

# TL97x Output Rail-To-Rail Very-Low-Noise Operational Amplifiers

## 1 Features

- Rail-to-Rail Output Voltage Swing:  $\pm 2.4$  V at  $V_{CC} = \pm 2.5$  V
- Very Low Noise Level: 4 nV/ $\sqrt{\text{Hz}}$
- Ultra-Low Distortion: 0.003%
- High Dynamic Features: 12 MHz, 5 V/ $\mu\text{s}$
- Operating Range: 2.7 V to 12 V
- Latch-Up Performance Exceeds 100 mA Per JESD 78, Class II
- ESD Performance Tested Per JESD 22
  - 2000-V Human-Body Model
  - 1500-V Charged-Device Model

## 2 Applications

- Portable Equipment
  - Music Players
  - Tablets
  - Cell Phones
- Instrumentation and Sensors
- Professional Audio Circuits

## 3 Description

The TL97x family of single, dual, and quad operational amplifiers operates at voltages as low as  $\pm 1.35$  V and features output rail-to-rail signal swing. The TL97x boast characteristics that make them particularly well suited for portable and battery-supplied equipment. Very low noise and low distortion characteristics make them ideal for audio preamplification.

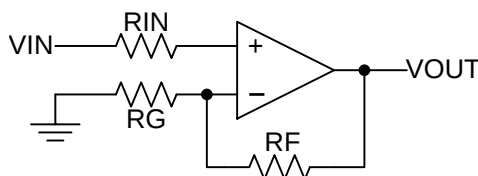
The TL971 is housed in the space-saving 5-pin SOT-23 package, which simplifies board design because of the ability to be placed anywhere (outside dimensions are 2.8 mm  $\times$  2.9 mm).

**Device Information<sup>(1)</sup>**

| PART NUMBER | PACKAGE (PIN) | BODY SIZE (NOM)           |
|-------------|---------------|---------------------------|
| TL971       | SOIC (8)      | 4.90 mm $\times$ 3.90 mm  |
|             | SOT-23 (5)    | 2.80 mm $\times$ 2.90 mm  |
| TL972       | MSOP (8)      | 3.00 mm $\times$ 3.00 mm  |
|             | PDIP (8)      | 9.60 mm $\times$ 6.40 mm  |
|             | SOIC (8)      | 4.90 mm $\times$ 3.90 mm  |
|             | TSSOP (8)     | 3.00 mm $\times$ 4.40 mm  |
| TL974       | PDIP (14)     | 19.30 mm $\times$ 6.40 mm |
|             | SOIC (14)     | 8.60 mm $\times$ 3.90 mm  |
|             | TSSOP (14)    | 5.00 mm $\times$ 4.40 mm  |

(1) For all available packages, see the orderable addendum at the end of the data sheet.

## 4 Simplified Schematic



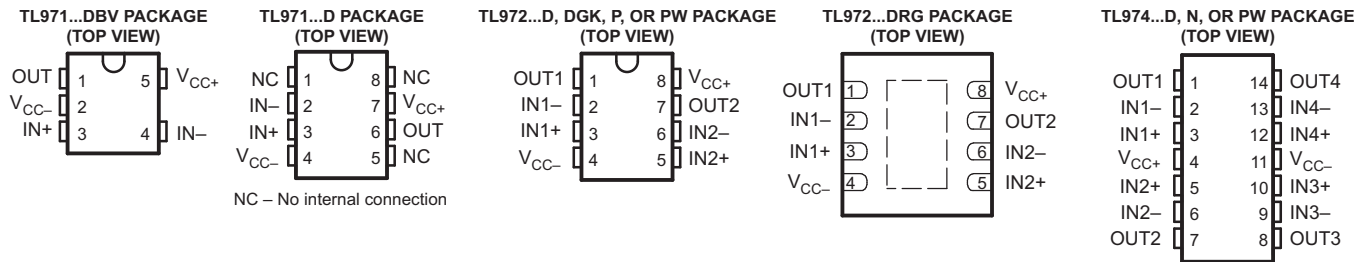
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## 5 Revision History

| Changes from Revision G (May 2012) to Revision H                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | Page       |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| <ul style="list-style-type: none"> <li>Added <i>Applications</i>, <i>Device Information</i> table, <i>Pin Functions</i> table, <i>ESD Ratings</i> table, <i>Thermal Information</i> table, <i>Typical Characteristics</i>, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section. ....</li> <li>Deleted <i>Ordering Information</i> table. ....</li> </ul> | <br>1<br>1 |
| Changes from Revision F (December 2009) to Revision G                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Page       |
| <ul style="list-style-type: none"> <li>Changed slew rate MIN value. ....</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              | 5          |

## 6 Pin Configuration and Functions



### Pin Functions

| NAME             | PIN   |       |               |     |          | TYPE | DESCRIPTION        |
|------------------|-------|-------|---------------|-----|----------|------|--------------------|
|                  | TL971 | TL971 | TL972         |     | TL974    |      |                    |
|                  | DBV   | D     | D, DGK, P, PW | DRG | D, N, PW |      |                    |
| IN+              | 3     | 3     | —             | —   | —        | I    | Noninverting input |
| IN-              | 4     | 2     | —             | —   | —        | I    | Inverting input    |
| IN1+             | —     | —     | 3             | 3   | 3        | I    | Noninverting input |
| IN1-             | —     | —     | 2             | 2   | 2        | I    | Inverting input    |
| IN2+             | —     | —     | 5             | 5   | 5        | I    | Noninverting input |
| IN2-             | —     | —     | 6             | 6   | 6        | I    | Inverting input    |
| IN3+             | —     | —     | —             | —   | 10       | I    | Noninverting input |
| IN3-             | —     | —     | —             | —   | 9        | I    | Inverting input    |
| IN4+             | —     | —     | —             | —   | 12       | I    | Noninverting input |
| IN4-             | —     | —     | —             | —   | 13       | I    | Inverting input    |
| NC               | —     | 1     | —             | —   | —        | —    | No Connect         |
|                  |       | 5     |               |     |          |      |                    |
|                  |       | 8     |               |     |          |      |                    |
| OUT              | 1     | 6     | —             | —   | —        | O    | Output             |
| OUT1             | —     | —     | 1             | 1   | 1        | O    | Output             |
| OUT2             | —     | —     | 7             | 7   | 7        | O    | Output             |
| OUT3             | —     | —     | —             | —   | 8        | O    | Output             |
| OUT4             | —     | —     | —             | —   | 14       | O    | Output             |
| V <sub>CC+</sub> | 5     | 7     | 8             | 8   | 4        | -    | Positive supply    |
| V <sub>CC-</sub> | 2     | 4     | 4             | 4   | 11       | -    | Negative supply    |

## 7 Specifications

### 7.1 Absolute Maximum Ratings

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

|                  |                                           | MIN                    | MAX                    | UNIT |
|------------------|-------------------------------------------|------------------------|------------------------|------|
| V <sub>CC</sub>  | Supply voltage range                      | 2.7                    | 15                     | V    |
| V <sub>ID</sub>  | Differential input voltage <sup>(2)</sup> |                        | ±1 V                   | V    |
| V <sub>IN</sub>  | Input voltage range <sup>(3)</sup>        | V <sub>CC-</sub> – 0.3 | V <sub>CC+</sub> + 0.3 | V    |
| T <sub>J</sub>   | Maximum junction temperature              |                        | 150                    | °C   |
| T <sub>stg</sub> | Storage temperature range                 | –65                    | 150                    | °C   |

- (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) Differential voltages for the noninverting input terminal are with respect to the inverting input terminal.
- (3) The input and output voltages must never exceed V<sub>CC</sub> + 0.3 V.

### 7.2 ESD Ratings

|                    |                                                                                          | VALUE | UNIT |
|--------------------|------------------------------------------------------------------------------------------|-------|------|
| V <sub>(ESD)</sub> | Electrostatic discharge                                                                  |       |      |
|                    | Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins <sup>(1)</sup>              | 2000  | V    |
|                    | Charged device model (CDM), per JEDEC specification JESD22-C101, all pins <sup>(2)</sup> | 1500  |      |

- (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.

### 7.3 Recommended Operating Conditions

|                  |                                | MIN                     | MAX                     | UNIT |
|------------------|--------------------------------|-------------------------|-------------------------|------|
| V <sub>CC</sub>  | Supply voltage                 | 2.7                     | 12                      | V    |
| V <sub>ICM</sub> | Common-mode input voltage      | V <sub>CC-</sub> + 1.15 | V <sub>CC+</sub> – 1.15 | V    |
| T <sub>A</sub>   | Operating free-air temperature | –40                     | 125                     | °C   |

### 7.4 Thermal Information

| THERMAL METRIC <sup>(1)</sup> |                                                 | TL971            |                    | TL972            |                    |                    |                  |                   | TL974            |                  |                   | UNIT |
|-------------------------------|-------------------------------------------------|------------------|--------------------|------------------|--------------------|--------------------|------------------|-------------------|------------------|------------------|-------------------|------|
|                               |                                                 | D <sup>(2)</sup> | DBV <sup>(2)</sup> | D <sup>(2)</sup> | DGK <sup>(3)</sup> | DRG <sup>(3)</sup> | P <sup>(2)</sup> | PW <sup>(2)</sup> | D <sup>(2)</sup> | N <sup>(2)</sup> | PW <sup>(2)</sup> |      |
|                               |                                                 | 8 PINS           | 5 PINS             | 8 PINS           |                    |                    |                  |                   | 14 PINS          |                  |                   |      |
| R <sub>θJA</sub>              | Package thermal impedance, junction to free air | 97               | 206                | 97               | 172                | 44                 | 85               | 149               | 86               | 80               | 113               | °C/W |

- (1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report (SPRA953).
- (2) Package thermal impedance is calculated in accordance with JESD 51-7.
- (3) Package thermal impedance is calculated in accordance with JESD 51-5.

