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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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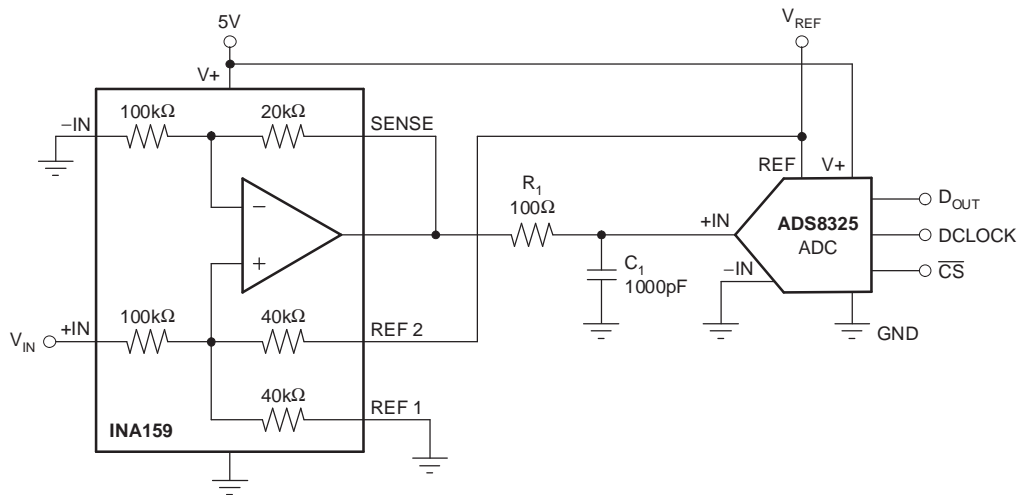


Figure 1. Typical Application



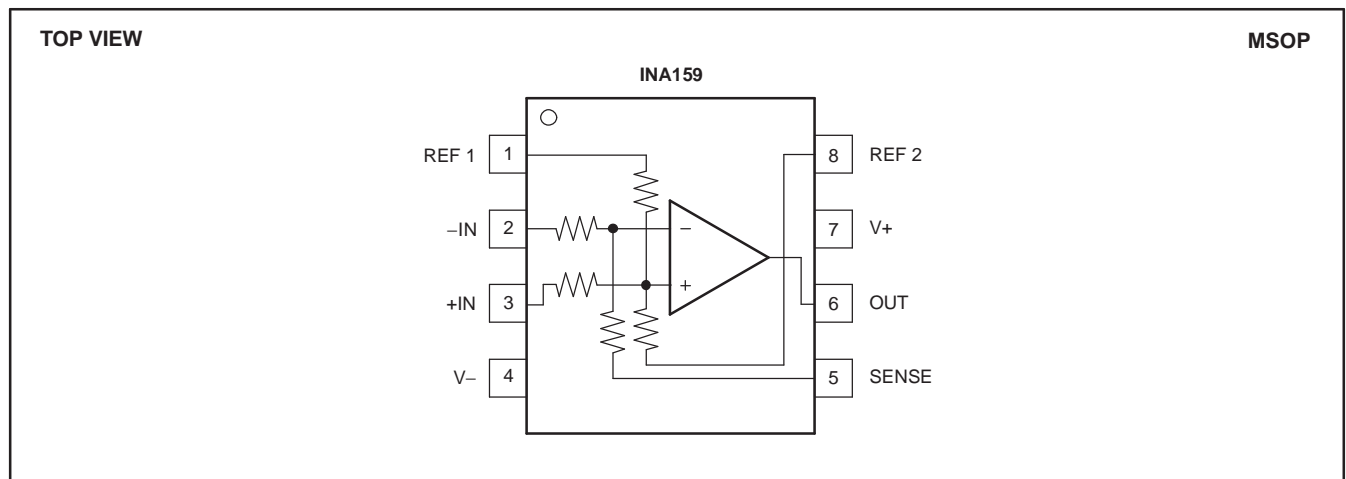
This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

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		$\mu\text{VPP}$
$f = 10\text{ kHz}$			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		$\mu\text{s}$

