

**LOW-NOISE, LOW QUIESCENT
CURRENT, PRECISION OPERATIONAL AMPLIFIER**

Description

The DIODES™ AS2376 is a low noise ($9.5\text{nV}/\sqrt{\text{Hz}}$), low offset ($25\mu\text{V}$, maximum) operational amplifier that is precision optimized using post package trim. With a 5.5-MHz bandwidth the device is suitable for a wide array of filtering and control applications.

The low operating voltage range, low quiescent current of $950\mu\text{A}$ (maximum), and excellent PSRR allow for noise sensitive applications which are supplied from noisy low voltage rails.

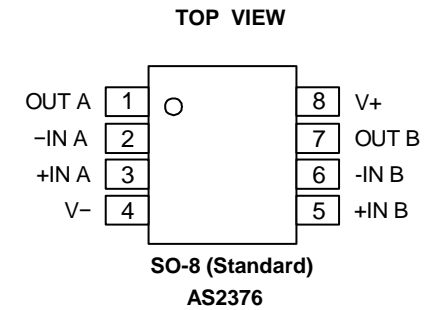
The dual AS2376 is offered in the SO-8 (Standard) package specified for operation from -40°C to $+125^{\circ}\text{C}$.

Features

- Low Noise: $9.5\text{nV}/\sqrt{\text{Hz}}$ at 1kHz
- 0.1Hz to 10Hz Noise: $0.8\mu\text{V}_{\text{pp}}$
- Quiescent Current: $760\mu\text{A}$ (typical)
- Low Offset Voltage: $5\mu\text{V}$ (typ)
- Gain Bandwidth Product: 5.5MHz
- Rail-to-Rail Input and Output
- Single-Supply Operation
- Supply Voltage: 2.2V to 5.5V
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **An automotive-compliant part is available under separate datasheet ([AS2376Q](#))**

- 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.

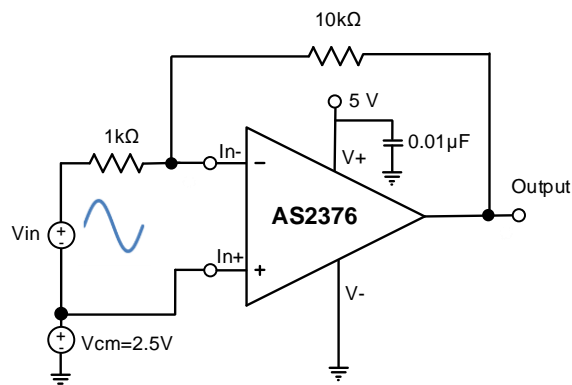
Pin Assignments



Applications

- Auto pump
- Position sensor
- Vehicle occupant detection sensor
- Airbag
- Onboard charge (OBC)
- DC-DC converter
- Battery management system (BMS)

Typical Applications Circuit

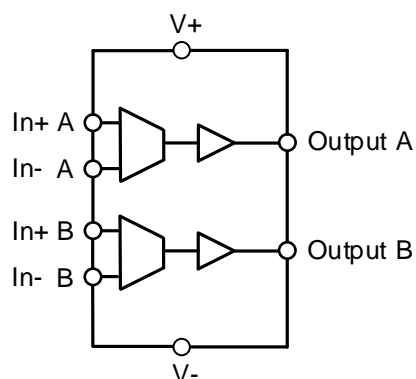


Basic Single Power Amplifier Connection

Pin Description

PIN		I/O	DESCRIPTION
NAME	SO-8 (Standard)		
+IN A	3	I	Noninverting input, channel A
+IN B	5	I	Noninverting input, channel B
-IN A	2	I	Inverting input, channel A
-IN B	6	I	Inverting input, channel B
OUT A	1	O	Output, channel A
OUT B	7	O	Output, channel B
V+	8	—	Positive (highest) power supply
V-	4	—	Negative (lowest) power supply

Functional Block Diagram



AS2376 Functional Block

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

Symbol	Parameter	Rating		Unit
V+ -V-	Supply Voltage	6.5		V
	Output Short Circuit to V+	(Note 5)		
	Output Short Circuit to V-	(Note 6)		
Current	Signal input terminals (Note 7)	(Note 7)		mA
	Output short-circuit (Note 8)	Continuous		mA
T _{ST}	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 (Standard)	115	°C/W
R _{θJC}	Junction-to-Case Thermal Resistance	SO-8 (Standard)	18	°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. Operating Ratings 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. Shorting output to V+ will adversely affect reliability.
 6. Shorting output to V- will adversely affect reliability.
 7. 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.
 8. Short-circuit to ground.

Recommended Operating Conditions

Symbol	Parameter	Min.	Max.	Unit
V _{CC}	Supply Voltage	2.2	5.5	V
T _A	Ambient Operating Temperature Range	-40	+125	°C

