

# TLVx365 50MHz、ゼロ クロスオーバー、高 CMRR、RRIO オペアンプ

## 1 特長

- ゲイン帯域幅: 50 MHz
- ゼロ クロスオーバー歪みトポロジ:
  - CMRR: 115dB (標準値)
  - レール ツー レール 入出力
    - 電源レールを 100mV 超える入力
- ノイズ: 4.5nV/√Hz
- スルーレート: 27V/μs
- 高速セトリング: 0.01% まで 0.2μs
- 精度:
  - オフセットドリフト: 2μV/°C (最大値)
  - 入力バイアス電流: 20pA (最大値)
- 動作電圧 2.2V~5.5V

## 2 アプリケーション

- シグナル・コンディショニング
- データ・アキュイジション
- アクティブ・フィルタ
- 試験用機器
- オーディオ
- 広帯域アンプ
- ラック・サーバー

## 3 概要

TLV365 および TLV2365 デバイス (TLVx365) は、ゼロクロスオーバー、レール ツー レール入出力の CMOS オペアンプのファミリーで、低電圧およびコスト重視のアプリケーション向けに最適化されています。低ノイズ (4.5nV/√Hz) および高速動作 (50MHz のゲイン帯域幅) であることから、これらのデバイスはローサイド電流センシング、オーディオ、シグナル コンディショニング、センサ増幅などのアプリケーションのサンプリング A/D コンバータ (ADC) を駆動するのに最適です。

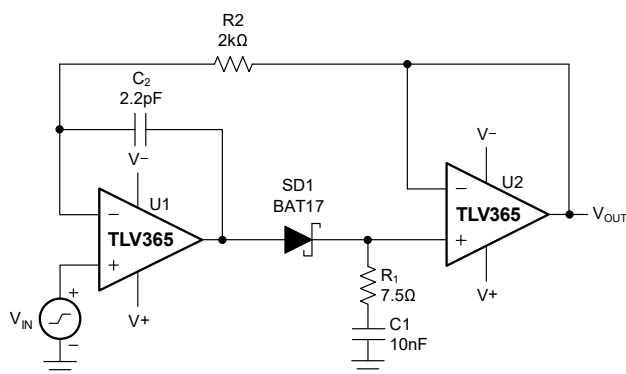
特長として、優れた同相除去比 (CMRR)、クロスオーバー歪みがない入力段、高い入力インピーダンス、およびレール ツー レールの入出力スイング能力が挙げられます。入力同相範囲には、負と正の電源の両方が含まれています。出力電圧のスイングは、レールの 10mV の範囲内です。

TLVx365 は、-40°C~+125°Cでの動作が規定されています。

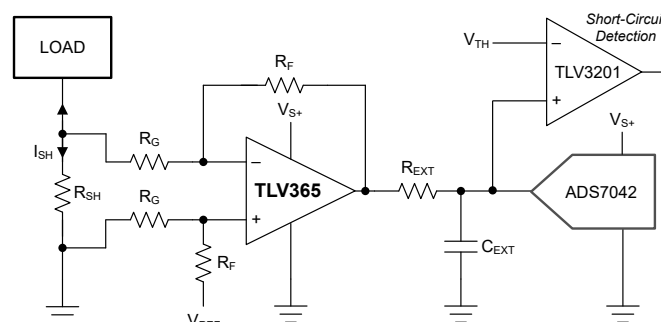
### 製品情報

| 部品番号    | チャンネル数 | パッケージ (1)       |
|---------|--------|-----------------|
| TLV365  | シングル   | DBV (SOT-23, 5) |
| TLV2365 | デュアル   | D (SOIC, 8)     |
|         | デュアル   | DGK (VSSOP, 8)  |

(1) 詳細については、[セクション 11](#) を参照してください。



高速セトリング ピーク検出器



電流検出



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## 4 Device Comparison Table

| DEVICE  | INPUT TYPE | OFFSET<br>DRIFT<br>TYPICAL<br>( $\mu\text{V}/^\circ\text{C}$ ) | MINIMUM<br>GAIN STABLE<br>(V/V) | $I_Q$ /CHANNEL<br>TYPICAL<br>(mA) | GAIN<br>BANDWIDTH<br>(MHz) | SLEW RATE<br>(V/ $\mu\text{s}$ ) | VOLTAGE<br>NOISE<br>(nV/ $\sqrt{\text{Hz}}$ ) |
|---------|------------|----------------------------------------------------------------|---------------------------------|-----------------------------------|----------------------------|----------------------------------|-----------------------------------------------|
| TLVx365 | CMOS       | 0.5                                                            | 1                               | 4.6                               | 50                         | 27                               | 4.5                                           |
| OPAx607 | CMOS       | 0.3                                                            | 6                               | 0.9                               | 50                         | 24                               | 3.8                                           |
| OPAx365 | CMOS       | 1                                                              | 1                               | 4.6                               | 50                         | 25                               | 4.5                                           |

## 5 Pin Configuration and Functions

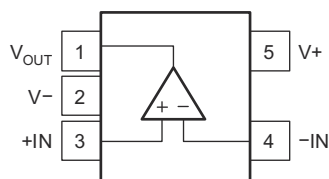


図 5-1. TLV365 DBV Package, 5-Pin SOT-23 (Top View)

表 5-1. Pin Functions: TLV365

| PIN              |     | TYPE   | DESCRIPTION                          |
|------------------|-----|--------|--------------------------------------|
| NAME             | NO. |        |                                      |
| –IN              | 4   | Input  | Negative (inverting) input signal    |
| +IN              | 3   | Input  | Positive (noninverting) input signal |
| V–               | 2   | —      | Negative (lowest) power supply       |
| V+               | 5   | —      | Positive (highest) power supply      |
| V <sub>OUT</sub> | 1   | Output | Output                               |

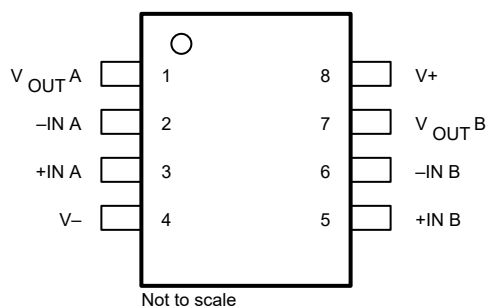


図 5-2. TLV2365 D Package, 8-Pin SOIC and DGK Package, 8-Pin VSSOP (Top View)

表 5-2. Pin Functions: TLV2365

| PIN                |     | TYPE   | DESCRIPTION                                     |
|--------------------|-----|--------|-------------------------------------------------|
| NAME               | NO. |        |                                                 |
| –IN A              | 2   | Input  | Negative (inverting) input signal, channel A    |
| –IN B              | 6   | Input  | Negative (inverting) input signal, channel B    |
| +IN A              | 3   | Input  | Positive (noninverting) input signal, channel A |
| +IN B              | 5   | Input  | Positive (noninverting) input signal, channel B |
| V–                 | 4   | —      | Negative (lowest) power supply                  |
| V+                 | 8   | —      | Positive (highest) power supply                 |
| V <sub>OUT</sub> A | 1   | Output | Output, channel A                               |
| V <sub>OUT</sub> B | 7   | Output | Output, channel B                               |

## 6 Specifications

### 6.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted)<sup>(1)</sup>

|                  |                                              | MIN        | MAX        | UNIT |
|------------------|----------------------------------------------|------------|------------|------|
| V <sub>S</sub>   | Supply voltage, V <sub>S</sub> = (V+) – (V–) |            | 6          | V    |
| V <sub>I</sub>   | Input voltage                                | (V–) – 0.5 | (V+) + 0.5 | V    |
| V <sub>ID</sub>  | Differential input voltage                   |            | ±5         | V    |
| I <sub>I</sub>   | Continuous input current <sup>(2)</sup>      |            | ±10        | mA   |
| I <sub>SC</sub>  | Output short-circuit <sup>(3)</sup>          | Continuous |            |      |
| T <sub>A</sub>   | Operating temperature                        | –40        | 125        | °C   |
| T <sub>J</sub>   | Junction temperature                         |            | 150        | °C   |
| T <sub>stg</sub> | Storage temperature                          | –65        | 150        | °C   |

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.

(2) Input pins are diode-clamped to the power-supply rails. Limit the current of input signals that can swing more than 0.5 V beyond the supply rails to 10 mA or less.

(3) Short-circuit to ground, one amplifier per package.

### 6.2 ESD Ratings

|                    |                         |                                                                       | VALUE | UNIT |
|--------------------|-------------------------|-----------------------------------------------------------------------|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>     | ±2000 | V    |
|                    |                         | Charged device model (CDM), per ANSI/ESDA/JEDEC JS-002 <sup>(2)</sup> | ±1000 |      |

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.

(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

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

|                |                                              | MIN | NOM | MAX | UNIT |
|----------------|----------------------------------------------|-----|-----|-----|------|
| V <sub>S</sub> | Supply voltage, V <sub>S</sub> = (V+) – (V–) | 2.2 |     | 5.5 | V    |
| T <sub>A</sub> | Specified temperature                        | –40 | 25  | 125 | °C   |

### 6.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                              | TLV365       | TLV2365  |             | UNIT |
|-------------------------------|----------------------------------------------|--------------|----------|-------------|------|
|                               |                                              | DBV (SOT-23) | D (SOIC) | DGK (VSSOP) |      |
|                               |                                              | 5 PINS       | 8 PINS   | 8 PINS      |      |
| R <sub>θJA</sub>              | Junction-to-ambient thermal resistance       | 179          | 140      | 179         | °C/W |
| R <sub>θJC(top)</sub>         | Junction-to-case (top) thermal resistance    | 78           | 89       | 71          | °C/W |
| R <sub>θJB</sub>              | Junction-to-board thermal resistance         | 46           | 80       | 101         | °C/W |
| ψ <sub>JT</sub>               | Junction-to-top characterization parameter   | 19           | 28       | 13          | °C/W |
| ψ <sub>JB</sub>               | Junction-to-board characterization parameter | 46           | 80       | 100         | °C/W |

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.5 Electrical Characteristics

at  $V_S = 2.2\text{ V to }5.5\text{ V}$ ,  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$ ,  $V_{CM} = V_{OUT} = \text{mid-supply}$ , and gain = 1 V/V (unless otherwise noted)

