1.8-V, 7-MHz, 90-dB CMRR, SINGLE-SUPPLY, RAIL-TO-RAIL I/O OPERATIONAL AMPLIFIER

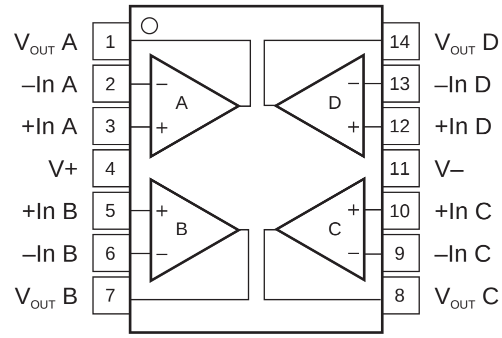
FEATURES

- **Qualified for Automotive Applications**
- **1.8-V Operation**
- **Bandwidth: 7 MHz**
- **CMRR: 90 dB (Typ)**
- **Slew Rate: 5 V/μs**
- **Low Offset: 500 μV (Max)**
- **Quiescent Current: 750 μA/Channel (Max)**
- **Shutdown Mode: <1 μA/Channel**

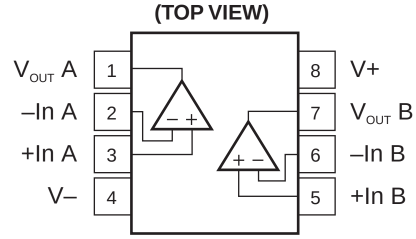
APPLICATIONS

- **Signal Conditioning**
- **Data Acquisition**
- **Process Control**
- **Active Filters**
- **Test Equipment**

OPA4364...D PACKAGE (TOP VIEW)



OPA2364...D PACKAGE (TOP VIEW)



DESCRIPTION

The OPA2364 and OPA4364 are high-performance CMOS operational amplifiers optimized for low-voltage single-supply operation. These miniature low-cost amplifiers are designed to operate on single supplies from 1.8 V (±0.9 V) to 5.5 V (±2.75 V). Applications include sensor amplification and signal conditioning in battery-powered systems.

The OPAx364 family offers excellent CMRR without the crossover associated with traditional complimentary input stages. This results in excellent performance for driving analog-to-digital (A/D) converters without degradation of differential linearity and total harmonic distortion (THD). The input common-mode range includes both the negative and positive supplies. The output voltage swing is within 10 mV of the rails.

The dual version is available in an SO-8 package and the quad package is available in an SO-14 package. All versions are specified for operation from –40°C to 125°C.

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

ORDERING INFORMATION

PRODUCT	PACKAGE LEAD	PACKAGE DESIGNATOR	T_A	PACKAGE MARKING	ORDERING NUMBER	TRANSPORT MEDIA, QUANTITY
OPA2364AQDRQ1	SO-8	D	–40°C to 125°C	OP2364	OPA2364AQDRQ1	Tape and reel, 2500
OPA4364AQDRQ1	SO-14	D	–40°C to 125°C	OPA4364AQ	OPA4364AQDRQ1	Tape and reel, 2500

ABSOLUTE MAXIMUM RATINGS(1)

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

			MIN	MAX	UNIT
	Supply voltage			5.5	V
	Signal input terminals	Voltage range(2)	–0.5	(V+) + 0.5	V
		Current(2)		±10	mA
	Enable input range		(V–) –0.5	5.5	V
	Output short circuit(3)			Continuous	
	Operating temperature range		–40	150	°C
T_{stg}	Storage temperature range		–65	150	°C
T_J	Junction temperature			150	°C
	Lead temperature (soldering, 10 s)			300	°C

(1) Stresses above these ratings may cause permanent damage. Exposure to absolute maximum conditions for extended periods may degrade device reliability. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those specified is not implied.
(2) Input terminals are diode clamped to the power-supply rails. Input signals that can swing more than 0.5 V beyond the supply rails should be current limited to 10 mA or less.
(3) Short circuit to ground one amplifier per package

ELECTRICAL CHARACTERISTICS: V_S = 1.8 V to 5.5 V

Boldface limits apply over the specified temperature range, **T_A = –40°C to 125°C**, T_A = 25°C, R_L = 10 kΩ connected to V_S/2, and V_{OUT} = V_S/2, V_{CM} = V_S/2 (unless otherwise noted)

PARAMETER			TEST CONDITIONS		MIN	TYP	MAX	UNIT
Offset Voltage								
V_{OS}	Input offset voltage		V_S = 5 V			1	3	mV
dV_{OS}/dT	**Drift**					**3**		**μV/°C**
PSRR	**Power-supply rejection ratio**		**V_S = 1.8 V to 5.5 V, V_{CM} = 0**			**80**	**330**	**μV/V**
	Channel separation, dc					1		μV/V
Input Bias Current								
I_B	Input bias current					±1	±10	pA
			Over temperature		See Typical Characteristics			
I_{OS}	Input offset current					±1	±10	pA
Noise								
e_n	Input voltage noise		f = 0.1 Hz to 10 Hz			10		μV_{P-P}
	Input voltage noise density		f = 10 kHz			17		nV/√Hz
i_n	Input current noise density		f = 10 kHz			0.6		fA/√Hz
Input Voltage Range								
V_{CM}	Common-mode voltage range				(V–) – 0.1		(V+) + 0.1	V
CMRR	**Common-mode rejection ratio**		**(V–) – 0.1 V < V_{CM} < (V+) + 0.1 V**		**74**	**90**		**dB**
Input Capacitance								
	Differential					2		pF
	Common mode					3		pF
Open-Loop Gain								
A_{OL}	Open-loop voltage gain		R_L = 10 kΩ, 100 mV < V_O < (V+) – 100 mV		94	100		dB
			OPA4364A		90			
			Over temperature, V_S = 1.8 V to 5.5 V		**86**			**dB**
Frequency Response								
GBW	Gain bandwidth product		C_L = 100 pF			7		MHz
SR	Slew rate		C_L = 100 pF, G = 1			5		V/μs
t_s	Settling time	0.1%	C_L = 100 pF, V_S = 5 V, 4-V step, G = 1			1		μs
		0.01%	C_L = 100 pF, V_S = 5 V, 4-V step, G = 1			1.5		μs
	Overload recovery time		C_L = 100 pF, V_{IN} × Gain > V_S			0.8		μs
THD+N	Total harmonic distortion + noise		C_L = 100 pF, V_S = 5 V, G = 1, f = 20 Hz to 20 kHz			0.002%		
Output								
	Voltage output swing	From rail	R_L = 10 kΩ			10	20	mV
		Over temperature	**R_L = 10 kΩ**	**V_{OL}**			**20**	**mV**
				V_{OH}			**40**	
I_{SC}	Short-circuit current				See Typical Characteristics			
C_{LOAD}	Capacitive load drive				See Typical Characteristics			
Power Supply								
V_S	Specified voltage				1.8		5.5	V
	Operating voltage				1.8 to 5.5			V
I_Q	**Quiescent current (per amplifier)**		**V_S = 1.8 V**			**650**	**750**	**μA**
			V_S = 3.6 V			**850**	**1000**	**μA**
			V_S = 5.5 V			**1.1**	**1.4**	**mA**