Electrical Characteristics (Limits in standard typeface are for $T_A = +25^\circ\text{C}$, **bold** typeface applies over -40°C to $+125^\circ\text{C}$ (Note 9), $R_L = 10\text{ k}\Omega$ connected to $V_S / 2$, $V_{CM} = V_S / 2$, and $V_{OUT} = V_S / 2$, unless otherwise noted.)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE					
V_{OS} Input offset voltage (Note 10)		-	5	25	μV
	Long-term stability (Note 11)	-	-	60	μV
	Package level shift (Note 12)	-	-	320	μV
$\Delta V_{OS}/\Delta T$ Input offset voltage versus temperature	$T_A = -40^\circ\text{C}$ to $+85^\circ\text{C}$	-	0.26	1.2	$\mu\text{V}/^\circ\text{C}$
	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	-	0.32	2	$\mu\text{V}/^\circ\text{C}$
PSRR Input offset voltage versus power supply	$T_A = 25^\circ\text{C}$, $V_S = 2.2\text{V}$ to 5.5V , $V_{CM} < (V^+) - 1.3\text{V}$	-	5	20	$\mu\text{V}/\text{V}$
	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$, $V_S = 2.2\text{V}$ to 5.5V , $V_{CM} < (V^+) - 1.3\text{V}$	-	5	-	$\mu\text{V}/\text{V}$
Channel separation, dc		-	0.5	-	mV/V
INPUT BIAS CURRENT					
I_B Input bias current	$T_A = 25^\circ\text{C}$	-	0.2	70	pA
	$T_A = -40^\circ\text{C}$ to $+125^\circ\text{C}$	See Typical Characteristics			pA
IOS Input offset current		-	0.2	70	pA
NOISE					
Input voltage noise	$f = 0.1\text{Hz}$ to 10Hz	-	0.8	-	μV_{PP}
e_n Input voltage noise density	$f = 1\text{kHz}$	-	9.5	-	$\text{nV}/\sqrt{\text{Hz}}$
I_n Input current noise	$f = 1\text{kHz}$	-	2	-	$\text{fA}/\sqrt{\text{Hz}}$
INPUT VOLTAGE RANGE					
V_{CM} Common-mode voltage range		$(V^-) - 0.1$		$(V^+) + 0.1$	V
CMRR Common-mode rejection ratio	$(V^-) < V_{CM} < (V^+) - 1.3\text{V}$	76	90		dB
INPUT CAPACITANCE					
Differential		-	6.5	-	pF
Common-mode		-	13	-	pF
OPEN-LOOP GAIN					
A_{OL} Open-loop voltage gain	$50\text{mV} < V_O < (V^+) - 50\text{mV}$, $R_L = 10\text{k}\Omega$	120	134	-	dB
	$100\text{mV} < V_O < (V^+) - 100\text{mV}$, $R_L = 2\text{k}\Omega$	120	126	-	dB
FREQUENCY RESPONSE $C_L = 100\text{ pF}$, $V_S = 5.5\text{ V}$					
GBW Gain-bandwidth product		-	5.5	-	MHz
SR Slew rate	$G = 1$	-	2	-	$\text{V}/\mu\text{s}$
t_s Settling time	Settling to 0.1%, 2-V step, $G = 1$	-	1.6	-	μs
	Settling to 0.01%, 2-V step, $G = 1$	-	2	-	μs
Overload recovery time	$V_{IN} \times \text{gain} > V_S$	-	0.33	-	μs
Overload recovery time	$V_{IN} \times \text{gain} > V_S$	-	0.33	-	μs