| PARAMETER                                 |                                                  | TEST CONDITIONS                                                          | MIN        | TYP                             | MAX  | UNIT             |
|-------------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------|------------|---------------------------------|------|------------------|
| OFFSET VOLTAGE                            |                                                  |                                                                          |            |                                 |      |                  |
| V <sub>OS</sub>                           | Input offset voltage                             |                                                                          |            | ±0.4                            | ±1.9 | mV               |
| dV <sub>OS</sub> /dT                      | Input offset voltage drift                       | T <sub>A</sub> = −40°C to +125°C                                         |            | ±0.5                            | ±2.6 | μV/°C            |
| PSRR                                      | Power-supply rejection ratio                     | V <sub>S</sub> = 2.2 V to 5.5 V, T <sub>A</sub> = −40 to +125°C          |            | 100                             |      | dB               |
| INPUT BIAS CURRENT                        |                                                  |                                                                          |            |                                 |      |                  |
| I <sub>B</sub>                            | Input bias current                               |                                                                          |            | ±5                              | ±20  | pA               |
|                                           |                                                  | T <sub>A</sub> = −40°C to +125°C                                         |            | See <a href="#">Figure 6-5</a>  |      |                  |
| NOISE                                     |                                                  |                                                                          |            |                                 |      |                  |
|                                           | Input voltage noise (peak-to-peak)               | f = 0.1 Hz to 10 Hz                                                      |            | 5.4                             |      | μV <sub>PP</sub> |
| e <sub>N</sub>                            | Input voltage noise density                      | f = 500 kHz                                                              |            | 4.5                             |      | nV/√Hz           |
| i <sub>n</sub>                            | Input current noise density                      | f = 1 kHz                                                                |            | 5.8                             |      | fA/√Hz           |
| INPUT VOLTAGE                             |                                                  |                                                                          |            |                                 |      |                  |
| V <sub>CM</sub>                           | Common-mode voltage                              |                                                                          | (V−) − 0.1 | (V+) + 0.1                      |      | V                |
| CMRR                                      | Common-mode rejection ratio                      | (V−) − 100 mV < V <sub>CM</sub> < (V+) + 100 mV                          | 100        | 115                             |      | dB               |
|                                           |                                                  | T <sub>A</sub> = −40°C to +125°C                                         |            | 110                             |      |                  |
| INPUT IMPEDANCE                           |                                                  |                                                                          |            |                                 |      |                  |
| C <sub>IN</sub>                           | Differential                                     |                                                                          |            | 5                               |      | pF               |
|                                           | Common-mode                                      |                                                                          |            | 1                               |      |                  |
| OPEN-LOOP GAIN                            |                                                  |                                                                          |            |                                 |      |                  |
| A <sub>OL</sub>                           | Open-loop voltage gain                           | R <sub>L</sub> = 10 kΩ, (V−) + 0.1 V < V <sub>OUT</sub> < (V+) − 0.1 V   | 100        | 120                             |      | dB               |
|                                           |                                                  | R <sub>L</sub> = 10 kΩ, T <sub>A</sub> = −40 to +125°C                   |            | 113                             |      |                  |
|                                           |                                                  | R <sub>L</sub> = 600 Ω, (V−) + 0.2 V < V <sub>OUT</sub> < (V+) − 0.2 V   | 100        | 120                             |      |                  |
|                                           |                                                  | R <sub>L</sub> = 600 Ω, T <sub>A</sub> = −40 to +125°C                   |            | 110                             |      |                  |
|                                           | Phase margin                                     |                                                                          |            | 56                              |      | °                |
| FREQUENCY RESPONSE (V <sub>S</sub> = 5 V) |                                                  |                                                                          |            |                                 |      |                  |
| GBW                                       | Gain-bandwidth product                           |                                                                          |            | 50                              |      | MHz              |
| SR                                        | Slew rate                                        |                                                                          |            | 27                              |      | V/μs             |
| t <sub>S</sub>                            | Settling time                                    | 0.1%, 4-V step                                                           |            | 0.15                            |      | μs               |
|                                           |                                                  | 0.01%, 4-V step                                                          |            | 0.2                             |      |                  |
|                                           | Overdrive recovery time                          | V <sub>IN+</sub> × gain > V <sub>S</sub>                                 |            | < 0.1                           |      | μs               |
| THD + N                                   | Total harmonic distortion + noise <sup>(1)</sup> | V <sub>OUT</sub> = 4 V <sub>PP</sub> , f = 1 kHz, R <sub>L</sub> = 600 Ω |            | 0.00025                         |      | %                |
|                                           | Channel-to-channel crosstalk (TLV2365 only)      | V <sub>OUT</sub> = 2 V <sub>PP</sub> , f = 100 kHz                       |            | 108                             |      | dBc              |
| OUTPUT                                    |                                                  |                                                                          |            |                                 |      |                  |
|                                           | Output voltage swing from supply rails           |                                                                          |            |                                 | 10   | mV               |
|                                           |                                                  | T <sub>A</sub> = −40°C to +125°C                                         |            |                                 | 12   |                  |
| I <sub>SC</sub>                           | Short-circuit current                            |                                                                          |            | ±85                             |      | mA               |
|                                           | Capacitive load drive                            |                                                                          |            | See <a href="#">Figure 6-16</a> |      |                  |
| Z <sub>O</sub>                            | Open-loop output impedance                       | f = 1 MHz, I <sub>O</sub> = 0 mA                                         |            | 40                              |      | Ω                |
| POWER SUPPLY                              |                                                  |                                                                          |            |                                 |      |                  |
| I <sub>Q</sub>                            | Quiescent current per amplifier                  | I <sub>O</sub> = 0 mA                                                    |            | 4.6                             | 5.8  | mA               |
|                                           |                                                  | I <sub>O</sub> = 0 mA, T <sub>A</sub> = −40°C to +125°C                  |            |                                 | 6.3  |                  |

(1) Low-pass-filter bandwidth is 20 kHz for  $f = 1\text{ kHz}$ .

