HIGH-SIDE MEASUREMENT CURRENT SHUNT MONITOR

FEATURES

- **Qualified for Automotive Applications**
- **ESD Protection Exceeds 2000 V Per MIL-STD-883, Method 3015; Exceeds 200 V Using Machine Model (C = 200 pF, R = 0)**
- **Complete Unipolar High-Side Current Measurement Circuit**
- **Wide Supply and Common-Mode Ranges**
  - **INA139: 2.7 V to 40 V**
  - **INA169: 2.7 V to 60 V**
- **Independent Supply and Input Common-Mode Voltages**
- **Single Resistor Gain Set**
- **Low Quiescent Current (60 μA Typ)**
- **Wide Temperature Range: −40°C to +125°C**
- **TSSOP-8 Package**

APPLICATIONS

- **Current Shunt Measurement:**
  - **Automotive, Telephone, Computers**
- **Portable And Battery-Backup Systems**
- **Battery Chargers**
- **Power Management**
- **Cell Phones**
- **Precision Current Source**

DESCRIPTION

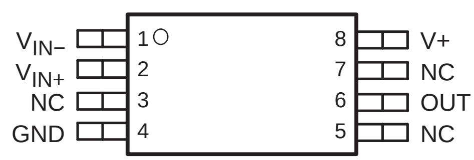
The INA139 and INA169 are high-side, unipolar, current shunt monitors. Wide input common-mode voltage range, high-speed, low quiescent current, and tiny TSSOP-8 packaging enable use in a variety of applications.

Input common-mode and power-supply voltages are independent and can range from 2.7 V to 40 V for the INA139 and 2.7 V to 60 V for the INA169. Quiescent current is only 60 μA, which permits connecting the power supply to either side of the current measurement shunt with minimal error.

The device converts a differential input voltage to a current output. This current is converted back to a voltage with an external load resistor that sets any gain from 1 to over 100. Although designed for current shunt measurement, the circuit invites creative applications in measurement and level shifting.

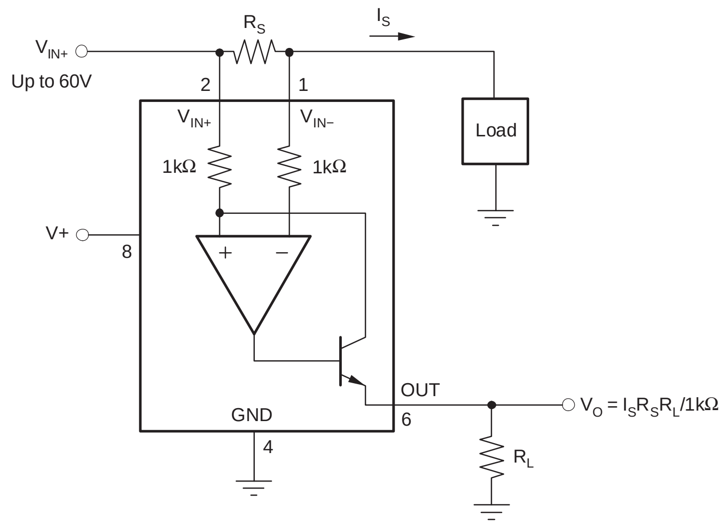
Both the INA139 and INA169 are available in TSSOP-8 and are specified for the −40°C to 125°C temperature range.

PW PACKAGE (TOP VIEW)



NC − No internal connection

These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.



ORDERING INFORMATION(1)

PRODUCT	PACKAGE−LEAD	PACKAGE DESIGNATOR(2)	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	TRANSPORT MEDIA, QUANTITY
INA139QPWRQ1	TSSOP−8	PW	−40°C to 125°C	INA139	Tape and Reel, 2000
INA169QPWRQ1	TSSOP−8	PW	−40°C to 125°C	INA169	Tape and Reel, 2000

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

ABSOLUTE MAXIMUM RATINGS

over operating free-air temperature range unless otherwise noted(1)

Supply voltage range, V+	INA139-Q1	−0.3 V to 60 V
	INA169-Q1	−0.3 V to 75 V
Analog input voltage range, V_{IN+}, V_{IN-} , Common mode	INA139-Q1	−0.3 V to 60 V
	INA169-Q1	−0.3 V to 75 V
Analog input voltage range, (V_{IN+}) − (V_{IN-}), Differential		−40 V to 2 V
Analog output range, out		−0.3 V to 40 V
Operating temperature range		−55°C to 125°C
Storage temperature range		−65°C to 150°C
Maximum junction temperature		150°C
Thermal resistance, junction-to-ambient, $R_{\Theta JA}$		150°C/W
Lead temperature (soldering, 10 seconds)		260°C