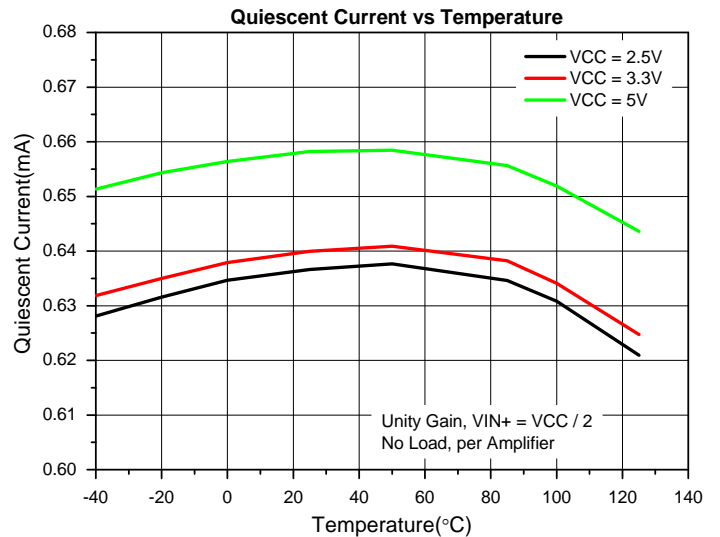
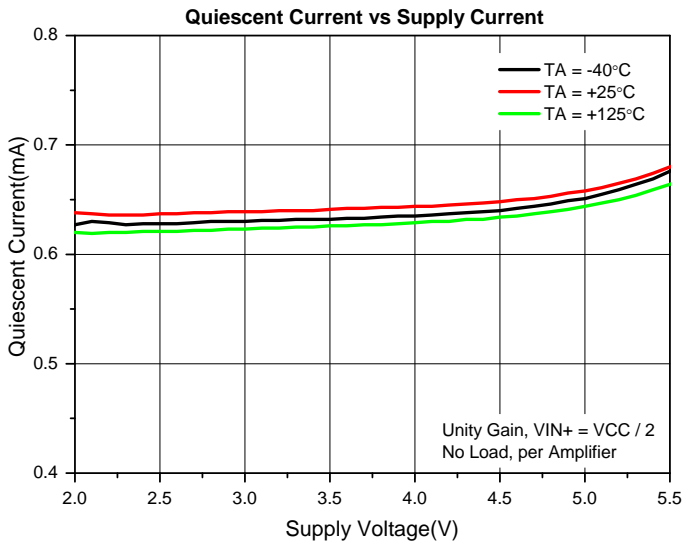
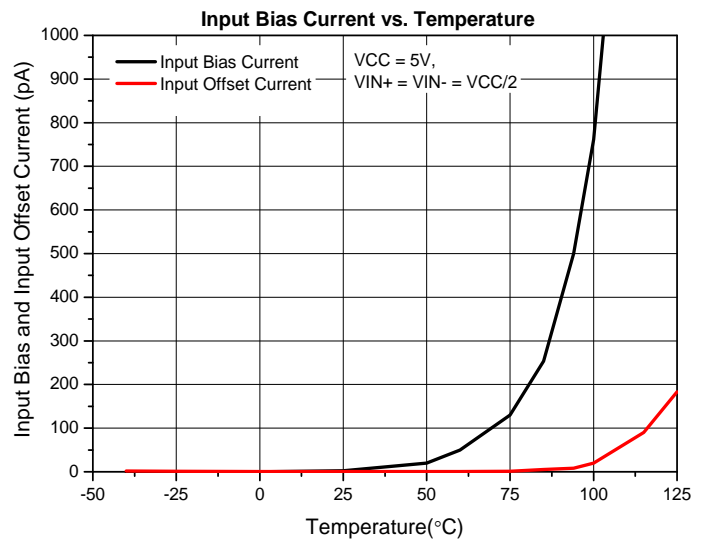
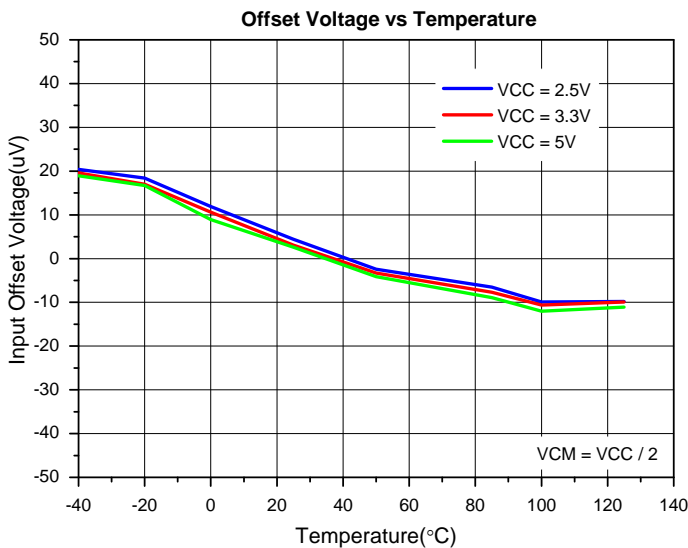
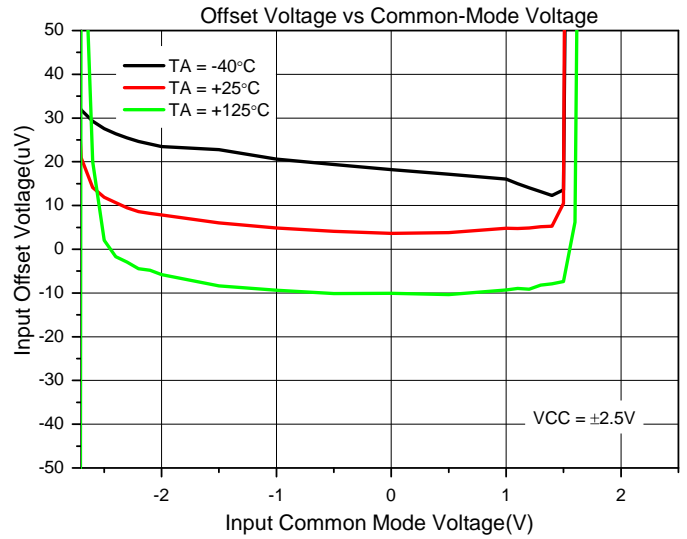
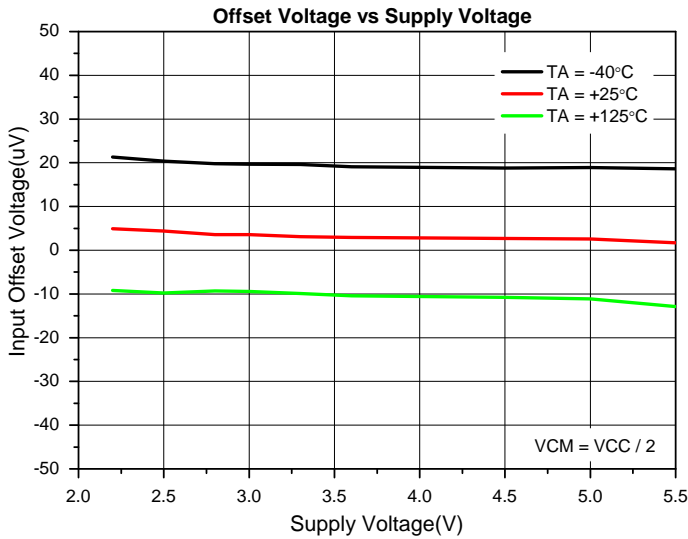
- Notes:
- Limits over the full temperature are guaranteed by design, but not tested in production.
 - After mounted to PCB, V_{OS} value will be different to spec, the delta value depend on PCB solder stress, the max value is between $\pm 80\mu\text{V}$, per our experiment.
 - AS2376Q, the long-term stability is defined as MAX. V_{OS} shift during life HTOL 1000 hours with $T_A = +125^\circ\text{C}$ ($T_J = 150^\circ\text{C}$). This V_{OS} drift with time is not a linear function of time, and the shift is greater initially and diminishes over time. This parameter is guaranteed by design.
 - After HTSL 2000 hours with $T_A = +150^\circ\text{C}$, the V_{OS} drift test condition is $T_A = +125^\circ\text{C}$.

Electrical Characteristics (continued) (Limits in standard typeface are for $T_A = +25^\circ\text{C}$, **bold** typeface applies over -40°C to $+125^\circ\text{C}$ (Note 9), $R_L = 10\text{k}\Omega$ connected to $V_S / 2$, $V_{CM} = V_S / 2$, and $V_{OUT} = V_S / 2$, unless otherwise noted.)