ELECTRICAL CHARACTERISTICS: V_S = 1.8 V to 5.5 V (continued)

Boldface limits apply over the specified temperature range, **T_A = –40°C to 125°C**, T_A = 25°C, R_L = 10 kΩ connected to V_S/2, and V_{OUT} = V_S/2, V_{CM} = V_S/2 (unless otherwise noted)

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
Temperature Range							
	Specified range			–40		125	°C
	Storage range			–65		150	°C
θ_{JA}	Thermal resistance	SO-8			150		°C/W
		SO-14			100		

TYPICAL CHARACTERISTICS

At T_{CASE} = 25°C, R_L = 10 kΩ, and connected to V_S/2, V_{OUT} = V_S/2, V_{CM} = V_S/2 (unless otherwise noted)

OPEN-LOOP GAIN/PHASE
vs
FREQUENCY

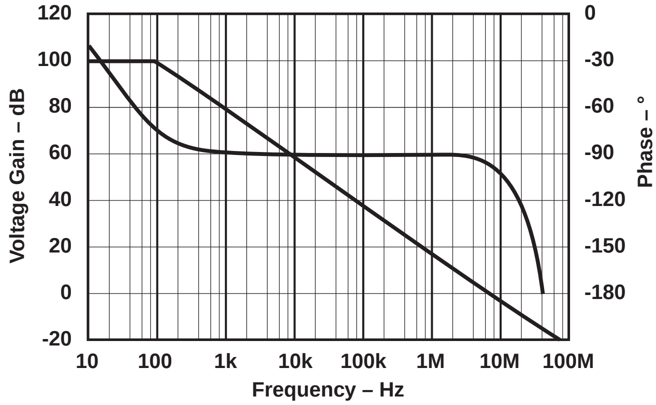


Figure 1.

COMMON-MODE REJECTION RATIO
vs
FREQUENCY

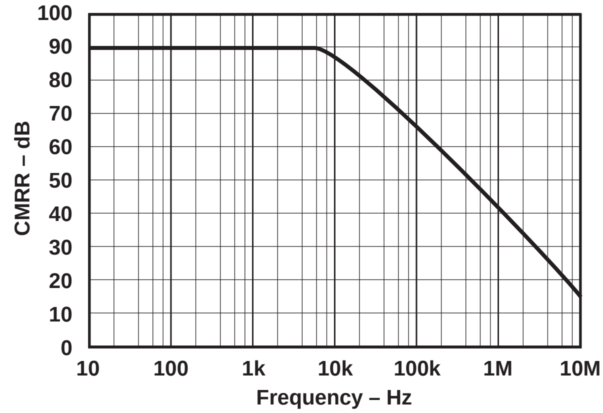


Figure 2.

POWER-SUPPLY REJECTION RATIO
vs
FREQUENCY

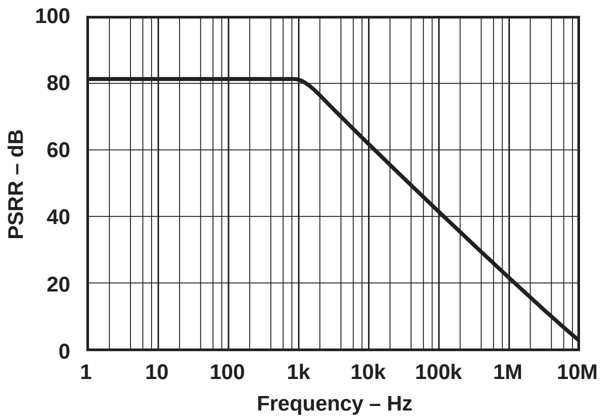


Figure 3.

QUIESCENT CURRENT
vs
SUPPLY VOLTAGE

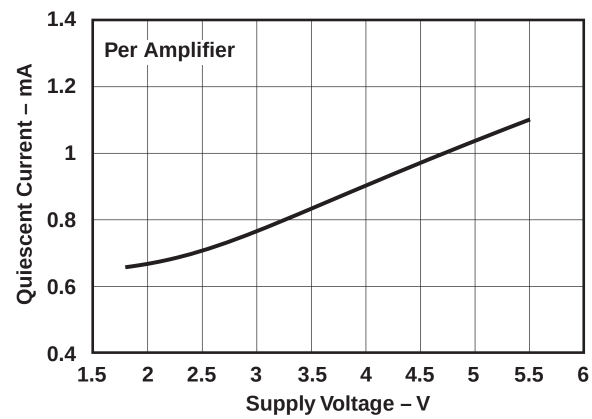


Figure 4.

TYPICAL CHARACTERISTICS (continued)

At T_{CASE} = 25°C, R_L = 10 kΩ, and connected to V_S/2, V_{OUT} = V_S/2, V_{CM} = V_S/2 (unless otherwise noted)

TOTAL HARMONIC DISTORTION + NOISE
vs
FREQUENCY

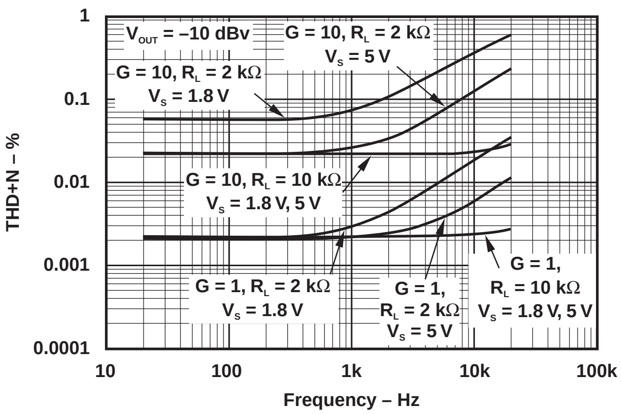


Figure 5.

TOTAL HARMONIC DISTORTION + NOISE
vs
FREQUENCY

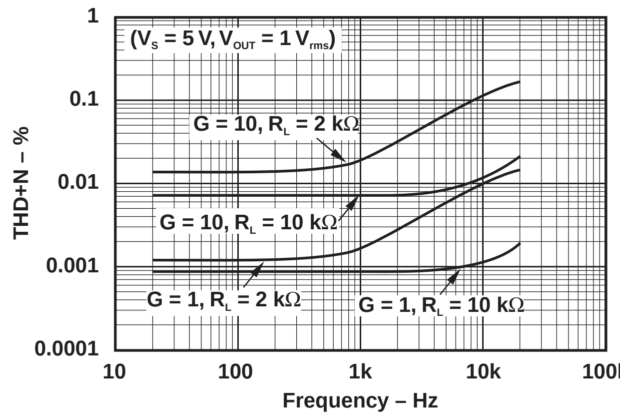


Figure 6.

