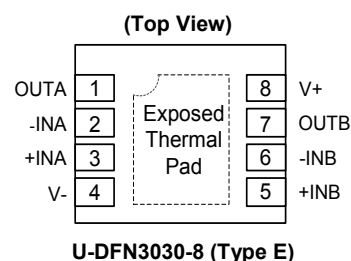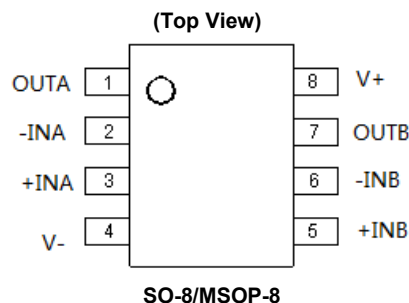**Lead-free Green**

Description

The AS2333 is dual CMOS operational amplifier designed with chopping stabilization technique. This product can provide ultra-low input offset voltage (8µV typical) and near zero-drift over time and temperature. This technique also eliminates 1/f noise and the cross-over distortion present in most rail-to-rail input operational amplifiers. The high-precision, low quiescent current amplifier offers high-impedance inputs that have a common-mode range 100mV beyond the rails, and a rail-to-rail output that swings within 50mV of the rails. Single or dual supplies as low as 1.8V (±0.9V) and up to 5.5V (±2.75V) can be used.

The device is optimized for low voltage single supply application, especially for low-power high-precision applications.

The AS2333 is available in the standard 8-pin SO-8, MSOP-8, and U-DFN3030-8 (Type E) packages, and is specified for operation from -40°C to +125°C.

Pin Assignments

(Top View)

```
OUTA  1        8  V+
-INA  2        7  OUTB
+INA  3        6  -INB
V-    4        5  +INB
```

SO-8/MSOP-8

(Top View)

```
OUTA  1   Exposed   8  V+
-INA  2   Thermal   7  OUTB
+INA  3   Pad       6  -INB
V-    4             5  +INB
```

U-DFN3030-8 (Type E)

Features

- Low Input Offset Voltage: 8µV (typ)
- Zero Drift: 0.02µV/°C (typ)
- 0.01Hz to 10Hz Noise: $1.1\mu V_{PP}$
- Low Quiescent Current: 12µA per Amplifier
- Supply Voltage: 1.8V to 5.5V
- Rail-to-Rail Input and Output
- Bandwidth 350kHz
- Slew Rate 0.12V/µs (typ)
- MSOP-8, SO-8, and U-DFN3030-8 (Type E) Packages
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen- and Antimony-Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

Applications

- Battery-Powered Instruments
- Handheld Test Equipment
- Medical Instrumentation
- Sensor Signal Conditioning
- Low Voltage Current Sensing

Notes: 1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

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Typical Application
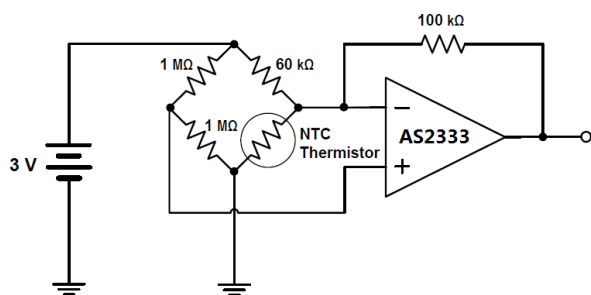
Thermistor Measurement
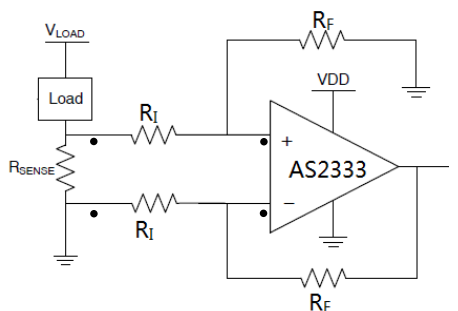
Low-Side Current Monitor

Pin Descriptions

Pin Number	Pin Name	I/O	Description
3	+INA	I	Noninverting input, channel A
5	+INB	I	Noninverting input, channel B
2	-INA	I	Inverting input, channel A
6	-INB	I	Inverting input, channel B
1	OUTA	O	Output, channel A
7	OUTB	O	Output, channel B
8	V+	—	Positive Power Supply Recommend to place a minimum 0.1μF decoupling capacitor between V+ pin and GND as close as possible.
4	V-	—	Negative Power Supply Single power supply application, it is normally tied to ground. Split power supply application, a minimum 0.1μF decouple capacitor is recommended to be placed between V- pin and GND as close as possible.

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Absolute Maximum Ratings (Note 4) (@ T$_A$ = +25°C, unless otherwise specified.)

Symbol	Parameter	Rating		Unit
V$_S$ = V+ - V-	Supply Voltage Range	6.5		V
V$_{-IN}$ / V$_{+IN}$	Signal Input Terminals (Note 5)	V- - 0.3V to V+ + 0.3V		V
—	Signal Input Terminals (Note 5)	-1 to +1		mA
	Output Short-Circuit (Note 6)	Continuous		mA
T$_{STG}$	Storage Temperature	-65 to +150		°C
T$_J$	Maximum Junction Temperature	+150		°C
T$_{LEAD}$	Lead Temperature (Soldering, 10 Seconds)	+260		°C
R$_{θJA}$	Junction-to-Ambient Thermal Resistance	SO-8	139	°C/W
		MSOP-8	184	°C/W
		U-DFN3030-8 (Type E)	—	°C/W
R$_{θJC}$	Junction-to-Case Thermal Resistance	SO-8	25	°C/W
		MSOP-8	18	°C/W
		U-DFN3030-8 (Type E)	—	°C/W
ESD HBM	Human Body Model ESD Protection	4		kV
ESD CDM	Charged-Device Model ESD Protection	1		kV

Notes: 4. *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Recommended Operating Conditions* indicate conditions for which the device is intended to be functional, but specific performance is not guaranteed. For guaranteed specifications and the test conditions, see the *Electrical Characteristics*.
5. Input terminals are diode-clamped to the power-supply rails. Input signals that can swing more than 0.3V beyond the supply rails should be current limited to 10mA or less.
6. Short-circuit to ground.

