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## PRECISION, GAIN OF 0.2 LEVEL TRANSLATION DIFFERENCE AMPLIFIER

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### FEATURES

- Gain of 0.2 to Interface  $\pm 10$ -V Signals to Single-Supply ADCs
- Gain Accuracy:  $\pm 0.024\%$  (max)
- Wide Bandwidth: 1.5 MHz
- High Slew Rate: 15 V/ $\mu$ s
- Low Offset Voltage:  $\pm 100$   $\mu$ V
- Low Offset Drift:  $\pm 1.5$   $\mu$ V/ $^{\circ}$ C
- Single-Supply Operation Down to 1.8 V

### APPLICATIONS

- Industrial Process Controls
- Instrumentation
- Differential to Single-Ended Conversion
- Audio Line Receivers

### SUPPORTS DEFENSE, AEROSPACE, AND MEDICAL APPLICATIONS

- Controlled Baseline
- One Assembly/Test Site
- One Fabrication Site
- Available in Military ( $-55^{\circ}$ C/ $125^{\circ}$ C) Temperature Range<sup>(1)</sup>
- Extended Product Life Cycle
- Extended Product-Change Notification
- Product Traceability

(1) Additional temperature ranges are available - contact factory

### DESCRIPTION

The INA159 is a high slew rate,  $G = 1/5$  difference amplifier consisting of a precision op amp with a precision resistor network. The gain of  $1/5$  makes the INA159 useful to couple  $\pm 10$ -V signals to single-supply analog-to-digital converters (ADCs), particularly those operating on a single +5-V supply. The on-chip resistors are laser-trimmed for accurate gain and high common-mode rejection. Excellent temperature coefficient of resistance (TCR) tracking of the resistors maintains gain accuracy and common-mode rejection over temperature. The input common-mode voltage range extends beyond the positive and negative supply rails. It operates on a total of 1.8-V to 5.5-V single or split supplies. The INA159 reference input uses two resistors for easy mid-supply or reference biasing.

The difference amplifier is the foundation of many commonly-used circuits. The INA159 provides this circuit function without using an expensive external precision resistor network. The INA159 is available in an MSOP-8 surface-mount package and is specified for operation over the extended industrial temperature range,  $-55^{\circ}$ C to  $125^{\circ}$ C.



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.

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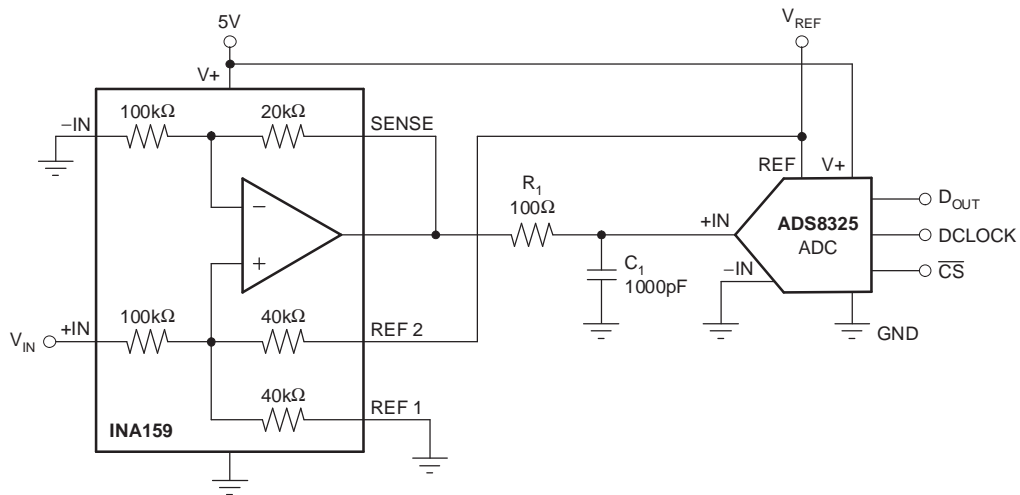


Figure 1. Typical Application



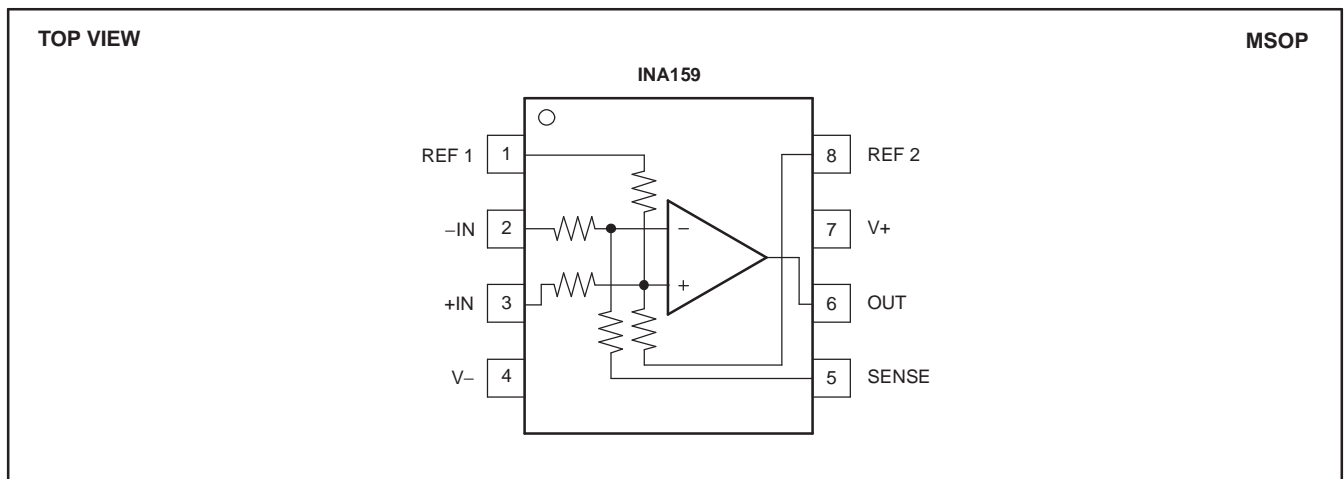
This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

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.

