



SBOS181A - DECEMBER 2000 - REVISED JANUARY 2003

High-Side Measurement CURRENT SHUNT MONITOR

FEATURES

- COMPLETE UNIPOLAR HIGH-SIDE **CURRENT MEASUREMENT CIRCUIT**
- WIDE SUPPLY AND COMMON-MODE RANGE
- INA139: 2.7V to 40V
- INA169: 2.7V to 60V
- INDEPENDENT SUPPLY AND INPUT COMMON-**MODE VOLTAGES**
- SINGLE RESISTOR GAIN SET
- LOW QUIESCENT CURRENT (60µA typ)
- SOT23-5 PACKAGE

APPLICATIONS

- **CURRENT SHUNT MEASUREMENT:** Automotive, Telephone, Computers
- PORTABLE AND BATTERY-BACKUP **SYSTEMS**
- BATTERY CHARGERS
- POWER MANAGEMENT
- CELL PHONES
- PRECISION CURRENT SOURCE

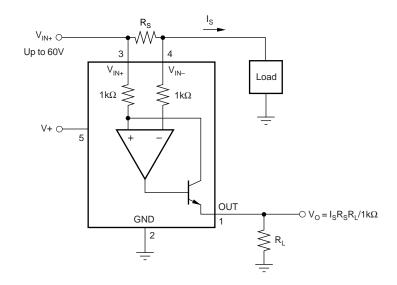
DESCRIPTION

The INA139 and INA169 are high-side, unipolar, current shunt monitors. Wide input common-mode voltage range, high-speed, low quiescent current, and tiny SOT23 packaging enable use in a variety of applications.

Input common-mode and power-supply voltages are independent and can range from 2.7V to 40V for the INA139 and 2.7V to 60V for the INA169. Quiescent current is only 60μA, 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

Both the INA139 and INA169 are available in SOT23-5 packages and are specified for the -40°C to +85°C industrial temperature range.





Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.



PACKAGE/ORDERING INFORMATION

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR ⁽¹⁾	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
INA139	SOT23-5 Surface-Mount	DBV	-40°C to +85°C	E39	INA139NA/250	Tape and Reel, 250
"	"	п	"	"	INA139NA/3K	Tape and Reel, 3000
INA169	SOT23-5 Surface-Mount	DBV	-40°C to +85°C	A69	INA169NA/250	Tape and Reel, 250
"	II II	II .	"	"	INA169NA/3K	Tape and Reel, 3000

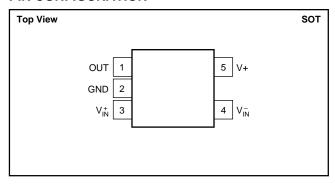
NOTE: (1) For the most current specifications and package information, refer to our web site at www.ti.com.

ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage, V+	
INA1390.3V to 60V	/
INA169 –0.3V to 75V	/
Analog Inputs, V _{IN+} , V _{IN-}	
INA139	
Common Mode0.3V to 60V	/
Differential $(V_{IN+}) - (V_{IN-})$	/
INA169	
Common Mode0.3V to 75V	/
Differential $(V_{IN+}) - (V_{IN-})$	/
Analog Output, Out0.3V to 40V	/
Operating Temperature55°C to +125°C	
Storage Temperature55°C to +125°C)
Junction Temperature+150°C)
Lead Temperature (soldering, 10s)+300°C)

NOTE: (1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.

PIN CONFIGURATION





ELECTROSTATIC DISCHARGE SENSITIVITY

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ELECTRICAL CHARACTERISTICS

At T_A = -40°C to +85°C, V_S = 5V, V_{IN+} = 12V, and R_{OUT} = 25k\Omega, unless otherwise noted.

