TEXAS INSTRUMENTS

LMV931-N
LMV932-N, LMV934-N

SNOS993P – NOVEMBER 2001 – REVISED APRIL 2017

# LMV93x-N Single, Dual, Quad 1.8-V, RRIO Operational Amplifiers

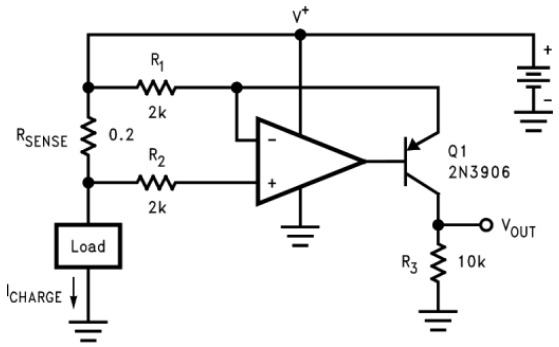
## 1 Features

- Typical 1.8-V Supply Values; Unless Otherwise Noted
- Specified at 1.8 V, 2.7 V and 5 V
- Output Swing
  - With 600-Ω Load 80 mV from Rail
  - With 2-kΩ Load 30 mV from Rail
- $V_{CM}$ 200 mV Beyond Rails
- Supply Current (per Channel) 100 μA
- Gain Bandwidth Product 1.4 MHz
- Maximum $V_{OS}$ 4 mV
- Ultra Tiny Packages
- Temperature Range −40°C to +125°C
- Create a Custom Design Using the LMV93x-N With the WEBENCH® Power Designer

## 2 Applications

- Phones
- Tablets
- Wearables
- Health Monitoring
- Portable and Battery-Powered Electronic Equipment
- Battery Monitoring

**High-Side Current Sense Amplifier**




$$V_{OUT} = \frac{R_{SENSE} \bullet R_3}{R_1} \bullet I_{Charge} = 1\,\Omega \bullet I_{Charge}$$

## 3 Description

The LMV93x-N family (LMV931-N single, LMV932-N dual and LMV934-N quad) are low-voltage, low-power operational amplifiers. The LMV93x-N family operates from 1.8-V to 5.5-V supply voltages and have rail-to-rail input and output. The input common-mode voltage extends 200 mV beyond the supplies which enables user enhanced functionality beyond the supply voltage range. The output can swing rail-to-rail unloaded and within 105 mV from the rail with 600-Ω load at 1.8-V supply. The LMV93x-N devices are optimized to work at 1.8 V, which make them ideal for portable two-cell, battery-powered systems and single-cell Li-Ion systems.

LMV93x-N devices exhibit an excellent speed-power ratio, achieving 1.4-MHz gain bandwidth product at 1.8-V supply voltage with very low supply current. The LMV93x-N devices can drive a 600-Ω load and up to 1000-pF capacitive load with minimal ringing. These devices also have a high DC gain of 101 dB, making them suitable for low-frequency applications.

The single LMV93x-N is offered in space-saving 5-pin SC70 and SOT-23 packages. The dual LMV932-N are in 8-pin VSSOP and SOIC packages and the quad LMV934-N are in 14-pin TSSOP and SOIC packages. These small packages are ideal solutions for area constrained PC boards and portable electronics such as mobile phones and tablets.

**Device Information(1)**

| PART NUMBER | PACKAGE | BODY SIZE (NOM) |
|---|---|---|
| LMV931-N | SOT-23 (5) | 2.90 mm × 1.60 mm |
| | SC-70 (5) | 2.00 mm × 1.25 mm |
| LMV932-N | VSSOP (8) | 3.00 mm × 3.00 mm |
| | SOIC (8) | 4.90 mm × 3.91 mm |
| LMV934-N | TSSOP (8) | 5.00 mm × 4.40 mm |
| | SOIC (14) | 8.60 mm × 3.90 mm |

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

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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## 4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

**Changes from Revision O (December 2014) to Revision P** — **Page**

- Deleted information specific to automotive grade - created separate automotive data sheet SNOSD49 ... 1
- Added links for WEBENCH ... 1
- Moved storage temperature to *Abs Max* table and changed *Handling Ratings* tables to *ESD Ratings* tables per new format ... 4
- Changed values in the *Thermal Information* table to align with JEDEC standards ... 4
- Changed Slew Rate vs Supply Voltage title to reflect LMV931 and LMV934 only ... 14
- Added Slew Rate vs Supply graph for LMV932 only ... 14
- Added *Receiving Notification of Documentation Updates* and *Community Resources* subsections ... 25

**Changes from Revision N (June 2014) to Revision O** — **Page**

- Added *Pin Configuration and Functions* section, *Handling Rating* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation*, *Power Supply Recommendations*, *Layout* , *Device and Documentation Support* , and *Mechanical, Packaging, and Orderable Information* sections ... 1

**Changes from Revision M (November 2013) to Revision N** — **Page**

- Complete rewrite for GDS standard. ... 1
- Added LMV934-N-Q1. The other Q grades were added in previous revision. ... 1

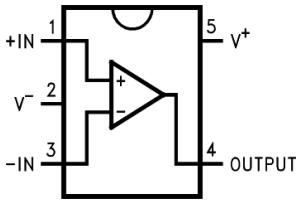
**Changes from Revision L (March 2013) to Revision M** — **Page**

- Added Automotive Q Grade. ... 1

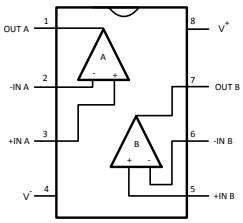

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# 5 Pin Configuration and Functions

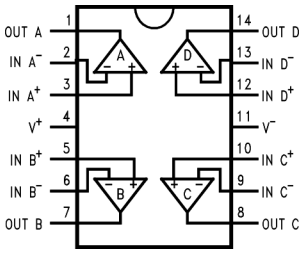
**DBV and DCK Package**
**5-Pin SC-70 and SOT-23**
**LMV931-N Top View**




**DGK and D Package**
**8-Pin VSSOP and SOIC**
**LMV932-N Top View**




**DGK and D Package**
**14-Pin TSSOP and SOIC**
**LMV934-N Top View**




**Pin Functions: LMV931**

| PIN | | I/O | DESCRIPTION |
|---|---|---|---|
| NAME | LMV931 DBV, DCK | | |
| +IN | 1 | I | Noninverting Input |
| -IN | 3 | I | Inverting Input |
| OUT | 4 | O | Output |
| V- | 2 | P | Negative Supply |
| V+ | 5 | P | Positive Supply |

**Pin Functions: LMV932 and LMV934**

| PIN | | | I/O | DESCRIPTION |
|---|---|---|---|---|
| NAME | LMV932 D, DGK | LMV934 D, PW | | |
| +IN A | 3 | 3 | I | Noninverting input, channel A |
| +IN B | 5 | 5 | I | Noninverting input, channel B |
| +IN C | — | 10 | I | Noninverting input, channel C |
| +IN D | — | 12 | I | Noninverting input, channel D |
| –IN A | 2 | 2 | I | Inverting input, channel A |
| –IN B | 6 | 6 | I | Inverting input, channel B |
| –IN C | — | 9 | I | Inverting input, channel C |
| –IN D | — | 13 | I | Inverting input, channel D |
| OUT A | 1 | 1 | O | Output, channel A |
| OUT B | 7 | 7 | O | Output, channel B |
| OUT C | — | 8 | O | Output, channel C |
| OUT D | — | 14 | O | Output, channel D |
| V+ | 8 | 4 | P | Positive (highest) power supply |
| V– | 4 | 11 | P | Negative (lowest) power supply |

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# 6 Specifications

## 6.1 Absolute Maximum Ratings

See (1)(2).

| | MIN | MAX | UNIT |
|---|---|---|---|
| Supply voltage ( $V^+ – V^-$ ) | –0.3 | 6 | V |
| Differential input voltage | $V^-$ | $V^+$ | V |
| Voltage at input/output pins | ($V^-$ ) - 0.3 | ($V^+$) + 0.3 | V |
| Junction temperature(3) | –40 | 150 | °C |
| Storage temperature, $T_{stg}$ | –65 | 150 | °C |

(1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Recommended Operating Conditions* indicate conditions for which the device is intended to be functional, but specific performance is not specified. For specifications and the test conditions, see the *Electrical Characteristics*.
(2) If Military/Aerospace specified devices are required, contact the TI Sales Office/Distributors for availability and specifications.
(3) The maximum power dissipation is a function of $T_{J(max)}$ , $R_{\theta JA}$, and $T_A$. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(max)}–T_A)/R_{\theta JA}$. All numbers apply for packages soldered directly into a PC board.

## 6.2 ESD Ratings (Commercial)

| | | | VALUE | UNIT |
|---|---|---|---|---|
| $V_{(ESD)}$ | Electrostatic discharge | Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1) | ±2000 | V |
| | | Charged-device model (CDM), per JEDEC specification JESD22-C101(2) | ±750 | |
| | | Machine model (MM)(3) | ±200 | |

(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.
(3) Machine model, 200 Ω in series with 100 pF.

## 6.3 Recommended Operating Ratings

See(1).

| | MIN | MAX | UNIT |
|---|---|---|---|
| Supply voltage range ( $V^+ – V^-$ ) | 1.8 | 5.5 | V |
| Ambient temperature | −40 | 125 | °C |

(1) *Absolute Maximum Ratings* indicate limits beyond which damage to the device may occur. *Recommended Operating Conditions* indicate conditions for which the device is intended to be functional, but specific performance is not specified. For specifications and the test conditions, see the *Electrical Characteristics*.

## 6.4 Thermal Information

| THERMAL METRIC(1) | | LMV931-N | | LMV932-N | | LMV934-N | | UNIT |
|---|---|---|---|---|---|---|---|---|
| | | DBV (SOT-23) | DCK (SC70) | D (SOIC) | DGK (VSSOP) | D (SOIC) | PW (TSSOP) | |
| | | 5 PINS | 5 PINS | 8 PINS | 8 PINS | 14 PINS | 14 PINS | |
| $R_{\theta JA}$ | Junction-to-ambient thermal resistance | 197.2 | 285.9 | 125.9 | 184.5 | 94.4 | 124.8 | °C/W |
| $R_{\theta JC(top)}$ | Junction-to-case (top) thermal resistance | 156.7 | 115.9 | 70.2 | 74.3 | 52.5 | 51.4 | °C/W |
| $R_{\theta JB}$ | Junction-to-board thermal resistance | 55.6 | 63.7 | 66.5 | 105.1 | 48.9 | 67.2 | °C/W |
| $\psi_{JT}$ | Junction-to-top characterization parameter | 41.4 | 4.5 | 19.8 | 13.1 | 14.3 | 6.6 | °C/W |
| $\psi_{JB}$ | Junction-to-board characterization parameter | 55 | 62.9 | 65.9 | 103.6 | 48.6 | 66.6 | °C/W |
| $R_{\theta JC(bot)}$ | Junction-to-case (bottom) thermal resistance | — | — | — | — | — | — | °C/W |

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


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## 6.5 DC Electrical Characteristics 1.8 V

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 1.8 V, $V^-$ = 0 V, $V_{CM}$ = $V^+/2$, $V_O$ = $V^+/2$ and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | LMV931 (Single) | 25°C | | 1 | 4 | mV |
| | | | Full Range | | | 6 | |
| | | LMV932 (Dual), LMV934 (Quad) | 25°C | | 1 | 5.5 | mV |
| | | | Full Range | | | 7.5 | |
| $TCV_{OS}$ | Input Offset Voltage Average Drift | | Full Range | | 5.5 | | µV/°C |
| $I_B$ | Input Bias Current | | 25°C | | 15 | 35 | nA |
| | | | Full Range | | | 50 | |
| $I_{OS}$ | Input Offset Current | | 25°C | | 13 | 25 | nA |
| | | | Full Range | | | 40 | |
| $I_S$ | Supply Current (per channel) | | 25°C | | 103 | 185 | µA |
| | | | Full Range | | | 205 | |
| CMRR | Common-Mode Rejection Ratio | LMV931, 0 ≤ $V_{CM}$ ≤ 0.6 V<br>1.4 V ≤ $V_{CM}$ ≤ 1.8 V (2) | 25°C | 60 | 78 | | dB |
| | | | Full Range | 55 | | | |
| | | LMV932 and LMV934<br>0 ≤ $V_{CM}$ ≤ 0.6 V<br>1.4 V ≤ $V_{CM}$ ≤ 1.8 V (2) | 25°C | 55 | 76 | | dB |
| | | | Full Range | 50 | | | |
| | | −0.2 V ≤ $V_{CM}$ ≤ 0 V<br>1.8 V ≤ $V_{CM}$ ≤ 2.0 V | 25°C | 50 | 72 | | dB |
| PSRR | Power Supply Rejection Ratio | 1.8 V ≤ $V^+$ ≤ 5 V | 25°C | 75 | 100 | | dB |
| | | | Full Range | 70 | | | |
| CMVR | Input Common-Mode Voltage Range | For CMRR Range ≥ 50dB | 25°C | $V^-$ − 0.2 | −0.2 to 2.1 | $V^+$ + 0.2 | V |
| | | | −40°C to 85°C | $V^-$ | | $V^+$ | |
| | | | 125°C | $V^-$ + 0.2 | | $V^+$ − 0.2 | |
| $A_V$ | Large Signal Voltage Gain LMV931-N (Single) | $R_L$ = 600 Ω to 0.9 V,<br>$V_O$ = 0.2 V to 1.6 V,<br>$V_{CM}$ = 0.5 V | 25°C | 77 | 101 | | dB |
| | | | Full Range | 73 | | | |
| | | $R_L$ = 2 kΩ to 0.9 V,<br>$V_O$ = 0.2 V to 1.6 V,<br>$V_{CM}$ = 0.5 V | 25°C | 80 | 105 | | dB |
| | | | Full Range | 75 | | | |
| | Large Signal Voltage Gain LMV932-N (Dual) LMV934-N (Quad) | $R_L$ = 600 Ω to 0.9 V,<br>$V_O$ = 0.2 V to 1.6 V,<br>$V_{CM}$ = 0.5 V | 25°C | 75 | 90 | | dB |
| | | | Full Range | 72 | | | |
| | | $R_L$ = 2 kΩ to 0.9 V,<br>$V_O$ = 0.2 V to 1.6 V,<br>$V_{CM}$ = 0.5 V | 25°C | 78 | 100 | | dB |
| | | | Full Range | 75 | | | |
| $V_O$ | Output Swing | $R_L$ = 600 Ω to 0.9 V<br>$V_{IN}$ = ±100 mV | 25°C | 1.65 | 1.72 | | V |
| | | | | | 0.077 | 0.105 | |
| | | | Full Range | 1.63 | | 0.120 | |
| | | $R_L$ = 2 kΩ to 0.9 V<br>$V_{IN}$ = ±100 mV | 25°C | 1.75 | 1.77 | | V |
| | | | | | 0.024 | 0.035 | |
| | | | Full Range | 1.74 | | 0.04 | |

(1) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
(2) For specified temperature ranges, see the CMVR parameter in *DC Electrical Characteristics 1.8 V* for the input common-mode voltage specifications.

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## DC Electrical Characteristics 1.8 V (continued)

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 1.8 V, $V^-$ = 0 V, $V_{CM}$ = $V^+/2$, $V_O$ = $V^+/2$ and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $I_O$ | Output Short Circuit Current (3) | Sourcing, $V_O$ = 0 V<br>$V_{IN}$ = 100 mV | 25°C | 4 | 8 | | mA |
| | | | Full Range | 3.3 | | | |
| | | Sinking, $V_O$ = 1.8 V<br>$V_{IN}$ = −100 mV | 25°C | 7 | 9 | | mA |
| | | | Full Range | 5 | | | |

(3) Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C. Output currents in excess of 45 mA over long term may adversely affect reliability.

## 6.6 AC Electrical Characteristics 1.8 V

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 1.8 V, $V^-$ = 0 V, $V_{CM}$ = $V^+/2$, $V_O$ = $V^+/2$ and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew Rate | See (2). | | 0.35 | | V/μs |
| GBW | Gain-Bandwidth Product | | | 1.4 | | MHz |
| $\Phi_m$ | Phase Margin | | | 67 | | deg |
| $G_m$ | Gain Margin | | | 7 | | dB |
| $e_n$ | Input-Referred Voltage Noise | f = 10 kHz, $V_{CM}$ = 0.5 V | | 60 | | nV/√Hz |
| $i_n$ | Input-Referred Current Noise | f = 10 kHz | | 0.08 | | pA/√Hz |
| THD | Total Harmonic Distortion | f = 1 kHz, $A_V$ = +1<br>$R_L$ = 600 Ω, $V_{IN}$ = 1 $V_{PP}$ | | 0.023% | | |
| | Amplifier-to-Amplifier Isolation | See (3) | | 123 | | dB |

(1) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
(2) Connected as voltage follower with input step from $V^-$ to $V^+$. Number specified is the slower of the positive and negative slew rates.
(3) Input referred, $R_L$ = 100 kΩ connected to $V^+/2$. Each amplifier excited in turn with 1 kHz to produce $V_O$ = 3 $V_{PP}$ (For supply voltages < 3 V, $V_O$ = $V^+$).

