LOW-NOISE, LOW QUIESCENT CURRENT, PRECISION OPERATIONAL AMPLIFIER

Description

The AS2376Q is a low noise (9.5nV/$\sqrt{\text{Hz}}$), low offset (25µV, maximum), operational amplifier that is precision optimized by using post-package trim. With a 5.5MHz bandwidth, the device is suitable for a wide array of filtering and control applications. The low voltage operation, low quiescent current of 950µA (maximum), and excellent PSRR makes the AS2376Q suitable for direct battery-powered applications and noise-sensitive applications with noisy low-voltage rails.

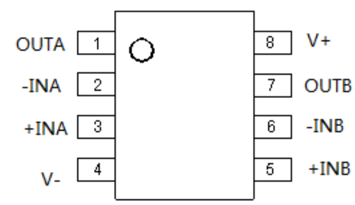
The dual AS2376Q is offered in the SO-8 and MSOP-8 package, specified for operation from -40°C to +125°C. The device is qualified to AEC-Q100 Grade 1 with automotive-grade supporting PPAPs.

Features

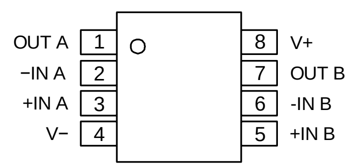
- Low Noise: 9.5nV/$\sqrt{\text{Hz}}$ at 1kHz
- 0.1Hz to 10Hz Noise: 0.8µV_{PP}
- Quiescent Current: 760µA (typical)
- Low Offset Voltage: 5µV (typ)
- Gain Bandwidth Product: 5.5MHz
- Rail-to-Rail Input and Output
- Single-Supply Operation
- Supply Voltage: 2.2V to 5.5V
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **The AS2376Q is suitable for automotive applications requiring specific change control; this part is AEC-Q100 qualified, PPAP capable, and manufactured in IATF 16949 certified facilities.**
  https://www.diodes.com/quality/product-definitions/

Pin Assignments

TOP VIEW



SO-8



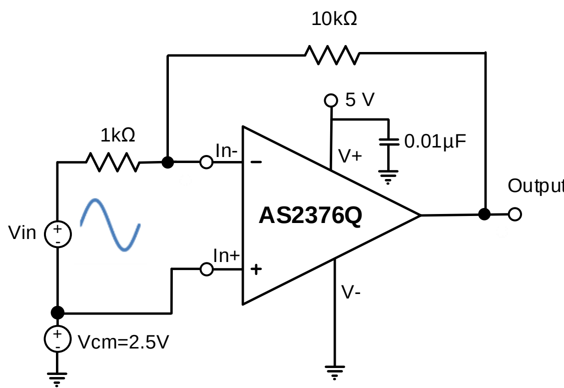
MSOP-8

Applications

- Auto pumps
- Position sensors
- Vehicle occupant detection sensors
- Airbags
- Onboard charges (OBC)
- DC-DC converters
- Battery management systems (BMS)

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 Applications Circuit

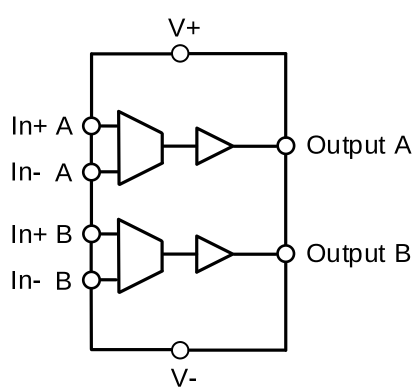


Basic Single Power Amplifier Connection

Pin Description

PIN		I/O	DESCRIPTION
NAME	SO-8/MSOP-8		
+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



AS2376Q 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	115	°C/W
		MSOP-8	210	
$R_{θJC}$	Junction-to-Case Thermal Resistance	SO-8	18	°C/W
		MSOP-8	40	
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°C, **bold** typeface applies over -40°C to +125°C (Note 9), R_L = 10kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2, unless otherwise noted.)

SYMBOL	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°C to +85°C	-	0.26	1.2	μV/°C
		T_A = -40°C to +125°C	-	0.32	2	μV/°C
PSRR	Input offset voltage versus power supply	T_A = 25°C, V_S = 2.2V to 5.5 V, V_{CM} < (V^+) – 1.3 V	-	5	20	μV/V
		T_A = -40°C to +125°C V_S = 2.2 V to 5.5 V, V_{CM} < (V^+) – 1.3 V	-	5	-	μV/V
-	Channel separation, dc		-	0.5	-	mV/V
INPUT BIAS CURRENT						
I_B	Input bias current	T_A = 25°C	-	0.2	70	pA
		T_A = –40°C to +125°C	See *Typical Characteristics*			pA
IOS	Input offset current		-	0.2	70	pA
NOISE						-
-	Input voltage noise	f = 0.1 Hz to 10 Hz	-	0.8	-	μVPP
e_n	Input voltage noise density	f = 1 kHz	-	9.5	-	nV/√Hz
I_n	Input current noise	f = 1 kHz	-	2	-	fA/√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 V	76	90		dB
INPUT CAPACITANCE						
-	Differential	-	-	6.5	-	pF
-	Common-mode	-	-	13	-	pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	50 mV < V_O < (V^+) – 50 mV, R_L = 10 kΩ	120	134	-	dB
		100 mV < V_O < (V^+) – 100 mV, R_L = 2 kΩ	120	126	-	dB
FREQUENCY RESPONSE C_L = 100 pF, V_S = 5.5 V						
GBW	Gain-bandwidth product	-	-	5.5	-	MHz
SR	Slew rate	G = 1	-	2	-	V/μs
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} × gain > V_S	-	0.33	-	μs
-	Overload recovery time	V_{IN} × gain > V_S	-	0.33	-	μs