$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$			INA139NA		INA169NA				
	RAMETER	CONDITION	MIN	TYP	MAX	MIN	TYP	MAX	UNITS
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	TU								
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		$V_{SENSE} = (V_{IN+}) - (V_{IN-})$		100	500		*	*	mV
$\begin{array}{cccccccccccccccccccccccccccccccccccc$	mmon-Mode Input Range		2.7		40	*		60	V
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	mmon-Mode Rejection		100	115					dB
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		$V_{IN+} = 2.7V$ to 60V, $V_{SENSE} = 50$ mV				100	_		dB
No Non Non Non Non Non Non Non Non Non N					±1		1 -	*	mV
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	•						*		μV/°C
	s Power Supply, V+			0.5	10				μV/V
OUTPUT Transconductance vs Temperature V _{SENSE} = 10mV - 150mV 990 1000 1010 * * * µA Nonlinearity Error Vsense = 10mV to 150mV Vsense = 10mV to 150mV 100.01 ±0.1 * * * % Total Output Error Vsense = 100mV ±0.01 ±0.1 * * * %	. 5: 0						_	10	μV/V
Transconductance	ut Bias Current	$(V_{IN+}) - (V_{IN-})$		10			*		uA
vs Temperature VsENSE = 100mV 10 * nA/ Nonlinearity Error VsENSE = 10mV to 150mV ±0.01 ±0.1 * * * % Total Output Error Vsense = 100mV ±0.5 ±2 * * * %	TPUT								
Nonlinearity Error $V_{SENSE} = 10 \text{mV} \text{ to } 150 \text{mV}$ ± 0.01 ± 0.1	insconductance	$V_{SENSE} = 10mV - 150mV$	990	1000	1010	*	*	*	μA/V
Total Output Error $V_{SENSE} = 100 \text{mV}$ ± 0.5 ± 2 $*$ $*$ $\%$	s Temperature	V _{SENSE} = 100mV		10			*		nA/°C
JENJE I JENJE	,	V _{SENSE} = 10mV to 150mV		±0.01	±0.1		*	*	%
	•	V _{SENSE} = 100mV		1	±2			*	%
				1 5			*		GΩ pF
Voltage Output									
-::::3								1	V
Swing to Common Mode, V_{CM} $V_{CM} - 0.6$ $V_{CM} - 1.0$ * * V	wing to Common Mode, V _{CM}			$V_{CM} - 0.6$	V _{CM} - 1.0		*	*	V
FREQUENCY RESPONSE	EQUENCY RESPONSE								
Bandwidth R _{OUT} = 10kΩ 440 * kH	ndwidth	$R_{OUT} = 10k\Omega$		440			*		kHz
				220			*		kHz
	tling Time (0.1%)	5V Step, $R_{OUT} = 10kΩ$		-			*		μs
5V Step, R _{OUT} = 20kΩ		5V Step, $R_{OUT} = 20kΩ$		5.0			*		μs
NOISE	ISE								
Output-Current Noise Density 20 * pA/v	tput-Current Noise Density			20			*		pA/√Hz
Total Output-Current Noise BW = 100kHz 7	al Output-Current Noise	BW = 100kHz		7			*		nA RMS
POWER SUPPLY	WER SUPPLY								
Operating Range, V+ 2.7 40 * 60 V	erating Range, V+		2.7		40	*		60	V
	0 0 ,	$V_{SENSE} = 0, I_O = 0$		60	125		*	1	μΑ
TEMPERATURE RANGE	MPERATURE RANGE								
			-40		85	*		*	°C
			-						.c
	3				-				∘C
	S			200			*		°C/W

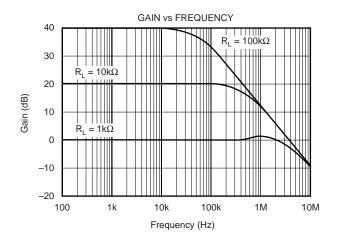
^{*} Specification same as for the INA139NA.

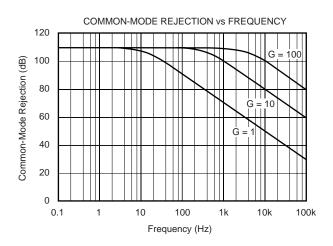
NOTE: (1) Defined as the amount of input voltage, V_{SENSE} , to drive the output to zero.