ORDERING INFORMATION<sup>(1)</sup>

TEMPERATURE	ORDERABLE PART NUMBER <sup>(2)</sup>	PACKAGE LEAD	PACKAGE DESIGNATOR	TOP-SIDE MARKING
-55°C to 125°C	INA159AMDGKTEP	MSOP-8 Tape and reel	DGK	OAA

- (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](http://www.ti.com).
- (2) Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at [www.ti.com/sc/package](http://www.ti.com/sc/package).



**ABSOLUTE MAXIMUM RATINGS<sup>(1)</sup>**

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

		<b>MIN</b>	<b>MAX</b>	<b>UNIT</b>
Supply voltage			+5.5	V
Signal input terminals (–IN and +IN), voltage			±30	V
Reference (REF 1 and REF2) and sense pins	Current		±10	mA
	Voltage	(V–) – 0.5	(V+) + 0.5	V
Output short circuit			Continuous	
Operating temperature		–55	+125	°C
Storage temperature		–65	+150	°C
Junction temperature			+150	°C
ESD rating	Human-Body Model		4000	V
	Charged-Device Model		1000	V

- (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 supported.

## ELECTRICAL CHARACTERISTICS

**Boldface** limits apply over the specified temperature range,  $T_A = -55^\circ\text{C}$  to  $+125^\circ\text{C}$ .

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.

PARAMETER	CONDITIONS	INA159			UNIT
		MIN	TYP	MAX	
<b>OFFSET VOLTAGE</b> <sup>(1)</sup>	RTO				
Initial <sup>(1)</sup>	$V_{OS}$ $V_S = \pm 2.5\text{ V}$ , Reference and Input Pins Grounded		$\pm 100$	$\pm 500$	$\mu\text{V}$
<b>Over Temperature</b>				<b><math>\pm 1450</math></b>	$\mu\text{V}$
vs Power Supply	PSRR $V_S = \pm 0.9\text{ V}$ to $\pm 2.75\text{ V}$		$\pm 20$	$\pm 100$	$\mu\text{V/V}$
<b>Over Temperature</b>	PSRR $V_S = \pm 0.9\text{ V}$ to $\pm 2.75\text{ V}$			<b><math>\pm 200</math></b>	$\mu\text{V/V}$
Reference Divider Accuracy <sup>(2)</sup>			$\pm 0.002$	$\pm 0.024$	%
<b>over Temperature</b>			<b><math>\pm 0.002</math></b>	<b><math>\pm 0.050</math></b>	%
<b>INPUT IMPEDANCE</b> <sup>(3)</sup>					
Differential			240		$\text{k}\Omega$
Common-Mode			60		$\text{k}\Omega$
<b>INPUT VOLTAGE RANGE</b>	RTI				
Common-Mode Voltage Range	$V_{CM}$				
Positive			17.5		V
Negative			-12.5		V
Common-Mode Rejection Ratio	CMRR $V_{CM} = -10\text{ V}$ to $+10\text{ V}$ , $R_S = 0\ \Omega$	80	96		dB
<b>over Temperature</b>		<b>74</b>	<b>94</b>		<b>dB</b>
<b>OUTPUT VOLTAGE NOISE</b> <sup>(4)</sup>	RTO				
$f = 0.1\text{ Hz}$ to $10\text{ Hz}$			10		$\mu\text{V}_{PP}$
$f = 10\text{ kHz}$			30		$\text{nV}/\sqrt{\text{Hz}}$
<b>GAIN</b>	$V_{REF2} = 4.096\text{ V}$ , $R_L$ Connected to GND, $(V_{IN+}) - (V_{IN-}) = -10\text{ V}$ to $+10\text{ V}$ , $V_{CM} = 0\text{ V}$				
Initial	G		0.2		V/V
Error			$\pm 0.005$	$\pm 0.024$	%
<b>vs Temperature</b>				<b><math>\pm 0.035</math></b>	%
Nonlinearity			$\pm 0.0002$		% of FS
<b>OUTPUT</b>					
Voltage, Positive	$V_{REF2} = 4.096\text{ V}$ , $R_L$ Connected to GND	$(V+) - 0.1$	$(V+) - 0.02$		V
<b>over Temperature</b>		<b><math>(V+) - 0.2</math></b>			<b>V</b>
Voltage, Negative	$V_{REF2} = 4.096\text{ V}$ , $R_L$ Connected to GND	$(V-) + 0.048$	$(V-) + 0.01$		V
<b>over Temperature</b>		<b><math>(V-) + 0.070</math></b>			<b>V</b>
Current Limit, Continuous to Common			$\pm 60$		mA
Capacitive Load			See Typical Characteristic		pF
Open-Loop Output Impedance	$R_O$ $f = 1\text{ MHz}$ , $I_O = 0$		110		$\Omega$
<b>FREQUENCY RESPONSE</b>					
Small-Signal Bandwidth		-3 dB	1.5		MHz
Slew Rate	SR		15		$\text{V}/\mu\text{s}$
Settling Time, 0.01%	$t_S$ 4 V Output Step, $C_L = 100\text{ pF}$		1		$\mu\text{s}$

(1) Includes effects of amplifier input bias and offset currents.

