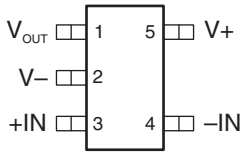
# 50-MHz Low-Distortion High-CMRR Rail-to-Rail I/O, Single-Supply Operational Amplifier

Check for Samples: OPA365-Q1, OPA2365-Q1

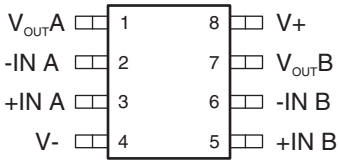
## FEATURES

- Qualified for Automotive Applications
- AEC-Q100 Qualified With the Following Results:
  - Device Temperature Grade 1: –40°C to 125°C Ambient Operating Temperature Range
  - Device HBM ESD Classification Level H2
  - Device CDM ESD Classification Level C3B
- Gain Bandwidth: 50 MHz
- Zero-Crossover Distortion Topology
  - Excellent THD+N: 0.0004%
  - CMRR: 100 dB (Min)
  - Rail-to-Rail Input and Output
  - Input 100 mV Beyond Supply Rail
- Low Noise: 4.5 nV/$\sqrt{\text{Hz}}$ at 100 kHz
- Slew Rate: 25 V/µs
- Fast Settling: 0.3 µs to 0.01%
- Precision
  - Low Offset: 100 µV
  - Low Input Bias Current: 0.2 pA
- 2.2-V to 5.5-V Operation

OPA365
DBV PACKAGE
(TOP VIEW)




OPA2365
D PACKAGE
(TOP VIEW)




## DESCRIPTION

The OPAx365 zero-crossover family, rail-to-rail, high-performance, CMOS operational amplifiers are optimized for very low voltage, single-supply applications. Rail-to-rail input/output, low-noise (4.5 nV/$\sqrt{\text{Hz}}$) and high-speed operation (50-MHz gain bandwidth) make these devices ideal for driving sampling analog-to-digital converters (ADCs). Applications include audio, signal conditioning, and sensor amplification. The OPA365 family of op amps are also well-suited for cell phone power amplifier control loops.

Special features include an excellent common-mode rejection ratio (CMRR), no input stage crossover distortion, high input impedance, and rail-to-rail input and output swing. The input common-mode range includes both the negative and positive supplies. The output voltage swing is within 10 mV of the rails.

The OPA365 (single version) is available in the SOT23-5 package. The OPA2365 (dual version) is available in the SO-8 package. All versions are specified for operation from −40°C to 125°C. Single and dual versions have identical specifications for maximum design flexibility.

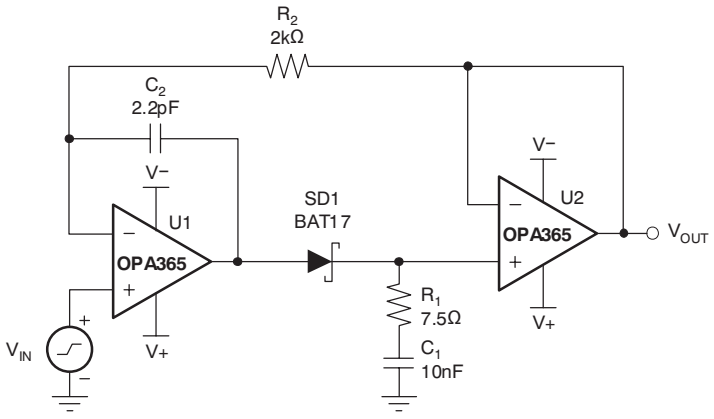



**Figure 1. Fast-Settling Peak Detector**

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(1)

| $T_A$ | PACKAGE(2) | | | ORDERABLE PART NUMBER | TOP-SIDE MARKING |
|---|---|---|---|---|---|
| –40°C to 125°C | Single | SOT23 – DBV | Reel of 2500 | OPA365AQDBVRQ1 | OTNQ |
| | Dual | SOIC – D | Reel of 2500 | OPA2365AQDRQ1 | O2365Q |

(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

## ABSOLUTE MAXIMUM RATINGS(1)

| | | | |
|---|---|---|---|
| $V_{CC}$ | Supply voltage | | +5.5 V |
| $V_I$ | Signal input terminals, voltage(2) | | (V−) − 0.5V to (V+) + 0.5 V |
| $I_I$ | Signal input terminals, current(2) | | ±10 mA |
| $t_{OSC}$ | Output short-circuit duration(3) | | Continuous |
| $T_{OP}$ | Operating temperature | | −40°C to 150°C |
| $T_{stg}$ | Storage temperature | | –65°C to 150°C |
| $T_J$ | Junction temperature | | 150°C |
| ESD | Electrostatic discharge rating | Human Body Model (HBM) AEC-Q100 Classification Level H2 | 2 kV |
| | | Charged Device Model (CDM) AEC-Q100 Classification Level C3B | 750 V |

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

## ELECTRICAL CHARACTERISTICS

$V_S$ = +2.2V to +5.5V, $R_L$ = 10kΩ connected to $V_S/2$, $V_{CM} = V_S/2$, and $V_{OUT} = V_S/2$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ (1) | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| **OFFSET VOLTAGE** | | | | | | | |
| $V_{OS}$ | Input offset voltage | | 25°C | | 100 | 200 | µV |
| $V_{OS}$ (2) | Input offset voltage | | 25°C | | 100 | 230 | µV |
| $dV_{OS}/dT$ | Input offset voltage drift | | Full range | | 1 | | µV/°C |
| PSRR | Input offset voltage vs power supply | $V_S$ = +2.2V to +5.5V | Full range | | 10 | 100 | µV/V |
| | Channel separation, dc | | 25°C | | 0.2 | | µV/V |
| **INPUT BIAS CURRENT** | | | | | | | |
| $I_B$ | Input bias current | | 25°C | | ±0.2 | ±10 | pA |
| | | | Full range | See Typical Characteristics | | | |
| $I_{OS}$ | Input offset current | | 25°C | | ±0.2 | ±10 | pA |
| **NOISE** | | | | | | | |
| $e_n$ | Input voltage noise | f = 0.1Hz to 10Hz | 25°C | | 5 | | $\mu V_{PP}$ |
| $e_n$ | Input voltage noise density | f = 100kHz | 25°C | | 4.5 | | $nV/\sqrt{Hz}$ |
| $i_n$ | Input current noise density | f = 10kHz | 25°C | | 4 | | $fA/\sqrt{Hz}$ |
| **INPUT VOLTAGE RANGE** | | | | | | | |
| $V_{CM}$ | Common-mode voltage range | | 25°C | (V-) – 0.1 | | (V+) + 0.1 | V |
| CMRR | Common-mode rejection ratio | (V-) – 0.1V ≤ $V_{CM}$ ≤ (V+) + 0.1V | Full range | 100 | 120 | | dB |
| **INPUT CAPACITANCE** | | | | | | | |
| | Differential | | 25°C | | 6 | | pF |
| | Common-mode | | 25°C | | 2 | | pF |
| **OPEN-LOOP GAIN** | | | | | | | |
| $A_{OL}$ | Open-loop voltage gain | $R_L$ = 10kΩ, 100mV < $V_O$ < (V+) – 100mV | Full range | 100 | 120 | | dB |
| | | $R_L$ = 600Ω, 200mV < $V_O$ < (V+) – 200mV | 25°C | 100 | 120 | | |
| | | $R_L$ = 600Ω, 200mV < $V_O$ < (V+) – 200mV | Full range | 94 | | | |
| **FREQUENCY RESPONSE** | | | | | | | |
| GBW | Gain-bandwidth product | | 25°C | | 50 | | MHz |
| SR | Slew rate | $V_S$ = 5V, G = +1 | 25°C | | 25 | | V/µs |
| $t_S$ | Settling time | 0.1%, $V_S$ = 5V, 4V Step, G = +1 | 25°C | | 200 | | ns |
| | | 0.01%, $V_S$ = 5V, 4V Step, G = +1 | 25°C | | 300 | | |
| | Overload recovery time | $V_S$ = 5V, $V_{IN}$ x Gain > $V_S$ | 25°C | | < 0.1 | | µs |
| THD+N | Total harmonic distortion + noise (3) | $V_S$ = 5V, $R_L$ = 600Ω, $V_O$ = 4VPP, G = +1, f = 1kHz | 25°C | | 0.0004 | | % |
| **OUTPUT** | | | | | | | |
| | Voltage output swing from rail | $R_L$ = 10kΩ, $V_S$ = 5.5V | Full range | | 10 | 20 | mV |
| $I_{SC}$ | Short-circuit current | | 25°C | | ±65 | | mA |
| $C_L$ | Capacitive load drive | | 25°C | See Typical Characteristics | | | |
| | Open-loop output impedance | f = 1MHz, $I_O$ = 0 | 25°C | | 30 | | Ω |
| **POWER SUPPLY** | | | | | | | |
| $V_S$ | Specified voltage range | | 25°C | 2.2 | | 5.5 | V |

(1) Full range $T_A$ = −40°C to +125°C
(2) For OPA2365-Q1 only
(3) Third-order filter, bandwidth 80kHz at −3dB.