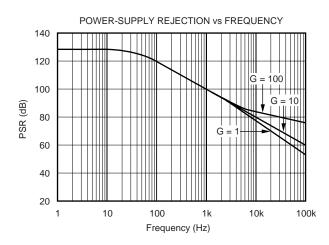


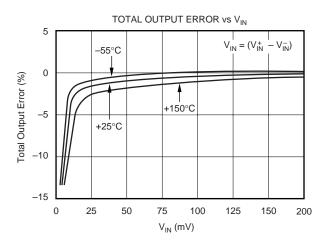
TYPICAL CHARACTERISTICS

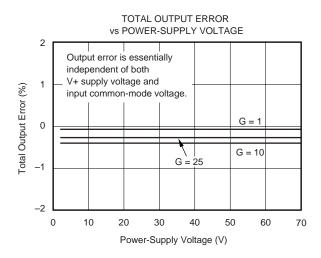
At T_A = +25°C, V+ = 5V, V_{IN+} = 12V, and R_L = 25k Ω , unless otherwise noted.

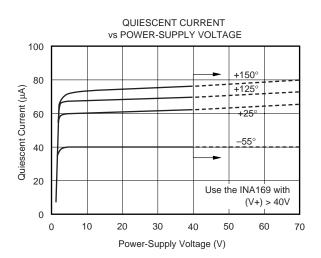






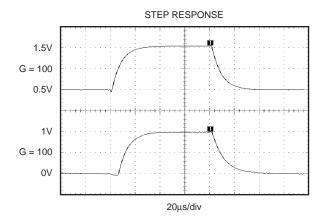


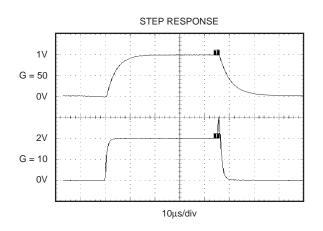




TYPICAL CHARACTERISTICS (Cont.)

At T_A = +25°C, V+ = 5V, V_{IN+} = 12V, and R_L = 25k Ω , unless otherwise noted.





OPERATION

Figure 1 shows the basic circuit diagram for both the INA139 and the INA169. Load current, I_{S} , is drawn from the supply, V_{S} , through the shunt resistor, R_{S} . The voltage drop in the shunt resistor, V_{S} , is forced across R_{G1} by the internal op amp, causing current to flow into the collector of Q1. The external resistor, R_{L} , converts the output current to a voltage, V_{OUT} , at the OUT pin.

The transfer function for the INA139 is:

$$I_{O} = g_{m} (V_{IN+}) - (V_{IN-})$$
 (1)

where
$$g_m = 1000\mu A/V$$
 (2)

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

$$V_{OUT} = (I_S) (R_S) (1000 \mu A/V) (R_L)$$
 (3)

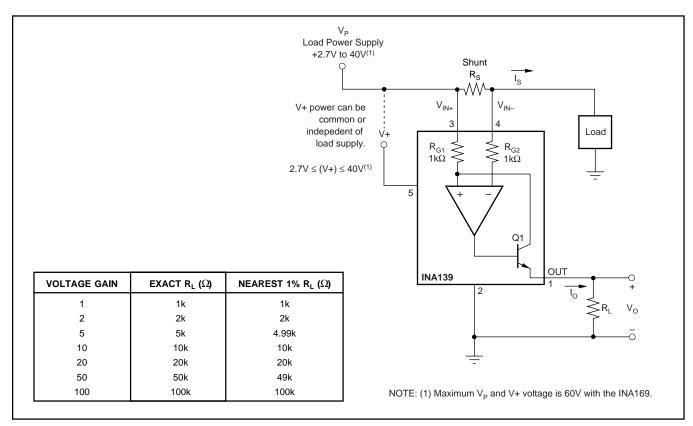


FIGURE 1. Basic Circuit Connections.



The maximum differential input voltage for accurate measurements is 0.5V, which produces a 500µA output current. A differential input voltage of up to 2V will not cause damage. Differential measurements (pins 3 and 4) must be unipolar with a more-positive voltage applied to pin 3. If a morenegative voltage is applied to pin 3, the output current (I_0) is zero, but will not cause damage.

