













OPA2333-HT

SBOS483I - JULY 2009 - REVISED MAY 2015

OPA2333-HT 1.8-V Micropower CMOS Operational Amplifier Zero-Drift Series

1 Features

Low Offset Voltage: 26 μV (Maximum)
 0.01-Hz to 10-Hz Noise: 1.5 μV_{PP}

Quiescent Current: 50 µASingle-Supply Operation

Supply Voltage: 1.8 V to 5.5 V

• Rail-to-Rail Input and Output

• Supports Extreme Temperature Applications

Controlled Baseline

• One Assembly/Test Site

• One Fabrication Site

Available in Extreme (–55°C to 210°C)
 Temperature Range

• Extended Product Life Cycle

· Extended Product-Change Notification

· Product Traceability

 Texas Instruments' high temperature products use highly optimized silicon (die) solutions with design and process enhancements to maximize performance over extended temperatures.

NOTE: Custom temperature ranges available

2 Applications

- Down-Hole Drilling
- High Temperature Environments

3 Description

The OPA2333 series of CMOS operational amplifiers uses a proprietary auto-calibration technique to simultaneously provide very low offset voltage and near-zero drift over time and temperature⁽¹⁾. These miniature, high-precision, low-quiescent-current amplifiers offer high-impedance inputs that have a common-mode range 100 mV beyond the rails, and rail-to-rail output that swings within 150 mV of the rails. Single or dual supplies as low as 1.8 V (±0.9 V) and up to 5.5 V (±2.75 V) may be used. They are optimized for low-voltage single-supply operation.

The OPA2333 offers excellent common-mode rejection ratio (CMRR) without the crossover associated with traditional complementary input stages. This design results in superior performance for driving analog-to-digital converters (ADCs) without degradation of differential linearity.

Device Information⁽²⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)		
	SOIC (8)	4.90 mm × 3.91 mm		
OPA2333-HT	CFP (8)	6.90 mm × 5.65 mm		
	CFP (8)	7.035 mm × 5.75 mm		
	CDIP SB (8)	18.55 mm × 7.49 mm		

- (1) See *Electrical Characteristics* for performance degradation over temperature.
- (2) For all available packages, see the orderable addendum at the end of the data sheet.

Typical Application

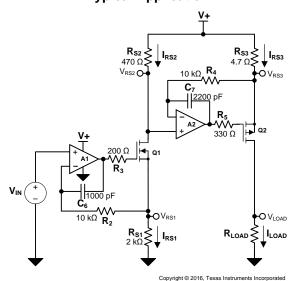




Table of Contents

Features 1	7.4 Device Functional Modes	. 14
Applications 1	8 Application and Implementation	15
• •	8.1 Application Information	. 15
	8.2 Typical Applications	. 15
-	8.3 System Examples	. 20
	9 Power Supply Recommendations	22
•	10 Layout	23
G		
3	10.2 Layout Example	
	11 Device and Documentation Support	24
	11.1 Device Support	
	11.2 Community Resources	. 24
	11.3 Trademarks	
	11.4 Electrostatic Discharge Caution	. 24
	11.5 Glossary	. 24
7.3 Feature Description	12 Mechanical, Packaging, and Orderable Information	
	Applications 1 Description 1 Revision History 2 Pin Configuration and Functions 3 Specifications 5 6.1 Absolute Maximum Ratings 5 6.2 ESD Ratings 5 6.3 Recommended Operating Conditions 5 6.4 Thermal Information 5 6.5 Electrical Characteristics 6 6.6 Typical Characteristics 9 Detailed Description 12 7.1 Overview 12 7.2 Functional Block Diagrams 12	Applications18Application and ImplementationDescription18.1 Application InformationRevision History28.2 Typical ApplicationsPin Configuration and Functions38.3 System ExamplesSpecifications59 Power Supply Recommendations6.1 Absolute Maximum Ratings510 Layout6.2 ESD Ratings510.1 Layout Guidelines6.3 Recommended Operating Conditions510.2 Layout Example6.4 Thermal Information511 Device and Documentation Support6.5 Electrical Characteristics611.1 Device Support6.6 Typical Characteristics911.2 Community ResourcesDetailed Description1211.3 Trademarks7.1 Overview1211.4 Electrostatic Discharge Caution7.2 Functional Block Diagrams1211.5 Glossary7.3 Feature Description12Mechanical, Packaging, and Orderable

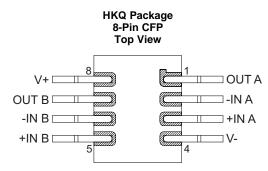
4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

C	Changes from Revision H (November 2013) to Revision I		
•	Added Pin Configuration and Functions section, ESD Ratings table, Feature Description section, Device Functional Modes, Application and Implementation section, Power Supply Recommendations section, Layout section, Device and Documentation Support section, and Mechanical, Packaging, and Orderable Information section	1	
•	Removed Ordering Information table	1	
•	Moved temperature range from Electrical Characteristics table to the Absolute Maximum Ratings and Recommended Operating Conditions tables	5	



5 Pin Configuration and Functions



HKQ as formed or HKL mounted dead bug

Pin Functions

PIN		1/0	DECEDIPTION		
NO.	NAME	1/0	DESCRIPTION		
1	OUT A	0	Analog output channel A		
2	−IN A	1	Inverting analog input channel A		
3	+IN A	1	Noninverting analog input channel A		
5	+IN B	1	Noninverting analog input channel B		
6	–IN B	1	Inverting analog input channel B		
4	V–	_	Negative (lowest) power supply		
7	OUT B	0	Analog output channel B		
8	V+	_	Positive (highest) power supply		

Product Folder Links: OPA2333-HT



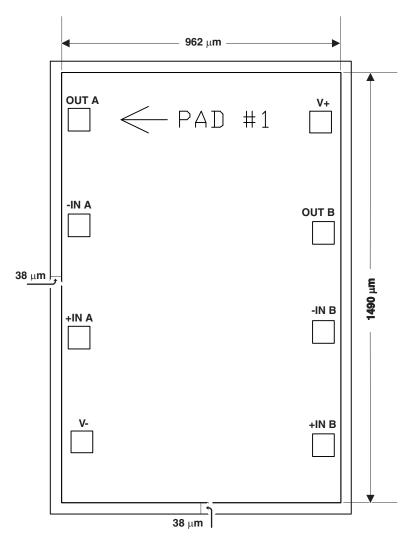


Table 1. Bare Die Information

DIE THICKNESS	BACKSIDE FINISH	BACKSIDE POTENTIAL	BOND PAD METALLIZATION COMPOSITION
15 mils.	Silicon with backgrind	V-	Al-Si-Cu (0.5%)