Recommended Operating Conditions (@ T$_A$ = +25°C, unless otherwise specified.)

Symbol	Parameter	Rating	Unit
V$_S$ = V+ - V-	Supply Voltage Range	1.8 to 5.5	V
T$_A$	Operating Ambient Temperature Range	-40 to +125	°C

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Electrical Characteristics (@ T_A = +25°C, V_S = 5.0V, R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2, unless otherwise specified.)

| Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Offset Voltage							
V_{OS}	Input Offset Voltage	V_S = 5V		—	8	22	µV
$\Delta V_{OS}/\Delta T$	Input Offset Voltage Drift (Note 7)	T_A = -40°C to +85°C		—	0.02	0.1	µV/°C
		T_A = -40°C to +125°C		—	—	0.2	µV/°C
PSRR	Power-Supply Rejection Ratio	V_S = 1.8V to 5.5V, T_A = -40°C to +125°C		—	1	5	µV/V
—	Long-Term Stability	—			(Note 7)		µV
—	Channel Separation, DC	—		—	0.1	—	µV/V
Input Bias Current							
I_B	Input Bias Current	T_A = +25°C		—	±70	±200	pA
		T_A = -40°C to +125°C		—	±400	—	
I_{OS}	Input Offset Current	—		—	±140	±400	
Noise							
V_N	Input Voltage Noise	f = 0.01Hz to 1Hz		—	0.3	—	µV$_{PP}$
		f = 0.1Hz to 10Hz		—	1.1	—	
I_N	Input Current Noise	f = 10Hz		—	100	—	fA/√Hz
Input Voltage							
V_{CM}	Common-Mode Voltage Range	—		(V-) - 0.1	—	(V+) + 0.1	V
CMRR	Common-Mode Rejection Ratio	(V-) - 0.1V < V_{CM} < (V+) + 0.1V, T_A = -40°C to +125°C		106	120	—	dB
Input Capacitance							
—	Differential	—		—	2	—	pF
—	Common-Mode	—		—	4	—	pF
Open-Loop Gain							
A_{OL}	Open-Loop Voltage Gain	(V-) + 100mV < V_O < (V+) - 100mV, R_L = 10kΩ, T_A = -40°C to +125°C		106	130	—	dB
Frequency Response							
GBW	Gain-Bandwidth Product	C_L = 100pF		—	350	—	kHz
SR	Slew Rate	G = +1		—	0.12	—	V/µs
Output							
—	Voltage Output Swing from Rail	Positive Rail R_L = 10kΩ	T_A = +25°C	—	30	50	mV
			T_A = -40°C to +125°C	—	—	70	
		Negative Rail R_L = 10kΩ	T_A = +25°C	—	10	50	
			T_A = -40°C to +125°C	—	—	70	
I_{SC}	Short-Circuit Current	Source Current		—	5	—	mA
		Sink Current		—	25	—	mA
—	Open-Loop Output Impedance	f = 350kHz, I_O = 0A		—	2	—	kΩ
Power Supply							
V_S	Specified Voltage Range	—		1.8	—	5.5	V
I_Q	Quiescent Current per Amplifier	I_O = 0A, T_A = +25°C		—	12	20	µA
		I_O = 0A, T_A = -40°C to +125°C		—	—	28	
t_{ON}	Turn-On Time	V_S = 5V		—	100	—	µs

Note: 7. 300-hour life test at +150°C demonstrated randomly distributed variation of approximately 1µV.
This parameter guaranteed by design and characterization, not by testing.

