

## Description

The DIODES™ AS2333Q is a dual CMOS operational amplifier designed with chopping stabilization technique. This product can provide ultra-low input offset voltage (8 $\mu$ V typical) and near zero-drift over time and temperature. This technique also eliminates 1/f noise and the cross over distortion presented 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 rail-to-rail output that swings within 50mV of the rails. Single or dual supplies as low as 1.8V ( $\pm 0.9$ V) and up to 5.5V ( $\pm 2.75$ V) can be used.

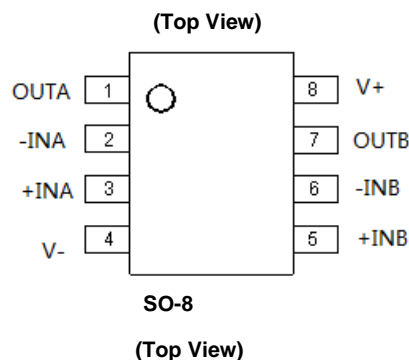
The device is optimized for low voltage single supply applications, especially for low-power high precision applications.

The AS2333Q is available in standard the 8-pin SO-8 package. The device is AEC-qualified for automotive applications and is temperature grade 1, which is specified for operation from -40°C to +125°C.

## Features

- Low Input Offset Voltage: 8 $\mu$ V (typ)
- Zero Drift: 0.02 $\mu$ V/°C (typ)
- 0.01Hz to 10Hz Noise: 1.1 $\mu$ V<sub>PP</sub>
- Low Quiescent Current: 12 $\mu$ A per Amplifier
- Supply Voltage: 1.8V to 5.5V
- Rail-to-Rail Input and Output
- Bandwidth 350kHz
- Slew Rate 0.12V/ $\mu$ s (typ)
- SO-8 Package
- **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, PPAP capable, and manufactured in IATF 16949 certified facilities), please [contact us](mailto:contact@diodes.com) or your local Diodes representative. <https://www.diodes.com/quality/product-definitions/>**

## Pin Assignments



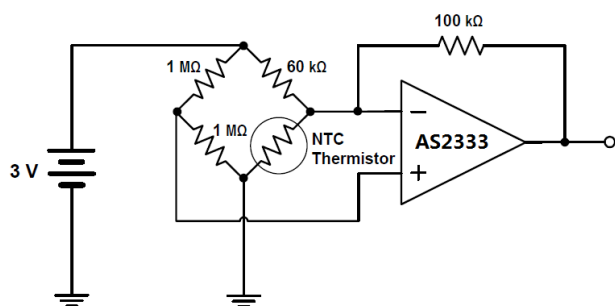
## Applications

- Battery-powered instruments
- Pumps
- Airbags
- Position sensors
- Vehicle occupant detection sensors

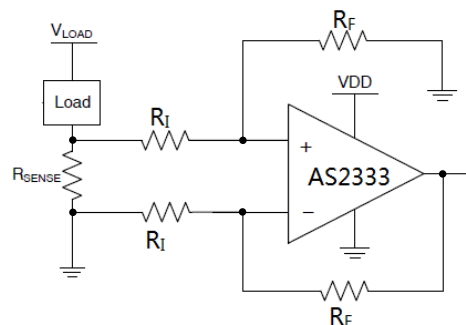
Notes:

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.

## 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<br>Recommend to place a minimum 0.1μF decoupling capacitor between V+ pin and GND as close as possible.  |
| 4          | V-       | —   | Negative Power Supply<br>Single power supply application, it is normally tied to ground.<br>Split power supply application, a minimum 0.1μF decouple capacitor will be recommended to place between V- pin and GND as close as possible. |

## Absolute Maximum Ratings (Note 4) (@T<sub>A</sub> = +25°C, unless otherwise specified.)

| Symbol   | Parameter                                | Rating   |     | Unit |
|--|--|--|-----|------|
| V <sub>S</sub> = V <sub>+</sub> - V <sub>-</sub> | Supply Voltage Range                     | 6.5  |     | V    |
| V <sub>-IN</sub> / V <sub>+IN</sub>              | Signal Input Terminals (Note 5)          | V <sub>-</sub> - 0.3V to V <sub>+</sub> + 0.3V |     | V    |
| —  | Signal Input Terminals (Note 5)          | -1 to +1                                       |     | mA   |
|  | Output Short-Circuit (Note 6)            | Continuous                                     |     | mA   |
| T <sub>STG</sub>                                 | Storage Temperature                      | -65 to +150                                    |     | °C   |
| T <sub>J</sub>                                   | Maximum Junction Temperature             | +150   |     | °C   |
| T <sub>LEAD</sub>                                | Lead Temperature (Soldering, 10 Seconds) | +260   |     | °C   |
| R <sub>θJA</sub>                                 | Junction-to-Ambient Thermal Resistance   | SO-8   | 139 | °C/W |
| R <sub>θJC</sub>                                 | Junction-to-Case Thermal Resistance      | SO-8   | 25  | °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<sub>A</sub> = +25°C, unless otherwise specified.)

