PRECISION, GAIN OF 0.2 LEVEL TRANSLATION DIFFERENCE AMPLIFIER

FEATURES

- **Gain of 0.2 to Interface ±10-V Signals to Single-Supply ADCs**
- **Gain Accuracy: ±0.024% (max)**
- **Wide Bandwidth: 1.5 MHz**
- **High Slew Rate: 15 V/μs**
- **Low Offset Voltage: ±100 μV**
- **Low Offset Drift: ±1.5 μV/°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°C/125°C) Temperature Range**(1)
- **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 ±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°C to 125°C.

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PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of the Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

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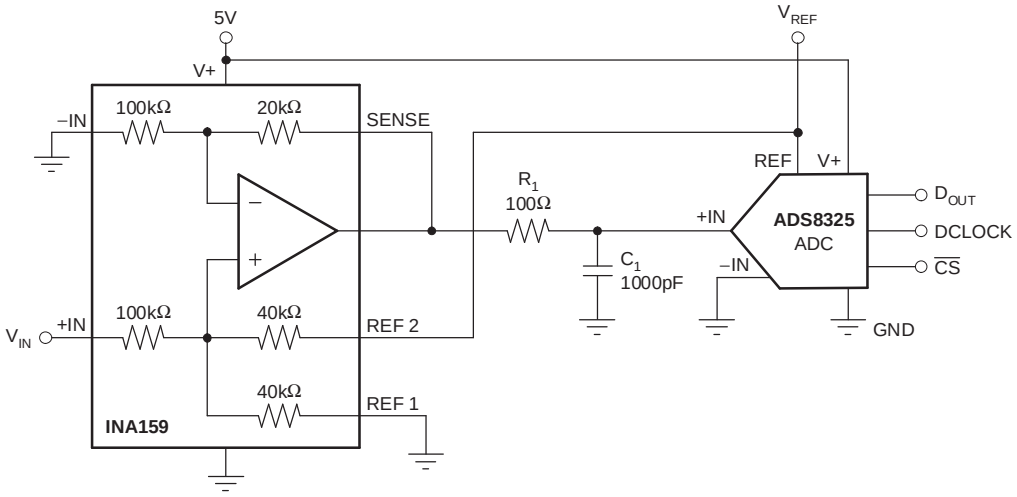


Figure 1. Typical Application

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.

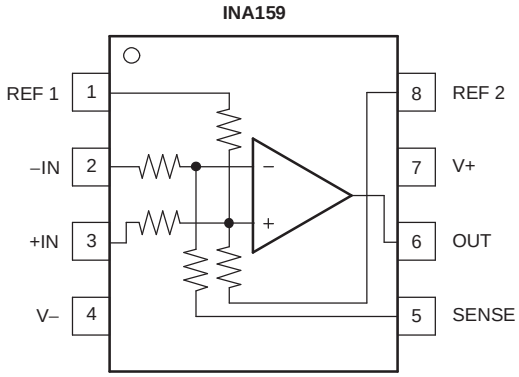
ORDERING INFORMATION(1)

TEMPERATURE	ORDERABLE PART NUMBER(2)	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.

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

TOP VIEW **MSOP**



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ABSOLUTE MAXIMUM RATINGS(1)

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

		MIN	MAX	UNIT
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.

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ELECTRICAL CHARACTERISTICS

Boldface limits apply over the specified temperature range, **T_A = –55°C to +125°C**.
At T_A = +25°C, R_L = 10 kΩ connected to V_S/2, REF pin 1 connected to ground, and REF pin 2 connected to V_{REF} = 5 V, unless otherwise noted.

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

(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.

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ELECTRICAL CHARACTERISTICS (continued)

Boldface limits apply over the specified temperature range, **T_A = –55°C to +125°C**.
At T_A = +25°C, R_L = 10 kΩ connected to V_S/2, REF pin 1 connected to ground, and REF pin 2 connected to V_{REF} = 5 V, unless otherwise noted.

PARAMETER		CONDITIONS	INA159			UNIT
			MIN	TYP	MAX	
Overload Recovery Time		50% Overdrive		250		ns
POWER SUPPLY						
Specified Voltage Range	V_S				+5	V
Operating Voltage Range			+1.8		+5.5	V
Quiescent Current	I_Q	I_O = 0 mA, V_S = ±2.5 V, Reference and Input Pins Grounded		1.1	1.5	mA
over Temperature					**2.0**	**mA**
TEMPERATURE RANGE						
Specified Range			–55		+125	°C
Operating Range			–55		+125	°C
Storage Range			–65		+150	°C
Thermal Resistance	θJA					
MSOP-8		Surface Mount		150		°C/W