## 7.5 Electrical Characteristics

$V_{CC+} = 2.5\text{ V}$ ,  $V_{CC-} = -2.5\text{ V}$ , full-range  $T_A = -40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  (unless otherwise noted)

| PARAMETER                                  | TEST CONDITIONS                                                         | $T_A$                | MIN   | TYP   | MAX  | UNIT                           |
|--------------------------------------------|-------------------------------------------------------------------------|----------------------|-------|-------|------|--------------------------------|
| $V_{IO}$ Input offset voltage              |                                                                         | $25^{\circ}\text{C}$ |       | 1     | 4    | mV                             |
|                                            |                                                                         | Full range           |       |       | 6    |                                |
| $\alpha V_{IO}$ Input offset voltage drift | $V_{ICM} = 0\text{ V}$ , $V_O = 0\text{ V}$                             | $25^{\circ}\text{C}$ |       | 5     |      | $\mu\text{V}/^{\circ}\text{C}$ |
| $I_{IO}$ Input offset current              | $V_{ICM} = 0\text{ V}$ , $V_O = 0\text{ V}$                             | $25^{\circ}\text{C}$ |       | 10    | 150  | nA                             |
| $I_{IB}$ Input bias current                | $V_{ICM} = 0\text{ V}$ , $V_O = 0\text{ V}$                             | $25^{\circ}\text{C}$ |       | 200   | 750  | nA                             |
|                                            |                                                                         | Full range           |       |       | 1000 |                                |
| $V_{ICM}$ Common-mode input voltage        |                                                                         | $25^{\circ}\text{C}$ | -1.35 |       | 1.35 | V                              |
| CMRR Common-mode rejection ratio           | $V_{ICM} = \pm 1.35\text{ V}$                                           | $25^{\circ}\text{C}$ | 60    | 85    |      | dB                             |
| SVR Supply-voltage rejection ratio         | $V_{CC} = \pm 2\text{ V}$ to $\pm 3\text{ V}$                           | $25^{\circ}\text{C}$ | 60    | 70    |      | dB                             |
| $A_{VD}$ Large-signal voltage gain         | $R_L = 2\text{ k}\Omega$                                                | $25^{\circ}\text{C}$ | 70    | 80    |      | dB                             |
| $V_{OH}$ High-level output voltage         | $R_L = 2\text{ k}\Omega$                                                | $25^{\circ}\text{C}$ | 2     | 2.4   |      | V                              |
| $V_{OL}$ Low-level output voltage          | $R_L = 2\text{ k}\Omega$                                                | $25^{\circ}\text{C}$ |       | -2.4  | -2   | V                              |
| $I_{source}$ Output source current         | $V_{OUT} = \pm 2.5\text{ V}$                                            | $25^{\circ}\text{C}$ | 1.2   | 1.4   |      | mA                             |
|                                            |                                                                         | Full range           | 1     |       |      |                                |
| $I_{sink}$ Output sink current             | $V_{OUT} = \pm 2.5\text{ V}$                                            | $25^{\circ}\text{C}$ | 50    | 80    |      | mA                             |
|                                            |                                                                         | Full range           | 25    |       |      |                                |
| $I_{CC}$ Supply current (per amplifier)    | Unity gain, No load                                                     | $25^{\circ}\text{C}$ |       | 2     | 2.8  | mA                             |
|                                            |                                                                         | Full range           |       |       | 3.2  |                                |
| GBWP Gain bandwidth product                | $f = 100\text{ kHz}$ , $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$ | $25^{\circ}\text{C}$ | 8.5   | 12    |      | MHz                            |
| SR Slew rate                               | $A_V = 1$ , $V_{IN} = \pm 1\text{ V}$                                   | $25^{\circ}\text{C}$ | 2.8   | 5     |      | V/ $\mu\text{s}$               |
|                                            |                                                                         | Full range           | 2.8   |       |      |                                |
| $\Phi_m$ Phase margin at unity gain        | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$                        | $25^{\circ}\text{C}$ |       | 60    |      | $^{\circ}$                     |
| Gm Gain margin                             | $R_L = 2\text{ k}\Omega$ , $C_L = 100\text{ pF}$                        | $25^{\circ}\text{C}$ |       | 10    |      | dB                             |
| $V_n$ Equivalent input noise voltage       | $f = 100\text{ kHz}$                                                    | $25^{\circ}\text{C}$ |       | 4     |      | $\text{nV}/\sqrt{\text{Hz}}$   |
| THD Total harmonic distortion              | $f = 1\text{ kHz}$ , $A_V = -1$ , $R_L = 10\text{ k}\Omega$             | $25^{\circ}\text{C}$ |       | 0.003 |      | %                              |

## 7.6 Typical Characteristics

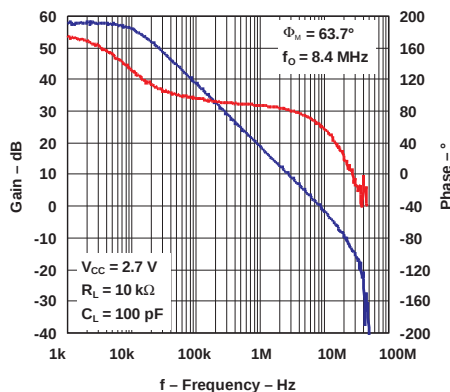


Figure 1. Gain And Phase vs Frequency

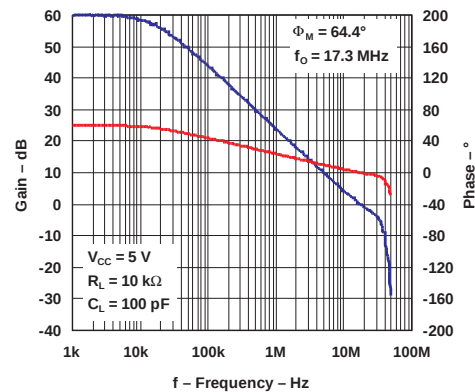


Figure 2. Gain And Phase vs Frequency

## Typical Characteristics (continued)

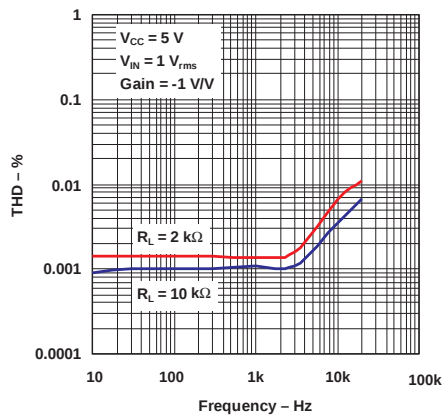


Figure 3. Total Harmonic Distortion vs Frequency

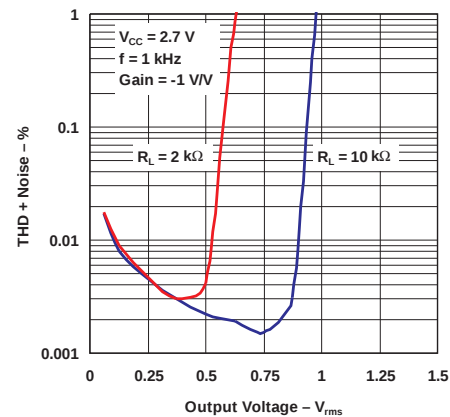


Figure 4. Total Harmonic Distortion + Noise vs Output Voltage

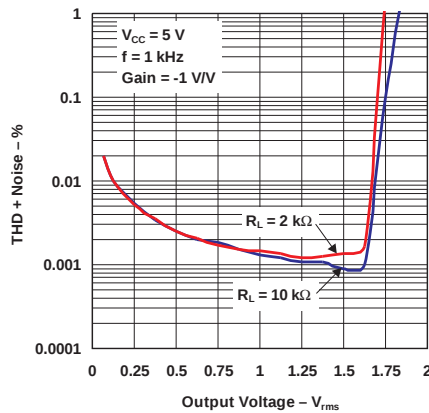


Figure 5. Total Harmonic Distortion + Noise vs Output Voltage

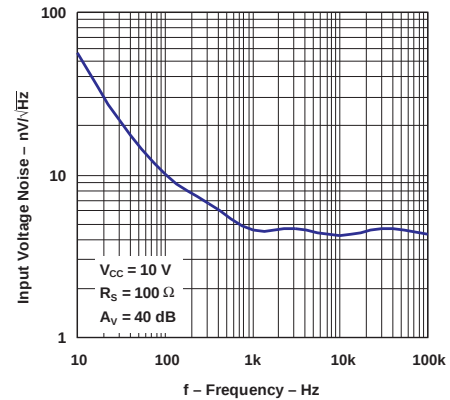


Figure 6. Input Voltage Noise vs Frequency

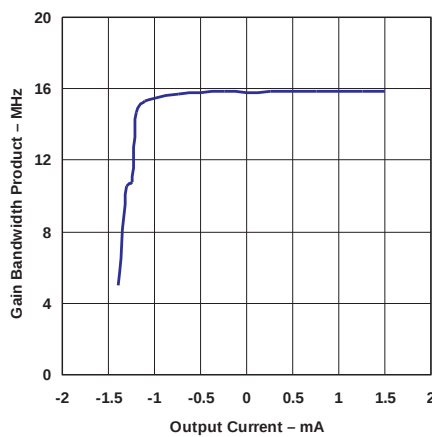


Figure 7. Gain Bandwidth Product vs Output Current

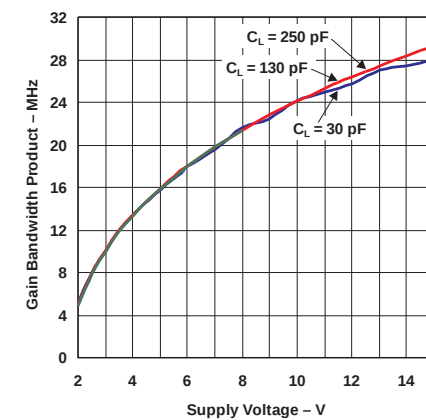
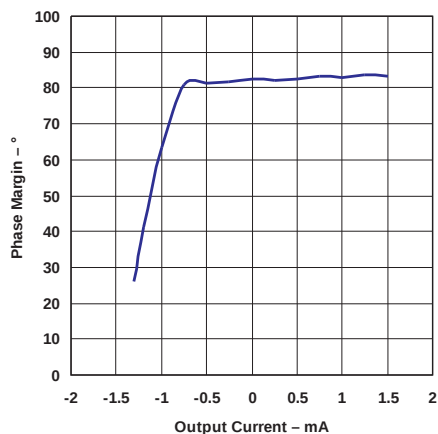
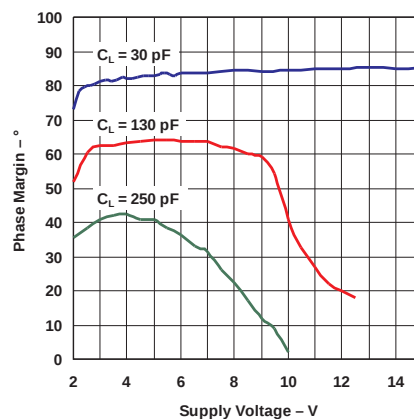


