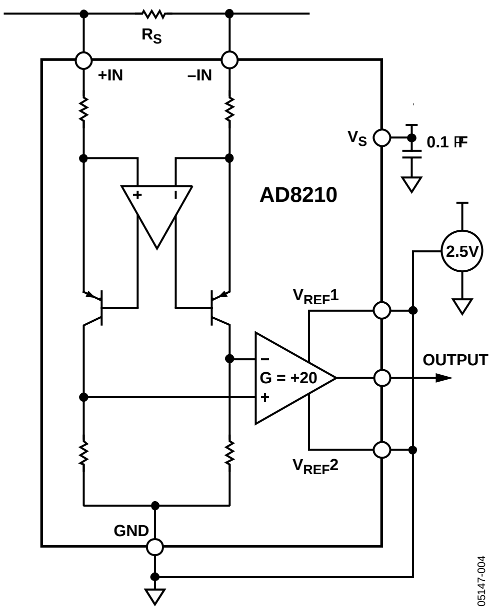


Figure 19. External Reference Output

SPLITTING AN EXTERNAL REFERENCE

In this case, an external reference is divided by 2 with an accuracy of approximately 0.5% by connecting one V_{REF} pin to ground and the other V_{REF} pin to the reference (see Figure 20).

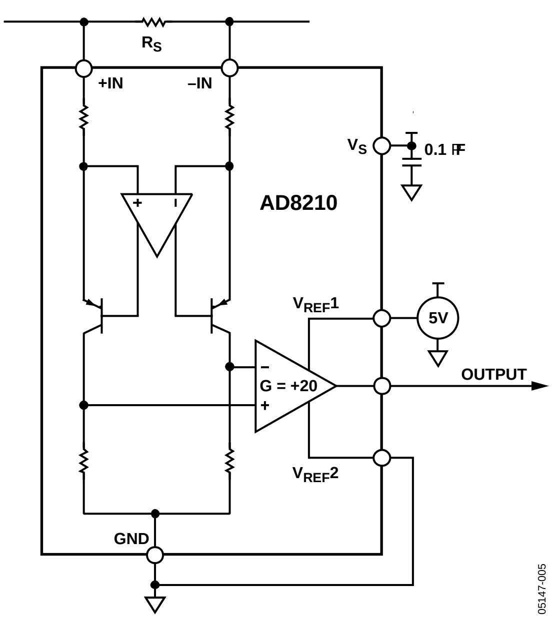


Figure 20. Split External Reference

SPLITTING THE SUPPLY

By tying one reference pin to V+ and the other to the GND pin, the output is set at half of the supply when there is no differential input (see Figure 21). The benefit is that no external reference is required to offset the output for bidirectional current measurement. This creates a midscale offset that is ratiometric to the supply, which means that if the supply increases or decreases, the output remains at half the supply. For example, if the supply is 5.0 V, the output is at half scale or 2.5 V. If the supply increases by 10% (to 5.5 V), the output goes to 2.75 V.

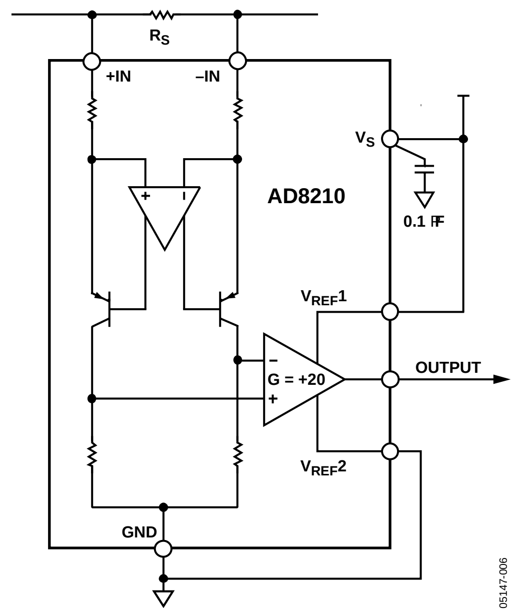


Figure 21. Split Supply

APPLICATIONS

A typical application for the AD8210 is high-side measurement of a current through a solenoid for PWM control of the solenoid opening. Typical applications include hydraulic transmission control and diesel injection control.

Two typical circuit configurations are used for this type of application.

HIGH-SIDE CURRENT SENSE WITH A LOW-SIDE SWITCH

In this case, the PWM control switch is ground referenced. An inductive load (solenoid) is tied to a power supply. A resistive shunt is placed between the switch and the load (see Figure 22). An advantage of placing the shunt on the high side is that the entire current, including the recirculation current, can be measured since the shunt remains in the loop when the switch is off. In addition, diagnostics can be enhanced because shorts to ground can be detected with the shunt on the high side.

In this circuit configuration, when the switch is closed, the common-mode voltage moves down to near the negative rail. When the switch is opened, the voltage reversal across the inductive load causes the common-mode voltage to be held one diode drop above the battery by the clamp diode.