Notes:
9. Limits over the full temperature are guaranteed by design, but not tested in production.
10. After mounted to PCB, Vos value will be different to spec, the delta value depend on PCB solder stress, the max value is between +/- 80uV, per our experiment.
11. AS2376Q, the long-term stability is defined as MAX. VOS shift during life HTOL 1000 hours with TA=+125°C.(Tj=150°C) This Vos 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.
12. After HTSL 2000 hours with TA=+150°C, the Vos drift test condition is TA=+125°C

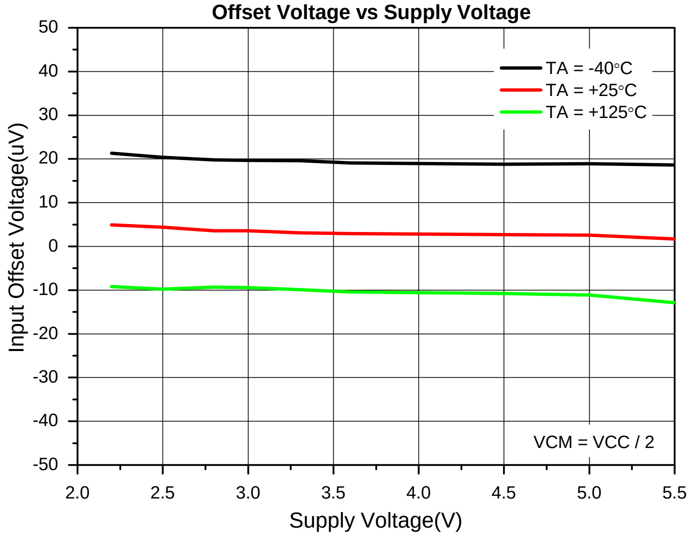
Electrical Characteristics (Limits in standard typeface are for T_A = +25°C, **bold** typeface applies over -40°C to +125°C (Note 9), R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2, unless otherwise noted.)

	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
OUTPUT						
-	Voltage output swing from rail	T_A = 25°C, R_L = 10 kΩ	-	10	20	mV
		T_A = –40°C to +125°C, R_L = 10 kΩ	-	-	40	mV
		T_A = 25°C, R_L = 2 kΩ	-	40	50	mV
		T_A = –40°C to +125°C, R_L = 2 kΩ	-	-	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, VCM< (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

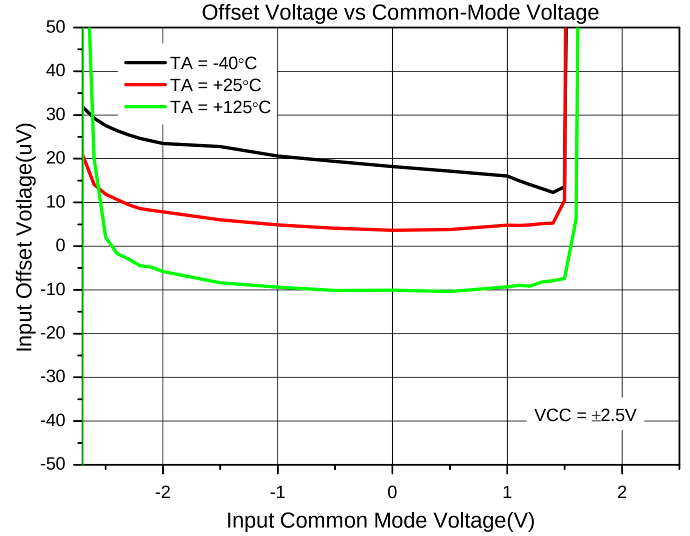
Note: 9. Limits over the full temperature are guaranteed by design, but not tested in production.