Figure 8. Gain Bandwidth Product vs Supply Voltage

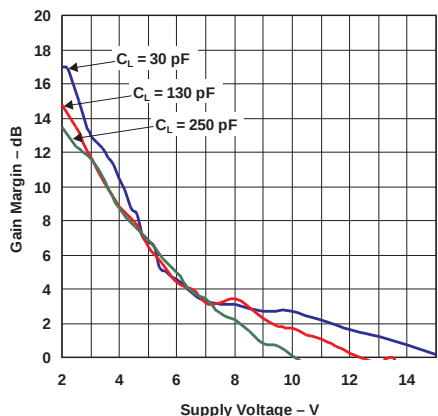
## Typical Characteristics (continued)



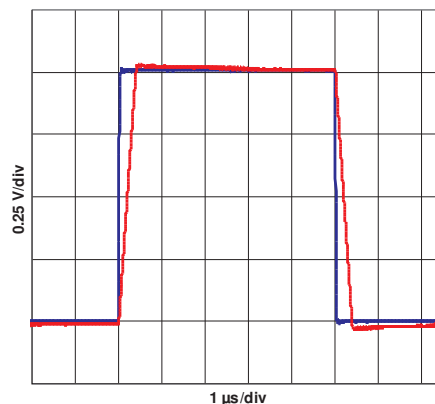
**Figure 9. Phase Margin vs Output Current**



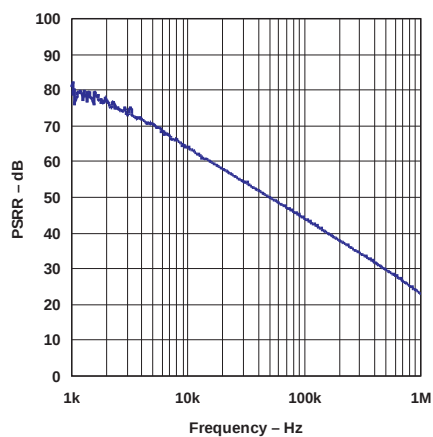
**Figure 10. Phase Margin vs Supply Voltage**



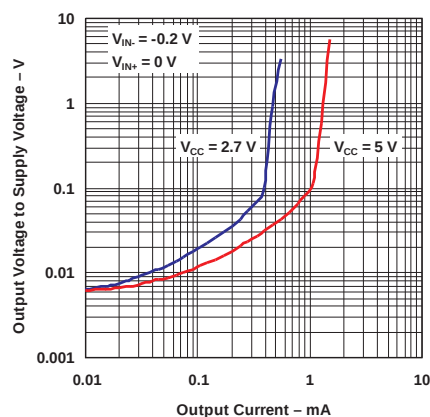
**Figure 11. Gain Margin vs Supply Voltage**



**Figure 12. Input Response**

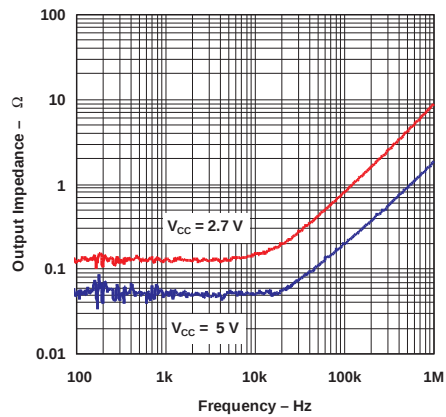


**Figure 13. Power-Supply Ripple Rejection vs Frequency**

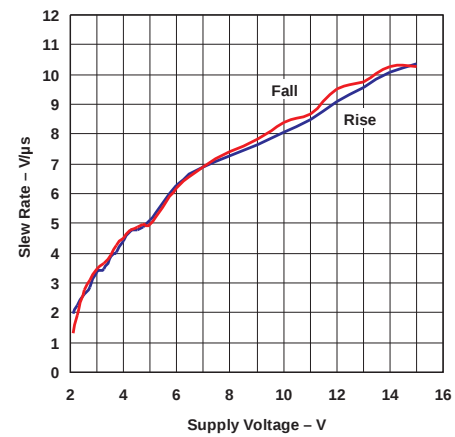


**Figure 14. Output Voltage vs Output Current**

## Typical Characteristics (continued)



**Figure 15. Output Impedance vs Frequency**



**Figure 16. Slew Rate vs Supply Voltage**

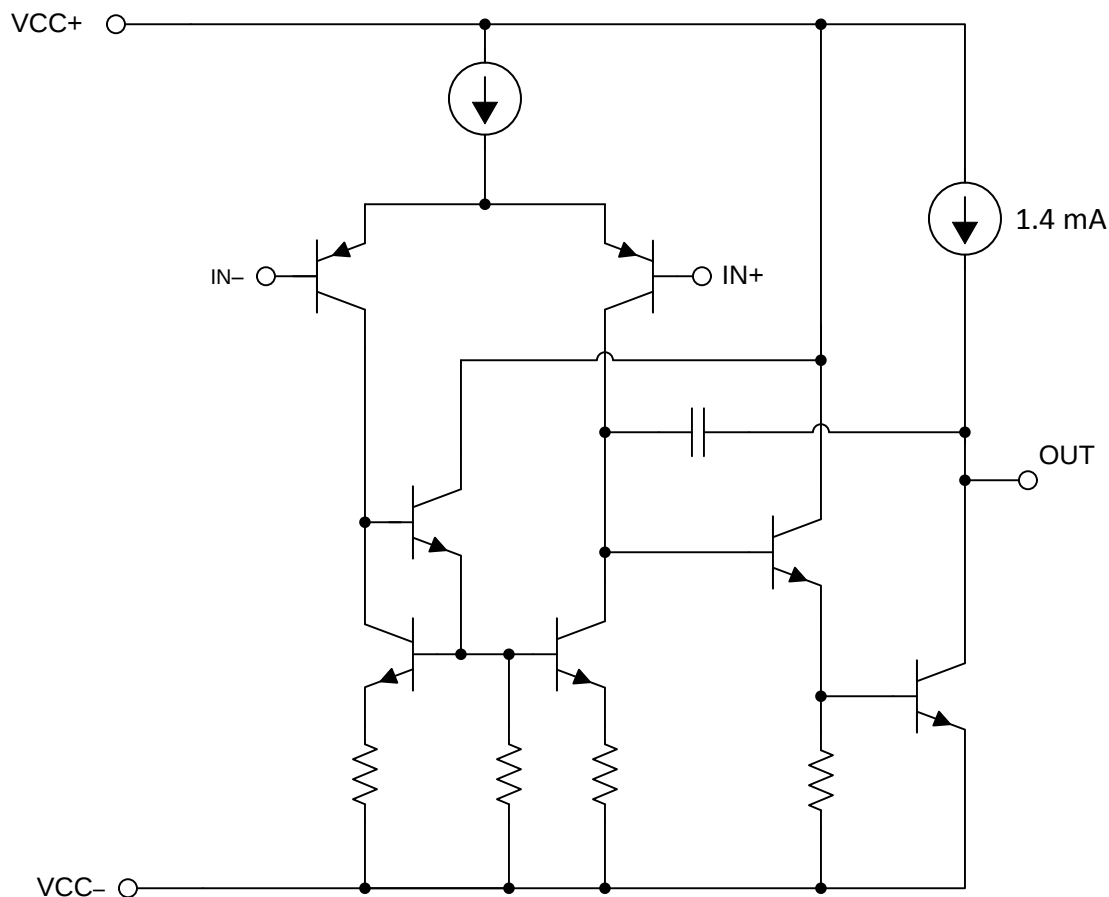
## 8 Detailed Description

### 8.1 Overview

The TL97x family of operational amplifiers operates at voltages as low as  $\pm 1.35$  V and features output rail-to-rail signal swing. The TL97x boast characteristics that make them particularly well suited for portable and battery-supplied equipment. Very low noise and low distortion characteristics make them ideal for audio preamplification. The TL97x family comes in single, dual, and quad operational amplifier packages of varying sizes.

The TL971 is housed in the space-saving 5-pin SOT-23 package, which simplifies board design because of the ability to be placed anywhere (outside dimensions are 2.8 mm  $\times$  2.9 mm).

### 8.2 Functional Block Diagram



### 8.3 Feature Description

#### 8.3.1 Slew Rate

The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. The TL97x devices have a 5 V/ $\mu$ s slew rate.

#### 8.3.2 Unity-Gain Bandwidth

The unity-gain bandwidth is the frequency up to which an amplifier with a unity gain may be operated without greatly distorting the signal. The TL97x devices have a 12-MHz unity-gain bandwidth.

## **Feature Description (continued)**

### **8.3.3 Low Total Harmonic Distortion**

Harmonic distortions to an audio signal are created by electronic components in a circuit. Total harmonic distortion (THD) is a measure of harmonic distortions accumulated by a signal in an audio system. The TL97x devices have a very low THD of 0.003% meaning that they will add little harmonic distortion when used in audio signal applications.

### **8.3.4 Operating Voltage**

The TL97x devices are fully specified and ensured for operation from 2.7 V to 12 V. In addition, many specifications apply from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ .

## **8.4 Device Functional Modes**

The TL97x devices are powered on when the supply is connected. Each of these devices can be operated as a single supply operational amplifier or dual supply amplifier depending on the application.

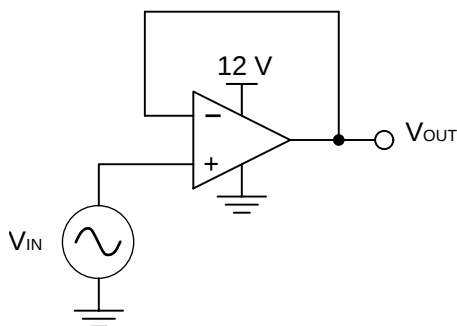
## 9 Application and Implementation

### NOTE

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. Customers should validate and test their design implementation to confirm system functionality.

### 9.1 Typical Application

The voltage follower configuration of the operational amplifier is used for applications where a weak signal is used to drive a relatively high current load. This circuit is also called a buffer amplifier or unity gain amplifier. The inputs of an operational amplifier have a very high resistance which puts a negligible current load on the voltage source. The output resistance of the operational amplifier is almost negligible, so it can provide as much current as necessary to the output load.