## ELECTRICAL CHARACTERISTICS (continued)

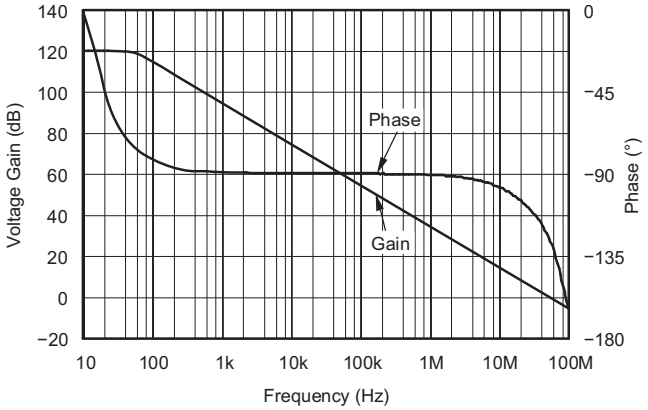
$V_S$ = +2.2V to +5.5V, $R_L$ = 10kΩ connected to $V_S/2$, $V_{CM} = V_S/2$, and $V_{OUT} = V_S/2$ (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $T_A$ (1) | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_Q$ | Quiescent current per amplifier | $I_O$ = 0 | 25°C | | 4.6 | 5 | mA |
| | | | Full range | | | 5.3 | |
| **TEMPERATURE RANGE** | | | | | | | |
| | Specified range | | 25°C | –40 | | 125 | °C |
| $\theta_{JA}$ | Thermal resistance | SOT23-5 | 25°C | | | | °C/W |
| | | SO-8 | 25°C | | 200 | | |

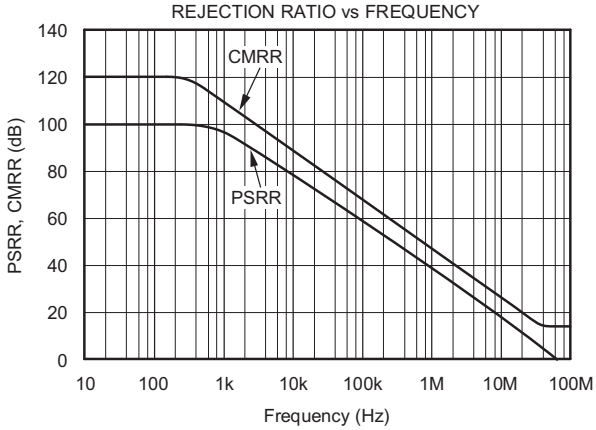
## TYPICAL CHARACTERISTICS

$T_A$ = +25°C, $V_S$ = +5V, $C_L$ = 0pF (unless otherwise noted)

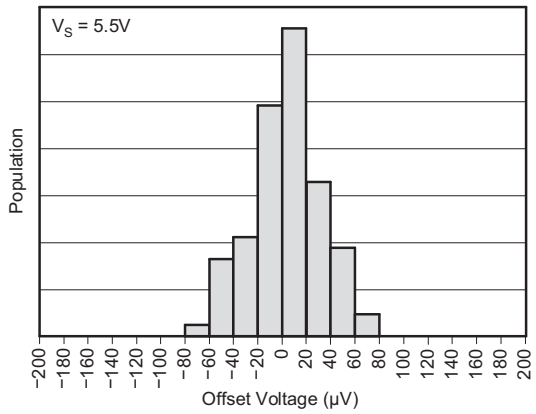
OPEN−LOOP GAIN/PHASE vs FREQUENCY



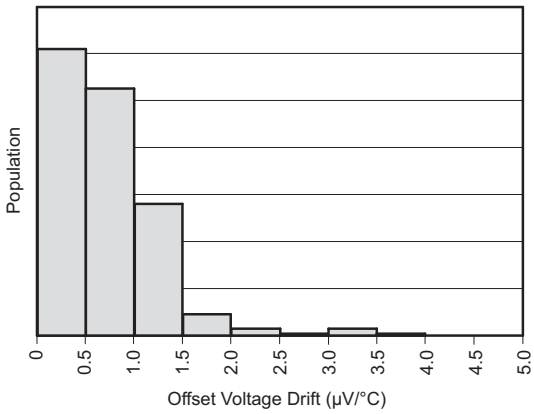

POWER SUPPLY AND COMMON−MODE REJECTION RATIO vs FREQUENCY



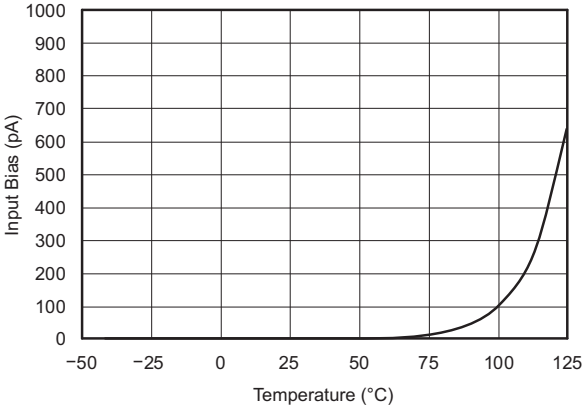

OFFSET VOLTAGE PRODUCTION DISTRIBUTION



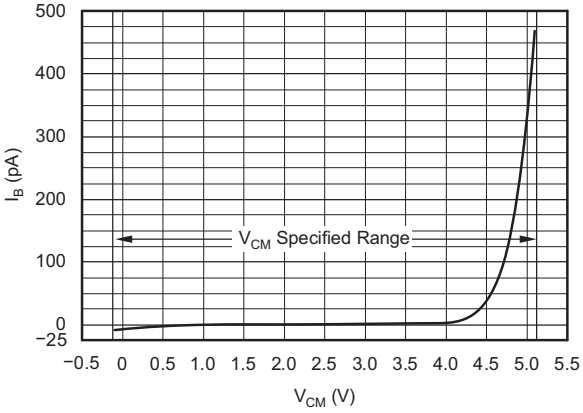

OFFSET VOLTAGE DRIFT PRODUCTION DISTRIBUTION




INPUT BIAS CURRENT vs TEMPERATURE



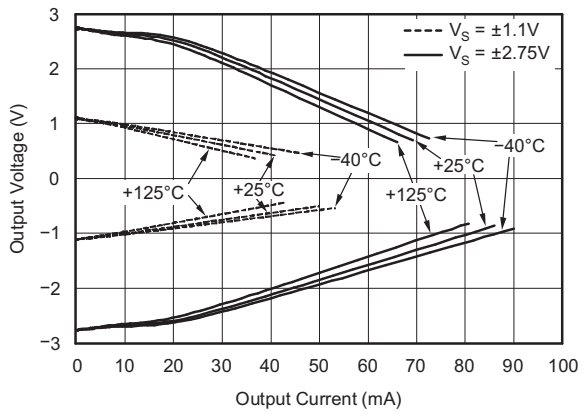

INPUT BIAS CURRENT vs COMMON−MODE VOLTAGE



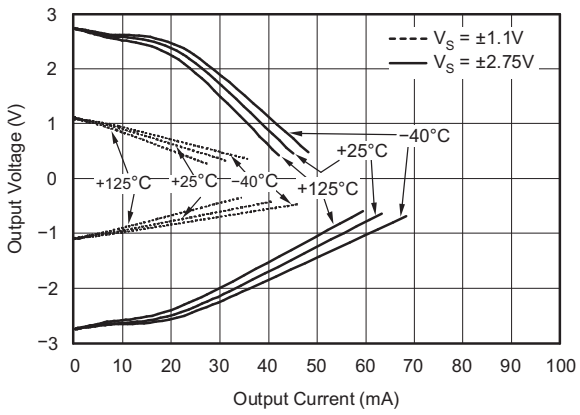
## TYPICAL CHARACTERISTICS (continued)

$T_A$ = +25°C, $V_S$ = +5V, $C_L$ = 0pF (unless otherwise noted)