## 6.6 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ , and gain = 1 V/V (unless otherwise noted)

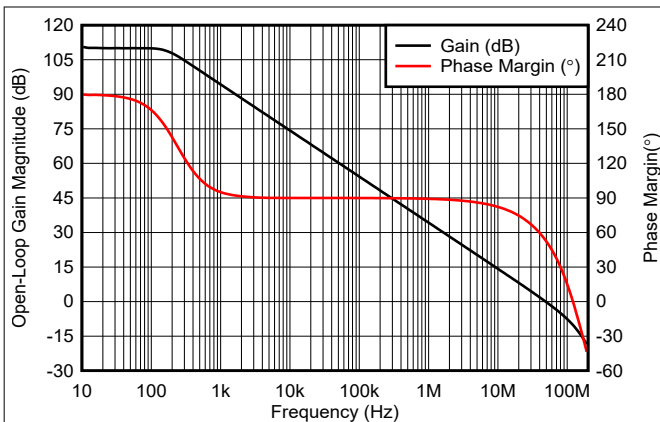


图 6-1. Open-Loop Gain and Phase vs Frequency

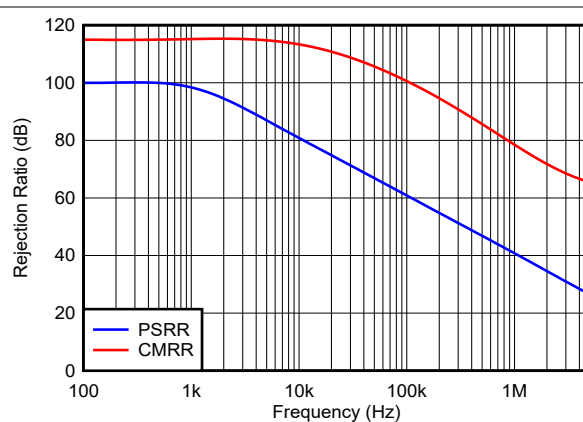


图 6-2. Power-Supply and Common-Mode Rejection Ratio

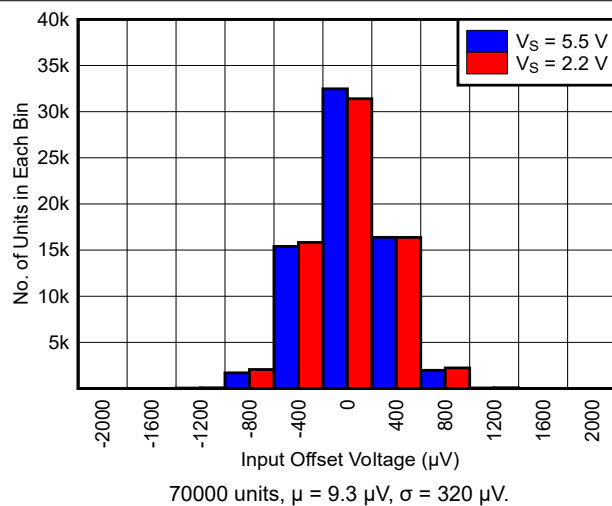


图 6-3. Offset Voltage Production Distribution

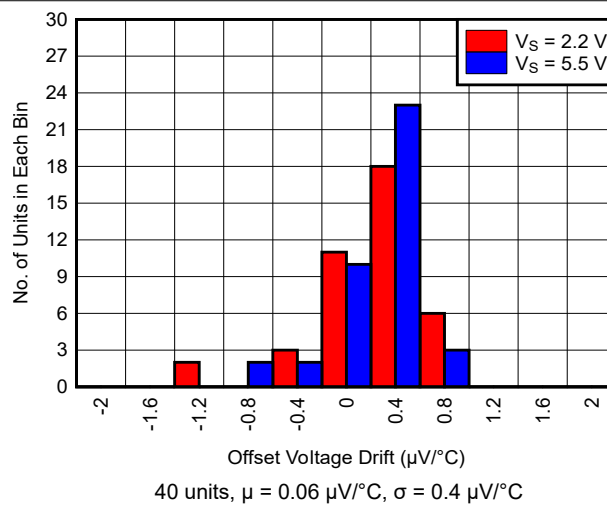


图 6-4. Offset Voltage Drift Distribution

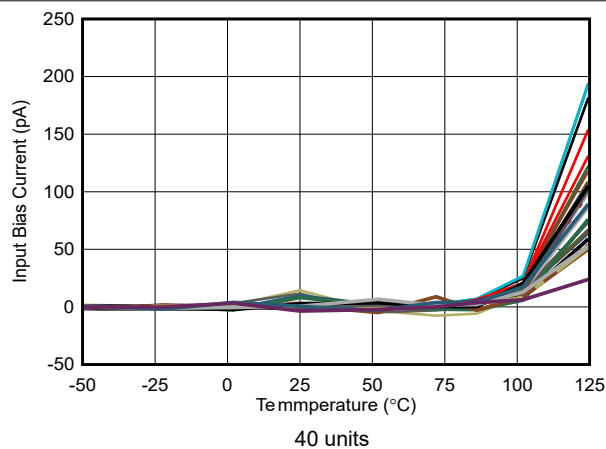


图 6-5. Input Bias Current vs Temperature

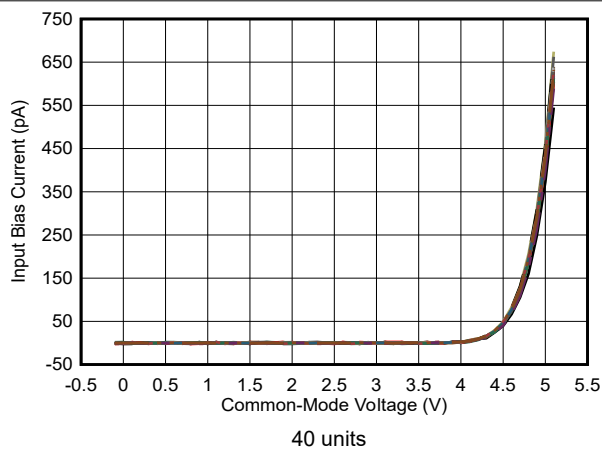


图 6-6. Input Bias Current vs Common-Mode Voltage

## 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ , and gain = 1 V/V (unless otherwise noted)

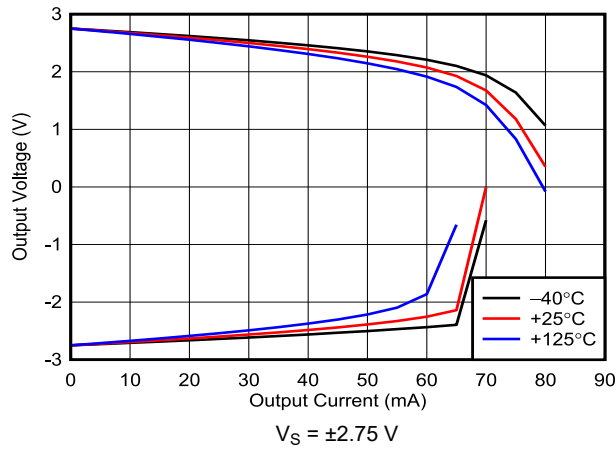


図 6-7. Output Voltage vs Output Current

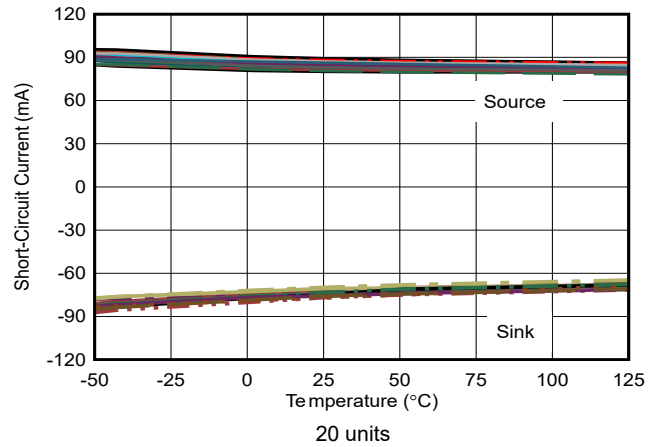


図 6-8. Short-Circuit Current vs Temperature

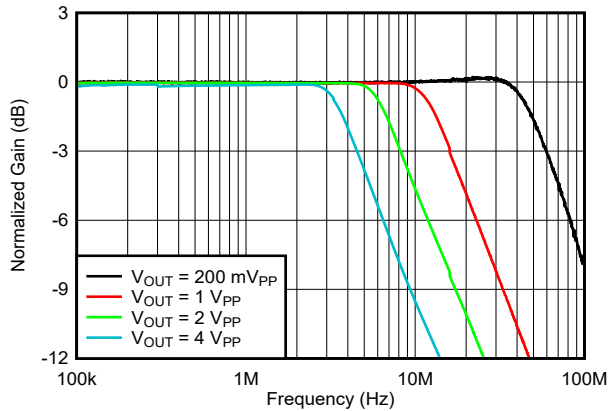


図 6-9. Frequency Response vs Output Voltage

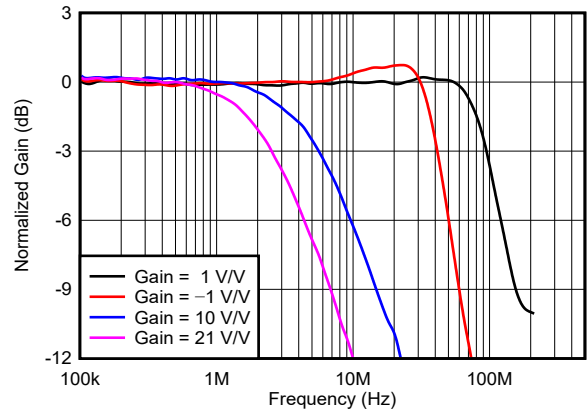


図 6-10. Small-Signal Frequency Response vs Gain

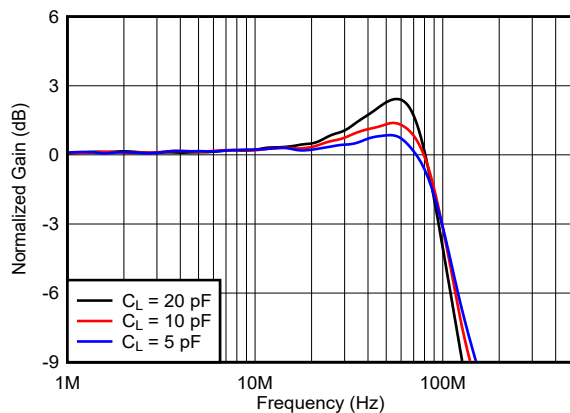


図 6-11. Small-Signal Response vs Capacitive Load

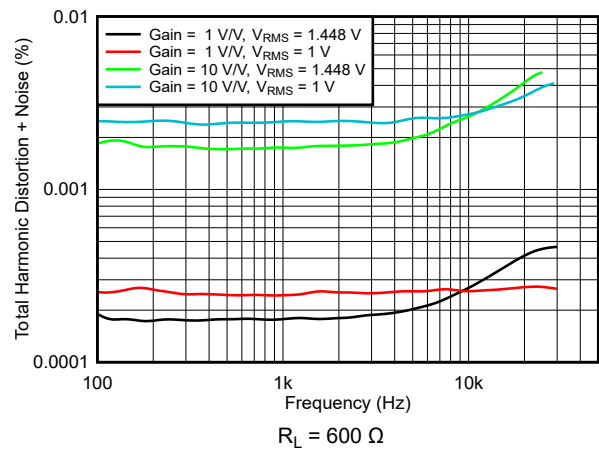


図 6-12. Total Harmonic Distortion + Noise vs Frequency

## 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ , and gain = 1 V/V (unless otherwise noted)

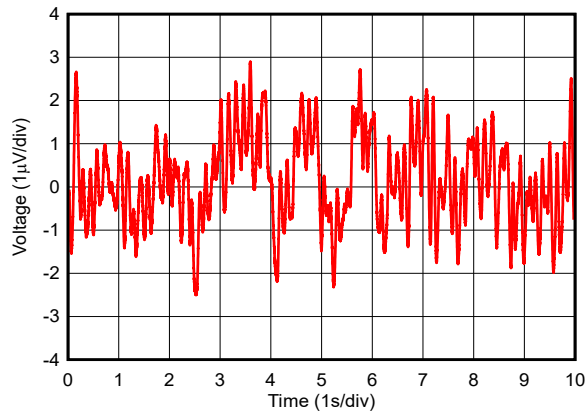


Figure 6-13. 0.1-Hz to 10-Hz Input Voltage Noise

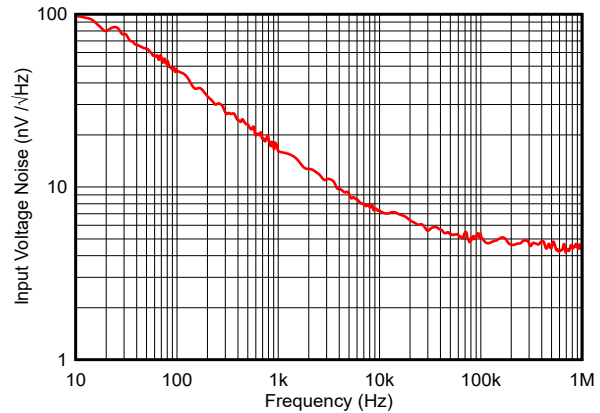


Figure 6-14. Input Voltage Noise Spectral Density

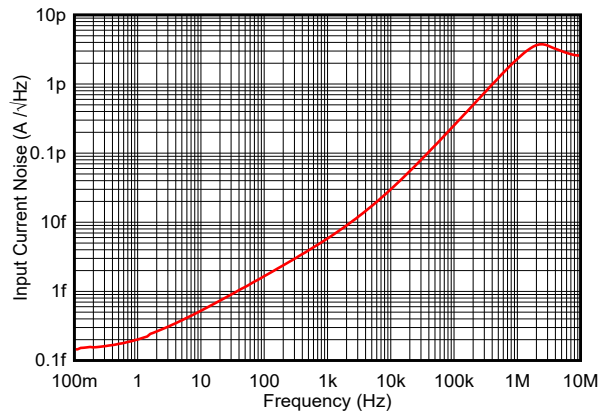
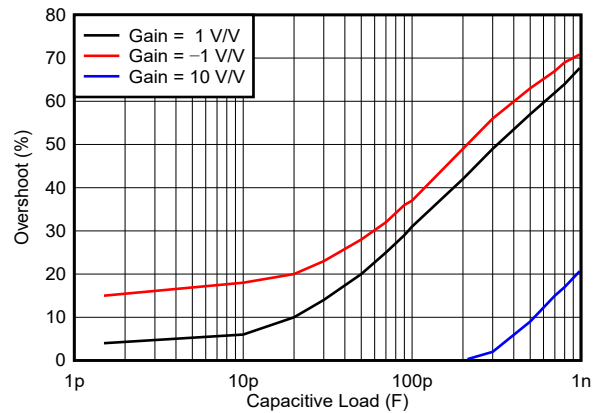


Figure 6-15. Input Current Noise Spectral Density



For gain  $\neq 1\text{ V/V}$ ,  $R_F = 1\text{ k}\Omega$   
 For gain = 1 V/V,  $R_F = 0\text{ }\Omega$

Figure 6-16. Overshoot vs Capacitive Load

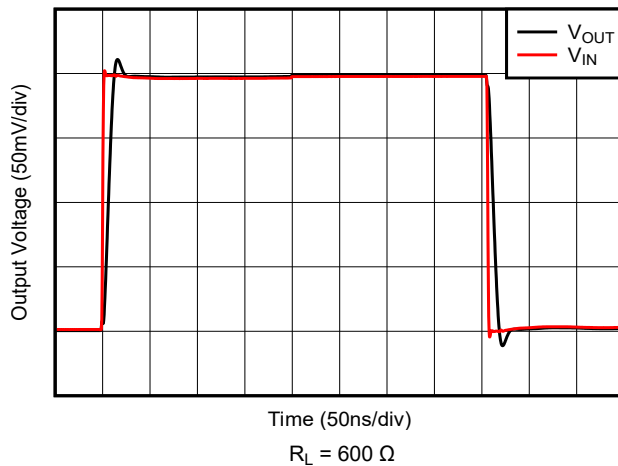


Figure 6-17. Small-Signal Step Response

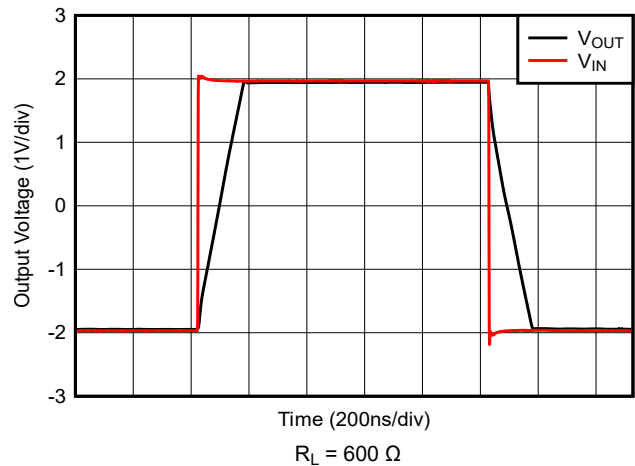


Figure 6-18. Large-Signal Step Response

## 6.6 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_S = 5\text{ V}$ ,  $R_L = 10\text{ k}\Omega$ , and gain = 1 V/V (unless otherwise noted)

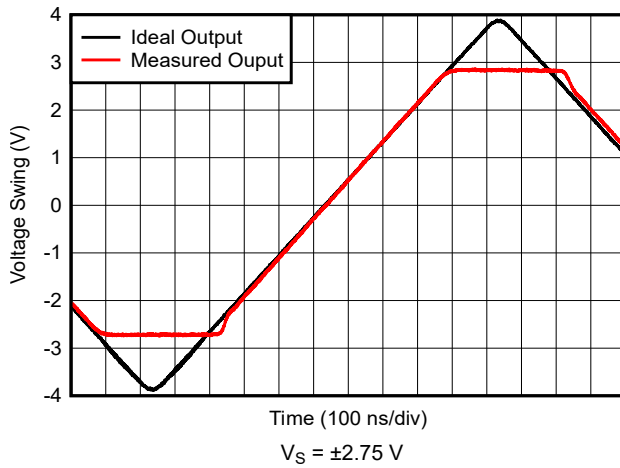


图 6-19. Overdrive Recovery

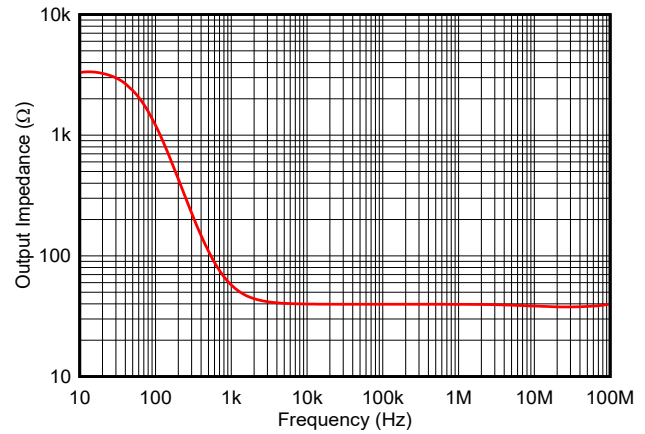


图 6-20. Open-Loop Output Impedance

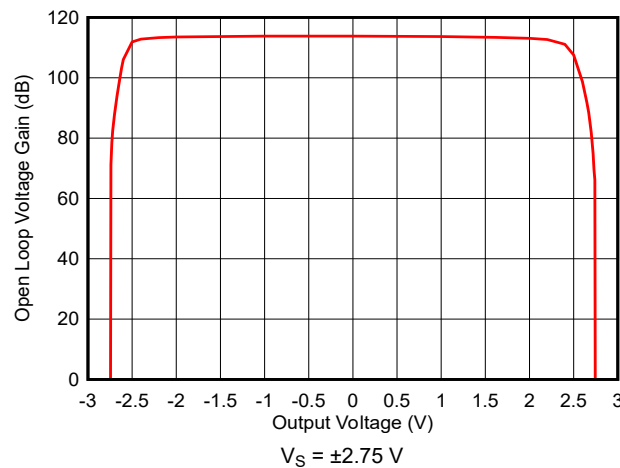


图 6-21. Open Loop Voltage Gain vs Output Voltage

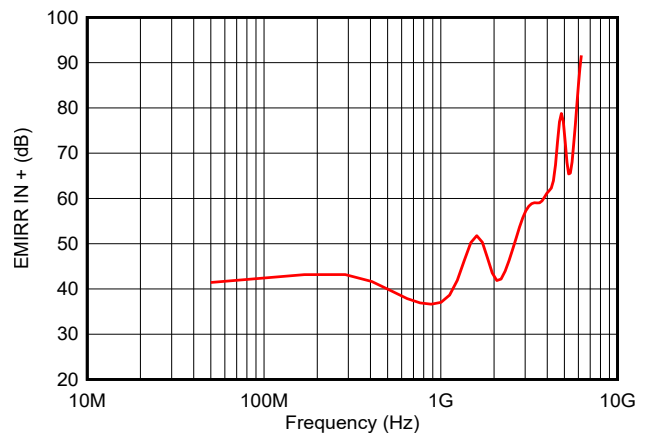


图 6-22. Electromagnetic Interference Rejection Ratio Referred to Noninverting Input (EMIRR+) vs Frequency

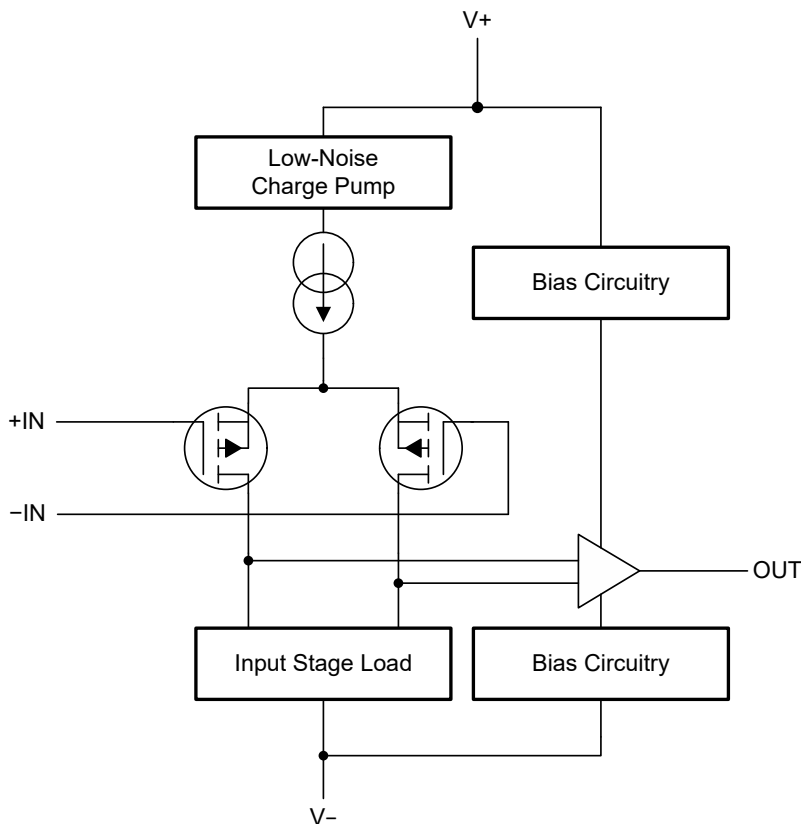
## 7 Detailed Description

### 7.1 Overview

The TLVx365 series of operational amplifiers feature rail-to-rail input and output, wide-bandwidth making these devices an excellent choice for driving ADCs. Other typical applications include signal conditioning, low-side current sensing, signal buffering and sensor amplification. The TLVx365 operates with either a single supply or dual supplies.