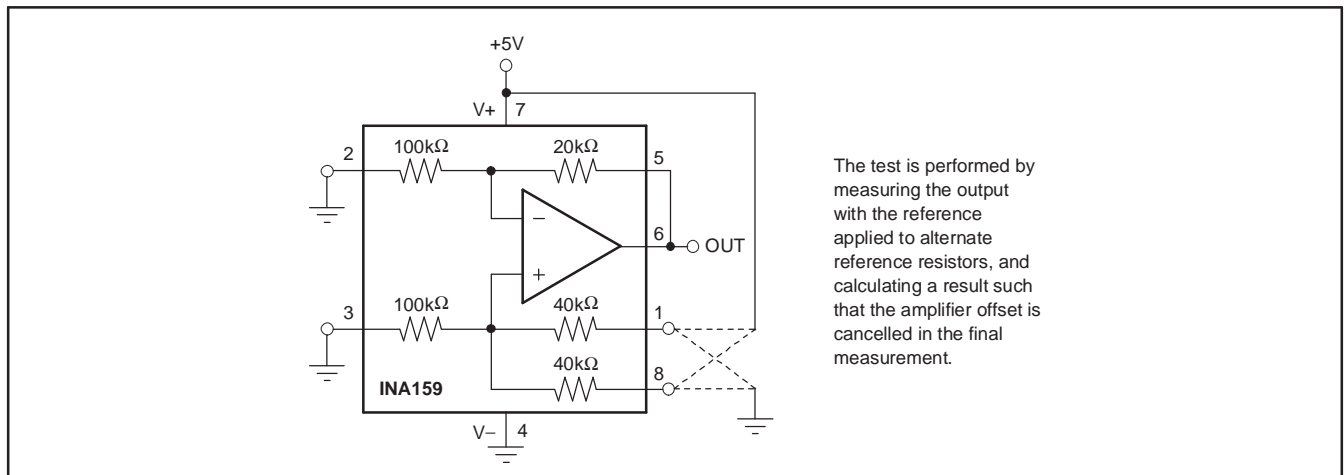
(1) Includes effects of amplifier input bias and offset currents.  
 (2) Reference divider accuracy specifies the match between the reference divider resistors using the configuration in [Figure 2](#).  
 (3) Internal resistors are ratio matched but have 20% absolute value.  
 (4) Includes effects of 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.

