

## LM290xLV 行业标准、低电压运算放大器

### 1 特性

- 适用于成本敏感型系统的业界通用放大器
- 低输入失调电压： $\pm 1\text{mV}$
- 共模电压范围包括接地
- 单位增益带宽： $1\text{MHz}$
- 低宽带噪声： $40\text{nV}/\sqrt{\text{Hz}}$
- 低静态电流： $90\mu\text{A}/\text{通道}$
- 单位增益稳定
- 可在  $2.7\text{V}$  至  $5.5\text{V}$  的电源电压范围内运行
- 提供双通道和四通道型号
- 严格的 ESD 规格： $2\text{kV HBM}$
- 工作温度范围： $-40^\circ\text{C}$  至  $125^\circ\text{C}$

### 2 应用

- 无线电器
- 不间断电源
- 电池组、充电器和测试设备
- 电源模块
- 环境传感器信号调节
- 现场变送器：温度传感器
- 示波器、数字万用表和信号分析器
- 机架式服务器
- HVAC：暖通空调
- 直流电机控制
- 低侧电流感测

### 3 说明

LM290xLV 系列包括双路 LM2904LV 和四路 LM2902LV 运算放大器。这些器件由  $2.7\text{V}$  至  $5.5\text{V}$  的低电压供电。

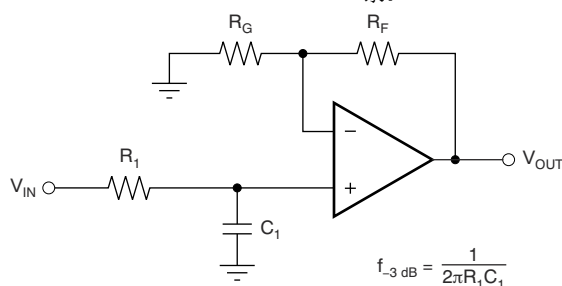
在成本敏感型低压应用中，这些运算放大器可作为 LM2904 和 LM2902 的替代产品。部分应用为大型电器、烟雾探测器和个人电子产品。LM290xLV 器件在低电压下可提供比 LM290x 器件更佳的性能，并且功耗更低。这些运算放大器具有单位增益稳定性，并且在过驱情况下不会出现相位反转。ESD 设计为 LM290xLV 系列提供了至少  $2\text{kV}$  的 HBM 规格。

LM290xLV 系列采用行业标准封装。这些封装包括 SOIC、VSSOP 和 TSSOP 封装。

器件信息

器件型号 <sup>(1)</sup>	封装	封装尺寸 (标称值)
LM2902LV	SOIC (14)	$8.65\text{mm} \times 3.91\text{mm}$
	TSSOP (14)	$4.40\text{mm} \times 5.00\text{mm}$
	SOT-23 (14)	$4.20\text{mm} \times 2.00\text{mm}$
LM2904LV	SOIC (8)	$3.91\text{mm} \times 4.90\text{mm}$
	TSSOP (8)	$3.00\text{mm} \times 4.40\text{mm}$
	SOT-23 (8)	$1.60\text{mm} \times 2.90\text{mm}$
	VSSOP (8)	$3.00\text{mm} \times 3.00\text{mm}$

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。



$$f_{-3\text{dB}} = \frac{1}{2\pi R_1 C_1}$$

$$\frac{V_{\text{OUT}}}{V_{\text{IN}}} = \left(1 + \frac{R_F}{R_G}\right) \left(\frac{1}{1 + sR_1 C_1}\right)$$

单极低通滤波器



## Table of Contents

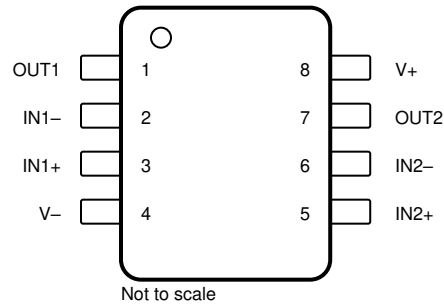
<b>1 特性</b> .....	<b>1</b>	<b>8 Application and Implementation</b> .....	<b>15</b>
<b>2 应用</b> .....	<b>1</b>	8.1 Application Information.....	15
<b>3 说明</b> .....	<b>1</b>	8.2 Typical Application.....	15
<b>4 Revision History</b> .....	<b>2</b>	<b>9 Power Supply Recommendations</b> .....	<b>17</b>
<b>5 Pin Configuration and Functions</b> .....	<b>3</b>	9.1 Input and ESD Protection.....	17
<b>6 Specifications</b> .....	<b>5</b>	<b>10 Layout</b> .....	<b>18</b>
6.1 Absolute Maximum Ratings.....	5	10.1 Layout Guidelines.....	18
6.2 ESD Ratings.....	5	10.2 Layout Example.....	18
6.3 Recommended Operating Conditions.....	5	<b>11 Device and Documentation Support</b> .....	<b>20</b>
6.4 Thermal Information: LM2904LV.....	5	11.1 Documentation Support.....	20
6.5 Thermal Information: LM2902LV.....	6	11.2 接收文档更新通知.....	20
6.6 Electrical Characteristics.....	6	11.3 支持资源.....	20
6.7 Typical Characteristics.....	8	11.4 Trademarks.....	20
<b>7 Detailed Description</b> .....	<b>13</b>	11.5 Electrostatic Discharge Caution.....	20
7.1 Overview.....	13	11.6 术语表.....	20
7.2 Functional Block Diagram.....	13	<b>12 Mechanical, Packaging, and Orderable Information</b> .....	<b>20</b>
7.3 Feature Description.....	13		
7.4 Device Functional Modes.....	14		