INPUT VOLTAGE NOISE SPECTRAL DENSITY
vs
FREQUENCY

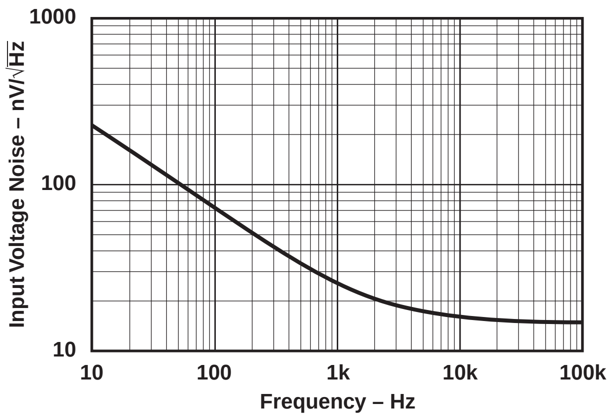


Figure 7.

SHORT-CIRCUIT CURRENT
vs
SUPPLY VOLTAGE

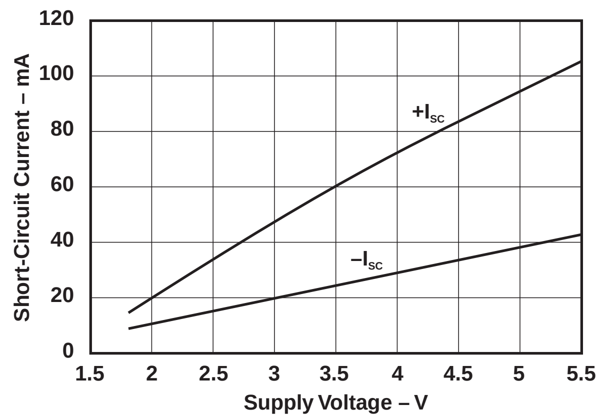


Figure 8.

TYPICAL CHARACTERISTICS (continued)

At T_{CASE} = 25°C, R_L = 10 kΩ, and connected to V_S/2, V_{OUT} = V_S/2, V_{CM} = V_S/2 (unless otherwise noted)

OUTPUT VOLTAGE SWING vs OUTPUT CURRENT

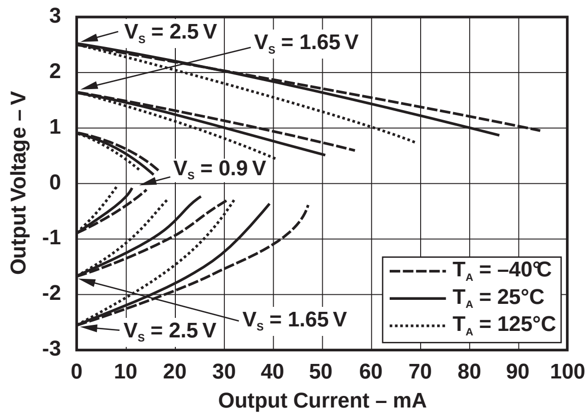


Figure 9.

INPUT BIAS CURRENT vs INPUT COMMON-MODE VOLTAGE

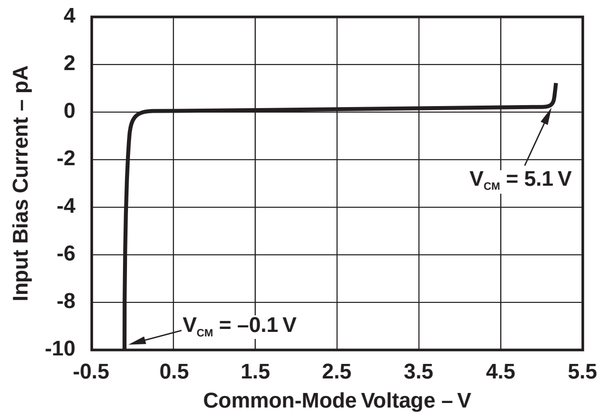


Figure 10.

INPUT OFFSET CURRENT vs TEMPERATURE

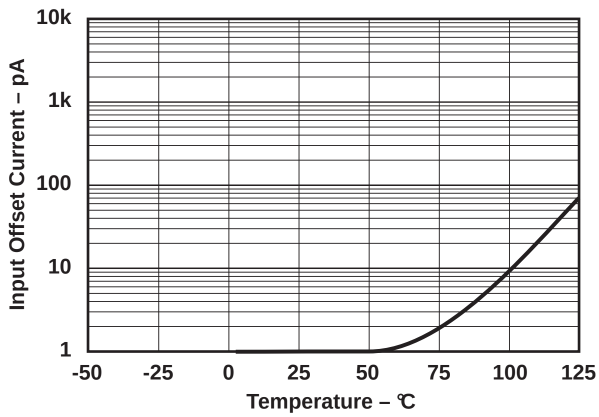


Figure 11.

INPUT BIAS CURRENT vs TEMPERATURE

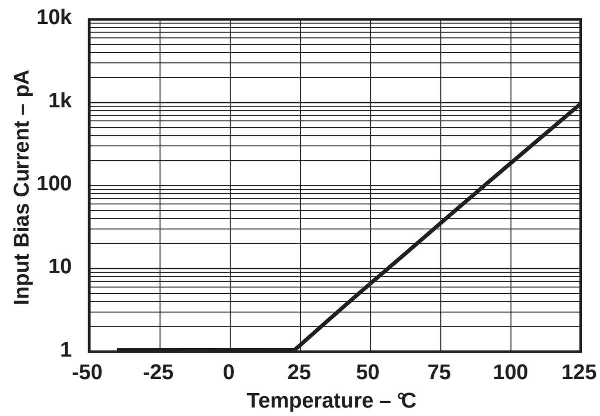


Figure 12.

TYPICAL CHARACTERISTICS (continued)

At T_{CASE} = 25°C, R_L = 10 kΩ, and connected to $V_S/2$, V_{OUT} = $V_S/2$, V_{CM} = $V_S/2$ (unless otherwise noted)

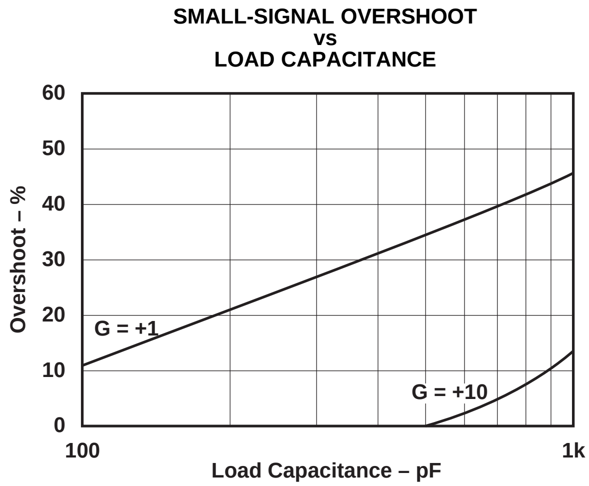


Figure 13.