Table 2. Bond Pad Coordinates

DESCRIPTION	PAD NUMBER	Α	В	С	D
OUT A	1	21.20	1288.50	97.20	1364.50
−IN A	2	21.20	923.65	97.20	999.65
+IN A	3	21.20	533.05	97.20	609.05
V-	4	31.30	172.20	107.30	248.20
+IN B	5	864.80	162.25	940.80	238.25
–IN B	6	864.80	552.65	940.80	628.65
OUT B	7	864.80	897.10	940.80	973.10
V+	8	854.70	1280.45	930.70	1356.45

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6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)⁽¹⁾

		MIN	MAX	UNIT	
Supply voltage			7	V	
Signal input terminals, voltage (2)		-0.3	(V+) + 0.3	V	
Output short circuit (3)		Con	Continuous		
On a serific and a series a series as	JD, HKJ, HKQ packages	-55	210		
Operating temperature	D package	-55	175	°C	
Lucation to a second	JD, HKJ, HKQ packages		210	00	
Junction temperature	D package		175	°C	
Storage temperature, T _{stg}	·	-65	210	°C	

⁽¹⁾ Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

6.2 ESD Ratings

			VALUE	UNIT
V	Electrostatic	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±4000	\/
V _(ESD)	discharge	Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	V

⁽¹⁾ JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT	
Supply voltage, $V_S = (V+) - (V-)$		1.8 (±0.9)	5 (±2.5)	5.5 (±2.75)	V	
	JD, HKJ, HKQ packages	- 55		210	°C	
Operating temperature	D package	– 55		175		

6.4 Thermal Information

				OPA233	3-HT		
	THERMAL N	IETRIC ⁽¹⁾	JD (CDIP SB)	HKJ (CFP)	HKQ (CFP)	D (SOIC)	UNIT
			8 PINS	8 PINS	8 PINS	8 PINS	
В	Junction-to-ambient thermal	High-K board (3), no airflow	_	_		°C/W	
$R_{\theta JA}$	resistance ⁽²⁾	No airflow	_	_	_	(SOIC) 8 PINS 117.5	C/VV
			53.8	57.7		62.0 15.2 —	
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	to ceramic side of case	_	_	15.2	_	°C/W
	.65.6.465	to top of case lid (metal side of case)	_	_	_	_	
$R_{\theta JB}$	Junction-to-board thermal resistance	High-K board without underfill	76.0	61.0	151.6	57.7	°C/W
Ψ_{JT}	Junction-to-top characterization pa	rameter	_	_	_	19.4	°C/W
ΨЈВ	Junction-to-board characterization	parameter	_	_	_	57.2	°C/W
R _{0JC(bot)}	Junction-to-case (bottom) thermal	resistance	26.7	15.2	56.9	_	°C/W

For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report, SPRA953.

⁽²⁾ Input terminals are diode clamped to the power-supply rails. Input signals that can swing more than 0.3 V beyond the supply rails should be current limited to 10 mA or less.

⁽³⁾ Short circuit to ground, one amplifier per package.

⁽²⁾ JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

⁽²⁾ The intent of R_{0JA} specification is solely for a thermal performance comparison of one package to another in a standardized environment.

This methodology is not meant to and will not predict the performance of a package in an application-specific environment.

³⁾ JED51-7, high effective thermal conductivity test board for leaded surface mount packages



6.5 Electrical Characteristics

40\/+0 E E \/ T = 25°C D = 10 kO

	PARAMETER	TEST CON	IDITIONS	MIN	TYP MAX	UNIT
OFFSET	VOLTAGE					
			T _A = 25°C		2 10	
			$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$		22	μV
/os	Input offset voltage	$V_S = 5 \text{ V} \qquad \begin{array}{c} T_A = 25^{\circ}\text{C} \\ T_A = -55^{\circ}\text{C to } 125^{\circ}\text{C} \\ T_A = -55^{\circ}\text{C to } 175^{\circ}\text{C}^{(1)} \\ T_A = -55^{\circ}\text{C to } 125^{\circ}\text{C} \\ T_A = -55^{\circ}\text{C to } 175^{\circ}\text{C} \\ T_A = -55^{\circ$				
					26	μV
					0.02	
dV _{OS} /d _T	Input Offset Voltage	V _S = 5 V			0.05	μV/°C
	Temperature Drift		$T_A = -55^{\circ}C \text{ to } 210^{\circ}C^{(2)}$		0.05	-
					1 6	
PSRR	Input Offset Voltage vs	V _S = 1.8 V to 5.5 V			1.2 8	μV/V
	Power Supply				1.7 11	·
NPUT BI	AS CURRENT					
		T _A = 25°C			±70 ±200	-
1_	Input hige current	$T_A = -55$ °C to 125°C			±150	~ Λ
l _B	Input bias current	$T_A = -55$ °C to 175°C		±	1250	pA
		$T_A = -55$ °C to 210°C		±	5300	
		$T_A = -55^{\circ}C$ to 125°C		:	±140 ±400	
os	Input offset current	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C$:	±700	pA
		$T_A = -55$ °C to 210°C		±10	0600	
NOISE						
			$T_A = -55$ °C to 125°C		0.3	
		$T_A = -55^{\circ}C \text{ to } 210^{\circ}C^{(2)}$	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C^{(1)}$		1	μV_{PP}
	Input Noise Voltage		$T_A = -55$ °C to 210°C ⁽²⁾		1	
	input Noise voitage			1.1	-	
		f = 0.1 Hz to 10 Hz	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C^{(1)}$		1.5	μV _{PP}
			$T_A = -55$ °C to 210°C ⁽²⁾		1.5	
n	Input Noise Current Density	f = 10 Hz	T _A = 25°C		100	fA/√H
NPUT VO	DLTAGE RANGE ⁽³⁾					
	0	$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$		(V-) - 0.1	(V+) + 0.1	
V _{CM}	Common mode voltage range	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C$		(V-) - 0.25	(V+) + 0.25	V
		$T_A = -55^{\circ}C \text{ to } 210^{\circ}C$		(V-) - 0.25	(V+) + 0.25	
	O Mada Daiastian	0/) 04)/ .)/ ()/.)		102	130	
CMRR	Common-Mode Rejection Ratio	$(v-) - 0.1 V < V_{CM} < (V+) + 0.1 V$	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C$		101	dB
			$T_A = -55^{\circ}C \text{ to } 210^{\circ}C$		91	
NPUT CA	APACITANCE					
		$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$			2	
	Differential	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C$			4.25	pF
		$T_A = -55^{\circ}C \text{ to } 210^{\circ}C$			4.25	
		$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$			4	
	Common mode	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C$		1	2.25	pF
		$T_A = -55$ °C to 210°C		1	2.25	
)PEN-LO	OP GAIN					
		(\(\) \(\)	$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$	104	130	
A OL	Open-loop voltage gain	$(V-) + 100 \text{ mV} < V_O < (V+) - 100 \text{ mV}, R_L = 10 \text{ k}\Omega$	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C^{(1)}$	93	110	dB
		, , ,	$T_A = -55^{\circ}C \text{ to } 210^{\circ}C^{(2)}$	85	93	

 ⁽¹⁾ Minimum and maximum parameters are characterized for operation at T_A = 175°C, but may not be production tested at that temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.
 (2) Minimum and maximum parameters are characterized for operation at T_A = 210°C, but may not be production tested at that

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temperature. Production test limits with statistical guardbands are used to ensure high temperature performance.