(2) Reference divider accuracy specifies the match between the reference divider resistors using the configuration in [Figure 2](#).

(3) Internal resistors are ratio matched but have 20% absolute value.

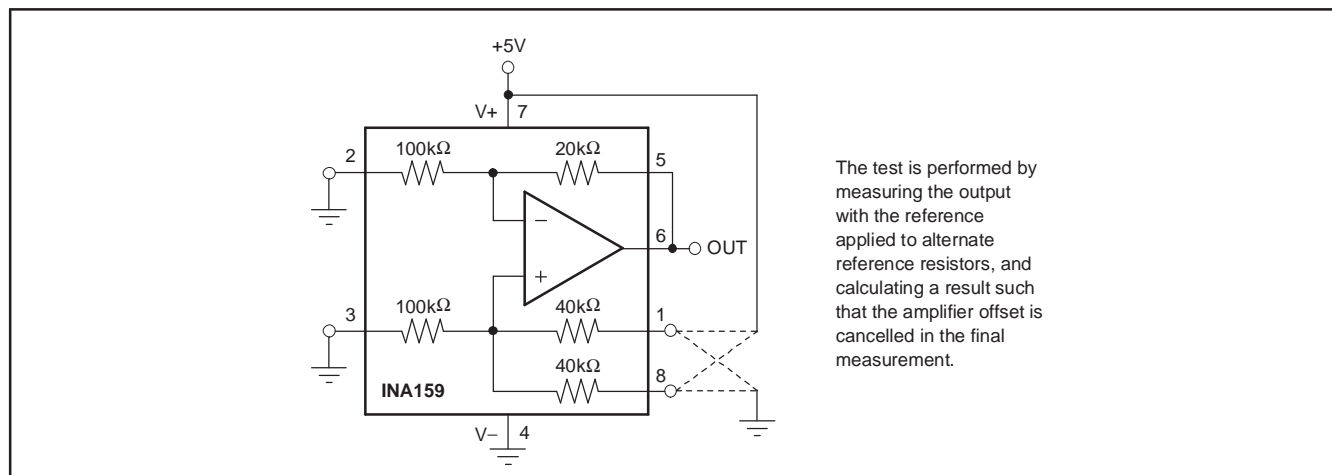
(4) Includes effects of amplifier input current noise and thermal noise contribution of resistor network.

**ELECTRICAL CHARACTERISTICS (continued)**

**Boldface** limits apply over the specified temperature range,  $T_A = -55^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

At  $T_A = +25^{\circ}\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.

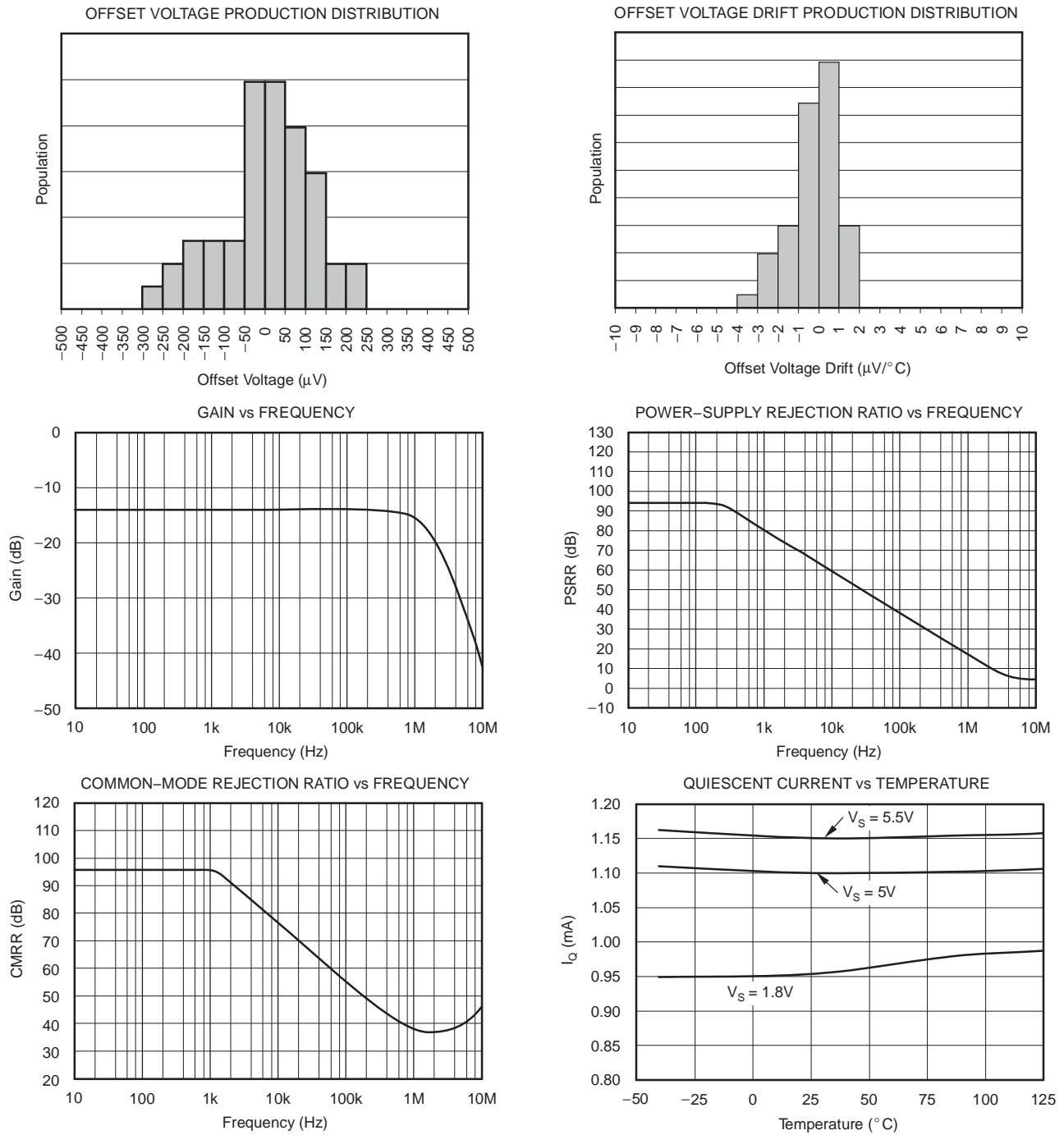
PARAMETER	CONDITIONS	INA159			UNIT
		MIN	TYP	MAX	
Overload Recovery Time	50% Overdrive		250		ns
<b>POWER SUPPLY</b>					
Specified Voltage Range	$V_S$			+5	V
Operating Voltage Range		+1.8		+5.5	V
Quiescent Current	$I_Q$	$I_O = 0\text{ mA}$ , $V_S = \pm 2.5\text{ V}$ , Reference and Input Pins Grounded			mA
<b>over Temperature</b>					<b>2.0</b>
<b>TEMPERATURE RANGE</b>					
Specified Range		-55		+125	$^{\circ}\text{C}$
Operating Range		-55		+125	$^{\circ}\text{C}$
Storage Range		-65		+150	$^{\circ}\text{C}$
Thermal Resistance	$\theta_{JA}$				
MSOP-8	Surface Mount		150		$^{\circ}\text{C}/\text{W}$