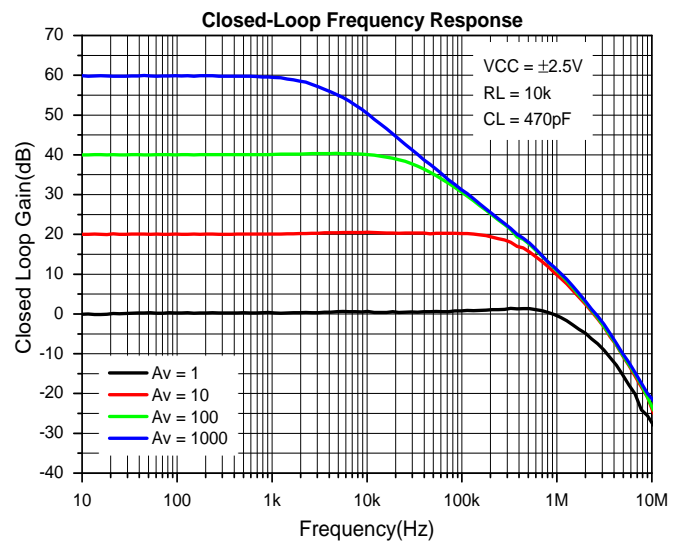
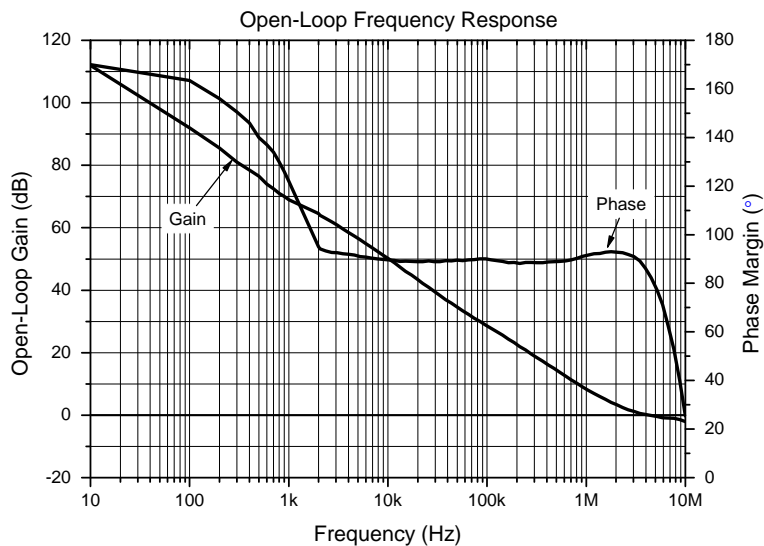
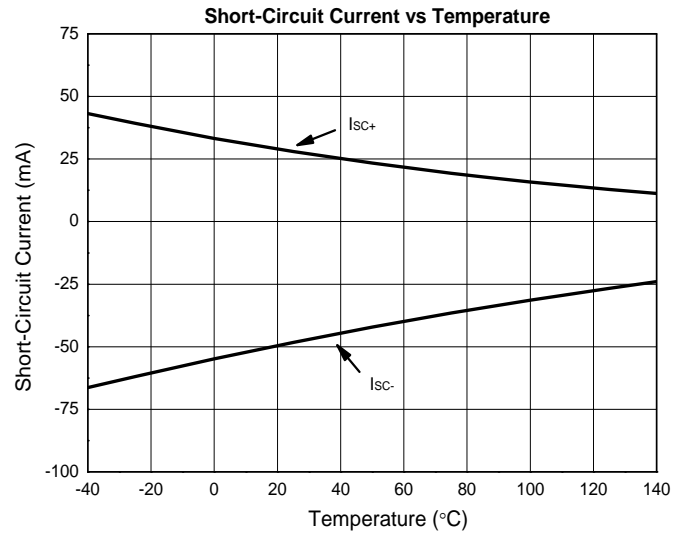
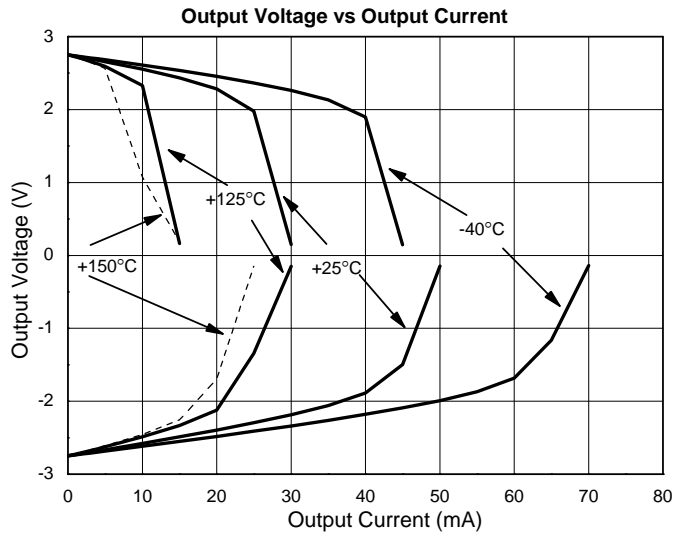
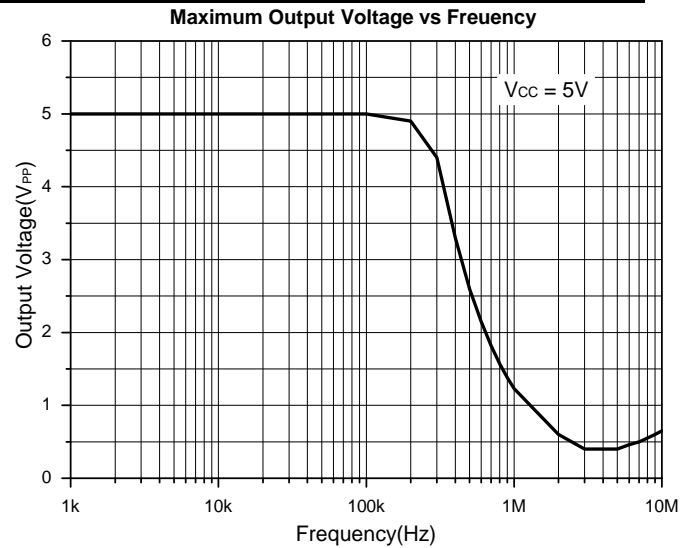
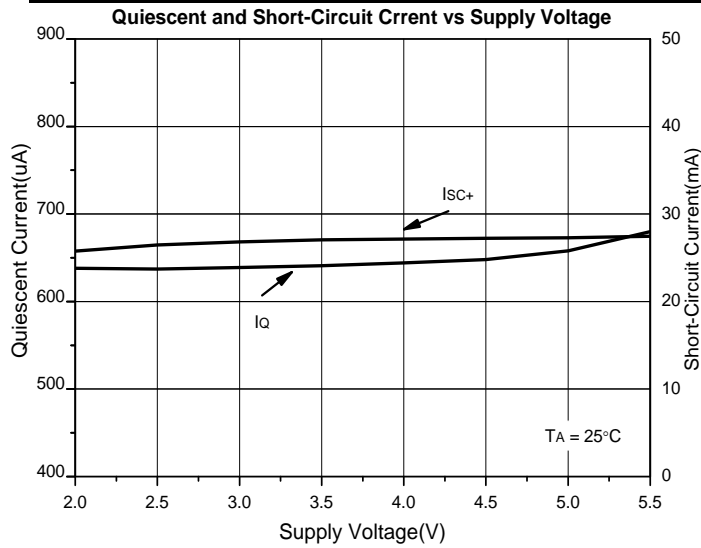
	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
	Voltage output swing from rail	T _A = 25°C, R _L = 10kΩ	-	10	20	mV
		T _A = -40°C to +125°C, R _L = 10kΩ	-	-	40	mV
		T _A = 25°C, R _L = 2kΩ	-	40	50	mV
		T _A = -40°C to +125°C, R _L = 2kΩ	-	-	80	mV
I _{SC}	Short-circuit current			+30, -50		mA
C _{LOAD}	Capacitive load drive		See Typical Characteristics			
R _O	Open-loop output		-	150		Ω
POWER SUPPLY						
V _s	Specified voltage range		2.2		5.5	V
	Operating voltage range		-	2 to 5.5		V
I _Q	Quiescent current per amplifier	T _A = 25°C, I = 0, V = 5.5 V, V _{CM} < (V ⁺) – 1.3 V	-	760	950	μA
		T _A = -40°C to +125°C	-	-	1	mA
TEMPERATURE						
	Specified range		-40	-	+125	°C
	Operating range		-40	-	+150	°C