## 6.7 DC Electrical Characteristics 2.7 V

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 2.7 V, $V^-$ = 0 V, $V_{CM}$ = $V^+/2$, $V_O$ = $V^+/2$ and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | LMV931 (Single) | 25°C | | 1 | 4 | mV |
| | | | Full Range | | | 6 | |
| | | LMV932 (Dual)<br>LMV934 (Quad) | 25°C | | 1 | 5.5 | mV |
| | | | Full Range | | | 7.5 | |
| $TCV_{OS}$ | Input Offset Voltage Average Drift | | Full Range | | 5.5 | | μV/°C |
| $I_B$ | Input Bias Current | | 25°C | | 15 | 35 | nA |
| | | | Full Range | | | 50 | |
| $I_{OS}$ | Input Offset Current | | 25°C | | 8 | 25 | nA |
| | | | Full Range | | | 40 | |
| $I_S$ | Supply Current (per channel) | | 25°C | | 105 | 190 | μA |
| | | | Full Range | | | 210 | |

(1) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.


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## DC Electrical Characteristics 2.7 V (continued)

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 2.7 V, $V^-$ = 0 V, $V_{CM}$ = $V^+/2$, $V_O$ = $V^+/2$ and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| CMRR | Common-Mode Rejection Ratio | LMV931, 0 ≤ $V_{CM}$ ≤ 1.5 V<br>2.3 V ≤ $V_{CM}$ ≤ 2.7 V(2) | 25°C | 60 | 81 | | dB |
| | | | Full Range | 55 | | | |
| | | LMV932 and LMV934<br>0 ≤ $V_{CM}$ ≤ 1.5 V<br>2.3 V ≤ $V_{CM}$ ≤ 2.7 V(2) | 25°C | 55 | 80 | | dB |
| | | | Full Range | 50 | | | |
| | | −0.2 V ≤ $V_{CM}$ ≤ 0 V<br>2.7 V ≤ $V_{CM}$ ≤ 2.9 V | 25°C | 50 | 74 | | dB |
| PSRR | Power Supply Rejection Ratio | 1.8 V ≤ $V^+$ ≤ 5 V<br>$V_{CM}$ = 0.5 V | 25°C | 75 | 100 | | dB |
| | | | Full Range | 70 | | | |
| $V_{CM}$ | Input Common-Mode Voltage Range | For CMRR Range ≥ 50 dB | 25°C | $V^-$ − 0.2 | −0.2 to 3.0 | $V^+$ + 0.2 | V |
| | | | −40°C to 85°C | $V^-$ | | $V^+$ | |
| | | | 125°C | $V^-$ + 0.2 | | $V^+$ − 0.2 | |
| $A_V$ | Large Signal Voltage Gain LMV931-N (Single) | $R_L$ = 600 Ω to 1.35 V,<br>$V_O$ = 0.2 V to 2.5 V | 25°C | 87 | 104 | | dB |
| | | | Full Range | 86 | | | |
| | | $R_L$ = 2 kΩ to 1.35 V,<br>$V_O$ = 0.2 V to 2.5 V | 25°C | 92 | 110 | | dB |
| | | | Full Range | 91 | | | |
| | Large Signal Voltage Gain LMV932-N (Dual) LMV934-N (Quad) | $R_L$ = 600 Ω to 1.35 V,<br>$V_O$ = 0.2 V to 2.5 V | 25°C | 78 | 90 | | dB |
| | | | Full Range | 75 | | | |
| | | $R_L$ = 2 kΩ to 1.35 V,<br>$V_O$ = 0.2 V to 2.5 V | 25°C | 81 | 100 | | dB |
| | | | Full Range | 78 | | | |
| $V_O$ | Output Swing | $R_L$ = 600 Ω to 1.35 V<br>$V_{IN}$ = ±100 mV | 25°C | 2.55 | 2.62 | | V |
| | | | | | 0.083 | 0.110 | |
| | | | Full Range | 2.53 | | 0.130 | |
| | | $R_L$ = 2 kΩ to 1.35 V<br>$V_{IN}$ = ±100 mV | 25°C | 2.65 | 2.675 | | V |
| | | | | | 0.025 | 0.04 | |
| | | | Full Range | 2.64 | | 0.045 | |
| $I_O$ | Output Short Circuit Current(3) | Sourcing, $V_O$ = 0 V<br>$V_{IN}$ = +100 mV | 25°C | 20 | 30 | | mA |
| | | | Full Range | 15 | | | |
| | | Sinking,<br>$V_O$ = 2.7 V<br>$V_{IN}$ = −100 mV | 25°C | 18 | 25 | | mA |
| | | | Full Range | 12 | | | |

(2) For specified temperature ranges, see the CMVR parameter in *DC Electrical Characteristics 1.8 V* for the input common-mode voltage specifications.
(3) Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C. Output currents in excess of 45 mA over long term may adversely affect reliability.

## 6.8 AC Electrical Characteristics 2.7 V

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 2.7 V, $V^-$ = 0 V, $V_{CM}$ = 1.0 V, $V_O$ = 1.35 V and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew Rate | See(2) | | 0.4 | | V/µs |
| GBW | Gain-Bandwidth Product | | | 1.4 | | MHz |
| $\Phi_m$ | Phase Margin | | | 70 | | deg |
| $G_m$ | Gain Margin | | | 7.5 | | dB |
| $e_n$ | Input-Referred Voltage Noise | f = 10 kHz, $V_{CM}$ = 0.5 V | | 57 | | nV/√Hz |
| $i_n$ | Input-Referred Current Noise | f = 10 kHz | | 0.08 | | pA/√Hz |

(1) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
(2) Connected as voltage follower with input step from $V^-$ to $V^+$. Number specified is the slower of the positive and negative slew rates.

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## AC Electrical Characteristics 2.7 V (continued)

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 2.7 V, $V^-$ = 0 V, $V_{CM}$ = 1.0 V, $V_O$ = 1.35 V and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|
| THD | Total Harmonic Distortion | f = 1 kHz, $A_V$ = +1<br>$R_L$ = 600 Ω, $V_{IN}$ = 1 $V_{PP}$ | | 0.022% | | |
| | Amp-to-Amp Isolation | See (3) | | 123 | | dB |

(3) Input referred, $R_L$ = 100 kΩ connected to $V^+/2$. Each amplifier excited in turn with 1 kHz to produce $V_O$ = 3 $V_{PP}$ (For supply voltages < 3 V, $V_O$ = $V^+$).


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## 6.9 Electrical Characteristics 5 V DC

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 5 V, $V^-$ = 0 V, $V_{CM}$ = $V^+/2$, $V_O$ = $V^+/2$ and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | LMV931 (Single) | 25°C | | 1 | 4 | mV |
| | | | Full Range | | | 6 | |
| | | LMV932 (Dual)<br>LMV934 (Quad) | 25°C | | 1 | 5.5 | mV |
| | | | Full Range | | | 7.5 | |
| $TCV_{OS}$ | Input Offset Voltage Average Drift | | | | 5.5 | | µV/°C |
| $I_B$ | Input Bias Current | | 25°C | | 14 | 35 | nA |
| | | | Full Range | | | 50 | |
| $I_{OS}$ | Input Offset Current | | 25°C | | 9 | 25 | nA |
| | | | Full Range | | | 40 | |
| $I_S$ | Supply Current (per channel) | | 25°C | | 116 | 210 | µA |
| | | | Full Range | | | 230 | |
| CMRR | Common-Mode Rejection Ratio | 0 ≤ $V_{CM}$ ≤ 3.8 V<br>4.6 V ≤ $V_{CM}$ ≤ 5 V (2) | 25°C | 60 | 86 | | dB |
| | | | Full Range | 55 | | | |
| | | −0.2 V ≤ $V_{CM}$ ≤ 0 V<br>5 V ≤ $V_{CM}$ ≤ 5.2 V | 25°C | 50 | 78 | | dB |
| PSRR | Power Supply Rejection Ratio | 1.8 V ≤ $V^+$ ≤ 5 V<br>$V_{CM}$ = 0.5 V | 25°C | 75 | 100 | | dB |
| | | | Full Range | 70 | | | |
| CMVR | Input Common-Mode Voltage Range | For CMRR Range ≥ 50 dB | 25°C | $V^-$ − 0.2 | −0.2 to 5.3 | $V^+$ + 0.2 | V |
| | | | −40°C to 85°C | $V^-$ | | $V^+$ | |
| | | | 125°C | $V^-$ + 0.3 | | $V^+$ − 0.3 | |
| $A_V$ | Large Signal Voltage Gain LMV931-N (Single) | $R_L$ = 600 Ω to 2.5 V,<br>$V_O$ = 0.2 V to 4.8 V | 25°C | 88 | 102 | | dB |
| | | | Full Range | 87 | | | |
| | | $R_L$ = 2 kΩ to 2.5 V,<br>$V_O$ = 0.2 V to 4.8 V | 25°C | 94 | 113 | | dB |
| | | | Full Range | 93 | | | |
| | Large Signal Voltage Gain LMV932-N (Dual) LMV934-N (Quad) | $R_L$ = 600 Ω to 2.5 V,<br>$V_O$ = 0.2 V to 4.8 V | 25°C | 81 | 90 | | dB |
| | | | Full Range | 78 | | | |
| | | $R_L$ = 2 kΩ to 2.5 V,<br>$V_O$ = 0.2 V to 4.8 V | 25°C | 85 | 100 | | dB |
| | | | Full Range | 82 | | | |
| $V_O$ | Output Swing | $R_L$ = 600 Ω to 2.5 V<br>$V_{IN}$ = ±100 mV | 25°C | 4.855 | 4.890 | | V |
| | | | | | 0.120 | 0.160 | |
| | | | Full Range | 4.835 | | 0.180 | |
| | | $R_L$ = 2 kΩ to 2.5 V<br>$V_{IN}$ = ±100 mV | 25°C | 4.945 | 4.967 | | V |
| | | | | | 0.037 | 0.065 | |
| | | | Full Range | 4.935 | | 0.075 | |
| $I_O$ | Output Short Circuit Current (3) | LMV931, Sourcing, $V_O$ = 0 V<br>$V_{IN}$ = +100 mV | 25°C | 80 | 100 | | mA |
| | | | Full Range | 68 | | | |
| | | Sinking, $V_O$ = 5 V<br>$V_{IN}$ = −100 mV | 25°C | 58 | 65 | | mA |
| | | | Full Range | 45 | | | |

(1) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
(2) For specified temperature ranges, see the CMVR parameter in *DC Electrical Characteristics 1.8 V* for the input common-mode voltage specifications.
(3) Applies to both single-supply and split-supply operation. Continuous short circuit operation at elevated ambient temperature can result in exceeding the maximum allowed junction temperature of 150°C. Output currents in excess of 45 mA over long term may adversely affect reliability.

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## 6.10 AC Electrical Characteristics 5 V

Unless otherwise specified, all limits specified for $T_J$ = 25°C. $V^+$ = 5 V, $V^-$ = 0 V, $V_{CM}$ = $V^+$/2, $V_O$ = 2.5 V and $R_L$ > 1 MΩ.

| PARAMETER | | TEST CONDITIONS | MIN | TYP (1) | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew Rate | See .(2) | | 0.42 | | V/µs |
| GBW | Gain-Bandwidth Product | | | 1.5 | | MHz |
| $\Phi_m$ | Phase Margin | | | 71 | | deg |
| $G_m$ | Gain Margin | | | 8 | | dB |
| $e_n$ | Input-Referred Voltage Noise | f = 10 kHz, $V_{CM}$ = 1 V | | 50 | | nV/√Hz |
| $i_n$ | Input-Referred Current Noise | f = 10 kHz | | 0.08 | | pA/√Hz |
| THD | Total Harmonic Distortion | f = 1 kHz, $A_V$ = 1<br>$R_L$ = 600 Ω, $V_O$ = 1 $V_{PP}$ | | 0.022% | | |
| | Amplifier-to-Amplifier Isolation | See(3) | | 123 | | dB |

(1) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.
(2) Connected as voltage follower with input step from $V^-$ to $V^+$. Number specified is the slower of the positive and negative slew rates.
(3) Input referred, $R_L$ = 100 kΩ connected to $V^+$/2. Each amplifier excited in turn with 1 kHz to produce $V_O$ = 3 $V_{PP}$ (For supply voltages < 3 V, $V_O$ = $V^+$).


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## 6.11 Typical Characteristics

Unless otherwise specified, $V_S$ = 5 V, single-supply, $T_A$ = 25°C.

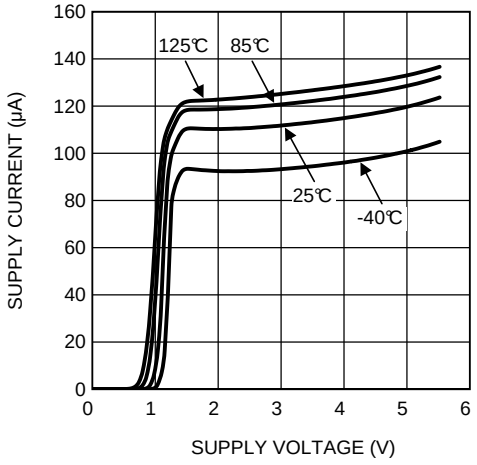



**Figure 1. Supply Current vs Supply Voltage (LMV931-N)**

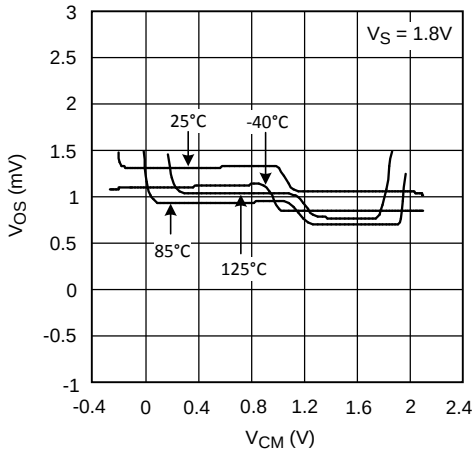



**Figure 2. Offset Voltage vs Common-Mode Range**

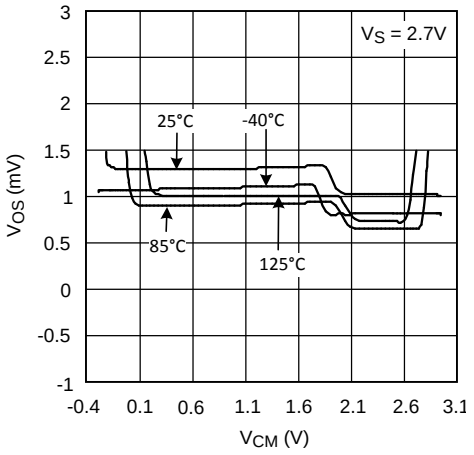



**Figure 3. Offset Voltage vs Common-Mode Range**

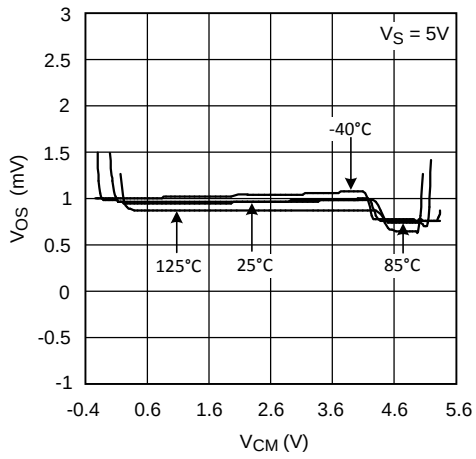



**Figure 4. Offset Voltage vs Common-Mode Range**

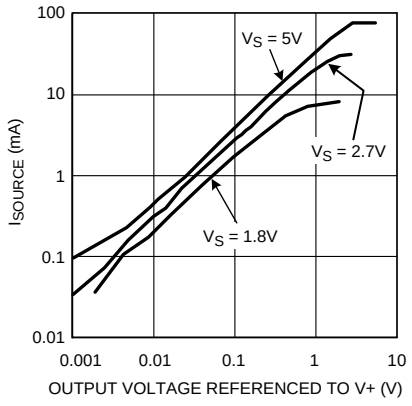



**Figure 5. Sourcing Current vs Output Voltage**

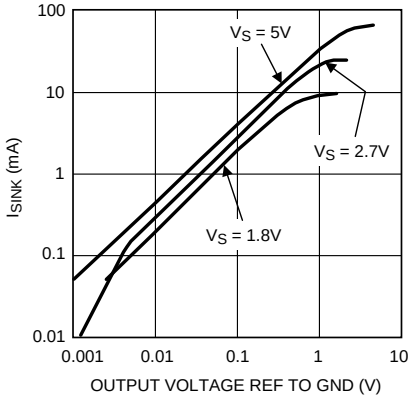



**Figure 6. Sinking Current vs Output Voltage**

## Typical Characteristics (continued)

Unless otherwise specified, $V_S$ = 5 V, single-supply, $T_A$ = 25°C.