The OPA2333-HT is not intended to be used as a comparator due to its limited differential input range capability.



Electrical Characteristics (continued)

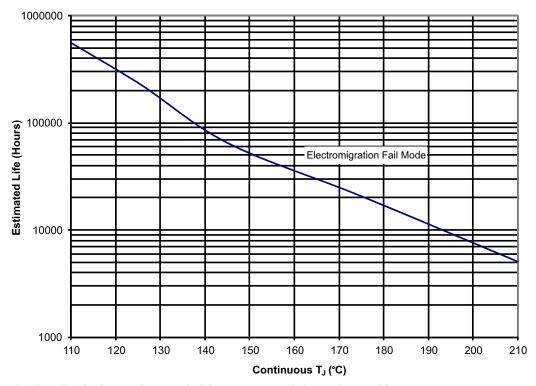
 V_S = 1.8 V to 5.5 V, T_A = 25°C, R_L = 10 k Ω connected to $V_S/2$, V_{CM} = $V_S/2$, and V_{OUT} = $V_S/2$ (unless otherwise noted).

	PARAMETER	TEST C	ONDITIONS	MIN	TYP	MAX	UNIT
FREQU	ENCY RESPONSE		·			-	
			T _A = -55°C to 125°C		350		
GBW	Gain-bandwidth product	C _L = 100 pF	$T_A = -55$ °C to 175°C		350		kHz
			T _A = -55°C to 210°C		350		
			$T_A = -55^{\circ}C \text{ to } 125^{\circ}C$		0.16		
SR	Slew rate	G = 1	T _A = -55°C to 175°C		0.25		V/µs
			$T_A = -55$ °C to 210°C		0.25		
OUTPU	Г						
			T _A = 25°C		30	50	mV
	Voltage output swing from	$R_1 = 10 \text{ k}\Omega$	$T_A = -55$ °C to 125°C			85	
	rail	$K_L = 10 \text{ K}\Omega$	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C^{(1)}$			110	
			$T_A = -55^{\circ}C \text{ to } 210^{\circ}C^{(2)}$			150	
ISC	Short-circuit current	T _A = 25°C			±5		mA
	Open-loop output impedance ⁽⁴⁾	f = 350 kHz, I _O = 0			2		kΩ
POWER	SUPPLY		·				
Vs	Specified voltage range	$T_A = -55^{\circ}C \text{ to } 210^{\circ}C^{(2)}$		1.8		5.5	V
			T _A = 25°C		17	25	
	Quiescent current per		T _A = -55°C to 125°C			30	μΑ
lQ	amplifier	I _O = 0	$T_A = -55^{\circ}C \text{ to } 175^{\circ}C^{(1)}$		35	40	
			$T_A = -55^{\circ}C \text{ to } 210^{\circ}C^{(2)}$		50	80	
	Turnon time	V _S = 5 V	T _A = 25°C		100		μs

⁽⁴⁾ See Typical Characteristics.

Product Folder Links: OPA2333-HT





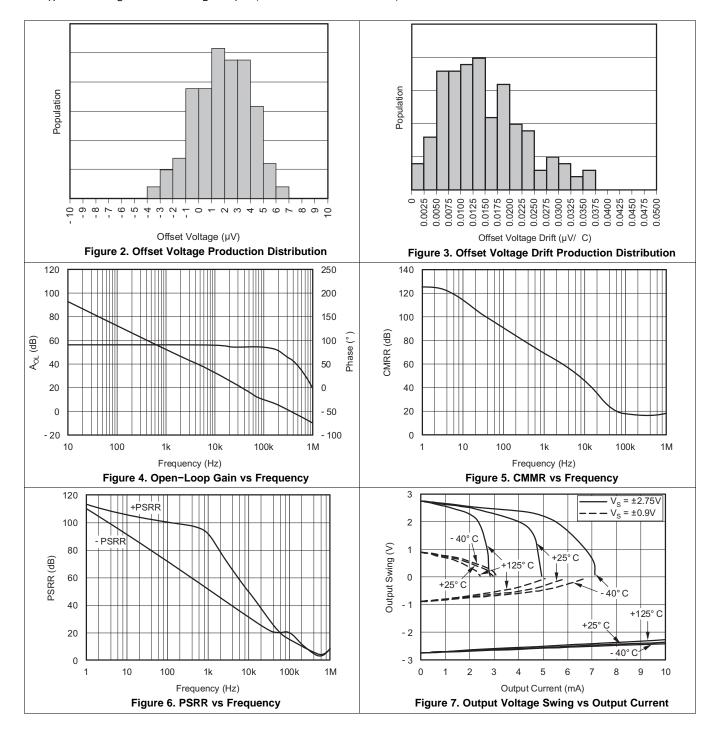
- (1) See datasheet for absolute maximum and minimum recommended operating conditions.
- (2) Silicon operating life design goal is 10 years at 105°C junction temperature (does not include package interconnect life).
- (3) The predicted operating lifetime vs. junction temperature is based on reliability modeling using electromigration as the dominant failure mechanism affecting device wearout for the specific device process and design characteristics.
- (4) This device is qualified for 1000 hours of continuous operation at maximum rated temperature.

Figure 1. OPA2333SKGD1 and OPA2333HD Operating Life Derating Chart



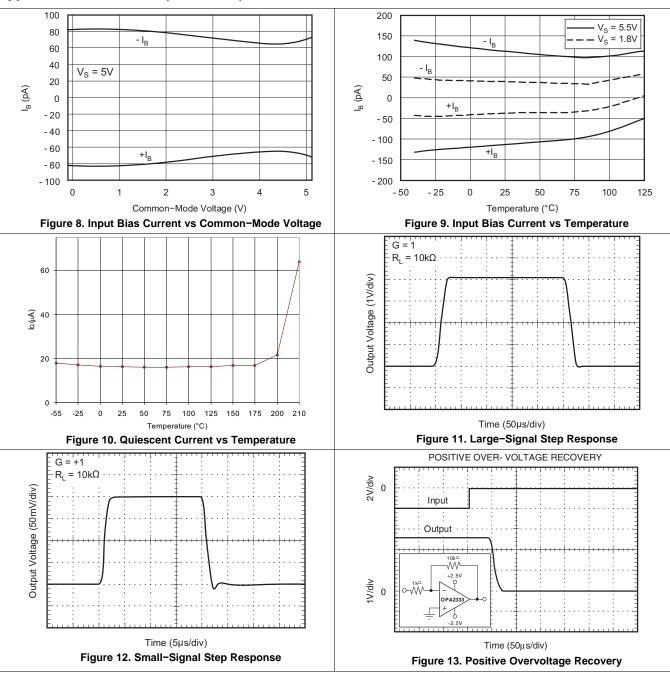
6.6 Typical Characteristics

At $T_A = 25$ °C, $V_S = 5$ V, and $C_L = 0$ pF (unless otherwise noted).