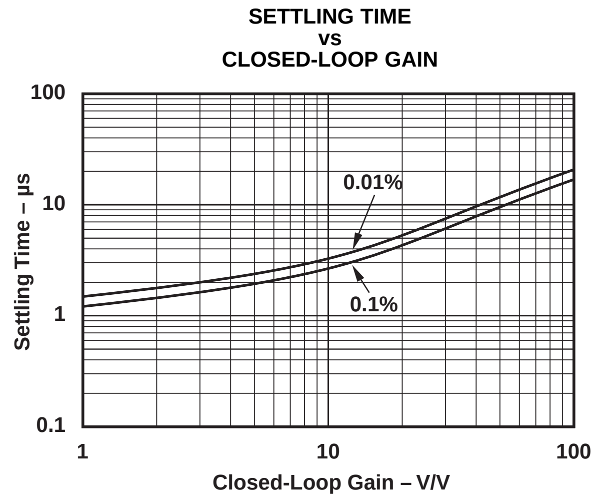


Figure 14.

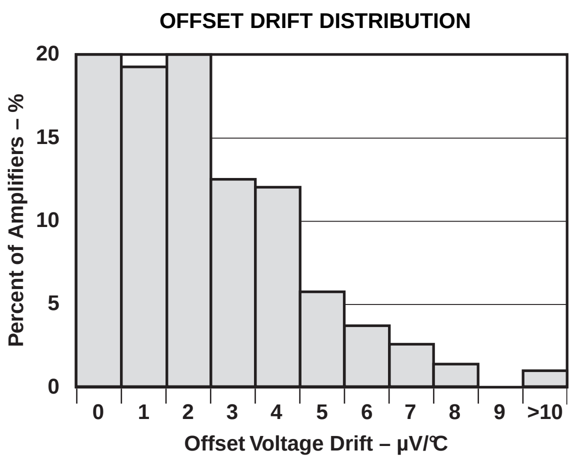


Figure 15.

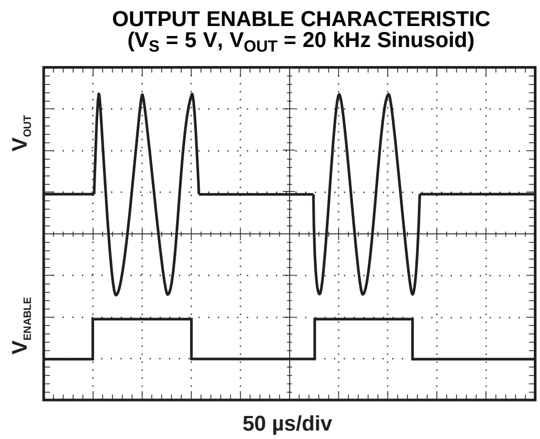


Figure 16.

TYPICAL CHARACTERISTICS (continued)

At T_{CASE} = 25°C, R_L = 10 kΩ, and connected to $V_S/2$, $V_{OUT} = V_S/2$, $V_{CM} = V_S/2$ (unless otherwise noted)

CHANNEL SEPARATION vs FREQUENCY

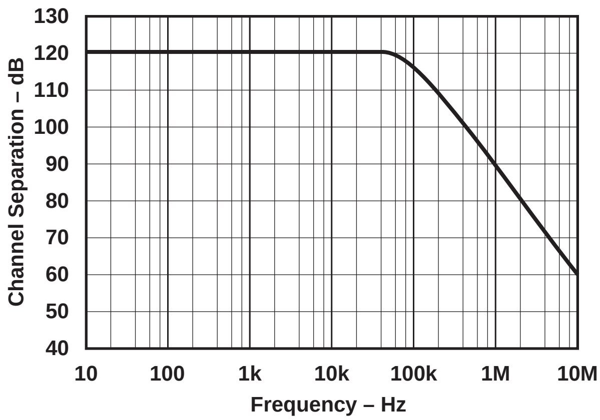


Figure 17.

SMALL-SIGNAL STEP RESPONSE (C_L = 100 pF)

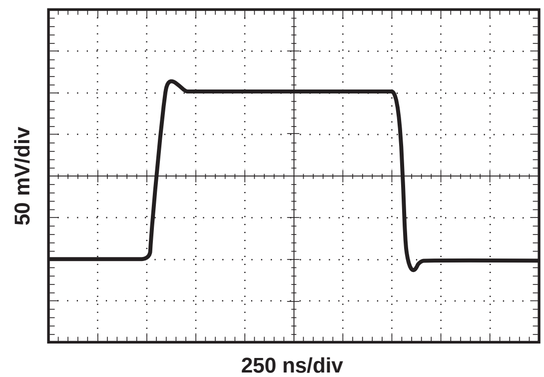


Figure 18.

LARGE-SIGNAL STEP RESPONSE (C_L = 100 pF)

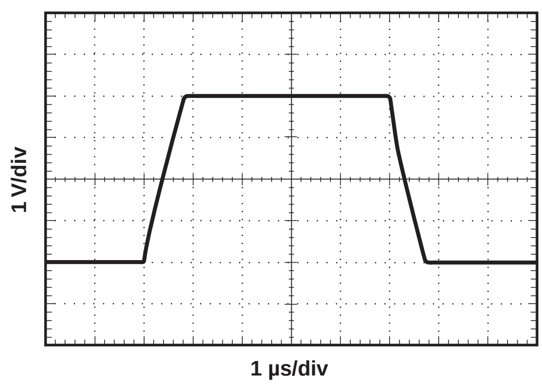


Figure 19.

APPLICATION INFORMATION

The OPAx364 series op amps are rail-to-rail operational amplifiers with excellent CMRR, low noise, low offset, and wide bandwidth on supply voltages as low as ±0.9 V. This family does not exhibit phase reversal and is unity-gain stable. Specified over the industrial temperature range of –40°C to 125°C, the OPAx364 family offers precision performance for a wide range of applications.

Rail-to-Rail Input

The OPAx364 features excellent rail-to-rail operation, with supply voltages as low as ±0.9 V. The input common-mode voltage range of the OPAx364 family extends 100 mV beyond supply rails. The unique input topology of the OPAx364 eliminates the input offset transition region typical of most rail-to-rail complimentary stage operational amplifiers, allowing the OPAx364 to provide superior common-mode performance over the entire common-mode input range (see Figure 20). This feature prevents degradation of the differential linearity error and THD when driving A/D converters. A simplified schematic of the OPAx364 is shown in Figure 21.