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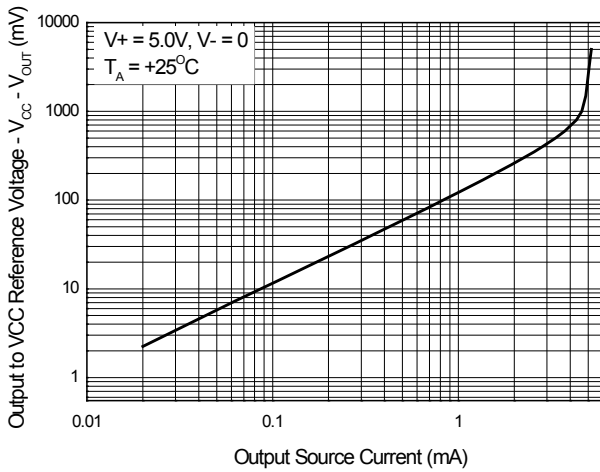## Typical Performance Characteristics
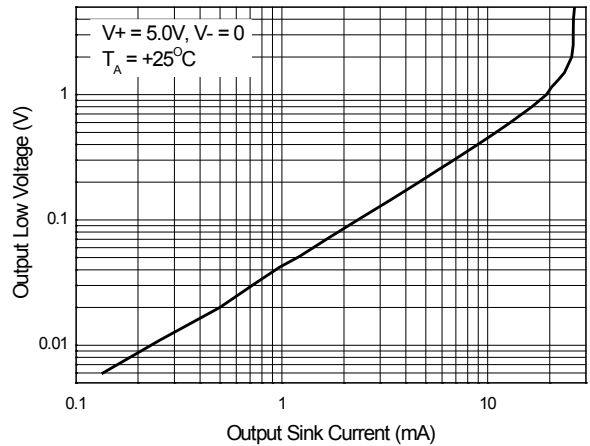
Supply Current vs. Temperature
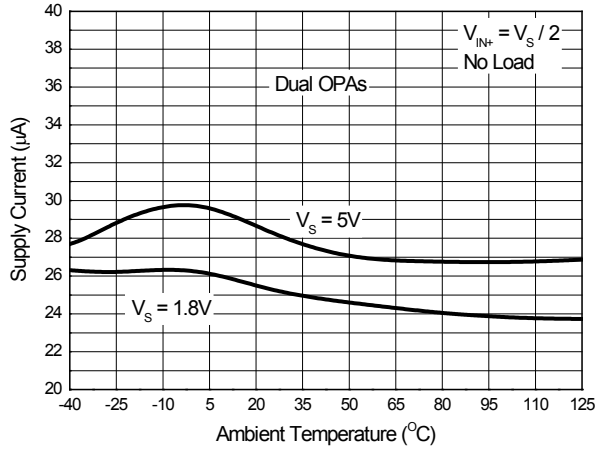
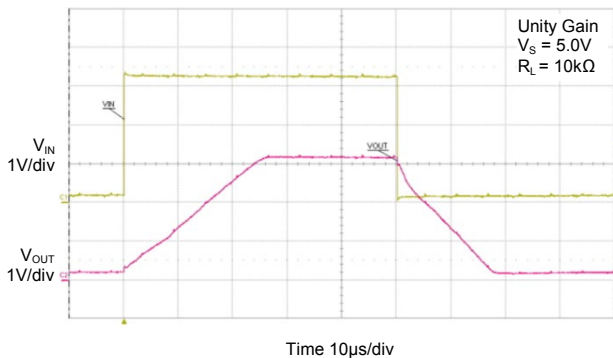### Input Offset Voltage vs. Input Common Mode Voltage
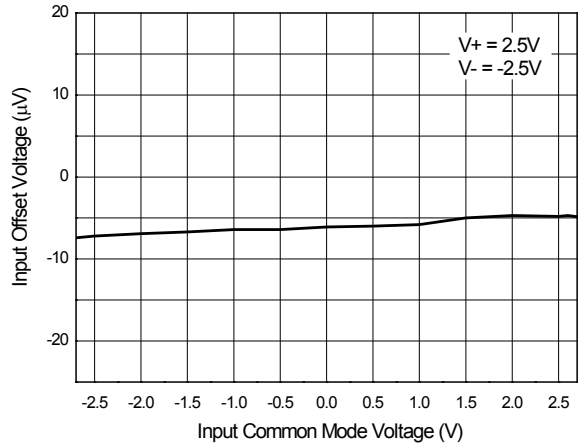
Output Characteristics-Sourcing Current

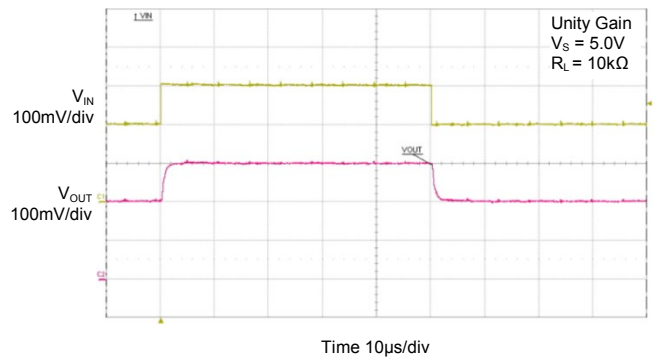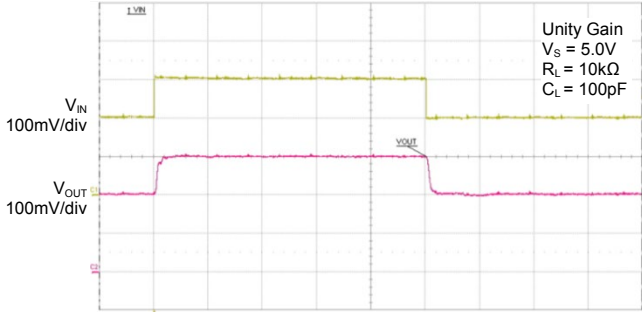### Output Characteristics-Sinking Current

Large Signal Response

Small Signal Response

AS2333
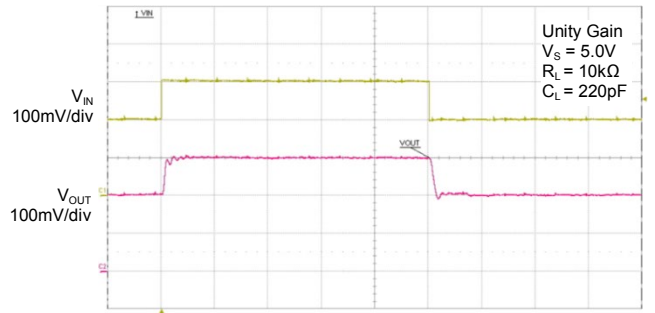Document number: DS42770 Rev. 3 - 2

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Typical Performance Characteristics (continued)