Furthermore, the TLVx365 amplifier parameters are fully specified from 2.2 V to 5.5 V. Many of the specifications apply from  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$ .

### 7.2 Functional Block Diagram



## 7.3 Feature Description

### 7.3.1 Rail-to-Rail Input

The TLVx365 product family features true rail-to-rail input operation, with supply voltages as low as  $\pm 1.1$  V (2.2 V). A unique zero-crossover input topology eliminates the input offset transition region typical of many rail-to-rail, complementary stage operational amplifiers. As shown in [Figure 7-1](#), this topology also allows the TLVx365 to provide excellent common-mode performance over the entire input range, which extends 100 mV beyond both power-supply rails. When driving ADCs, the highly linear  $V_{CM}$  range of the TLVx365 makes sure that the system linearity performance is not compromised. For a simplified schematic illustrating the rail-to-rail input circuitry, see [Section 7.2](#).

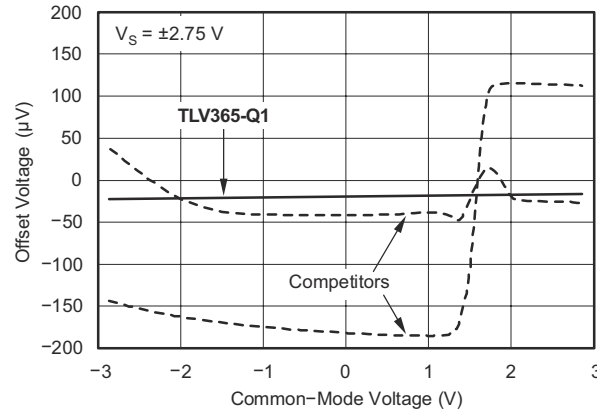


**Figure 7-1. TLVx365 Linear Offset Over the Entire Common-Mode Range**

### 7.3.2 Input and ESD Protection

[Figure 7-2](#) shows that the TLVx365 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 if the current is limited to 10 mA; see also [Section 6.1](#). [Figure 7-3](#) shows how a series input resistor can be added to the driven input to limit the input current. The added resistor contributes thermal noise at the amplifier input; the resistor must be kept to the minimum value in noise-sensitive applications.

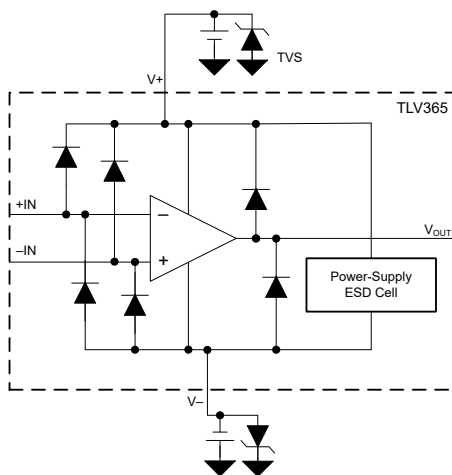


**Figure 7-2. ESD Protection Scheme**

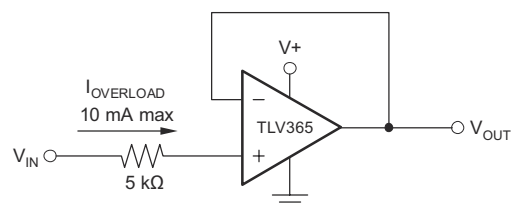


**Figure 7-3. Input Current Protection**

### 7.3.3 Driving Capacitive Loads

The TLVx365 can be used in applications where driving a capacitive load is required. An op amp in a unity-gain, buffer configuration and driving a capacitive load exhibits a greater tendency to be unstable than an amplifier operated at a higher gain. The capacitive load, in conjunction with the op-amp output impedance, creates a pole within the feedback loop that degrades the phase margin. The degradation of the phase margin increases as the capacitive loading increases.

**Improving Capacitive Load Drive** shows one technique to increase the capacitive-load drive capability of the amplifier operating in unity gain is to insert a small resistor,  $R_{ISO}$ , in series with the output. This resistor significantly reduces the overshoot and ringing associated with capacitive loads.

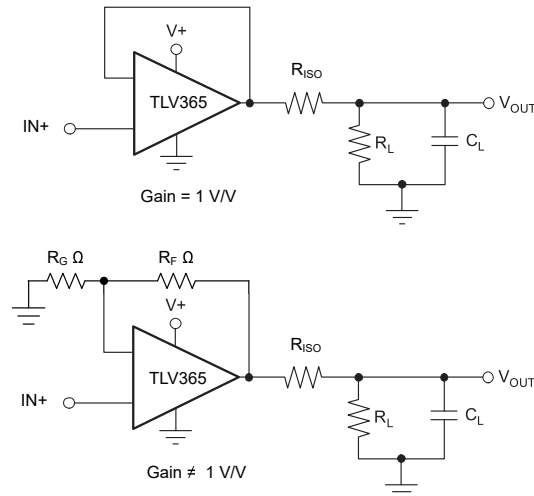


图 7-4. Improving Capacitive Load Drive

A possible drawback of this technique is the voltage divider created with the added series resistor ( $R_{ISO}$ ) and any resistor ( $R_L$ ) connected in parallel with the capacitive load. The voltage divider introduces a gain error at the output that also reduces the output swing. The error contributed by the voltage divider can be insignificant. For instance, with a load resistance of  $R_L = 10 \text{ k}\Omega$  and  $R_{ISO} = 20 \Omega$ , the gain error is only approximately 0.2%.

The following figure shows the recommended isolation resistor ( $R_{ISO}$ ) to be connected at the output of TLVx365 for different capacitive loads. The TLVx365 can drive higher capacitive loads without the need of isolation resistors at higher gains.

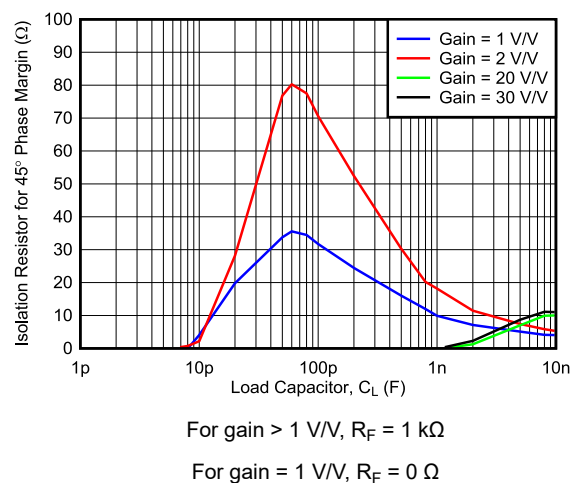


图 7-5. Recommended Isolation Resistor vs Capacitive Load

### 7.3.4 Active Filter

The TLVx365 is an excellent choice for active filter applications requiring a wide bandwidth, fast slew rate, low-noise, single-supply operational amplifier. Figure 7-6 shows a 500-kHz, second-order, low-pass filter using a multiple-feedback (MFB) topology. The components have been selected to provide a maximally-flat Butterworth response. Beyond the cutoff frequency, rolloff is  $-40$  dB/dec. The Butterworth response is designed for applications requiring predictable gain characteristics, such as the antialiasing filter used ahead of an ADC.

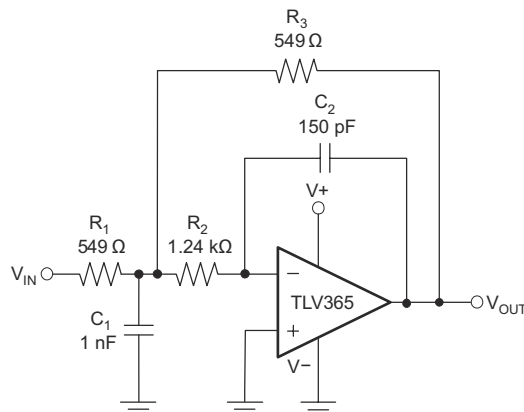


Figure 7-6. Second-Order Butterworth, 500-kHz Low-Pass Filter

When considering the MFB filter, the output is inverted, relative to the input. If this inversion is not desired, then a noninverting output can be achieved through one of these options:

- add an inverting amplifier
- add an additional second-order MFB stage
- use a noninverting filter topology, such as the Sallen-Key

Figure 7-7 shows the Sallen-Key topology.

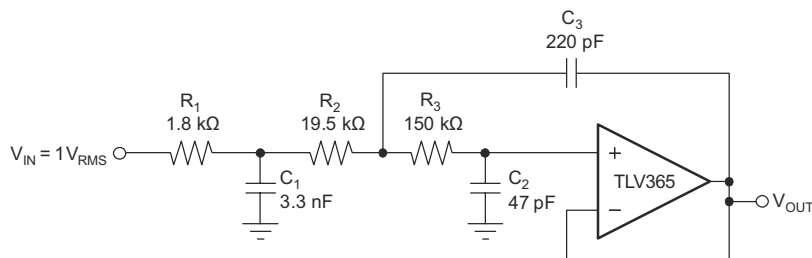


Figure 7-7. Configured as a Three-Pole, 20-kHz, Sallen-Key Filter

## 7.4 Device Functional Modes

The TLVx365 have a single-mode of operation. The devices can be configured with unipolar supplies, split and symmetrical bipolar supplies ( $\pm 2.5$  V, for example), or split and asymmetrical supplies ( $+4$  V and  $-1$  V, for example). There are no power-down or low-power modes in the TLVx365.

## 8 Application and Implementation

### 注

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

### 8.1 Application Information

The TLVx365 offer outstanding dc and ac performance. These devices operate with up to a 5.5-V power supply, offer an ultra-low input bias current and a 50-MHz bandwidth with true rail-to-rail input capability.

#### 8.1.1 Overdrive Recovery Performance

The TLVx365 family exhibits excellent overdrive recovery when the output is driven well beyond the  $V_+$  or  $V_-$  supplies. When configured in a low-side current-sensing configuration (see [Figure 8-1](#)), the output of the op amp (TLVx365) is often driven to or less than ground as a result of ground bounce at the power ground or the  $\leq 0$ -A current being measured across shunt resistance  $R_{SH}$ . The TLVx365 has the ability to recover from an overdrive event in  $< 100$  ns. [Figure 8-2](#) shows the comparison of the overdrive recovery performance of TLVx365 and other popular op amps in the same category.