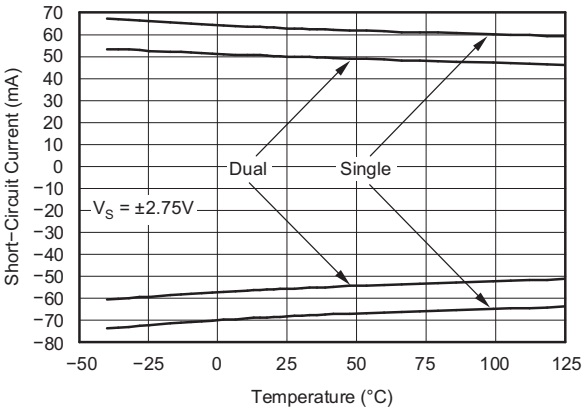
OPA365 OUTPUT VOLTAGE vs OUTPUT CURRENT



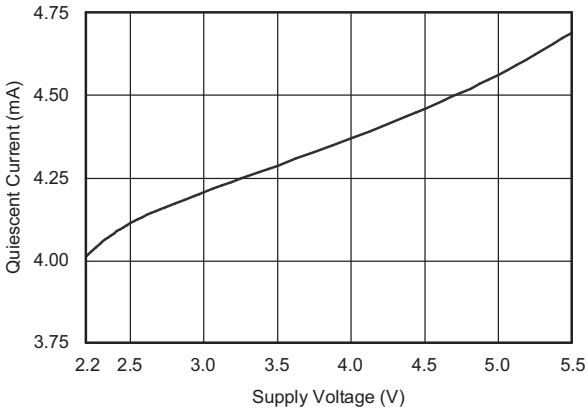

OPA2365 OUTPUT VOLTAGE SWING vs OUTPUT CURRENT



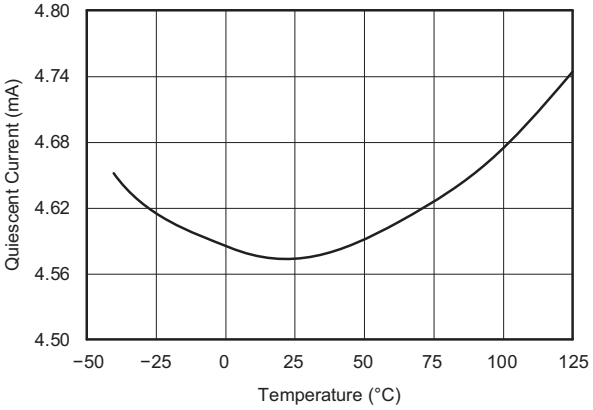

SHORT−CIRCUIT CURRENT vs TEMPERATURE



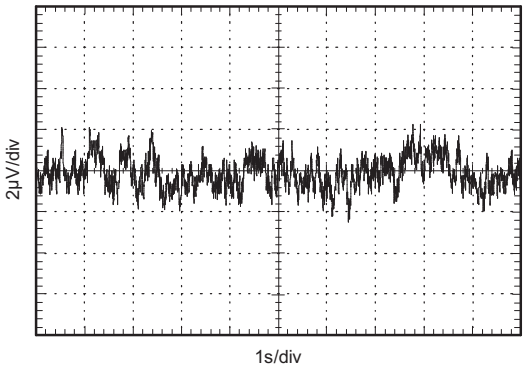

QUIESCENT CURRENT vs SUPPLY VOLTAGE




QUIESCENT CURRENT vs TEMPERATURE



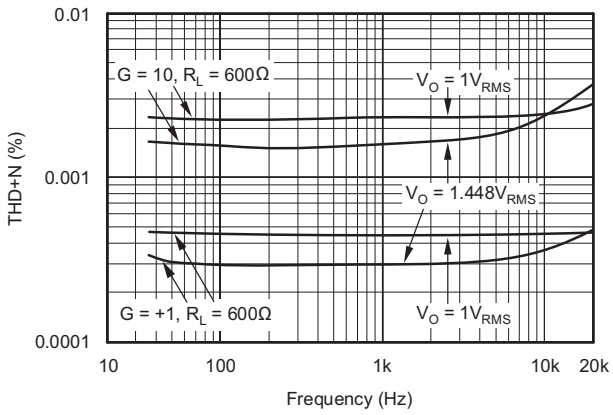

0.1Hz to 10Hz INPUT VOLTAGE NOISE



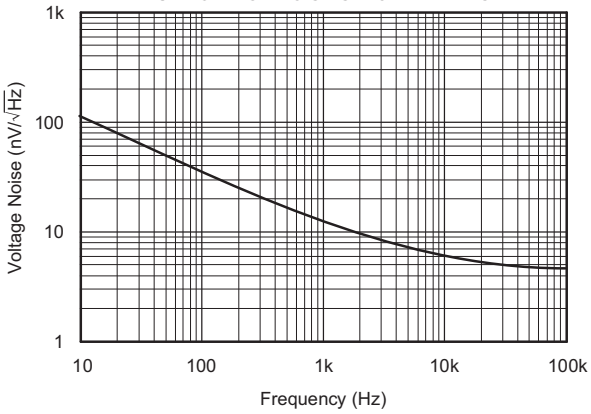
## TYPICAL CHARACTERISTICS (continued)

$T_A$ = +25°C, $V_S$ = +5V, $C_L$ = 0pF (unless otherwise noted)

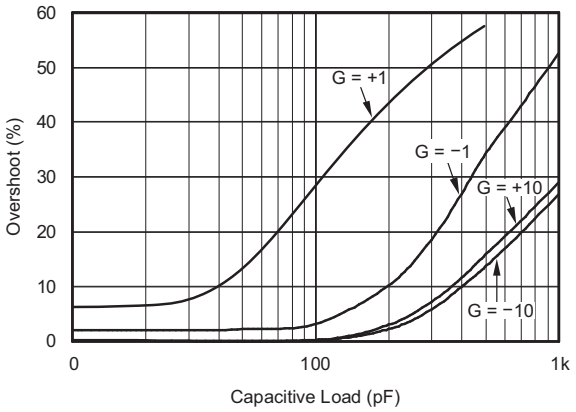
TOTAL HARMONIC DISTORTION + NOISE vs FREQUENCY



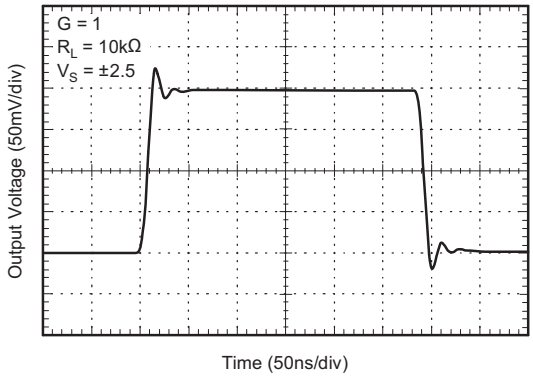

INPUT VOLTAGE NOISE SPECTRAL DENSITY



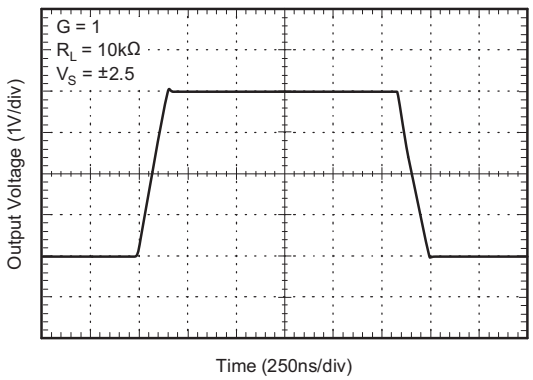

OVERSHOOT vs CAPACITIVE LOAD



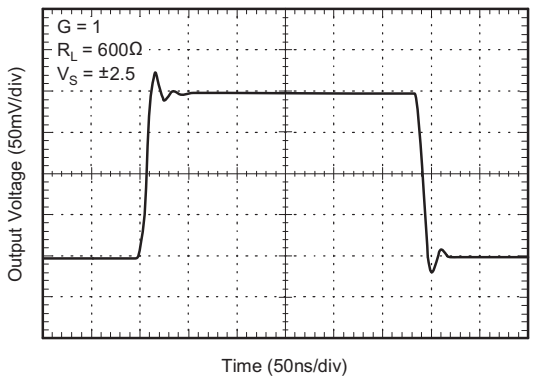

SMALL−SIGNAL STEP RESPONSE




LARGE−SIGNAL STEP RESPONSE



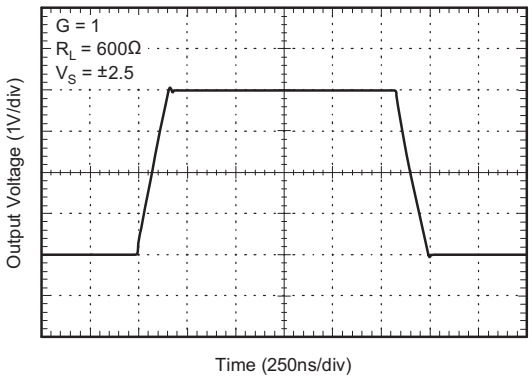

SMALL−SIGNAL STEP RESPONSE



## TYPICAL CHARACTERISTICS (continued)

$T_A$ = +25°C, $V_S$ = +5V, $C_L$ = 0pF (unless otherwise noted)

LARGE−SIGNAL STEP RESPONSE



# APPLICATION INFORMATION

## Operating Characteristics

The OPA365 amplifier parameters are fully specified from +2.2V to +5.5V. Many of the specifications apply from −40°C to +125°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in *Typical Characteristics*.

## General Layout Guidelines

The OPA365 is a wideband amplifier. To realize the full operational performance of the device, good high-frequency printed circuit board (PCB) layout practices are required. Low-loss 0.1µF bypass capacitors must be connected between each supply pin and ground as close to the device as possible. The bypass capacitor traces should be designed for minimum inductance.