Small Signal Response

Unity Gain
$V_S = 5.0V$
$R_L = 10k\Omega$
$C_L = 100pF$

V_{IN} 100mV/div

V_{OUT} 100mV/div

Time 10µs/div

Small Signal Response

Unity Gain
$V_S = 5.0V$
$R_L = 10k\Omega$
$C_L = 220pF$

V_{IN} 100mV/div

V_{OUT} 100mV/div

Time 10µs/div

Negative Overvoltage Response

V+ = 2.5V, V- = -2.5V
Av = -10

V_{IN} 1V/div

V_{OUT} 500mV/div
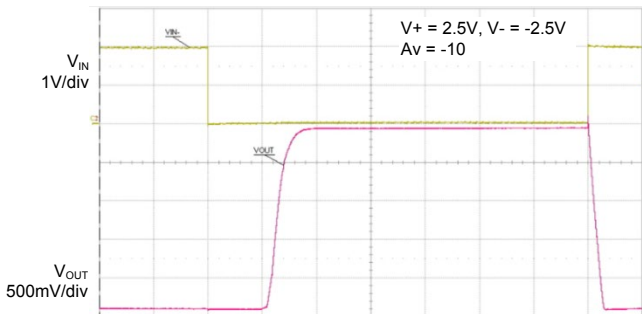
Time 50µs/div

Positive Overvoltage Response
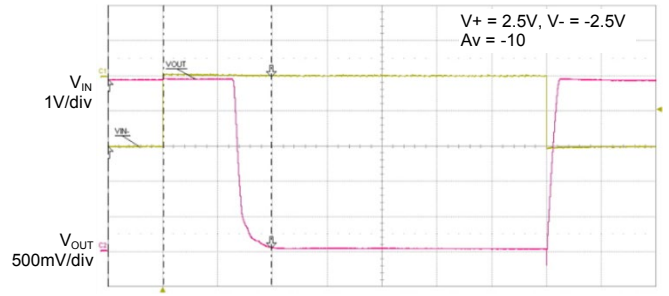
V+ = 2.5V, V- = -2.5V
Av = -10

V_{IN} 1V/div

V_{OUT} 500mV/div

Time 50µs/div

Output Voltage Swing from Rail

$V_S = 5.0V$
$R_L = 10k\Omega$ to $V_S / 2$

Positive

Negative

X-axis: Ambient Temperature (°C), -40 to 125
Y-axis: Output Voltage Swing from Rail (mV), 0 to 70

Voltage Noise Spectral Density

X-axis: Frequency (Hz), 100 to 10k
Y-axis: Voltage Noise Spectral Density (nV/√Hz), 1 to 1000

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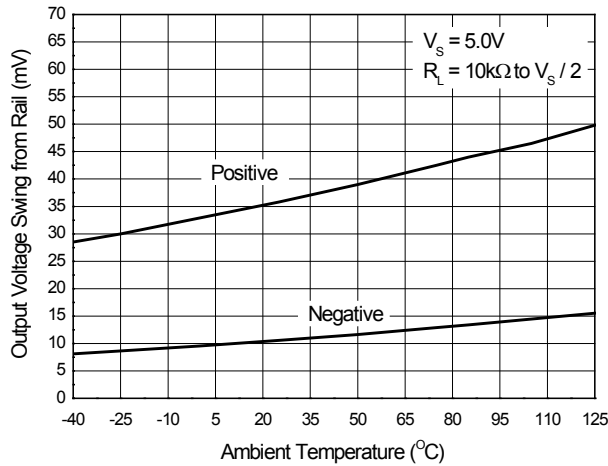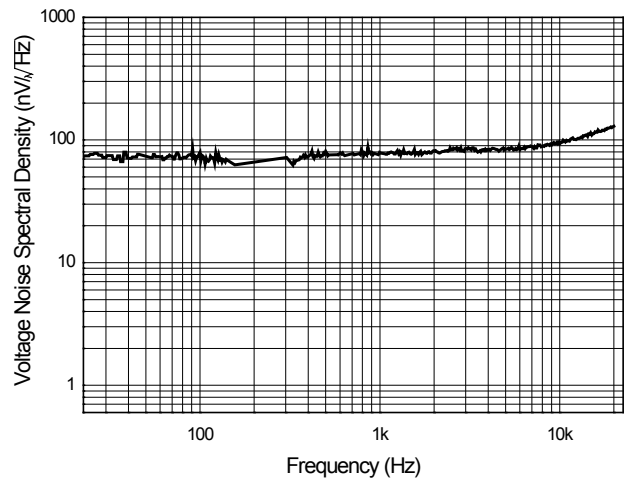
Typical Performance Characteristics (continued)

Frequency Response

V+ = 2.5V, V- = -2.5V
R_L = 10kΩ
C_L = 100pF

Power Supply Rejection Ration vs. Frequency

V+ = 5.0V
V- = 0
Ripple = 500mV

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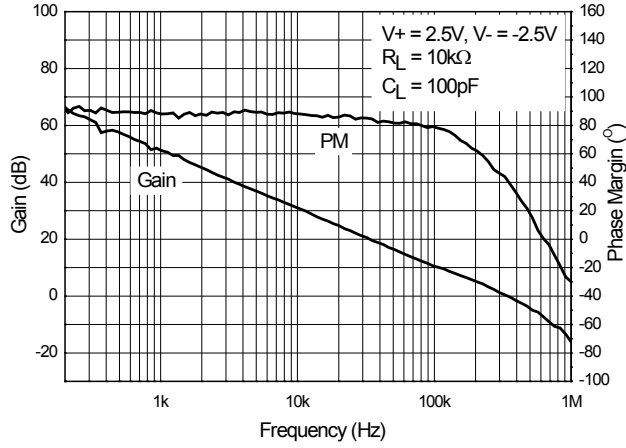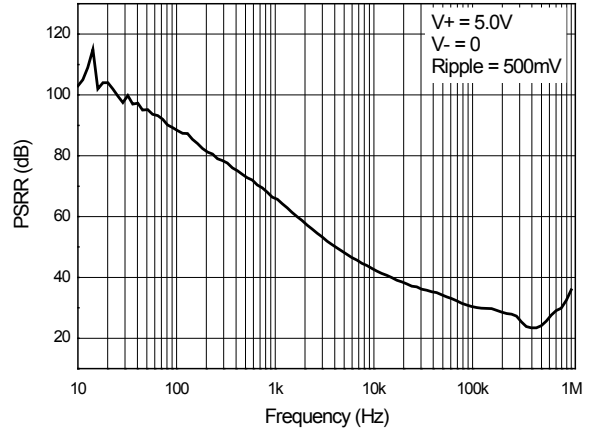
Application Information