(1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

T_A = −40°C to 125°C, V_S = 5 V, V_{IN+} = 12 V, and R_{OUT} = 25 kΩ unless otherwise noted

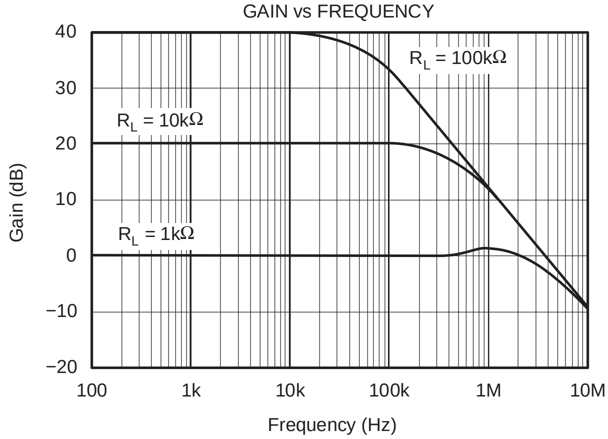
PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT						
Full-scale sense voltage	$V_{SENSE} = V_{IN+} - V_{IN-}$			100	500	mV
Common-mode input range (V_{IN+})		INA139	2.7		40	V
		INA169	2.7		60	
Common-mode rejection	V_{IN+} = 2.7 V to 40 V, V_{SENSE} = 50 mV	INA139	100	115		dB
	V_{IN+} = 2.7 V to 60 V, V_{SENSE} = 50 mV	INA169	100	120		
Offset voltage(1) RTI				±0.2	±2	mV
Offset voltage vs temperature				1		μV/°C
Offset voltage vs power supply, V+	V+ = 2.7 V to 40 V, V_{SENSE} = 50 mV	INA139		0.5	10	μV/V
	V+ = 2.7 V to 60 V, V_{SENSE} = 50 mV	INA169		0.1	10	
Input bias current				10		μA
OUTPUT						
Transconductance	V_{SENSE} = 10 mV to 150 mV		980	1000	1020	μA/V
Transconductance vs temperature	V_{SENSE} = 100 mV			10		nA/°C
Nonlinearity error	V_{SENSE} = 10 mV to 150 mV			±0.01 %	±0.2%	
Total output error	V_{SENSE} = 100 mV			±0.5%	±2%	
Output impedance				1		GΩ
				5		pF
Voltage output swing to power supply, V+				(V+) − 0.9	(V+) − 1.2	V
Voltage output swing to common mode, V_{CM}				V_{CM} − 0.6	V_{CM} − 1	V
FREQUENCY RESPONSE						
Bandwidth		R_{OUT} = 10 kΩ		440		kHz
		R_{OUT} = 20 kΩ		220		
Settling time (0.1%)	5 V step	R_{OUT} = 10 kΩ		2.5		μs
		R_{OUT} = 20 kΩ		5		
NOISE						
Output-current noise density				20		pA/√Hz
Total output-current noise	BW = 100 kHz			7		nA RMS
POWER SUPPLY						
Operating range, V+		INA139	2.7		40	V
		INA169	2.7		60	
Quiescent current	V_{SENSE} = 0, I_O = 0			60	125	μA

(1) Defined as the amount of input voltage, V_{SENSE}, to drive the output to zero.

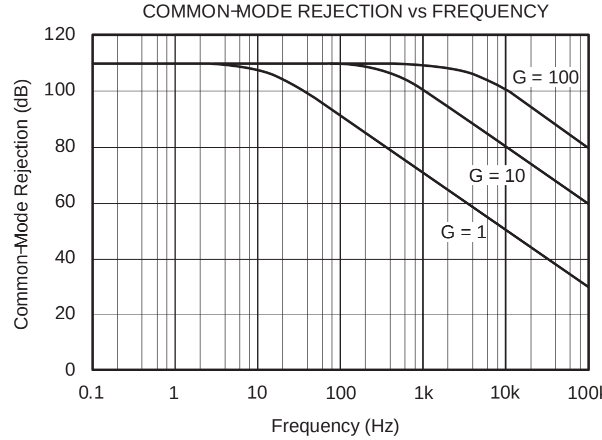
TYPICAL CHARACTERISTICS

Typical characteristics are at T_A = 25°C, V+ = 5 V, V_{IN+} = 12 V, and R_L = 125 kΩ, unless otherwise noted.