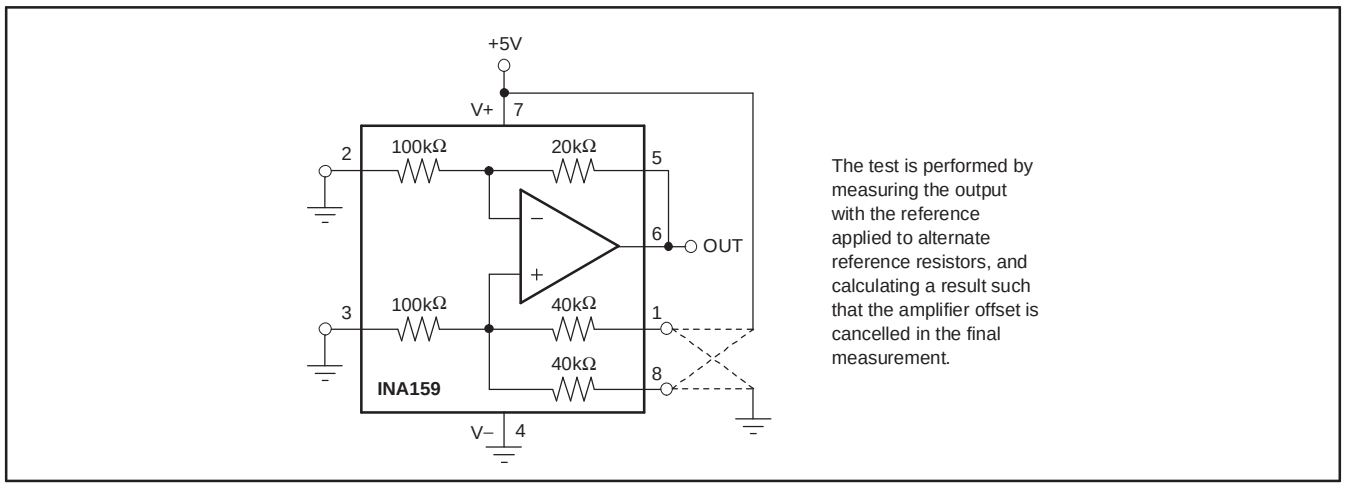
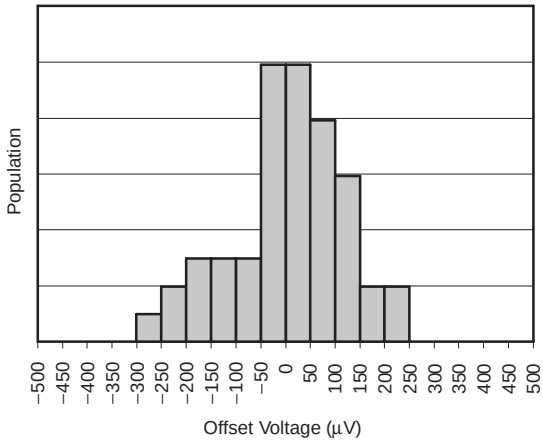


Figure 2. Test Circuit for Reference Divider Accuracy

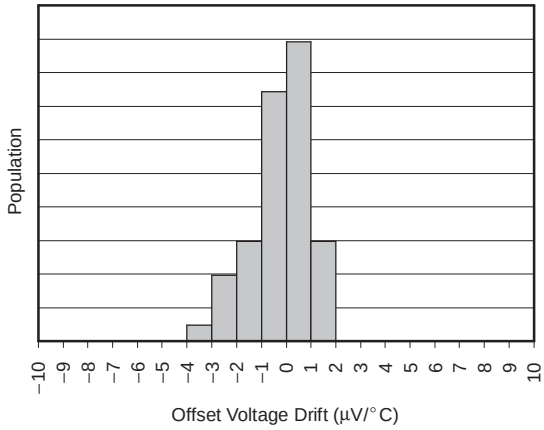
TYPICAL CHARACTERISTICS

At T_A = +25°C, R_L = 10 kΩ connected to V_S/2, REF pin 1 connected to ground, and REF pin 2 connected to V_{REF} = 5 V, unless otherwise noted.

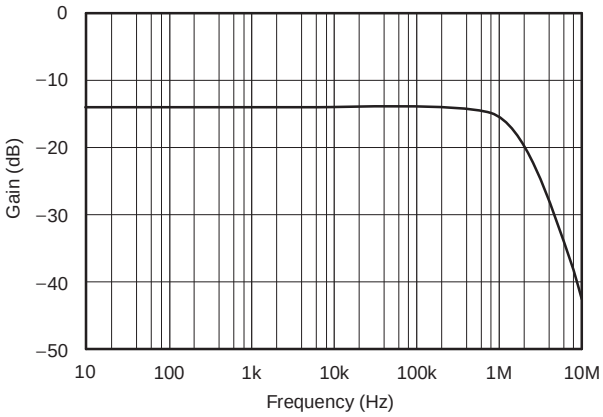
OFFSET VOLTAGE PRODUCTION DISTRIBUTION



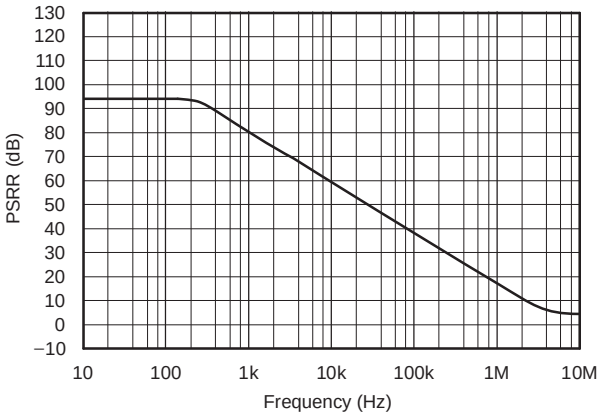
OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION



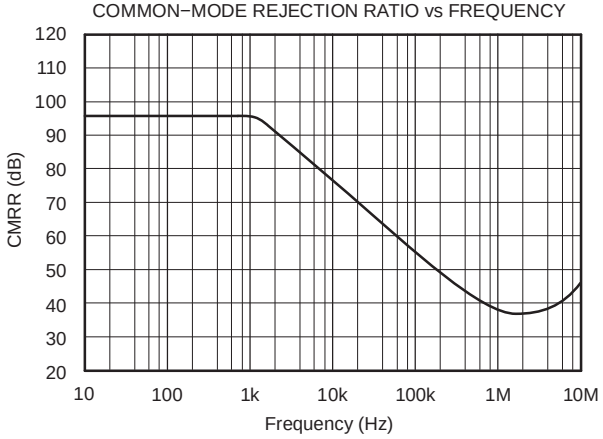
GAIN vs FREQUENCY



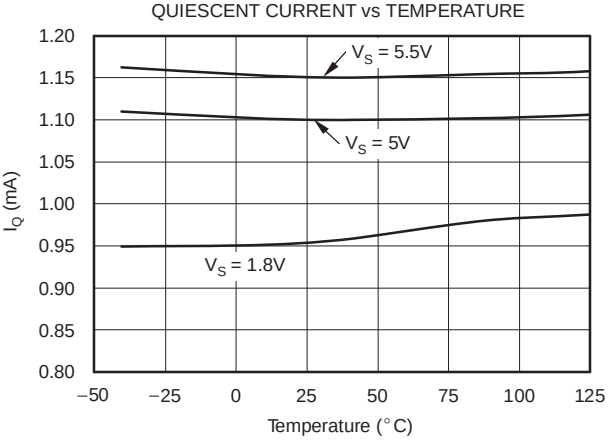
POWER−SUPPLY REJECTION RATIO vs FREQUENCY