TEXAS INSTRUMENTS

Typical Characteristics (continued)

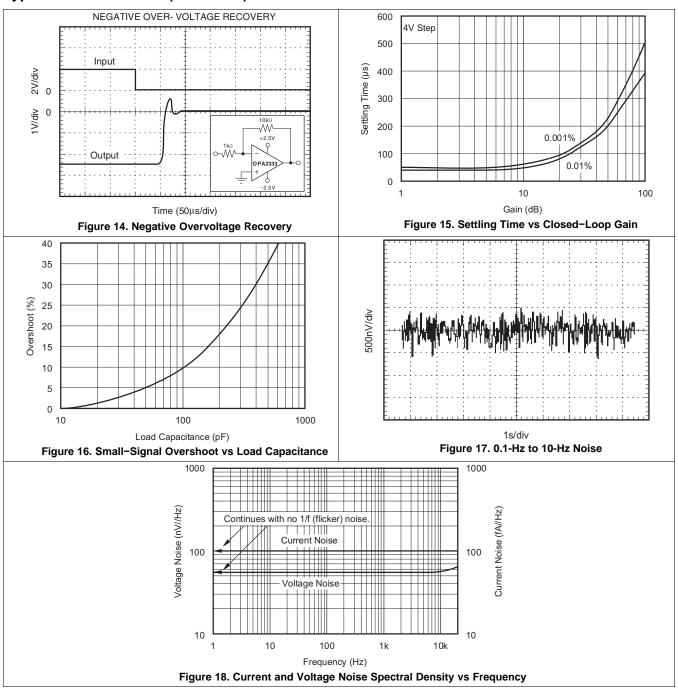


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Typical Characteristics (continued)





7 Detailed Description

7.1 Overview

The OPA2333 is a Zero-Drift, low-power, rail-to-rail input and output dual operational amplifier. The device operates from 1.8 V to 5.5 V, is unity-gain stable, and is suitable for a wide range of general-purpose applications. The Zero-Drift architecture provides low offset voltage and near zero offset voltage drift.

7.2 Functional Block Diagrams

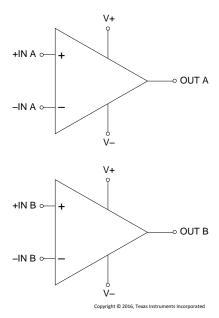


Figure 19. Functional Block Diagram for A and B Amps

7.3 Feature Description

The OPA2333 is unity-gain stable and free from unexpected output phase reversal. It uses a proprietary auto-calibration technique to provide low offset voltage and very low drift over time and temperature. For lowest offset voltage and precision performance, circuit layout and mechanical conditions should be optimized. Avoid temperature gradients that create thermoelectric (Seebeck) effects in the thermocouple junctions formed from connecting dissimilar conductors. These thermally-generated potentials can be made to cancel by ensuring they are equal on both input terminals. Other layout and design considerations include: (5)

- Use low thermoelectric-coefficient conditions (avoid dissimilar metals)
- Thermally isolate components from power supplies or other heat sources
- · Shield operational amplifier and input circuitry from air currents, such as cooling fans

Following these guidelines will reduce the likelihood of junctions being at different temperatures, which can cause thermoelectric voltages of 0.1 µV/°C or higher, depending on materials used.

7.3.1 Operating Voltage

The OPA2333 operational amplifier operates over a power-supply range of 1.8 V to 5.5 V (±0.9 V to ±2.75 V). Supply voltages higher than 7 V (absolute maximum) can permanently damage the device. Parameters that vary over supply voltage or temperature are shown in *Typical Characteristics*.

(5) At $T_A = 25$ °C (unless otherwise noted).

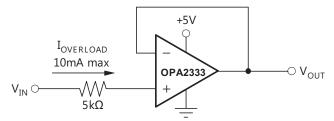


Feature Description (continued)

7.3.2 Input Voltage

The OPA2333 input common-mode voltage range extends 0.1 V beyond the supply rails. The OPA2333 is designed to cover the full range without the troublesome transition region found in some other rail-to-rail amplifiers.

Normally, input bias current is about 70 pA; however, input voltages exceeding the power supplies can cause excessive current to flow into or out of the input pins. Momentary voltages greater than the power supply can be tolerated if the input current is limited to 10 mA. This limitation is easily accomplished with an input resistor (see Figure 20).



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Current-limiting resistor required if input voltage exceeds supply rails by ≥ 0.5 V

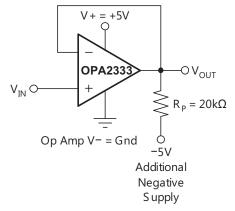
Figure 20. Input Current Protection

7.3.3 Internal Offset Correction

The OPA2333 operational amplifier uses an auto-calibration technique with a time-continuous 350-kHz operational amplifier in the signal path. This amplifier is zero corrected every 8 μ s using a proprietary technique. Upon power up, the amplifier requires approximately 100 μ s to achieve specified V_{OS} accuracy. This design has no aliasing or flicker noise.

7.3.4 Achieving Output Swing to the Operational Amplifier Negative Rail

Some applications require output voltage swings from 0 V to a positive full-scale voltage (such as 2.5 V) with excellent accuracy. With most single-supply operational amplifiers, problems arise when the output signal approaches 0 V, near the lower output swing limit of a single-supply operational amplifier. A good single-supply operational amplifier may swing close to single-supply ground, but will not reach ground. The output of the OPA2333 can be made to swing to ground, or slightly below, on a single-supply power source. To do so requires the use of another resistor and an additional, more negative, power supply than the operational amplifier negative supply. A pulldown resistor may be connected between the output and the additional negative supply to pull the output down below the value that the output would otherwise achieve (see Figure 21).



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Figure 21. V_{OUT} Range to Ground

Product Folder Links: OPA2333-HT



Feature Description (continued)

The OPA2333 has an output stage that allows the output voltage to be pulled to its negative supply rail, or slightly below, using the technique previously described. This technique only works with some types of output stages. The OPA2333 has been characterized to perform with this technique; however, the recommended resistor value is approximately 20 k Ω .

NOTE

This configuration will increase the current consumption by several hundreds of microamps.

Accuracy is excellent down to 0 V and as low as -2 mV. Limiting and nonlinearity occurs below -2 mV, but excellent accuracy returns as the output is again driven above -2 mV. Lowering the resistance of the pulldown resistor allows the operational amplifier to swing even further below the negative rail. Resistances as low as 10 $k\Omega$ can be used to achieve excellent accuracy down to -10 mV.