| Symbol   | Parameter                           | Rating      | Unit |
|--|-------------------------------------|-------------|------|
| V <sub>S</sub> = V <sub>+</sub> - V <sub>-</sub> | Supply Voltage Range                | 1.8 to 5.5  | V    |
| T <sub>A</sub>                                   | Operating Ambient Temperature Range | -40 to +125 | °C   |

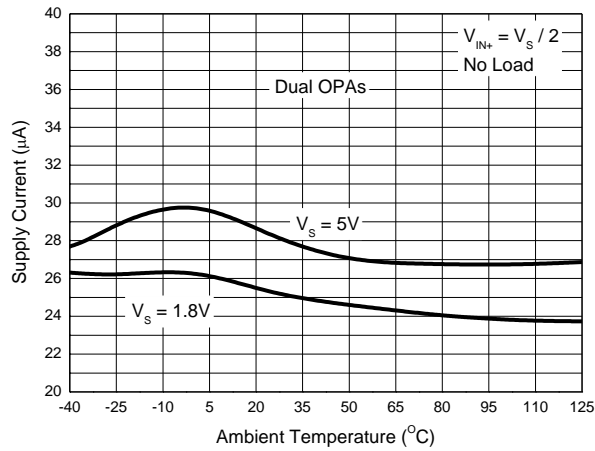
## Electrical Characteristics (@T<sub>A</sub> = +25°C, V<sub>S</sub> = 5.0V, R<sub>L</sub> = 10kΩ connected to V<sub>S</sub> / 2, V<sub>CM</sub> = V<sub>S</sub> / 2, and V<sub>OUT</sub> = V<sub>S</sub> / 2, unless otherwise specified.)

| Symbol               | Parameter                           | Conditions  | Min                              | Typ  | Max        | Unit             |    |
|----------------------|-------------------------------------|---|----------------------------------|------|------------|------------------|----|
| Offset Voltage       |                                     |   |                                  |      |            |                  |    |
| V <sub>OS</sub>      | Input Offset Voltage                | V <sub>S</sub> = 5V   | —                                | 8    | 22         | μV               |    |
| ΔV <sub>OS</sub> /ΔT | Input Offset Voltage Drift (Note 7) | T <sub>A</sub> = -40°C to +85°C   | —                                | 0.02 | 0.1        | μV/°C            |    |
|                      |                                     | T <sub>A</sub> = -40°C to +125°C  | —                                | —    | 0.2        | μV/°C            |    |
| PSRR                 | Power-Supply Rejection Ratio        | V <sub>S</sub> = 1.8V to 5.5V, T <sub>A</sub> = -40°C to +125°C                                       | —                                | 1    | 10         | μV/V             |    |
| —                    | Long-Term Stability                 | —   | (Note 7)                         |      |            | μV               |    |
| —                    | Channel Separation, DC              | —   | —                                | 0.1  | —          | μV/V             |    |
| Input Bias Current   |                                     |   |                                  |      |            |                  |    |
| I <sub>B</sub>       | Input Bias Current                  | T <sub>A</sub> = +25°C  | —                                | ±70  | ±200       | pA               |    |
|                      |                                     | T <sub>A</sub> = -40°C to +125°C  | —                                | ±400 | —          |                  |    |
| I <sub>OS</sub>      | Input Offset Current                | —   | —                                | ±140 | ±400       |                  |    |
| Noise                |                                     |   |                                  |      |            |                  |    |
| V <sub>N</sub>       | Input Voltage Noise                 | f = 0.01Hz to 1Hz   | —                                | 0.3  | —          | μV <sub>PP</sub> |    |
|                      |                                     | f = 0.1Hz to 10Hz   | —                                | 1.1  | —          |                  |    |
| I <sub>N</sub>       | Input Current Noise                 | f = 10Hz  | —                                | 100  | —          | fA/√Hz           |    |
| Input Voltage        |                                     |   |                                  |      |            |                  |    |
| V <sub>CM</sub>      | Common-Mode Voltage Range           | —   | (V-) - 0.1                       | —    | (V+) + 0.1 | V                |    |
| CMRR                 | Common-Mode Rejection Ratio         | (V-) - 0.1V < V <sub>CM</sub> < (V+) + 0.1V, T <sub>A</sub> = -40°C to +125°C                         | 90                               | 120  | —          | dB               |    |
| Input Capacitance    |                                     |   |                                  |      |            |                  |    |
| —                    | Differential                        | —   | —                                | 2    | —          | pF               |    |
| —                    | Common-Mode                         | —   | —                                | 4    | —          | pF               |    |
| Open-Loop Gain       |                                     |   |                                  |      |            |                  |    |
| A <sub>OL</sub>      | Open-Loop Voltage Gain              | (V-) + 100mV < V <sub>O</sub> < (V+) - 100mV, R <sub>L</sub> = 10kΩ, T <sub>A</sub> = -40°C to +125°C | 102                              | 130  | —          | dB               |    |
| Frequency Response   |                                     |   |                                  |      |            |                  |    |
| GBW                  | Gain-Bandwidth Product              | C <sub>L</sub> = 100pF  | —                                | 350  | —          | kHz              |    |
| SR                   | Slew Rate                           | G = +1  | —                                | 0.12 | —          | V/μs             |    |
|                      |                                     |   |                                  |      |            |                  |    |
| Output               |                                     |   |                                  |      |            |                  |    |
| —                    | Voltage Output Swing from Rail      | Positive Rail<br>R <sub>L</sub> = 10kΩ  | T <sub>A</sub> = +25°C           | —    | 30         | 50               | mV |
|                      |                                     |   | T <sub>A</sub> = -40°C to +125°C | —    | —          | 70               |    |
|                      |                                     | Negative Rail<br>R <sub>L</sub> = 10kΩ  | T <sub>A</sub> = +25°C           | —    | 10         | 50               |    |
|                      |                                     |   | T <sub>A</sub> = -40°C to +125°C | —    | —          | 70               |    |
| I <sub>SC</sub>      | Short-Circuit Current               | Source Current  | —                                | 5    | —          | mA               |    |
|                      |                                     | Sink Current  | —                                | 25   | —          | mA               |    |
| —                    | Open-Loop Output Impedance          | f = 350kHz, I <sub>O</sub> = 0A   | —                                | 2    | —          | kΩ               |    |
| Power Supply         |                                     |   |                                  |      |            |                  |    |
| V <sub>S</sub>       | Specified Voltage Range             | —   | 1.8                              | —    | 5.5        | V                |    |
| I <sub>Q</sub>       | Quiescent Current per Amplifier     | I <sub>O</sub> = 0A, T <sub>A</sub> = +25°C   | —                                | 12   | 20         | μA               |    |
|                      |                                     | I <sub>O</sub> = 0A, T <sub>A</sub> = -40°C to +125°C   | —                                | —    | 28         |                  |    |
| t <sub>ON</sub>      | Turn-On Time                        | V <sub>S</sub> = 5V   | —                                | 100  | —          | μs               |    |