**Figure 2. Test Circuit for Reference Divider Accuracy**

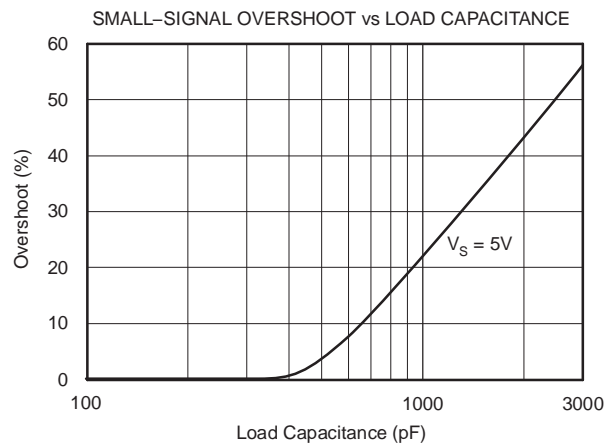
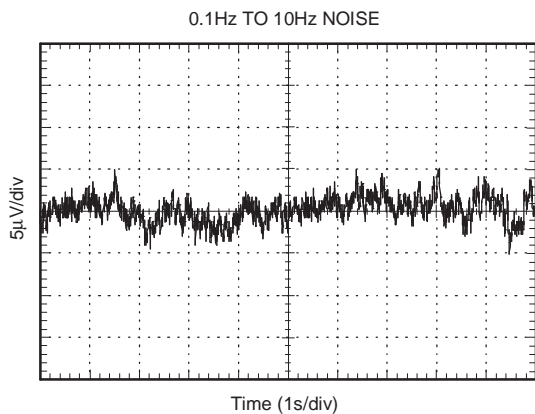
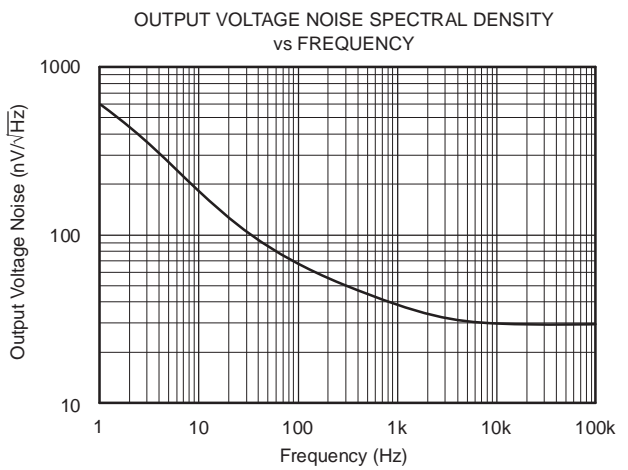
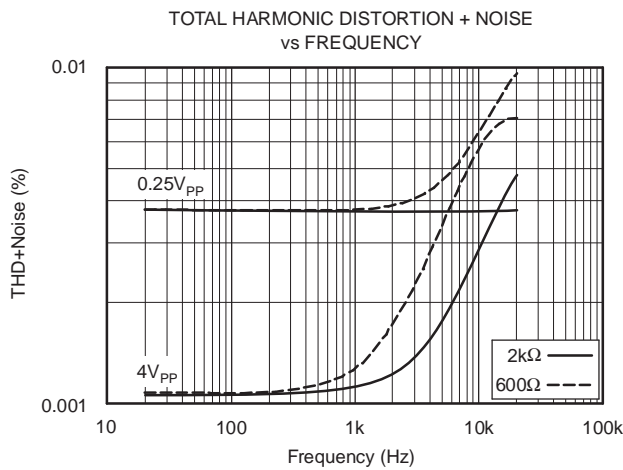
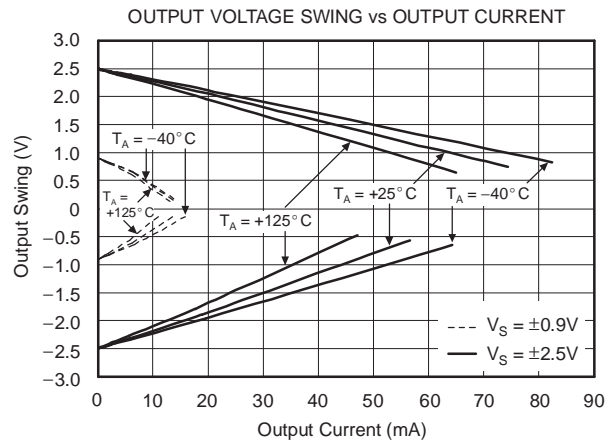
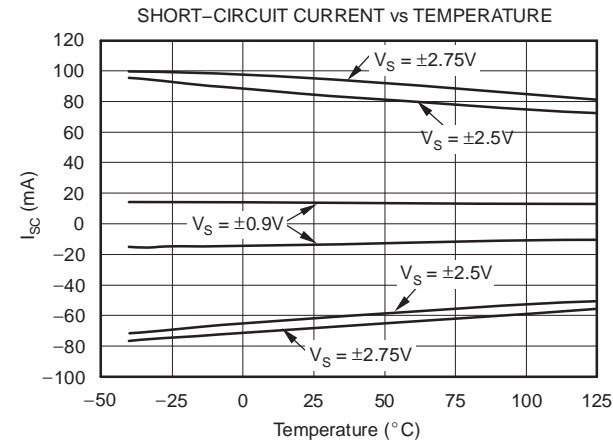
### TYPICAL CHARACTERISTICS