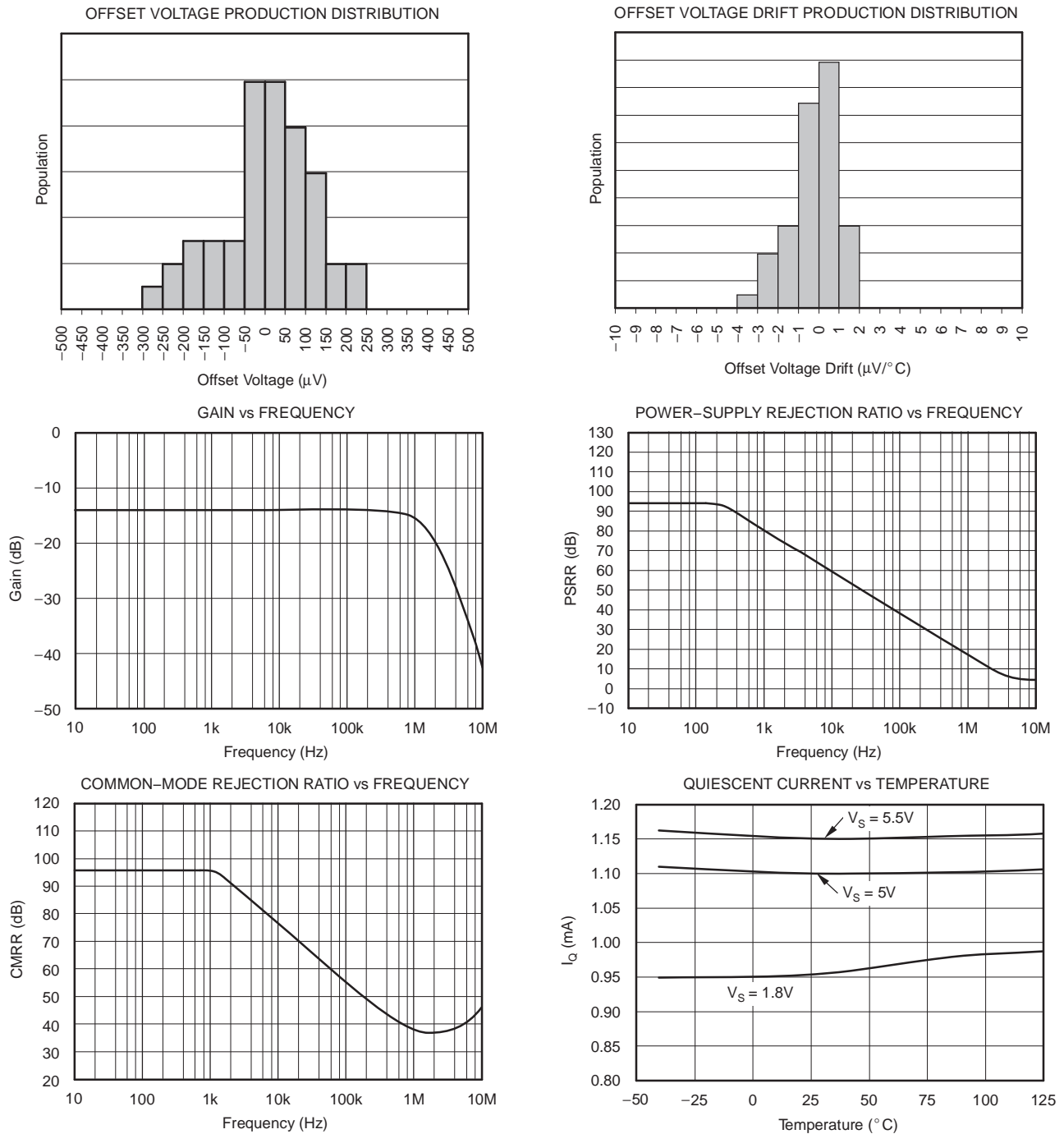
PARAMETER	CONDITIONS	INA159			UNIT
		MIN	TYP	MAX	
Overload Recovery Time	50% Overdrive		250		ns
<b>POWER SUPPLY</b>					
Specified Voltage Range	$V_S$			+5	V
Operating Voltage Range		+1.8		+5.5	V
Quiescent Current	$I_Q$	$I_O = 0\text{ mA}$ , $V_S = \pm 2.5\text{ V}$ , Reference and Input Pins Grounded			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**