COMMON−MODE REJECTION RATIO vs FREQUENCY



QUIESCENT CURRENT vs TEMPERATURE



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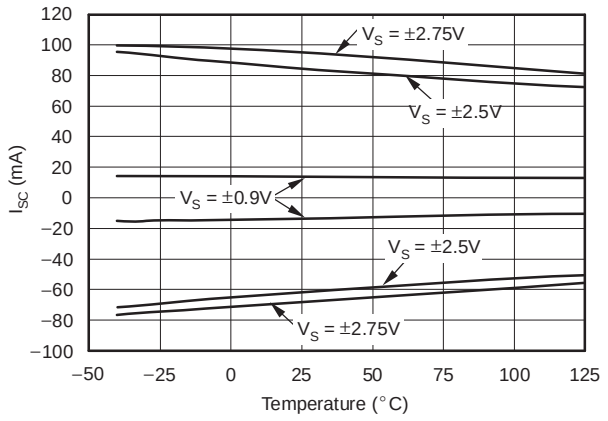
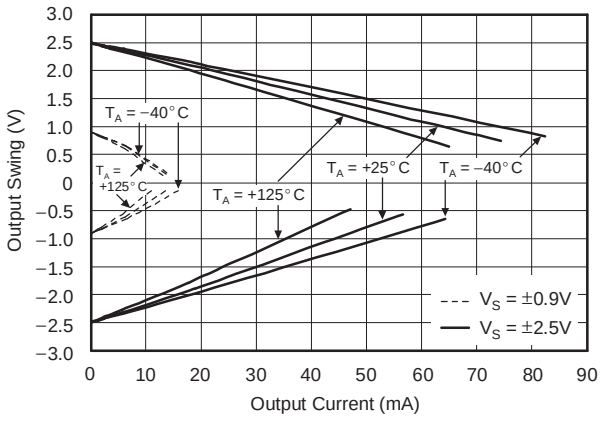
TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, R_L = 10 kΩ connected to V_S/2, REF pin 1 connected to ground, and REF pin 2 connected to V_{REF} = 5 V, unless otherwise noted.

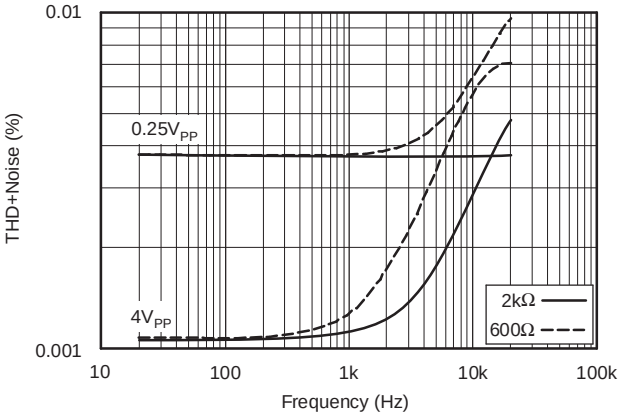
SHORT−CIRCUIT CURRENT vs TEMPERATURE



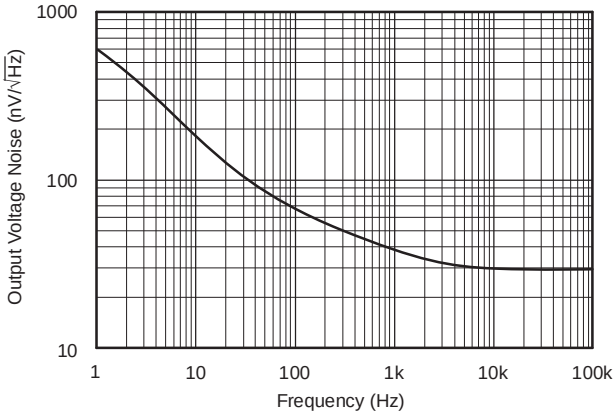
OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



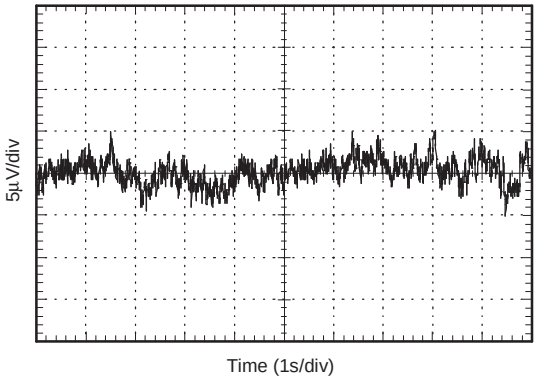
TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY



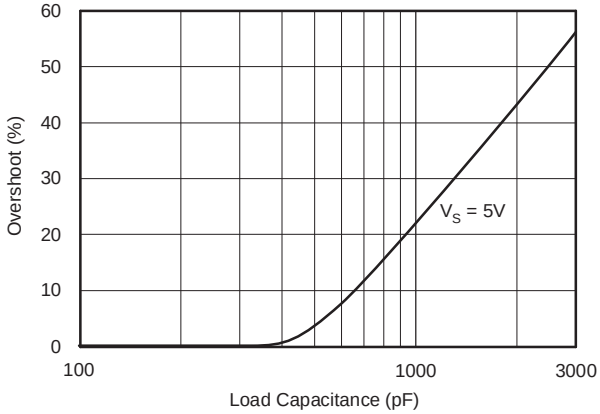
OUTPUT VOLTAGE NOISE SPECTRAL DENSITY vs FREQUENCY