At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.



TYPICAL CHARACTERISTICS (continued)

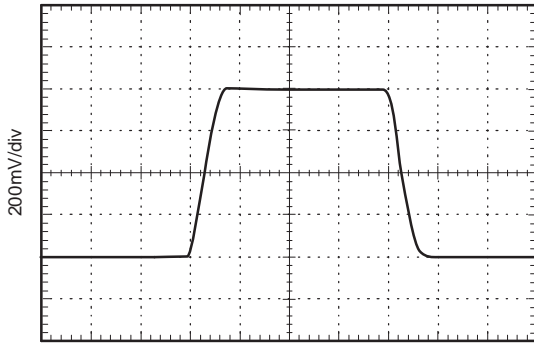
At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.



**TYPICAL CHARACTERISTICS (continued)**

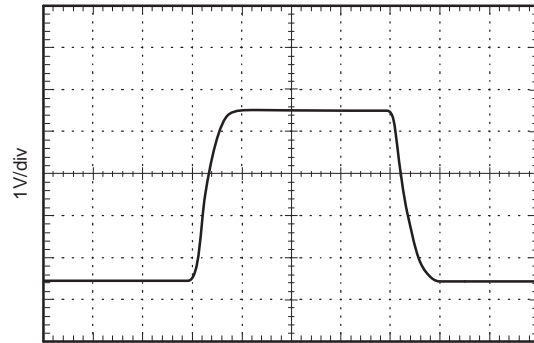
At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.

SMALL-SIGNAL STEP RESPONSE



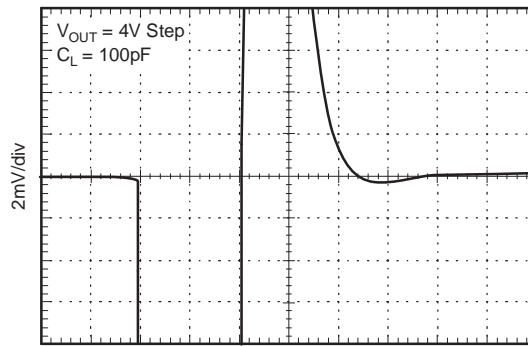
Time (500ns/div)

LARGE-SIGNAL STEP RESPONSE



Time (500ns/div)

SETTLING TIME



Time (250ns/div)



## APPLICATION INFORMATION

The internal op amp of the INA159 has a rail-to-rail common-mode voltage capability at its inputs. A rail-to-rail op amp allows the use of  $\pm 10$ -V inputs into a circuit biased to 1/2 of a 5-V reference (2.5-V quiescent output). The inputs to the op amp will swing from approximately 400 mV to 3.75 V in this application.

The unique input topology of the INA159 eliminates the input offset transition region typical of most rail-to-rail complementary stage operational amplifiers. This allows the INA159 to provide superior glitch- and transition-free performance over the entire common-mode range.

Good layout practice includes the use of a 0.1- $\mu$ F bypass capacitor placed closely across the supply pins.