Performance Characteristics

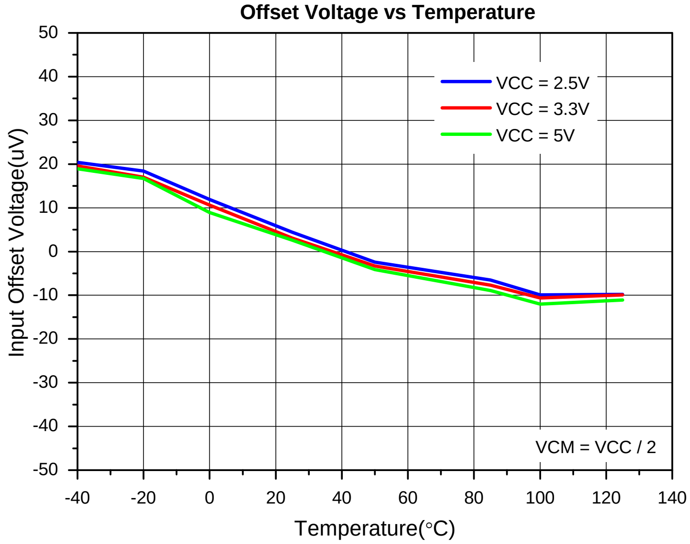
Offset Voltage vs Supply Voltage



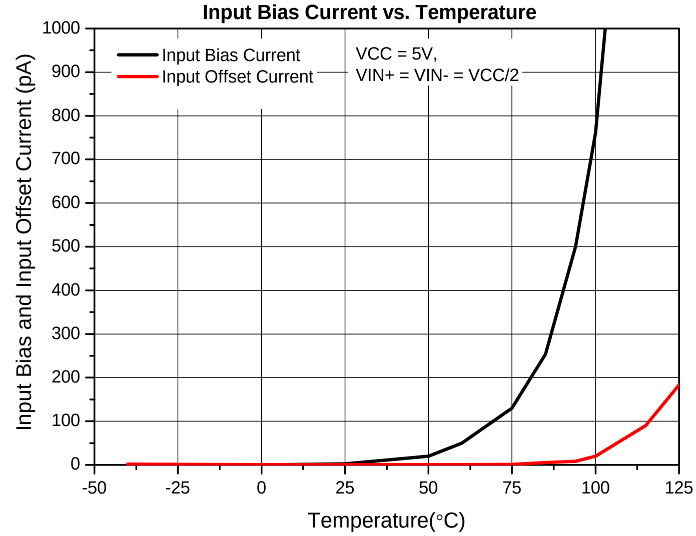
Offset Voltage vs Common-Mode Voltage



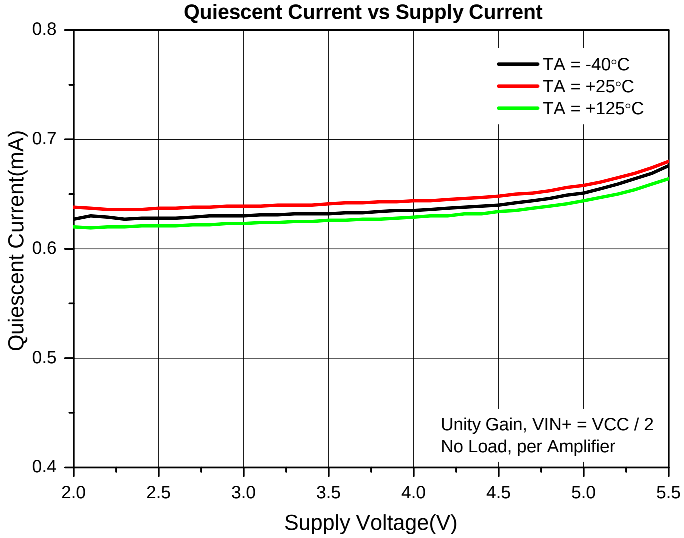
Offset Voltage vs Temperature



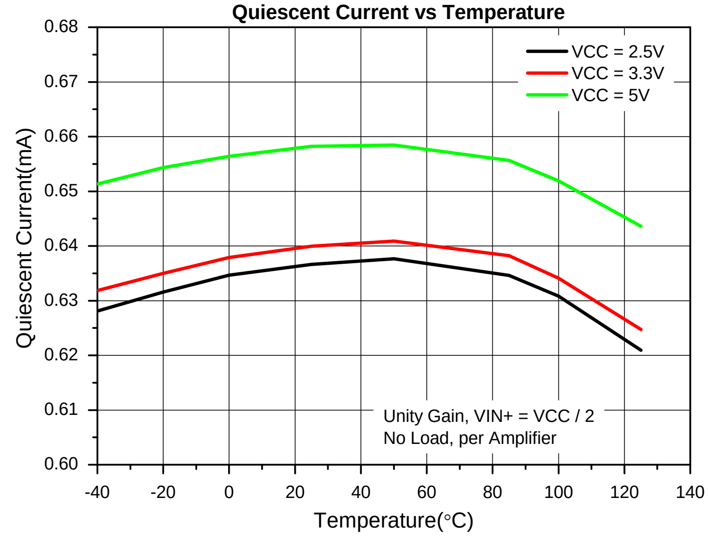
Input Bias Current vs. Temperature



Quiescent Current vs Supply Current

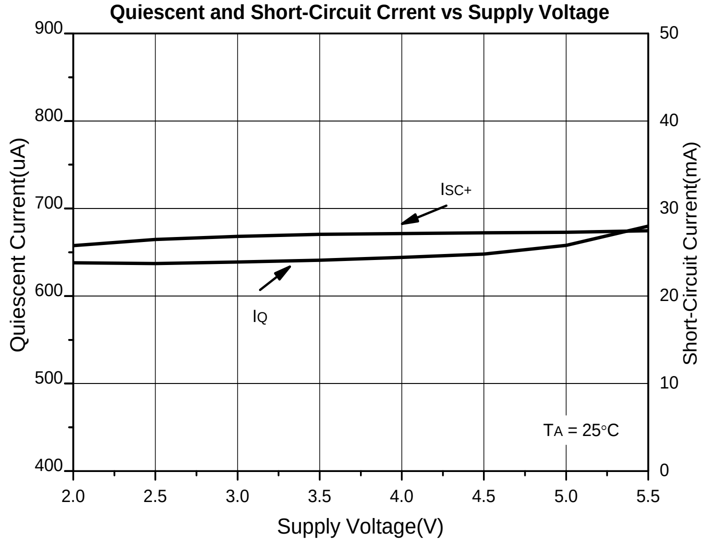


Quiescent Current vs Temperature

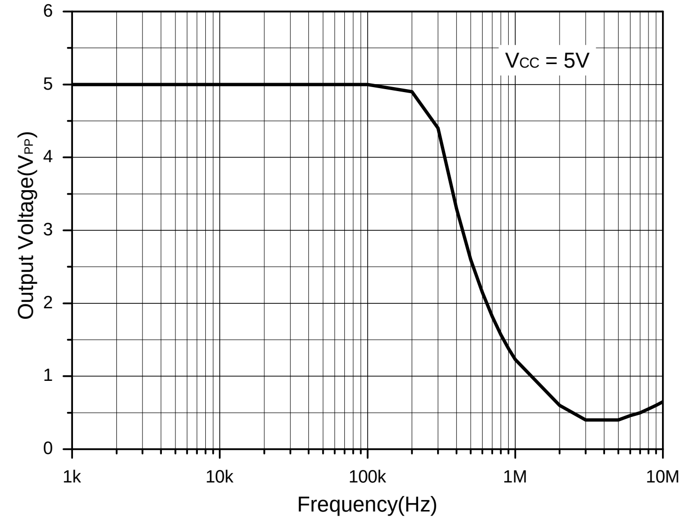


Performance Characteristics (continued)