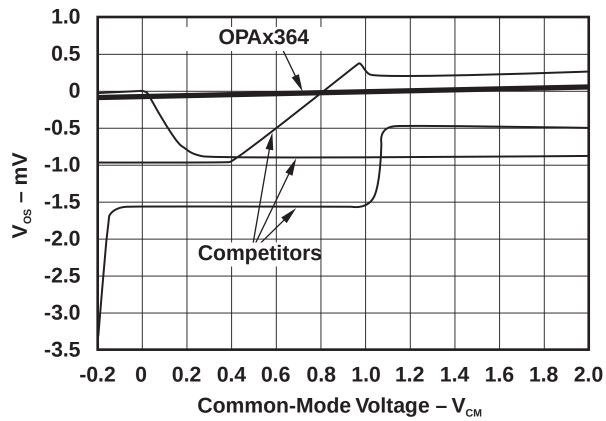


Figure 20. OPAx364 Linear Offset Over Entire Common-Mode Range

APPLICATION INFORMATION (continued)

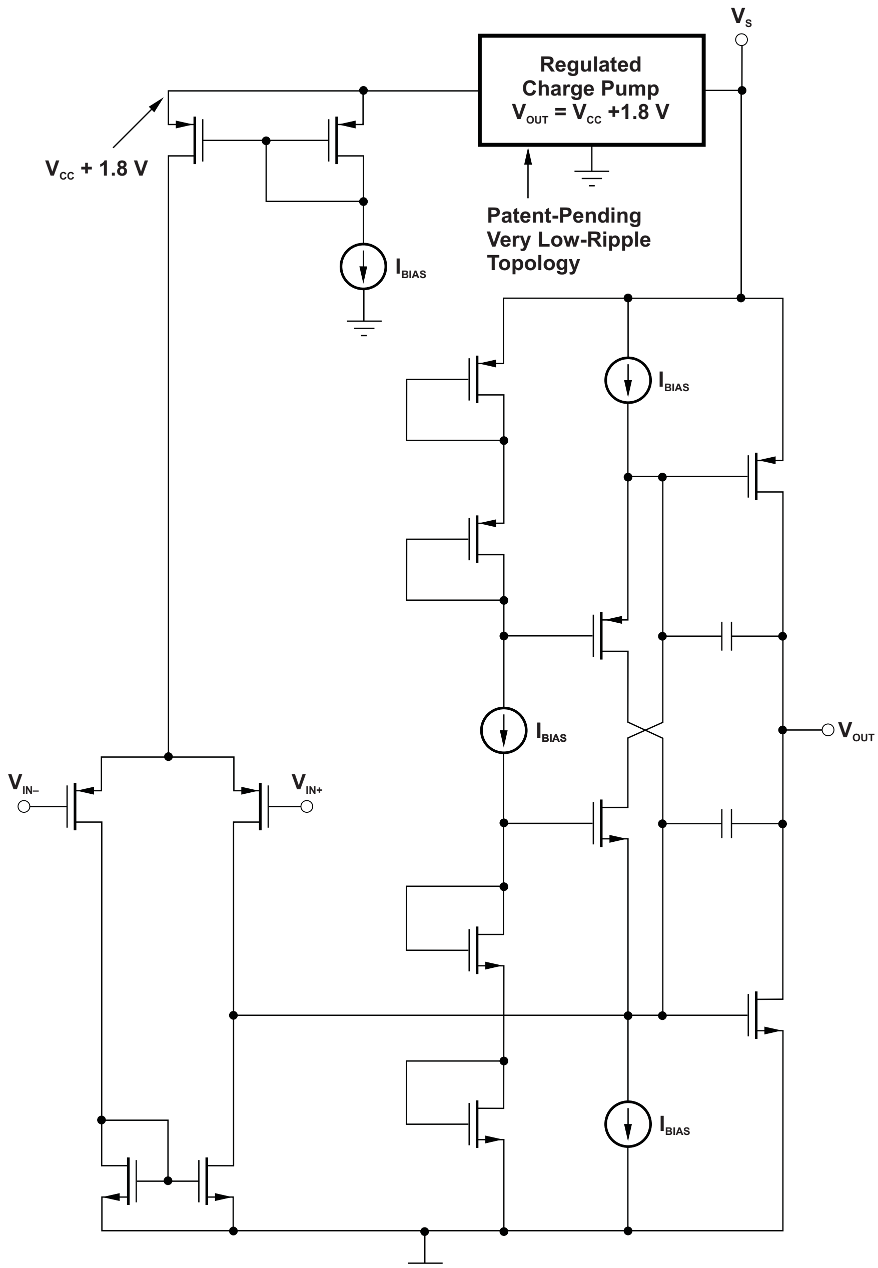


Figure 21. Simplified Schematic

Operating Voltage

The OPAx364 series of operational amplifier parameters are fully specified from 1.8 V to 5.5 V. Single 0.1-µF bypass capacitors should be placed across supply pins and as close to the part as possible. Supply voltages higher than 5.5 V (absolute maximum) may cause permanent damage to the amplifier. Many specifications apply from –40°C to 125°C. Parameters that vary significantly with operating voltages or temperature are shown in the Typical Characteristics.

APPLICATION INFORMATION (continued)

Capacitive Load

The OPAx364 series operational amplifiers can drive a wide range of capacitive loads. However, all operational amplifiers under certain conditions may become unstable. Operational amplifier configuration, gain, and load value are just a few of the factors to consider when determining stability. An operational amplifier in unity-gain configuration is the most susceptible to the effects of capacitive load. The capacitive load reacts with the output resistance of the operational amplifier to create a pole in the small-signal response, which degrades the phase margin.

In unity gain, the OPAx364 series operational amplifiers perform well with a pure capacitive load up to approximately 1000 pF. The equivalent series resistance (ESR) of the loading capacitor may be sufficient to allow the OPAx364 to directly drive large capacitive loads (>1 µF). Increasing gain enhances the amplifier's ability to drive more capacitance as shown in Figure 13.

One method of improving capacitive load drive in the unity gain configuration is to insert a 10-Ω to 20-Ω resistor in series with the output, as shown in Figure 22. This significantly reduces ringing with large capacitive loads. However, if there is a resistive load in parallel with the capacitive load, it creates a voltage divider introducing a dc error at the output and slightly reduces output swing. This error may be insignificant. For instance, with R_L = 10 kΩ and R_S = 20 Ω, there is only about a 0.2% error at the output.