Note: 9. Limits over the full temperature are guaranteed by design, but not tested in production.

Performance Characteristics

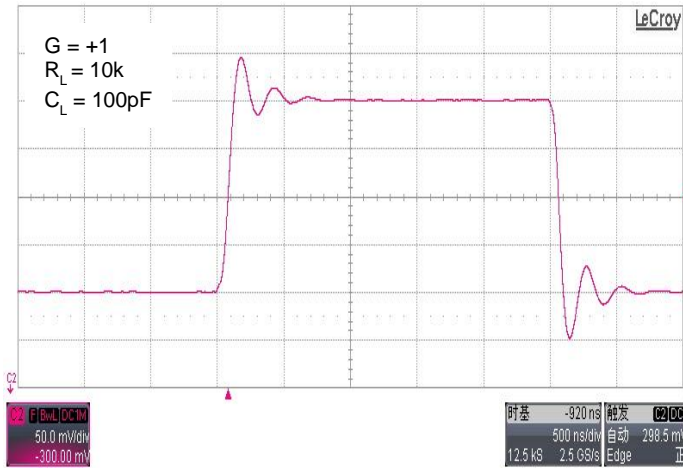


Performance Characteristics (continued)

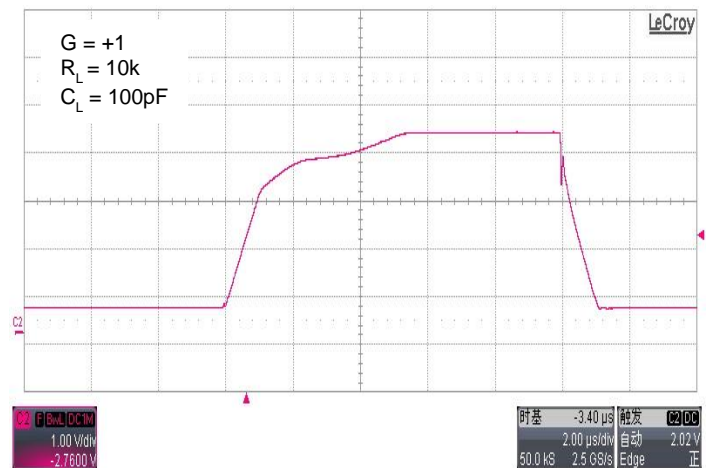


Performance Characteristics (continued)