## Basic Amplifier Configurations

As with other single-supply op amps, the OPA365 may be operated with either a single supply or dual supplies (see Figure 2). A typical dual-supply connection is shown in Figure 2, which is accompanied by a single-supply connection. The OPA365 is configured as a basic inverting amplifier with a gain of −10V/V. The dual-supply connection has an output voltage centered on zero, while the single− supply connection has an output centered on the common-mode voltage $V_{CM}$. For the circuit shown, this voltage is 1.5V, but may be any value within the common-mode input voltage range. The OPA365 $V_{CM}$ range extends 100mV beyond the power-supply rails.

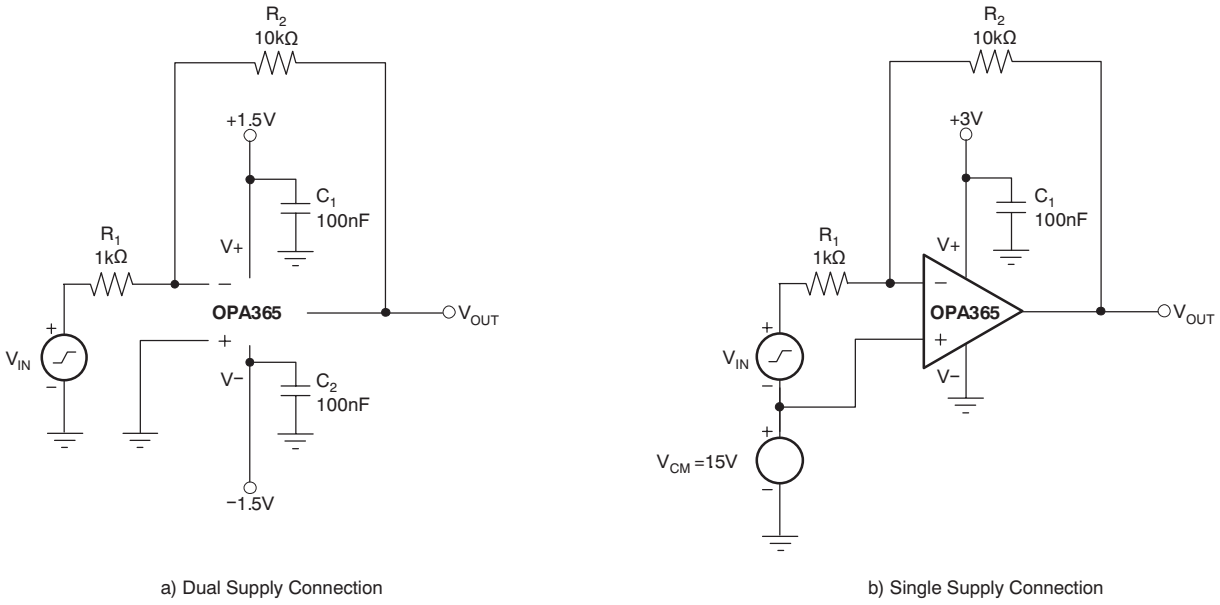



**Figure 2. Basic Circuit Connections**

Figure 3 shows a single-supply, electret microphone application where $V_{CM}$ is provided by a resistive divider. The divider also provides the bias voltage for the electret element.

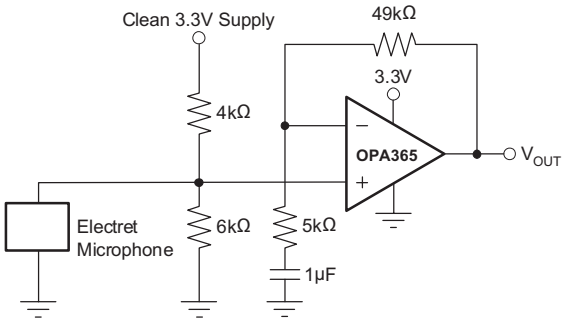



**Figure 3. Microphone Preamplifier**

## Input and ESD Protection

The OPA365 incorporates internal electrostatic discharge (ESD) protection circuits on all pins. In the case of input and output pins, this protection primarily consists of current steering diodes connected between the input and power-supply pins. These ESD protection diodes also provide in-circuit, input overdrive protection, provided that the current is limited to 10mA as stated in the Absolute Maximum Ratings. Figure 4 shows how a series input resistor may be added to the driven input to limit the input current. The added resistor contributes thermal noise at the amplifier input and its value should be kept to the minimum in noise-sensitive applications.

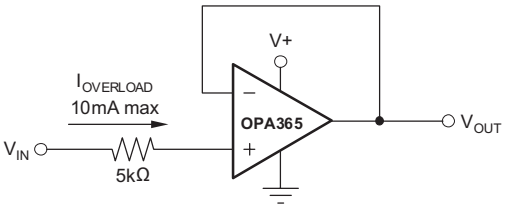



**Figure 4. Input Current Protection**

## Rail-to-Rail Input

The OPA365 product family features true rail-to-rail input operation, with supply voltages as low as ±1.1V (2.2V). A unique zero-crossover input topology eliminates the input offset transition region typical of many rail-to-rail, complementary stage operational amplifiers. This topology also allows the OPA365 to provide superior common-mode performance over the entire input range, which extends 100mV beyond both power-supply rails, as shown in Figure 5. When driving ADCs, the highly linear VCM range of the OPA365 assures that the op amp/ADC system linearity performance is not compromised.

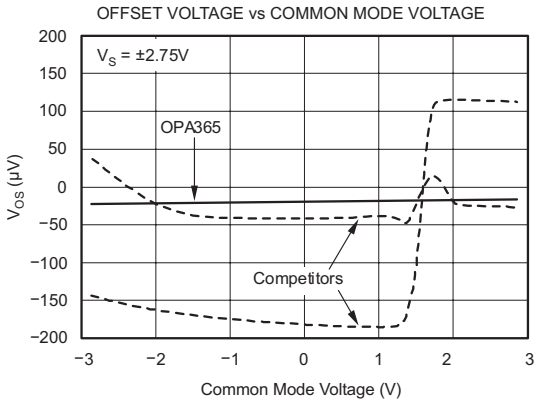



**Figure 5. OPA365 has Linear Offset Over the Entire Common-Mode Range**

A simplified schematic illustrating the rail-to-rail input circuitry is shown in Figure 6.

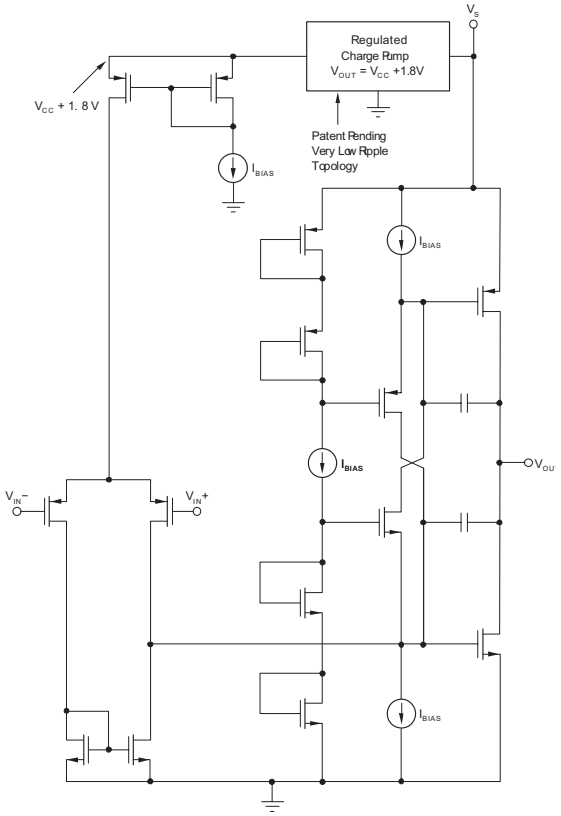



**Figure 6. Simplified Schematic**

## Capacitive Loads

The OPA365 may be used in applications where driving a capacitive load is required. As with all op amps, there may be specific instances where the OPA365 can become unstable, leading to oscillation. The particular op amp circuit configuration, layout, gain and output loading are some of the factors to consider when establishing whether an amplifier will be stable in operation. An op amp in the unity-gain (+1V/V) buffer configuration and driving a capacitive load exhibits a greater tendency to be unstable than an amplifier operated at a higher noise gain. The capacitive load, in conjunction with the op amp output resistance, creates a pole within the feedback loop that degrades the phase margin. The degradation of the phase margin increases as the capacitive loading increases.

When operating in the unity-gain configuration, the OPA365 remains stable with a pure capacitive load up to approximately 1nF. The equivalent series resistance (ESR) of some very large capacitors ($C_L$ > 1µF) is sufficient to alter the phase characteristics in the feedback loop such that the amplifier remains stable. Increasing the amplifier closed-loop gain allows the amplifier to drive increasingly larger capacitance. This increased capability is evident when observing the overshoot response of the amplifier at higher voltage gains. See the typical characteristic graph, Small-Signal Overshoot vs. Capacitive Load.