**Figure 17. Voltage follower schematic**

#### 9.1.1 Design Requirements

- Input at positive Terminal
- Output range of 0 V to 12 V
- Input range of 0 V to 12 V
- Short-circuit feedback to negative input for unity gain

#### 9.1.2 Detailed Design Procedure

##### 9.1.2.1 Output Voltage Swing

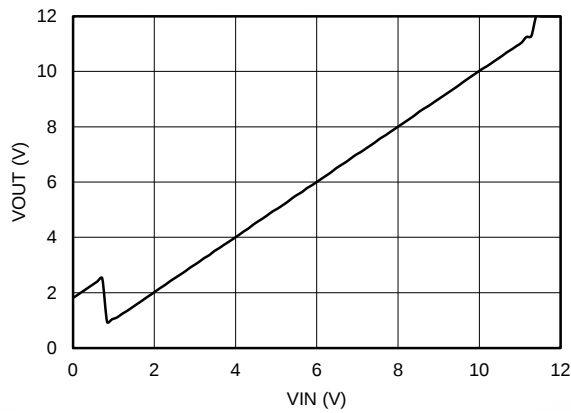
The output voltage of an operational amplifier is limited by its internal circuitry to some level below the supply rails. For this amplifier, the output voltage must be within  $\pm 12$  V.

##### 9.1.2.2 Supply and Input Voltage

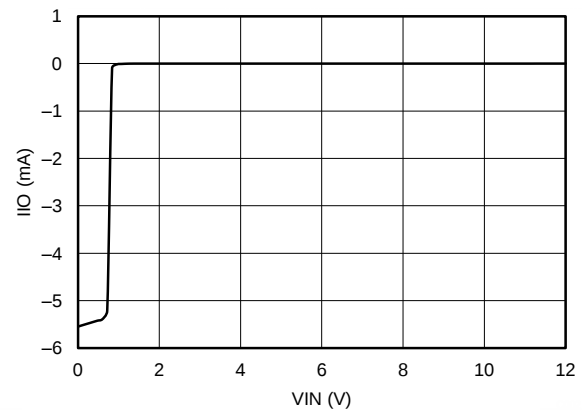
For correct operation of the amplifier, neither input must be higher than the recommended positive supply rail voltage or lower than the recommended negative supply rail voltage. The chosen amplifier must be able to operate at the supply voltage that accommodates the inputs. Because the input for this application goes up to 12 V, the supply voltage must be 15 V. Using a negative voltage on the lower rail rather than ground, allows the amplifier to maintain linearity for the full range of inputs.

## Typical Application (continued)

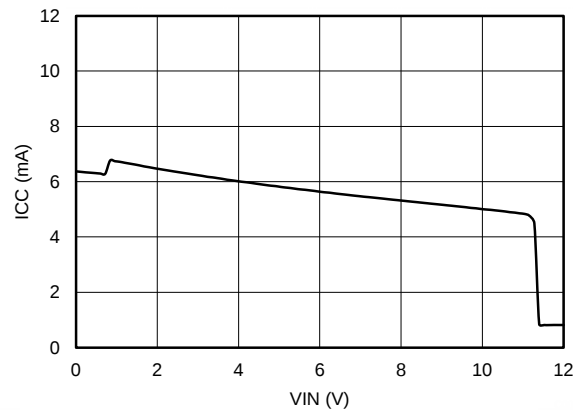
### 9.1.3 Application Curves for Output Characteristics



**Figure 18. Output Voltage vs Input Voltage**



**Figure 19. Current Drawn by Input of Voltage Follower ( $I_{IO}$ ) vs Input Voltage**



**Figure 20. Current Drawn from Supply ( $I_{CC}$ ) vs Input Voltage**

## 10 Power Supply Recommendations

The TL97x devices are specified for operation from 2.7 to 12 V; many specifications apply from -40 °C to 125 °C.

### CAUTION

Supply voltages larger than 15 V can permanently damage the device (see the [Absolute Maximum Ratings](#)).

Place 0.1-μF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high impedance power supplies. For more detailed information on bypass capacitor placement, refer to the [Layout Guidelines](#).

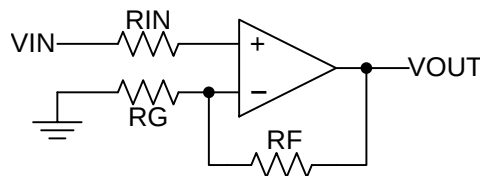
## 11 Layout

### 11.1 Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

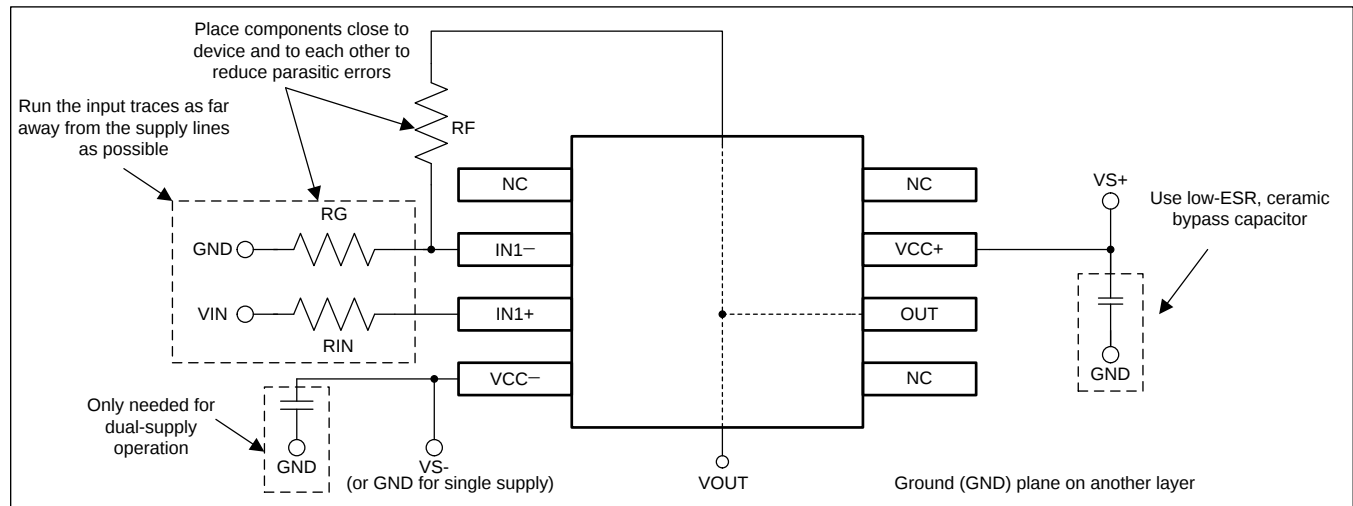
- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and the operational amplifier. Bypass capacitors are used to reduce the coupled noise by providing low impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-μF ceramic bypass capacitors 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.
- 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. For more detailed information, refer to Circuit Board Layout Techniques, [SLOA089](#).
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping RF and RG close to the inverting input minimizes parasitic capacitance, as shown in [Layout Example](#).
- 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.

### 11.2 Layout Example



**Figure 21. Operational Amplifier Schematic for Noninverting Configuration**

## Layout Example (continued)



**Figure 22. Operational Amplifier Board Layout for Noninverting Configuration**

## 12 Device and Documentation Support

### 12.1 Related Links

The table below lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

**Table 1. Related Links**

| PARTS | PRODUCT FOLDER             | SAMPLE & BUY               | TECHNICAL DOCUMENTS        | TOOLS & SOFTWARE           | SUPPORT & COMMUNITY        |
|-------|----------------------------|----------------------------|----------------------------|----------------------------|----------------------------|
| TL971 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TL972 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |
| TL974 | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> | <a href="#">Click here</a> |

### 12.2 Trademarks

All trademarks are the property of their respective owners.

### 12.3 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

### 12.4 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

## 13 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.

## 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) |
|-----------------------|---------------|----------------------|-----------------|-----------------------|-------------|--------------------------------------|-----------------------------------|--------------|---------------------|
| TL971ID               | Obsolete      | Production           | SOIC (D)   8    | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | Z971                |
| TL971IDR              | Active        | Production           | SOIC (D)   8    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | Z971                |
| TL972ID               | Obsolete      | Production           | SOIC (D)   8    | -                     | -           | Call TI                              | Call TI                           | -40 to 125   | Z972                |
| TL972IDGKR            | Active        | Production           | VSSOP (DGK)   8 | 2500   LARGE T&R      | Yes         | SN                                   | Level-1-260C-UNLIM                | -40 to 125   | TSA                 |
| TL972IDR              | Active        | Production           | SOIC (D)   8    | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | Z972                |
| TL972IP               | Active        | Production           | PDIP (P)   8    | 50   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 125   | TL972IP             |
| TL972IPWR             | Active        | Production           | TSSOP (PW)   8  | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | Z972                |
| TL974ID               | Active        | Production           | SOIC (D)   14   | 50   TUBE             | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | TL974I              |
| TL974IDR              | Active        | Production           | SOIC (D)   14   | 2500   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | TL974I              |
| TL974IN               | Active        | Production           | PDIP (N)   14   | 25   TUBE             | Yes         | NIPDAU                               | N/A for Pkg Type                  | -40 to 125   | TL974IN             |
| TL974IPW              | Active        | Production           | TSSOP (PW)   14 | 90   TUBE             | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | Z974                |
| TL974IPWR             | Active        | Production           | TSSOP (PW)   14 | 2000   LARGE T&R      | Yes         | NIPDAU                               | Level-1-260C-UNLIM                | -40 to 125   | Z974                |

<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.