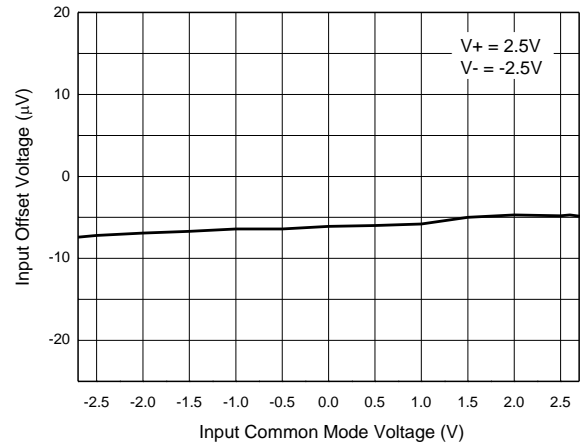
Note: 7. 300-hour life test at +150°C demonstrated randomly distributed variation of approximately 1μV. This parameter guaranteed by design and characterization, not by testing.

## Typical Performance Characteristics

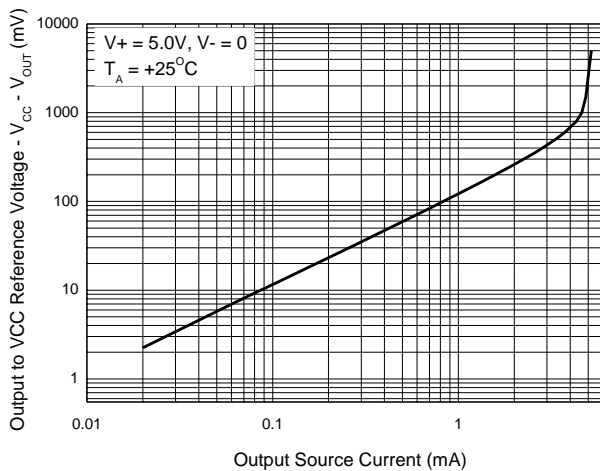
Supply Current vs. Temperature



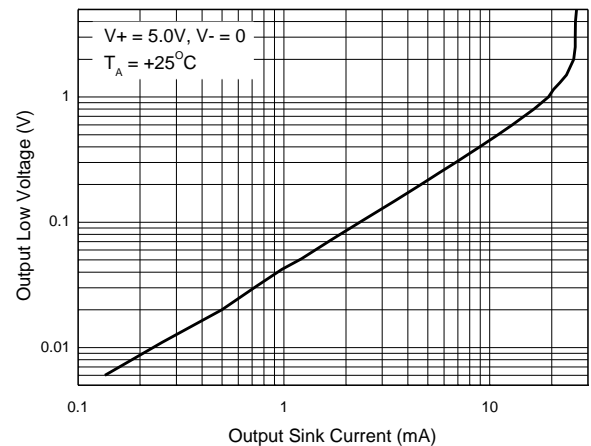
Input Offset Voltage vs. Input Common Mode Voltage