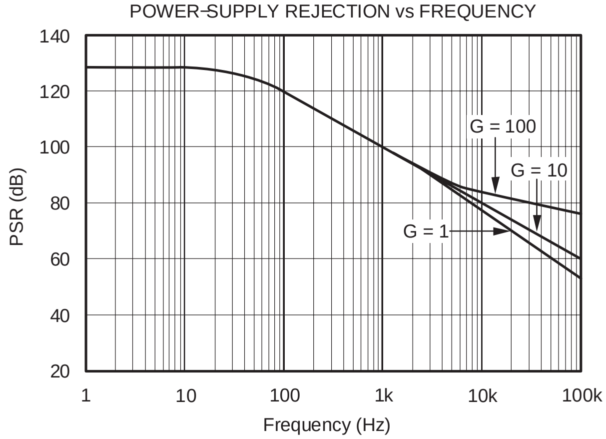
GAIN vs FREQUENCY



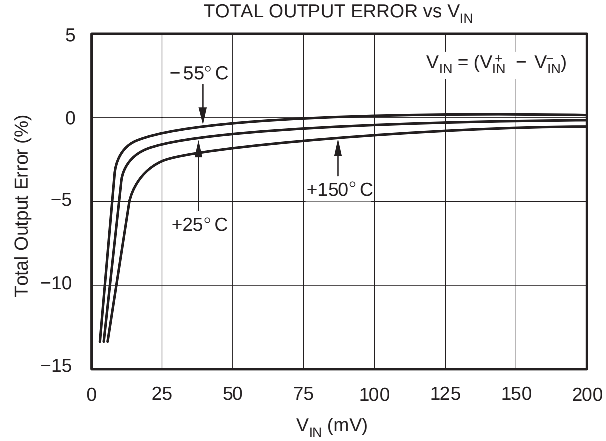
COMMON−MODE REJECTION vs FREQUENCY



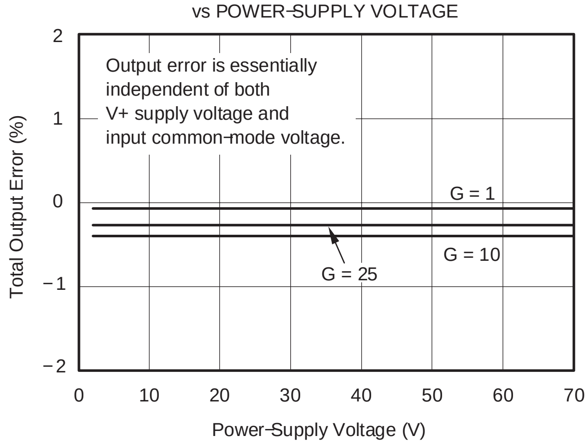
POWER−SUPPLY REJECTION vs FREQUENCY



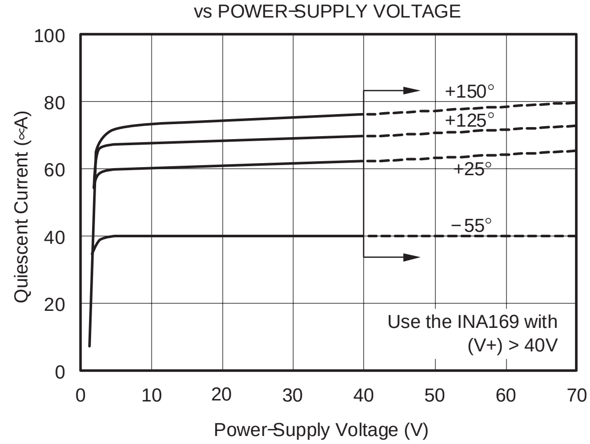
TOTAL OUTPUT ERROR vs V_{IN}



TOTAL OUTPUT ERROR
vs POWER−SUPPLY VOLTAGE



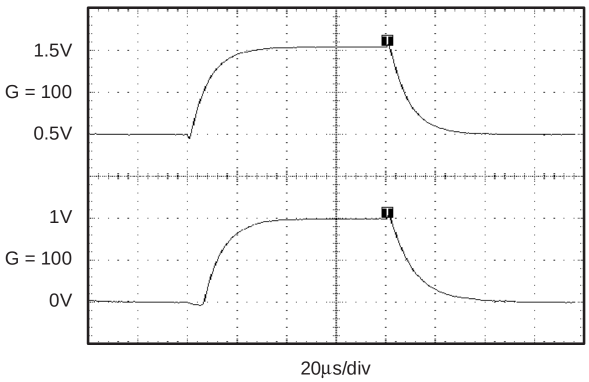
QUIESCENT CURRENT
vs POWER−SUPPLY VOLTAGE