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

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

**OTHER QUALIFIED VERSIONS OF TL971, TL972, TL974 :**

- Automotive : [TL971-Q1](#), [TL972-Q1](#), [TL974-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 |
|------------|--------------|-----------------|------|------|--------------------|--------------------|---------|---------|---------|---------|--------|---------------|
| TL971IDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TL972IDGKR | VSSOP        | DGK             | 8    | 2500 | 330.0              | 12.4               | 5.25    | 3.35    | 1.25    | 8.0     | 12.0   | Q1            |
| TL972IDR   | SOIC         | D               | 8    | 2500 | 330.0              | 12.4               | 6.4     | 5.2     | 2.1     | 8.0     | 12.0   | Q1            |
| TL972IPWR  | TSSOP        | PW              | 8    | 2000 | 330.0              | 12.4               | 7.0     | 3.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TL972IPWR  | TSSOP        | PW              | 8    | 2000 | 330.0              | 12.4               | 7.0     | 3.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TL974IDR   | SOIC         | D               | 14   | 2500 | 330.0              | 16.4               | 6.5     | 9.0     | 2.1     | 8.0     | 16.0   | Q1            |
| TL974IPWR  | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |
| TL974IPWR  | TSSOP        | PW              | 14   | 2000 | 330.0              | 12.4               | 6.9     | 5.6     | 1.6     | 8.0     | 12.0   | Q1            |

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

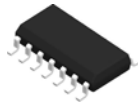
| Device     | Package Type | Package Drawing | Pins | SPQ  | Length (mm) | Width (mm) | Height (mm) |
|------------|--------------|-----------------|------|------|-------------|------------|-------------|
| TL971IDR   | SOIC         | D               | 8    | 2500 | 353.0       | 353.0      | 32.0        |
| TL972IDGKR | VSSOP        | DGK             | 8    | 2500 | 366.0       | 364.0      | 50.0        |
| TL972IDR   | SOIC         | D               | 8    | 2500 | 353.0       | 353.0      | 32.0        |
| TL972IPWR  | TSSOP        | PW              | 8    | 2000 | 353.0       | 353.0      | 32.0        |
| TL972IPWR  | TSSOP        | PW              | 8    | 2000 | 356.0       | 356.0      | 35.0        |
| TL974IDR   | SOIC         | D               | 14   | 2500 | 353.0       | 353.0      | 32.0        |
| TL974IPWR  | TSSOP        | PW              | 14   | 2000 | 353.0       | 353.0      | 32.0        |
| TL974IPWR  | TSSOP        | PW              | 14   | 2000 | 356.0       | 356.0      | 35.0        |

## TUBE

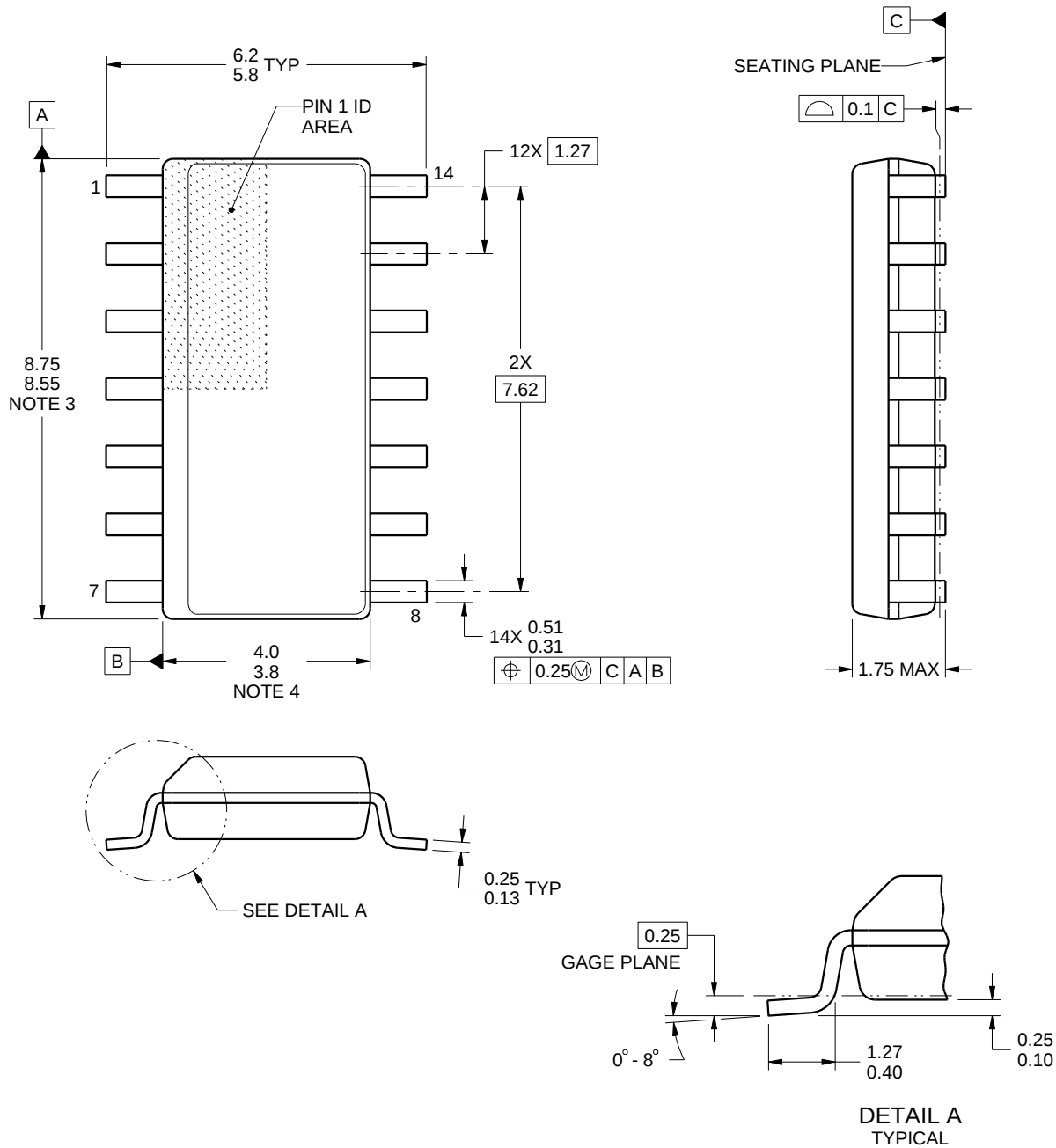


\*All dimensions are nominal

| Device   | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (μm) | B (mm) |
|----------|--------------|--------------|------|-----|--------|--------|--------|--------|
| TL972IP  | P            | PDIP         | 8    | 50  | 506    | 13.97  | 11230  | 4.32   |
| TL974ID  | D            | SOIC         | 14   | 50  | 507    | 8      | 3940   | 4.32   |
| TL974IN  | N            | PDIP         | 14   | 25  | 506    | 13.97  | 11230  | 4.32   |
| TL974IPW | PW           | TSSOP        | 14   | 90  | 530    | 10.2   | 3600   | 3.5    |

**D0014A****PACKAGE OUTLINE****SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT



4220718/A 09/2016

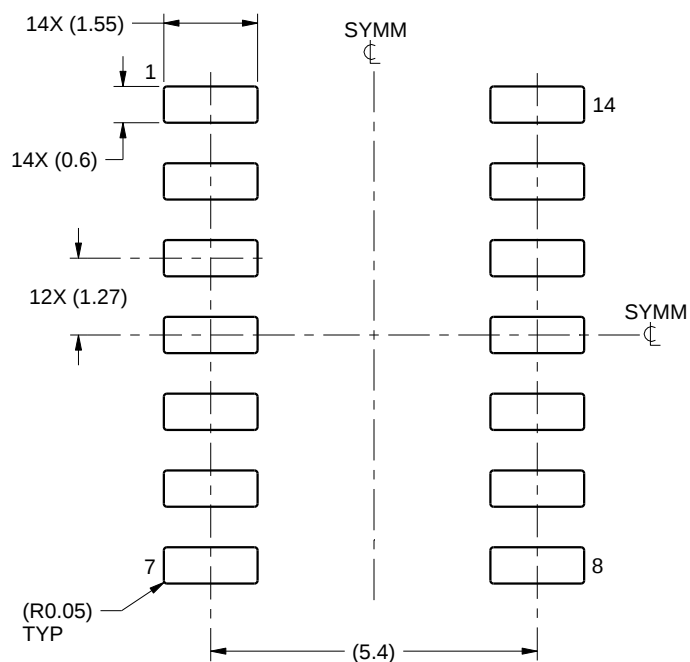
**NOTES:**

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

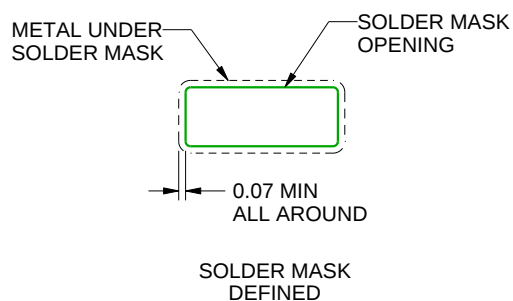
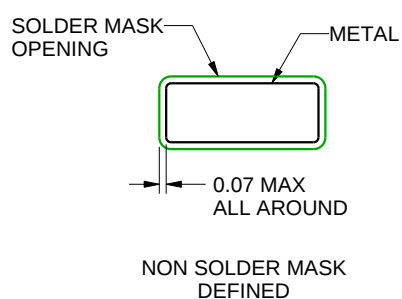
**D0014A**

**SOIC - 1.75 mm max height**

## SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
SCALE:8X



## SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

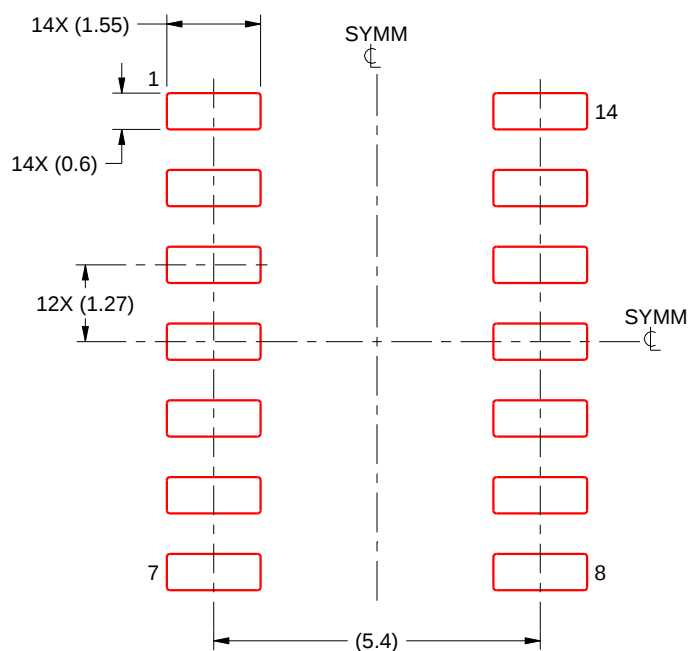
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## EXAMPLE STENCIL DESIGN

D0014A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



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

4220718/A 09/2016

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.