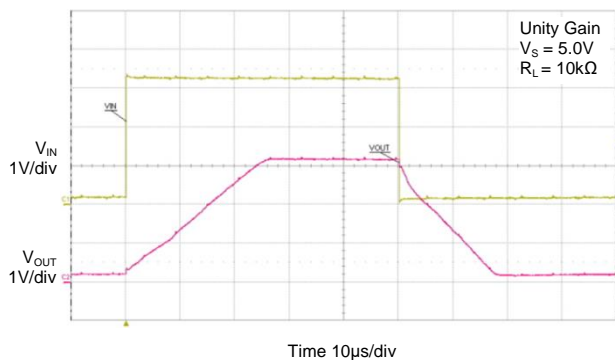
Output Characteristics-Sourcing Current



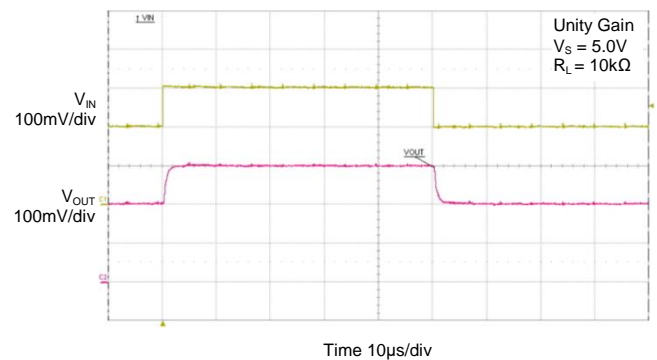
Output Characteristics-Sinking Current



Large Signal Response

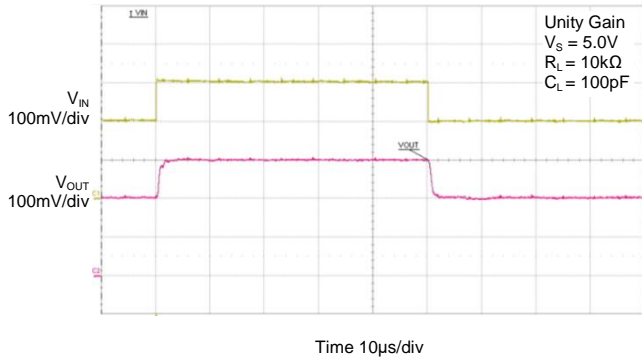


Small Signal Response

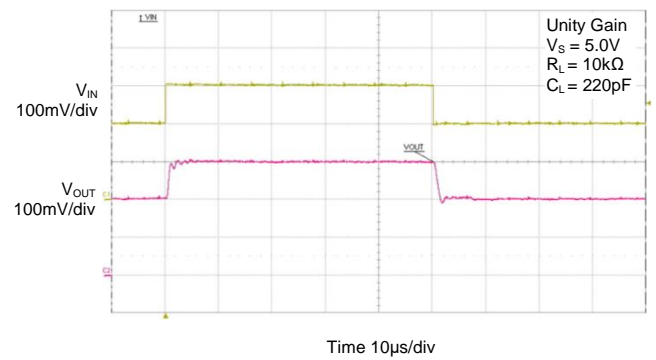


## Typical Performance Characteristics (continued)

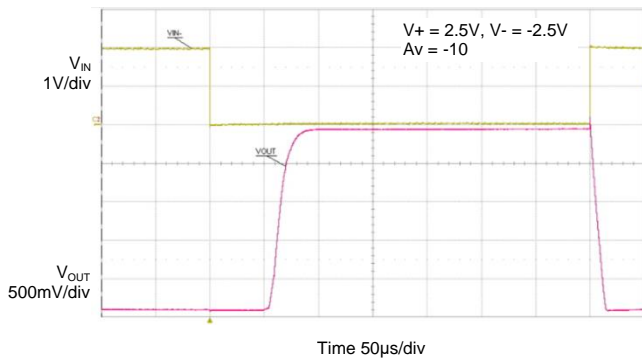
**Small Signal Response**



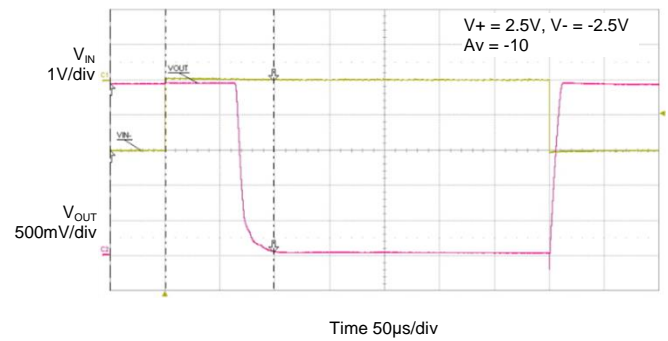
**Small Signal Response**



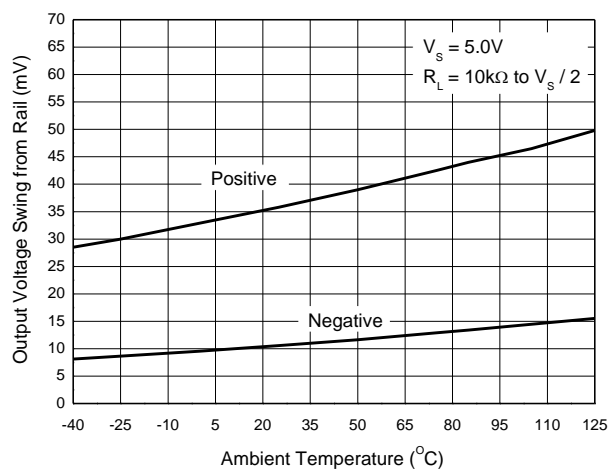
**Negative Overvoltage Response**



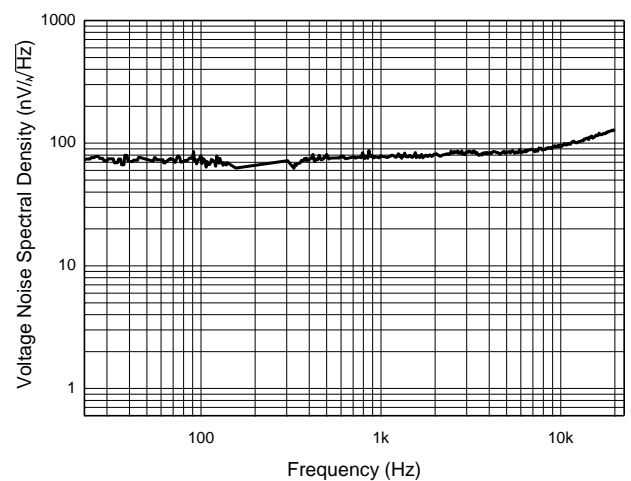
**Positive Overvoltage Response**



**Output Voltage Swing from Rail**

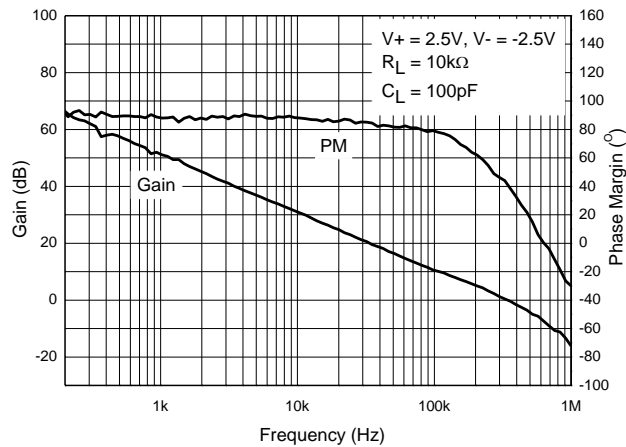