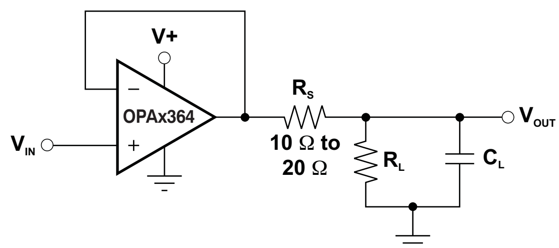


Figure 22. Improving Capacitive Load Drive

Input and ESD Protection

All OPAx364 pins are static protected with internal ESD protection diodes tied to the supplies. These diodes provide overdrive protection if the current is externally limited to 10 mA, as stated in the absolute maximum ratings and shown in Figure 23.

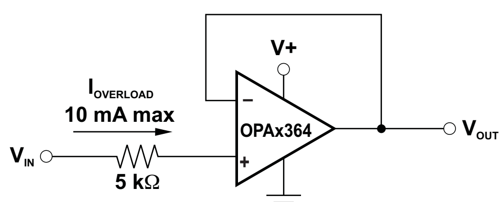


Figure 23. Input Current Protection

Achieving Output Swing to the Operational Amplifier's Negative Rail

Some applications require an accurate output voltage swing from 0 V to a positive full-scale voltage. A good single-supply operational amplifier may be able to swing within a few mV of single supply ground, but as the output is driven toward 0 V, the output stage of the amplifier prevents the output from reaching the negative supply rail of the amplifier.

The output of the OPAx364 can be made to swing to ground, or slightly below, on a single-supply power source. To do so requires use of another resistor and an additional, more-negative power supply than the operational amplifier's negative supply. A pulldown resistor may be connected between the output and the additional negative supply to pull the output down below the value that the output would otherwise achieve as shown in Figure 24.

APPLICATION INFORMATION (continued)

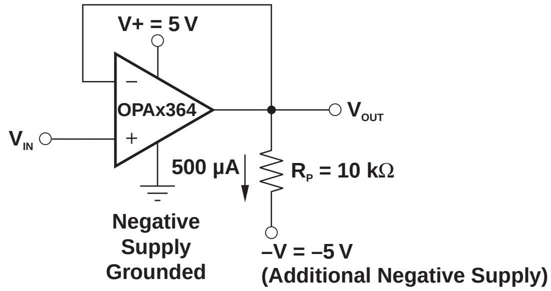


Figure 24. Swing to Ground

This technique does not work with all operational amplifiers. The output stage of the OPAx364 allows the output voltage to be pulled below that of most operational amplifiers, if approximately 500 µA is maintained through the output stage. To calculate the appropriate value load resistor and negative supply, R_L = –V/500 µA. The OPAx364 has been characterized to perform well under the described conditions, maintaining excellent accuracy down to 0 V and as low as –10 mV. Limiting and nonlinearity occurs below –10 mV, with linearity returning as the output is again driven above –10 mV.

Buffered Reference Voltage

Many single-supply applications require a mid-supply reference voltage. The OPAx364 offer excellent capacitive load drive capability and can be configured to provide a 0.9-V reference voltage (see Figure 25). For appropriate loading considerations, see the Capacitive Load section.

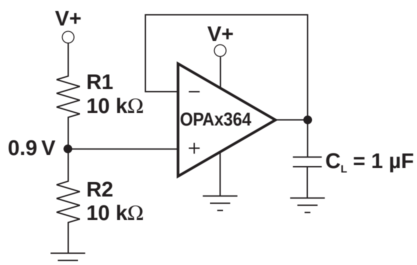


Figure 25. OPAx364 Provides a Stable Reference Voltage

APPLICATION INFORMATION (continued)

Directly Driving the ADS8324 and the MSP430

The OPAx364 series operational amplifiers are optimized for driving medium speed (up to 100 kHz) sampling A/D converters. However, they also offer excellent performance for higher-speed converters. The no crossover input stage of the OPAx364 directly drives A/D converters without degradation of differential linearity and THD. They provide an effective means of buffering the A/D converters input capacitance and resulting charge injection, while providing signal gain. Figure 26 and Figure 27 show the OPAx364 configured to drive the ADS8324 and the 12-bit A/D converter on the MSP430.

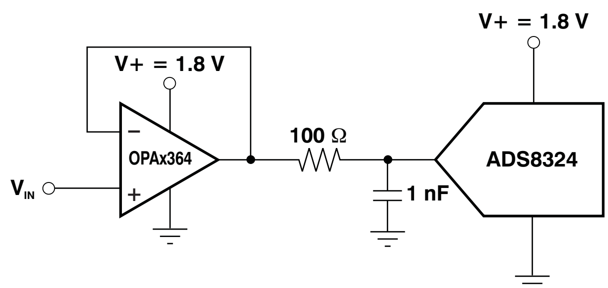


Figure 26. OPAx364 Directly Drives the ADS8324

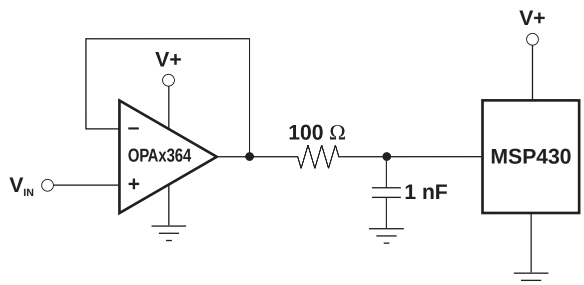


Figure 27. Driving the 12-Bit A/D Converter on the MSP430

Audio Applications

The OPAx364 family has linear offset voltage over the entire input common-mode range. Combined with low-noise, this feature makes the OPAx364 suitable for audio applications. Single-supply 1.8-V operation allows the OPA2364 to be an optimal candidate for dual stereo-headphone drivers and microphone preamplifiers in portable stereo equipment (see Figure 28).

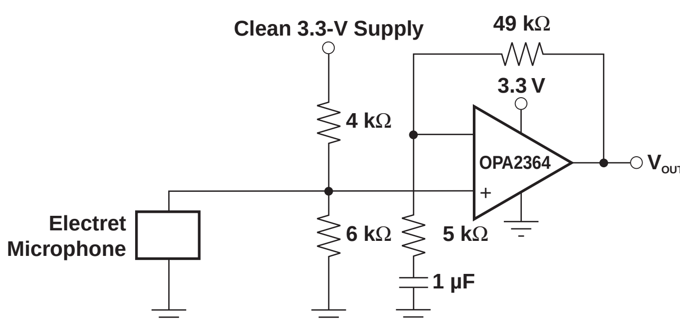


Figure 28. Microphone Preamplifier

APPLICATION INFORMATION (continued)

Active Filtering

Low harmonic distortion and noise specifications plus high gain and slew rate make the OPAx364 optimal candidates for active filtering. Figure 29 shows the implementation of a Sallen-Key, 3-pole, low-pass Bessel filter.