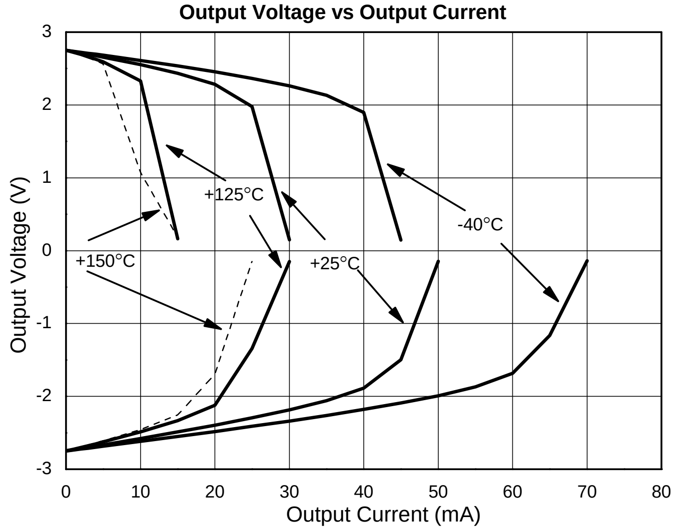
Quiescent and Short-Circuit Crrent vs Supply Voltage



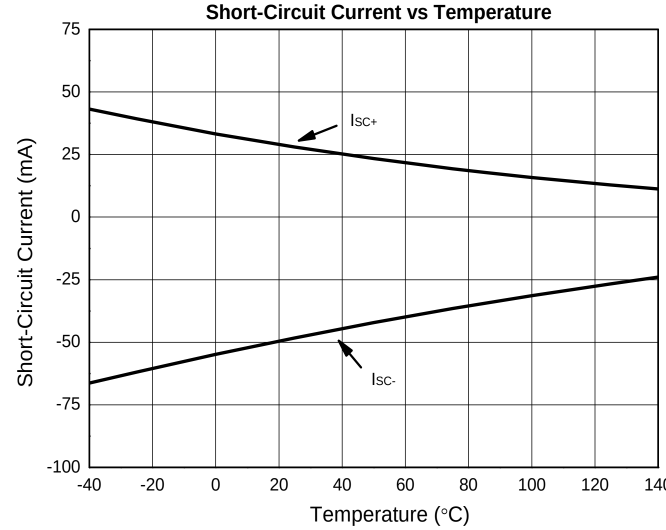
Maximum Output Voltage vs Freuency



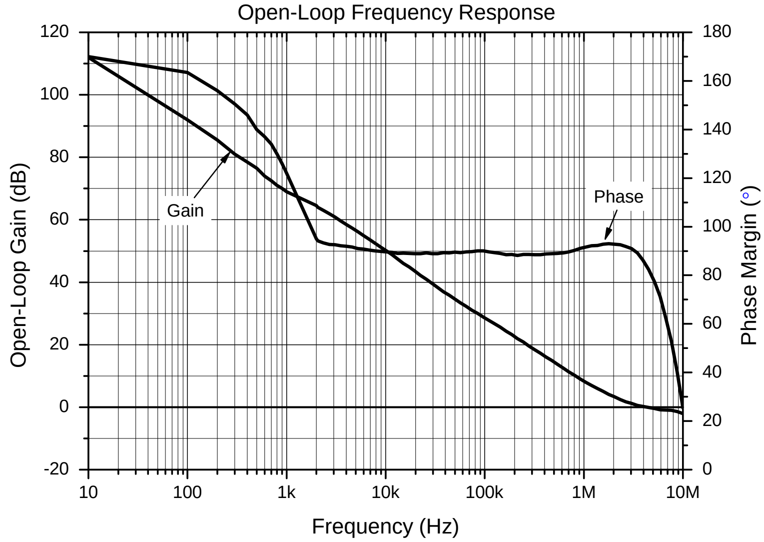
Output Voltage vs Output Current



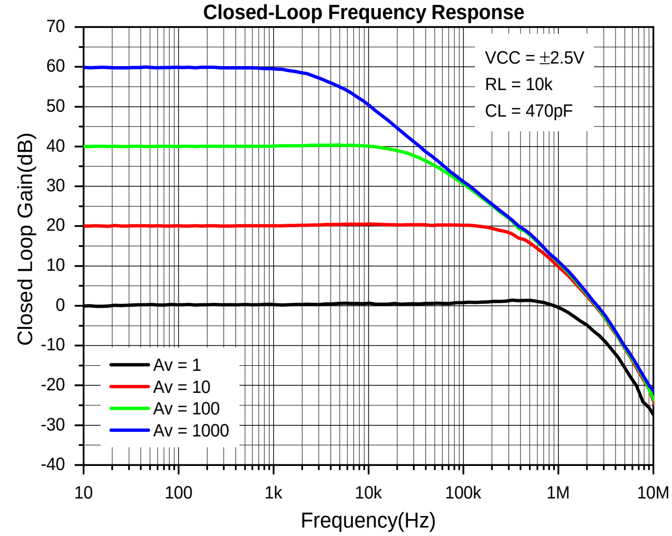
Short-Circuit Current vs Temperature



Open-Loop Frequency Response

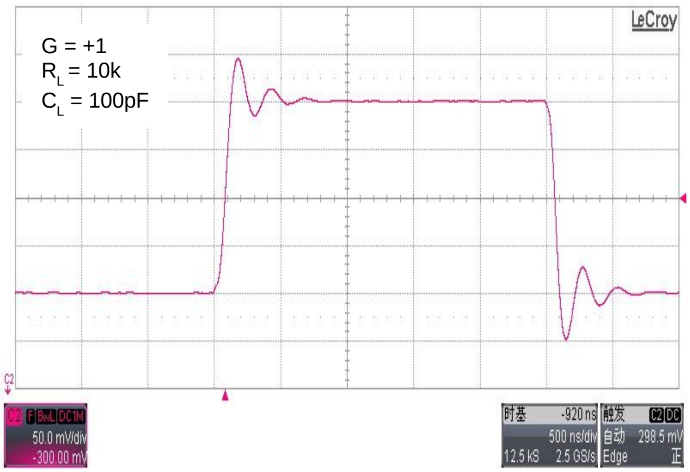


Closed-Loop Frequency Response

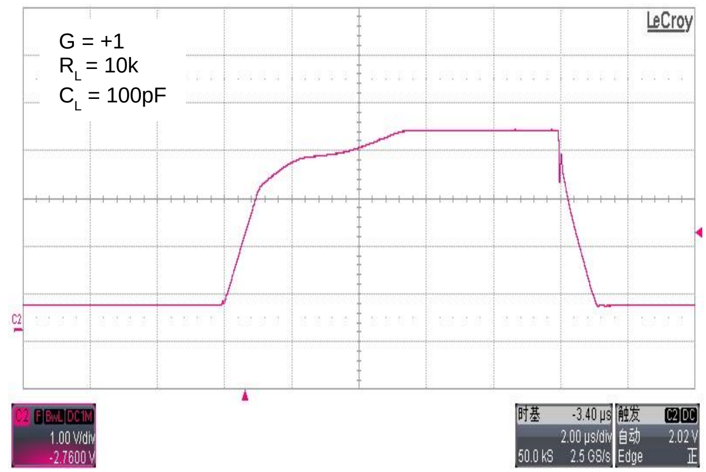


Performance Characteristics (continued)