**Voltage Noise Spectral Density**

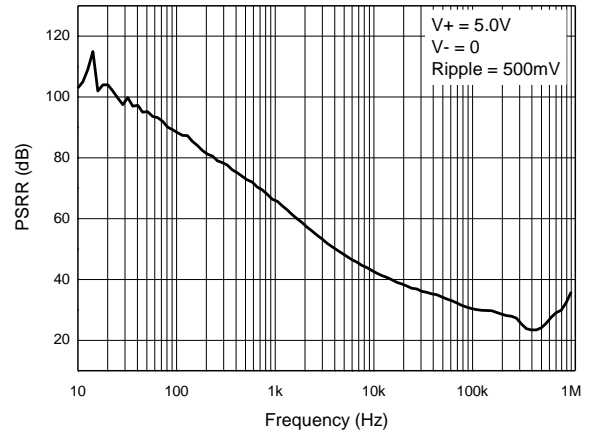


## Typical Performance Characteristics (continued)

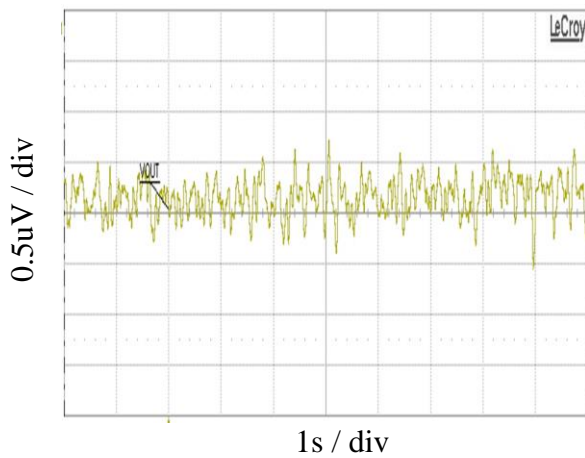
**Frequency Response**



**Power Supply Rejection Ratio vs. Frequency**



**0.1Hz to 10Hz Noise**



## Application Information

### Overview

The AS2333Q is a 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 part suitable for a wide range of general-purpose applications, especially for low-power high-precision applications.

### Low Input Referred Noise

The chopper-stabilized technique greatly reduces 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.

Below plots compared conventional amplifier voltage noise density behavior and zero-drift amplifier's, this 1/f noise elimination in