Overview

The AS2333 is low-power, zero-drift, high-precision, rail-to-rail input and output operational amplifier, which adopts chopper-stabilized function circuits to provide the advantage of minimizing input offset voltage and offset voltage drift over time and temperature. Its input common-mode voltage range extends 0.1V beyond the supply rails to allow for sensing near ground or system V_{DD}. The device operates from a single-supply voltage as low as 1.8V, is unity-gain stable, has no 1/f noise, and has good PSRR and CMRR performance. These features make the AS2333 suitable for a wide range of general-purpose applications, especially for low-power and high-precision applications.

Low Input Referred Noise

The device AS2333 is chopper-stabilized amplifier, which greatly reduces the flicker noise. The zero-drift chopper-stabilized amplifiers are especially suited for accurate, high-gain amplification at lower frequencies. In general, they do not exhibit the higher bandwidth of linear operational amplifiers, and the location of their clock frequency establishes a practical frequency limit on signal fidelity. This makes performance at low frequencies especially important, and the chopper-stabilized architecture further contributes to low-frequency usefulness by eliminating the classic linear operational amplifier 1/f input voltage noise. Many high-gain sensor applications are at low frequencies, making zero-drift amplifiers a natural choice for this function.

The below graphs compare the voltage noise density behaviors of conventional amplifiers and zero-drift amplifiers. The 1/f noise elimination in zero-drift amplifiers allow the AS2333 to have much lower noise at DC and low frequencies compared to the conventional low-noise amplifiers.
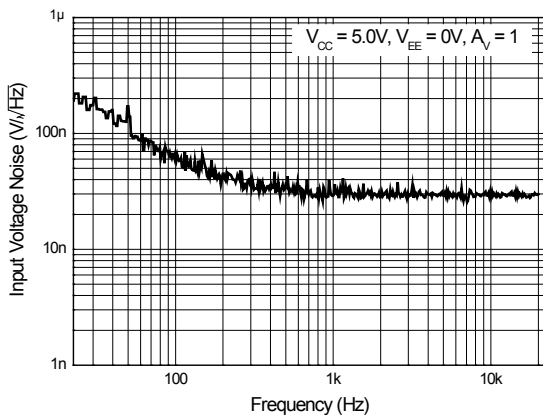

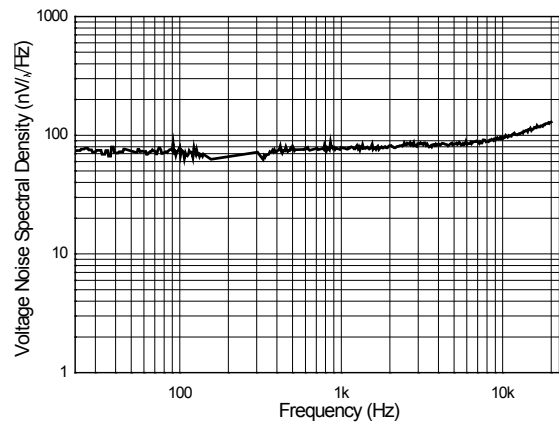**Figure 1. Input Voltage Noise in Conventional Amplifier (AZV832)**

Figure 2. Input Voltage Noise in Zero-Drift Amplifier (AS2333)

Driving a Capacitive Load

The AS2333 can directly drive 200pF in unity-gain without oscillation. The unity-gain follower is the most sensitive configuration to capacitive loading. Capacitive loading directly on the output terminal can decrease the device's phase margin, leading to high-frequency ringing or oscillation.

To drive a heavier capacitive load, the circuit in Figure 3 can be used. The resistor R_{NULL} and C_L form a pole to increase stability by adding more phase margin to the system. The bigger the R_{NULL} resistor value, the more stable V_{OUT} is. Figure 4 and Figure 5 show the AS2333's output pulse response waveforms with and without R_{NULL} 330Ω for load conditions C_L = 470pF and R_L = 10kΩ.

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Application Information (continued)
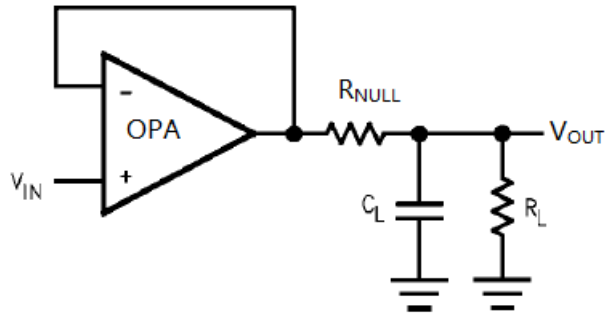
Figure 3. Capacitive Load with R$_{NULL}$