One technique for increasing the capacitive load drive capability of the amplifier operating in unity gain is to insert a small resistor, typically 10Ω to 20Ω, in series with the output; see Figure 7. This resistor significantly reduces the overshoot and ringing associated with large capacitive loads. A possible problem with this technique is that a voltage divider is created with the added series resistor and any resistor connected in parallel with the capacitive load. The voltage divider introduces a gain error at the output that reduces the output swing. The error contributed by the voltage divider may be insignificant. For instance, with a load resistance, $R_L$ = 10kΩ, and $R_S$ = 20Ω, the gain error is only about 0.2%. However, when $R_L$ is decreased to 600Ω, which the OPA365 is able to drive, the error increases to 7.5%.

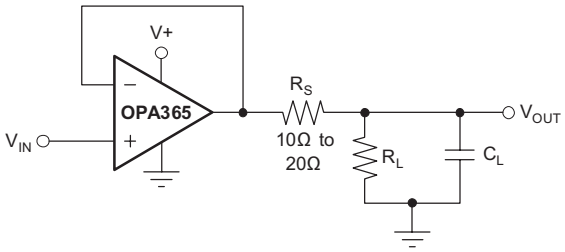



**Figure 7. Improving Capacitive Load Drive**

## Achieving an Output Level of Zero Volts (0V)

Certain single-supply applications require the op amp output to swing from 0V to a positive full-scale voltage and have high accuracy. An example is an op amp employed to drive a single-supply ADC having an input range from 0V to +5V. Rail-to-rail output amplifiers with very light output loading may achieve an output level within millivolts of 0V (or $+V_S$ at the high end), but not 0V. Furthermore, the deviation from 0V only becomes greater as the load current required increases. This increased deviation is a result of limitations of the CMOS output stage.

When a pulldown resistor is connected from the amplifier output to a negative voltage source, the OPA365 can achieve an output level of 0V, and even a few millivolts below 0V. Below this limit, nonlinearity and limiting conditions become evident. Figure 8 illustrates a circuit using this technique.

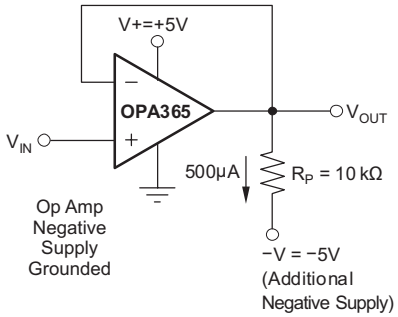



**Figure 8. Swing-to-Ground**

A pulldown current of approximately 500µA is required when OPA365 is connected as a unity-gain buffer. A practical termination voltage ($V_{NEG}$) is −5V, but other convenient negative voltages also may be used. The pulldown resistor $R_L$ is calculated from $R_L = [(V_O - V_{NEG})/(500\mu A)]$. Using a minimum output voltage ($V_O$) of 0V, $R_L = [0V-(-5V)]/(500\mu A)] = 10k\Omega$. Keep in mind that lower termination voltages result in smaller pulldown resistors that load the output during positive output voltage excursions.

Note that this technique does not work with all op amps and should only be applied to op amps such as the OPA365 that have been specifically designed to operate in this manner. Also, operating the OPA365 output at 0V changes the output stage operating conditions, resulting in somewhat lower open-loop gain and bandwidth. Keep these precautions in mind when driving a capacitive load because these conditions can affect circuit transient response and stability.

## Active Filtering

The OPA365 is well-suited for active filter applications requiring a wide bandwidth, fast slew rate, low-noise, single-supply operational amplifier. Figure 9 shows a 500kHz, 2nd-order, low-pass filter utilizing the multiple-feedback (MFB) topology. The components have been selected to provide a maximally-flat Butterworth response. Beyond the cutoff frequency, roll-off is −40dB/dec. The Butterworth response is ideal for applications requiring predictable gain characteristics such as the anti-aliasing filter used ahead of an ADC.

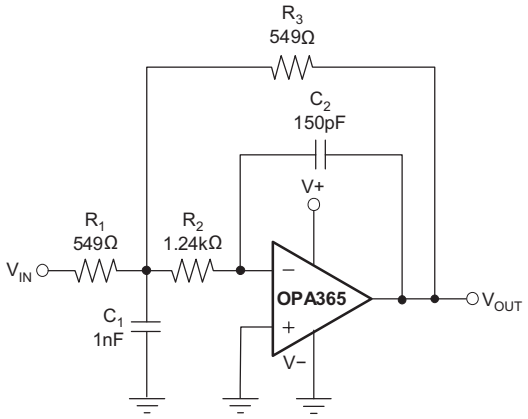



**Figure 9. Second-Order Butterworth 500kHz Low-Pass Filter**

One point to observe when considering the MFB filter is that the output is inverted, relative to the input. If this inversion is not required, or not desired, a noninverting output can be achieved through one of these options: 1) adding an inverting amplifier; 2) adding an additional 2nd-order MFB stage; or 3) using a noninverting filter topology such as the Sallen-Key (shown in Figure 10). MFB and Sallen-Key, low-pass and high-pass filter synthesis is quickly accomplished using TI's FilterPro program. This software is available as a free download at www.ti.com.

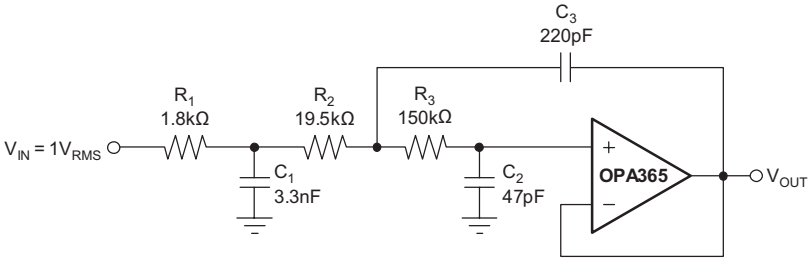



**Figure 10. Configured as a 3-Pole, 20kHz, Sallen-Key Filter**

## Driving an Analog-to-Digital Converter

Very wide common-mode input range, rail-to-rail input and output voltage capability and high speed make the OPA365 an ideal driver for modern ADCs. Also, because it is free of the input offset transition characteristics inherent to some rail-to-rail CMOS op amps, the OPA365 provides low THD and excellent linearity throughout the input voltage swing range. Figure 11 shows the OPA365 driving an ADS8326, 16-bit, 250kSPS converter. The amplifier is connected as a unity-gain, noninverting buffer and has an output swing to 0V, making it directly compatible with the ADC minus full-scale input level. The 0V level is achieved by powering the OPA365 V− pin with a small negative voltage established by the diode forward voltage drop. A small, signal-switching diode or Schottky diode provides a suitable negative supply voltage of −0.3 to −0.7V. The supply rail-to-rail is equal to V+, plus the small negative voltage.

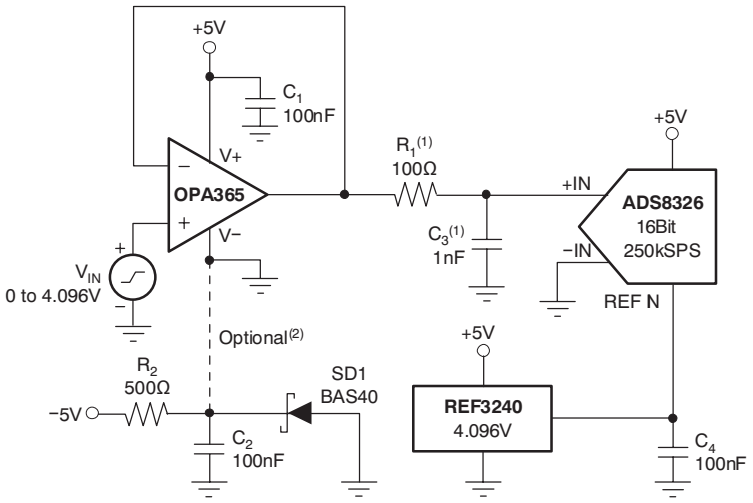



**Figure 11. Driving the ADS8326**

One method for driving an ADC that negates the need for an output swing down to 0V uses a slightly compressed ADC full-scale input range (FSR). For example, the 16-bit ADS8361 (shown in Figure 12) has a maximum FSR of 0V to 5V, when powered by a +5V supply and $V_{REF}$ of 2.5V. The idea is to match the ADC input range with the op amp full linear output swing range; for example, an output range of +0.1 to +4.9V. The reference output from the ADS8361 ADC is divided down from 2.5V to 2.4V using a resistive divider. The ADC FSR then becomes $4.8V_{PP}$ centered on a common-mode voltage of +2.5V. Current from the ADS8361 reference pin is limited to about ±10µA. Here, 5µA was used to bias the divider. The resistors must be precise to maintain the ADC gain accuracy. An additional benefit of this method is the elimination of the negative supply voltage; it requires no additional power-supply current.

