

SBOS193D - MARCH 2001 - REVISED JANUARY 2006

High-Side, Bidirectional CURRENT SHUNT MONITOR

FEATURES

- COMPLETE BIDIRECTIONAL CURRENT MEASUREMENT CIRCUIT
- WIDE SUPPLY RANGE: 2.7V to 40V
- SUPPLY-INDEPENDENT COMMON-MODE VOLTAGE: 2.7V TO 60V
- RESISTOR PROGRAMMABLE GAIN SET
- LOW QUIESCENT CURRENT: 75µA (typ)
- MSOP-8 PACKAGE

APPLICATIONS

- CURRENT SHUNT MEASUREMENT: Automotive, Telephone, Computers, Power Systems, Test, General Instrumentation
- PORTABLE AND BATTERY-BACKUP SYSTEMS
- BATTERY CHARGERS
- POWER MANAGEMENT
- CELL PHONES

DESCRIPTION

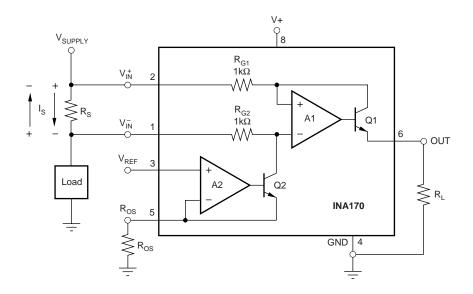
The INA170 is a high-side, bidirectional current shunt monitor featuring a wide input common-mode voltage range, low quiescent current, and a tiny MSOP-8 package.

Bidirectional current measurement is accomplished by output offsetting. The offset voltage level is set with an external resistor and voltage reference. This permits measurement of a bidirectional shunt current while using a single supply for the INA170.

Input common-mode and power-supply voltages are independent. Input voltage can range from +2.7V to +60V on any supply voltage from +2.7V to +40V. Low 10 μ A input bias current adds minimal error to the shunt current.

The INA170 converts a differential input voltage to a current output. This current develops a voltage across an external load resistor, setting any gain from 1 to over 100.

The INA170 is available in an MSOP-8 package, and is specified over the extended industrial temperature range, -40°C to +85°C with operation from -55°C to +125°C.





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ABSOLUTE MAXIMUM RATINGS(1)

Supply Voltage, V+ to GND	0.3V to 40V
Analog Inputs, Common Mode(2)	0.3V to 75V
Differential $(V_{IN}^+) - (V_{IN}^-)$	40V to 2V
Analog Output, Out(2)	0.3V to 40V
Input Current Into Any Pin	10mA
Operating Temperature	55°C to +125°C
Storage Temperature	65°C to +150°C
Junction Temperature	+150°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. (2) The input voltage at any pin may exceed the voltage shown if the current at that pin is limited to 10mA.

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.

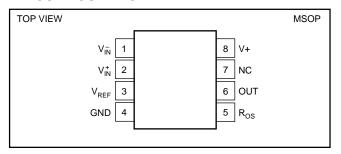
ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

PACKAGE/ORDERING INFORMATION(1)

PRODUCT	PACKAGE-LEAD	PACKAGE DESIGNATOR	SPECIFIED TEMPERATURE RANGE	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
INA170EA	MSOP-8	DGK	-40°C to +85°C	INA170EA	INA170EA/250	Tape and Reel, 250
"	II	II .	"	II	INA170EA/2K5	Tape and Reel, 2500

NOTE: (1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI website at www.ti.com.

PIN CONFIGURATION



PIN DESCRIPTION

PIN	DESIGNATOR	DESCRIPTION
1	V _{IN}	Inverting Input
2	V _{IN}	Noninverting Input
3	V _{REF}	Reference Voltage Input
4	GND	Ground
5	R _{os}	Offset Resistor
6	OUT	Output
7	NC	No Connection
8	V+	Supply Voltage
1	I	



ELECTRICAL CHARACTERISTICS

At T_A = -40°C to +85°C, V_S = 5V, V_{\text{IN}}^+ = 12V, R_OUT = 25k Ω , unless otherwise noted.