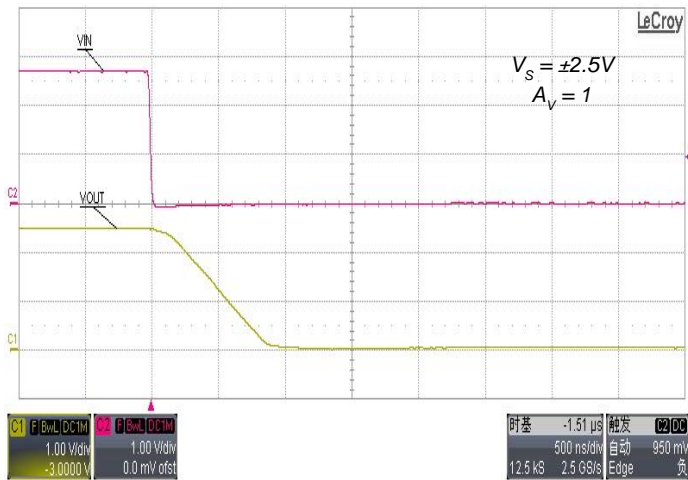
Small-Signal Pulse Response



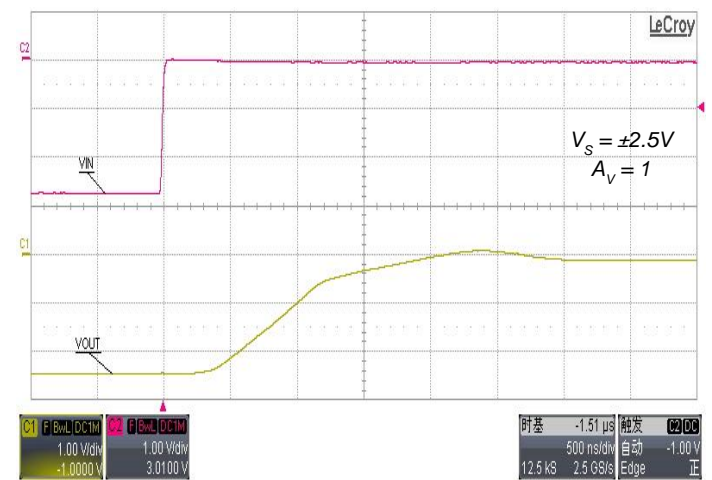
Large-Signal Pulse Response



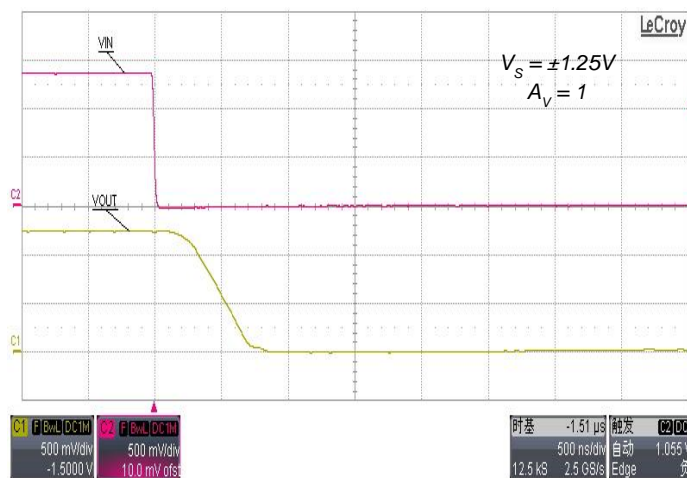
Positive Input Overload Recovery



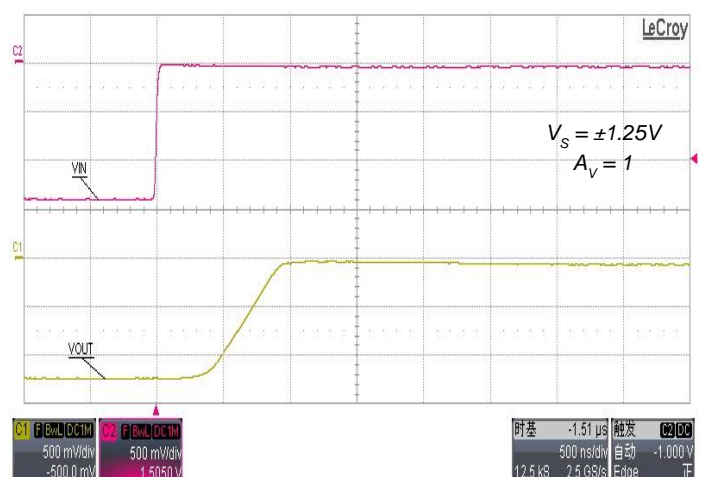
Negative Input Overload Recovery



Positive Input Overload Recovery

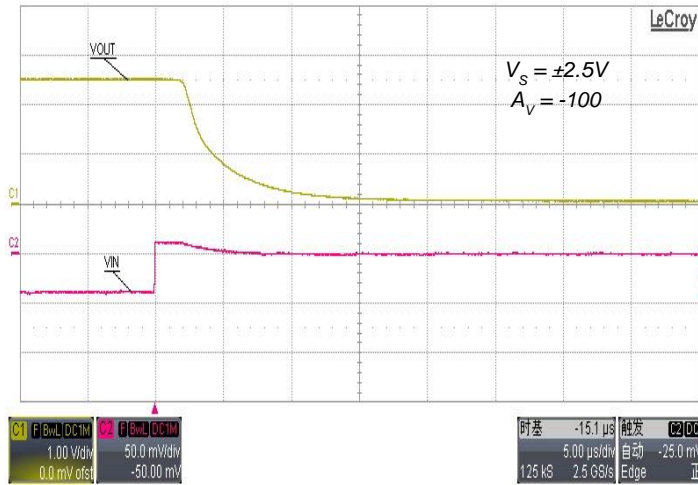


Negative Input Overload Recovery

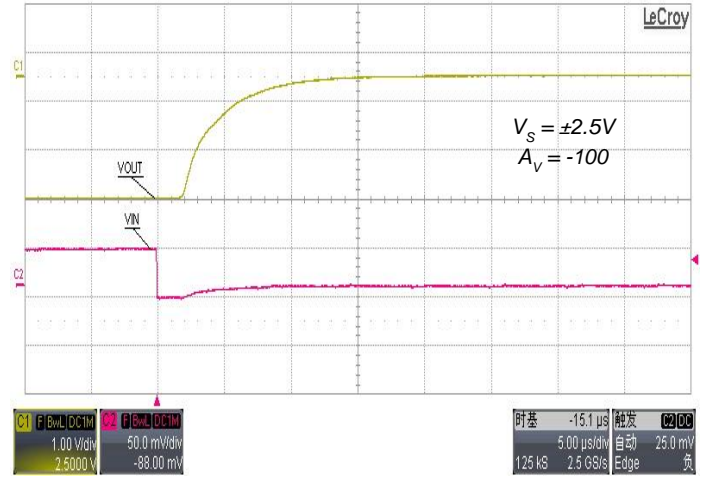


Performance Characteristics (continued)