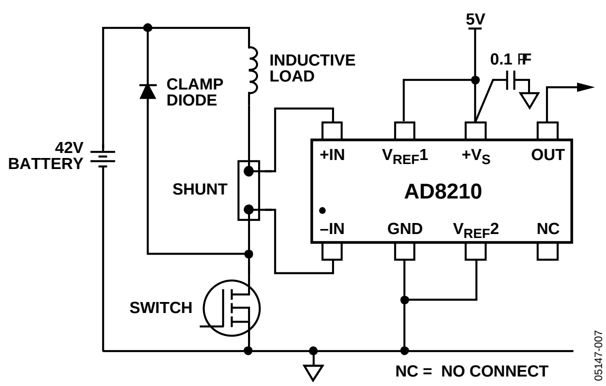


Figure 22. Low-Side Switch

HIGH-SIDE CURRENT SENSE WITH A HIGH-SIDE SWITCH

This configuration minimizes the possibility of unexpected solenoid activation and excessive corrosion (see Figure 23). In this case, both the switch and the shunt are on the high side. When the switch is off, this removes the battery from the load, which prevents damage from potential shorts to ground, while still allowing the recirculation current to be measured and providing for diagnostics. Removing the power supply from the load for the majority of the time minimizes the corrosive effects that could be caused by the differential voltage between the load and ground.

When using a high-side switch, the battery voltage is connected to the load when the switch is closed, causing the common-mode voltage to increase to the battery voltage. In this case, when the switch is opened, the voltage reversal across the inductive load causes the common-mode voltage to be held one diode drop below ground by the clamp diode.

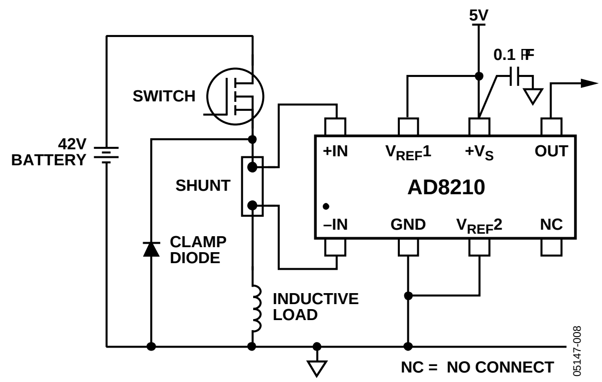


Figure 23. High-Side Switch

Another typical application for the AD8210 is as part of the control loop in H-bridge motor control. In this case, the AD8210 is placed in the middle of the H-bridge (see Figure 24) so that it can accurately measure current in both directions by using the shunt available at the motor. This is a better solution than a ground referenced op amp because ground is not typically a stable reference voltage in this type of application. This instability in the ground reference causes the measurements that could be made with a simple ground referenced op amp to be inaccurate.

The AD8210 measures current in both directions as the H-bridge switches and the motor changes direction. The output of the AD8210 is configured in an external reference bidirectional mode, see the Output Offset Adjustment.

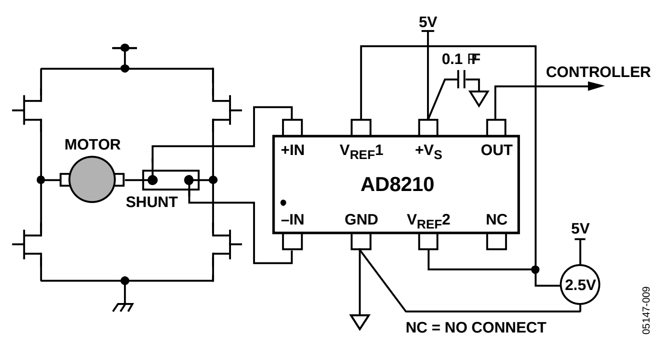
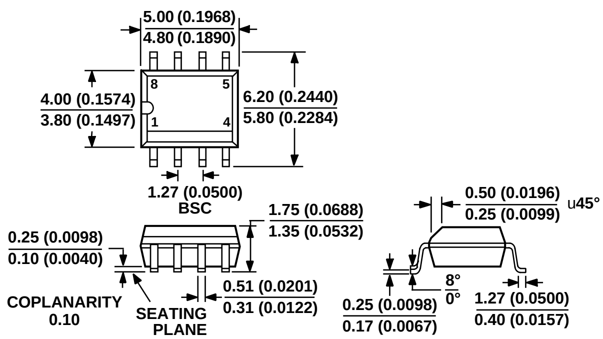


Figure 24. Motor Control Application

OUTLINE DIMENSIONS



COMPLIANT TO JEDEC STANDARDS MS-012AA
CONTROLLING DIMENSIONS ARE IN MILLIMETERS; INCH DIMENSIONS (IN PARENTHESES) ARE ROUNDED-OFF MILLIMETER EQUIVALENTS FOR REFERENCE ONLY AND ARE NOT APPROPRIATE FOR USE IN DESIGN

Figure 25. 8-Lead Standard Small Outline Package [SOIC]
Narrow Body
(R-8)
Dimensions shown in millimeters and (inches)

ORDERING GUIDE

Model	Temperature Range	Package Description	Package Option
AD8210YR	40°C to +125°C	8-Lead SOIC	R-8
AD8210YR-REEL	40°C to +125°C	8-Lead SOIC, 13 Tape and Reel	R-8
AD8210YR-REEL7	40°C to +125°C	8-Lead SOIC, 7 Tape and Reel	R-8
AD8210YCSURF	40°C to +150°C	Die Form	

PR05147 0 1/05(PrB)

ANALOG DEVICES

www.analog.com