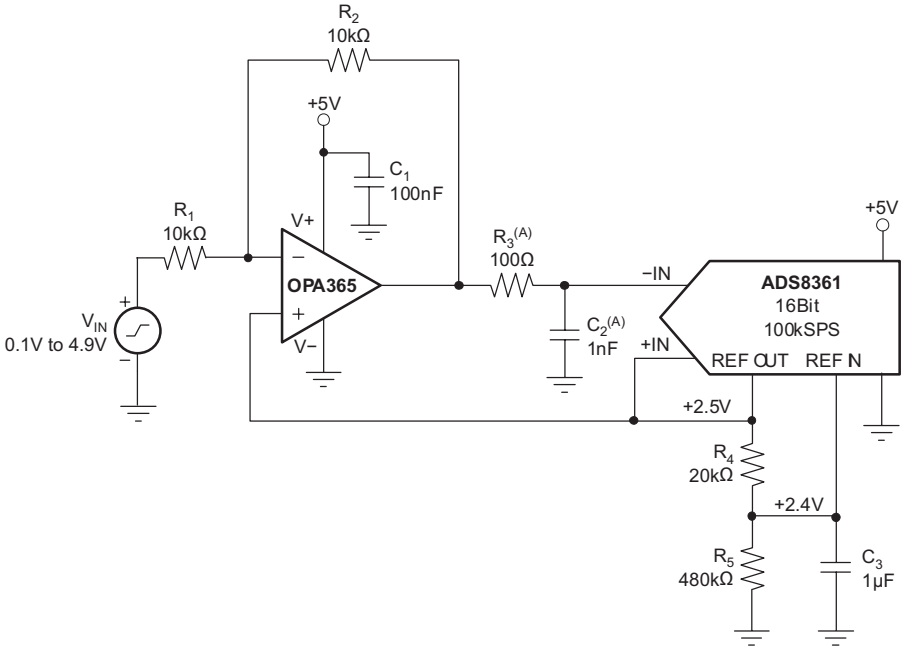



**Figure 12. Driving the ADS8361**

An RC network, consisting of R1 and C1, is included between the op amp and the ADS8361. It not only provides a high-frequency filter function, but more importantly serves as a charge reservoir used for charging the converter internal hold capacitance. This capability assures that the op amp output linearity is maintained as the ADC input characteristics change throughout the conversion cycle. Depending on the particular application and ADC, some optimization of the R1 and C1 values may be required for best transient performance.

Figure 13 illustrates the OPA2365 dual op amp providing signal conditioning within an ADS1258 bridge sensor circuit. It follows the ADS1258 16:1 multiplexer and is connected as a differential in/differential out amplifier. The voltage gain for this stage is approximately 10V/V. Driving the ADS1258 internal ADC in differential mode, rather than in a single-ended, exploits the full linearity performance capability of the converter. For best common-mode rejection the two R2 resistors should be closely matched.

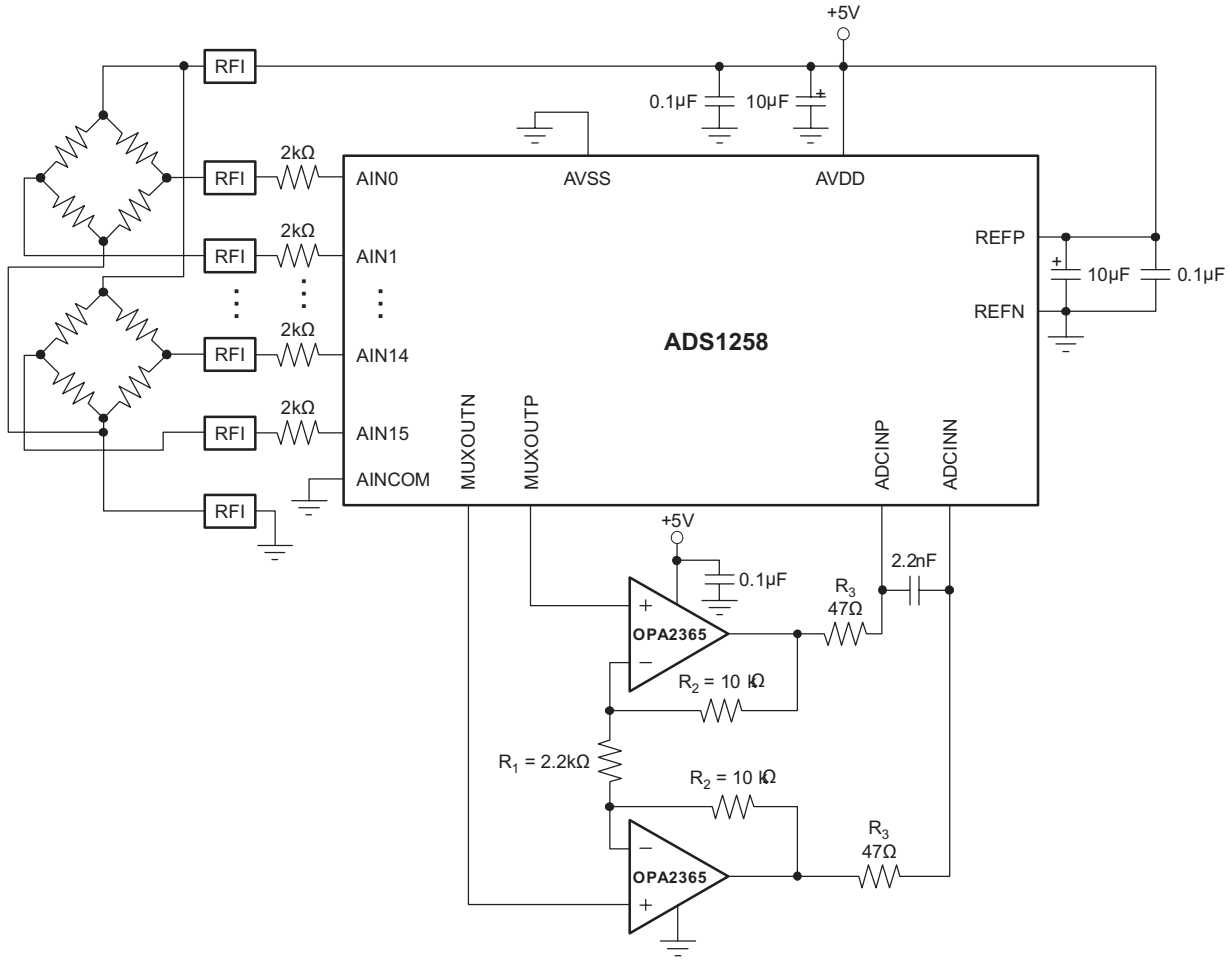



**Figure 13. Conditioning Input Signals to the ADS1258 on a Single-Supply**

Note that in Figure 13, the amplifiers, bridges, ADS1258, and internal reference are powered by the same single +5V supply. This ratiometric connection helps cancel excitation voltage drift effects and noise. For best performance, the +5V supply should be as free as possible of noise and transients.

When the ADS1258 data rate is set to maximum and the chop feature enabled, this circuit yields 12 bits of noise-free resolution with a 50mV full-scale input.

The chop feature is used to reduce the ADS1258 offset and offset drift to very low levels. A 2.2 nF capacitor is required across the ADC inputs to bypass the sampling currents. The 47Ω resistors provide isolation for the OPA2365 outputs from the relatively large, 2.2 nF capacitive load. For more information regarding the ADS1258, see the product data sheet available for download at www.ti.com.

## REVISION HISTORY

**Changes from Revision B (January 2012) to Revision C** **Page**

- Changed top-side marking to O2365Q ..... 2
- Added another row with $V_{OS}$ for OPA2365-Q1 only ..... 3
- Changed $I_Q$ upper limit to 5.3 from 5.5 ..... 4

## PACKAGING INFORMATION

| Orderable Device | Status (1) | Package Type | Package Drawing | Pins | Package Qty | Eco Plan (2) | Lead/Ball Finish | MSL Peak Temp (3) | Op Temp (°C) | Top-Side Markings (4) | Samples |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OPA2365AQDRQ1 | ACTIVE | SOIC | D | 8 | 2500 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-3-260C-168 HR | -40 to 125 | O2365Q | Samples |
| OPA365AQDBVRQ1 | ACTIVE | SOT-23 | DBV | 5 | 3000 | Green (RoHS & no Sb/Br) | CU NIPDAU | Level-1-260C-UNLIM | -40 to 125 | OTNQ | Samples |

(1) The marketing status values are defined as follows:
**ACTIVE:** Product device recommended for new designs.
**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.
**OBSOLETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
**TBD:** The Pb-Free/Green conversion plan has not been defined.
**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. -- The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) Multiple Top-Side Markings will be inside parentheses. Only one Top-Side Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Top-Side Marking for that device.