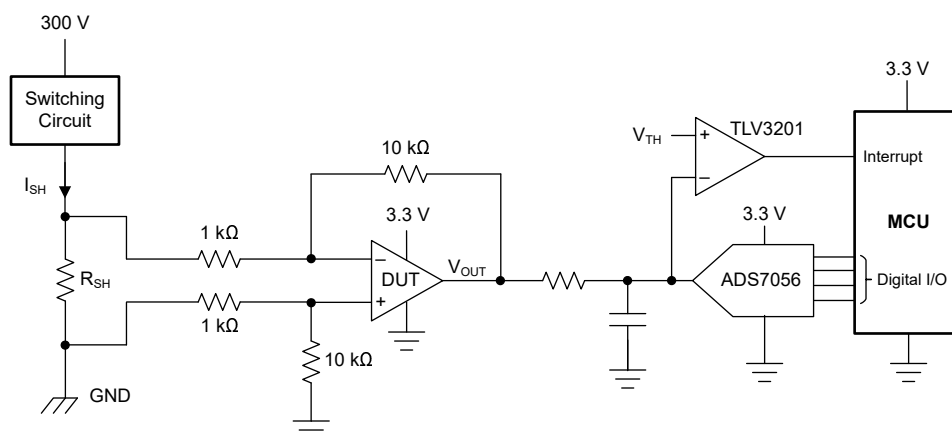
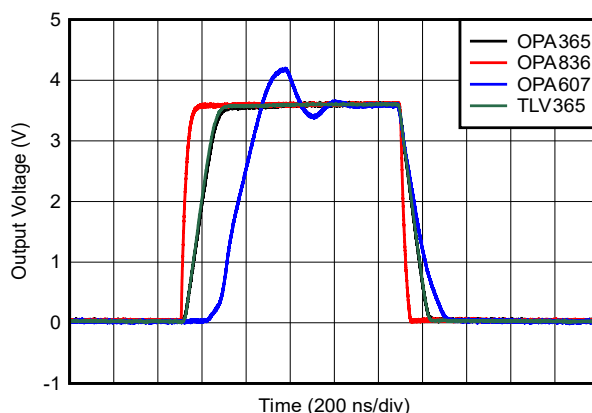


**Figure 8-1. Low-Side Current-Sensing Application Circuit**



Gain = 10 V/V,  $V_{OUT}$  driven to  $(V_-) - 1$  V

**Figure 8-2. TLVx365 Overdrive Recovery**

### 8.1.2 Achieving an Output Level of Zero Volts

Certain single-supply applications require the op-amp output to swing from 0 V 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 0 V to 3.3 V. Rail-to-rail output amplifiers with very light output loading can achieve an output level within few millivolts of 0 V (or V+ at the high end), but not true 0 V. Furthermore, the deviation from 0 V only becomes greater as the required load current 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 TLVx365 can achieve an output level of 0 V, and even a few millivolts below 0 V. Figure 8-3 shows a circuit using this technique.

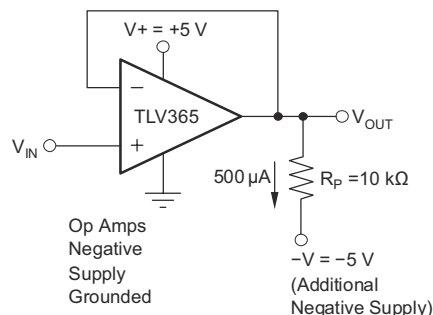


Figure 8-3. Swing-to-Ground

A pulldown current of approximately 500 μA is required when TLVx365 is connected as a unity-gain buffer. Pulldown resistor  $R_L$  is calculated from  $R_L = [(V_O - V_{NEG}) / (500 \mu A)]$ .

Figure 8-4 shows the offset voltage vs output swing.

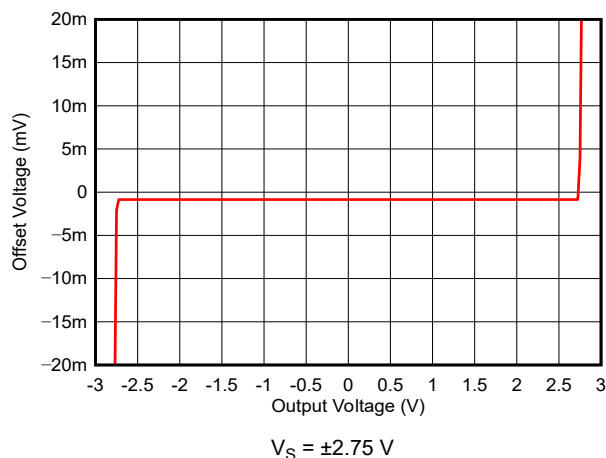
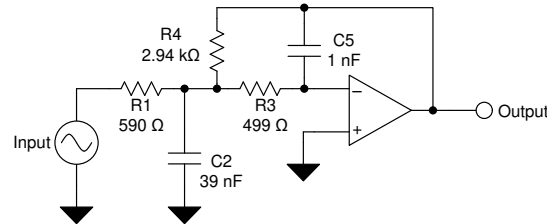


Figure 8-4. Offset Voltage vs Output Swing

## 8.2 Typical Applications

### 8.2.1 Second-Order Low-Pass Filter

Low-pass filters are commonly employed in signal processing applications to reduce noise and prevent aliasing. The TLVx365 is designed to construct high-speed, high-precision active filters. [Figure 8-5](#) shows a second-order low-pass filter commonly encountered in signal processing applications.



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**Figure 8-5. Second-Order Low-Pass Filter**

#### 8.2.1.1 Design Requirements

Use the following parameters for this design example:

- Gain = 5 V/V (inverting gain)
- Low-pass cutoff frequency = 25 kHz
- Second-order, Chebyshev filter response with 3-dB gain peaking in the pass band

#### 8.2.1.2 Detailed Design Procedure

[Figure 8-5](#) shows the infinite-gain, multiple-feedback circuit for a low-pass network function. Use [Equation 1](#) to calculate the voltage transfer function.

$$\frac{\text{Output}}{\text{Input}}(s) = \frac{-1/R_1 R_3 C_2 C_5}{s^2 + (s/C_2)(1/R_1 + 1/R_3 + 1/R_4) + 1/R_3 R_4 C_2 C_5} \quad (1)$$

This circuit produces a signal inversion. For this circuit, use [Equation 2](#) to calculate the gain at dc and the low-pass cutoff frequency.

$$\begin{aligned} \text{Gain} &= \frac{R_4}{R_1} \\ f_c &= \frac{1}{2\pi} \sqrt{(1/R_3 R_4 C_2 C_5)} \end{aligned} \quad (2)$$

### 8.2.1.3 Application Curve

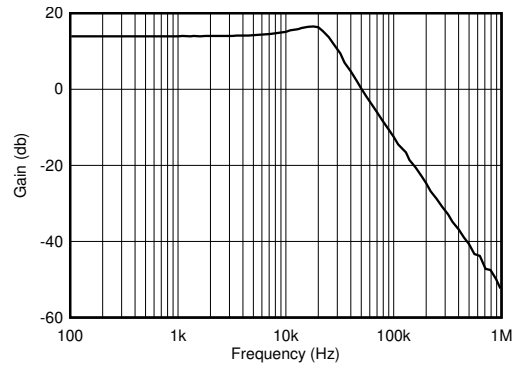


図 8-6. TLVx365 Second-Order 25 kHz, Chebyshev, Low-Pass Filter

### 8.2.2 ADC Driver and Reference Buffer

Figure 8-7 shows the use of a TLVx365 op amp as a SAR ADC input and reference pin driver. Sensors, which are used for interfacing with the physical environment, exhibit high output impedance and cannot drive SAR ADC inputs directly. The TLVx365 devices exhibit a very low-input bias current of 20 pA (maximum), and therefore do not load these high-output impedance sensors. A wide-GBW amplifier connected to the output of these sensors is needed to charge the switching capacitors at the SAR ADC input and to settle fast, to the required accuracy, within the given acquisition time.

The ADC core draws transient current from the reference input during the conversion (digitization) phase, which must be driven with a wide-GBW amplifier to offer fast settling and maintain a stable reference voltage for excellent digitization performance. The TLVx365 reference buffer is used in a composite loop with the OPA378 precision amplifier because of limitations in precision performance of wide-GBW amplifiers. The precision amplifier maintains low-offset output, whereas the TLVx365 provide the output drive and fast-settling performance.

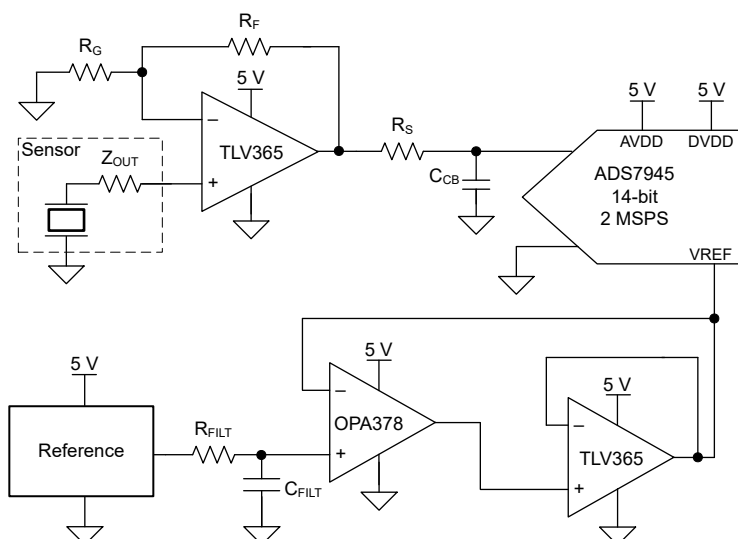


Figure 8-7. TLVx365 as a SAR ADC Driver

### 8.3 Power Supply Recommendations

The TLVx365 family can be configured with unipolar supplies, split and symmetrical bipolar supplies ( $\pm 2.5$  V, for example), or split and asymmetrical supplies (+4 V and  $-1$  V, for example). The maximum permissible voltage,  $V_S$ , is 6 V.

## 8.4 Layout

### 8.4.1 Layout Guidelines

For best operational performance of the device, use good printed circuit board (PCB) layout practices, including the following guidelines:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole or through the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1- $\mu$ F ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
  - The TLVx365 is capable of peak output current (in excess of 50 mA). Applications with low impedance loads or capacitive loads with fast transient signals demand large currents from the power supplies. Larger bypass capacitors, such as 1- $\mu$ F solid tantalum capacitors, can improve dynamic performance in these applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. [Figure 8-8](#) shows that keeping  $R_F$  and  $R_G$  close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.

### 8.4.2 Layout Example

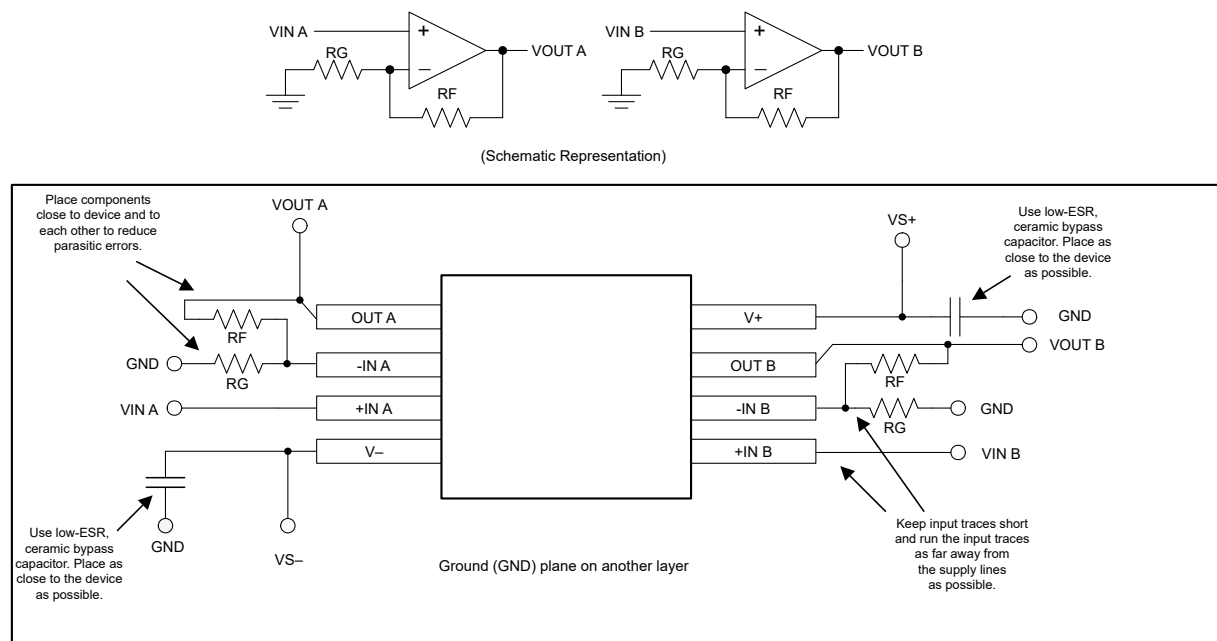


**Figure 8-8. Layout Recommendation for TLV2365 SOIC Package**

## 9 Device and Documentation Support

### 9.1 Device Support

#### 9.1.1 Development Support

##### 9.1.1.1 PSpice® for TI

**PSpice® for TI** は、アナログ回路の性能評価に役立つ設計およびシミュレーション環境です。レイアウトと製造に移る前に、サブシステムの設計とプロトタイプ・ソリューションを作成することで、開発コストを削減し、市場投入までの期間を短縮できます。