## PACKAGE OUTLINE

**SOIC - 1.75 mm max height**

SMALL OUTLINE INTEGRATED CIRCUIT

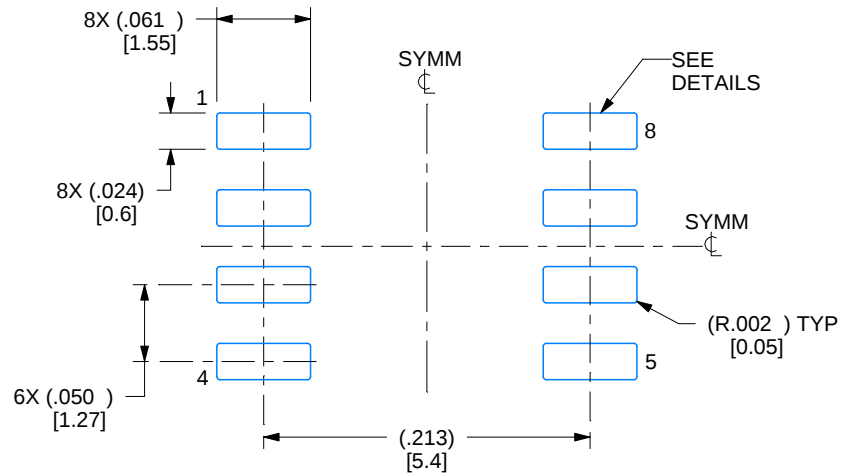


1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate 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.

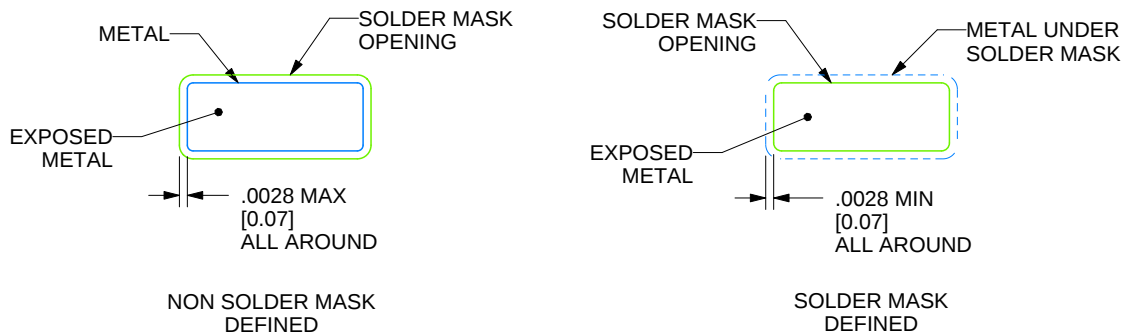
**D0008A**

**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.

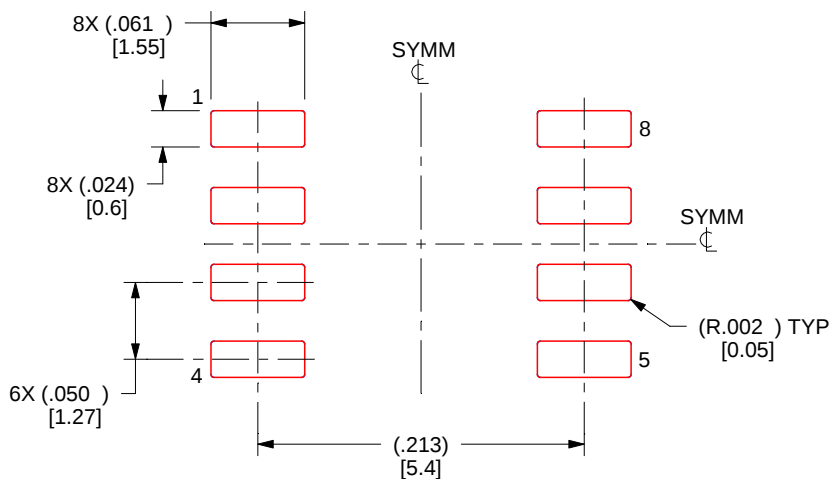
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

## 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

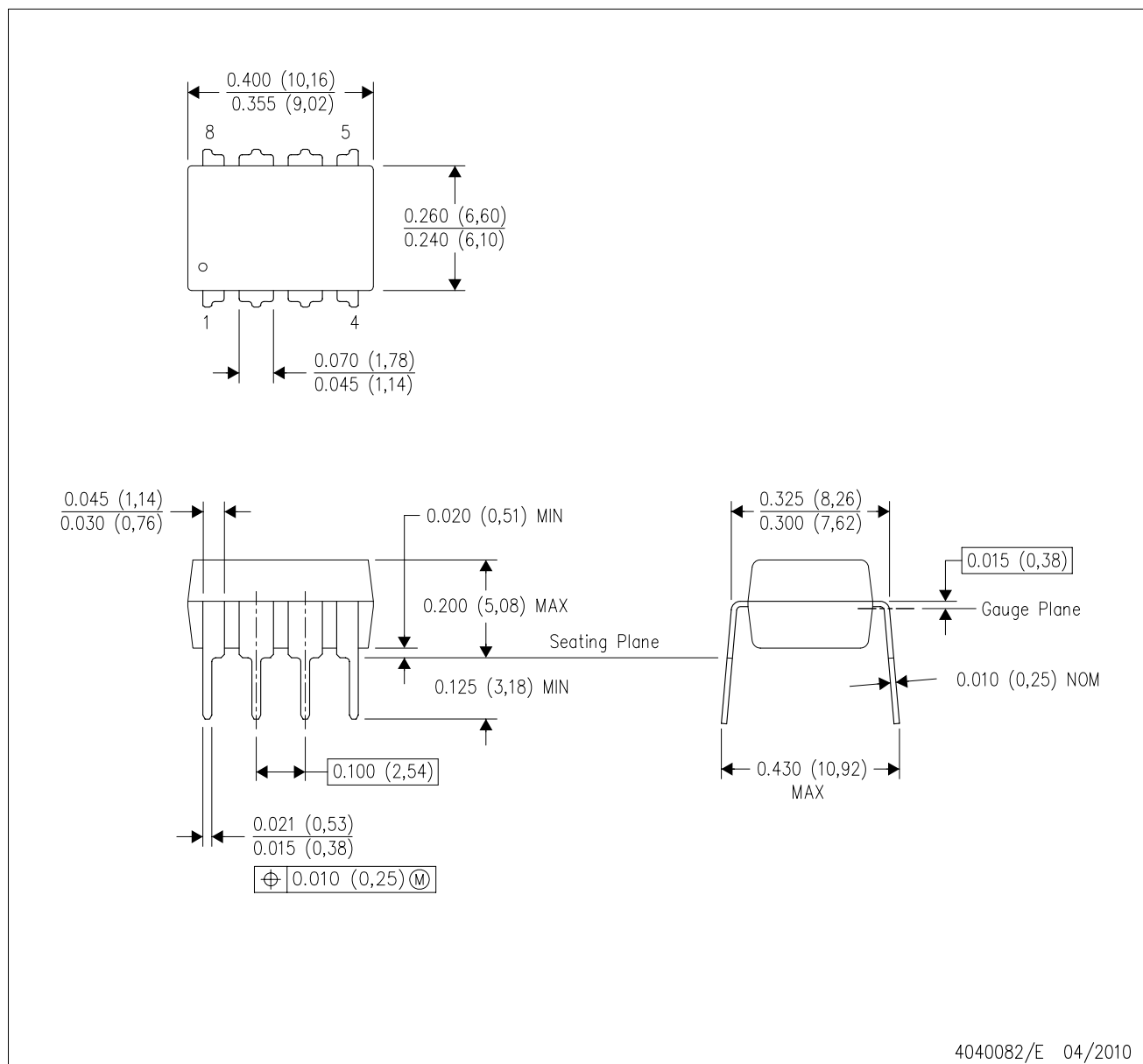
4214825/C 02/2019

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.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE

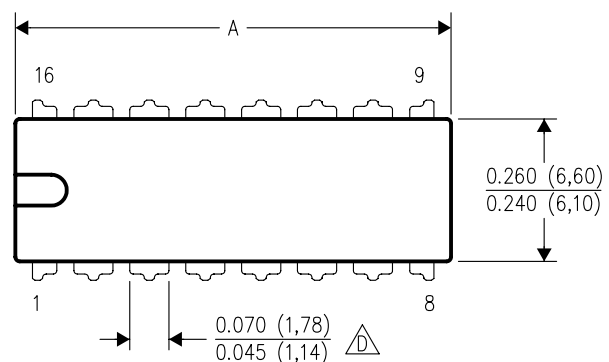


- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.

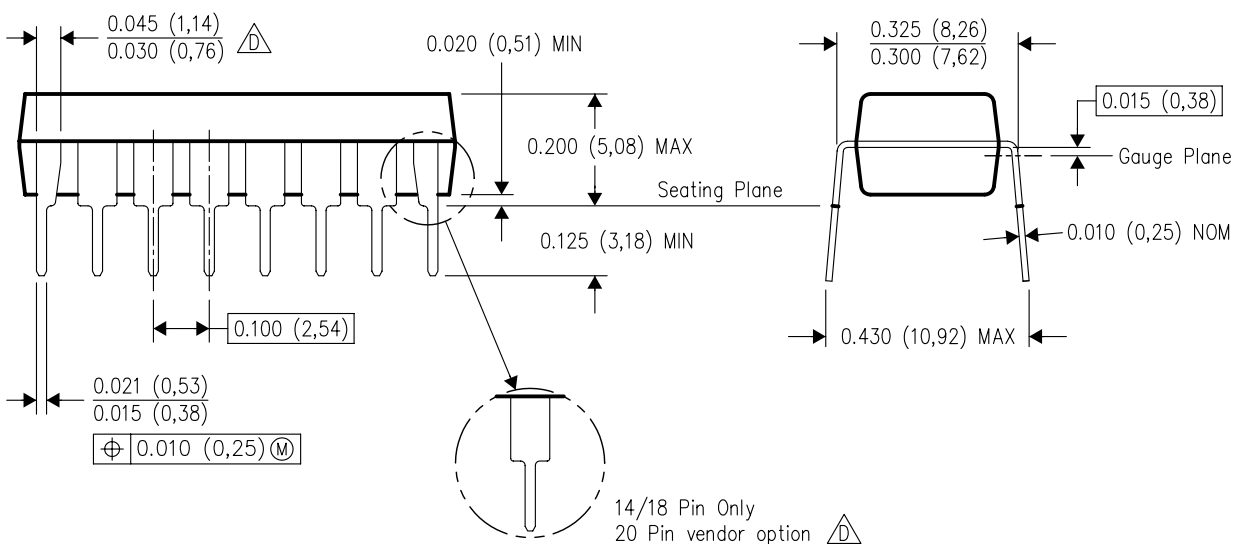
N (R-PDIP-T\*\*)