zero-drift amplifier allows the AS2333Q to have much lower noise at DC and low frequency compared to conventional low-noise amplifiers.

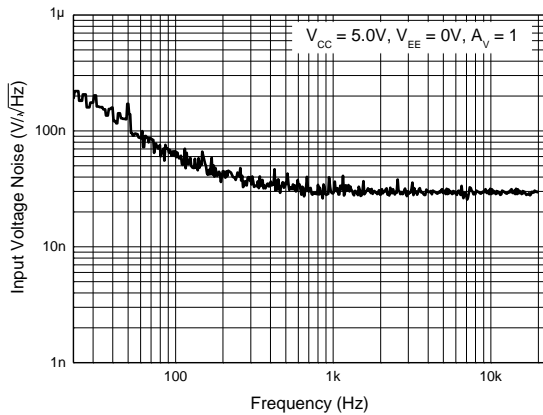


Figure 1. Input Voltage Noise in Conventional Amplifier

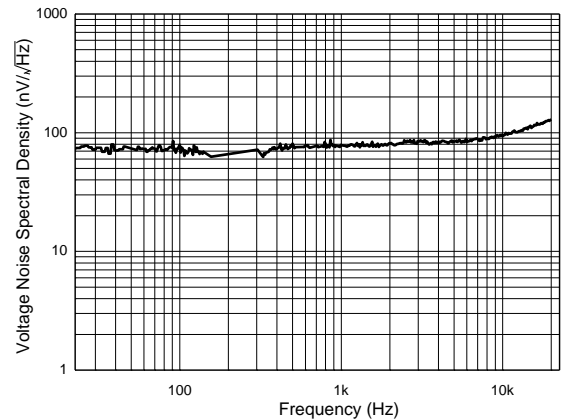


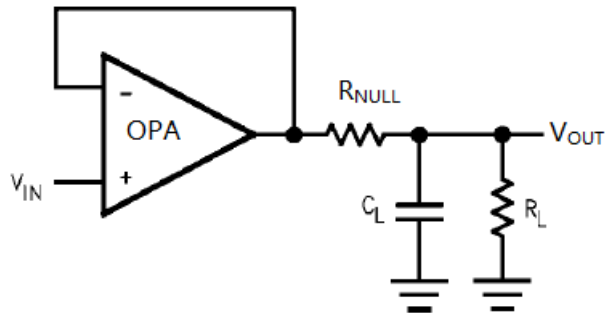
Figure 2. Input Voltage Noise in Zero-Drift Amplifier (AS2333Q)

### Driving a Capacitive Load

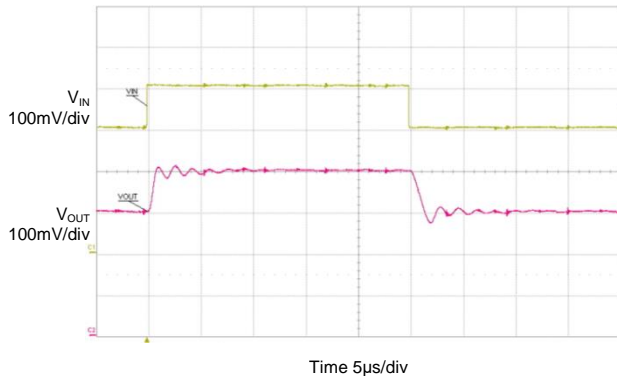
The AS2333Q can directly drive 200pF in unity-gain without oscillation. The unity-gain follower is the most sensitive configuration to capacitive loading. Capacitive loading directly on the output terminal can decrease the device's phase margin leading to high frequency ringing or oscillation.