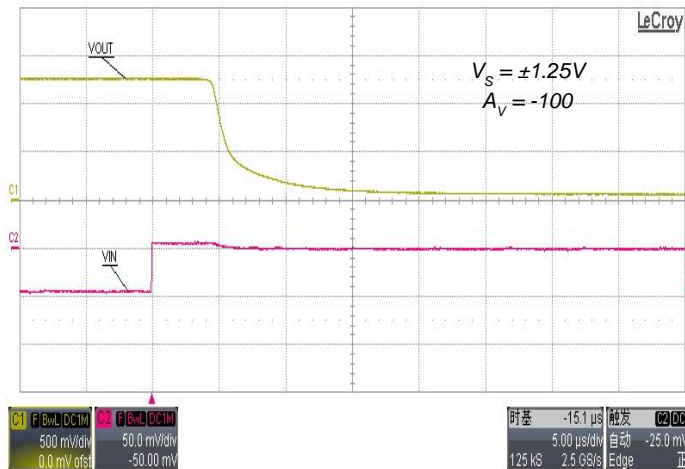
Positive Output Overload Recovery



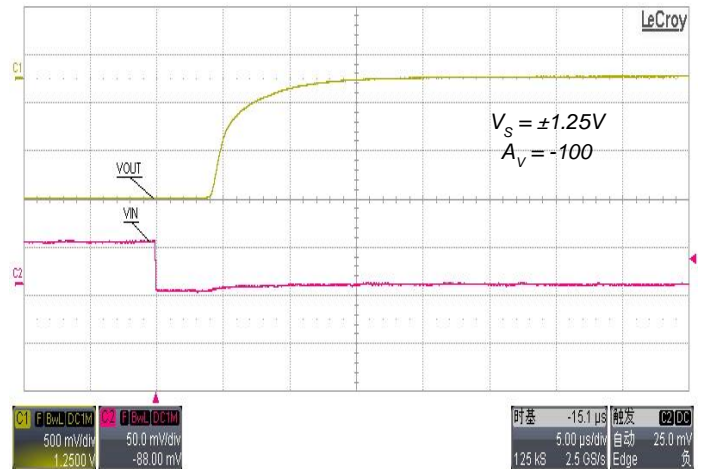
Negative Output Overload Recovery



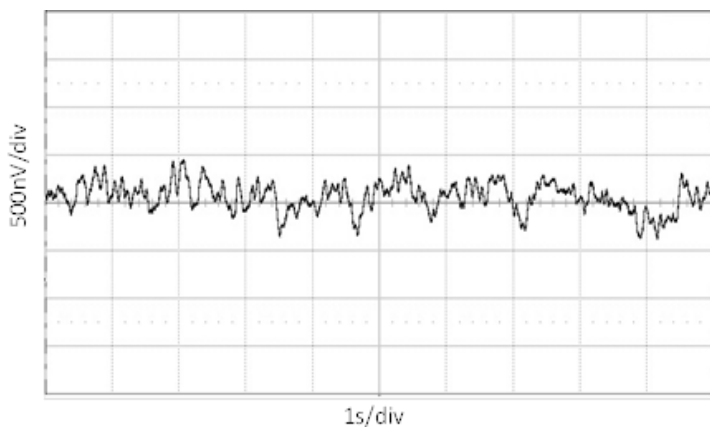
Positive Output Overload Recovery



Negative Output Overload Recovery

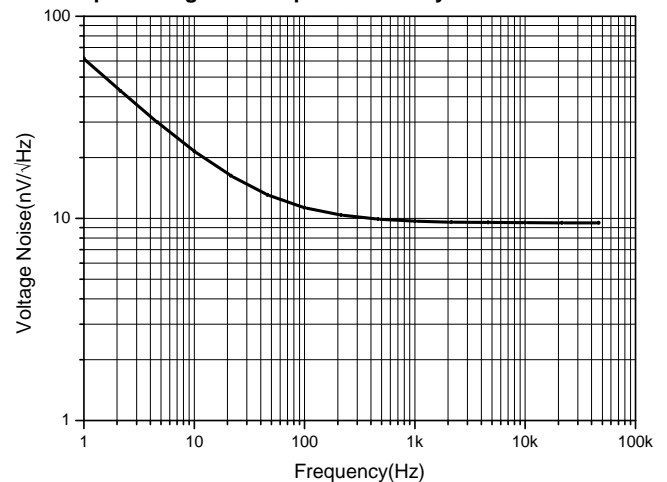


0.1-Hz to 10-Hz Input Voltage Noise



0.1-Hz to 10-Hz Input Voltage Noise

Input Voltage Noise Spectral Density



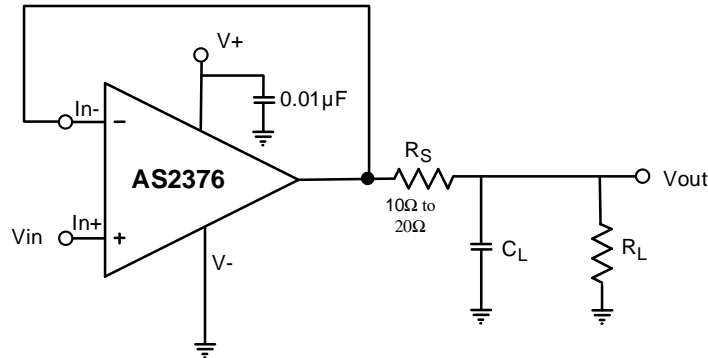
Application Information

Overview

The DIODES™ AS2376 combines low offset (25 μ V maximum) and 5.5-MHz bandwidth for a wide variety of filtering and control applications. Many op amps use chopper stabilization to achieve low offset voltage but this normally comes with a restriction of bandwidth to less than 500kHz. The offset of the AS2376 is addressed by using post package trim allowing for the retention of significant bandwidth.

Stability considerations when driving capacitive loads

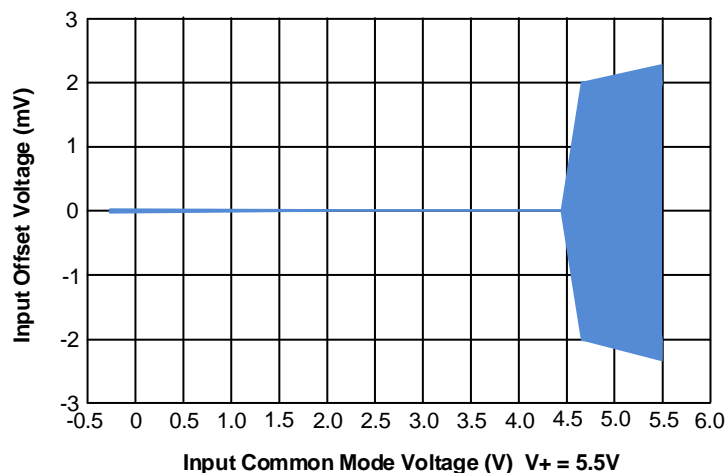
Operational amplifiers are prone to oscillation when required to drive large capacitive loads. The AS2376 is capable of driving a 250 picofarad load at unity gain. Larger loads will require the insertion of a nulling resistor (denoted as R_S) in series with the load capacitor. The suggested nulling resistor value is 10 Ω to 20 Ω . This addition will introduce a small error but is negligible in most applications.