16 PINS SHOWN

## PLASTIC DUAL-IN-LINE PACKAGE



| PINS **<br>DIM      | 14               | 16               | 18               | 20               |
|---------------------|------------------|------------------|------------------|------------------|
| A MAX               | 0.775<br>(19,69) | 0.775<br>(19,69) | 0.920<br>(23,37) | 1.060<br>(26,92) |
| A MIN               | 0.745<br>(18,92) | 0.745<br>(18,92) | 0.850<br>(21,59) | 0.940<br>(23,88) |
| MS-001<br>VARIATION | AA               | BB               | AC               | AD               |



4040049/E 12/2002

NOTES:

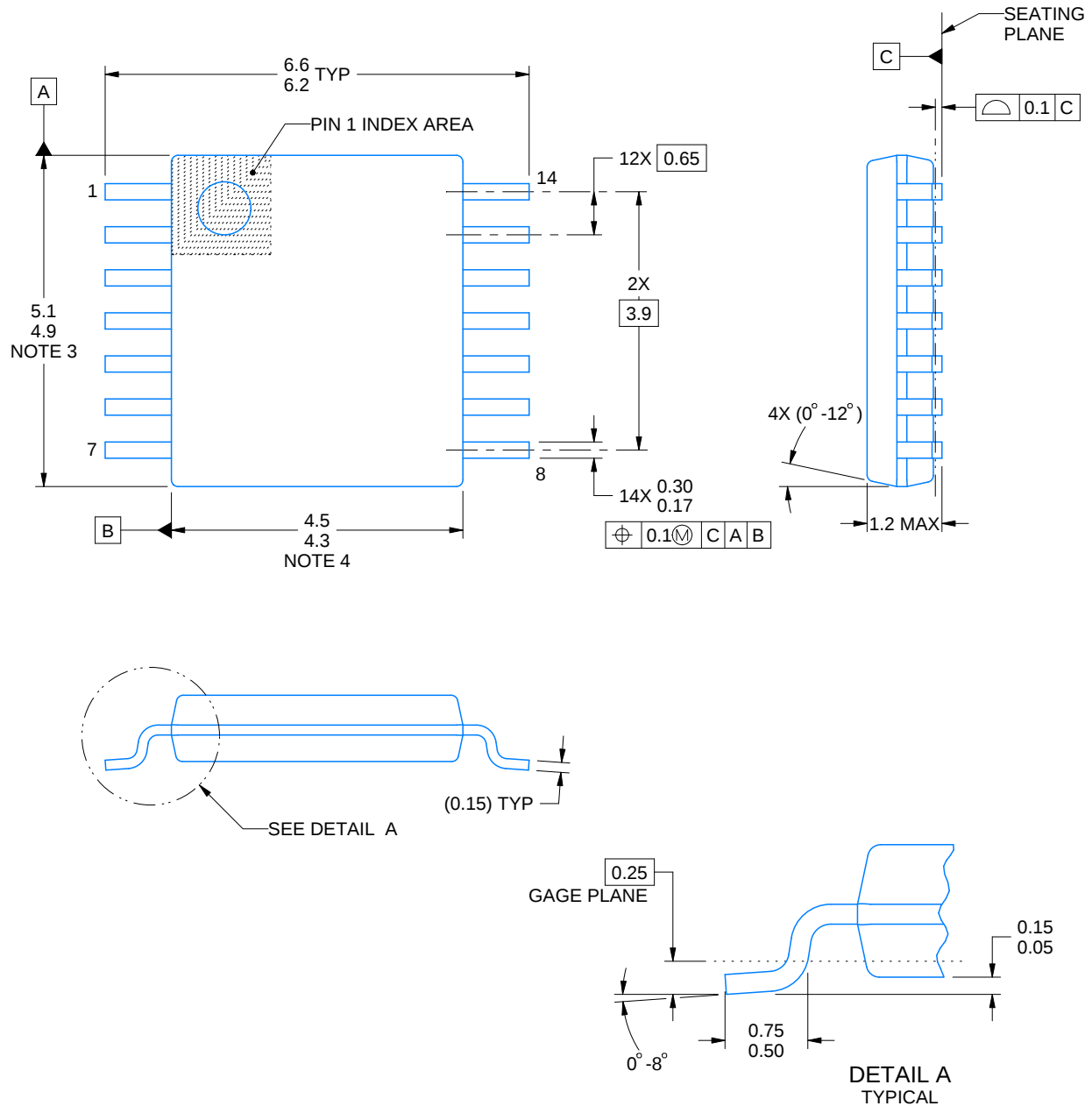
- A. All linear dimensions are in inches (millimeters).  
B. This drawing is subject to change without notice.
-  Falls within JEDEC MS-001, except 18 and 20 pin minimum body length (Dim A).  
 The 20 pin end lead shoulder width is a vendor option, either half or full width.

**PW0014A**

## PACKAGE OUTLINE

**TSSOP - 1.2 mm max height**

SMALL OUTLINE PACKAGE



4220202/B 12/2023

NOTES:

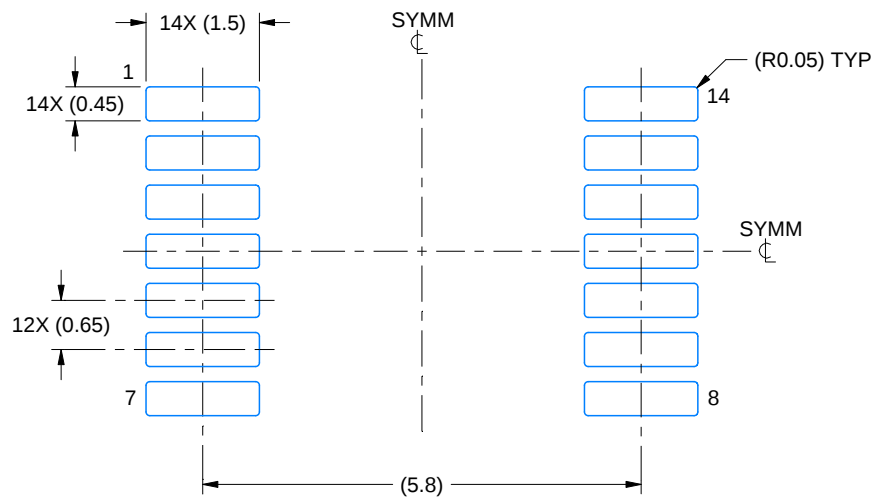
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or 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-153.

# EXAMPLE BOARD LAYOUT

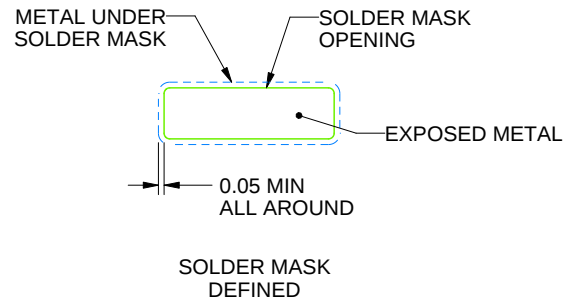
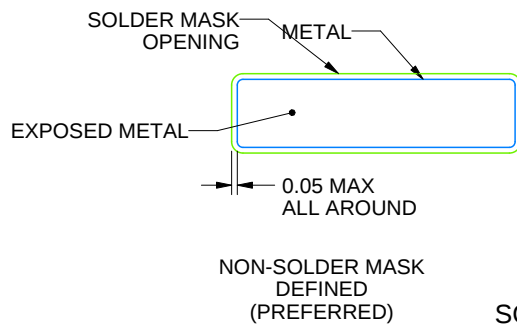
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

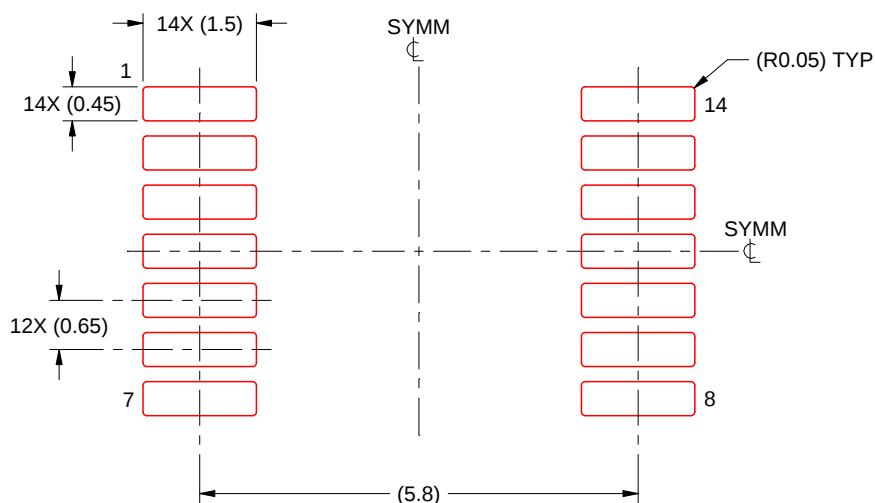
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE: 10X

4220202/B 12/2023

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.