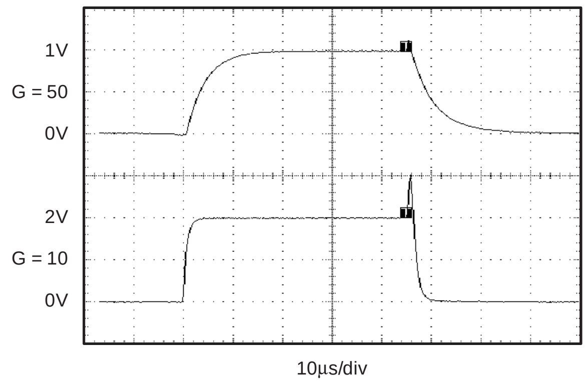
TYPICAL CHARACTERISTICS (CONTINUED)

Typical characteristics are at T_A = +25°C, V+ = 5 V, V_{IN+} = 12 V, and R_L = 125 kΩ, unless otherwise noted.

STEP RESPONSE



STEP RESPONSE



APPLICATION INFORMATION

Figure 1 illustrates the basic circuit diagram for both the INA139 and INA169. Load current I_S is drawn from supply V_S through shunt resistor R_S. The voltage drop in shunt resistor V_S is forced across R_{G1} by the internal operational amplifier, causing current to flow into the collector of Q1. External resistor R_L converts the output current to a voltage, V_{OUT}, at the OUT pin.

The transfer function for the INA139 is:

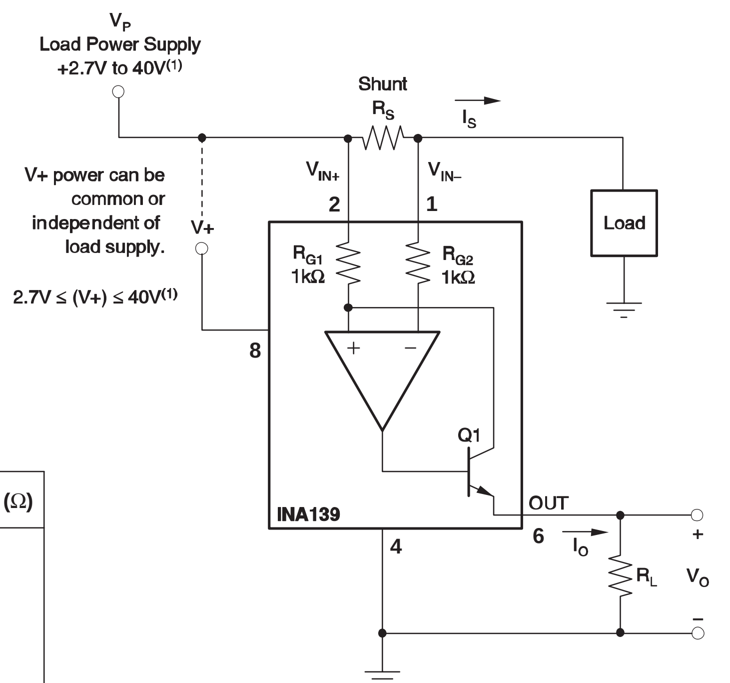
$$I_O = g_m\,(V_{IN+} - V_{IN-})$$

where g_m = 1000 µA/V.

In the circuit of Figure 1, the input voltage ($V_{IN}+ - V_{IN-}$) is equal to I_S x R_S and the output voltage (V_{OUT}) is equal to I_O x R_L. The transconductance (g_m) of the INA139 is 1000 µA/V. The complete transfer function for the current measurement amplifier in this application is:

$$V_{OUT} = (I_S)\,(R_S)\,(1000\ \mu A/V)\,(R_L)$$

The maximum differential input voltage for accurate measurements is 0.5 V, which produces a 500-µA output current. A differential input voltage of up to 2 V will not cause damage. Differential measurements (pins 3 and 4) must be unipolar with a more-positive voltage applied to pin 3. If a more-negative voltage is applied to pin 3, the output current, I_O, will be zero, but it will not cause damage.



VOLTAGE GAIN	EXACT R_L (Ω)	NEAREST 1% R_L (Ω)
1	1k	1k
2	2k	2k
5	5k	4.99k
10	10k	10k
20	20k	20k
50	50k	49k
100	100k	100k

NOTE: (1) Maximum V_P and V+ voltage is 60V with the INA169.

Figure 1. Basic Circuit Connections

BASIC CONNECTION

Figure 1 shows the basic connection of the INA139. The input pins, V_{IN+} and V_{IN-}, should be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance. The output resistor, R_L, is shown connected between pin 1 and ground. Best accuracy is achieved with the output voltage measured directly across R_L. This is especially important in high-current systems where load current could flow in the ground connections, affecting the measurement accuracy.