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  $R_{NULL}$  resistor value the more stable  $V_{OUT}$  is. Figure 4 and Figure 5 are AS2333Q output pulse response waveforms with and without  $R_{NULL}$  330Ω for load conditions  $C_L$  = 470pF and  $R_L$  = 10kΩ.

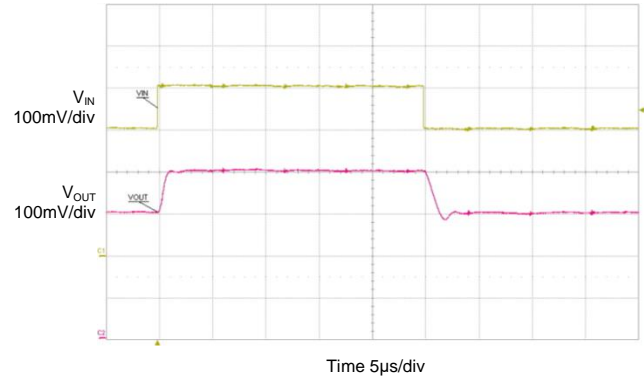
## Application Information (continued)



**Figure 3. Capacitive Load with  $R_{NULL}$**

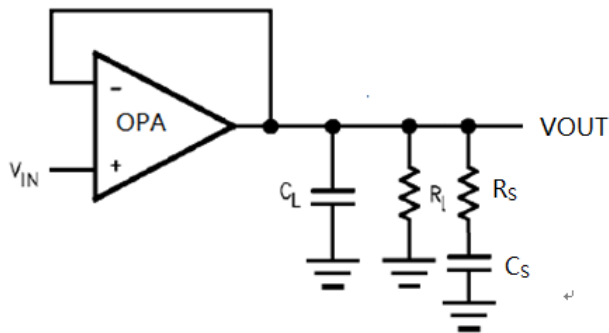


**Figure 4. Test Result Without  $R_{NULL}$**

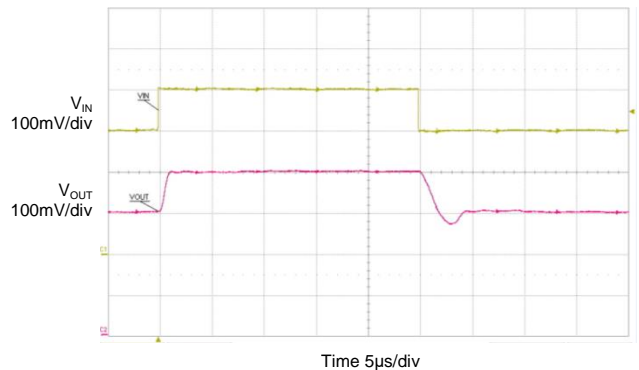


**Figure 5. Test Result with  $R_{NULL}$  330Ω**

Reducing capacitive load ringing and overshoot, the RC snubber circuit also can be used, shown in Figure 6, it does allow the amplifier to drive larger values of capacitance while maintaining a minimum of overshoot and ringing. Figure 7 shows AS2333Q test result for capacitive load 470pF with snubber circuit.



**Figure 6. Circuit with Snubber Circuit**



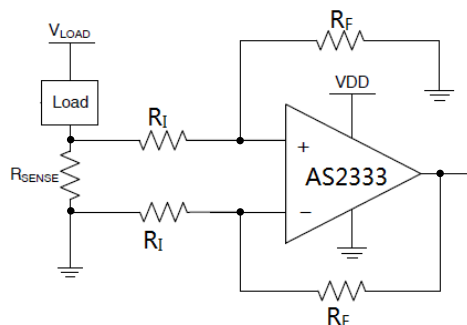
**Figure 7. Test Result with Snubber Circuit**



## Application Information (continued)

### Low-Side Current Monitor Application

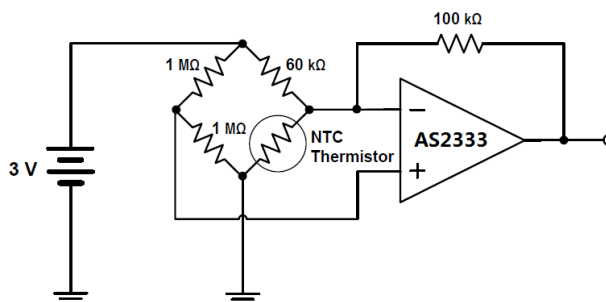
Low-side current sensing is used to monitor the current through a load. This method can be used to detect overcurrent conditions and is often used in feedback control, as shown in Figure 8. A sense resistor is placed in series with the load to ground. Precision resistors are required for high accuracy and the resulting voltage drop is amplified using AS2333Q.