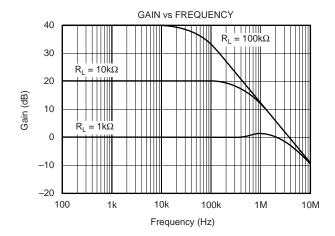
		INA170EA			
PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
INPUT Full-Scale Sense (Input) Voltage Common-Mode Input Range Common-Mode Rejection Offset Voltage(1) RTI vs Temperature vs Power Supply Input Bias Current	$V_{SENSE} = V_{1\bar{N}}^{+} - V_{1\bar{N}}$ $V_{1\bar{N}}^{+} = +2.7V \text{ to } +60V, V_{SENSE} = 50mV$ $T_{MIN} \text{ to } T_{MAX}$ $V+ = +2.7V \text{ to } +60V, V_{SENSE} = 50mV$ $V_{1\bar{N}}^{+}, V_{1\bar{N}}^{-}$	+2.7 100	100 120 ±0.2 1 0.1	500 +60 ±1	mV V dB mV μV/°C μV/V uA
OFFSETTING AMPLIFIER Offsetting Equation Input Voltage Input Offset Voltage vs Temperature Programming Current through Ros Input Impedance Input Bias Current	$V_{OS} = (R_L/R_{OS}) V_{REF}$ $T_{MIN} \text{ to } T_{MAX}$ V_{IN}^+, V_{IN}^-	1 0	±0.2 10 10 ¹⁰ 4 +10	V _S - 1 ±1	V mV μV/°C mA Ω pF nA
OUTPUT Transconductance vs Temperature Nonlinearity Error Total Output Error Output Impedance Voltage Output Swing to Power Supply, V+ Swing to Common Mode, V _{CM}	V _{SENSE} = 10mV to 150mV V _{SENSE} = 100mV V _{SENSE} = 10mV to 150mV V _{SENSE} = 100mV	0.990	1 50 ±0.01 ±0.5 1 5 (V+) - 0.9 V _{CM} - 0.6	1.01 ±0.1 ±2 (V+) - 1.2 V _{CM} - 1.0	mA/V nA/°C % % GΩ pF V
FREQUENCY RESPONSE Bandwidth Settling Time (0.1%)	R_{OUT} = 10kΩ 5V Step, R_{OUT} = 10kΩ		400 3		kHz μs
NOISE Output-Current Noise Density Total Output-Current Noise	BW = 100kHz		20 7		pA/√Hz nA RMS
POWER SUPPLY Operating Range Quiescent Current	V+ V _{SENSE} = 0, I _O = 0	+2.7	75	+40 125	V μA
TEMPERATURE RANGE Specification, T_{MIN} to T_{MAX} Operating Storage Thermal Resistance, θ_{JA}		-40 -55 -65	150	+85 +125 +150	°C °C °C °C

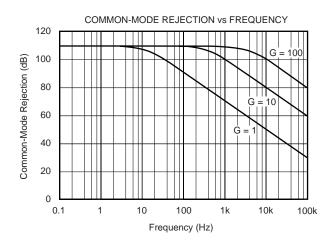
NOTE: (1) Defined as the amount of input voltage, $\ensuremath{V_{\text{SENSE}}},$ to drive the output to zero.

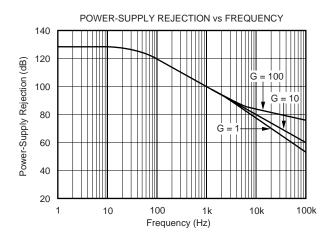


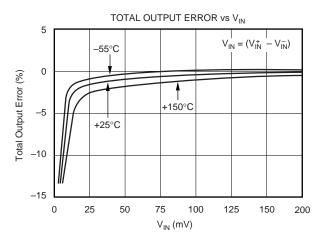
TYPICAL CHARACTERISTICS

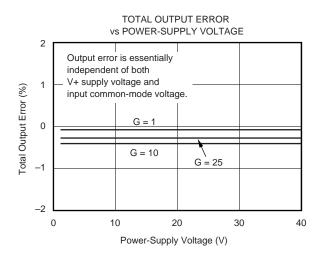
At T_A = +25°C, V+ = 5V, V_{IN}^+ = 12V, R_L = 25k Ω , unless otherwise noted.