No power-supply bypass capacitors are required for stability of the INA139. However, applications with noisy or high-impedance power supplies may require decoupling capacitors to reject power-supply noise; connect bypass capacitors close to the device pins.

POWER SUPPLIES

The input circuitry of the INA139 can accurately measure beyond its power-supply voltage, V+. For example, the V+ power supply can be 5 V, whereas the load power supply voltage is up to 36 V (or 60 V with the INA169). However, the output voltage range of the OUT terminal is limited by the lesser of the two voltages (see the *Output Voltage Range* section).

SELECTING R_S AND R_L

The value chosen for the shunt resistor, R_S , depends on the application and is a compromise between small-signal accuracy and maximum permissible voltage loss in the measurement line. High values of R_S provide better accuracy at lower currents by minimizing the effects of offset, while low values of R_S minimize voltage loss in the supply line. For most applications, best performance is attained with an R_S value that provides a full-scale shunt voltage range of 50 mV to 100 mV. Maximum input voltage for accurate measurements is 500 mV.

R_L is chosen to provide the desired full-scale output voltage. The output impedance of the INA139 OUT terminal is very high, which permits using values of R_L up to 100 kΩ with excellent accuracy. The input impedance of any additional circuitry at the output should be much higher than the value of R_L to avoid degrading accuracy.

Some analog-to-digital (A/D) converters have input impedances that significantly affect measurement gain. The input impedance of the A/D converter can be included as part of the effective R_L if its input can be modeled as a resistor to ground. Alternatively, an op amp can be used to buffer the A/D converter input as shown in Figure 2. See Figure 1 for recommended values of R_L.

OUTPUT VOLTAGE RANGE

The output of the INA139 is a current, which is converted to a voltage by the load resistor, R_L. The output current remains accurate within the compliance voltage range of the output circuitry. The shunt voltage and the input common-mode and power-supply voltages limit the maximum possible output swing. The maximum output voltage compliance is limited by the lower of the two equations below:

$$V_{OUT\ MAX} = (V+) - 0.7\ V - (V_{IN+} - V_{IN-})$$

or

$$V_{OUT\ MAX} = V_{IN-} - 0.5\ V$$

(whichever is lower)

BANDWIDTH

Measurement bandwidth is affected by the value of the load resistor, R_L. High gain produced by high values of R_L yields a narrower measurement bandwidth (see the *Typical Characteristics* section). For widest possible bandwidth, keep the capacitive load on the output to a minimum.

If bandwidth limiting (filtering) is desired, a capacitor can be added to the output (as shown in Figure 3), which will not cause instability.

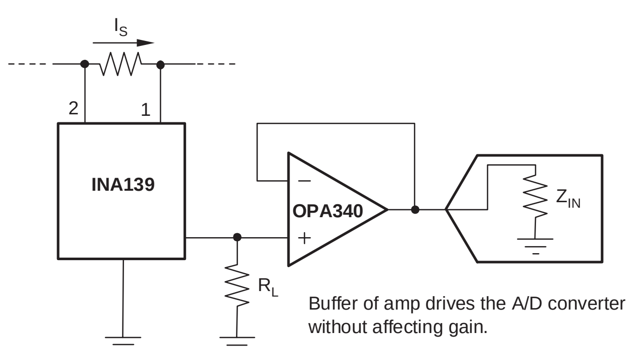


Figure 2. Buffering Output to Drive the A/D Converter

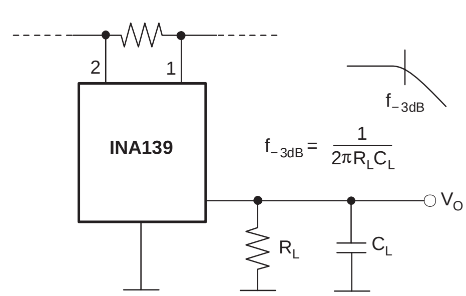


Figure 3. Output Filter

APPLICATIONS

The INA139 is designed for current shunt measurement circuits, as shown in Figure 1, but its basic function is useful in a wide range of circuitry. A few ideas are illustrated in Figure 4 through Figure 7.