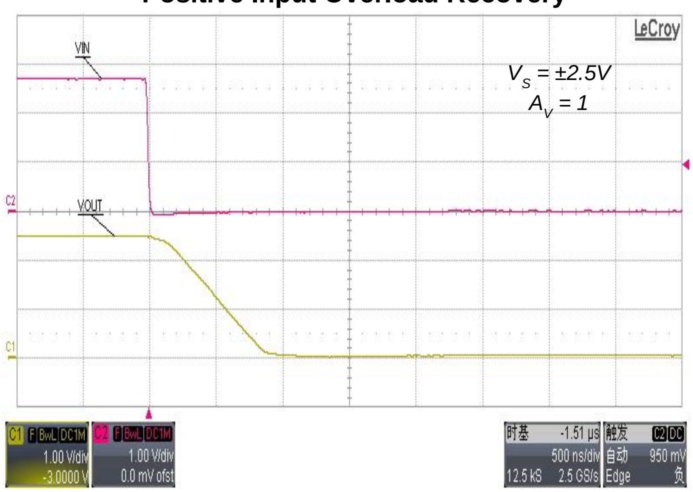
Small-Signal Pulse Response



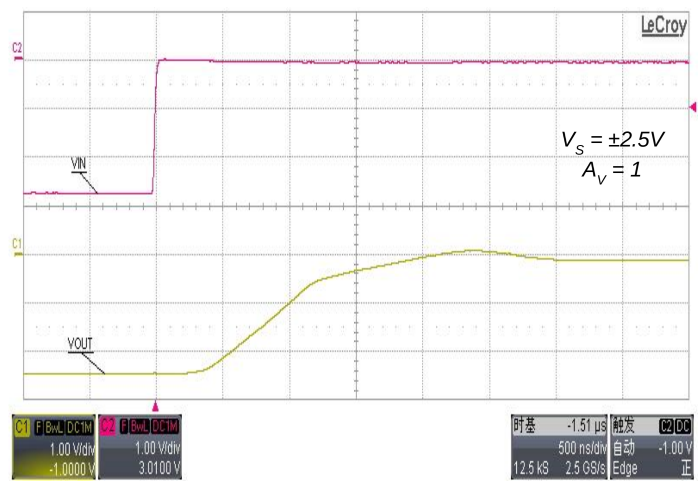
Large-Signal Pulse Response



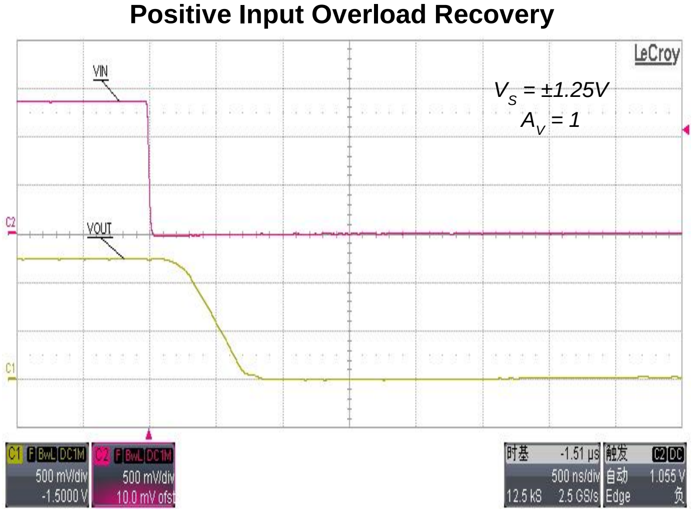
Positive Input Overload Recovery



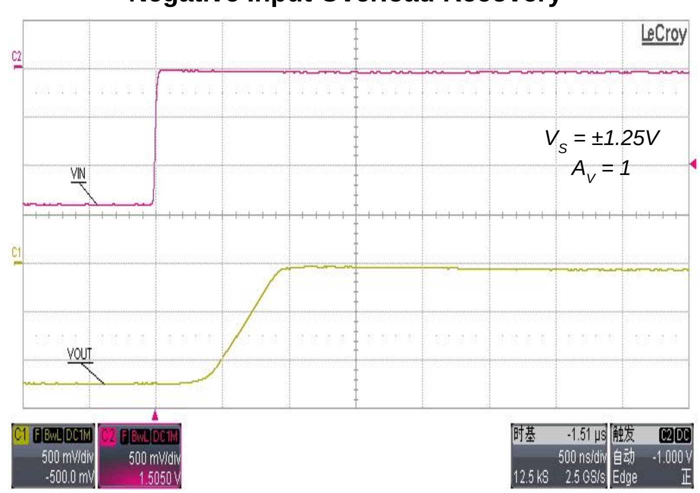
Negative Input Overload Recovery



Positive Input Overload Recovery

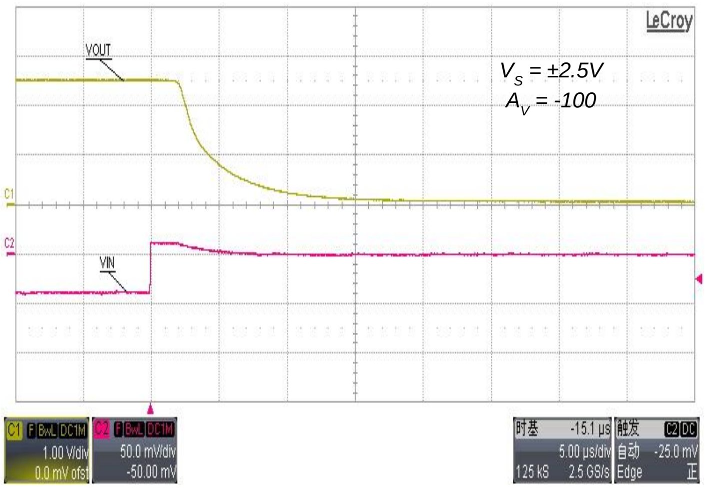


Negative Input Overload Recovery

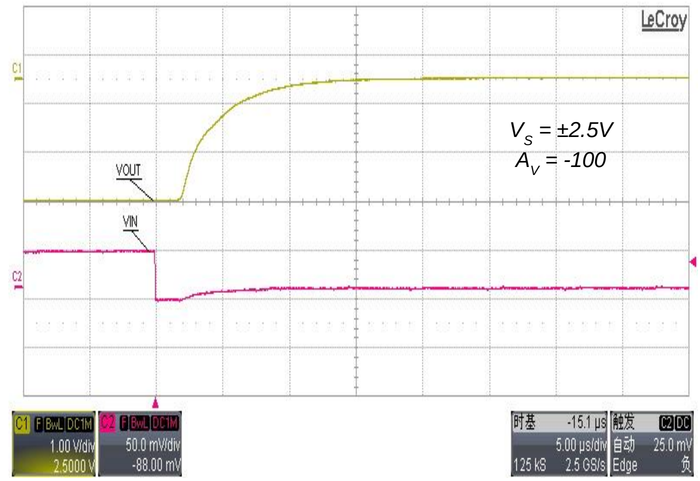


Performance Characteristics (continued)