**Figure 8. Low-Side Current Monitor Application**

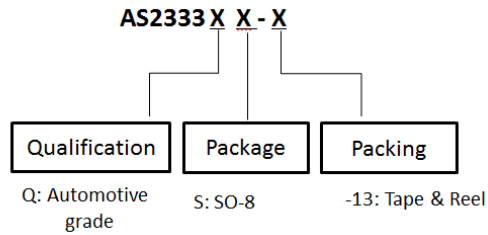
### Differential Amplifier for Bridged Circuits

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**

## Ordering Information

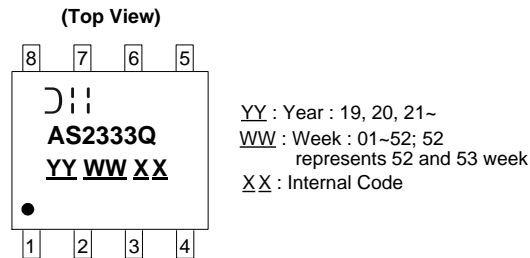


| Part Number | Identification Code | Package | Tape and Reel    |                    |
|-------------|---------------------|---------|------------------|--------------------|
|             |                     |         | Quantity         | Part Number Suffix |
| AS2333QS-13 | AS2333Q             | SO-8    | 2500/Tape & Reel | -13                |

Note: 8. This part will be developed in future.

## Marking Information

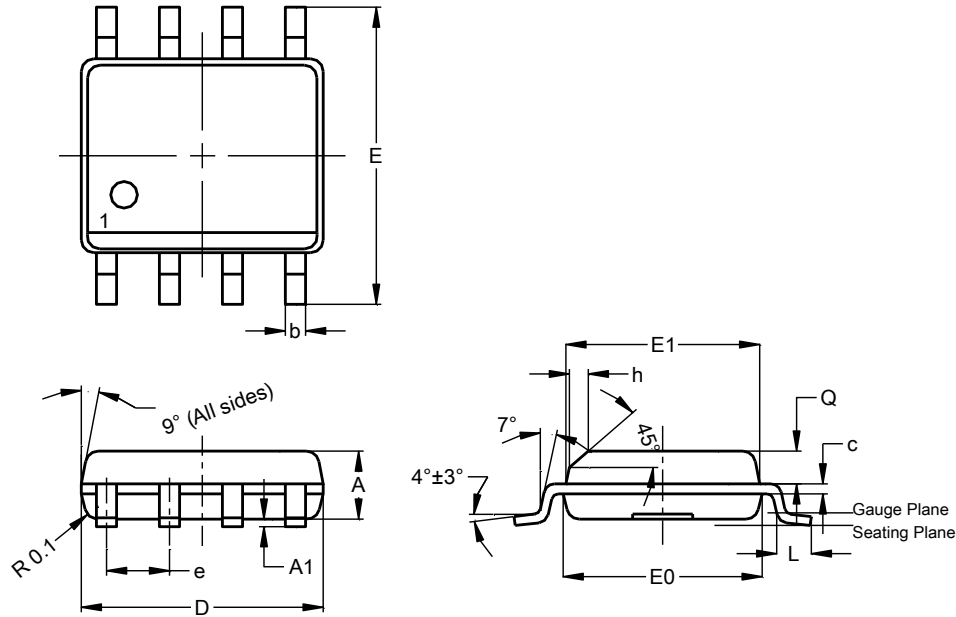
SO-8



## Package Outline Dimensions

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

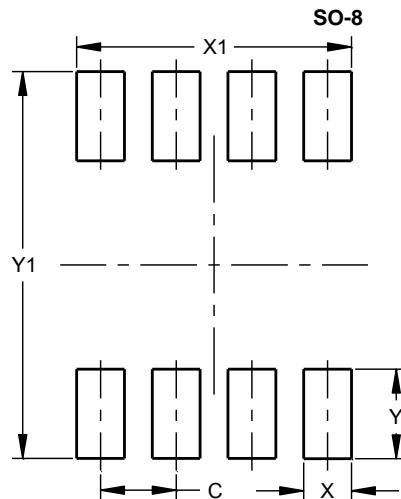
SO-8



| 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 |      |      |      |

## Suggested Pad Layout

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



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

## Mechanical Data

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

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