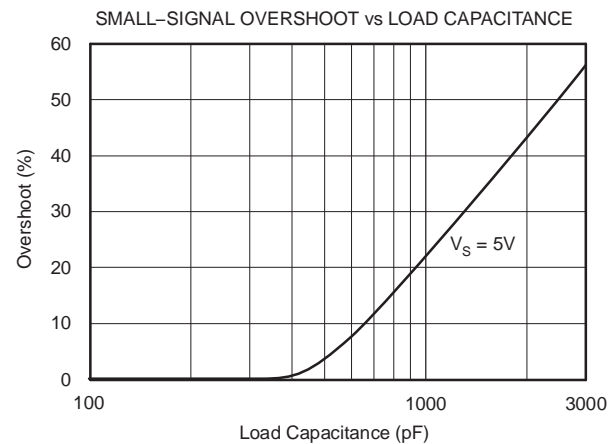
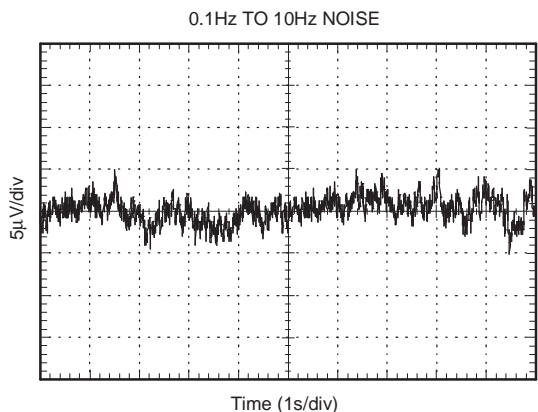
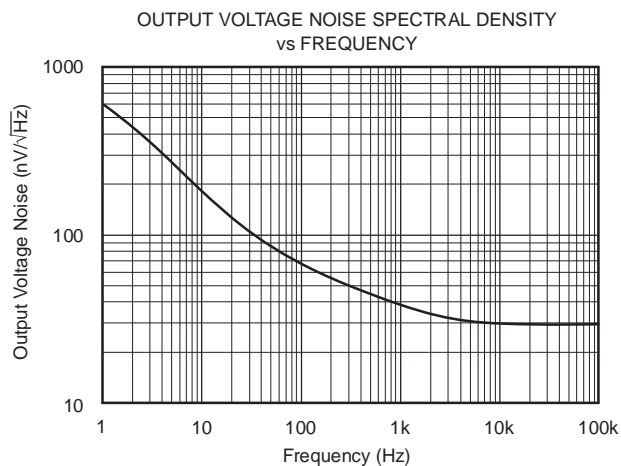
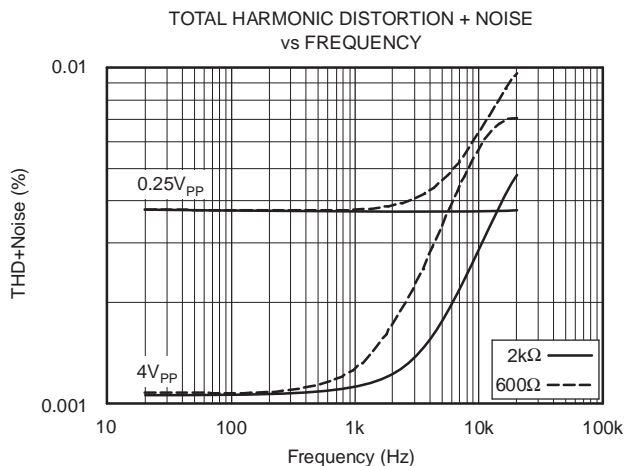
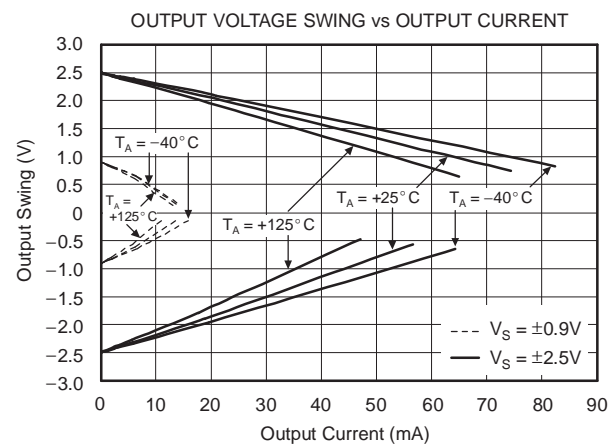
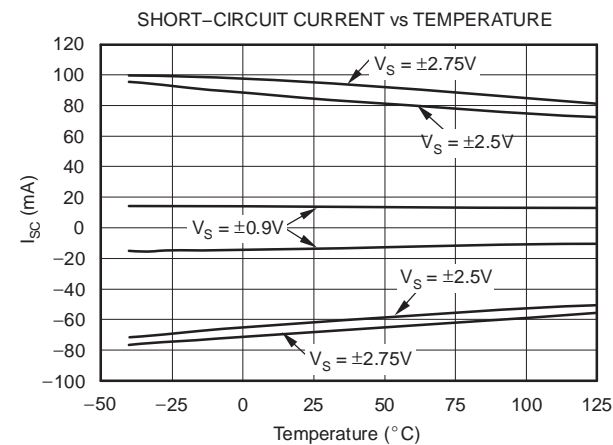
### TYPICAL CHARACTERISTICS

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)