0.1Hz TO 10Hz NOISE



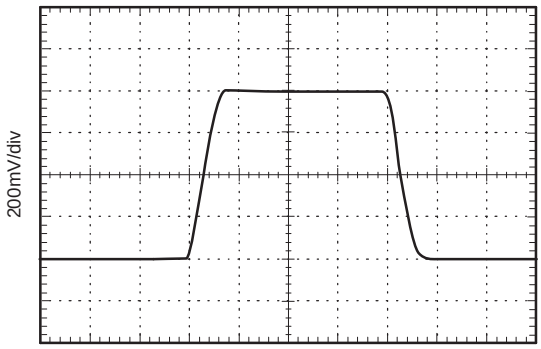
SMALL−SIGNAL OVERSHOOT vs LOAD CAPACITANCE



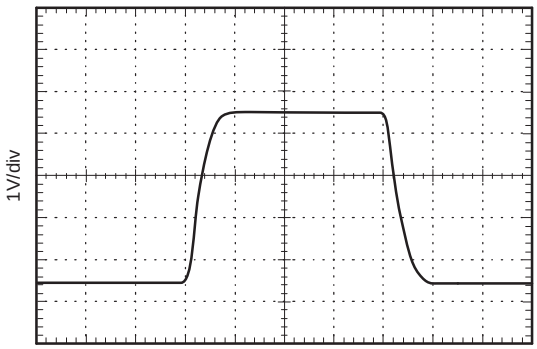
TYPICAL CHARACTERISTICS (continued)

At T_A = +25°C, R_L = 10 kΩ connected to V_S/2, REF pin 1 connected to ground, and REF pin 2 connected to V_{REF} = 5 V, unless otherwise noted.

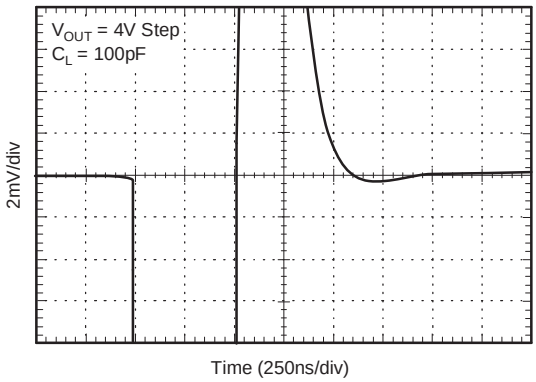
SMALL−SIGNAL STEP RESPONSE



LARGE−SIGNAL STEP RESPONSE



SETTLING TIME



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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 ±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-µF 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_{REF}**	**V_{CM+}**	**V_{CM-}**
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_{REF}**	**V_{CM+}**	**V_{CM-}**
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

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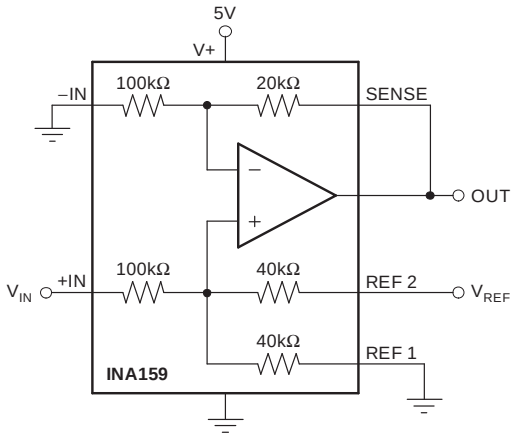
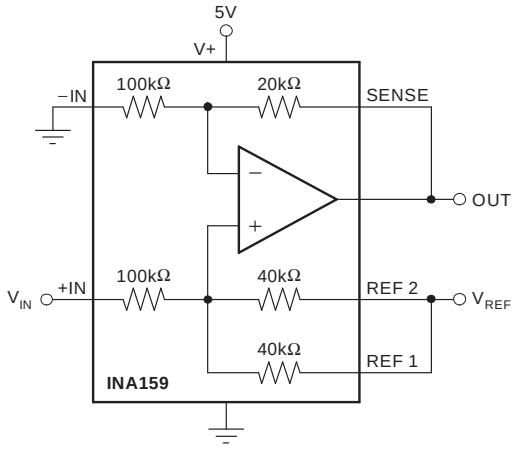
Input and Output Relationships for Various Reference and Connection Combinations