##### 9.1.1.2 TINA-TI™シミュレーション ソフトウェア (無償ダウンロード)

TINA-TI™ シミュレーション ソフトウェアは、SPICE エンジンに基づいた単純かつ強力な、使いやすい回路シミュレーション プログラムです。TINA-TI シミュレーション ソフトウェアは、TINA™ ソフトウェアのすべての機能を持つ無償バージョンで、パッシブ モデルとアクティブ モデルに加えて、マクロモデルのライブラリがプリロードされています。TINA-TI シミュレーション ソフトウェアには、SPICE の標準的な DC 解析、過渡解析、周波数ドメイン解析などの全機能に加え、追加の設計機能が搭載されています。

TINA-TI シミュレーション ソフトウェアは**設計およびシミュレーション ツール Web ページ**から**無料でダウンロード**でき、ユーザーが結果をさまざまな形式で処理できる、広範な後処理機能を備えています。仮想計測器により、入力波形を選択し、回路ノード、電圧、および波形をプローブして、動的なクイック スタート ツールを作成できます。

#### 注

これらのファイルを使用するには、TINA ソフトウェアまたは TINA-TI ソフトウェアがインストールされている必要があります。**TINA-TI™ ソフトウェア フォルダ**から、無償の TINA-TI シミュレーション ソフトウェアをダウンロードしてください。

##### 9.1.1.3 DIP アダプタ評価基板

**DIP アダプタ評価基板**は、オペアンプの迅速なプロトタイプ製作とテストを可能にする評価基板です。小型の表面実装デバイスとのインターフェイスを迅速、容易、低コストで実現します。付属の Samtec 端子ストリップか、直接配線により既存の回路へサポートされているオペアンプを接続します。DIP アダプタ評価基板キットは、以下の業界標準パッケージをサポートしています。D または U (SOIC-8)、PW (TSSOP-8)、DGK (VSSOP-8)、DBV (SOT-23-6、SOT-23-5、および SOT-23-3)、DCK (SC70-6 および SC70-5)、および DRL (SOT563-6)。

##### 9.1.1.4 DIYAMP-EVM

**DIYAMP-EVM** は、実際のアンプ回路を提供する独自の評価基板 (EVM) であり、設計コンセプトの迅速な評価とシミュレーションの検証を実現します。この評価基板は、3 つの業界標準パッケージ (SC70、SOT23、SOIC) で供給されており、シングル / デュアル電源向けに、アンプ、フィルタ、安定性補償、コンパレータの各構成など、12 の一般的なアンプ構成が可能です。

##### 9.1.1.5 TI のリファレンス・デザイン

TI のリファレンス・デザインは、TI の高精度アナログ・アプリケーション専門家により作成されたアナログ・ソリューションです。TI のリファレンス・デザインは、動作原理、部品の選択、シミュレーション、完全な PCB 回路図およびレイアウト、部品表、測定済みの性能を提供します。TI のリファレンス・デザインは、<http://www.ti.com/ww/en/analog/precision-designs/> からオンラインで入手できます。

##### 9.1.1.6 Analog Filter Designer

**Analog Filter Designer** は、**設計およびシミュレーション ツール Web ページ**から **Web ベースのツール**として利用でき、包括的な複数段アクティブ フィルタ ソリューションの設計、最適化、シミュレーションをわずか数分で行います。

## 9.2 Documentation Support

### 9.2.1 Related Documentation

The following documents are relevant to using the TLVx365, and recommended for reference. All are available for download at [www.ti.com](http://www.ti.com) unless otherwise noted.

- Texas Instruments, [FilterPro™ software user's guide](#)
- Texas Instruments, [Low Power Input and Reference Driver Circuit for ADS8318 and ADS8319 application report](#)
- Texas Instruments, [Op Amp Performance Analysis application bulletin](#)
- Texas Instruments, [Single-Supply Operation of Operational Amplifiers application bulletin](#)
- Texas Instruments, [The Best of Baker's Best – Amplifiers eBook reference book](#)

## 9.3 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、[www.tij.co.jp](http://www.tij.co.jp) のデバイス製品フォルダを開いてください。[通知] をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取ることができます。変更の詳細については、改訂されたドキュメントに含まれている改訂履歴をご覧ください。

## 9.4 サポート・リソース

テキサス・インスツルメンツ E2E™ サポート・フォーラムは、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計に必要な支援を迅速に得ることができます。

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## 9.5 Trademarks

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TINA™ is a trademark of DesignSoft, Inc.

PSpice® is a registered trademark of Cadence Design Systems, Inc.

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## 9.6 静電気放電に関する注意事項



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ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

## 9.7 用語集

[テキサス・インスツルメンツ用語集](#) この用語集には、用語や略語の一覧および定義が記載されています。

## 10 Revision History

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

| Changes from Revision B (September 2023) to Revision C (August 2024)                       | Page |
|--------------------------------------------------------------------------------------------|------|
| • データシートに TLV2365 DGK パッケージを追加.....                                                        | 1    |
| • Updated offset drift spec of TLVx365.....                                                | 2    |
| • Updated input offset voltage drift typical and maximum value.....                        | 5    |
| • Added CMRR minimum value for room temperature.....                                       | 5    |
| • Deleted A <sub>OL</sub> minimum values across temperature and added typical values ..... | 5    |
| • Updated <i>Device Functional Modes</i> .....                                             | 13   |

|                                                     |                    |
|-----------------------------------------------------|--------------------|
| • Updated <i>Power Supply Recommendations</i> ..... | <a href="#">18</a> |
|-----------------------------------------------------|--------------------|

|                                                                           |             |
|---------------------------------------------------------------------------|-------------|
| <b>Changes from Revision A (June 2023) to Revision B (September 2023)</b> | <b>Page</b> |
|---------------------------------------------------------------------------|-------------|

|                                                  |                   |
|--------------------------------------------------|-------------------|
| • TLV2365 のステータスを「事前情報」から「量産データ」(アクティブ) に変更..... | <a href="#">1</a> |
|--------------------------------------------------|-------------------|

|                                                                          |             |
|--------------------------------------------------------------------------|-------------|
| <b>Changes from Revision * (December 2022) to Revision A (June 2023)</b> | <b>Page</b> |
|--------------------------------------------------------------------------|-------------|

|                                              |                   |
|----------------------------------------------|-------------------|
| • TLV2365 のステータスを「開発中製品」から「事前情報」に変更.....     | <a href="#">1</a> |
| • Added <i>Device Comparison Table</i> ..... | <a href="#">2</a> |

## 11 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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## PACKAGING INFORMATION

| Orderable part number       | Status<br>(1) | Material type<br>(2) | Package   Pins   | Package qty   Carrier | RoHS<br>(3) | Lead finish/<br>Ball material<br>(4) | MSL rating/<br>Peak reflow<br>(5) | Op temp (°C) | Part marking<br>(6) |
|-----------------------------|---------------|----------------------|------------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| <a href="#">TLV2365DGKR</a> | Active        | Production           | VSSOP (DGK)   8  | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | 2365                |
| TLV2365DGKR.A               | Active        | Production           | VSSOP (DGK)   8  | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | 2365                |
| <a href="#">TLV2365DR</a>   | Active        | Production           | SOIC (D)   8     | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | T2365D              |
| TLV2365DR.A                 | Active        | Production           | SOIC (D)   8     | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | T2365D              |
| <a href="#">TLV365DBVR</a>  | Active        | Production           | SOT-23 (DBV)   5 | 3000   LARGE T&R      | Yes         | NIPDAU   SN                          | Level-1-260C-UNLIM                | -40 to 125   | T365                |
| TLV365DBVR.A                | Active        | Production           | SOT-23 (DBV)   5 | 3000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | T365                |

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **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.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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.

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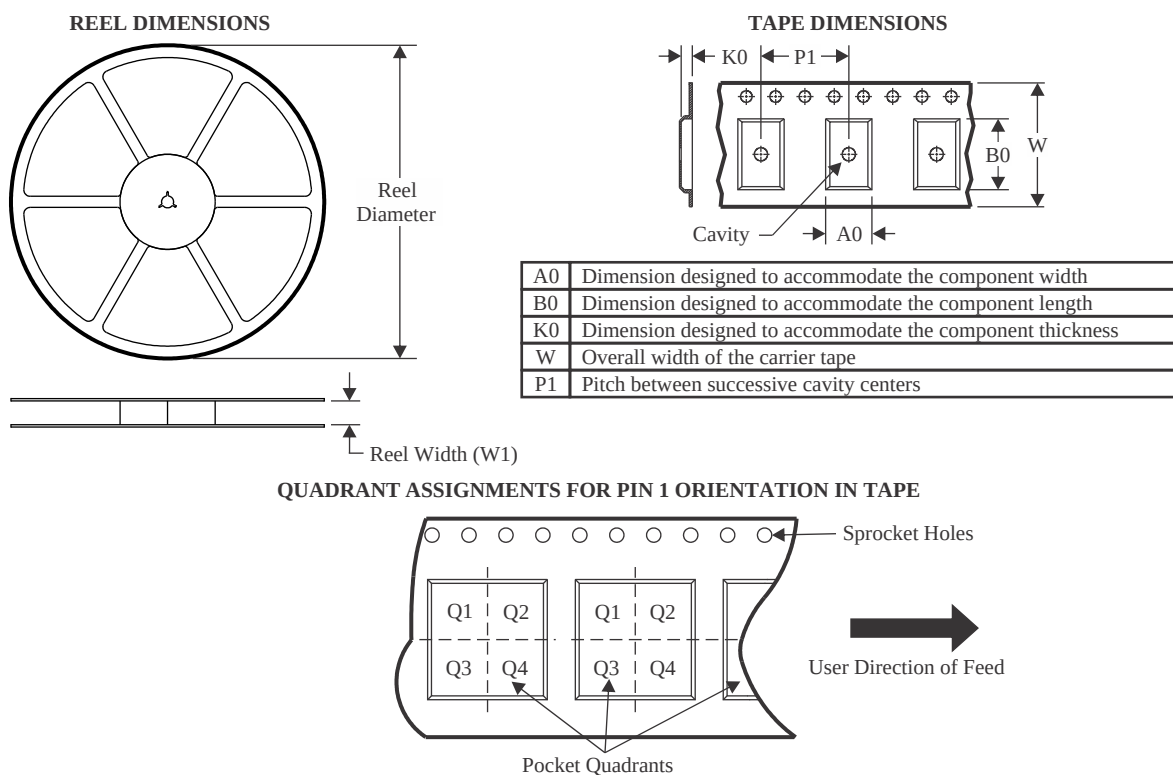
**OTHER QUALIFIED VERSIONS OF TLV2365, TLV365 :**

- Automotive : [TLV2365-Q1](#), [TLV365-Q1](#)

NOTE: Qualified Version Definitions:

- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

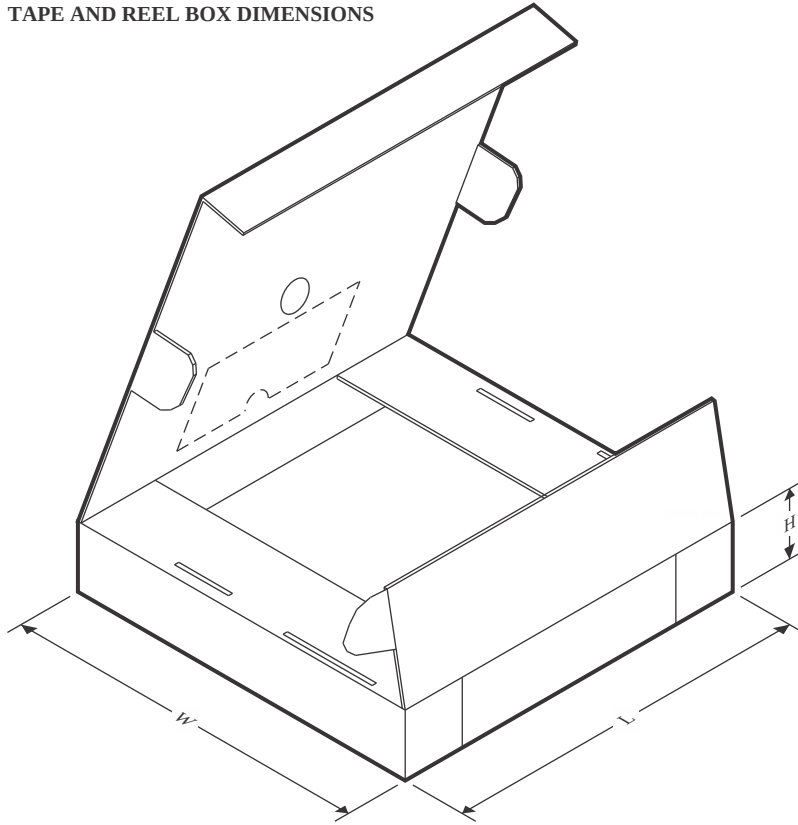
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