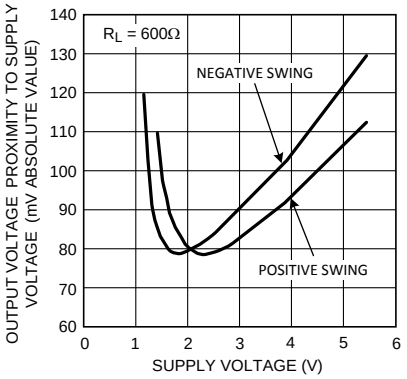



**Figure 7. Output Voltage Swing vs Supply Voltage**

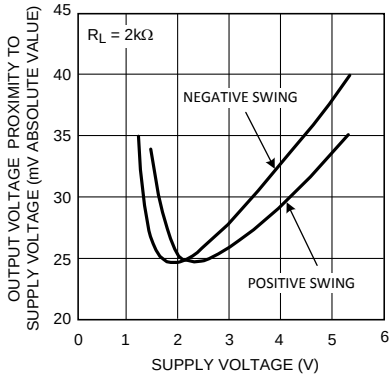



**Figure 8. Output Voltage Swing vs Supply Voltage**

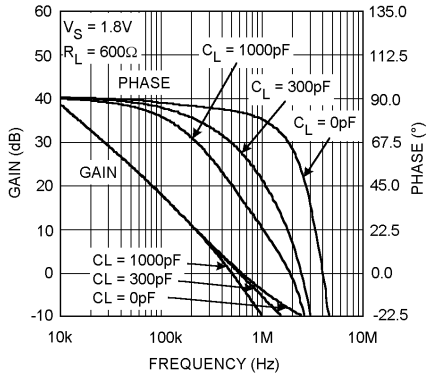



**Figure 9. Gain and Phase vs Frequency**

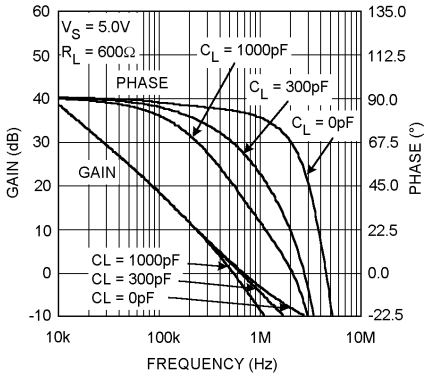



**Figure 10. Gain and Phase vs Frequency**

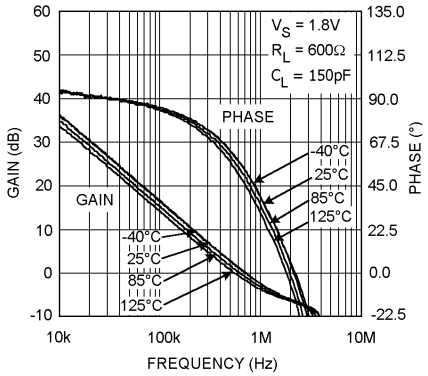



**Figure 11. Gain and Phase vs Frequency**

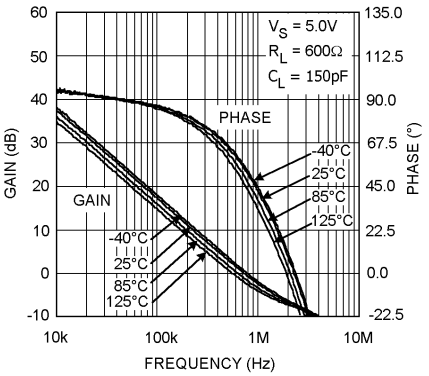



**Figure 12. Gain and Phase vs Frequency**


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## Typical Characteristics (continued)

Unless otherwise specified, $V_S$ = 5 V, single-supply, $T_A$ = 25°C.

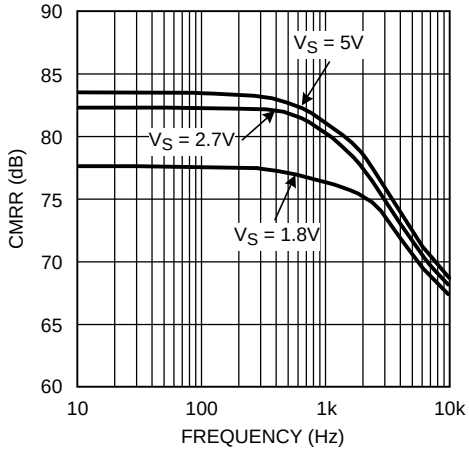



**Figure 13. CMRR vs Frequency**

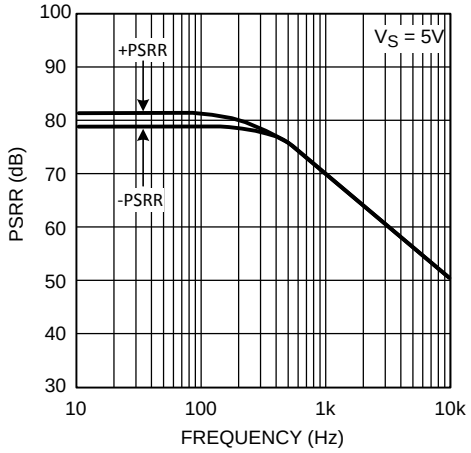



**Figure 14. PSRR vs Frequency**

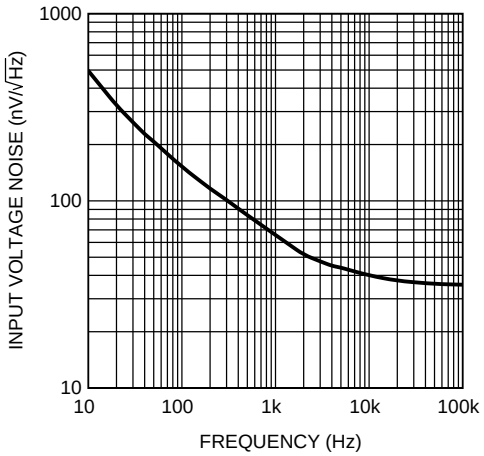



**Figure 15. Input Voltage Noise vs Frequency**

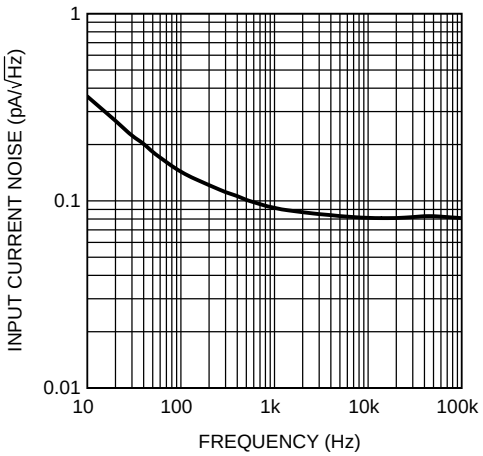



**Figure 16. Input Current Noise vs Frequency**

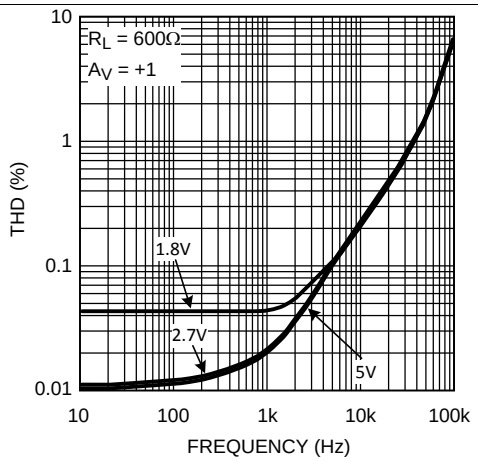



**Figure 17. THD vs Frequency**

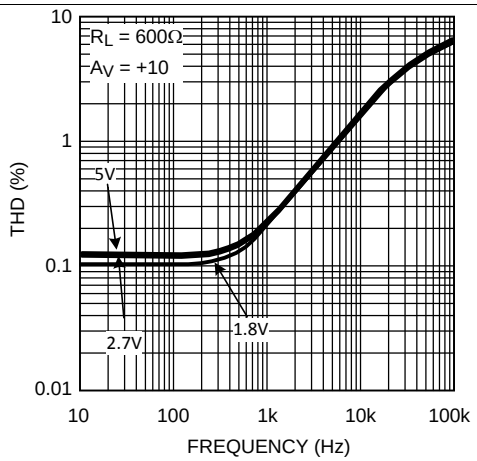



**Figure 18. THD vs Frequency**

## Typical Characteristics (continued)

Unless otherwise specified, $V_S$ = 5 V, single-supply, $T_A$ = 25°C.

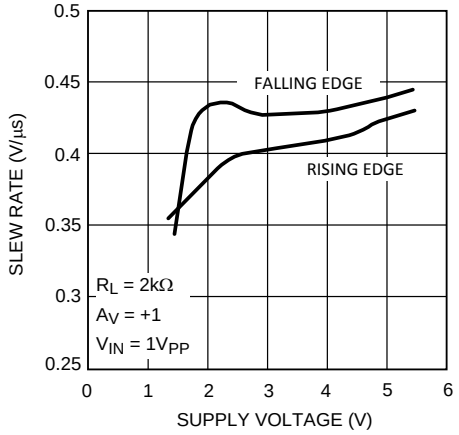



**Figure 19. Slew Rate vs Supply Voltage LMV931 and LMV934**

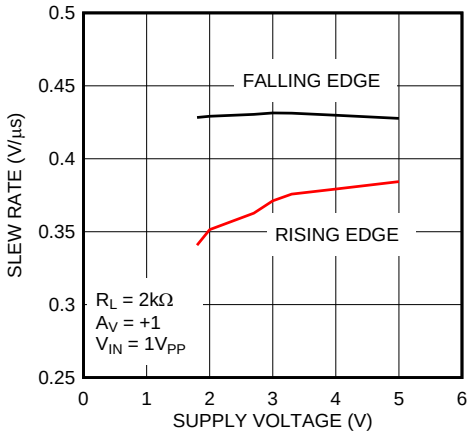



**Figure 20. Slew Rate vs Supply Voltage LMV932 Only**

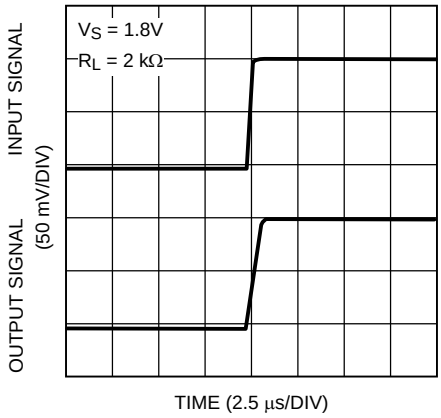



**Figure 21. Small Signal Noninverting Response**

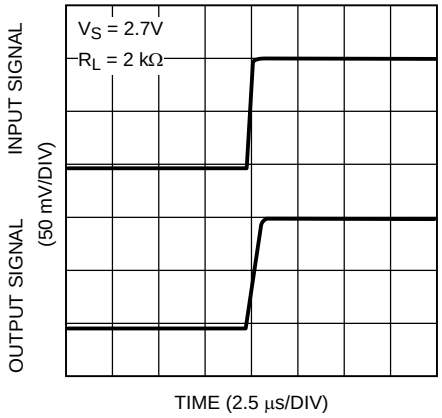



**Figure 22. Small Signal Noninverting Response**

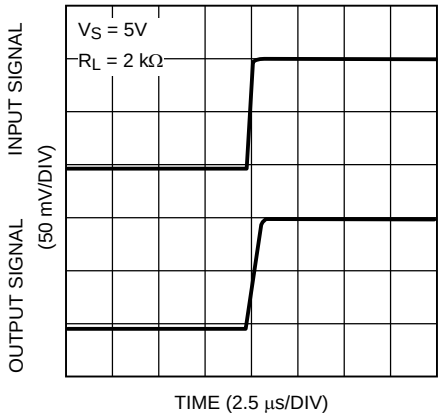



**Figure 23. Small Signal Noninverting Response**

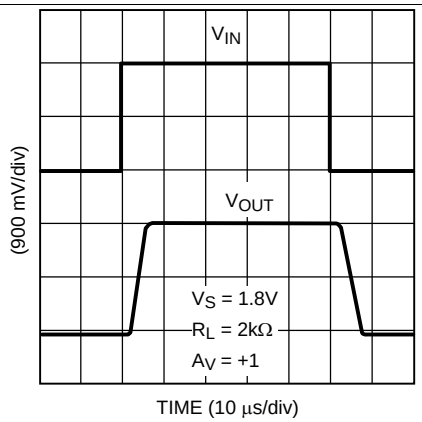



**Figure 24. Large Signal Noninverting Response**


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## Typical Characteristics (continued)

Unless otherwise specified, $V_S$ = 5 V, single-supply, $T_A$ = 25°C.

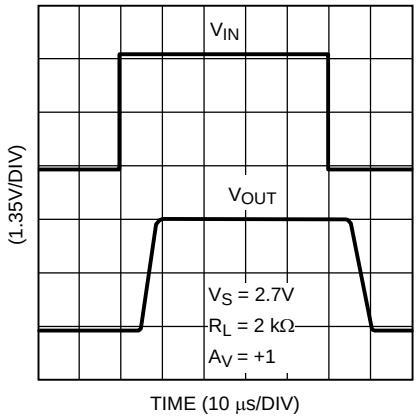



**Figure 25. Large Signal Noninverting Response**

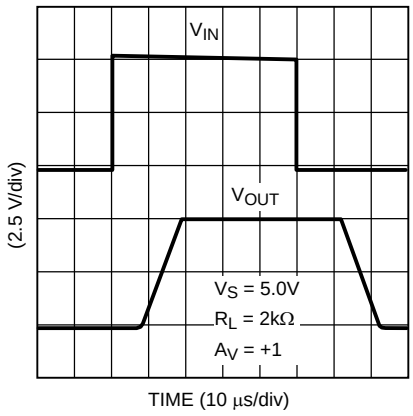



**Figure 26. Large Signal Noninverting Response**

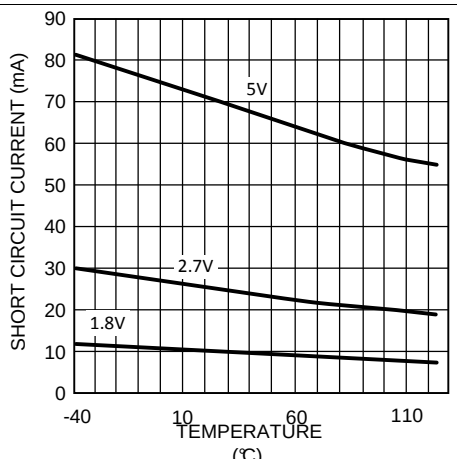



**Figure 27. Short Circuit Current vs Temperature (Sinking)**

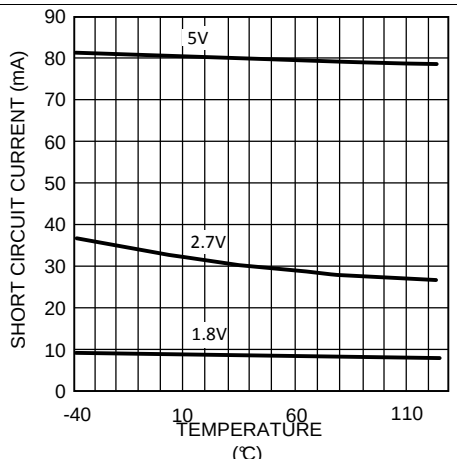


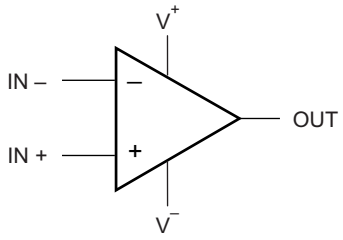

**Figure 28. Short Circuit Current vs Temperature (Sourcing)**

# 7 Detailed Description

## 7.1 Overview

The LMV93x-N are low-voltage, low-power operational amplifiers (op-amp) operating from 1.8-V to 5.5-V supply voltages and have rail-to-rail input and output. LMV93x-N input common-mode voltage extends 200 mV beyond the supplies which enables user enhanced functionality beyond the supply voltage range.

## 7.2 Functional Block Diagram




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(Each Amplifier)

## 7.3 Feature Description

The differential inputs of the amplifier consist of a noninverting input (+IN) and an inverting input (–IN). The amplifer amplifies only the difference in voltage between the two inputs, which is called the differential input voltage. The output voltage of the op-amp $V_{OUT}$ is given by Equation 1:

$$V_{OUT} = A_{OL} (IN^+ - IN^-) \quad (1)$$

where

- $A_{OL}$ is the open-loop gain of the amplifier, typically around 100 dB (100,000x, or 10 µV per volt).

## 7.4 Device Functional Modes

### 7.4.1 Input and Output Stage

The rail-to-rail input stage of this family provides more flexibility for the designer. The LMV93x-N use a complimentary PNP and NPN input stage in which the PNP stage senses common-mode voltage near $V^-$ and the NPN stage senses common-mode voltage near $V^+$. The transition from the PNP stage to NPN stage occurs 1 V below $V^+$. Because both input stages have their own offset voltage, the offset of the amplifier becomes a function of the input common-mode voltage and has a crossover point at 1 V below $V^+$.