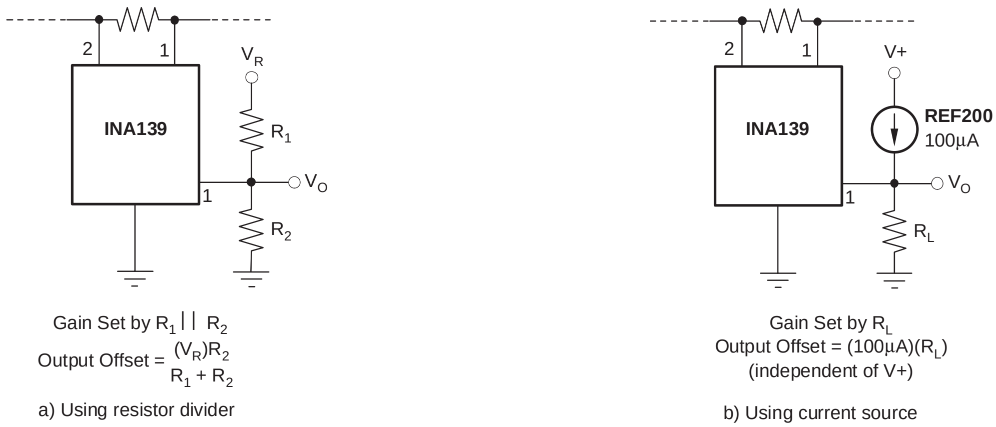


Figure 4. Offsetting the Output Voltage