### COMMON-MODE RANGE

The common-mode range of the INA159 is a function of supply voltage and reference. Where both pins, REF1 and REF2, are connected together:

$$V_{CM+} = (V+) + 5[(V+) - V_{REF}] \quad (1)$$

$$V_{CM-} = (V-) - 5[V_{REF} - (V-)] \quad (2)$$

Where one REF pin is connected to the reference, and the other pin grounded (1/2 reference connection):

$$V_{CM+} = (V+) + 5[(V+) - (0.5V_{REF})] \quad (3)$$

$$V_{CM-} = (V-) - 5[(0.5V_{REF}) - (V-)] \quad (4)$$

Some typical values are shown in [Table 1](#).

**Table 1. Common-Mode Range For Various Supply and Reference Voltages**

REF 1 and REF 2 Connected Together				
V+	V-	V <sub>REF</sub>	V <sub>CM+</sub>	V <sub>CM-</sub>
5	0	3	15	-15
5	0	2.5	17.5	-12.5
5	0	1.25	23.75	-6.25
1/2 Reference Connection				
V+	V-	V <sub>REF</sub>	V <sub>CM+</sub>	V <sub>CM-</sub>
5	0	5	17.5	-12.5
5	0	4.096	19.76	-10.24
5	0	2.5	23.75	-6.25
3.3	0	3.3	11.55	-8.25
3.3	0	2.5	13.55	-6.25
3.3	0	1.25	16.675	-3.125

**Input and Output Relationships for Various Reference and Connection Combinations**

$V_{REF}$ (V)	REF CONNECTION	$V_{OUT}$ for $V_{IN} = 0$ (V)	LINEAR $V_{IN}$ RANGE (V)	USEFUL $V_{OUT}$ SWING (V)
5		2.5	+10 0 -10	4.5 (±2V swing) 0.5
4.096		2.048	10 0 -10	4.048 (±2V swing) 0.048
3.3		1.65	+10 0 -7.885	3.65 (-1.577V, +2V swing) 0.048
2.5		1.25	+10 (also +5) 0 -6 (also -5)	3.25 (-1.2V, +2V swing) 0.048
1.8		0.9	+10 0 -4.26	2.9 (-0.852V, +2V swing) 0.048
2.5		2.5	+10 0 -10	4.5 (= 2V swing) 0.5
1.8		1.8	+10 0 -8.76	3.8 (-1.752V, +2V swing) 0.048
1.2		1.2	+10 0 -5.76	3.2 (-1.15V, +2V swing) 0.048