V$_{IN}$
100mV/div

V$_{OUT}$
100mV/div

Time 5µs/div

Figure 4. Test Result Without R$_{NULL}$

V$_{IN}$
100mV/div

V$_{OUT}$
100mV/div
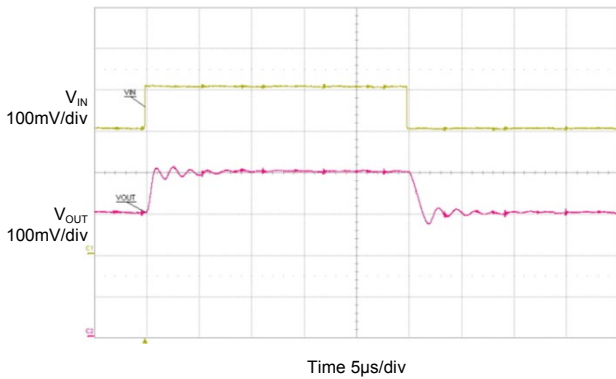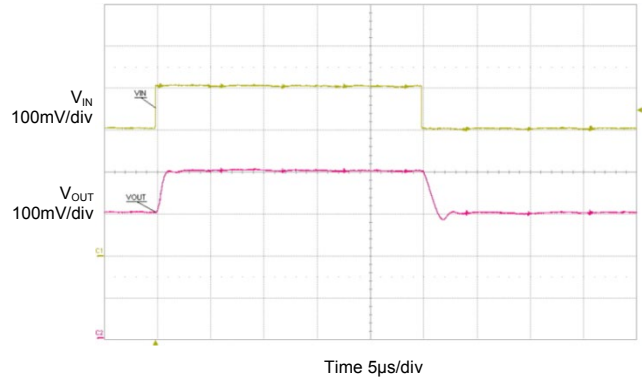
Time 5µs/div

Figure 5. Test Result with R$_{NULL}$ 330Ω

An RC snubber circuit can be used to reduce capacitive load ringing and overshoot, as shown in Figure 6. It allows the amplifier to drive larger values of capacitance while maintaining a minimum for overshoot and ringing. Figure 7 shows AS2333's test results for capacitive load 470pF with a snubber circuit.
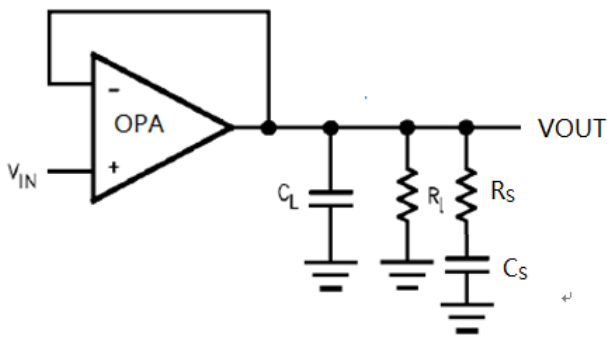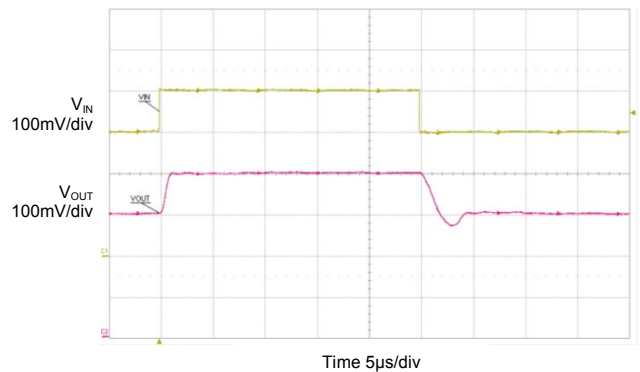

Figure 6. Circuit with Snubber Circuit

V$_{IN}$
100mV/div

V$_{OUT}$
100mV/div

Time 5µs/div

Figure 7. Test Result with Snubber Circuit

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Application Information (continued)

Low-Side Current Monitor Application

Low-side current sensing is used to monitor the current through a load. This method can be used to detect over-current conditions and is often used in feedback control, as shown in Figure 8. A sense resistor is placed in series with the load to the ground. Precision resistors are required for high accuracy and the resulting voltage drop is amplified using the AS2333.
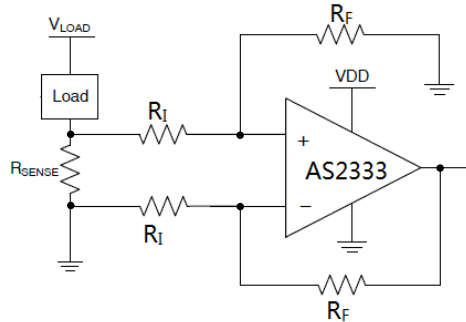
Figure 8. Low-Side Current Monitor Application

Differential Amplifier for Bridged Circuits

Sensors to measure strain, pressure, and temperature are often configured in a Wheatstone bridge circuit, as shown in Figure 9. In the measurement, the voltage change that is produced is relatively small and needs to be amplified before going into an ADC. Precision amplifiers are recommended in these types of applications due to their high gain, low noise, and low offset voltage.