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

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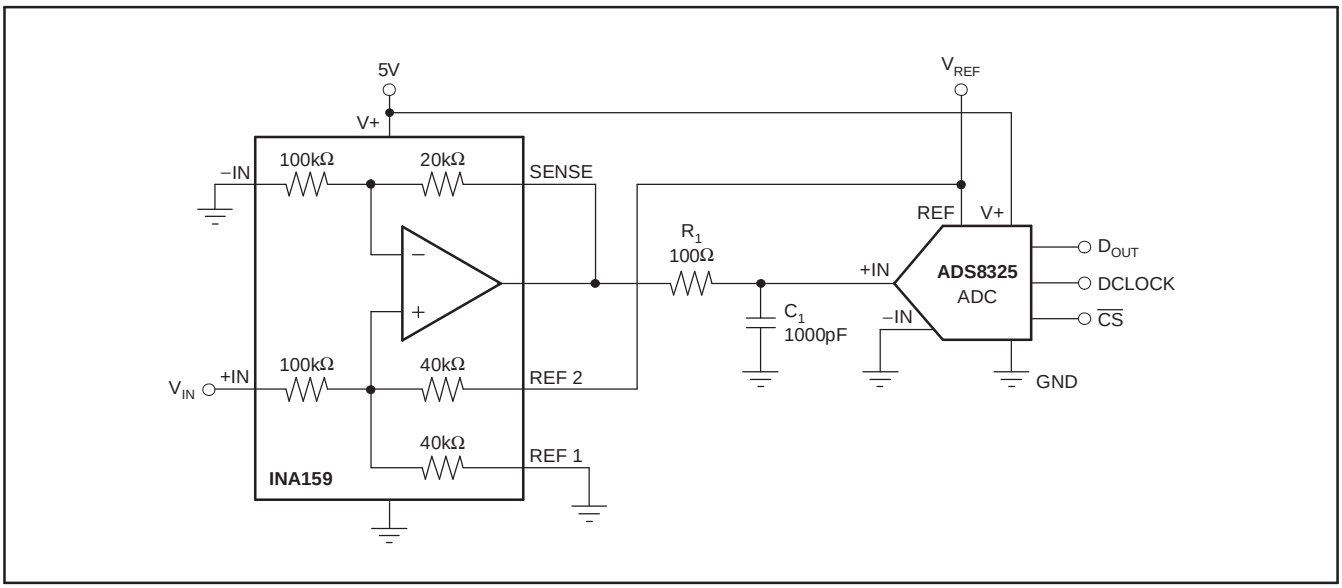

Figure 3. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs

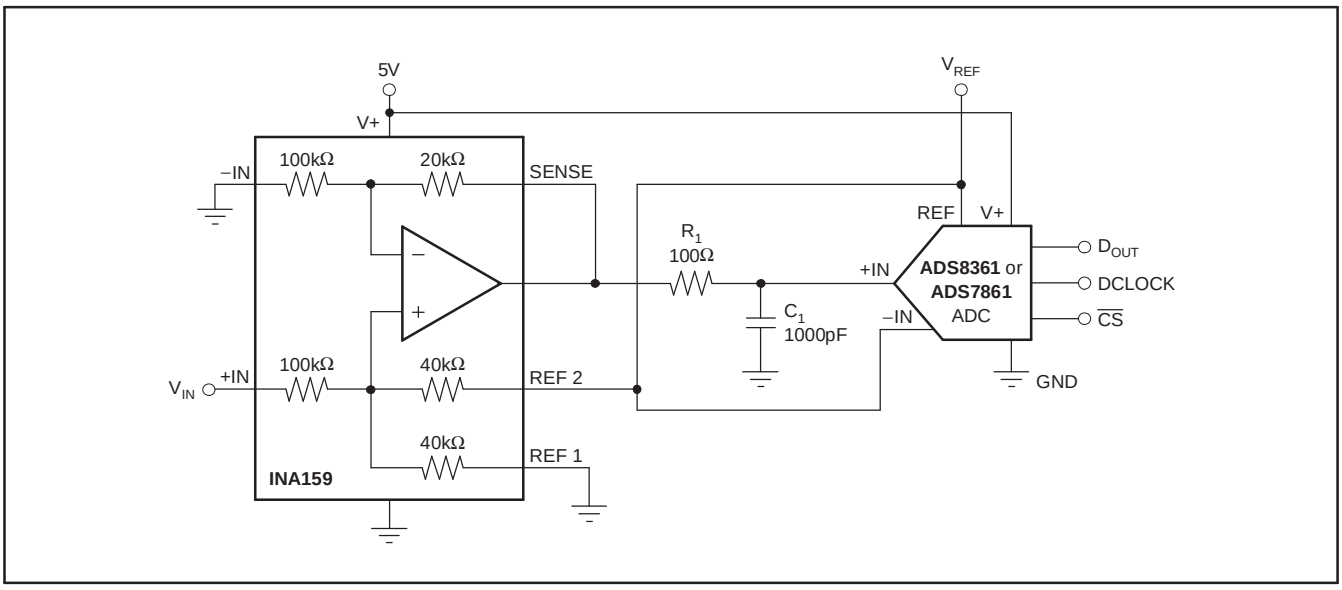

Figure 4. Typical Application Circuit Interfacing to Medium-Speed, Single-Supply ADCs with Pseudo-Differential Inputs (such as the ADS7861 and ADS8361)