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## Device Functional Modes (continued)

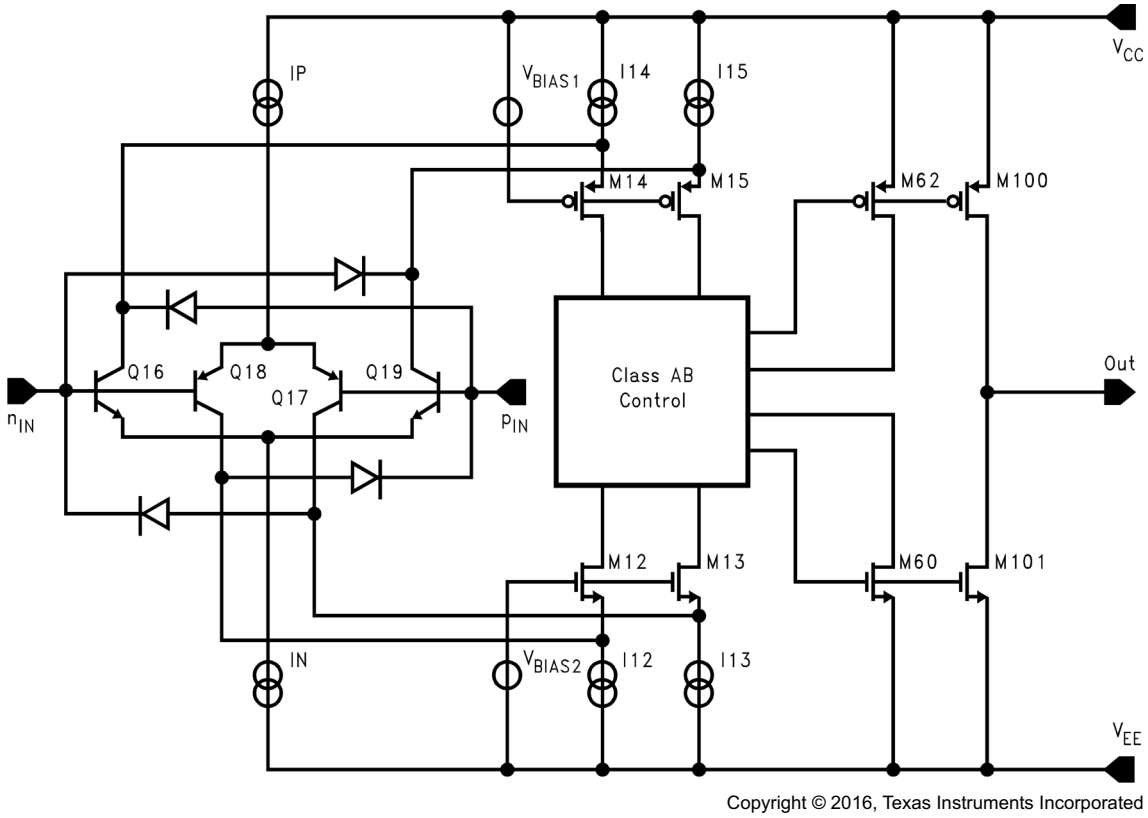



**Figure 29. Simplified Schematic Diagram**

This $V_{OS}$ crossover point can create problems for both DC− and AC-coupled signals if proper care is not taken. Large input signals that include the $V_{OS}$ crossover point will cause distortion in the output signal. One way to avoid such distortion is to keep the signal away from the crossover. For example, in a unity gain buffer configuration with $V_S$ = 5 V, a 5-V peak-to-peak signal will contain input-crossover distortion while a 3-V peak-to-peak signal centered at 1.5 V will not contain input-crossover distortion as it avoids the crossover point. Another way to avoid large signal distortion is to use a gain of −1 circuit which avoids any voltage excursions at the input terminals of the amplifier. In that circuit, the common-mode DC voltage can be set at a level away from the $V_{OS}$ cross-over point. For small signals, this transition in $V_{OS}$ shows up as a $V_{CM}$ dependent spurious signal in series with the input signal and can effectively degrade small signal parameters such as gain and common-mode rejection ratio. To resolve this problem, the small signal should be placed such that it avoids the $V_{OS}$ crossover point. In addition to the rail-to-rail performance, the output stage can provide enough output current to drive 600-Ω loads. Because of the high-current capability, take care not to exceed the 150°C maximum junction temperature specification.

### 7.4.2 Input Bias Current Consideration

The LMV93x-N family has a complementary bipolar input stage. The typical input bias current ($I_B$) is 15 nA. The input bias current can develop a significant offset voltage. This offset is primarily due to $I_B$ flowing through the negative feedback resistor, $R_F$. For example, if $I_B$ is 50 nA and $R_F$ is 100 kΩ, then an offset voltage of 5 mV will develop ($V_{OS}$ = $I_B$ x $R_F$). Using a compensation resistor ($R_C$), as shown in Figure 30, cancels this effect. But the input offset current ($I_{OS}$) will still contribute to an offset voltage in the same manner.

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## Device Functional Modes (continued)

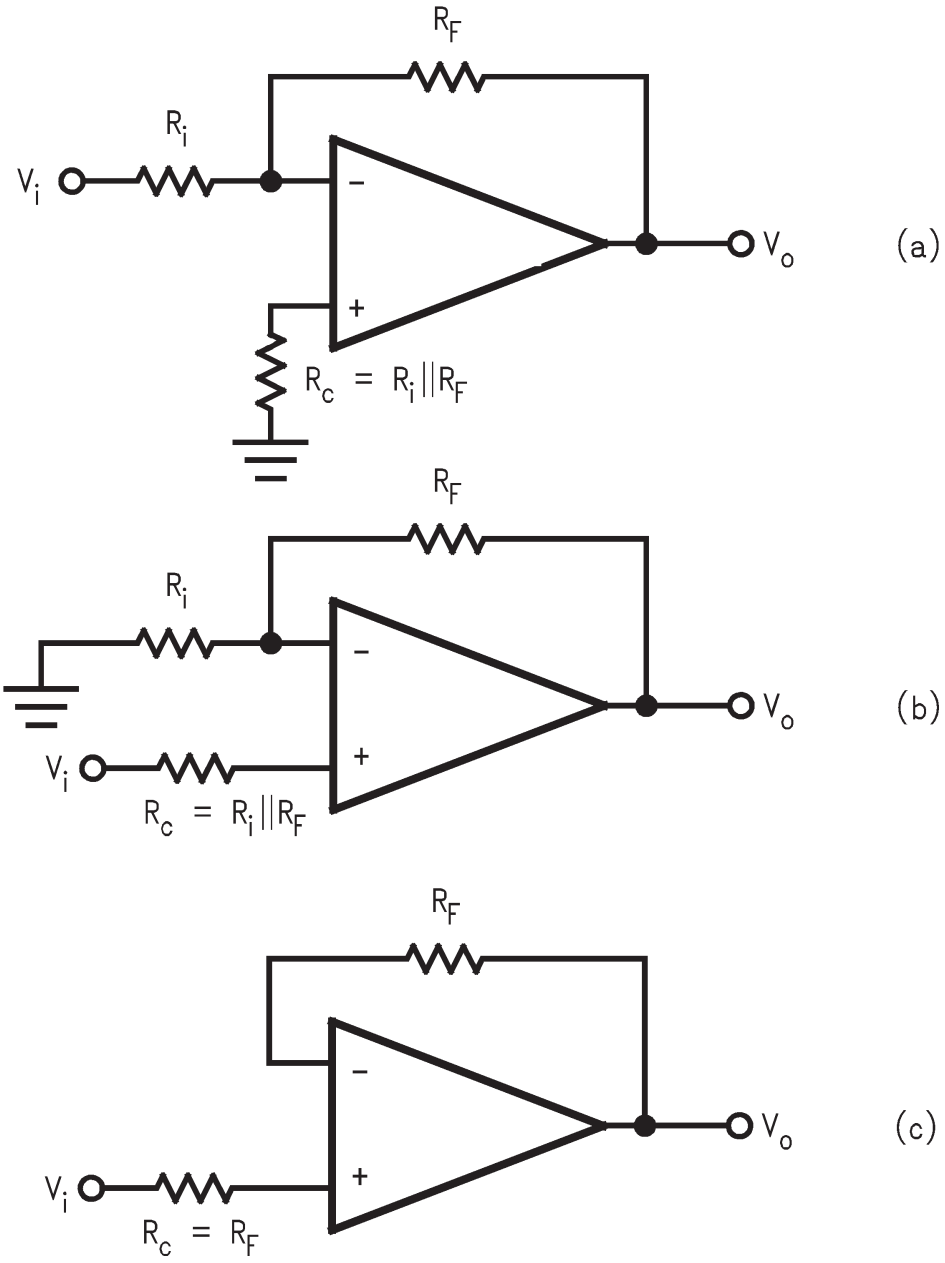



**Figure 30. Canceling the Offset Voltage due to Input Bias Current**


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# 8 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.

## 8.1 Application Information

The LMV93x-N devices bring performance, economy and ease-of-use to low-voltage, low-power systems. They provide rail-to-rail input and rail-to-rail output swings into heavy loads.

## 8.2 Typical Applications

### 8.2.1 High-Side Current-Sensing Application

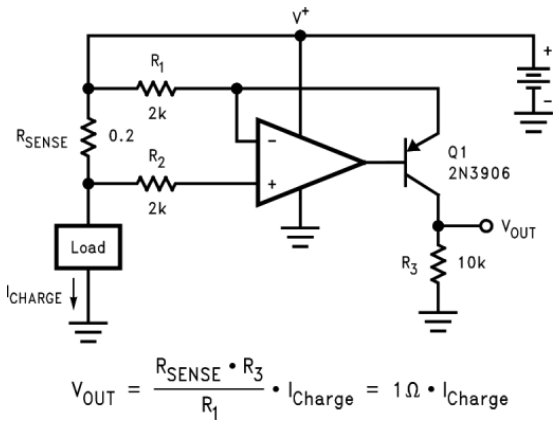



**Figure 31. High-Side Current Sensing**

#### *8.2.1.1 Design Requirements*

The high-side current-sensing circuit (Figure 31) is commonly used in a battery charger to monitor charging current to prevent overcharging. A sense resistor $R_{SENSE}$ is connected to the battery directly. This system requires an op amp with rail-to-rail input. The LMV93x-N are ideal for this application because its common-mode input range extends up to the positive supply.

##### 8.2.1.1.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LMV93x-N device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ($V_{IN}$), output voltage ($V_{OUT}$), and output current ($I_{OUT}$) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

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## Typical Applications (continued)

### 8.2.1.2 Detailed Design Procedure

As seen in Figure 31, the $I_{CHARGE}$ current flowing through sense resistor $R_{SENSE}$ develops a voltage drop equal to $V_{SENSE}$. The voltage at the negative sense point will now be less than the positive sense point by an amount proportional to the $V_{SENSE}$ voltage.

The low-bias currents of the LMV93x cause little voltage drop through $R_2$, so the negative input of the LMV93x amplifier is at essentially the same potential as the negative sense input.

The LMV93x will detect this voltage error between its inputs and servo the transistor base to conduct more current through Q1, increasing the voltage drop across $R_1$ until the LMV93x inverting input matches the noninverting input. At this point, the voltage drop across $R_1$ now matches $V_{SENSE}$.

$I_G$, a current proportional to $I_{CHARGE}$, will flow according to the following relation:

$$I_G = V_{RSENSE} / R_1 = ( R_{SENSE} * I_{CHARGE} ) / R_1 \quad (2)$$

$I_G$ also flows through the gain resistor $R_3$ developing a voltage drop equal to:

$$V_3 = I_G * R_3 = ( V_{RSENSE} / R_1 ) * R_3 = ( ( R_{SENSE} * I_{CHARGE} ) / R_2 ) * R_3 \quad (3)$$


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## Typical Applications (continued)

$V_{OUT} = (R_{SENSE} * I_{CHARGE}) * G$

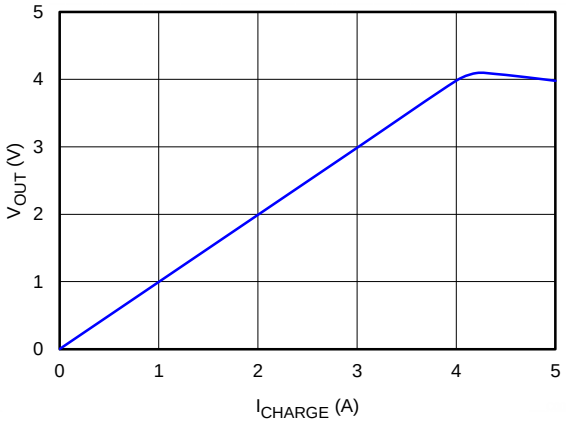
where

- $G = R_3 / R_1$ (4)

The other channel of the LMV93x may be used to buffer the voltage across R3 to drive the following stages.

### 8.2.1.3 Application Curve

Figure 32 shows the results of the example current sense circuit.




NOTE: the error after 4 V where transistor Q1 runs out of headroom and saturates, limiting the upper output swing.

**Figure 32. Current Sense Amplifier Results**

### 8.2.2 Half-Wave Rectifier Applications

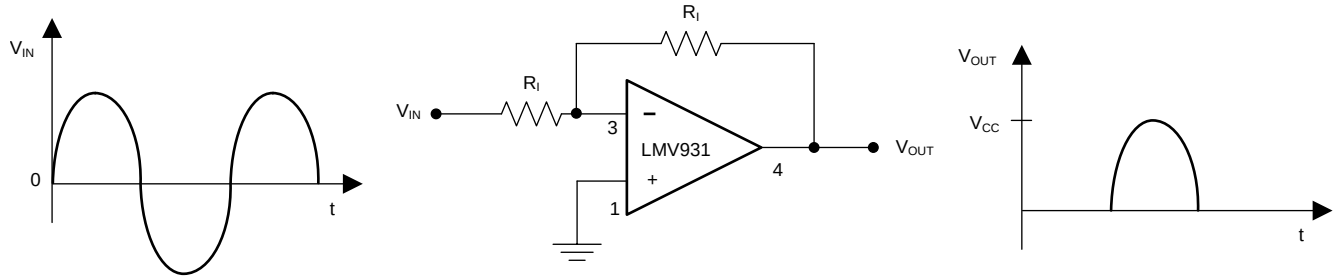



**Figure 33. Half-Wave Rectifier With Rail-To-Ground Output Swing Referenced to Ground**

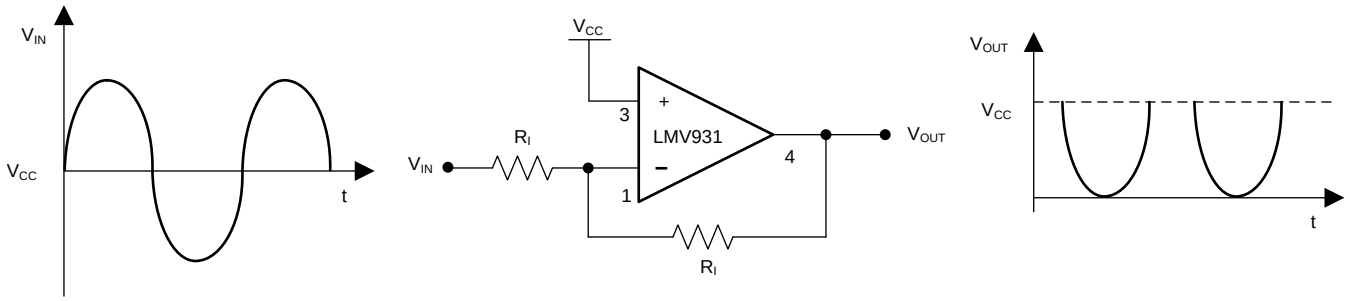



**Figure 34. Half-Wave Rectifier With Negative-Going Output Referenced to $V_{CC}$**

## Typical Applications (continued)

### 8.2.2.1 Design Requirements

Because the LMV931-N, LMV932-N, LMV934-N input common-mode range includes both positive and negative supply rails and the output can also swing to either supply, achieving half-wave rectifier functions in either direction is an easy task. All that is needed are two external resistors; there is no need for diodes or matched resistors. The half-wave rectifier can have either positive or negative going outputs, depending on the way the circuit is arranged.

### 8.2.2.2 Detailed Design Procedure

In Figure 33 the circuit is referenced to ground, while in Figure 34 the circuit is biased to the positive supply. These configurations implement the half-wave rectifier because the LMV93x-N can not respond to one-half of the incoming waveform. It can not respond to one-half of the incoming because the amplifier cannot swing the output beyond either rail therefore the output disengages during this half cycle. During the other half cycle, however, the amplifier achieves a half wave that can have a peak equal to the total supply voltage. $R_l$ should be large enough not to load the LMV93x-N.