Figure 9. Bridge Circuit Amplification

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Ordering Information

AS2333 X - X

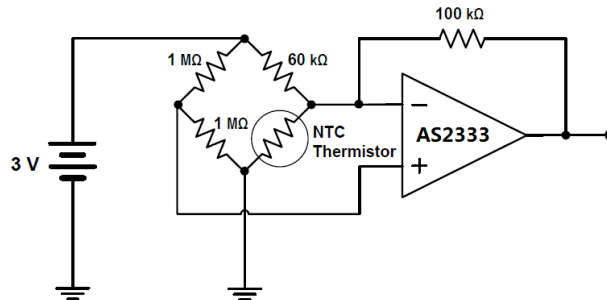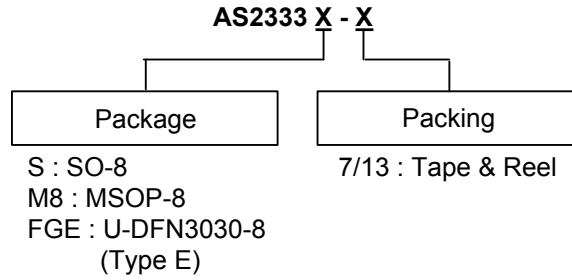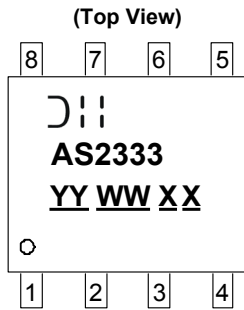| Package |
|---|
| S : SO-8 |
| M8 : MSOP-8 |
| FGE : U-DFN3030-8 |
| (Type E) |

Packing
7/13 : Tape & Reel

Part Number	Identification Code	Packaging	Tape and Reel	
			Quantity	Part Number Suffix
AS2333S-13	AS2333	SO-8	2500/Tape & Reel	-13
AS2333M8-13	AS2333	MSOP-8	2500/Tape & Reel	-13
AS2333FGE-7	ND	U-DFN3030-8 (Type E)	3000/Tape & Reel	-7

Marking Information

(1) SO-8

(Top View)

AS2333
YY WW X X

⊃¦¦ : Logo
AS2333 : Identification Code
YY : Year : 19, 20, 21~
WW : Week : 01~52; 52
        represents 52 and 53 week
X X : Internal Code

(2) MSOP-8

(Top View)

⊃¦¦ Y W X
AS2333
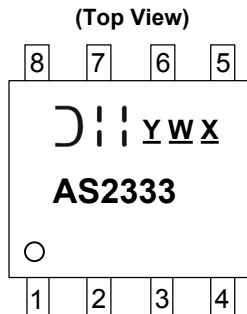
⊃¦¦ : Logo
AS2333 : Identification Code
Y : Year : 0 to 9
W : Week : A to Z : 1 to 26 week;
     a to z : 27 to 52 week; z represents
     52 and 53 week
X : Internal Code

(3) U-DFN3030-8 (Type E)

(Top View)

ND
Y W X
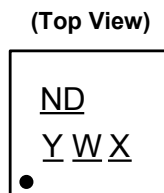
ND : Identification Code
Y : Year : 0~9
W : Week : A~Z : 1~26 week;
     a~z : 27~52 week; z represents
     52 and 53 week
X : Internal Code

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Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.

(1)   Package Type: SO-8

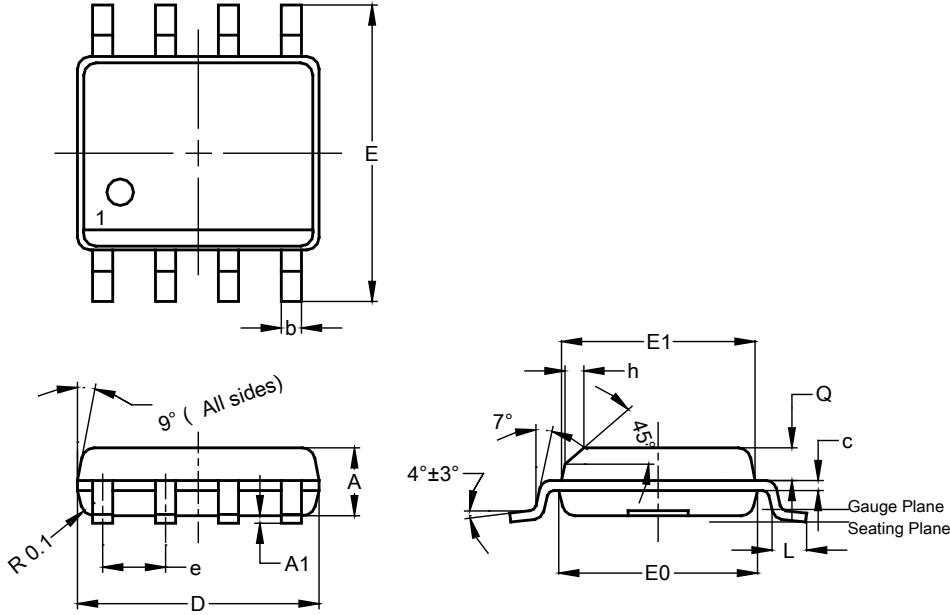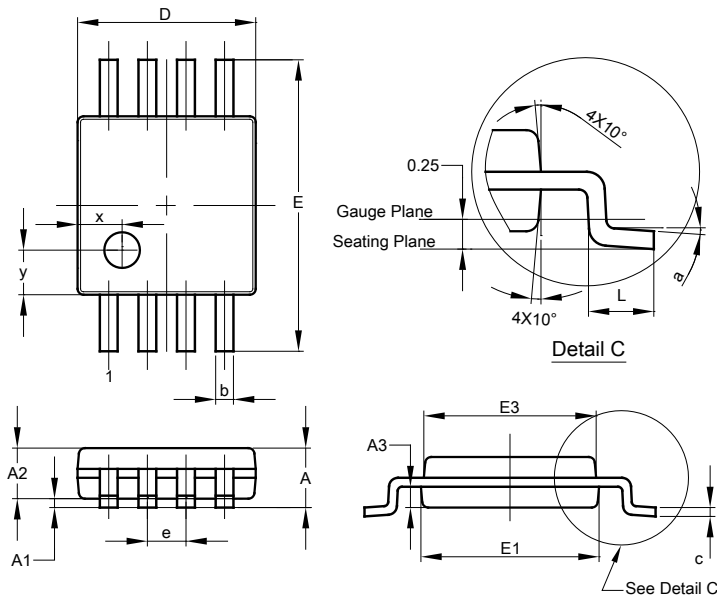| SO-8			
Dim	**Min**	**Max**	**Typ**
A	1.40	1.50	1.45
A1	0.10	0.20	0.15
b	0.30	0.50	0.40
c	0.15	0.25	0.20
D	4.85	4.95	4.90
E	5.90	6.10	6.00
E1	3.80	3.90	3.85
E0	3.85	3.95	3.90
e	--	--	1.27
h	--	--	0.35
L	0.62	0.82	0.72
Q	0.60	0.70	0.65
All Dimensions in mm			