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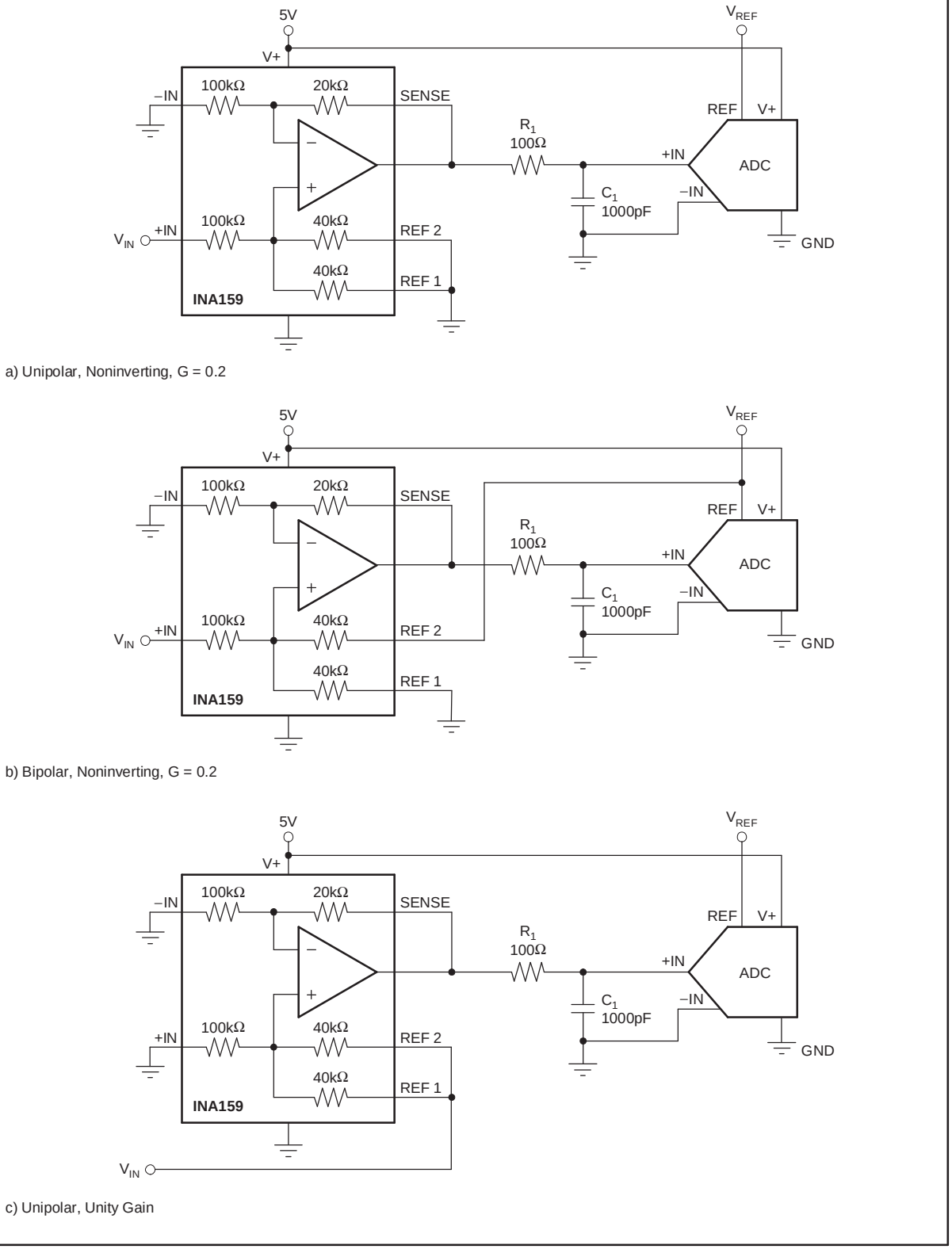

Figure 5. Basic INA159 Configurations

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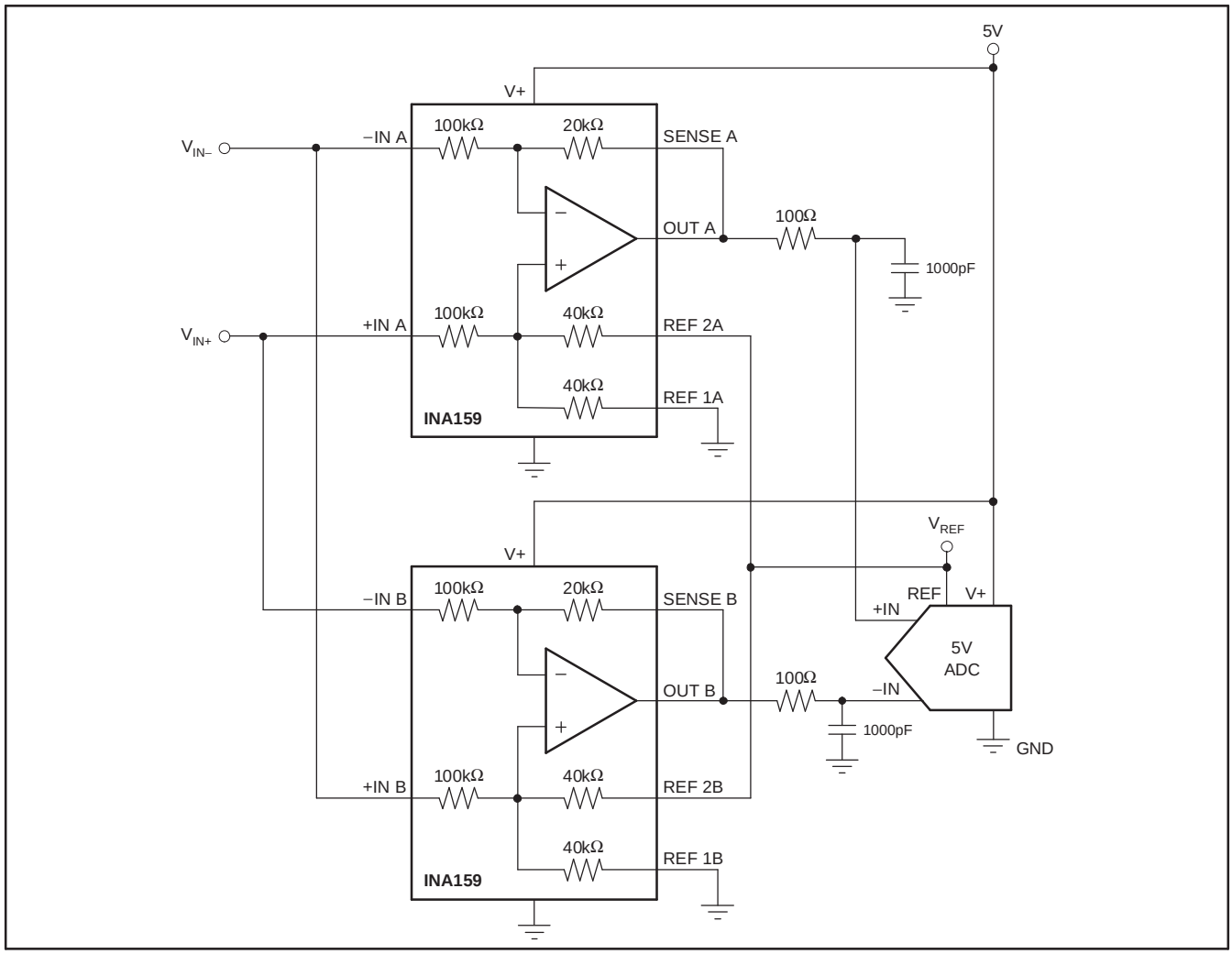

Figure 6. Differential ADC Drive

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
INA159AMDGKTEP	ACTIVE	VSSOP	DGK	8	250	RoHS & Green	NIPDAUAG	Level-1-260C-UNLIM	-55 to 125	OAA	Samples
V62/09613-01XE	ACTIVE	VSSOP	DGK	8	250	RoHS & Green	NIPDAUAG	Level-1-260C-UNLIM	-55 to 125	OAA	Samples

(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) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".
RoHS Exempt: TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.
Green: TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead finish/Ball material - Orderable Devices 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.