7.4 Device Functional Modes

The OPA2333 device has a single functional mode. The device is powered on as long as the power supply voltage is between 1.8 V (±0.9 V) and 5.5 V (±2.75 V).

Product Folder Links: OPA2333-HT



Application and Implementation

NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

8.1 Application Information

The OPA2333 family is a unity-gain stable, precision operational amplifier with very low offset voltage drift; these devices are also free from output phase reversal. Applications with noisy or high-impedance power supplies require decoupling capacitors close to the device power-supply pins. In most cases, 0.1-µF capacitors are adequate.

8.2 Typical Applications

8.2.1 High-Side Voltage-to-Current (V-I) Converter

The circuit shown in Figure 22 is a high-side voltage-to-current (V-I) converter. It translates in input voltage of 0 V to 2 V to and output current of 0 mA to 100 mA. Figure 23 shows the measured transfer function for this circuit. The low offset voltage and offset drift of the OPA2333 facilitate excellent dc accuracy for the circuit.

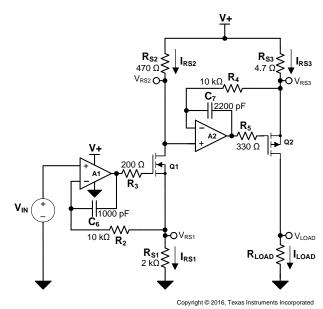


Figure 22. High-Side Voltage-to-Current (V-I) Converter

Product Folder Links: OPA2333-HT



Typical Applications (continued)

8.2.1.1 Design Requirements

The design requirements are as follows:

Supply Voltage: 5-V DC
Input: 0-V to 2-V DC
Output: 0-mA to 10-mA DC

8.2.1.2 Detailed Design Procedure

The V-I transfer function of the circuit is based on the relationship between the input voltage, V_{IN} , and the three current sensing resistors, R_{S1} , R_{S2} , and R_{S3} . The relationship between V_{IN} and R_{S1} determines the current that flows through the first stage of the design. The current gain from the first stage to the second stage is based on the relationship between R_{S2} and R_{S3} .

For a successful design, pay close attention to the DC characteristics of the operational amplifier chosen for the application. To meet the performance goals, this application benefits from an operational amplifier with low offset voltage, low temperature drift, and rail-to-rail output. The OPA2333 CMOS operational amplifier is a high-precision, 5-µV offset, 0.05-µV/°C drift amplifier optimized for low-voltage, single-supply operation with an output swing to within 50 mV of the positive rail. The OPA2333 family uses chopping techniques to provide low initial offset voltage and near-zero drift over time and temperature. Low offset voltage and low drift reduce the offset error in the system, making these devices appropriate for precise DC control. The rail-to-rail output stage of the OPA2333 ensures that the output swing of the operational amplifier is able to fully control the gate of the MOSFET devices within the supply rails.

See TIPD102 for a detailed error analysis, design procedure, and additional measured results.

8.2.1.3 Application Curve

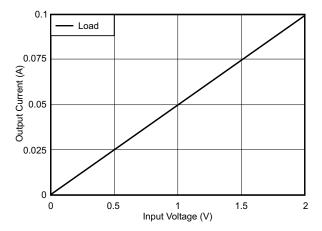


Figure 23. Measured Transfer Function for High-Side V-I Converter



Typical Applications (continued)

8.2.2 Precision, Low-Level Voltage-to-Current (V-I) Converter

The circuit shown in Figure 24 is a precision, low-level voltage-to-current (V-I) converter. The converter translates in input voltage of 0 V to 5 V and output current of 0 μ A to 5 μ A. Figure 25 shows the measured transfer function for this circuit. The low offset voltage and offset drift of the OPA2333 facilitate excellent dc accuracy for the circuit. Figure 26 shows the calibrated error for the entire range of the circuit.

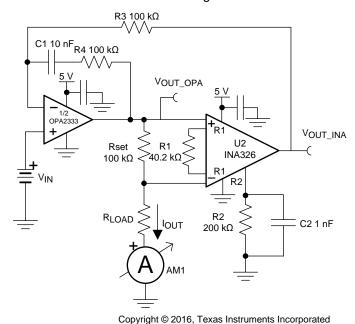


Figure 24. Low-Level, Precision V-I Converter

8.2.2.1 Design Requirements

The design requirements are as follows:

Supply Voltage: 5-V DC
Input: 0-V to 5-V DC
Output: 0-µA to 5-µA DC

8.2.2.2 Detailed Design Procedure

The V-I transfer function of the circuit is based on the relationship between the input voltage, V_{IN} , R_{SET} , and the instrumentation amplifier (INA) gain. During operation, the input voltage divided by the INA gain appears across the set resistor in Equation 1:

$$V_{SET} = V_{IN}/G_{INA} \tag{1}$$

The current through R_{SET} must flow through the load, so I_{OUT} is V_{SET} / R_{SET} . I_{OUT} remains a well-regulated current as long as the total voltage across R_{SET} and R_{LOAD} does not violate the output limits of the operational amplifier or the input common-mode limits of the INA. The voltage across the set resistor (V_{SET}) is the input voltage divided by the INA gain (that is, V_{SET} = 1 V / 10 = 0.1 V). The current is determined by V_{SET} and R_{SET} shown in Equation 2:

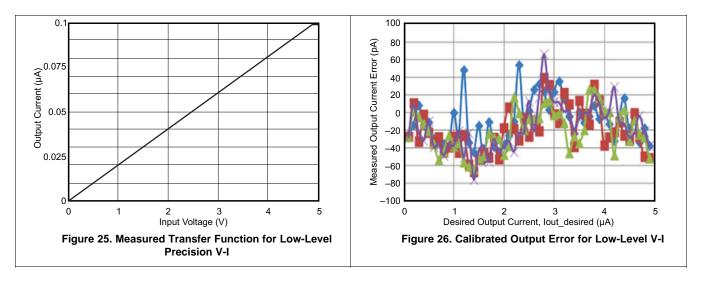
$$I_{OUT} = V_{SET} / R_{SET} = 0.1 \text{ V} / 100 \text{ k}\Omega = 1 \text{ }\mu\text{A}$$
 (2)

See TIPD107 for a detailed error analysis, design procedure, and additional measured results.

TEXAS INSTRUMENTS

Typical Applications (continued)

8.2.2.3 Application Curves



8.2.3 Composite Amplifier

The circuit shown in Figure 27 is a composite amplifier used to drive the reference on the ADS8881. The OPA2333 provides excellent dc accuracy, and the THS4281 allows the output of the circuit to respond quickly to the transient current requirements of a typical SAR data converter reference input. The ADS8881 system was optimized for THD and achieved a measured performance of -110 dB. The linearity of the ADC is shown Figure 28.