Circuit for Driving Large Capacitive Loads

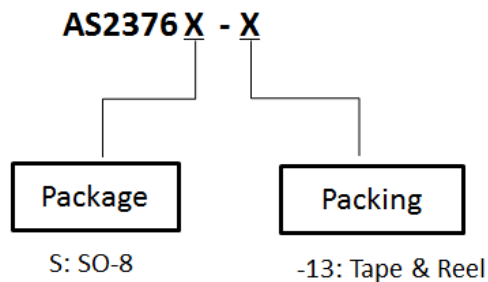
Offset voltage as input common mode approaches $V+$

The AS2376 has an input circuitry configuration that is common to most rail to rail input operational amplifiers. At the low end of the common mode input voltage range, the input signals are processed by a differential pair of PMOS transistors. This portion of the circuit is precision adjusted with post package trim allowing the offset to be in the microvolts range. As the input common mode voltage approaches approximately one volt less than the positive supply, the inputs are transitioned to a second differential pair of NMOS transistors. This portion of the op amp has an offset voltage similar to a conventional op amp. As noted in the heading of the Electrical Characteristics Section, the precision offset voltage is optimized at a common mode of one half of the supply voltage. This conceptual chart depicts the approximate best case of extending the precision common mode area by using the device at 5.5V supply.



Offset Voltage over Common Mode Voltage Range

Ordering Information (Note 10)

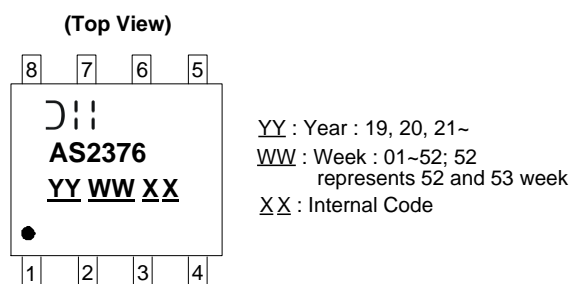


Part Number	Package Code	Packaging	Tape and Reel	
			Quantity	Part Number Suffix
AS2376S-13	S	SO-8 (Standard)	2500	-13

Note: 10. For packaging details, go to our website at <https://www.diodes.com/design/support/packaging/diodes-packaging/>.

Marking Information

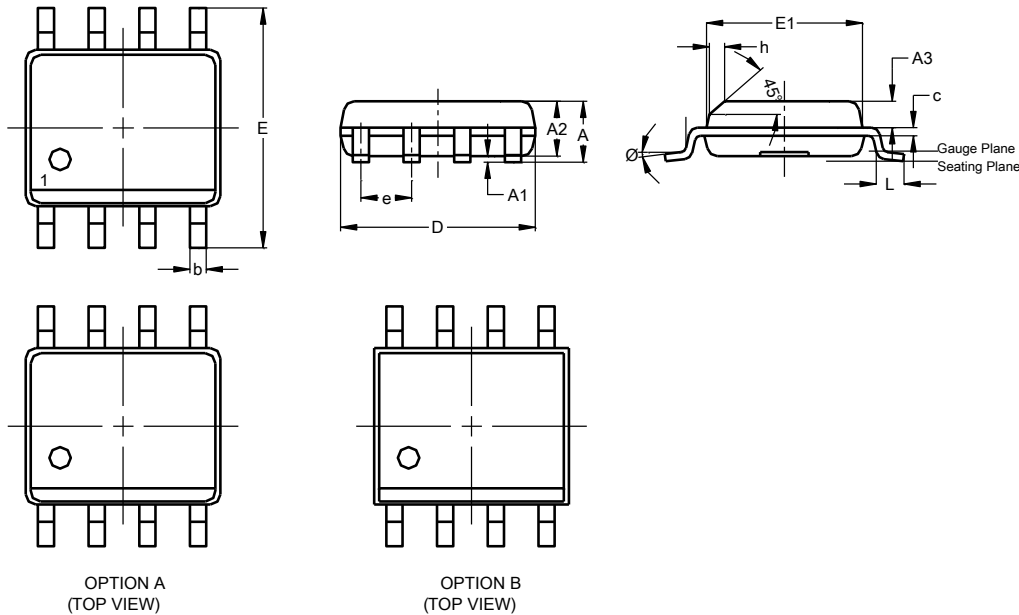
(1) SO-8 (Standard)



Part Number	Package	Identification Code
AS2376S-13	SO-8 (Standard)	AS2376

Package Outline Dimensions (All dimensions in mm.)

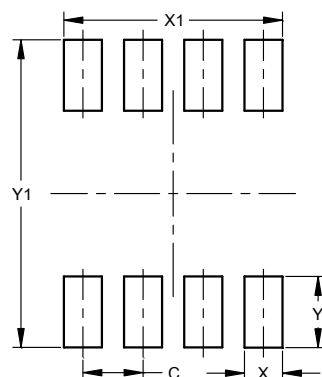
SO-8 (Standard)



SO-8 (Standard)			
Dim	Min	Max	Typ
A	--	1.75	--
A1	0.10	0.25	--
A2	1.25	1.65	--
A3	0.50	0.70	--
b	0.30	0.51	--
c	0.15	0.25	--
D	4.80	5.00	--
E	5.80	6.20	6.00
E1	3.80	4.00	--
e	--	--	1.27
h	0.25	0.50	--
L	0.45	0.82	--
Ø	0°	8°	--
All Dimensions in mm			

Suggested Pad Layout

SO-8 (Standard)



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

Mechanical Data

- Case Material: Molded Plastic, UL Flammability Rating 94V-0
- Terminals: Finish - Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208(e3)
- Weight: 0.074 grams (Approximate)
- Max Soldering Temperature +260°C for 30 secs as per JEDEC J-STD-020

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