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OTHER QUALIFIED VERSIONS OF INA159-EP :

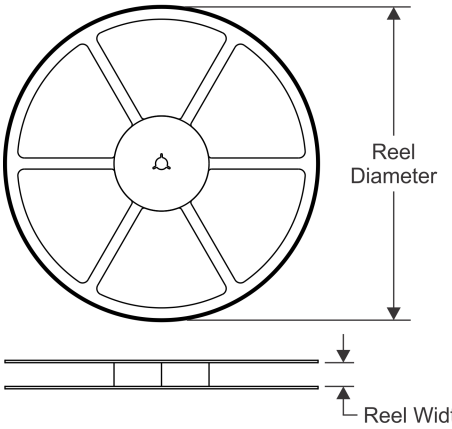
- Catalog: INA159

NOTE: Qualified Version Definitions:

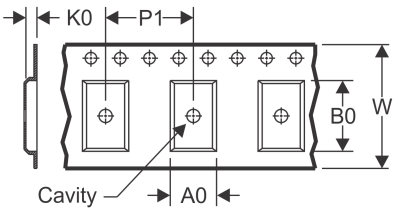
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION

REEL DIMENSIONS

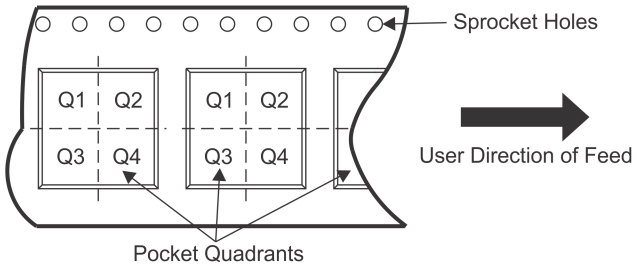


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	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

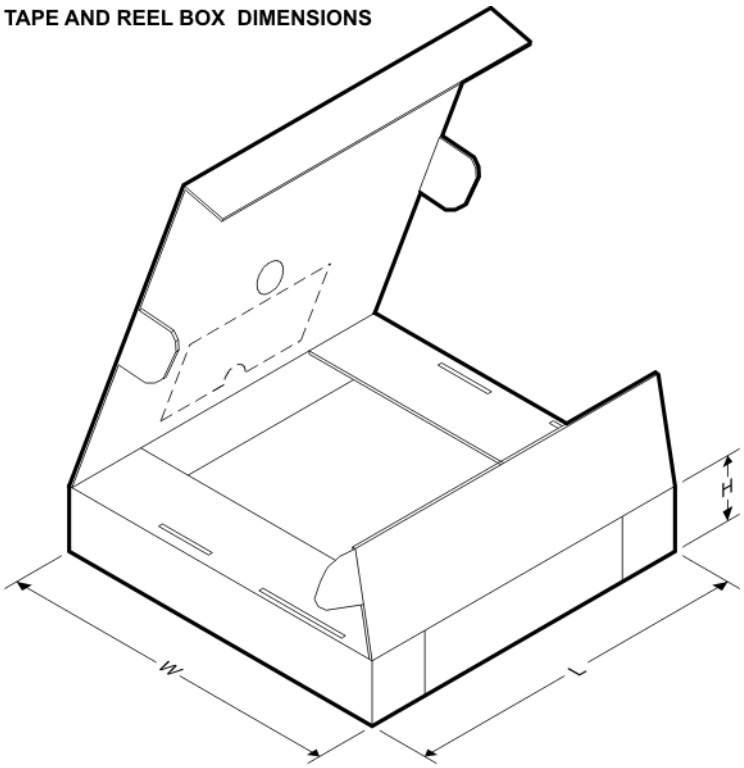
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
INA159AMDGKTEP	VSSOP	DGK	8	250	180.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