**OTHER QUALIFIED VERSIONS OF OPA2365-Q1, OPA365-Q1 :**

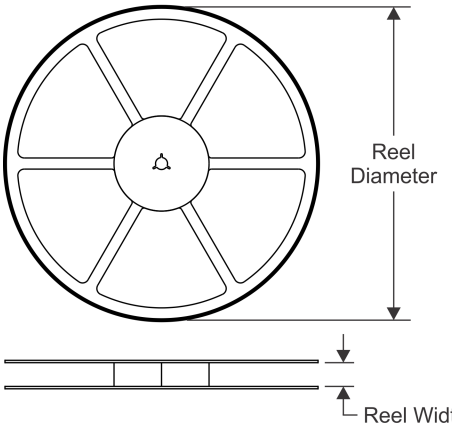
- Catalog: OPA2365, OPA365
- Enhanced Product: OPA365-EP

NOTE: Qualified Version Definitions:

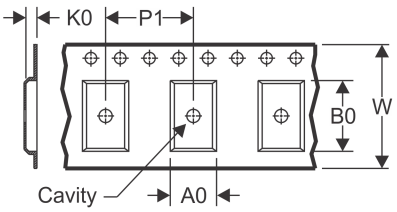
- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

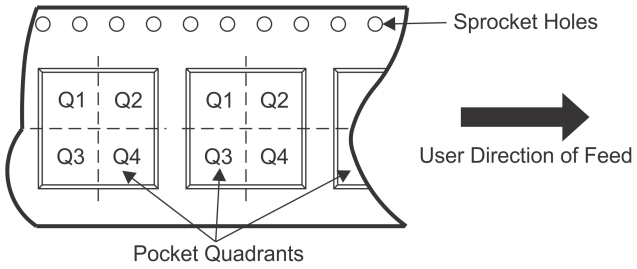



**TAPE DIMENSIONS**




| | |
|---|---|
| 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 |

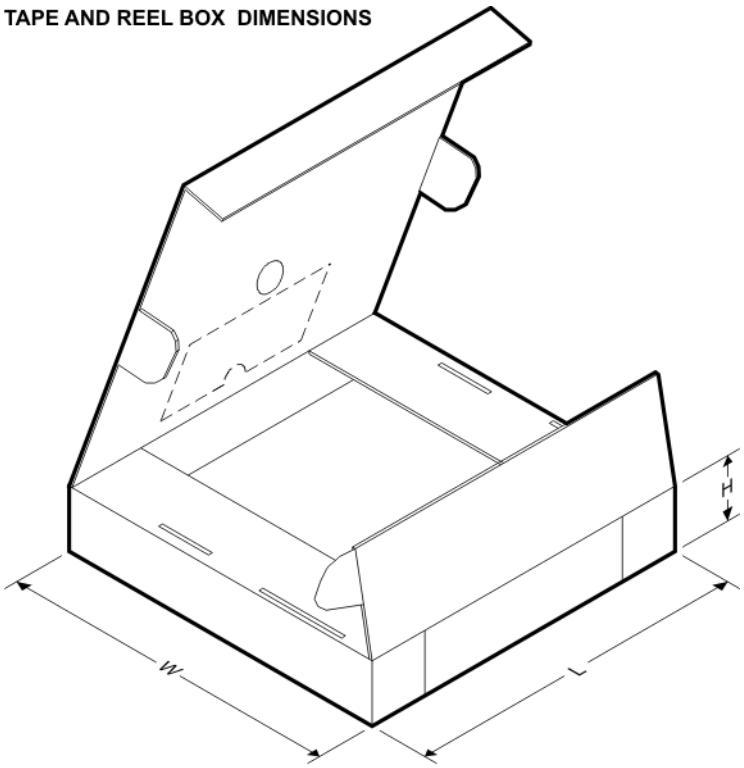
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OPA2365AQDRQ1 | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| OPA365AQDBVRQ1 | SOT-23 | DBV | 5 | 3000 | 179.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |

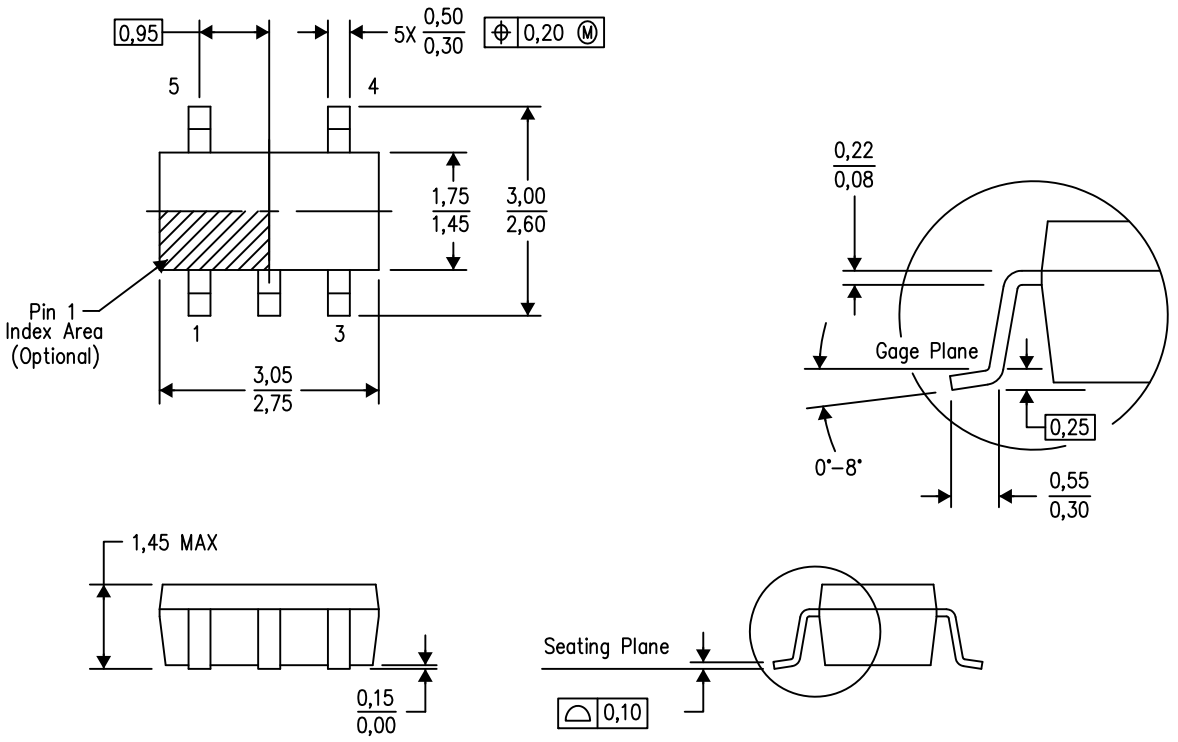
**TAPE AND REEL BOX DIMENSIONS**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| OPA2365AQDRQ1 | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| OPA365AQDBVRQ1 | SOT-23 | DBV | 5 | 3000 | 203.0 | 203.0 | 35.0 |

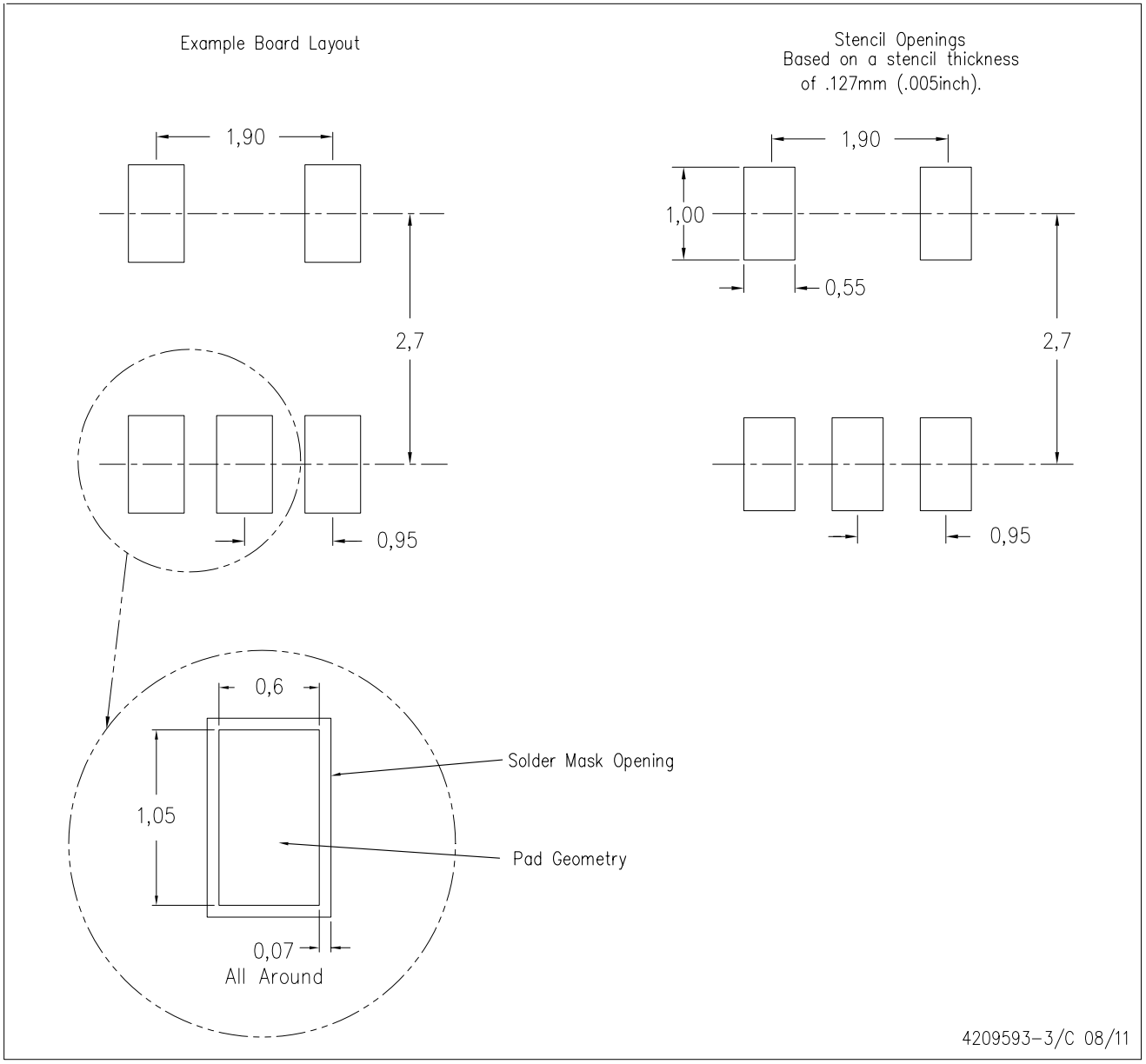
DBV (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE