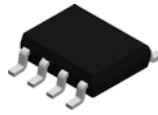
| Device      | Package Type | Package Drawing | Pins | SPQ  | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|-------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TLV2365DGKR | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.3     | 3.4     | 1.4     | 8.0     | 12.0   | Q1            |
| TLV2365DR   | SOIC         | D               | 8    | 3000 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TLV365DBVR  | SOT-23       | DBV             | 5    | 3000 | 180.0              | 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) |
|-------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TLV2365DGKR | VSSOP        | DGK             | 8    | 2500 | 353.0       | 353.0      | 32.0        |
| TLV2365DR   | SOIC         | D               | 8    | 3000 | 353.0       | 353.0      | 32.0        |
| TLV365DBVR  | SOT-23       | DBV             | 5    | 3000 | 210.0       | 185.0      | 35.0        |

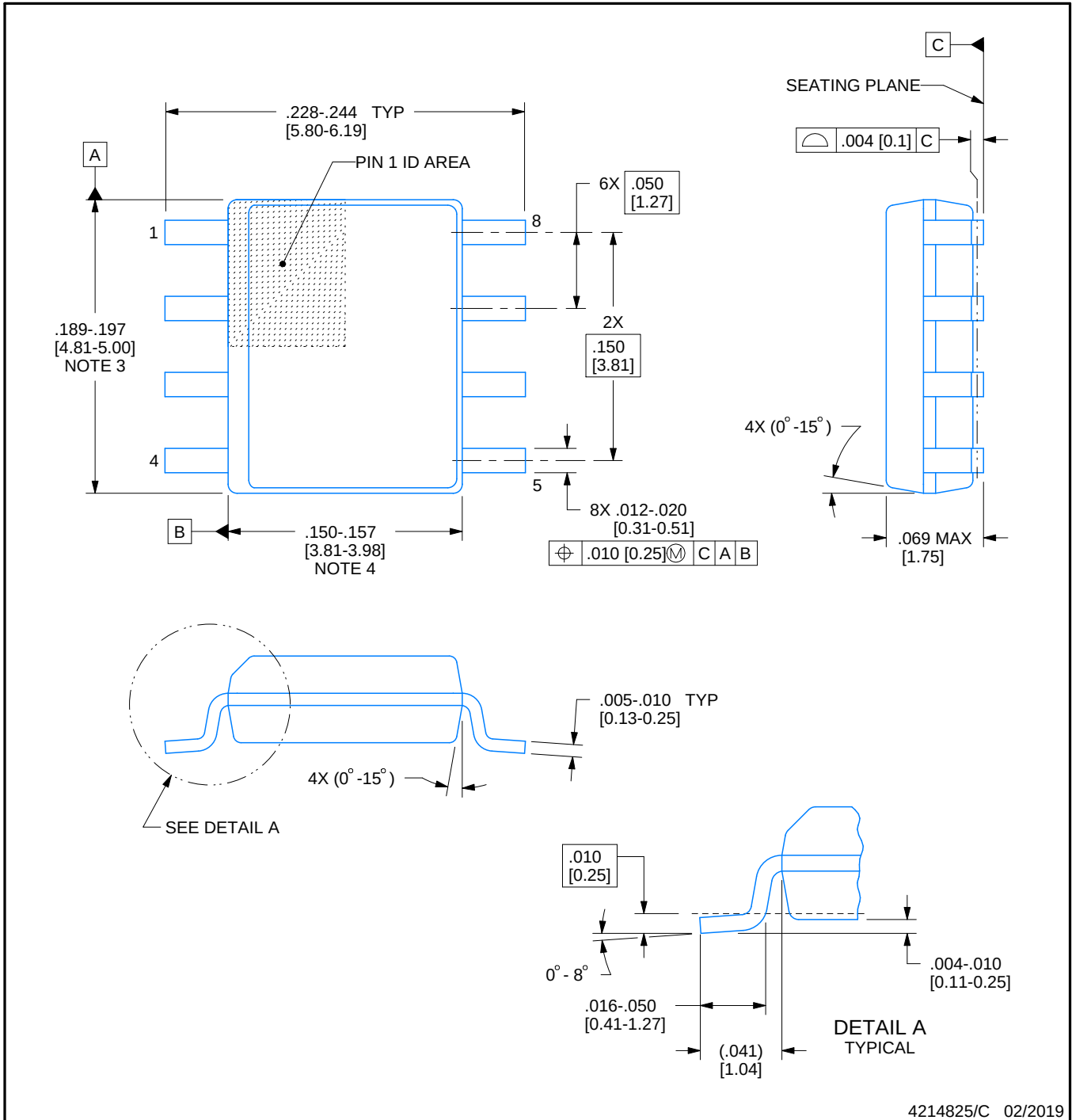


**D0008A**

# PACKAGE OUTLINE

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



## NOTES:

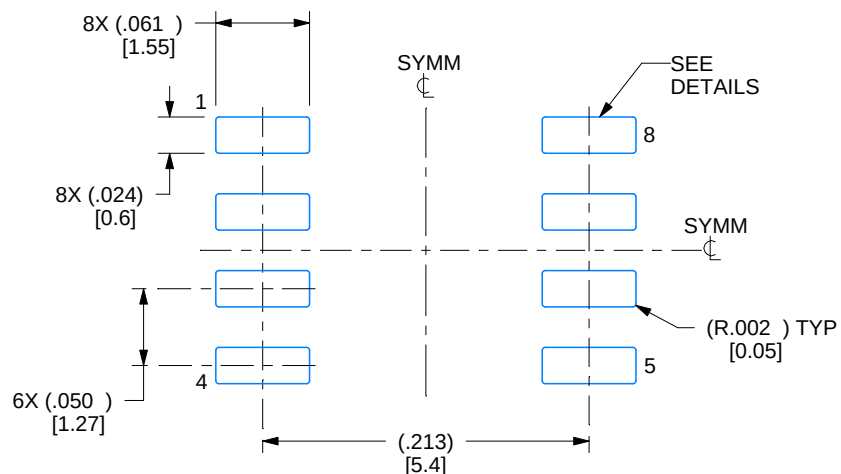
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.

# EXAMPLE BOARD LAYOUT

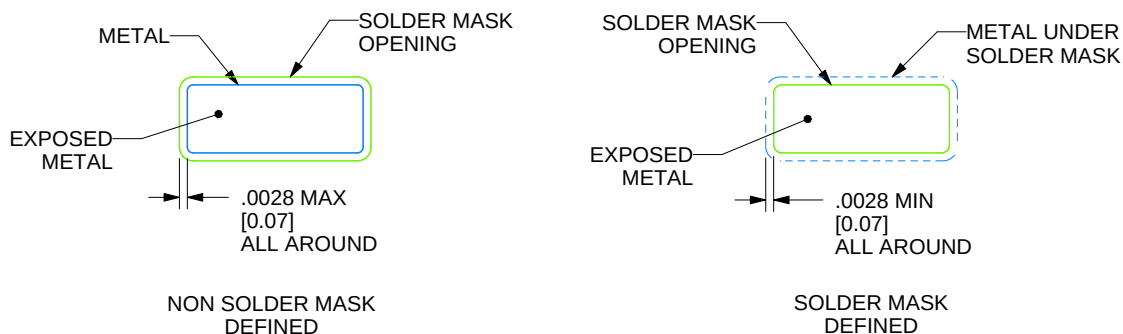
D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

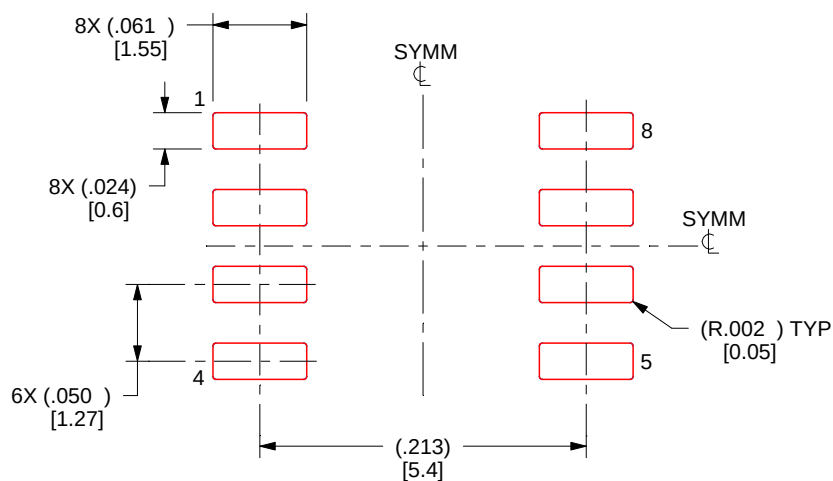
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

4214825/C 02/2019

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.

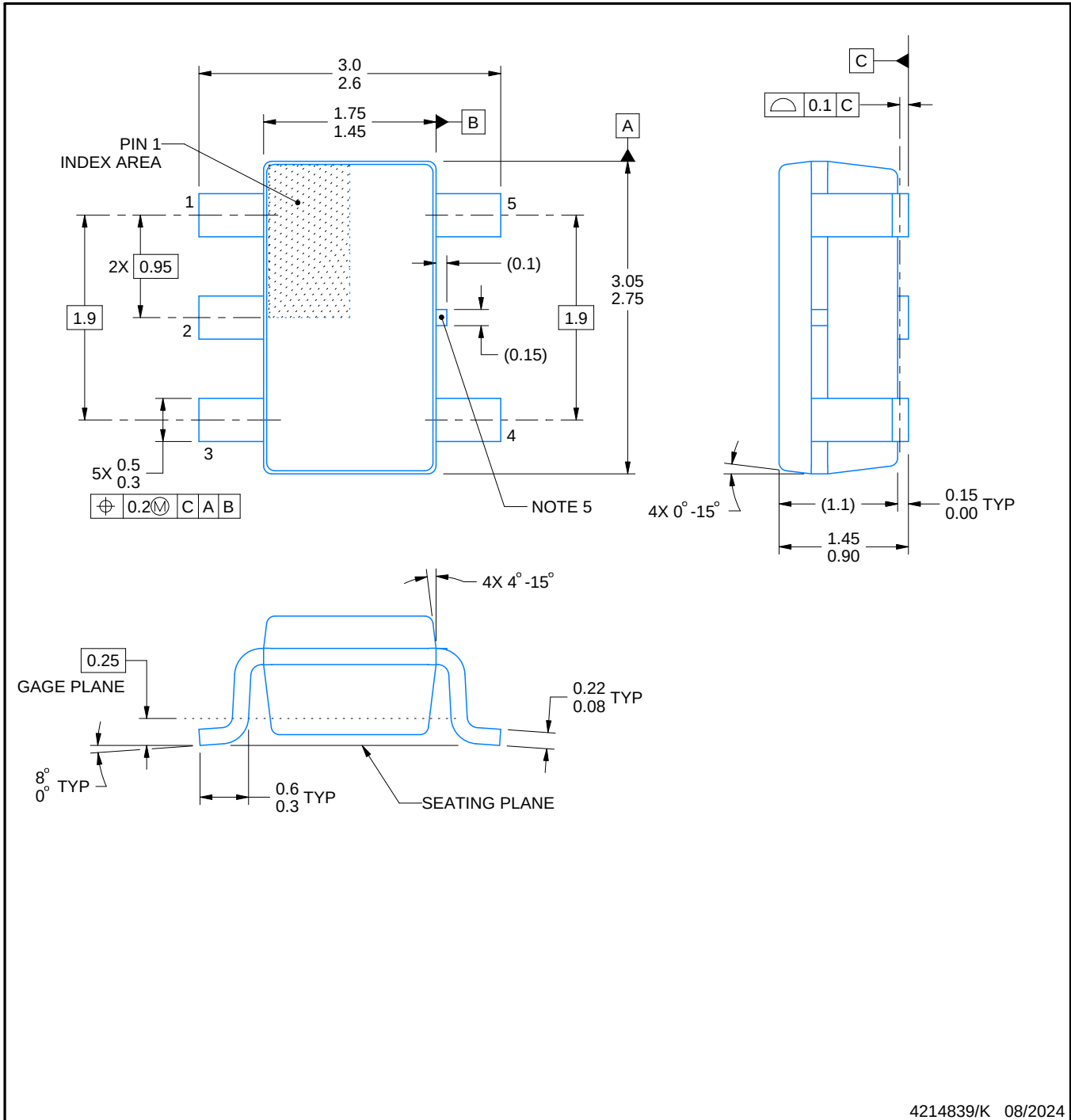


**DBV0005A**

# PACKAGE OUTLINE

**SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



4214839/K 08/2024

## NOTES:

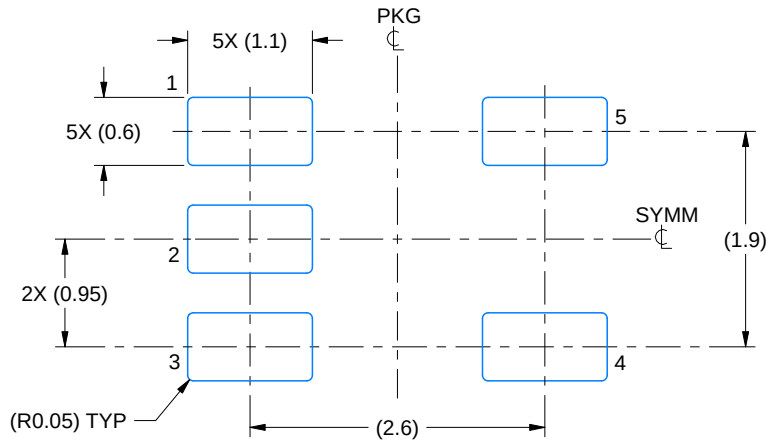
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.