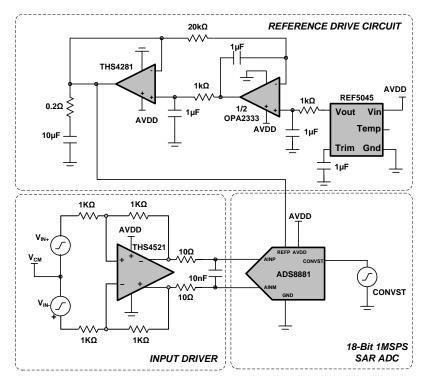


Figure 27. Composite Amplifier Reference Driver Circuit

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Typical Applications (continued)

8.2.3.1 Design Requirements

The design requirements for this block design are:

System Supply Voltage: 5-V DC
 ADC Supply Voltage: 3.3-V DC
 ADC Sampling Rate: 1 MSPS

• ADC Reference Voltage (VREF): 4.5-V DC

ADC Input Signal: A differential input signal with amplitude of V_{pk} = 4.315 V (-0.4 dBFS to avoid clipping) and frequency, f_{IN} = 10 kHz are applied to each differential input of the ADC

8.2.3.2 Detailed Design Procedure

The two primary design considerations to maximize the performance of a high-resolution SAR ADC are the input driver and the reference driver design. The circuit comprises the critical analog circuit blocks, the input driver, anti-aliasing filter, and the reference driver. Each analog circuit block should be carefully designed based on the ADC performance specifications in order to maximize the distortion and noise performance of the data acquisition system while consuming low power. The diagram includes the most important specifications for each individual analog block. This design systematically approaches the design of each analog circuit block to achieve a 16-bit, low-noise and low-distortion data acquisition system for a 10-kHz sinusoidal input signal. The first step in the design requires an understanding of the requirement of extremely low distortion input driver amplifier. This understanding helps in the decision of an appropriate input driver configuration and selection of an input amplifier to meet the system requirements. The next important step is the design of the anti-aliasing RC-filter to attenuate ADC kick-back noise while maintaining the amplifier stability. The final design challenge is to design a high-precision reference driver circuit, which would provide the required value VREF with low offset, drift, and noise contributions.

In designing a very low distortion data acquisition block, it is important to understand the sources of nonlinearity. Both the ADC and the input driver introduce nonlinearity in a data acquisition block. To achieve the lowest distortion, the input driver for a high-performance SAR ADC must have a distortion that is negligible against the ADC distortion. This parameter requires the input driver distortion to be 10 dB lower than the ADC THD. This stringent requirement ensures that overall THD of the system is not degraded by more than -0.5 dB.

$$THD_{AMP} < THD_{ADC} - 10 \text{ dB}$$
(3)

It is therefore important to choose an amplifier that meets the above criteria to avoid the system THD from being limited by the input driver. The amplifier nonlinearity in a feedback system depends on the available loop gain. See TIPD115 for a detailed error analysis, design procedure, and additional measured results.

8.2.3.3 Application Curve

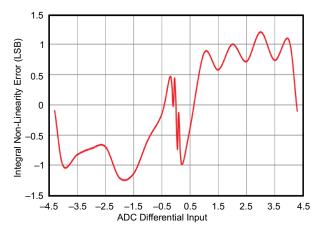


Figure 28. Linearity of the ADC8881 System

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8.3 System Examples

8.3.1 Temperature Measurement Application

Figure 29 shows a temperature measurement application.

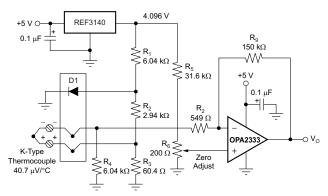


Figure 29. Temperature Measurementf

8.3.2 Single Operational Amplifier Bridge Amplifier Application

Figure 30 shows the basic configuration for a bridge amplifier.

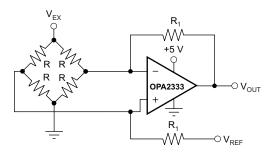
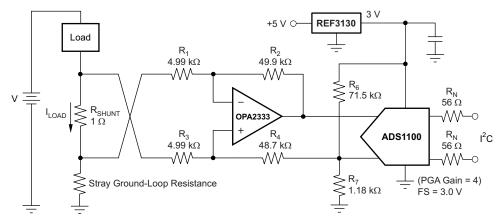


Figure 30. Single Operational Amplifier Bridge Amplifier

8.3.3 Low-Side Current Monitor Application

A low-side current shunt monitor is shown in Figure 31. R_N are operational resistors used to isolate the ADS1100 from the noise of the digital I^2C bus. The ADS1100 is a 16-bit converter; therefore, a precise reference is essential for maximum accuracy. If absolute accuracy is not required and the 5-V power supply is sufficiently stable, the REF3130 can be omitted.



NOTE: 1% resistors provide adequate common-mode rejection at small ground-loop errors.

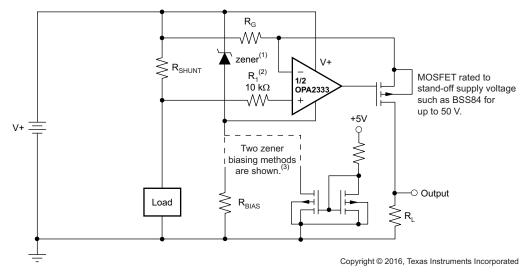
Figure 31. Low-Side Current Monitor

Product Folder Links: OPA2333-HT



8.3.4 Other Applications

Additional application ideas are shown in Figure 32 through Figure 35.



- (1) Zener rated for operational amplifier supply capability (that is, 5.1 V for OPA2333).
- (2) Current-limiting resistor.
- (3) Choose zener biasing resistor or dual N-MOSFETs (FDG6301N, NTJD4001N, or Si1034).

Figure 32. High-Side Current Monitor

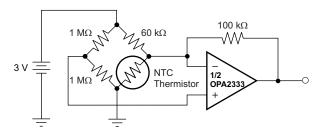


Figure 33. Thermistor Measurement

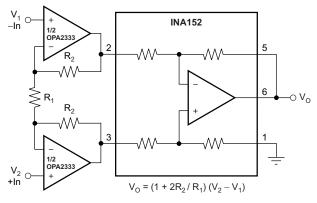
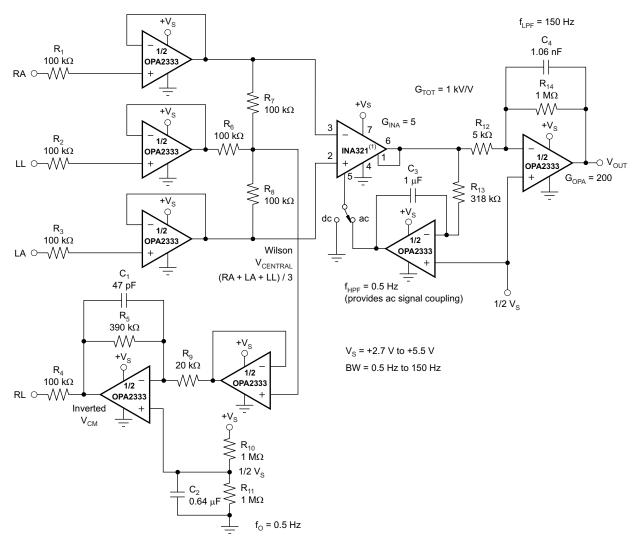


Figure 34. Precision Instrumentation Amplifier

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(1) Other instrumentation amplifiers can be used, such as the INA326, which has lower noise, but higher quiescent current.