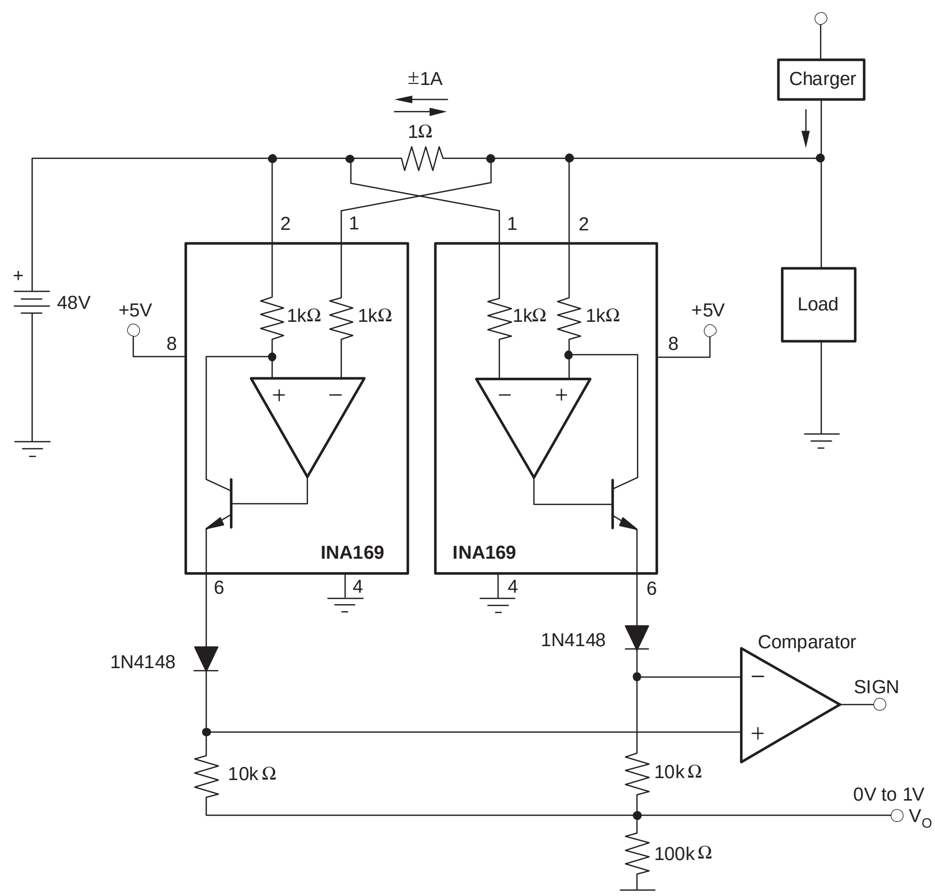
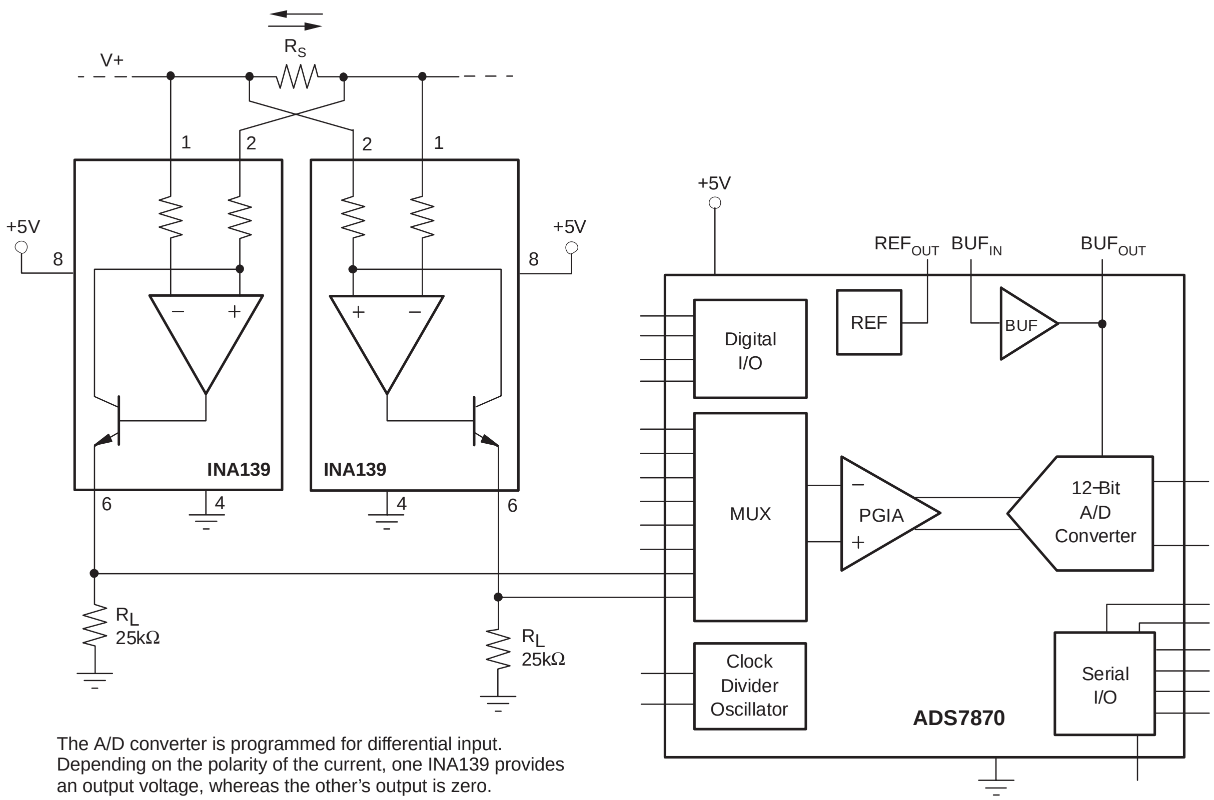