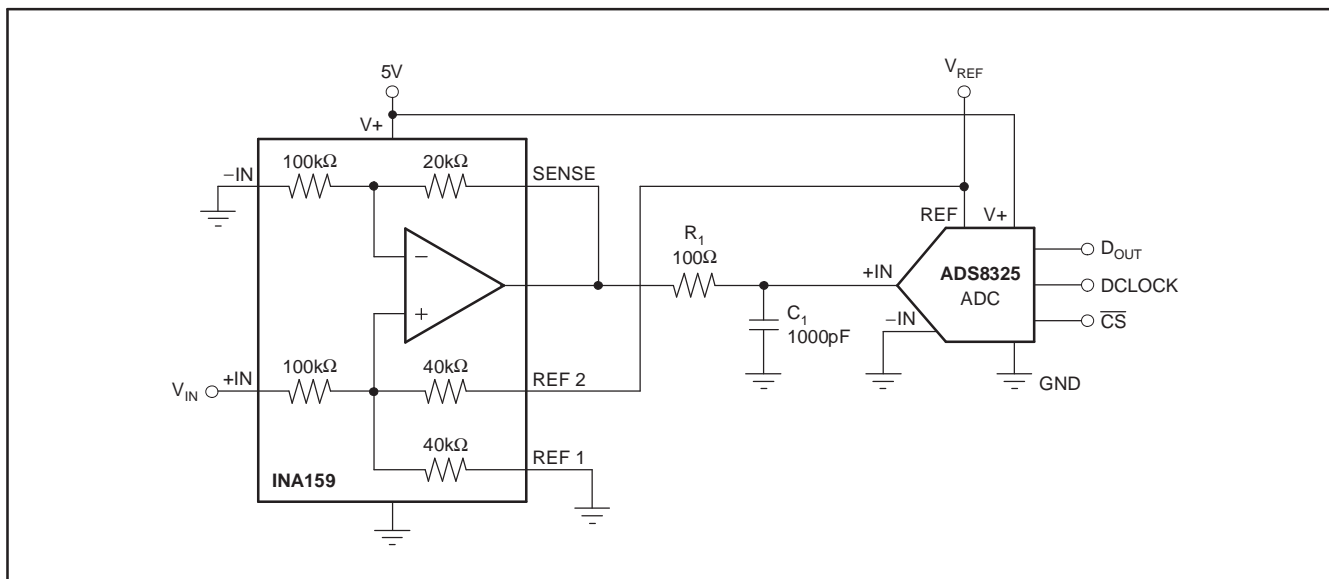


Figure 3. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs

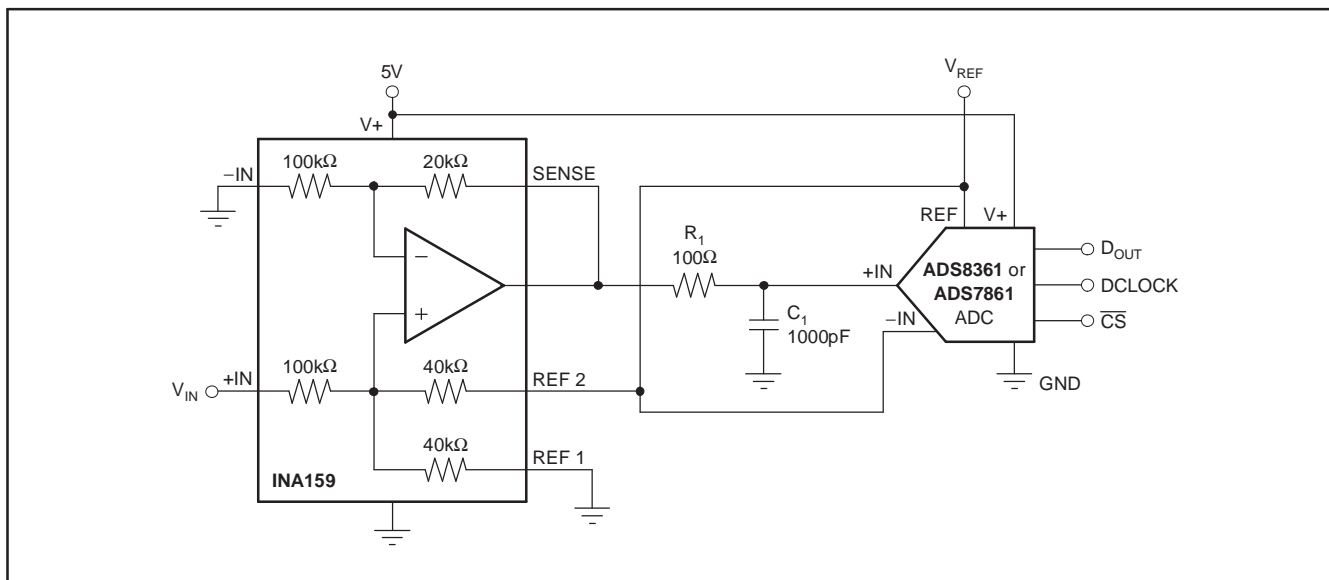


Figure 4. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs with Pseudo-Differential Inputs (such as the ADS7861 and ADS8361)