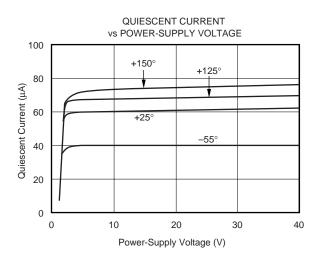






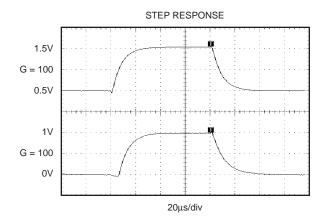


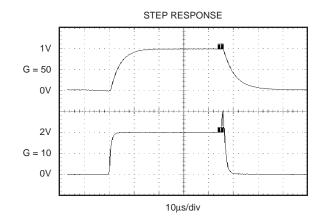




TYPICAL CHARACTERISTICS (Cont.)

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





OPERATION

Figure 1 shows the basic circuit diagram for the INA170. 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 op-amp, 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.

Without offset, the transfer function for the INA170 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 INA170 is $1000\mu A/V$. 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)

Applying a positive reference voltage to pin 3 causes a current to flow through R_{OS} , forcing output current I_O to be offset from zero. The transfer function then becomes:

$$V_{OUT} = \left(\frac{V_{REF} \cdot R_L}{R_{OS}}\right) \pm \left(\frac{I_S \cdot R_S \cdot R_L}{1k\Omega}\right)$$
(4)

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 1 and 2) can be

bipolar with a more-positive voltage applied to pin 2. If a more-negative voltage is applied to pin 1, output current I_O will decrease towards zero.

BASIC CONNECTION

Figure 1 shows the basic connection of the INA170. 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 6 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 INA170. However, applications with noisy or high impedance power supplies may require de-coupling capacitors to reject power-supply noise. Connect bypass capacitors close to the device pins.

POWER SUPPLIES

The input circuitry of the INA170 can accurately measure beyond its power-supply voltage, V+. For example, the V+ power supply can be 5V, while the load power-supply voltage (INA170 input voltage) is up to +60V. However, the output-voltage range of the OUT terminal (pin 6) is limited by the supply.

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

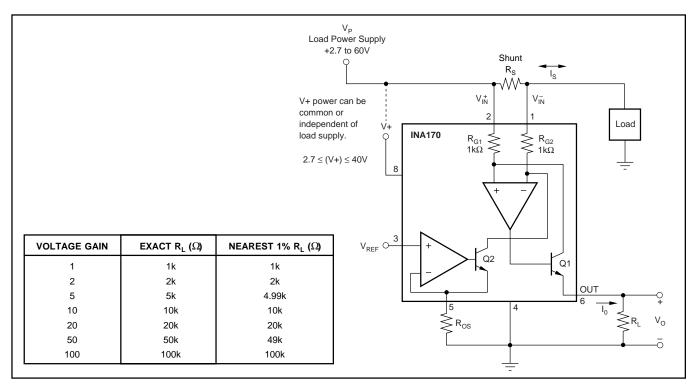


FIGURE 1. Basic Circuit Connections.



currents by minimizing the effects of offset, while low values of $R_{\rm S}$ minimize voltage loss in the supply line. For most applications, best performance is attained with an $R_{\rm S}$ 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 INA170 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 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 will 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 .

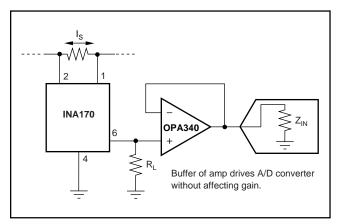


FIGURE 2. Buffering Output to Drive A/D Converter.

OUTPUT VOLTAGE RANGE

The output of the INA170 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:

$$V_{\text{out max}} = (V+) - 0.7V - (V_{\text{IN}}^+ - V_{\text{IN}}^-)$$
 (5)
or
 $V_{\text{out max}} = V_{\text{IN}}^- - 0.5V$ (6)
(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 Typical Characteristic Curves). 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. This will not cause instability.

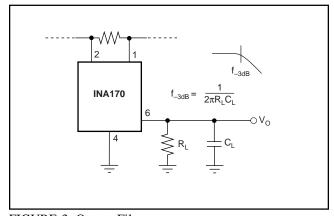


FIGURE 3. Output Filter.