(2)   Package Type: MSOP-8

Detail C

MSOP-8			
Dim	**Min**	**Max**	**Typ**
A	-	1.10	-
A1	0.05	0.15	0.10
A2	0.75	0.95	0.86
A3	0.29	0.49	0.39
b	0.22	0.38	0.30
c	0.08	0.23	0.15
D	2.90	3.10	3.00
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
E3	2.85	3.05	2.95
e	-	-	0.65
L	0.40	0.80	0.60
a	0°	8°	4°
x	-	-	0.750
y	-	-	0.750
All Dimensions in mm			

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Package Outline Dimensions (continued)

Please see http://www.diodes.com/package-outlines.html for the latest version.

(3)   Package Type: U-DFN3030-8 (Type E)
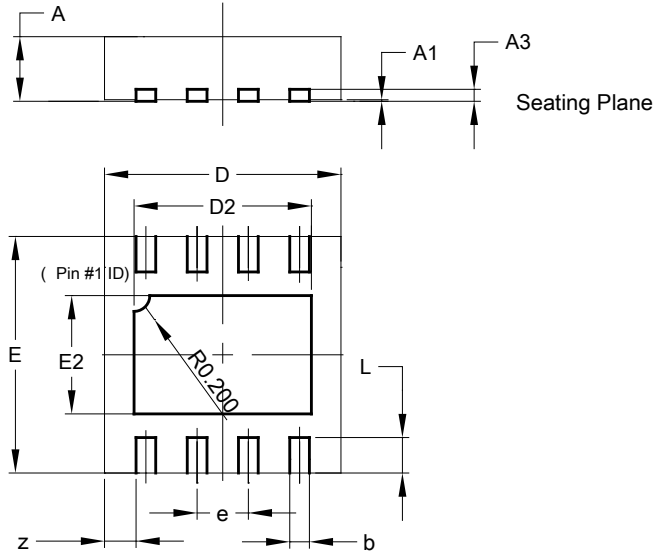
U-DFN3030-8 (Type E)			
Dim	**Min**	**Max**	**Typ**
A	0.57	0.63	0.60
A1	0.00	0.05	0.02
A3	-	-	0.15
b	0.20	0.30	0.25
D	2.95	3.05	3.00
D2	2.15	2.35	2.25
E	2.95	3.05	3.00
E2	1.40	1.60	1.50
e	-	-	0.65
L	0.30	0.60	0.45
z	-	-	0.40
All Dimensions in mm			

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Suggested Pad Layout

Please see http://www.diodes.com/package-outlines.html for the latest version.
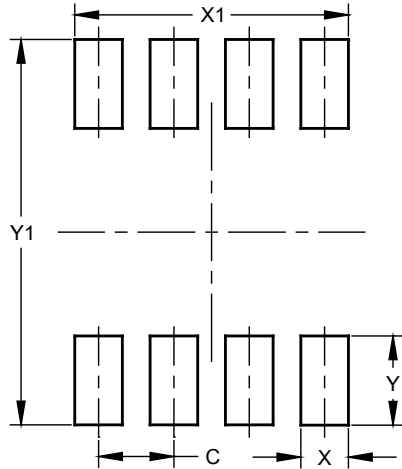
(1) Package Type: SO-8

Dimensions	Value (in mm)
C	1.27
X	0.802
X1	4.612
Y	1.505
Y1	6.50

(2) Package Type: MSOP-8
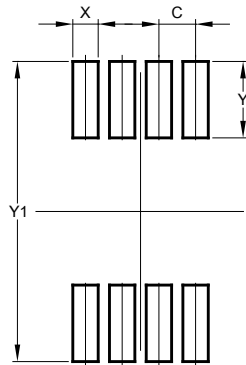
Dimensions	Value (in mm)
C	0.650
X	0.450
Y	1.350
Y1	5.300

(3) Package Type: U-DFN3030-8 (Type E)
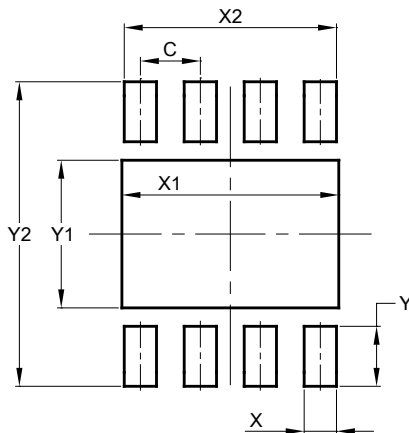
Dimensions	Value (in mm)
C	0.650
X	0.350
X1	2.350
X2	2.300
Y	0.650
Y1	1.600
Y2	3.300

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Mechanical Data

SO-8

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 (e3)
- Weight: 0.075 grams (Approximate)

MSOP-8

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 (e3)
- Weight: 0.025 grams (Approximate)

U-DFN3030-8 (Type E)

- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish NiPdAu over Copper Lead-Frame Solderable per MIL-STD-202, Method 208 (e4)
- Weight: 0.017 grams (Approximate)

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