### 8.2.2.3 Application Curve

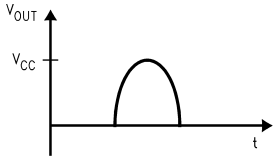



**Figure 35. Output of Ground-to-Rail Circuit**

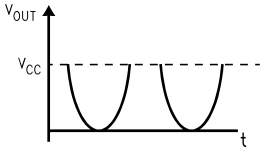



**Figure 36. Output of Rail-to-Ground Circuit**

### 8.2.3 Instrumentation Amplifier With Rail-to-Rail Input and Output Application

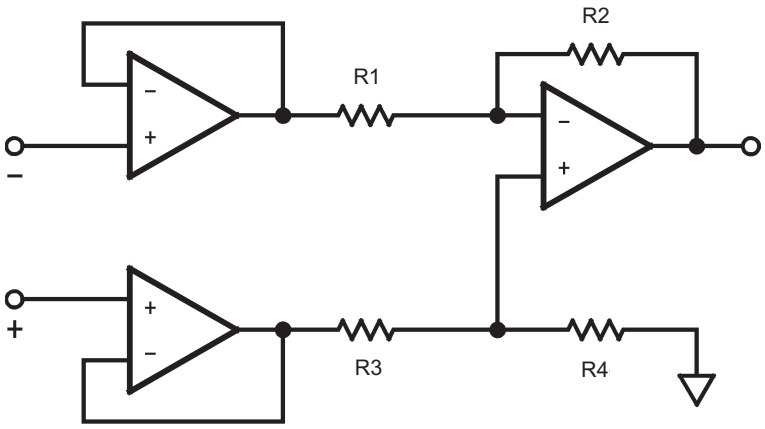



**Figure 37. Rail-to-Rail Instrumentation Amplifier**

### 8.2.3.1 Design Requirements

Using three of the LMV93x-N amplifiers, an instrumentation amplifier with rail-to-rail inputs and outputs can be made as shown in Figure 37.

### 8.2.3.2 Detailed Design Procedure

In this example, amplifiers on the left side act as buffers to the differential stage. These buffers assure that the input impedance is very high. They also assure that the difference amp is driven from a voltage source. This is necessary to maintain the CMRR set by the matching $R_1$-$R_2$ with $R_3$-$R_4$. The gain is set by the ratio of $R_2/R_1$ and $R_3$ should equal $R_1$ and $R_4$ equal $R_2$. With both rail-to-rail input and output ranges, the input and output are only limited by the supply voltages. Remember that even with rail-to-rail outputs, the output can not swing past the supplies so the combined common-mode voltages plus the signal should not be greater that the supplies or limiting will occur.


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## Typical Applications (continued)

### 8.2.3.3 Application Curve

Figure 38 shows the results of the instrumentation amplifier with $R_1$ and $R_3$ = 1 K, and $R_2$ and $R_4$ = 100 kΩ, for a gain of 100, running on a single 5-V supply with a input of $V_{CM} = V_S/2$. The combined effects of the individual offset voltages can be seen as a shift in the offset of the curve.

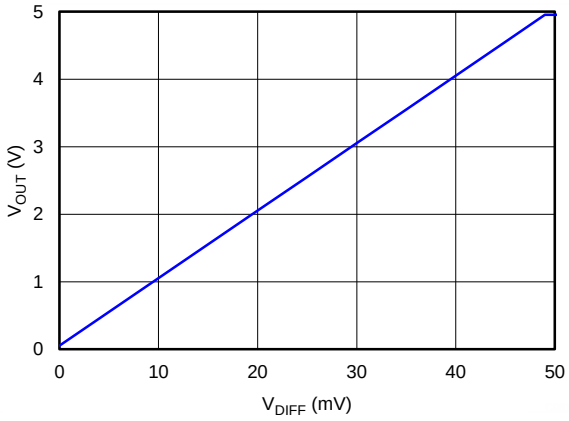



**Figure 38. Instrumentation Amplifier Output Results**

## 8.3 Dos and Don'ts

Do properly bypass the power supplies.

Do add series resistence to the output when driving capacitive loads, particularly cables, Muxes and ADC inputs.

Do add series current limiting resistors and external schottky clamp diodes if input voltage is expected to exceed the supplies. Limit the current to 1 mA or less (1 kΩ per volt).

# 9 Power Supply Recommendations

For proper operation, the power supplies must be properly decoupled. For decoupling the supply lines, TI recommends that 10-nF capacitors be placed as close as possible to the op amp power supply pins. For single-supply, place a capacitor between $V^+$ and $V^-$ supply leads. For dual supplies, place one capacitor between $V^+$ and ground, and one capacitor between $V^-$ and ground.

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# 10 Layout

## 10.1 Layout Guidelines

The $V^+$ pin must be bypassed to ground with a low-ESR capacitor.

The optimum placement is closest to the $V^+$ and ground pins.

Take care to minimize the loop area formed by the bypass capacitor connection between $V^+$ and ground.

The ground pin must be connected to the PCB ground plane at the pin of the device.

The feedback components should be placed as close as possible to the device minimizing strays.

## 10.2 Layout Example

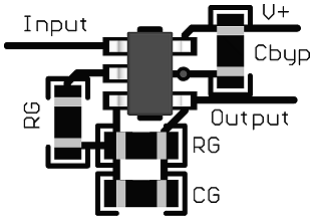



**Figure 39. SOT-23 Layout Example**


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# 11 Device and Documentation Support

## 11.1 Device Support

### 11.1.1 Custom Design With WEBENCH® Tools

Click here to create a custom design using the LMV93x-N device with the WEBENCH® Power Designer.

1. Start by entering the input voltage ($V_{IN}$), output voltage ($V_{OUT}$), and output current ($I_{OUT}$) requirements.
2. Optimize the design for key parameters such as efficiency, footprint, and cost using the optimizer dial.
3. Compare the generated design with other possible solutions from Texas Instruments.

The WEBENCH Power Designer provides a customized schematic along with a list of materials with real-time pricing and component availability.

In most cases, these actions are available:

- Run electrical simulations to see important waveforms and circuit performance
- Run thermal simulations to understand board thermal performance
- Export customized schematic and layout into popular CAD formats
- Print PDF reports for the design, and share the design with colleagues

Get more information about WEBENCH tools at www.ti.com/WEBENCH.

### 11.1.2 Development Support

LMV931 PSPICE Model (also applicable to the LMV932 and LMV934), http://www.ti.com/lit/zip/snom028

TINA-TI SPICE-Based Analog Simulation Program, http://www.ti.com/tool/tina-ti

DIP Adapter Evaluation Module, http://www.ti.com/tool/dip-adapter-evm

TI Universal Operational Amplifier Evaluation Module, http://www.ti.com/tool/opampevm

TI Filterpro Software, http://www.ti.com/tool/filterpro

## 11.2 Documentation Support

### 11.2.1 Related Documentation

For additional applications, see

*AN-31 Op Amp Circuit Collection*

## 11.3 Related Links

Table 1 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to order now.

**Table 1. Related Links**

| PARTS | PRODUCT FOLDER | ORDER NOW | TECHNICAL DOCUMENTS | TOOLS & SOFTWARE | SUPPORT & COMMUNITY |
|---|---|---|---|---|---|
| LMV931-N | Click here | Click here | Click here | Click here | Click here |
| LMV932-N | Click here | Click here | Click here | Click here | Click here |
| LMV934-N | Click here | Click here | Click here | Click here | Click here |

## 11.4 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

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### 11.5 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

**TI E2E™ Online Community** ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

**Design Support** ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

### 11.6 Trademarks

E2E is a trademark of Texas Instruments.
WEBENCH is a registered trademark of Texas Instruments.
All other trademarks are the property of their respective owners.

### 11.7 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.

### 11.8 Glossary

SLYZ022 — *TI Glossary*.

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

## 12 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 (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| LMV931MF/NOPB | Active | Production | SOT-23 (DBV) \| 5 | 1000 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A79A |
| LMV931MF/NOPB.A | Active | Production | SOT-23 (DBV) \| 5 | 1000 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A79A |
| LMV931MFX/NOPB | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A79A |
| LMV931MFX/NOPB.A | Active | Production | SOT-23 (DBV) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A79A |
| LMV931MG/NOPB | Active | Production | SC70 (DCK) \| 5 | 1000 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A74 |
| LMV931MG/NOPB.A | Active | Production | SC70 (DCK) \| 5 | 1000 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A74 |
| LMV931MGX/NOPB | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A74 |
| LMV931MGX/NOPB.A | Active | Production | SC70 (DCK) \| 5 | 3000 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A74 |
| LMV932MA/NOPB | Active | Production | SOIC (D) \| 8 | 95 \| TUBE | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV9 32MA |
| LMV932MA/NOPB.A | Active | Production | SOIC (D) \| 8 | 95 \| TUBE | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV9 32MA |
| LMV932MAX/NOPB | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV9 32MA |
| LMV932MAX/NOPB.A | Active | Production | SOIC (D) \| 8 | 2500 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV9 32MA |
| LMV932MM/NOPB | Active | Production | VSSOP (DGK) \| 8 | 1000 \| SMALL T&R | Yes | NIPDAUAG \| SN | Level-1-260C-UNLIM | -40 to 125 | A86A |
| LMV932MM/NOPB.A | Active | Production | VSSOP (DGK) \| 8 | 1000 \| SMALL T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A86A |
| LMV932MMX/NOPB | Active | Production | VSSOP (DGK) \| 8 | 3500 \| LARGE T&R | Yes | NIPDAUAG \| SN | Level-1-260C-UNLIM | -40 to 125 | A86A |
| LMV932MMX/NOPB.A | Active | Production | VSSOP (DGK) \| 8 | 3500 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | A86A |
| LMV934MA/NOPB | Active | Production | SOIC (D) \| 14 | 55 \| TUBE | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV934MA |
| LMV934MA/NOPB.A | Active | Production | SOIC (D) \| 14 | 55 \| TUBE | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV934MA |
| LMV934MAX/NOPB | Active | Production | SOIC (D) \| 14 | 2500 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV934MA |
| LMV934MAX/NOPB.A | Active | Production | SOIC (D) \| 14 | 2500 \| LARGE T&R | Yes | SN | Level-1-260C-UNLIM | -40 to 125 | LMV934MA |
| LMV934MT/NOPB | Active | Production | TSSOP (PW) \| 14 | 94 \| TUBE | Yes | NIPDAU \| SN | Level-1-260C-UNLIM | -40 to 125 | LMV93 4MT |
| LMV934MT/NOPB.A | Active | Production | TSSOP (PW) \| 14 | 94 \| TUBE | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LMV93 4MT |
| LMV934MT/NOPBG4 | Active | Production | TSSOP (PW) \| 14 | 94 \| TUBE | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LMV93 4MT |

| Orderable part number | Status (1) | Material type (2) | Package \| Pins | Package qty \| Carrier | RoHS (3) | Lead finish/ Ball material (4) | MSL rating/ Peak reflow (5) | Op temp (°C) | Part marking (6) |
|---|---|---|---|---|---|---|---|---|---|
| LMV934MT/NOPBG4.A | Active | Production | TSSOP (PW) \| 14 | 94 \| TUBE | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LMV93 4MT |
| LMV934MTX/NOPB | Active | Production | TSSOP (PW) \| 14 | 2500 \| LARGE T&R | Yes | NIPDAU \| SN | Level-1-260C-UNLIM | -40 to 125 | LMV93 4MT |
| LMV934MTX/NOPB.A | Active | Production | TSSOP (PW) \| 14 | 2500 \| LARGE T&R | Yes | NIPDAU | Level-1-260C-UNLIM | -40 to 125 | LMV93 4MT |

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

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

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

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

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

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

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

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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 LMV931-N, LMV932-N, LMV934-N :**

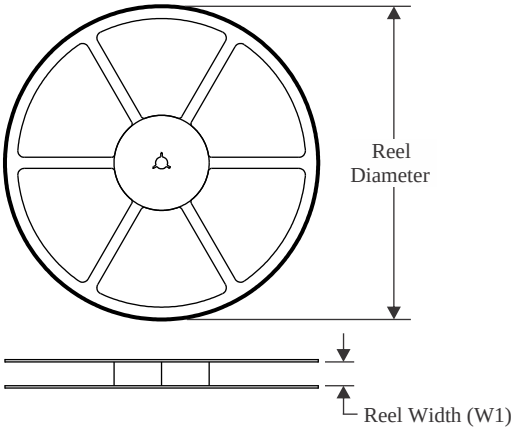
- Automotive : LMV931-N-Q1, LMV932-N-Q1, LMV934-N-Q1

NOTE: Qualified Version Definitions:

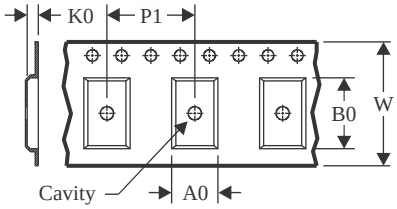
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

## TAPE AND REEL INFORMATION

**REEL DIMENSIONS**

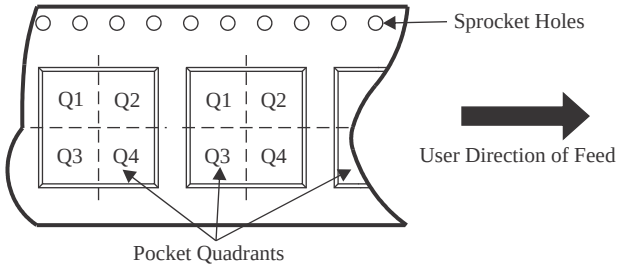



**TAPE DIMENSIONS**




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

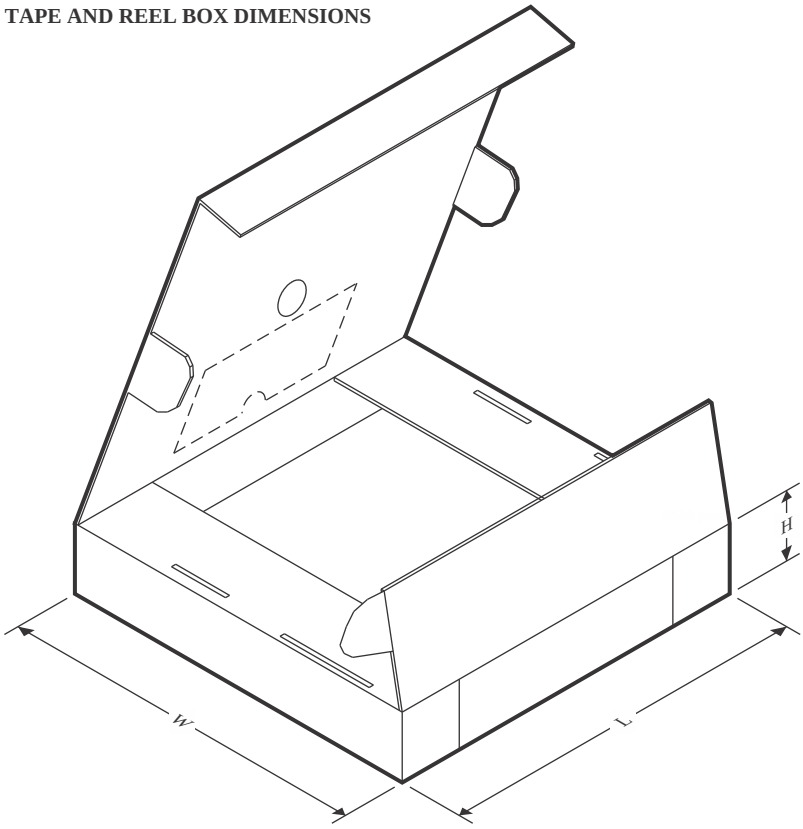
**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Reel Diameter (mm) | Reel Width W1 (mm) | A0 (mm) | B0 (mm) | K0 (mm) | P1 (mm) | W (mm) | Pin1 Quadrant |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LMV931MF/NOPB | SOT-23 | DBV | 5 | 1000 | 180.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| LMV931MF/NOPB | SOT-23 | DBV | 5 | 1000 | 178.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| LMV931MFX/NOPB | SOT-23 | DBV | 5 | 3000 | 178.0 | 8.4 | 3.2 | 3.2 | 1.4 | 4.0 | 8.0 | Q3 |
| LMV931MG/NOPB | SC70 | DCK | 5 | 1000 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LMV931MGX/NOPB | SC70 | DCK | 5 | 3000 | 178.0 | 8.4 | 2.25 | 2.45 | 1.2 | 4.0 | 8.0 | Q3 |
| LMV932MAX/NOPB | SOIC | D | 8 | 2500 | 330.0 | 12.4 | 6.4 | 5.2 | 2.1 | 8.0 | 12.0 | Q1 |
| LMV932MM/NOPB | VSSOP | DGK | 8 | 1000 | 177.8 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LMV932MMX/NOPB | VSSOP | DGK | 8 | 3500 | 330.0 | 12.4 | 5.3 | 3.4 | 1.4 | 8.0 | 12.0 | Q1 |
| LMV934MAX/NOPB | SOIC | D | 14 | 2500 | 330.0 | 16.4 | 6.5 | 9.35 | 2.3 | 8.0 | 16.0 | Q1 |
| LMV934MTX/NOPB | TSSOP | PW | 14 | 2500 | 330.0 | 12.4 | 6.9 | 5.6 | 1.6 | 8.0 | 12.0 | Q1 |