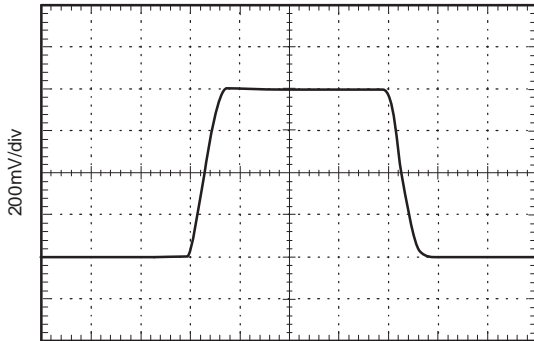
At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.



**TYPICAL CHARACTERISTICS (continued)**

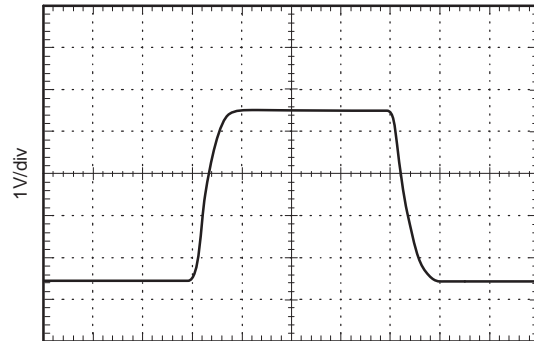
At  $T_A = +25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S/2$ , REF pin 1 connected to ground, and REF pin 2 connected to  $V_{REF} = 5\text{ V}$ , unless otherwise noted.

SMALL-SIGNAL STEP RESPONSE



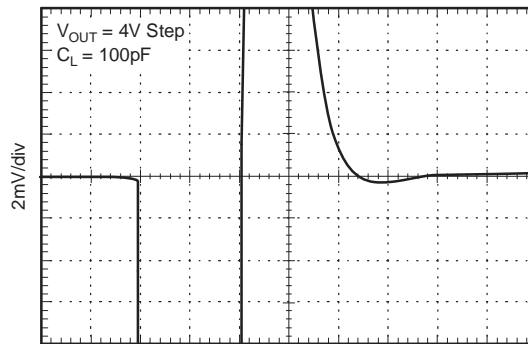
Time (500ns/div)