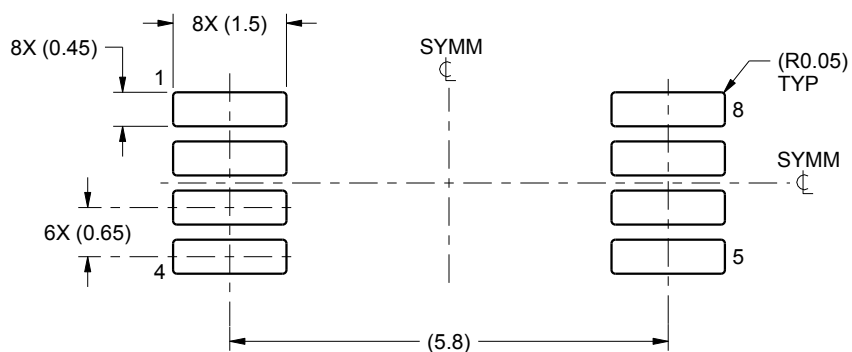


# EXAMPLE BOARD LAYOUT

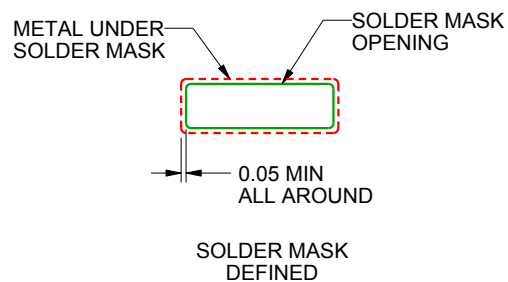
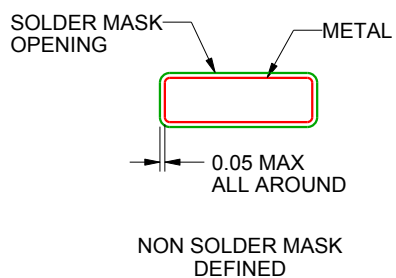
PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE  
SCALE:10X



SOLDER MASK DETAILS  
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

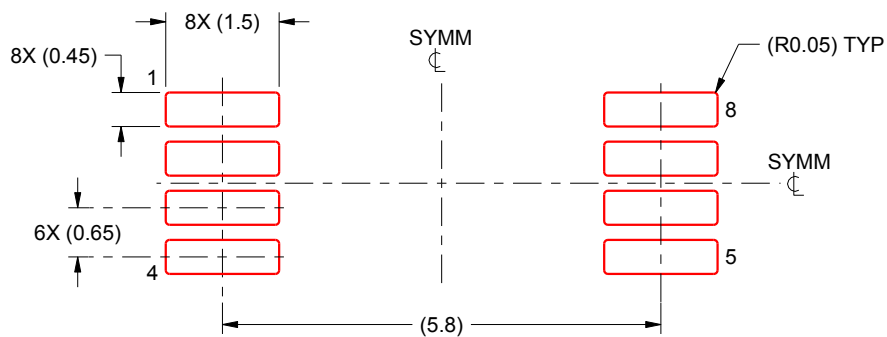
6. Publication IPC-7351 may have alternate designs.

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

**PW0008A**

## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



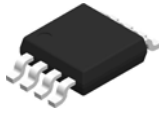
SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:10X

4221848/A 02/2015

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.

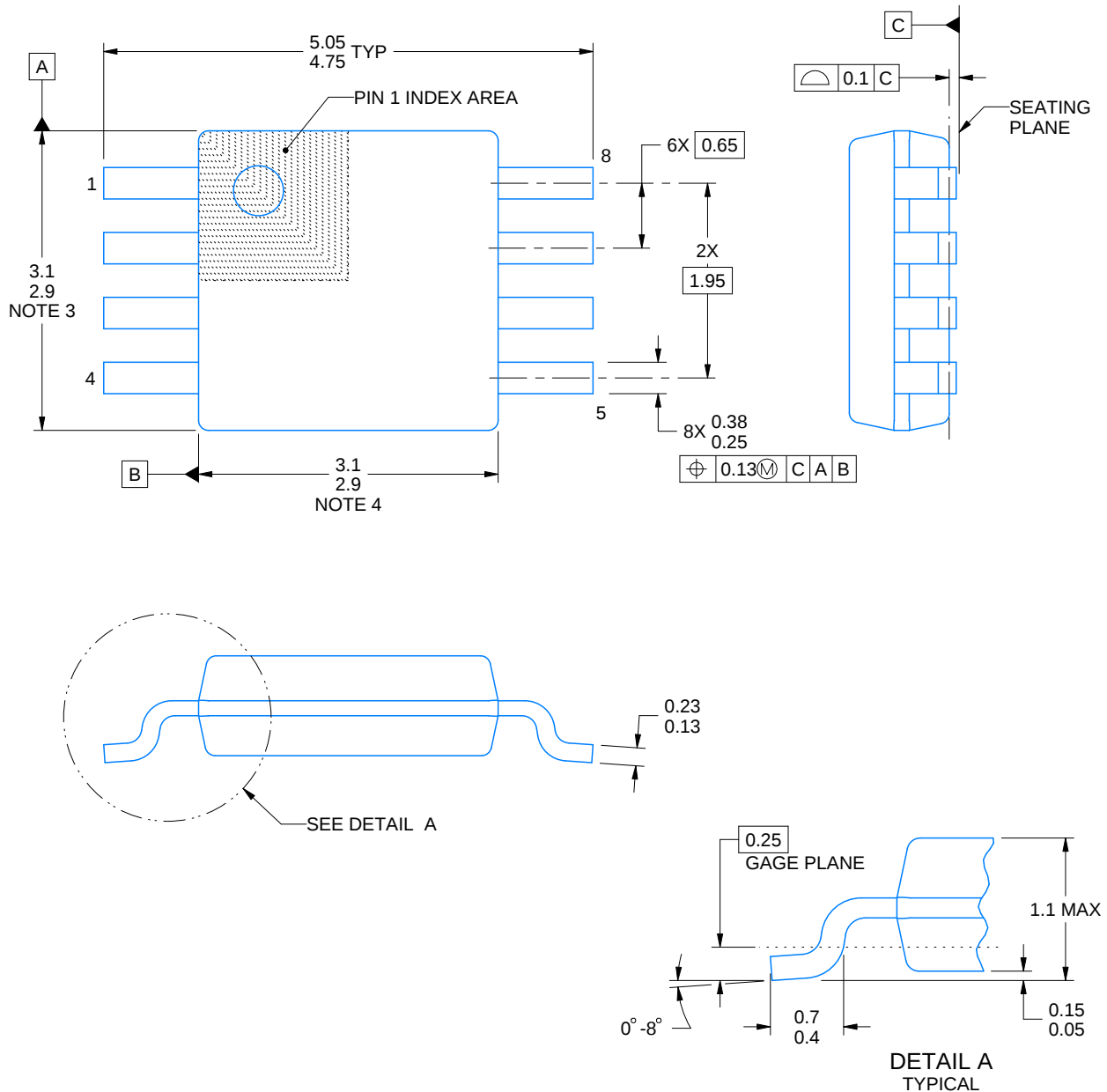
DGK0008A



## PACKAGE OUTLINE

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



4214862/A 04/2023

### NOTES:

PowerPAD is a trademark of Texas Instruments.

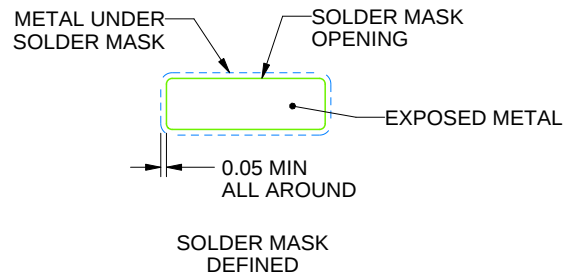
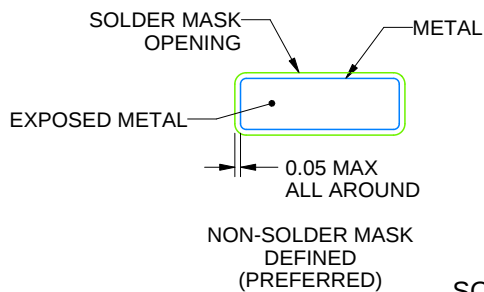
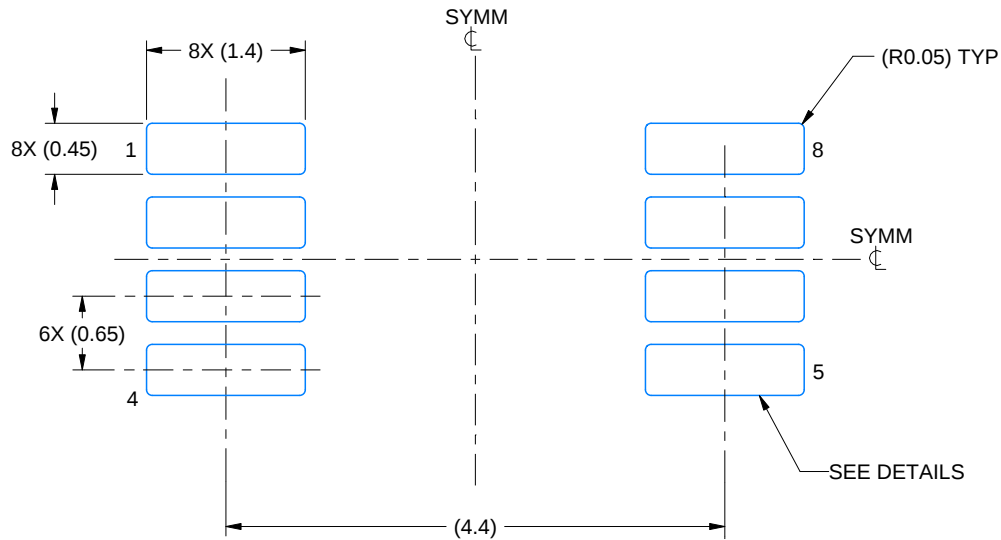
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or 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



SOLDER MASK DETAILS

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NOTES: (continued)

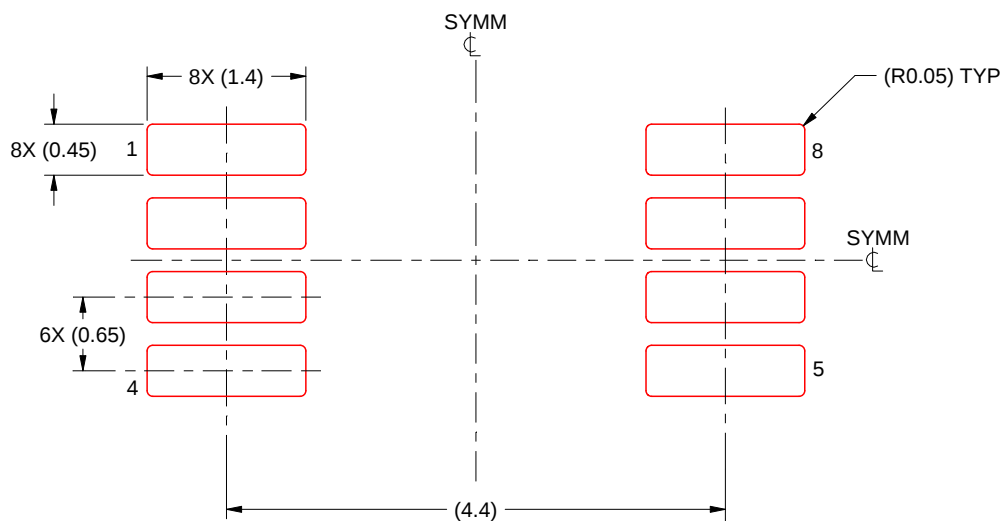
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It 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

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

SMALL OUTLINE PACKAGE



SOLDER PASTE EXAMPLE  
SCALE: 15X

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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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