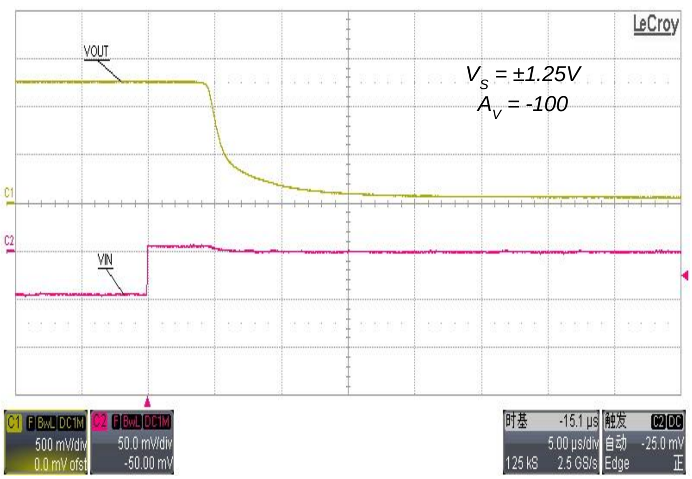
Positive Output Overload Recovery



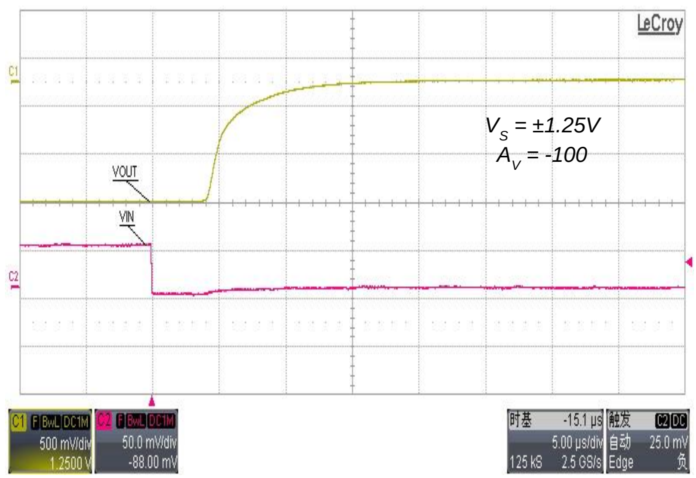
Negative Output Overload Recovery



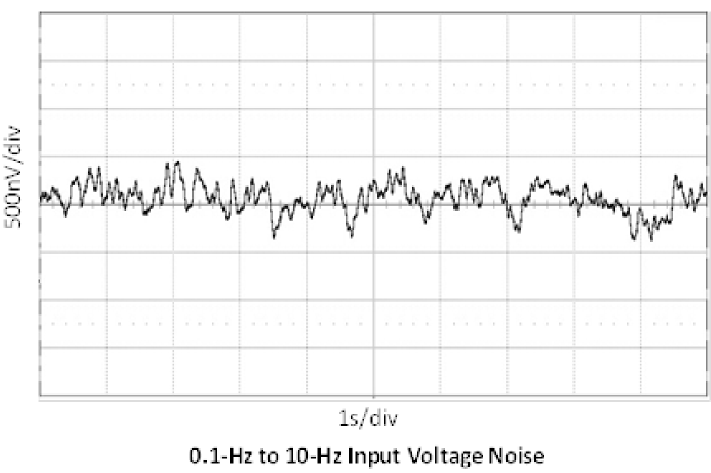
Positive Output Overload Recovery



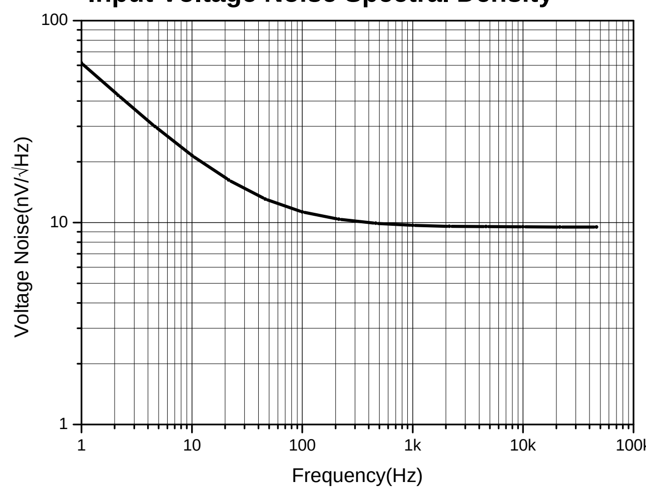
Negative Output Overload Recovery



0.1-Hz to 10-Hz Input Voltage Noise



Input Voltage Noise Spectral Density



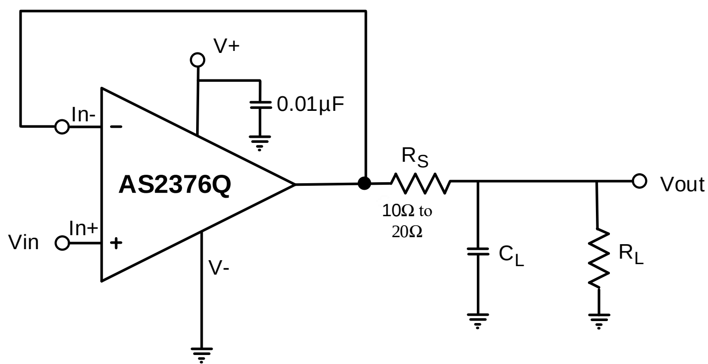
Application Information

Overview

The AS2376Q combines low offset (25µV, maximum) and 5.5MHz 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 AS2376Q is addressed by using post package trim allowing for the retention of significant bandwidth.

Stability Considerations when Driving Capacitive Loads

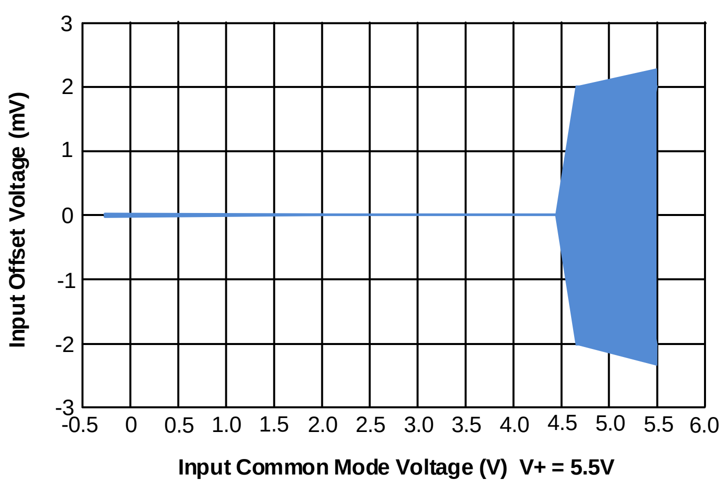
Operational amplifiers are prone to oscillation when required to drive large capacitive loads. The AS2376Q is capable of driving a 250 picofarad load at unity gain. Larger loads will