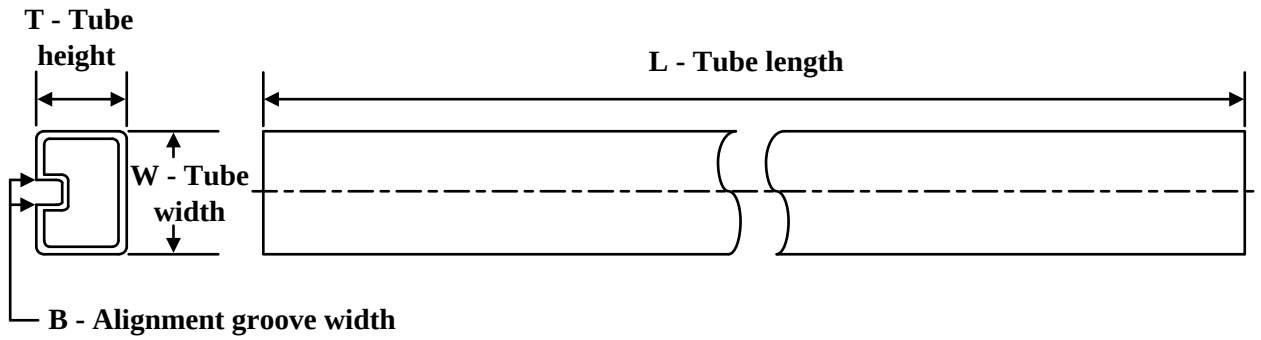
TAPE AND REEL BOX DIMENSIONS




*All dimensions are nominal

| Device | Package Type | Package Drawing | Pins | SPQ | Length (mm) | Width (mm) | Height (mm) |
|---|---|---|---|---|---|---|---|
| LMV931MF/NOPB | SOT-23 | DBV | 5 | 1000 | 210.0 | 185.0 | 35.0 |
| LMV931MF/NOPB | SOT-23 | DBV | 5 | 1000 | 208.0 | 191.0 | 35.0 |
| LMV931MFX/NOPB | SOT-23 | DBV | 5 | 3000 | 208.0 | 191.0 | 35.0 |
| LMV931MG/NOPB | SC70 | DCK | 5 | 1000 | 208.0 | 191.0 | 35.0 |
| LMV931MGX/NOPB | SC70 | DCK | 5 | 3000 | 208.0 | 191.0 | 35.0 |
| LMV932MAX/NOPB | SOIC | D | 8 | 2500 | 367.0 | 367.0 | 35.0 |
| LMV932MM/NOPB | VSSOP | DGK | 8 | 1000 | 208.0 | 191.0 | 35.0 |
| LMV932MMX/NOPB | VSSOP | DGK | 8 | 3500 | 367.0 | 367.0 | 35.0 |
| LMV934MAX/NOPB | SOIC | D | 14 | 2500 | 367.0 | 367.0 | 35.0 |
| LMV934MTX/NOPB | TSSOP | PW | 14 | 2500 | 367.0 | 367.0 | 35.0 |

## TUBE




*All dimensions are nominal

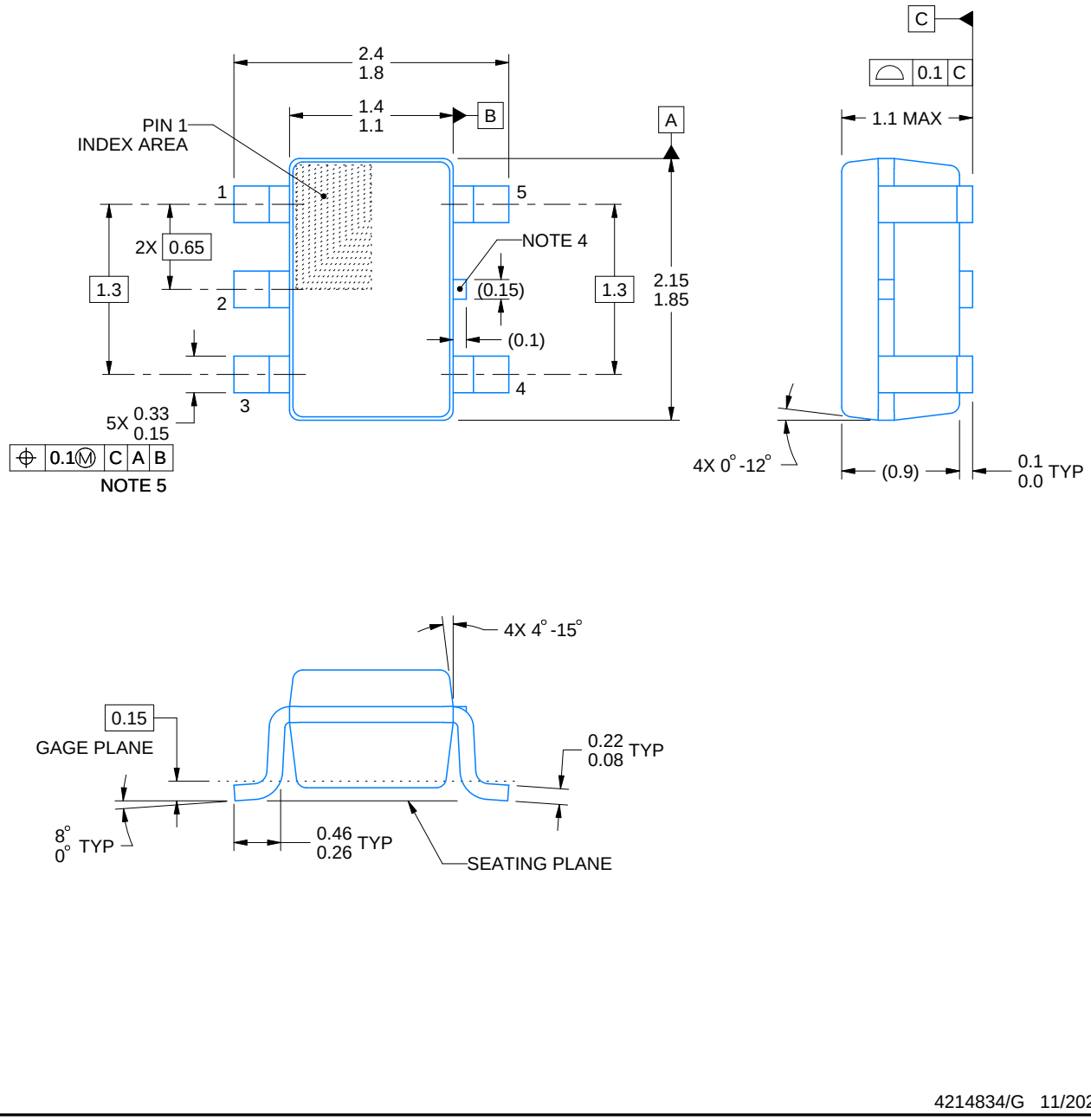
| Device | Package Name | Package Type | Pins | SPQ | L (mm) | W (mm) | T (µm) | B (mm) |
|---|---|---|---|---|---|---|---|---|
| LMV932MA/NOPB | D | SOIC | 8 | 95 | 495 | 8 | 4064 | 3.05 |
| LMV932MA/NOPB.A | D | SOIC | 8 | 95 | 495 | 8 | 4064 | 3.05 |
| LMV934MA/NOPB | D | SOIC | 14 | 55 | 495 | 8 | 4064 | 3.05 |
| LMV934MA/NOPB.A | D | SOIC | 14 | 55 | 495 | 8 | 4064 | 3.05 |
| LMV934MT/NOPB | PW | TSSOP | 14 | 94 | 530 | 10.2 | 3600 | 3.5 |
| LMV934MT/NOPB | PW | TSSOP | 14 | 94 | 495 | 8 | 2514.6 | 4.06 |
| LMV934MT/NOPB.A | PW | TSSOP | 14 | 94 | 530 | 10.2 | 3600 | 3.5 |
| LMV934MT/NOPB.A | PW | TSSOP | 14 | 94 | 495 | 8 | 2514.6 | 4.06 |
| LMV934MT/NOPBG4 | PW | TSSOP | 14 | 94 | 530 | 10.2 | 3600 | 3.5 |
| LMV934MT/NOPBG4.A | PW | TSSOP | 14 | 94 | 530 | 10.2 | 3600 | 3.5 |

# PACKAGE OUTLINE

## DCK0005A

## SOT - 1.1 max height

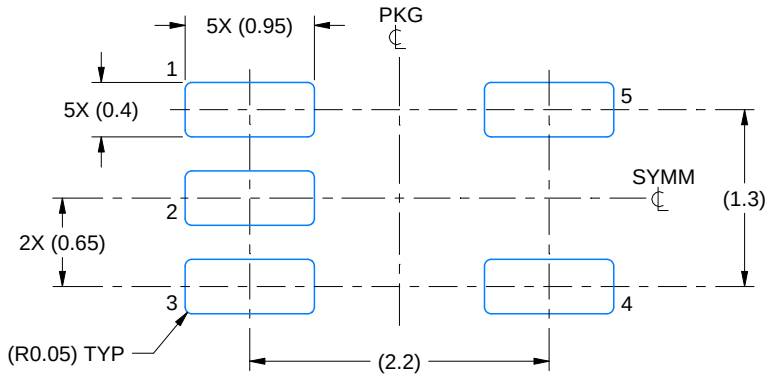
SMALL OUTLINE TRANSISTOR



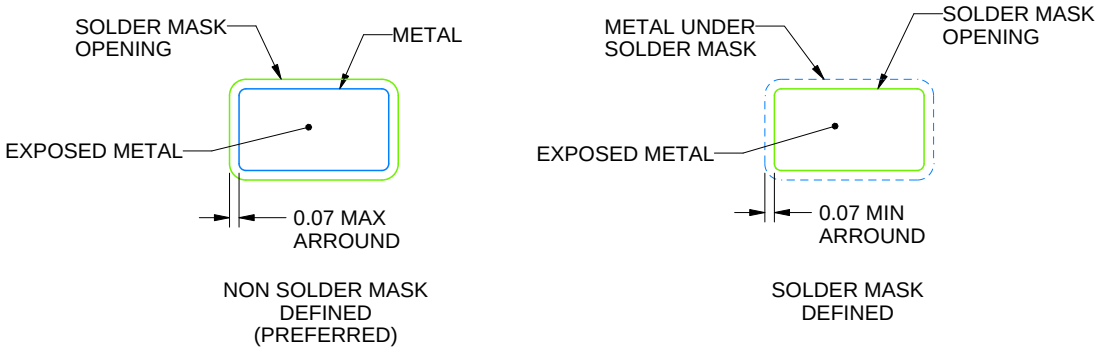

4214834/G 11/2024

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. Refernce JEDEC MO-203.
4. Support pin may differ or may not be present.
5. Lead width does not comply with JEDEC.
6. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

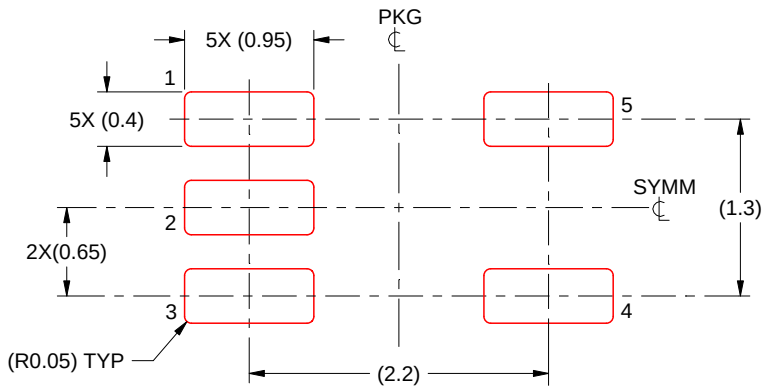



SOLDER MASK DETAILS

4214834/G 11/2024

NOTES: (continued)

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

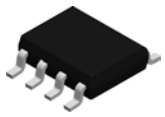



SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:18X

4214834/G 11/2024

NOTES: (continued)

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

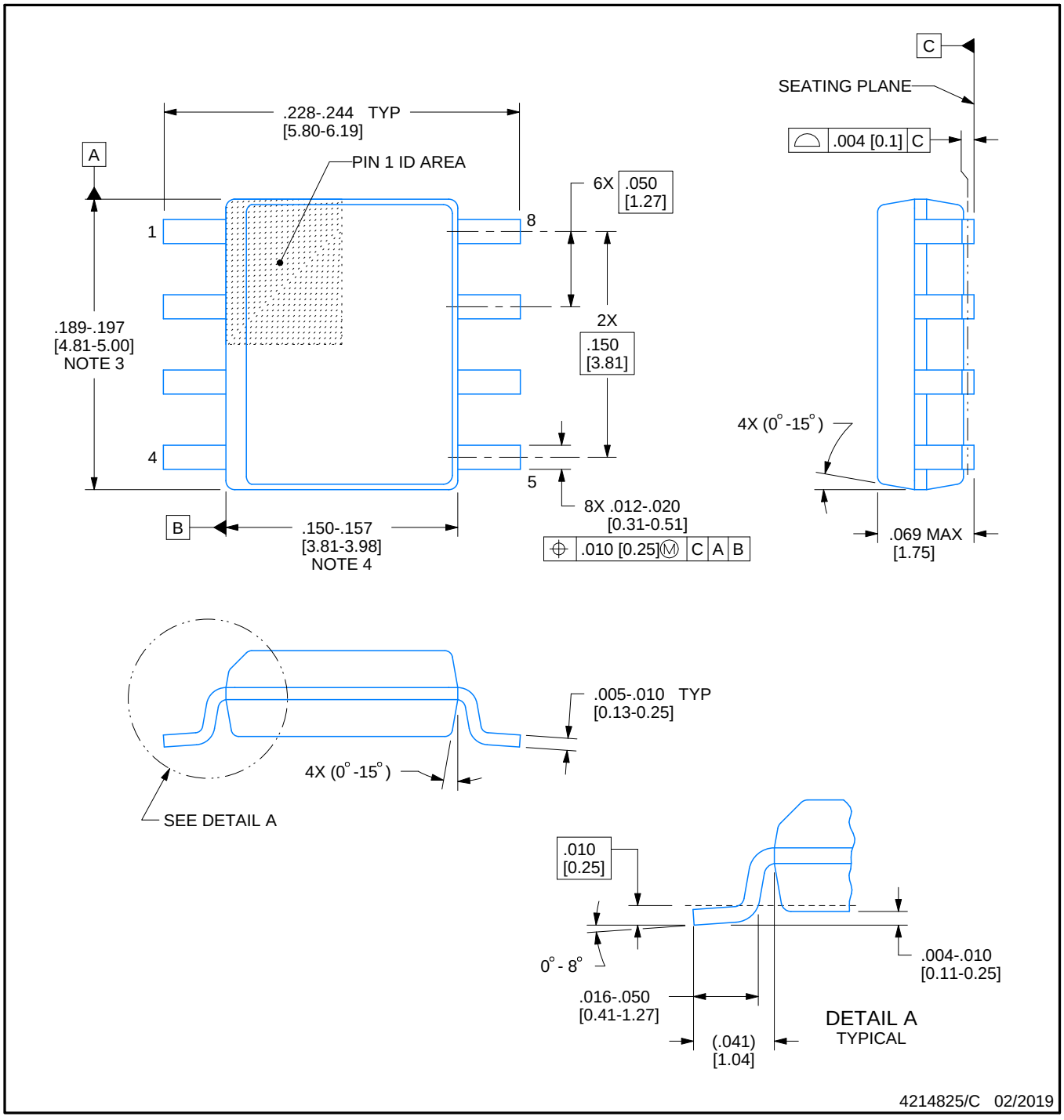


# PACKAGE OUTLINE

## D0008A

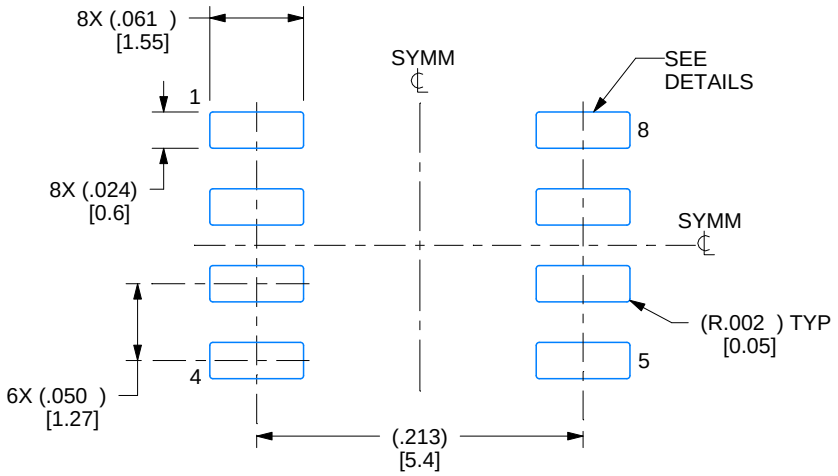
## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