APPLICATIONS

The INA170 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 creative engineer will find many unforeseen uses in measurement and level shifting circuits.

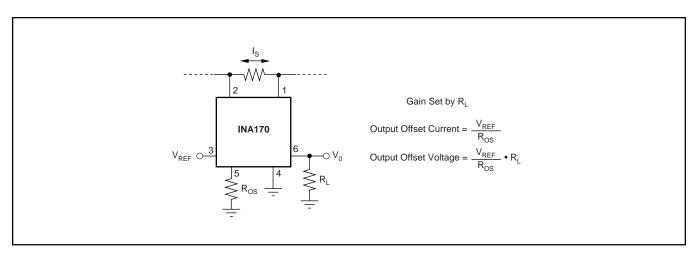


FIGURE 4. Offsetting the Output Voltage.

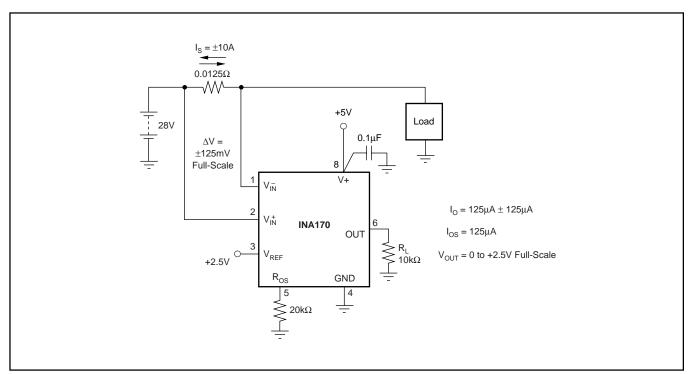


FIGURE 5. Bipolar Current Measurement.

11-Nov-2025 www.ti.com

PACKAGING INFORMATION

Orderable part nu	ımber Sta	tatus	Material type	Package Pins	Package qty Carrier	RoHS	Lead finish/	MSL rating/	Op temp (°C)	Part marking
		(1)	(2)			(3)	Ball material	Peak reflow		(6)
							(4)	(5)		
INA170EA/25	0 L	Last	Production	VSSOP (DGK) 8	250 SMALL T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	A70
	Time	ne Buy		. , , ,	·					
INA170EA/2K	.5 Ac	ctive	Production	VSSOP (DGK) 8	2500 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	A70
INA170EA/2K5	S.A Ac	ctive	Production	VSSOP (DGK) 8	2500 LARGE T&R	Yes	NIPDAUAG	Level-2-260C-1 YEAR	-40 to 85	A70

⁽¹⁾ Status: For more details on status, see our product life cycle.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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⁽²⁾ Material type: When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

⁽³⁾ RoHS values: Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

⁽⁴⁾ Lead finish/Ball material: Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

⁽⁵⁾ MSL rating/Peak reflow: The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

⁽⁶⁾ Part marking: There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

PACKAGE MATERIALS INFORMATION

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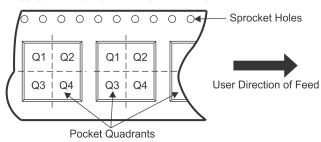
TAPE AND REEL INFORMATION





	Dimension designed to accommodate the component width
	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

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Device	Package Type	Package Drawing		SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
INA170EA/250	VSSOP	DGK	8	250	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
INA170EA/2K5	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

PACKAGE MATERIALS INFORMATION

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*All dimensions are nominal

	Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
I	INA170EA/250	VSSOP	DGK	8	250	366.0	364.0	50.0
I	INA170EA/2K5	VSSOP	DGK	8	2500	366.0	364.0	50.0



SMALL OUTLINE PACKAGE



NOTES:

PowerPAD is a trademark of Texas Instruments.

- 1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.

 2. This drawing is subject to change without notice.

 3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not
- exceed 0.15 mm per side.
- 4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
- 5. Reference JEDEC registration MO-187.



SMALL OUTLINE PACKAGE



NOTES: (continued)

- 6. Publication IPC-7351 may have alternate designs.
- 7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
- 8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
- 9. Size of metal pad may vary due to creepage requirement.



SMALL OUTLINE PACKAGE



NOTES: (continued)

- 11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
- 12. Board assembly site may have different recommendations for stencil design.



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