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

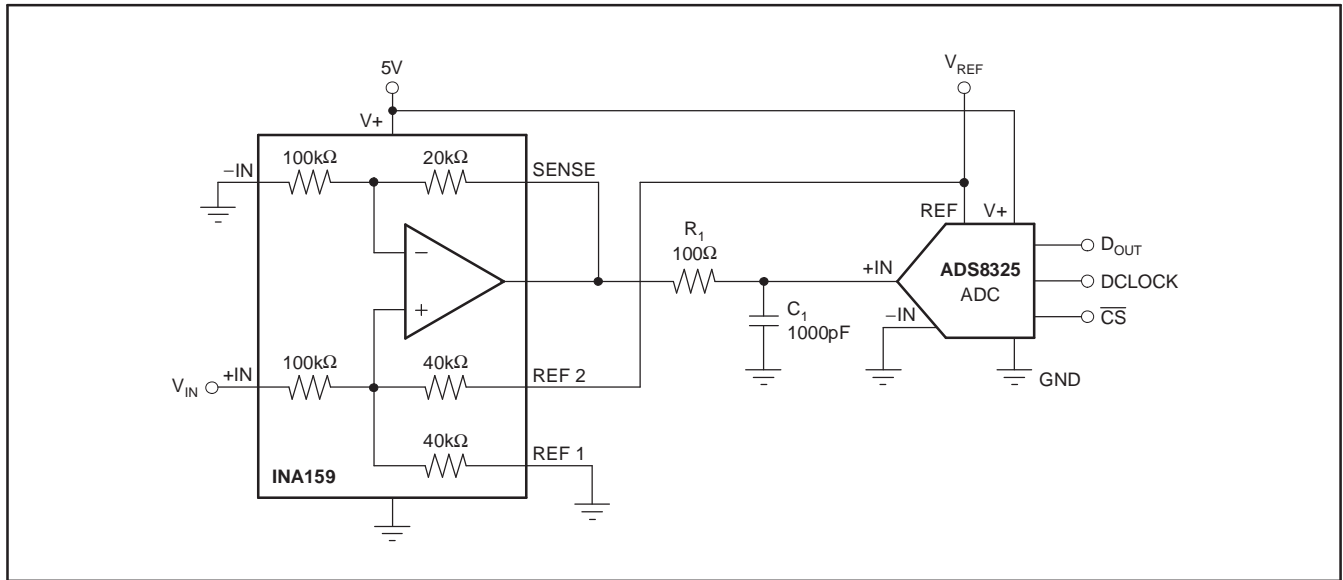


Figure 3. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs

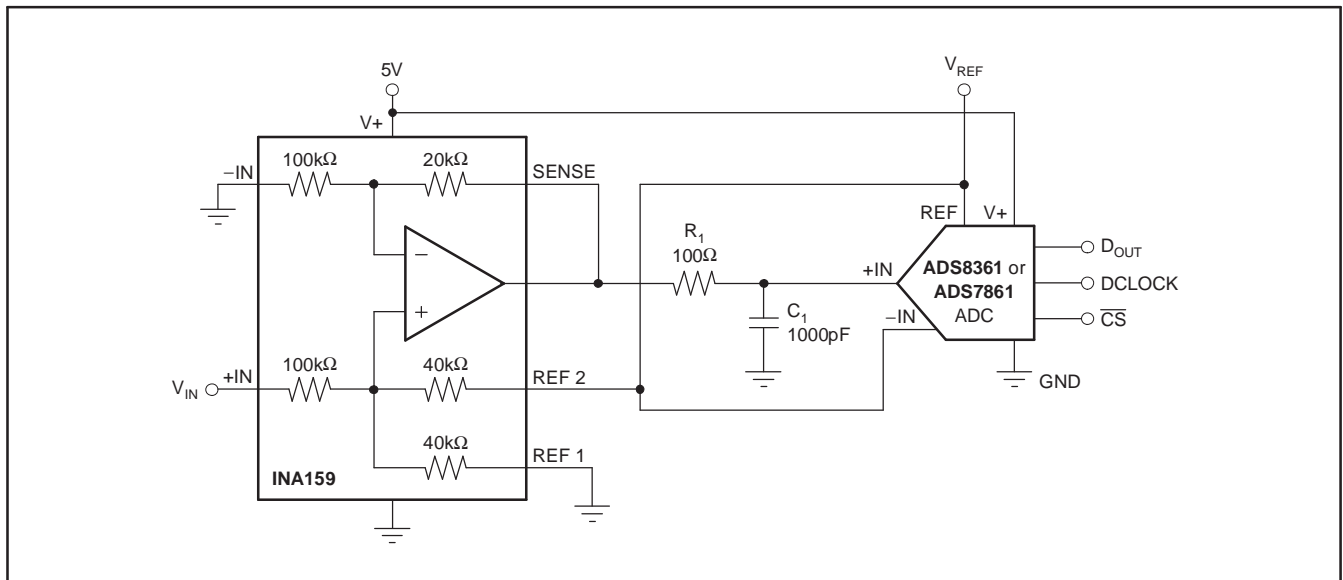


Figure 4. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs with Pseudo-Differential Inputs (such as the ADS7861 and ADS8361)