4073253–4/L 08/2013

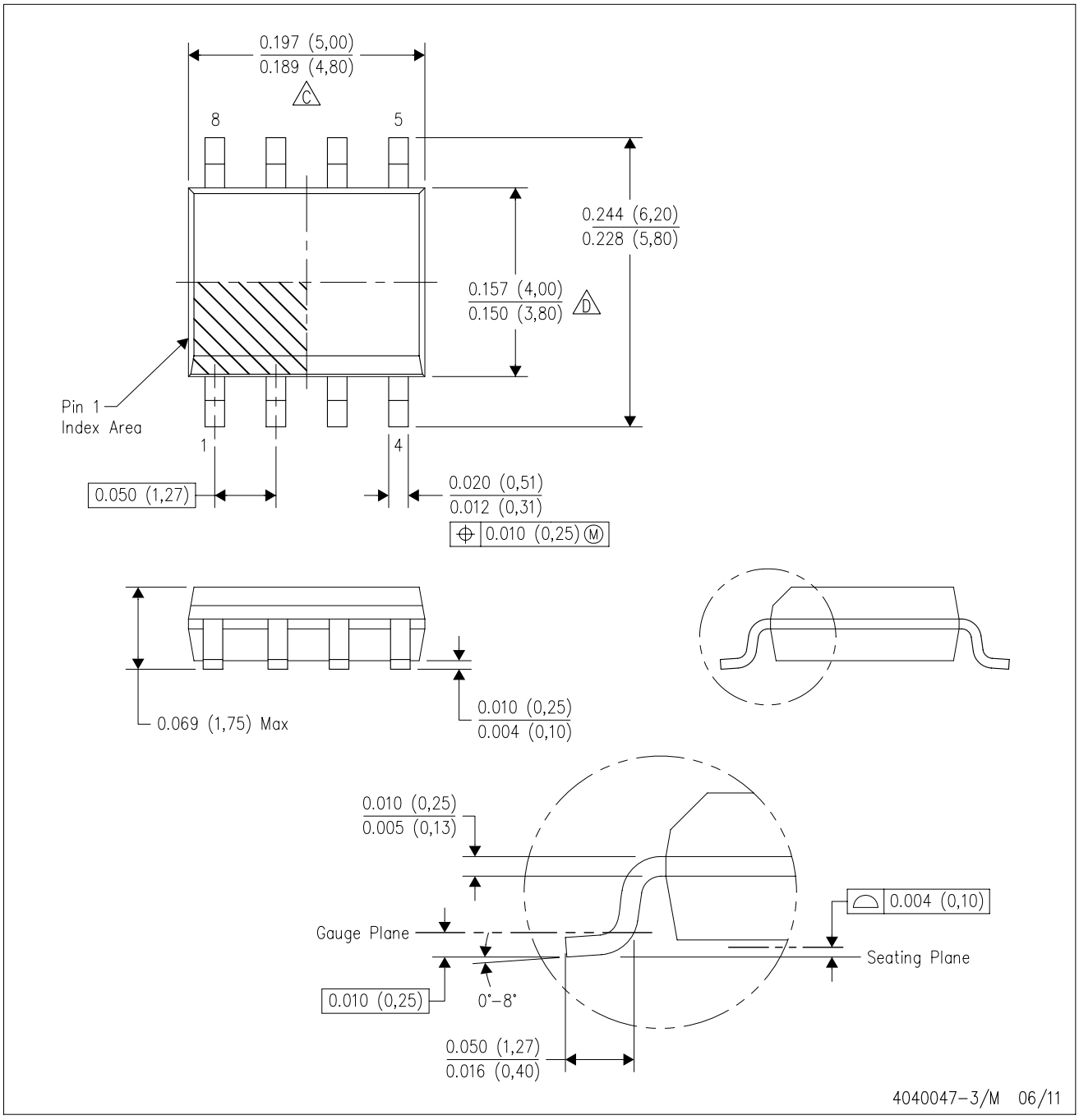
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–178 Variation AA.

DBV (R–PDSO–G5) PLASTIC SMALL OUTLINE




NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC–7351 is recommended for alternate designs.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE




NOTES:
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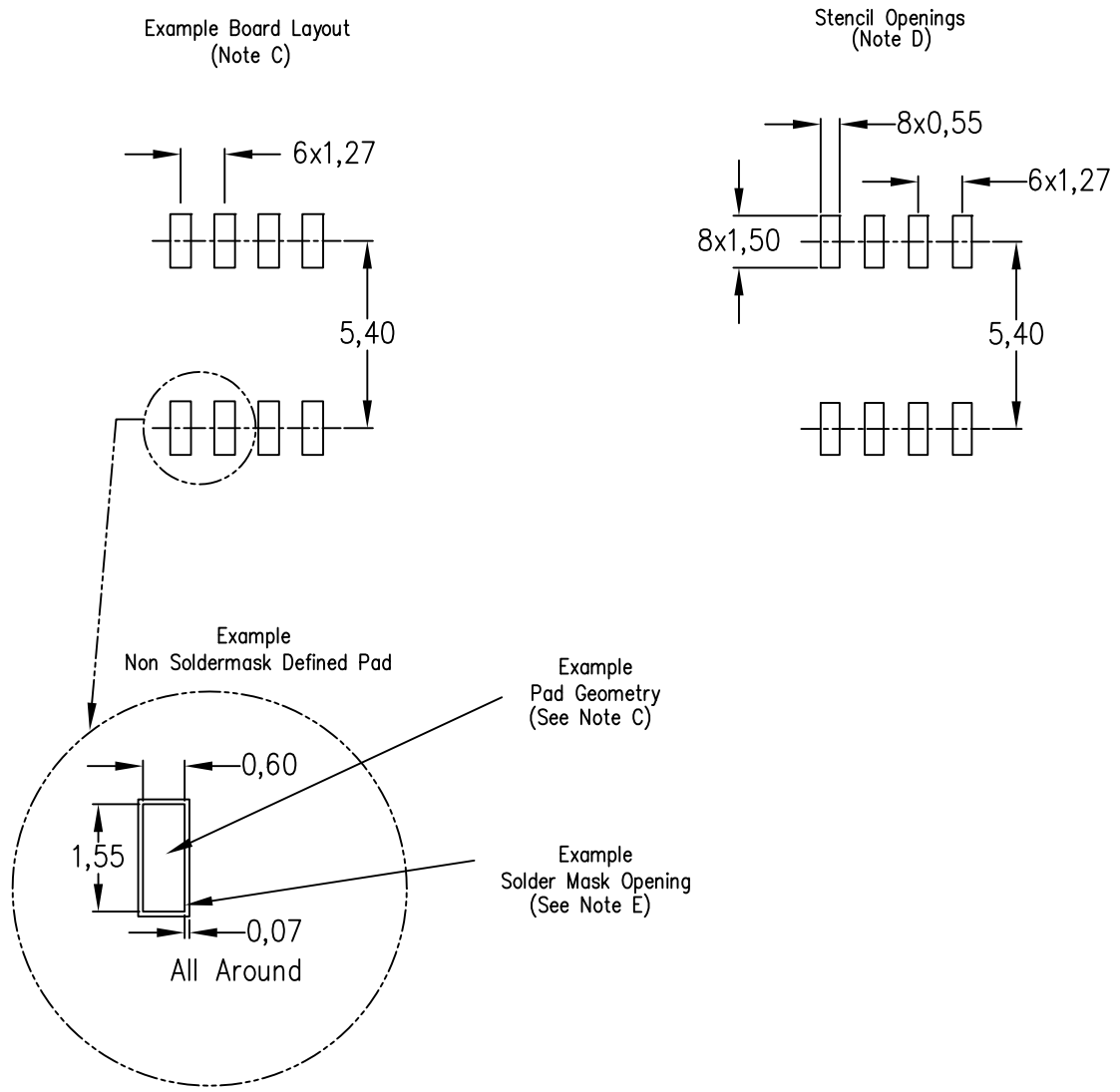
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AA.

D (R–PDSO–G8) PLASTIC SMALL OUTLINE




NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC–7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

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