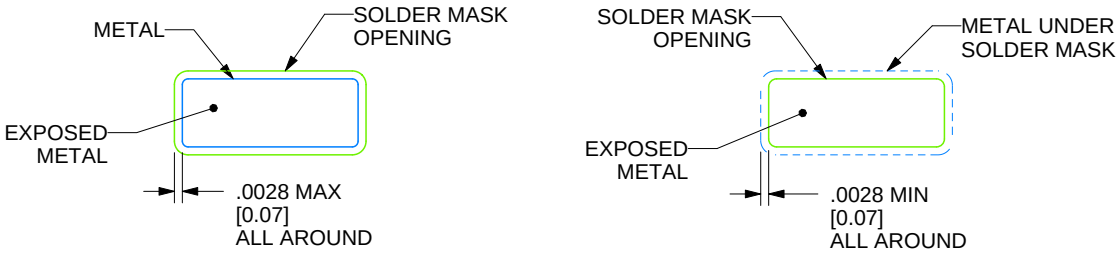



NOTES:

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.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X




SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

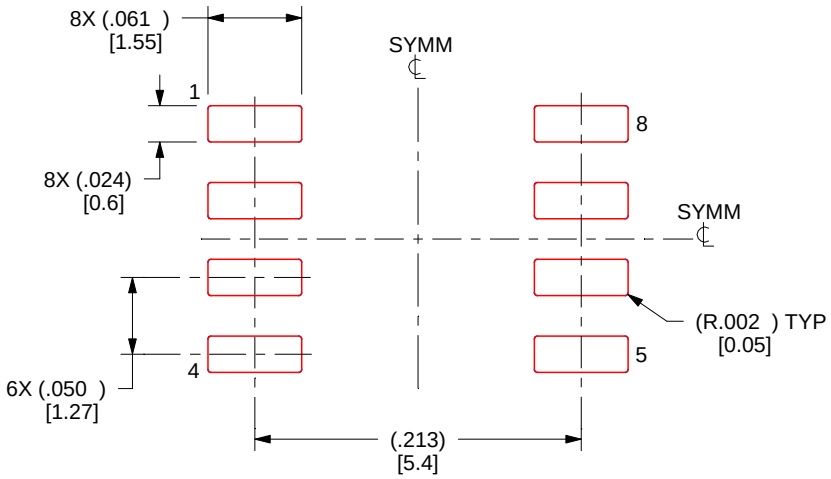
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# 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)

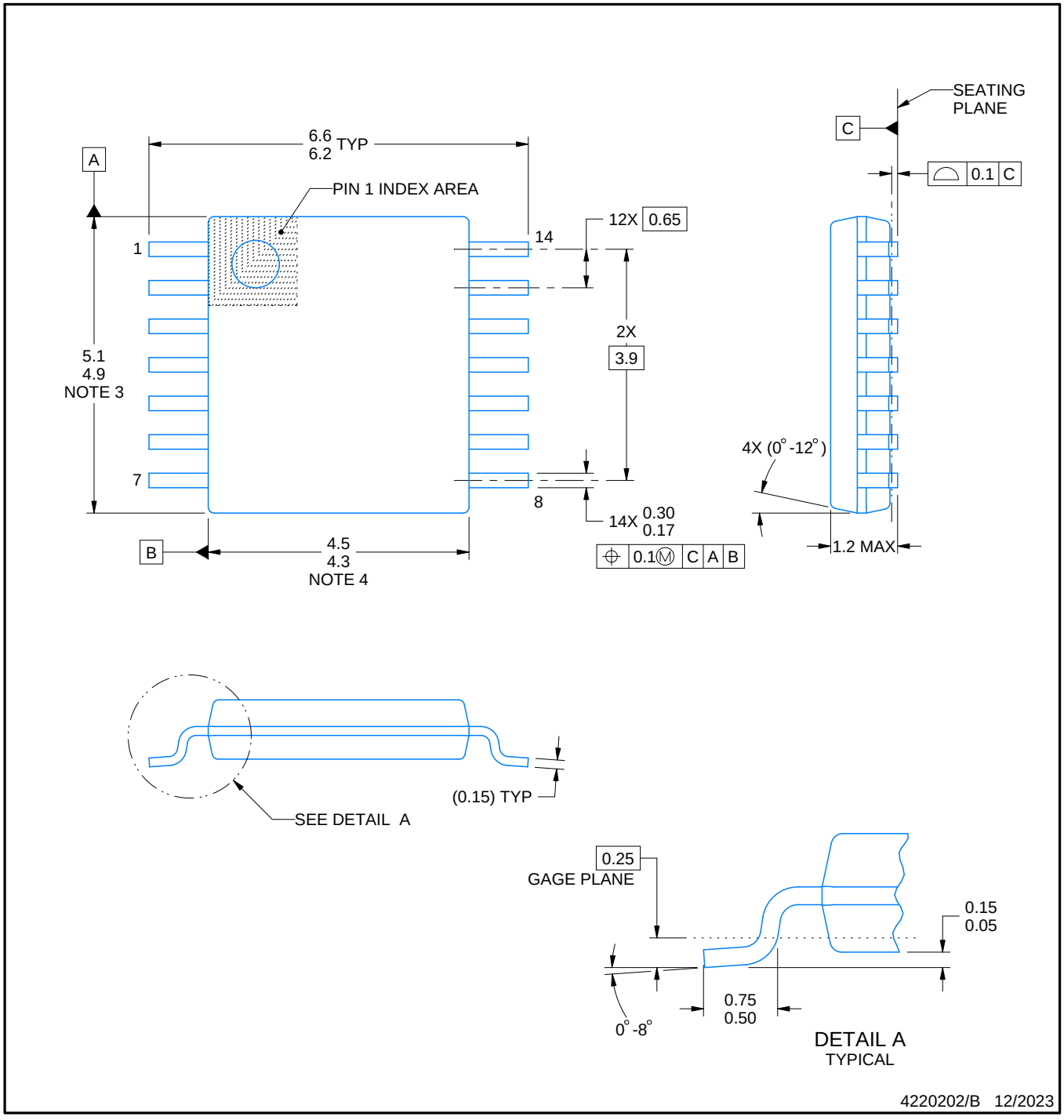
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# PACKAGE OUTLINE

## PW0014A

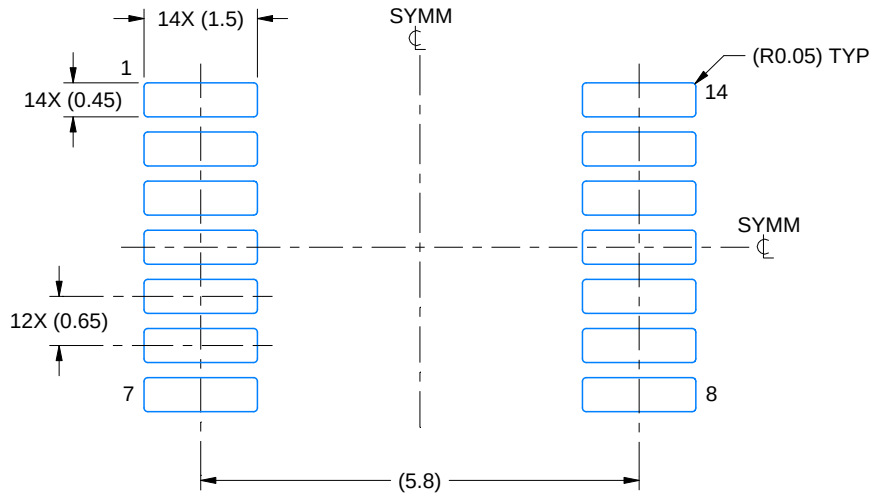
## TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

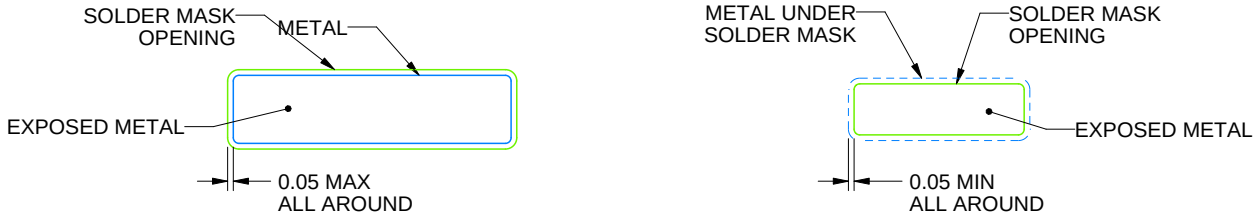



NOTES:

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.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X

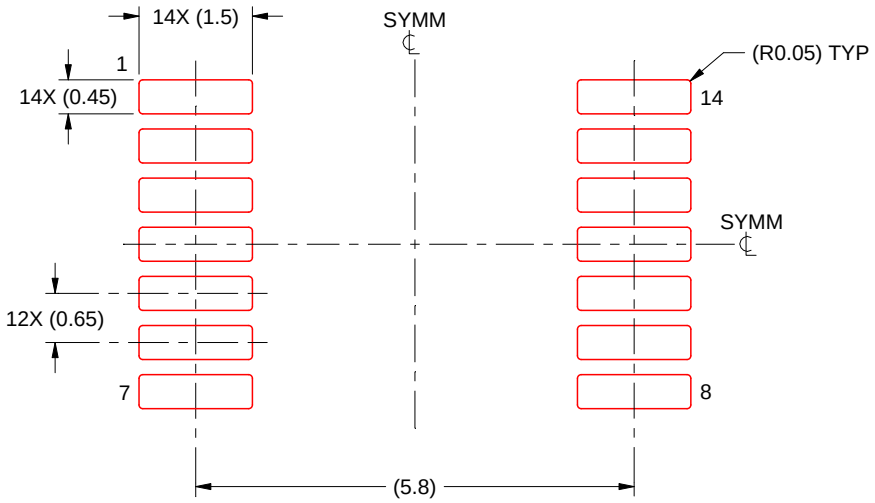



SOLDER MASK DETAILS

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.




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

4220202/B 12/2023

NOTES: (continued)

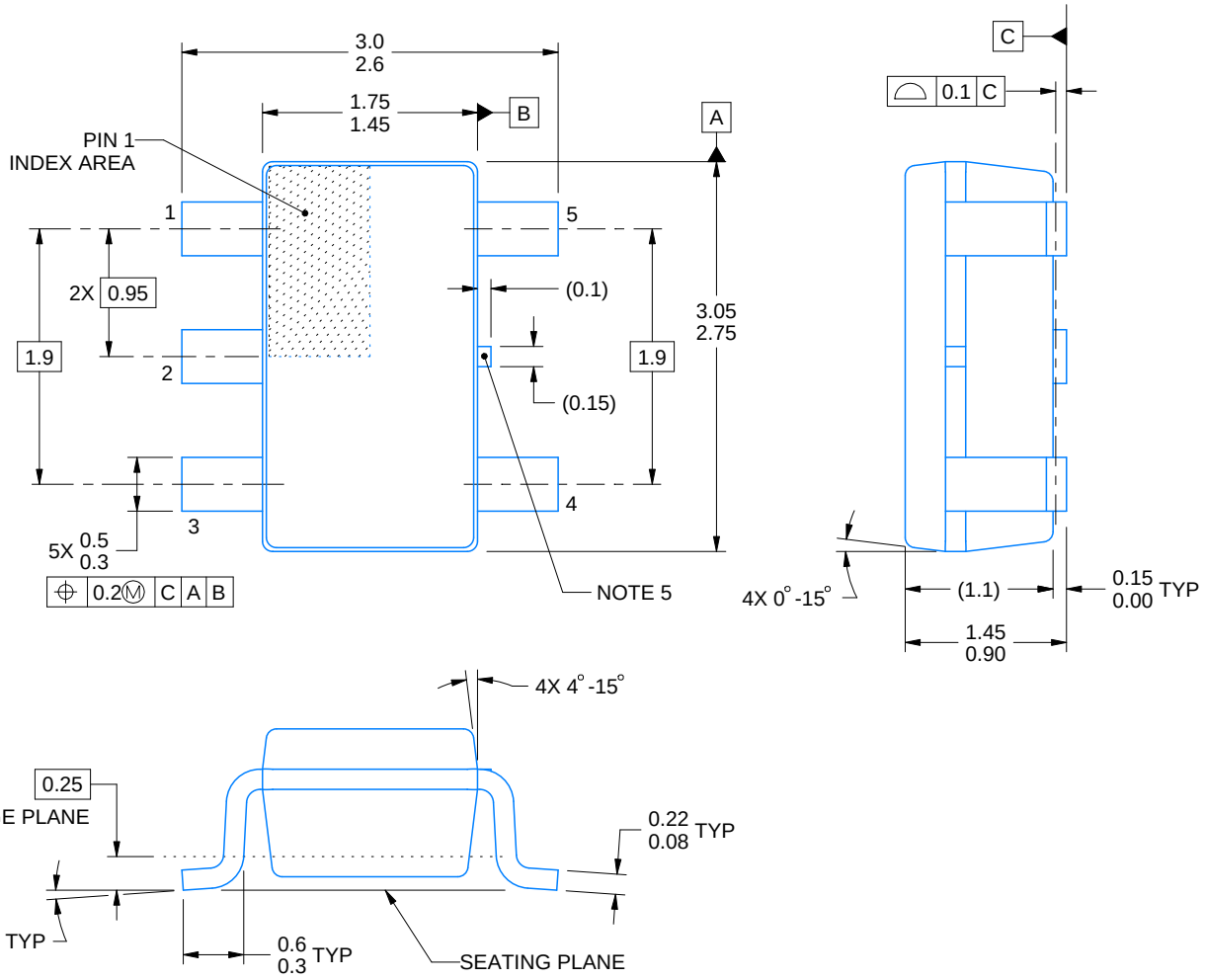
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# PACKAGE OUTLINE

## DBV0005A

## SOT-23 - 1.45 mm max height

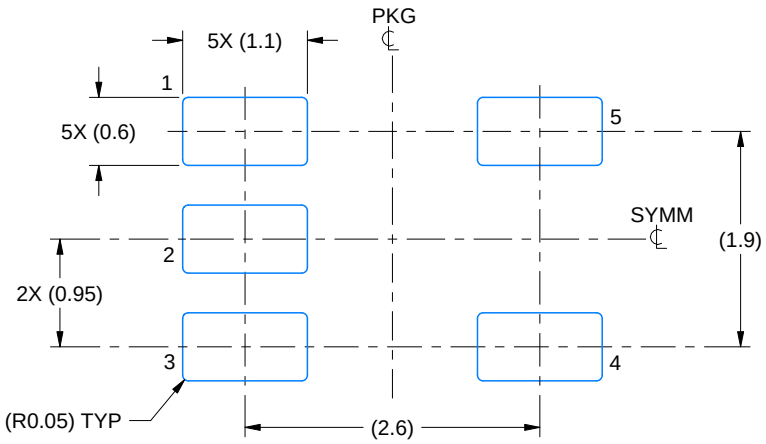
SMALL OUTLINE TRANSISTOR



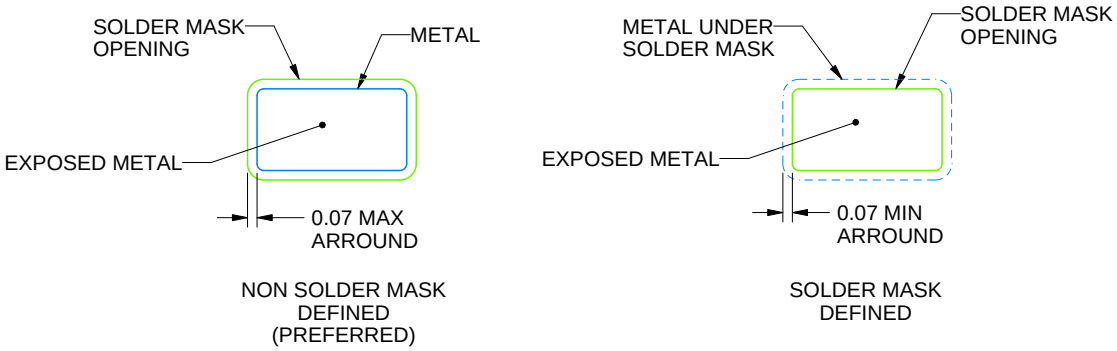

4214839/K 08/2024

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. Refernce 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.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

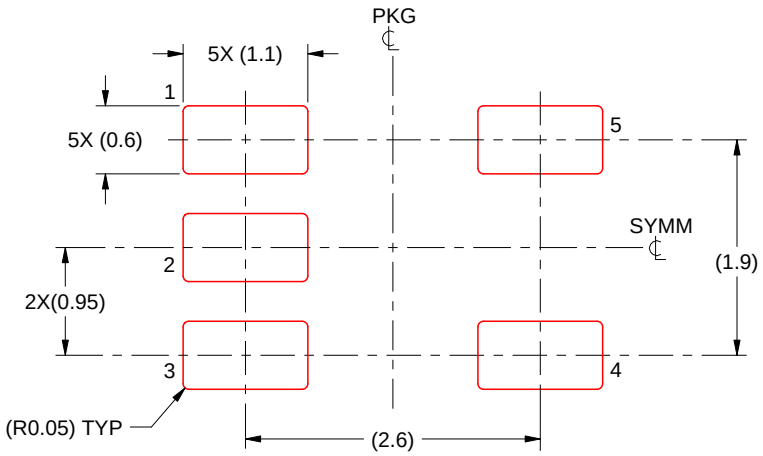



SOLDER MASK DETAILS

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.