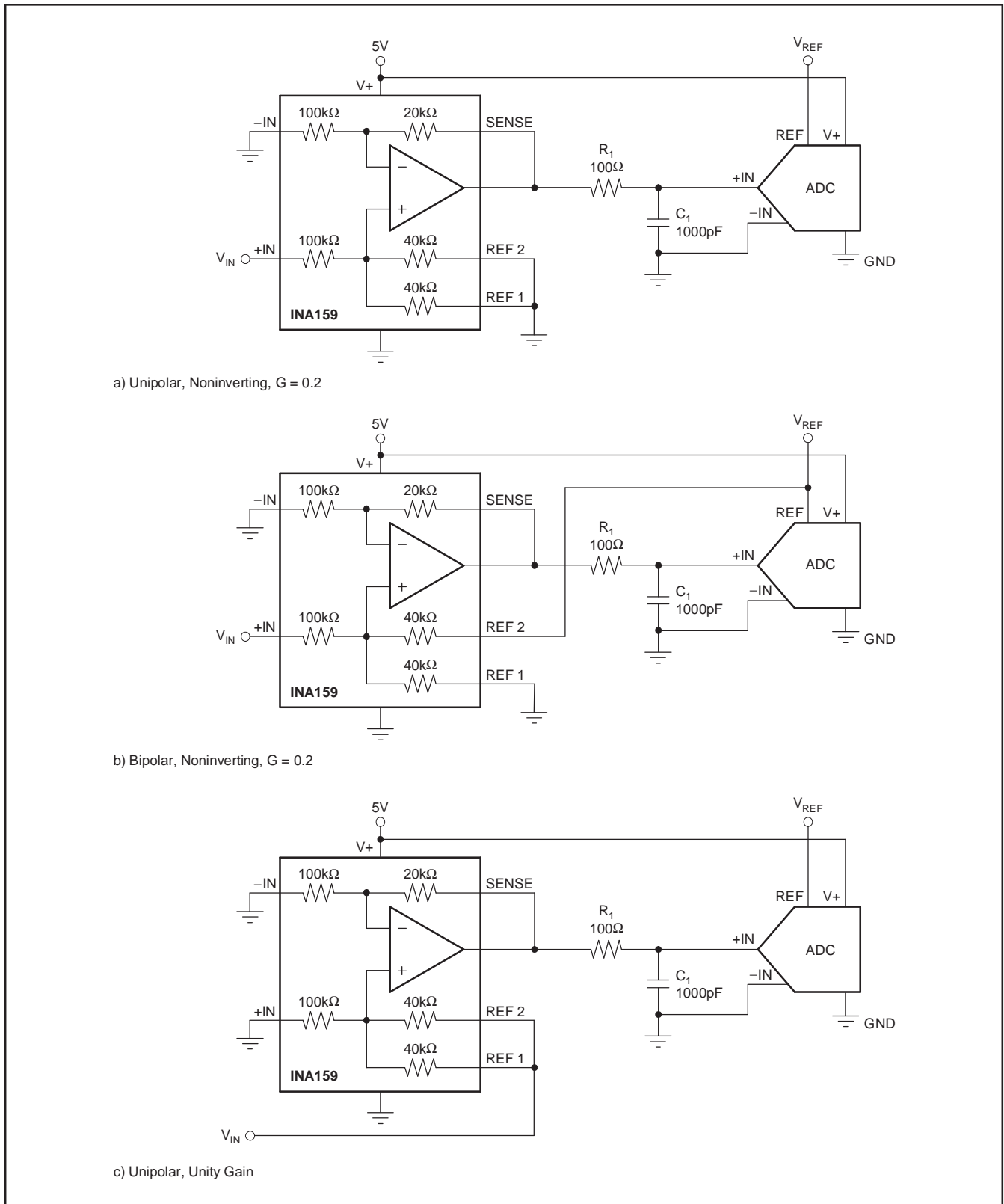


Figure 5. Basic INA159 Configurations

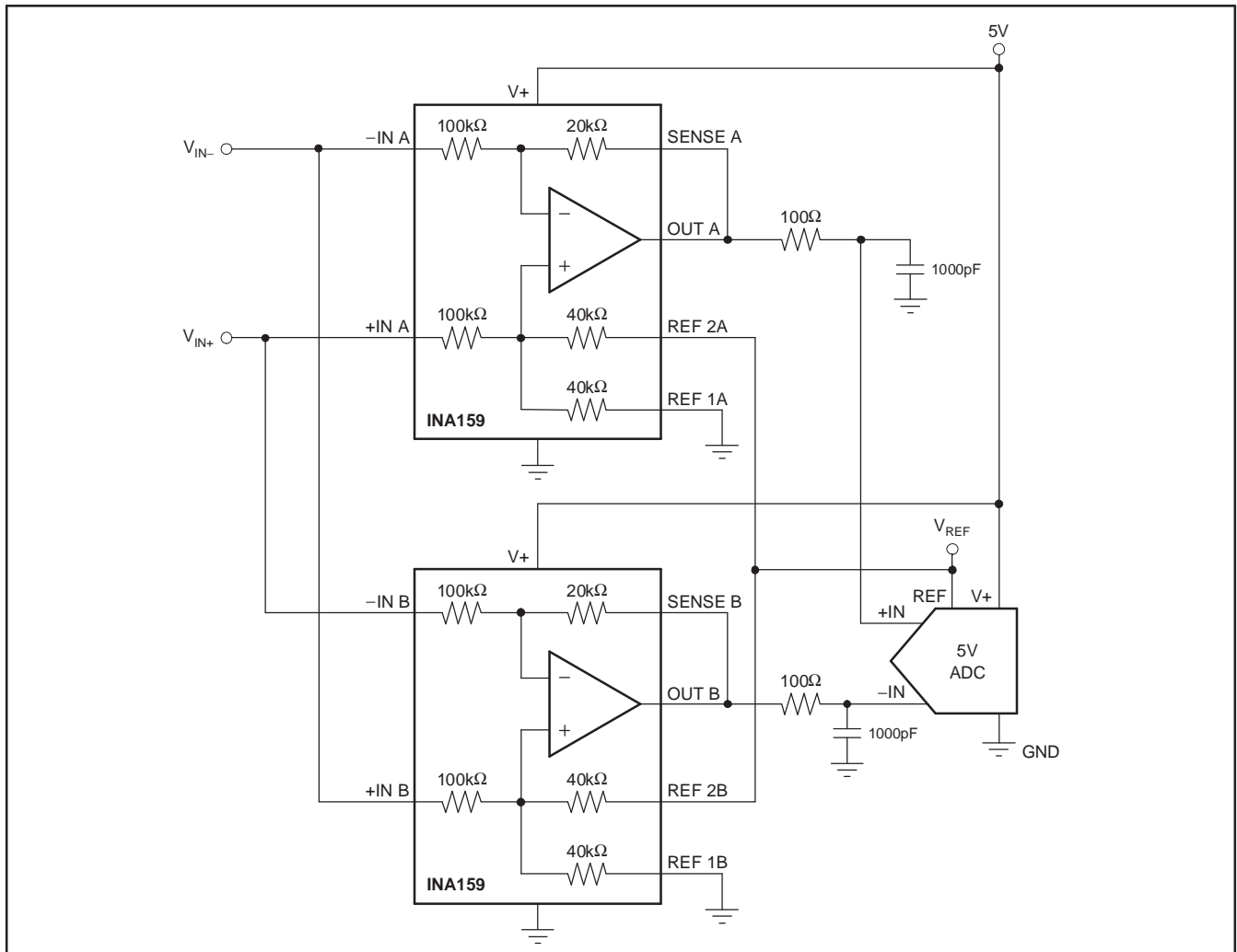


Figure 6. Differential ADC Drive

**PACKAGING INFORMATION**

Orderable Device	Status <sup>(1)</sup>	Package Type	Package Drawing	Pins	Package Qty	Eco Plan <sup>(2)</sup>	Lead/ Ball Finish	MSL Peak Temp <sup>(3)</sup>	Samples (Requires Login)
INA159AMDGKTEP	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-1-260C-UNLIM	
V62/09613-01XE	ACTIVE	MSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-1-260C-UNLIM	

<sup>(1)</sup> 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.

<sup>(2)</sup> 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)

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

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**OTHER QUALIFIED VERSIONS OF INA159-EP :**

- Catalog: [INA159](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

DGK (S-PDSO-G8)

PLASTIC SMALL-OUTLINE PACKAGE



- NOTES:
- A. All linear dimensions are in millimeters.
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
  - E. Falls within JEDEC MO-187 variation AA, except interlead flash.



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

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
RF/IF and ZigBee® Solutions	<a href="http://www.ti.com/lprf">www.ti.com/lprf</a>

### Applications

Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
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