# EXAMPLE BOARD LAYOUT

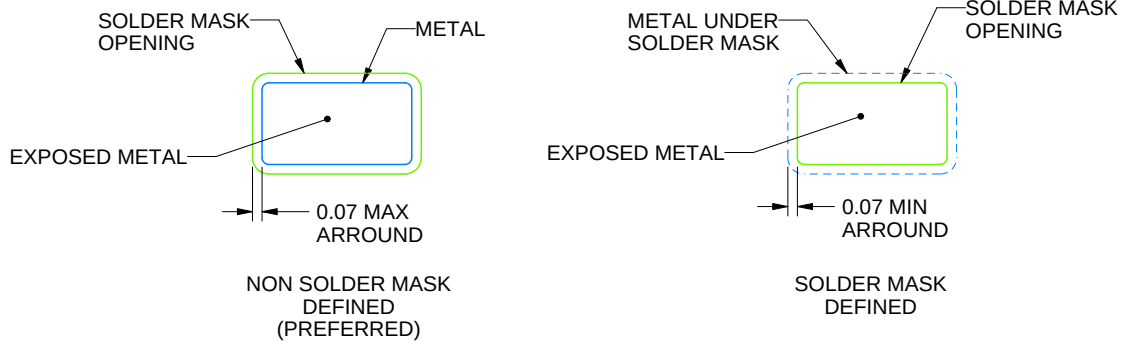
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

4214839/K 08/2024

NOTES: (continued)

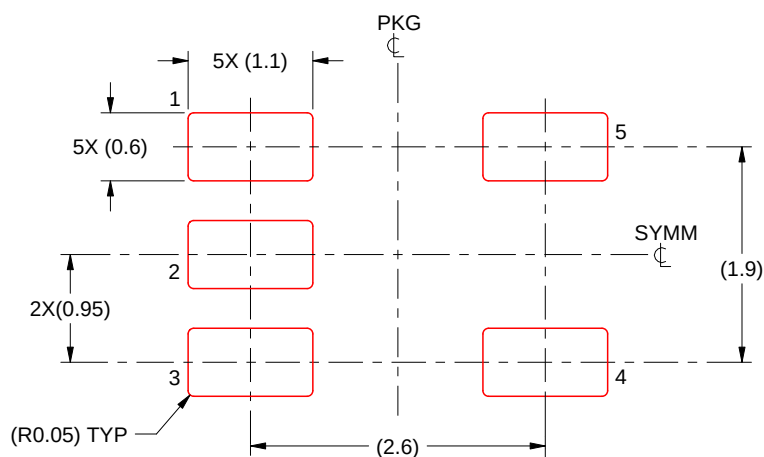
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



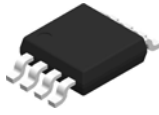
SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

4214839/K 08/2024

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.

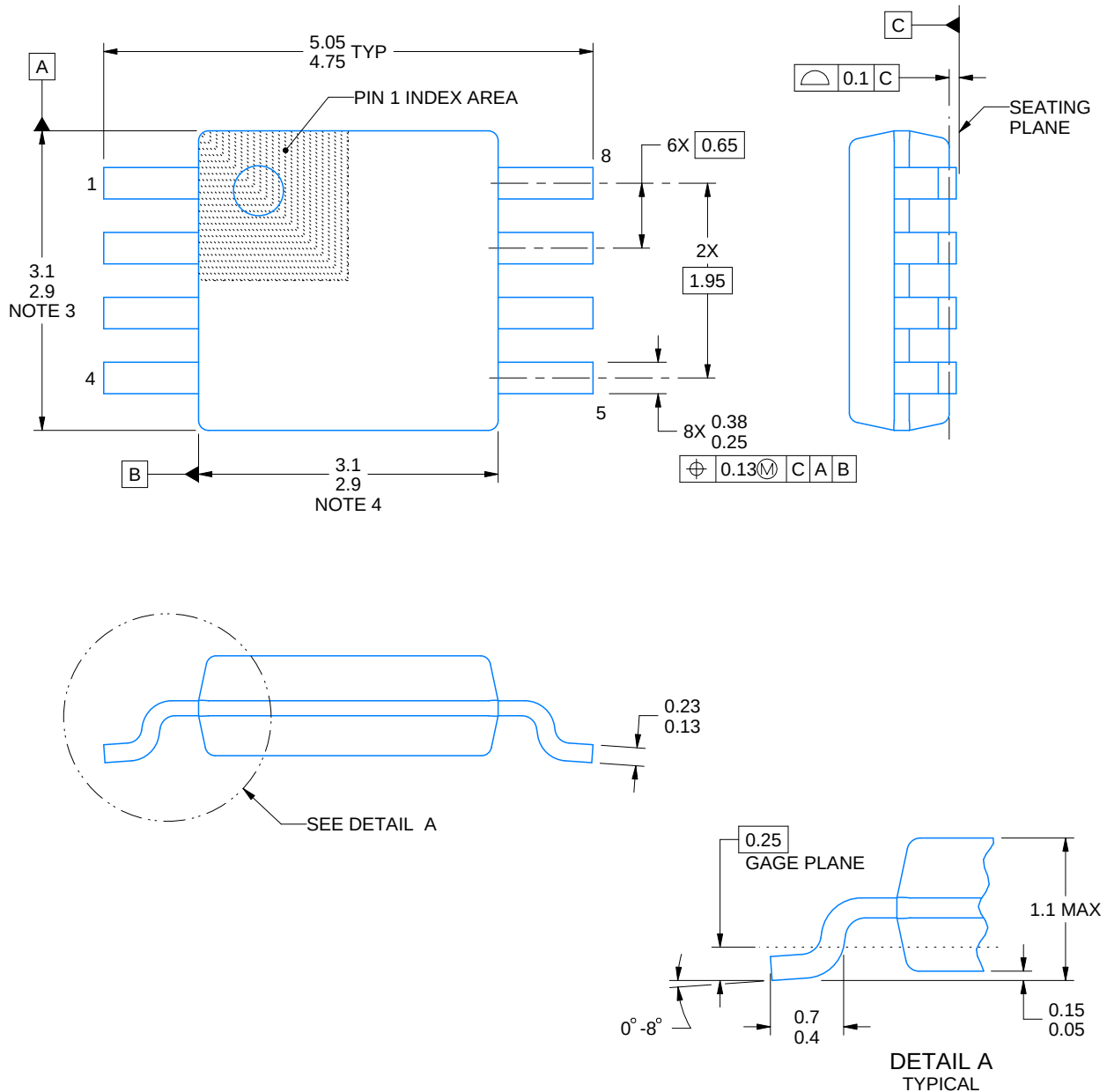
DGK0008A



# PACKAGE OUTLINE

## VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



4214862/A 04/2023

### NOTES:

PowerPAD is a trademark of Texas Instruments.

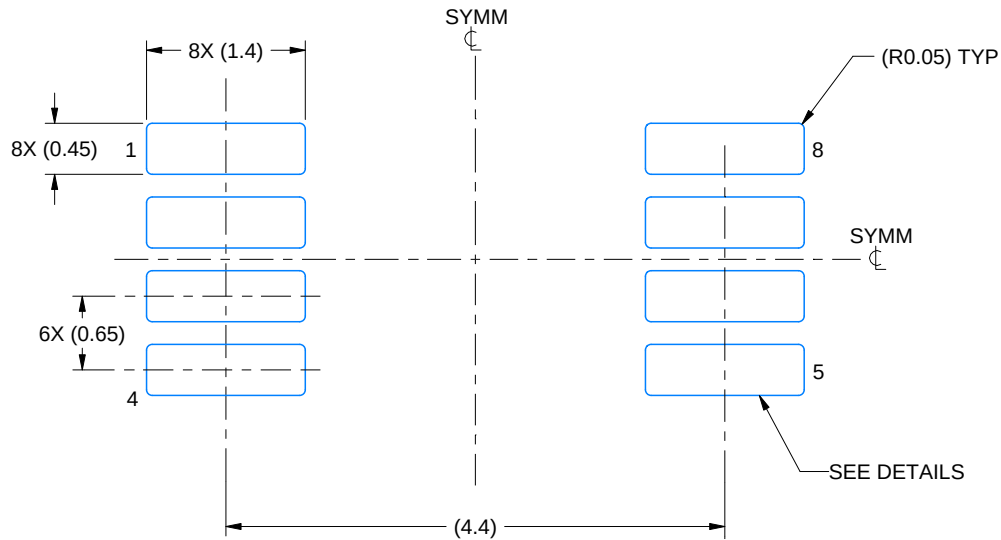
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

# EXAMPLE BOARD LAYOUT

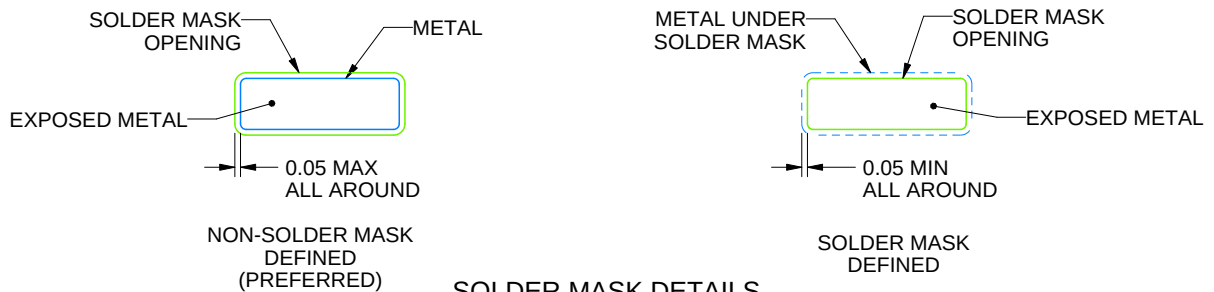
DGK0008A

<sup>TM</sup> VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 15X



SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

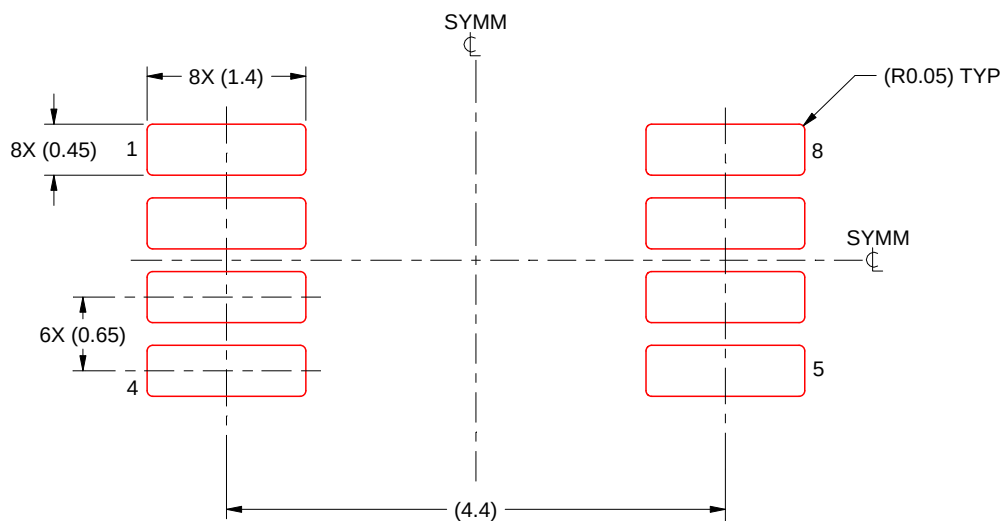
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

## EXAMPLE STENCIL DESIGN

DGK0008A

™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

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

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