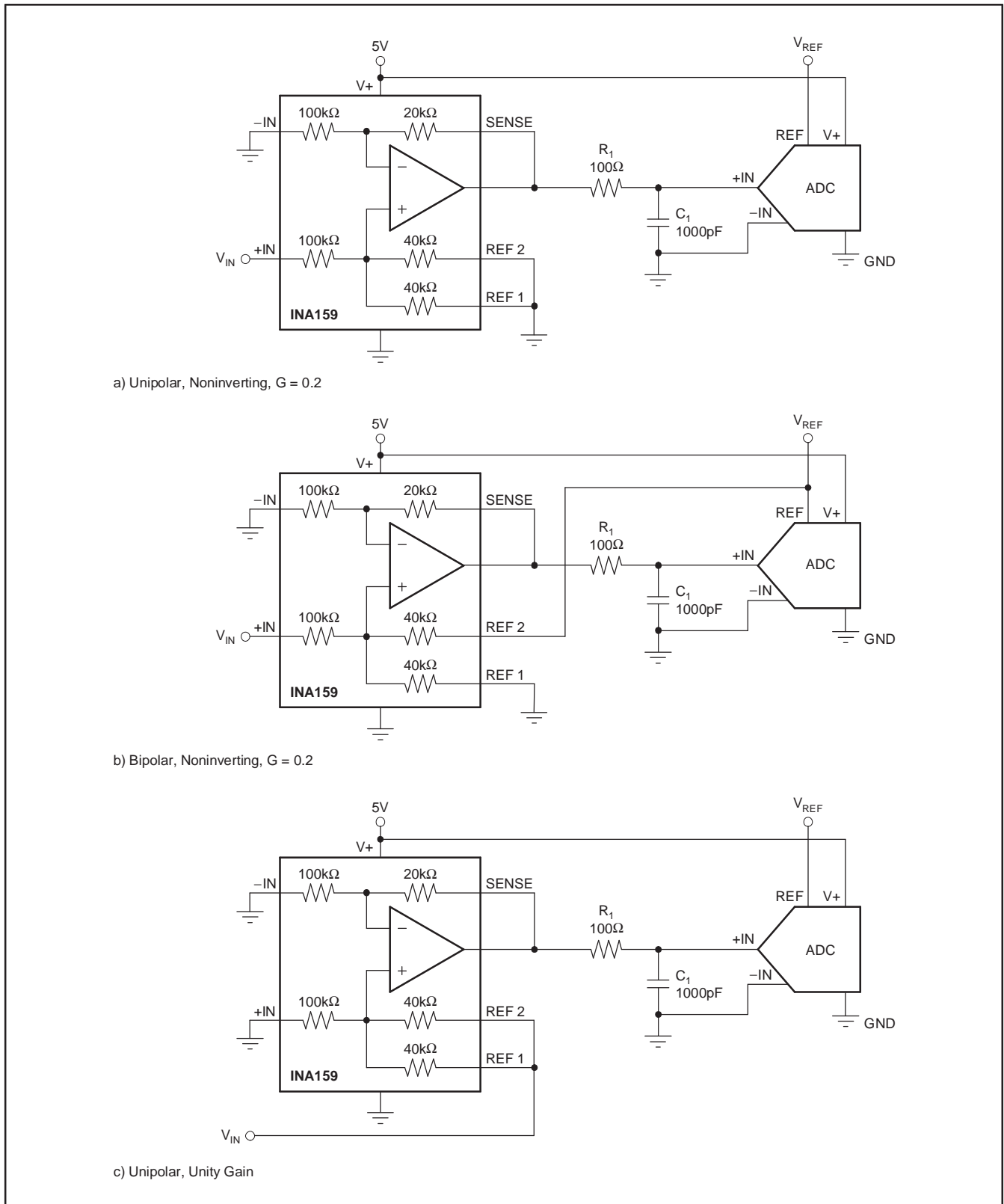


Figure 5. Basic INA159 Configurations

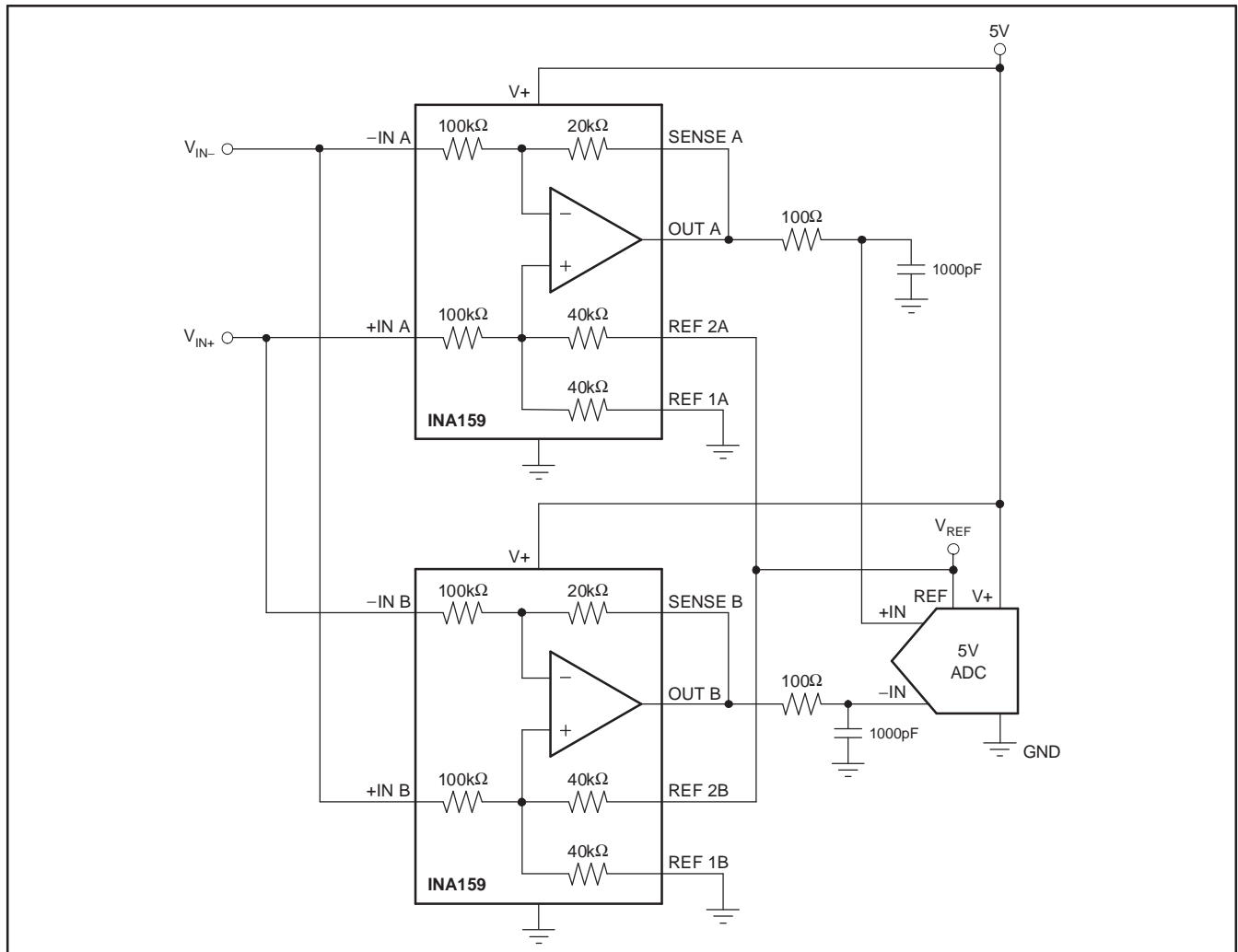


Figure 6. Differential ADC Drive

## PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">INA159AMDGKTEP</a>	Active	Production	VSSOP (DGK)   8	250   SMALL T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-55 to 125	OAA
INA159AMDGKTEP.A	Active	Production	VSSOP (DGK)   8	250   SMALL T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-55 to 125	OAA
<a href="#">V62/09613-01XE</a>	Active	Production	VSSOP (DGK)   8	250   SMALL T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-55 to 125	OAA

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

(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.

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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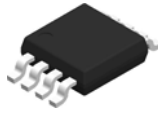
### OTHER QUALIFIED VERSIONS OF INA159-EP :

- Catalog : [INA159](#)

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

DGK0008A



# PACKAGE OUTLINE

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



4214862/A 04/2023

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.



# EXAMPLE BOARD LAYOUT

DGK0008A

™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



4214862/A 04/2023

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.

# EXAMPLE STENCIL DESIGN

DGK0008A

™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

4214862/A 04/2023

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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