require the insertion of a nulling resistor (denoted as R_S) in series with the load capacitor. The suggested nulling resistor value is 10Ω to 20Ω. This addition will introduce a small error but is negligible in most applications.



Circuit for Driving Large Capacitive Loads

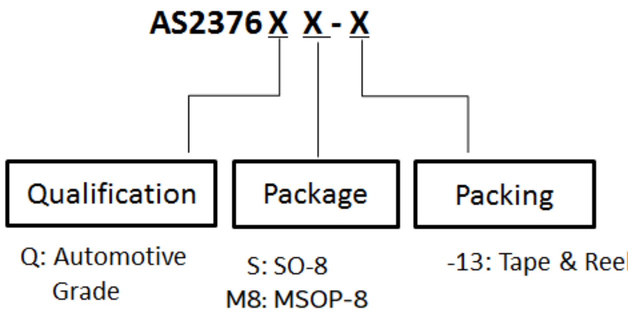
Offset Voltage as Input Common Mode Approaches V+

The AS236Q 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 has been 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

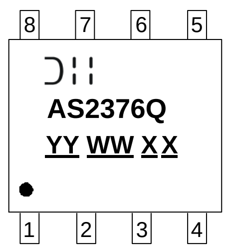
Ordering Information



Orderable Part Number	Package Code	Package	Packing		
			Quantity	Part Number Suffix	Carrier
AS2376QS-13	S	SO-8	2,500	-13	Tape and Reel
AS2376QM8-13	M8	MSOP-8	2,500	-13	Tape and Reel

Marking Information

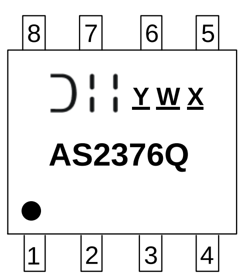
(Top View)



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

Orderable Part Number	Package	Identification Code
AS2376QS-13	SO-8	AS2376Q

(Top View)