Figure 35. Single-Supply, Very Low Power, ECG Circuit

9 Power Supply Recommendations

The OPA2333 is specified for operation from 1.8 V to 5.5 V (± 0.9 V to ± 2.75 V); many specifications apply from -40° C to 125°C. The *Recommended Operating Conditions* presents parameters that can exhibit significant variance with regard to operating voltage or temperature.

CAUTION

Supply voltages larger than 7 V can permanently damage the device (see the *Absolute Maximum Ratings*).

TI recommends placing 0.1-µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see *Layout*.

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10 Layout

10.1 Layout Guidelines

10.1.1 General Layout Guidelines

Pay attention to good layout practices. Keep traces short and when possible, use a printed-circuit board (PCB) ground plane with surface-mount components placed as close to the device pins as possible. Place a 0.1-µF capacitor closely across the supply pins. Apply these guidelines throughout the analog circuit to improve performance and provide benefits, such as reducing the electromagnetic interference (EMI) susceptibility.

Operational amplifiers vary in susceptibility to radio frequency interference (RFI). RFI can generally be identified as a variation in offset voltage or DC signal levels with changes in the interfering RF signal. The OPA2333 is specifically designed to minimize susceptibility to RFI and demonstrates remarkably low sensitivity compared to previous generation devices. Strong RF fields may still cause varying offset levels.

10.1.2 DFN Layout Guidelines

Solder the exposed leadframe die pad on the DFN package to a thermal pad on the PCB. A mechanical drawing showing an example layout is attached at the end of this data sheet. Refinements to this layout may be necessary based on assembly process requirements. Mechanical drawings located at the end of this data sheet list the physical dimensions for the package and pad. The five holes in the landing pattern are optional, and are intended for use with thermal vias that connect the leadframe die pad to the heatsink area on the PCB.

Soldering the exposed pad significantly improves board-level reliability during temperature cycling, key push, package shear, and similar board-level tests. Even with applications that have low-power dissipation, the exposed pad must be soldered to the PCB to provide structural integrity and long-term reliability.

10.2 Layout Example

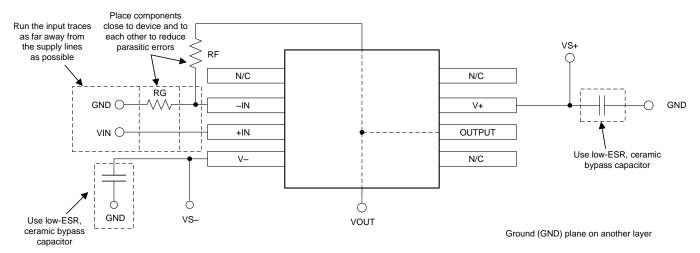


Figure 36. OPA2333-HT Layout Example

Product Folder Links: OPA2333-HT



11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

For development support on this product, see the following:

- High-Side V-I Converter, 0 V to 2 V to 0 mA to 100 mA, 1% Full-Scale Error, TIPD102
- Low-Level V-to-I Converter Reference Design, 0-V to 5-V Input to 0-μA to 5-μA Output, TIPD107
- 18-Bit, 1-MSPS, Serial Interface, microPower, Truly-Differential Input, SAR ADC, ADS8881
- Very Low-Power, High-Speed, Rail-To-Rail Input/Output, Voltage Feedback Operational Amplifier, THS4281
- Data Acquisition Optimized for Lowest Distortion, Lowest Noise, 18-bit, 1-MSPS Reference Design, TIPD115
- Self-Calibrating, 16-Bit Analog-to-Digital Converter, ADS1100
- 20-ppm/Degrees C Max, 100-uA, SOT23-3 Series Voltage Reference, REF3130
- Precision, Low Drift, CMOS Instrumentation Amplifier, INA326, INA326

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community TI's Engineer-to-Engineer (E2E) Community. Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support *TI's Design Support* Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

E2E is a trademark of Texas Instruments.

All other trademarks are the property of their respective owners.

11.4 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.5 Glossary

SLYZ022 — TI Glossary.

This glossary lists and explains terms, acronyms, and definitions.

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

Product Folder Links: OPA2333-HT

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10-Nov-2025

PACKAGING INFORMATION

Orderable part number	Status	Material type	Package Pins	Package qty Carrier	RoHS	Lead finish/ Ball material	MSL rating/ Peak reflow	Op temp (°C)	Part marking (6)
						(4)	(5)		
OPA2333HD	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-4-260C-72 HR	-55 to 175	O2333H
OPA2333HD.A	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-4-260C-72 HR	-55 to 175	O2333H
OPA2333HDG4	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-4-260C-72 HR	-55 to 210	O2333H
OPA2333HDG4.A	Active	Production	SOIC (D) 8	75 TUBE	Yes	NIPDAU	Level-4-260C-72 HR	-55 to 210	O2333H
OPA2333SHKJ	Active	Production	CFP (HKJ) 8	25 TUBE	Yes	Call TI	N/A for Pkg Type	-55 to 210	OPA2333S HKJ
OPA2333SHKJ.A	Active	Production	CFP (HKJ) 8	25 TUBE	Yes	Call TI	N/A for Pkg Type	-55 to 210	OPA2333S HKJ
OPA2333SHKQ	Active	Production	CFP (HKQ) 8	25 TUBE	Yes	AU	N/A for Pkg Type	-55 to 210	OPA2333S HKQ
OPA2333SHKQ.A	Active	Production	CFP (HKQ) 8	25 TUBE	Yes	AU	N/A for Pkg Type	-55 to 210	OPA2333S HKQ
OPA2333SJD	Active	Production	CDIP SB (JD) 8	45 TUBE	Yes	Call TI	N/A for Pkg Type	-55 to 210	OPA2333SJD
OPA2333SJD.A	Active	Production	CDIP SB (JD) 8	45 TUBE	Yes	Call TI	N/A for Pkg Type	-55 to 210	OPA2333SJD
OPA2333SKGD1	Active	Production	XCEPT (KGD) 0	100 NOT REQUIRED	Yes	Call TI	N/A for Pkg Type	-55 to 210	
OPA2333SKGD1.A	Active	Production	XCEPT (KGD) 0	100 NOT REQUIRED	Yes	Call TI	N/A for Pkg Type	-55 to 210	

⁽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.