BASIC CONNECTION

Figure 1 shows the basic connection of the INA139. The input pins, V_{IN+} and V_{IN-}, must be connected as closely as possible to the shunt resistor to minimize any resistance in series with the shunt resistance. The output resistor, R_I, is shown connected between pin 1 and ground. Best accuracy is achieved with the output voltage measured directly across R₁. This is especially important in high-current systems where load current can 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 highimpedance power supplies can require decoupling capacitors to reject power-supply noise; connect the 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 5V whereas the load power-supply voltage is up to +36V (or +60V with the INA169). However, the output voltage range of the OUT terminal (pin 1) 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, whereas 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 of 50mV to 100mV; maximum input voltage for accurate measurements is 500mV.

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 $100k\Omega$ with excellent accuracy. The input impedance of any additional circuitry at the output must be much higher than the value of R_L to avoid degrading accuracy.

Some Analog-to-Digital (A/D) converters have input impedances that will significantly affect measurement gain. The input impedance of the A/D converter can be included as part of the effective R_I 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.

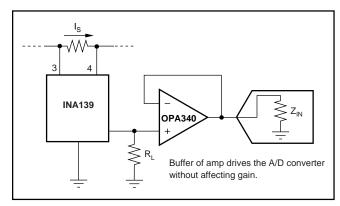


FIGURE 2. Buffering Output to Drive the A/D Converter.

OUTPUT VOLTAGE RANGE

The output of the INA139 is a current that 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:

$$V_{OUT\ MAX} = (V+) - 0.7V - (V_{IN+}) - (V_{IN-})$$
 (4)
or
 $V_{OUT\ MAX} = (V_{IN-}) - 0.5V$ (5)
(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 will yield a narrower measurement bandwidth (see the Typical Characteristics). 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.

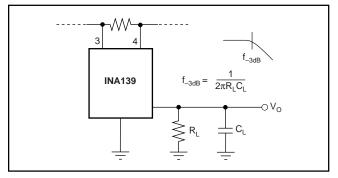


FIGURE 3. Output Filter.

APPLICATIONS

The INA139 is designed for current shunt measurement circuits (see Figure 1), but its basic function is useful in a wide range of circuitry. A creative engineer will find many unforeseen uses in measurement and level shifting circuits. A few ideas are illustrated in Figures 4 through 7.



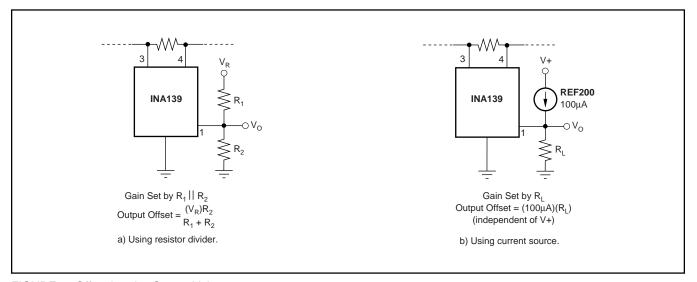


FIGURE 4. Offsetting the Output Voltage.

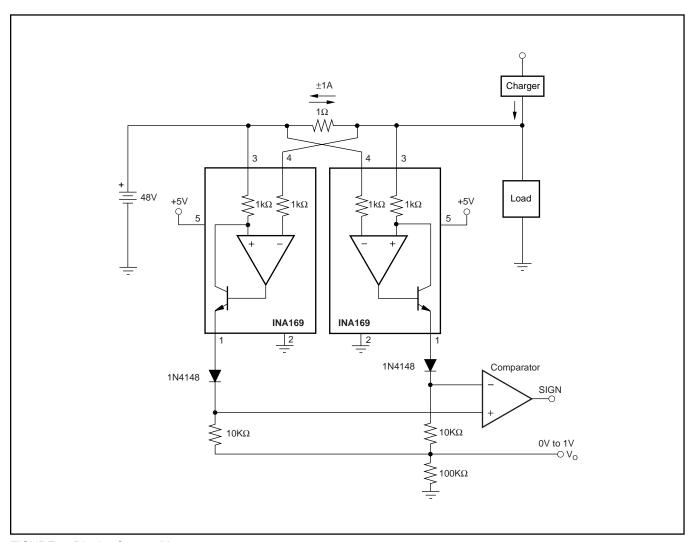


FIGURE 5. Bipolar Current Measurement.