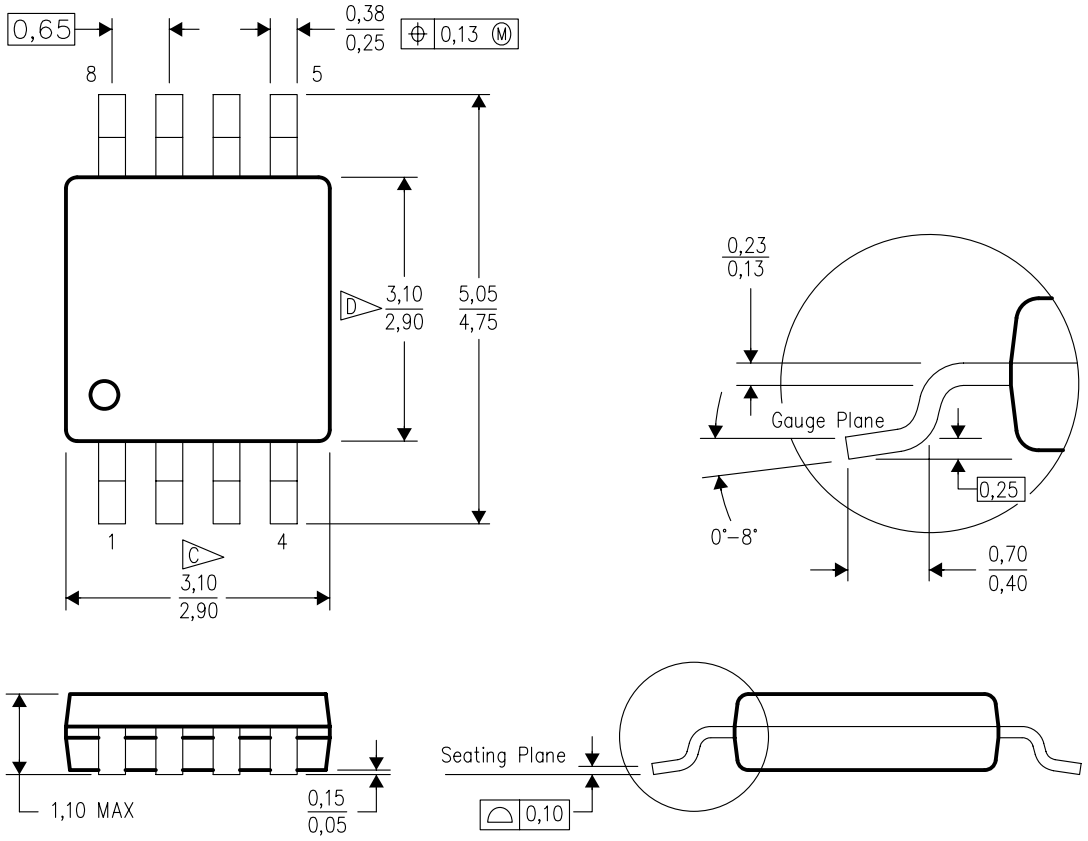
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
INA159AMDGKTEP	VSSOP	DGK	8	250	210.0	185.0	35.0

DGK (S–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



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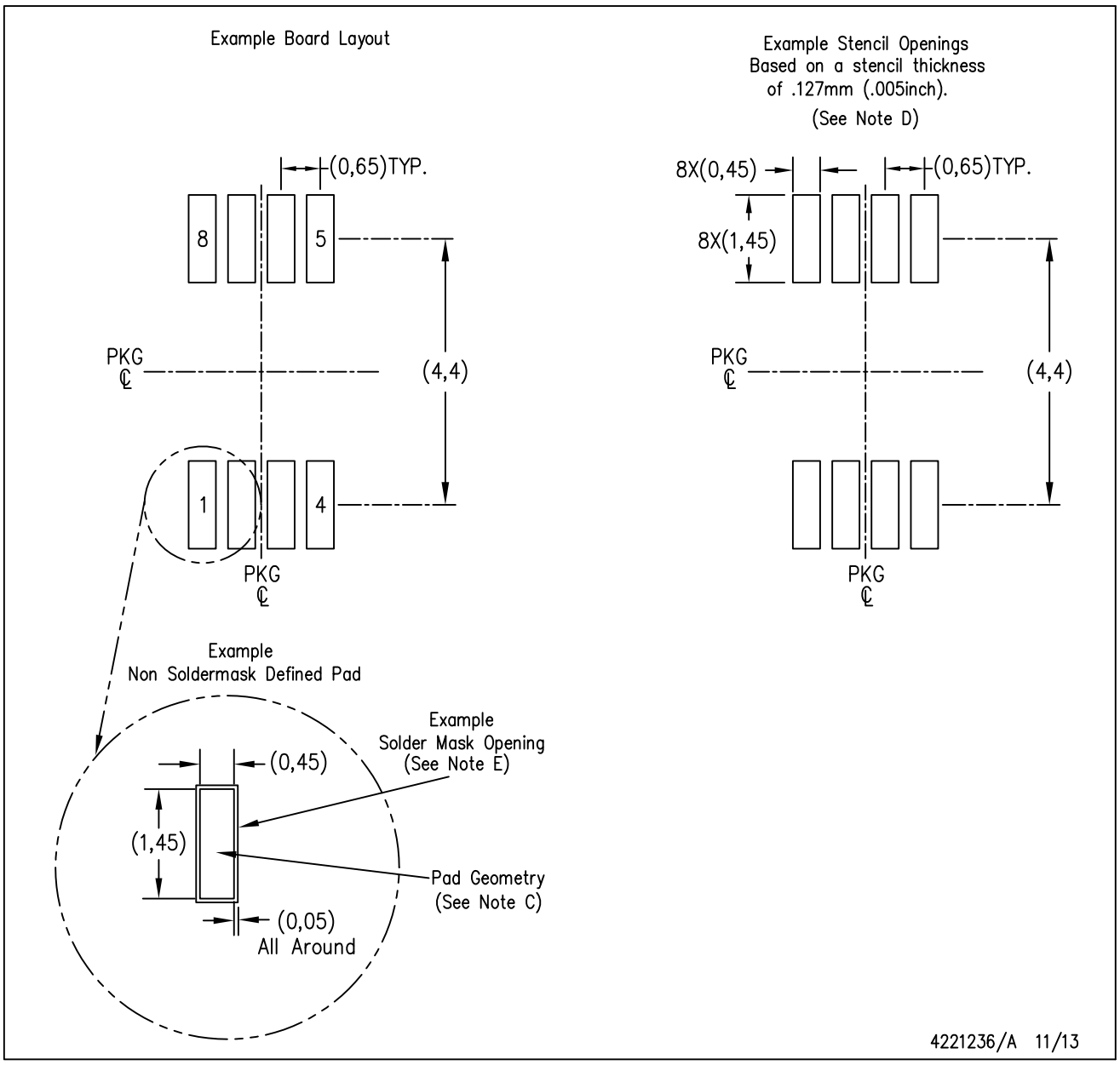
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead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

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. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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