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

4214839/K 08/2024

NOTES: (continued)

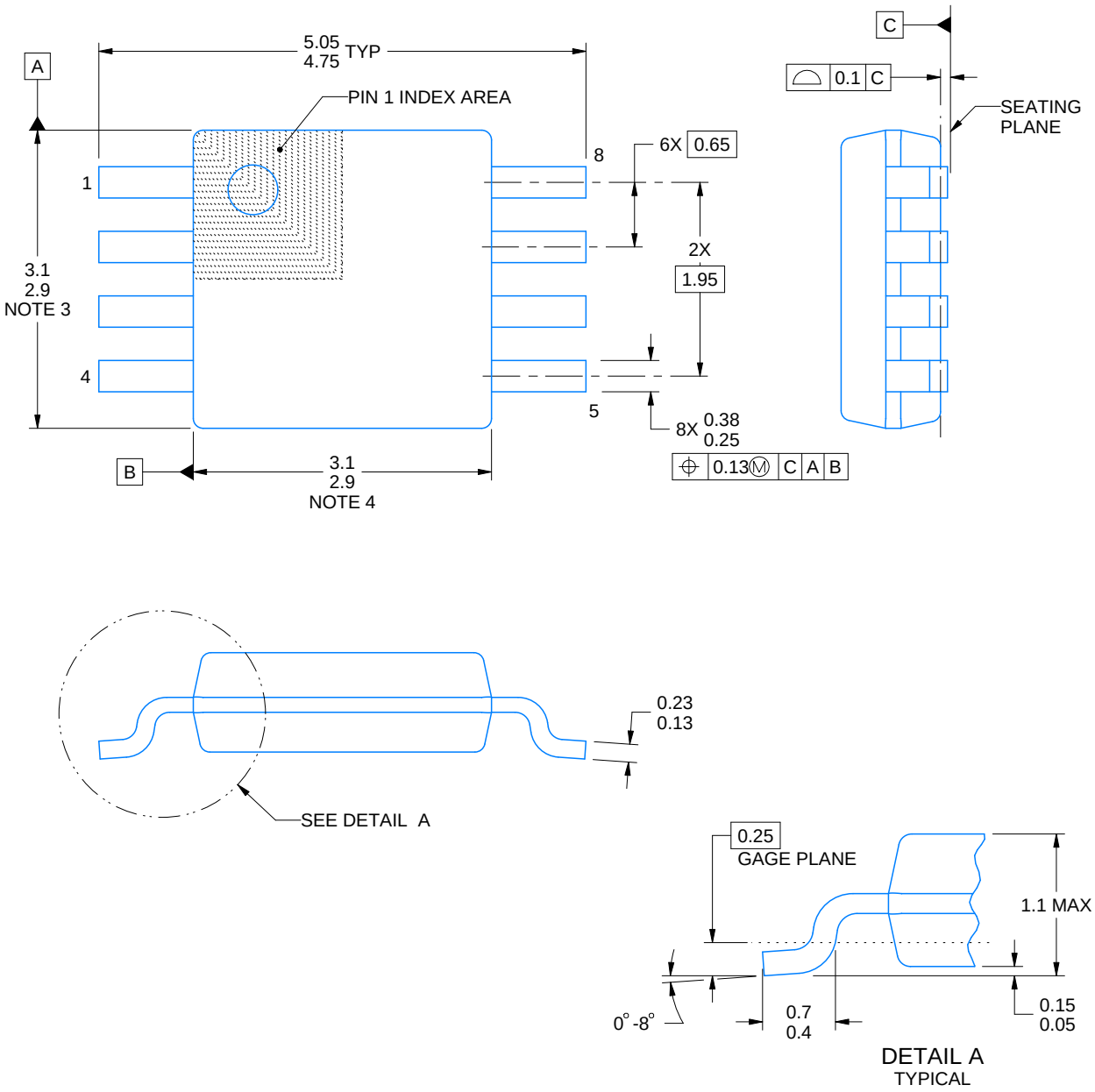
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

# PACKAGE OUTLINE

## DGK0008A

## VSSOP - 1.1 mm max height

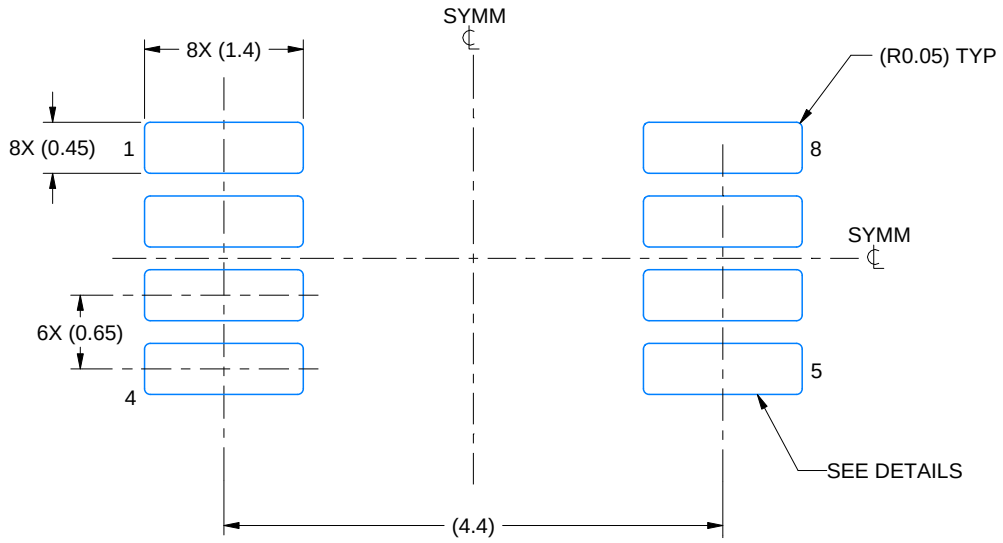
SMALL OUTLINE PACKAGE



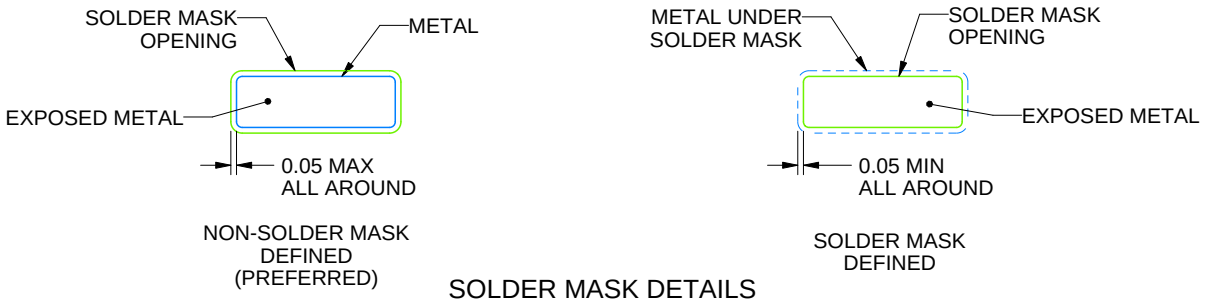

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NOTES:

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-187.




LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

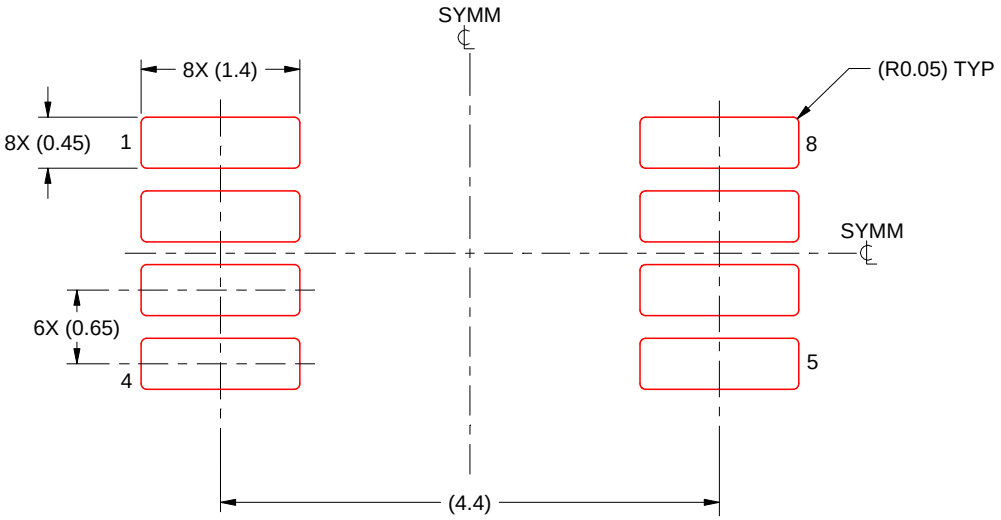



SOLDER MASK DETAILS

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.

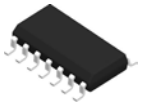



SOLDER PASTE EXAMPLE
SCALE: 15X

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.

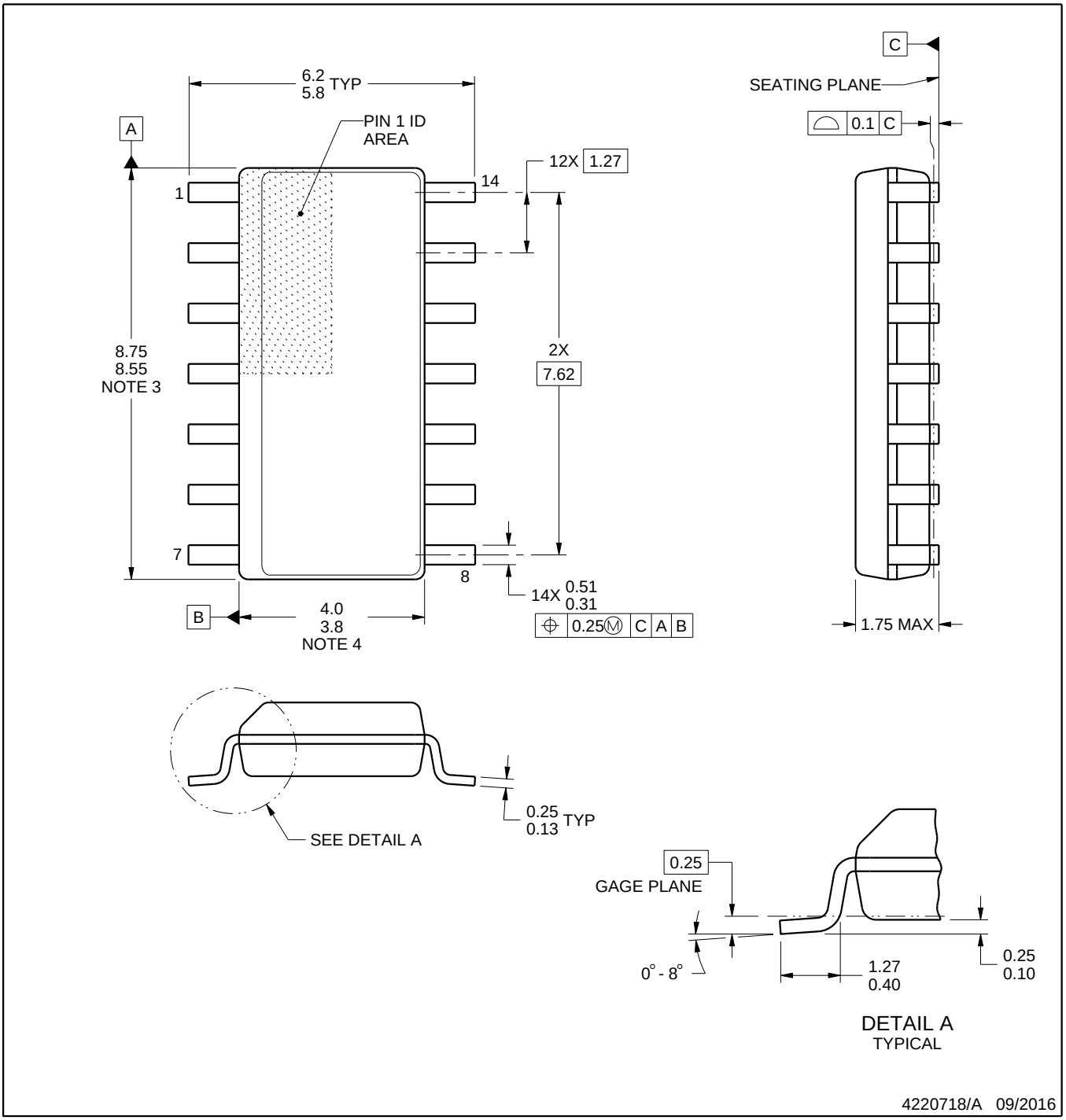


# PACKAGE OUTLINE

## D0014A

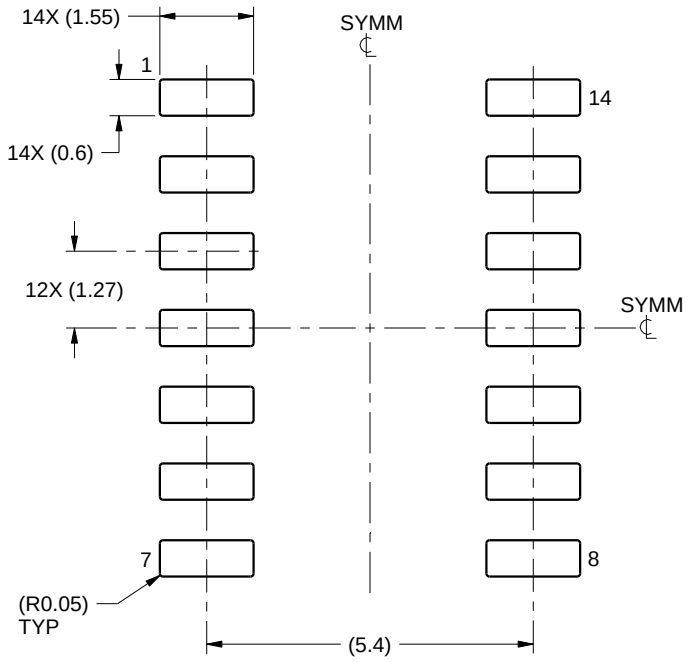
## SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

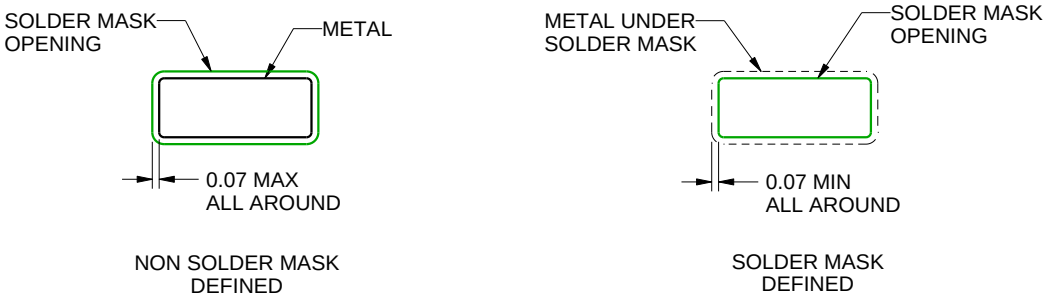



NOTES:

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




LAND PATTERN EXAMPLE
SCALE:8X




SOLDER MASK DETAILS

4220718/A 09/2016

NOTES: (continued)

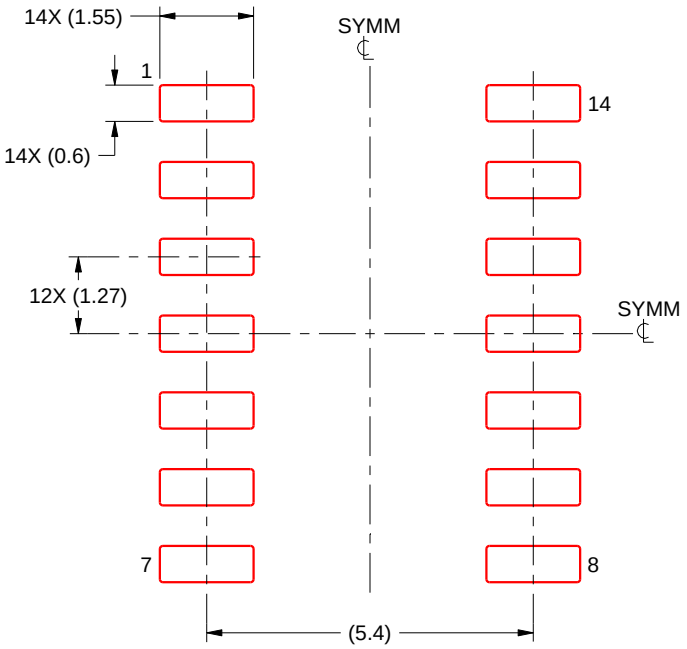
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# 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.

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