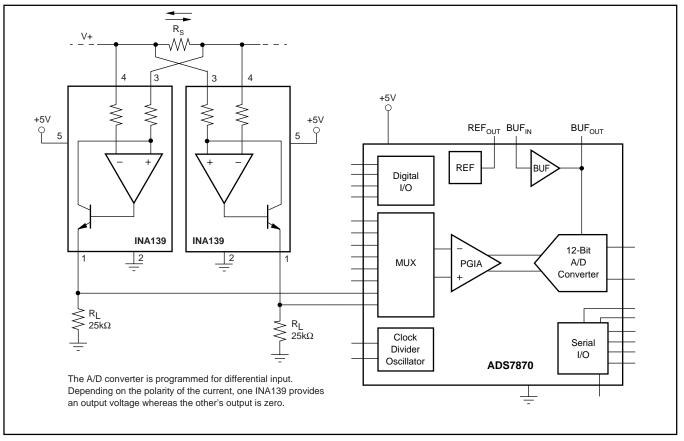


FIGURE 6. Bipolar Current Measurement Using a Differential Input of the A/D Converter.

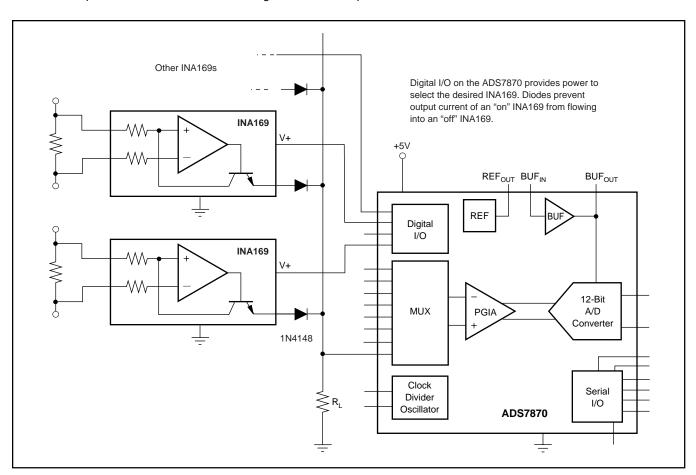
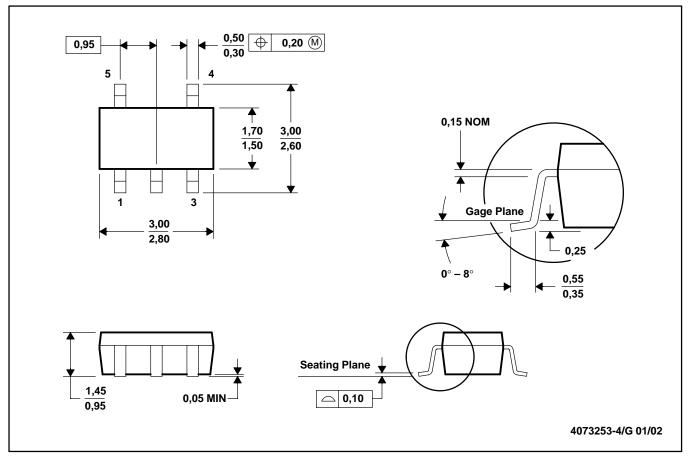


FIGURE 7. Multiplexed Measurement Using Logic Signal for Power.



DBV (R-PDSO-G5)

PLASTIC SMALL-OUTLINE



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.
- D. Falls within JEDEC MO-178

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Mailing Address:

Texas Instruments
Post Office Box 655303
Dallas, Texas 75265

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