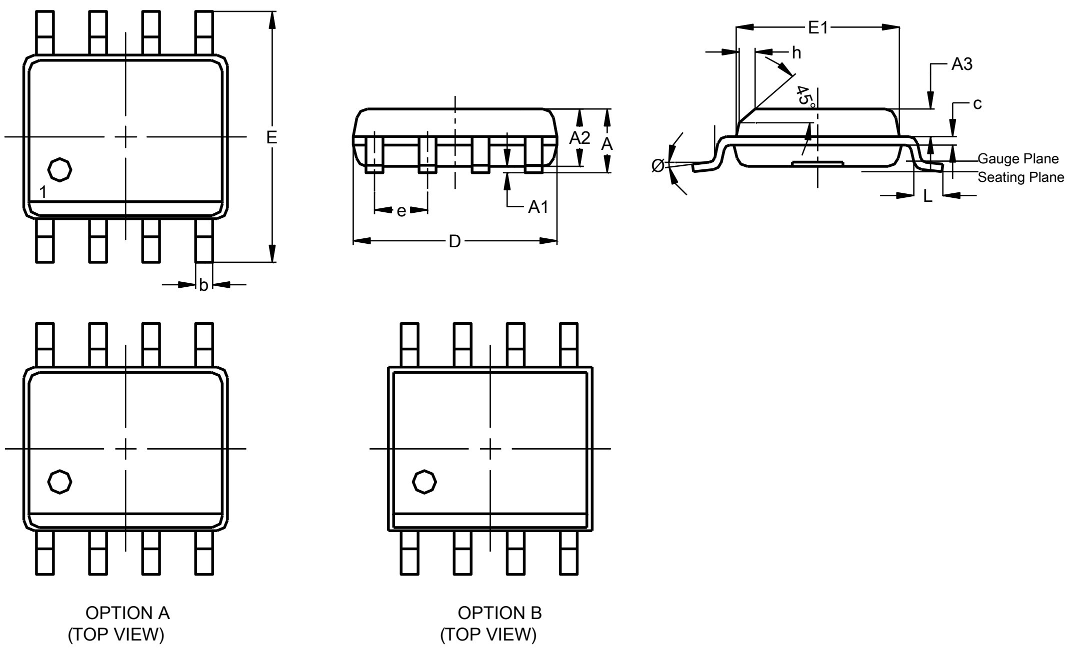
Y : Year : 0 to 9
W : Week : A to Z : 1 to 26 week; a to z : 27 to 52 week; z represents 52 and 53 week
X : Internal Code

Orderable Part Number	Package	Identification Code
AS2376QM8-13	MSOP-8	AS2376Q

Package Outline Dimensions

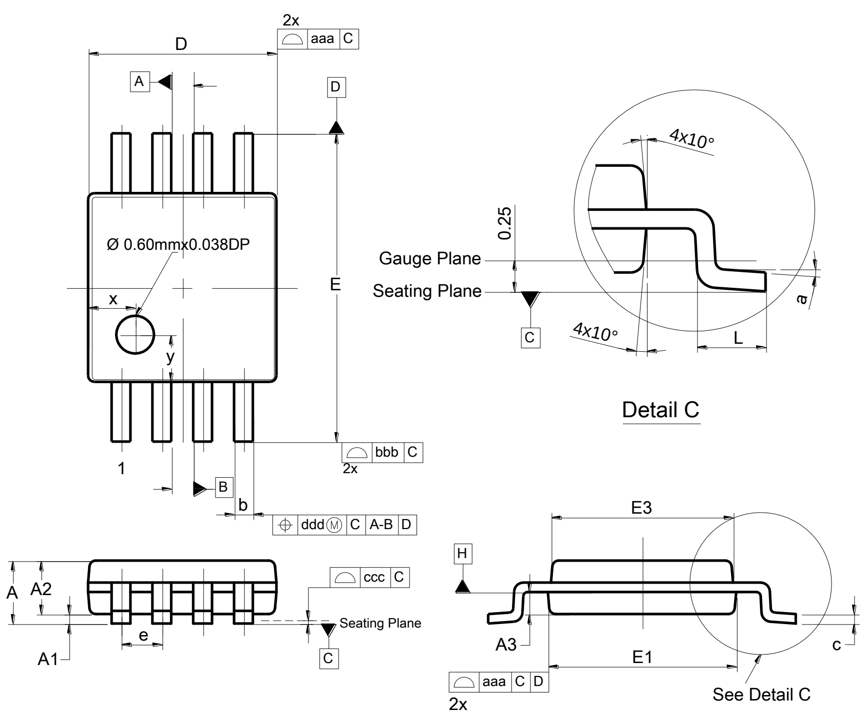
Please see http://www.diodes.com/package-outlines.html for the latest version.

SO-8



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			

MSOP-8

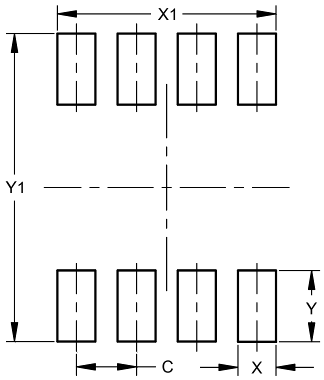


MSOP-8			
Dim	**Min**	**Max**	**Typ**
A	--	1.10	--
A1	0.05	0.15	0.10
A2	0.75	0.95	0.86
A3	0.29	0.49	0.39
b	0.22	0.38	0.30
c	0.08	0.23	0.15
D	2.90	3.10	3.00
E	4.70	5.10	4.90
E1	2.90	3.10	3.00
E3	2.85	3.05	2.95
e	--	--	0.65
L	0.40	0.80	0.60
a	0°	8°	4°
x	--	--	0.750
y	--	--	0.750
aaa	0.20		
bbb	0.25		
ccc	0.10		
ddd	0.13		
All Dimensions in mm			

Suggested Pad Layout

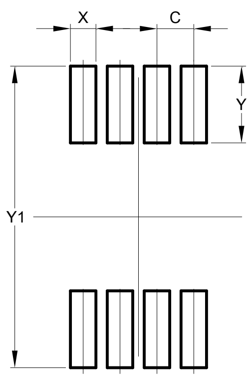
Please see http://www.diodes.com/package-outlines.html for the latest version.

SO-8



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

MSOP-8



Dimensions	Value (in mm)
C	0.650
X	0.450
Y	1.350
Y1	5.300

Mechanical Data

SO-8

- Package 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

MSOP-8

- Package Material: Molded Plastic, UL Flammability Rating 94V-0
- Terminals: Finish - Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 e3
- Weight: 0.035 grams (Approximate)
- Max Soldering Temperature +260°C for 30 secs as per JEDEC J-STD-020

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