Figure 5. Bipolar Current Measurement



The A/D converter is programmed for differential input. Depending on the polarity of the current, one INA139 provides an output voltage, whereas the other's output is zero.

Figure 6. Bipolar Current Measurement Using Differential Input of A/D Converter

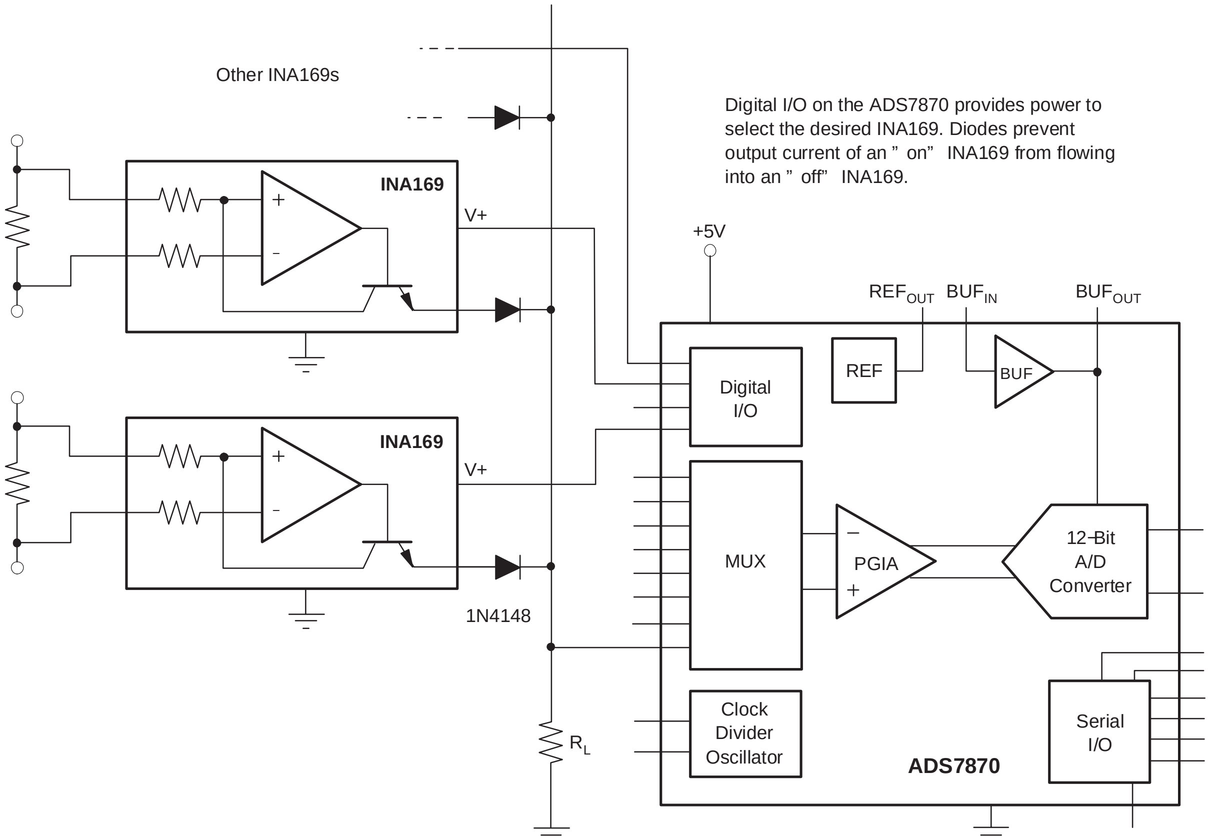


Figure 7. Multiplexed Measurement Using Logic Signal for Power

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
INA139QPWRG4Q1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
INA139QPWRQ1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR
INA169QPWRG4Q1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
INA169QPWRQ1	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF INA139-Q1, INA169-Q1 :

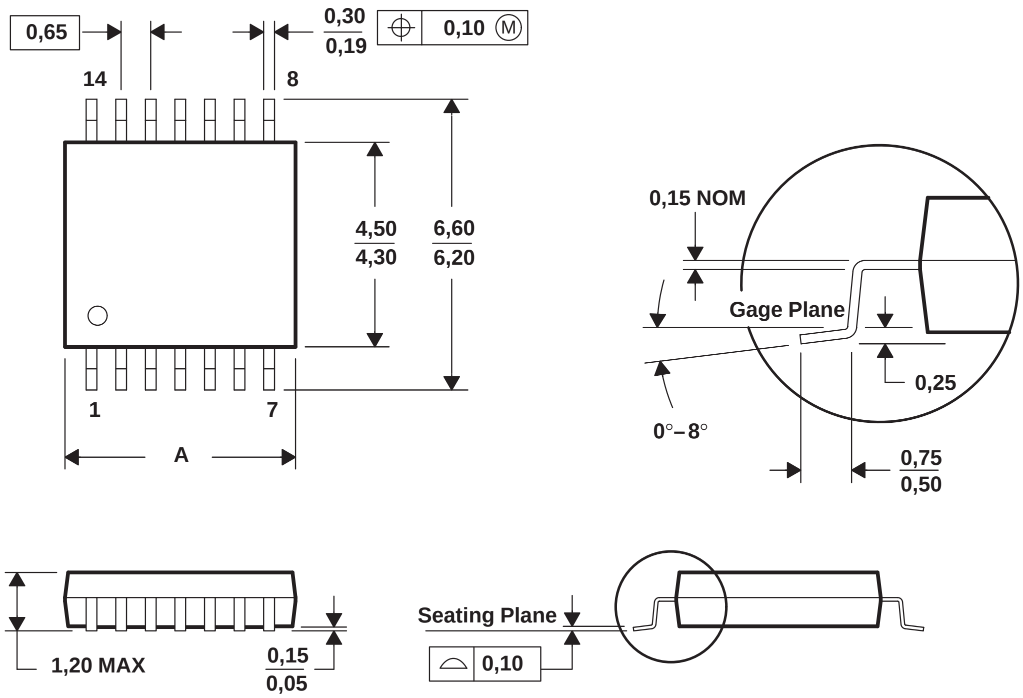
- Catalog: INA139, INA169

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

PW (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

14 PINS SHOWN



PINS ** / DIM	8	14	16	20	24	28
A MAX	3,10	5,10	5,10	6,60	7,90	9,80
A MIN	2,90	4,90	4,90	6,40	7,70	9,60

4040064/F 01/97

NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Body dimensions do not include mold flash or protrusion not to exceed 0,15.
- D. Falls within JEDEC MO-153

IMPORTANT NOTICE

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

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