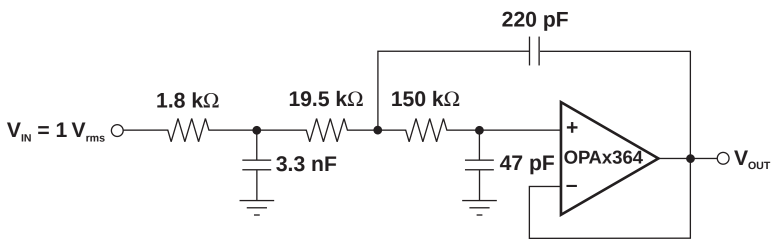


Figure 29. OPAx364 Configured as 3-Pole, 20-kHz, Sallen-Key Filter

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
OPA4364AQDRQ1	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	OPA4364Q
OPA4364AQDRQ1.B	Active	Production	SOIC (D) | 14	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	OPA4364Q

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

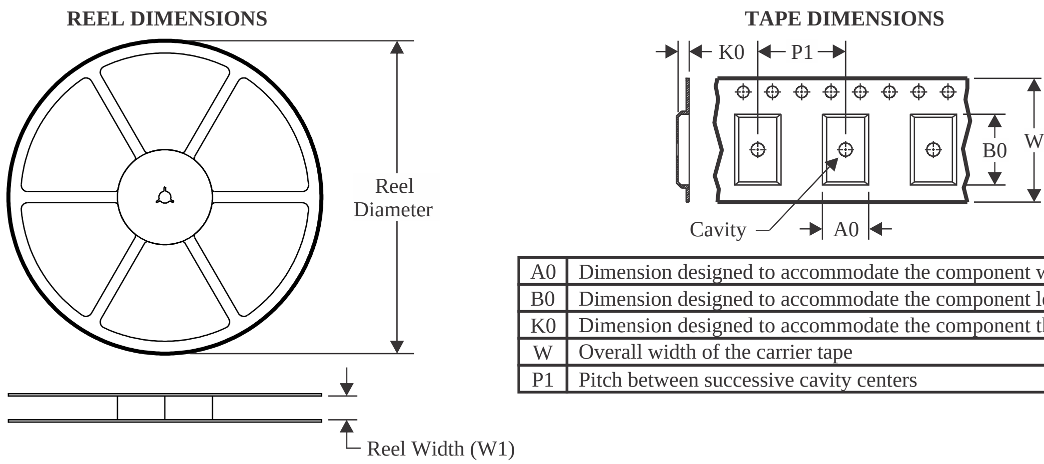
OTHER QUALIFIED VERSIONS OF OPA4364-Q1 :

- Catalog : OPA4364

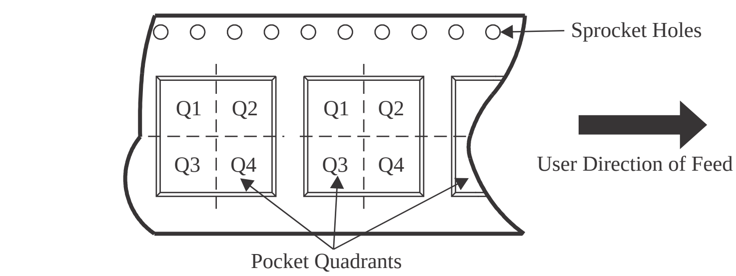
NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION



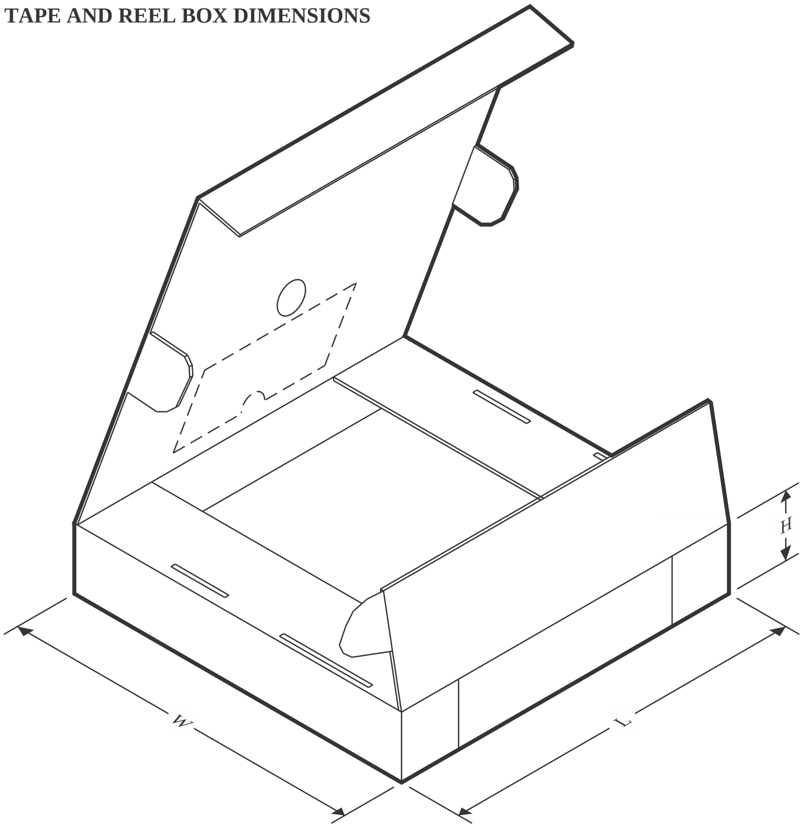
A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers



*All dimensions are nominal

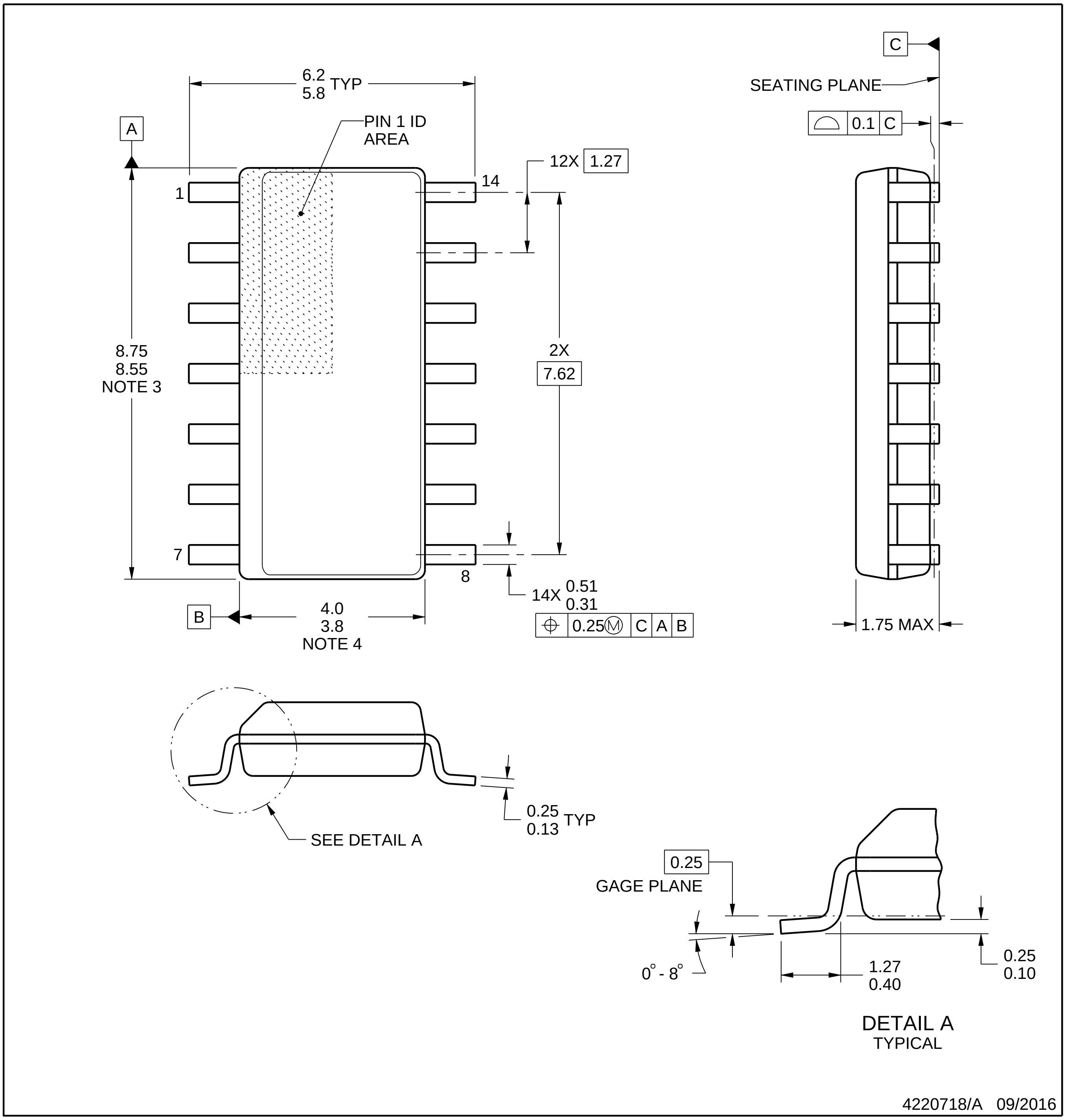
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
OPA4364AQDRQ1	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1

TAPE AND REEL BOX DIMENSIONS



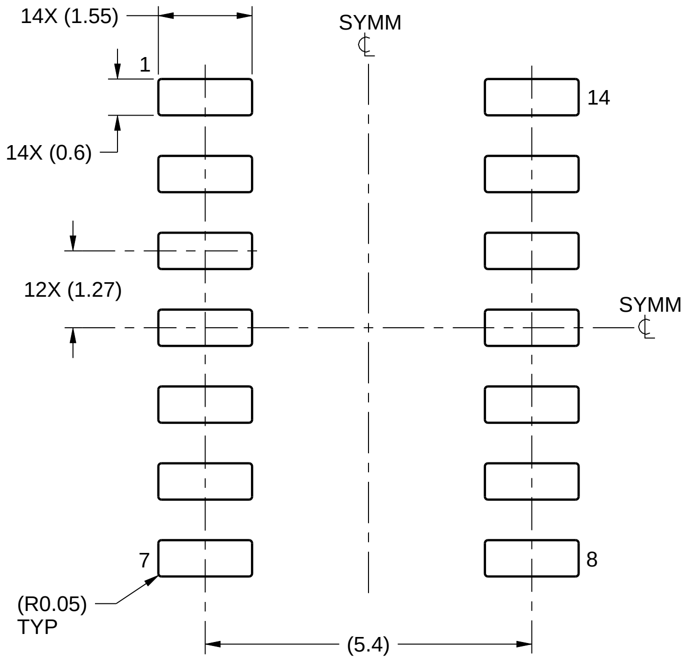
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
OPA4364AQDRQ1	SOIC	D	14	2500	353.0	353.0	32.0

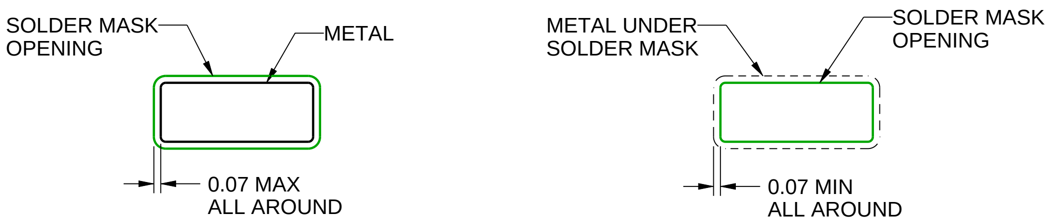


NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.43 mm, per side.
5. Reference JEDEC registration MS-012, variation AB.



LAND PATTERN EXAMPLE
SCALE:8X



NON SOLDER MASK DEFINED

SOLDER MASK DEFINED

SOLDER MASK DETAILS

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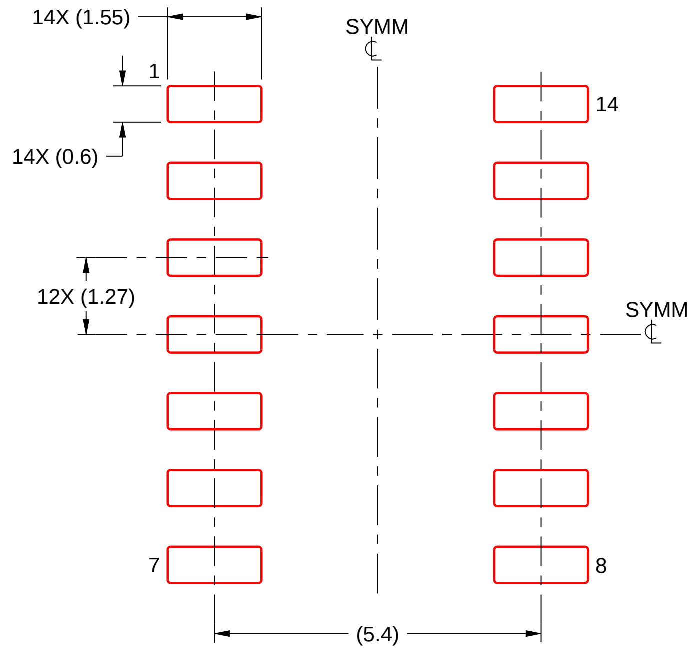
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:8X

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NOTES: (continued)

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