PACKAGE OPTION ADDENDUM

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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 OPA2333-HT:

Catalog: OPA2333

Automotive : OPA2333-Q1

NOTE: Qualified Version Definitions:

- Catalog TI's standard catalog product
- Automotive Q100 devices qualified for high-reliability automotive applications targeting zero defects

PACKAGE MATERIALS INFORMATION

www.ti.com 18-Jun-2025

TUBE

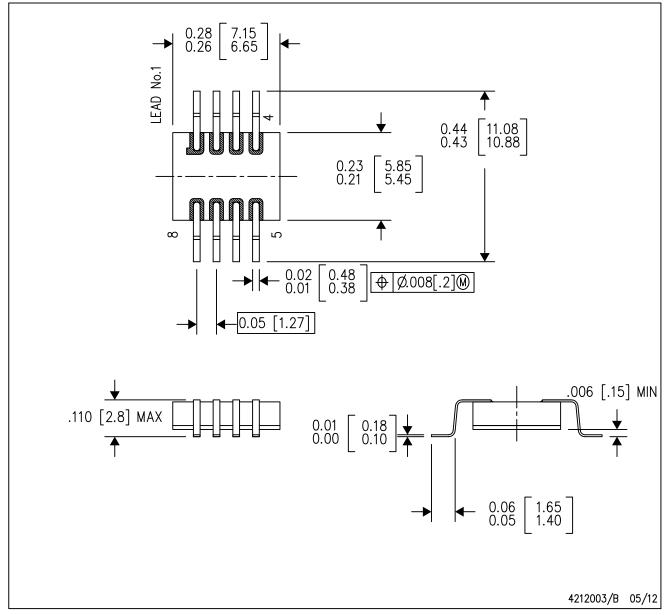


*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
OPA2333HD	D	SOIC	8	75	506.6	8	3940	4.32
OPA2333HD.A	D	SOIC	8	75	506.6	8	3940	4.32
OPA2333HDG4	D	SOIC	8	75	506.6	8	3940	4.32
OPA2333HDG4.A	D	SOIC	8	75	506.6	8	3940	4.32
OPA2333SHKJ	HKJ	CFP	8	25	506.98	26.16	6220	NA
OPA2333SHKJ.A	HKJ	CFP	8	25	506.98	26.16	6220	NA
OPA2333SHKQ	HKQ	CFP	8	25	506.98	26.16	6220	NA
OPA2333SHKQ.A	HKQ	CFP	8	25	506.98	26.16	6220	NA
OPA2333SJD	JD	CDIP SB	8	45	506.98	15.24	12290	NA
OPA2333SJD.A	JD	CDIP SB	8	45	506.98	15.24	12290	NA

HKQ (R-CDFP-G8)

CERAMIC GULL WING



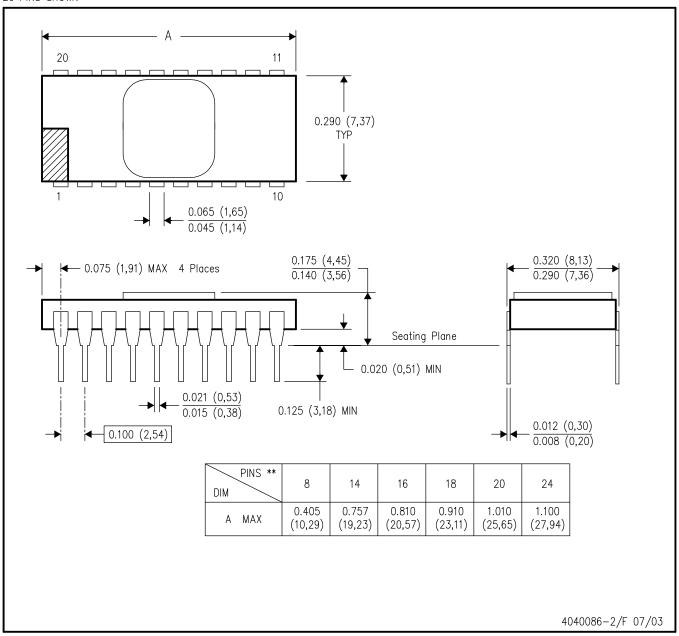
- All linear dimensions are in inches (millimeters).
- This drawing is subject to change without notice.
- This package can be hermetically sealed with a metal lid.
- D. The terminals will be gold plated.E. Lid is not connected to any lead.



JD (R-CDIP-T**)

CERAMIC SIDE-BRAZE DUAL-IN-LINE PACKAGE

20 PINS SHOWN



- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package is hermetically sealed with a metal lid.
- D. The terminals are gold plated.
- E. Falls within MIL STD 1835 CDIP2 T8, T14, T16, T18, T20 and T24 respectively.





SMALL OUTLINE INTEGRATED CIRCUIT



- 1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. 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 .006 [0.15] per side.
- 4. This dimension does not include interlead flash.
- 5. Reference JEDEC registration MS-012, variation AA.



SMALL OUTLINE INTEGRATED CIRCUIT



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.



SMALL OUTLINE INTEGRATED CIRCUIT



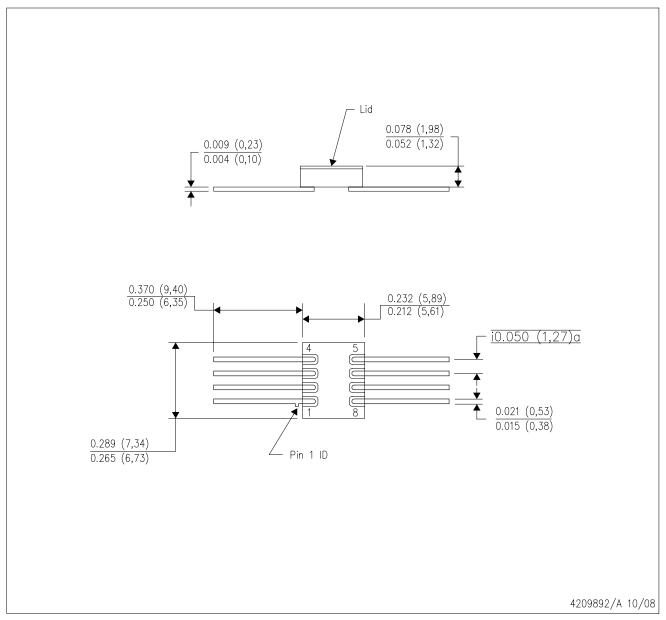
NOTES: (continued)

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



HKJ (R-CDFP-F8)

CERAMIC DUAL FLATPACK



- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a metal lid.
- D. The terminals will be gold plated.



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