## 4 Revision History

注：以前版本的页码可能与当前版本的页码不同

<b>Changes from Revision B (October 2019) to Revision C (February 2022)</b>	<b>Page</b>
• 更新了整个文档中的表格、图和交叉参考的编号格式.....	1
• 向“器件信息”表添加了 SOT-23 (DYY) 封装.....	1
• Added DYY (SOT-23) package to <i>Pin Configuration and Functions</i> section.....	3
• Added DYY (SOT-23) package to <i>Thermal Information: LM2902LV</i> section.....	6
<b>Changes from Revision A (May 2019) to Revision B (October 2019)</b>	<b>Page</b>
• 删除了所有 SOT-23 (DDF) 预发布备注.....	1
<b>Changes from Revision * (September 2018) to Revision A (May 2019)</b>	<b>Page</b>
• 向“器件信息”表添加了 SOT-23 (DDF) 封装.....	1
• Added DDF (SOT-23) package to <i>Pin Configuration and Functions</i> section.....	3
• Added DDF (SOT-23) <i>Thermal Information: LM2904LV</i> section.....	5

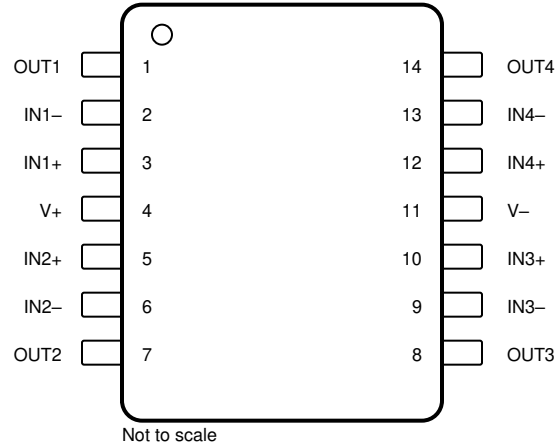
## 5 Pin Configuration and Functions



**图 5-1. LM2904LV D, DGK, PW, and DDF Package  
 8-Pin SOIC, VSSOP, TSSOP, and SOT-23  
 (Top View)**

**表 5-1. Pin Functions: LM2904LV**

PIN		I/O	DESCRIPTION
NAME	NO.		
IN1 -	2	I	Inverting input, channel 1
IN1+	3	I	Noninverting input, channel 1
IN2 -	6	I	Inverting input, channel 2
IN2+	5	I	Noninverting input, channel 2
OUT1	1	O	Output, channel 1
OUT2	7	O	Output, channel 2
V -	4	I or —	Negative (low) supply or ground (for single-supply operation)
V+	8	I	Positive (high) supply



**图 5-2. LM2902LV D, PW, DYY and Package 14-Pin SOIC, TSSOP, and SOT-23 (Top View)**

**表 5-2. Pin Functions: LM2902LV**

PIN		I/O	DESCRIPTION
NAME	NO.		
IN1 -	2	I	Inverting input, channel 1
IN1+	3	I	Noninverting input, channel 1
IN2 -	6	I	Inverting input, channel 2
IN2+	5	I	Noninverting input, channel 2
IN3 -	9	I	Inverting input, channel 3
IN3+	10	I	Noninverting input, channel 3
IN4 -	13	I	Inverting input, channel 4
IN4+	12	I	Noninverting input, channel 4
OUT1	1	O	Output, channel 1
OUT2	7	O	Output, channel 2
OUT3	8	O	Output, channel 3
OUT4	14	O	Output, channel 4
V -	11	I or —	Negative (low) supply or ground (for single-supply operation)
V+	4	I	Positive (high) supply

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating junction temperature range (unless otherwise noted)<sup>(1)</sup>

		MIN	MAX	UNIT	
Supply voltage, ([V+] - [V-])		0	6	V	
Signal input pins	Voltage <sup>(2)</sup>	Common-mode	(V-) - 0.5	(V+) + 0.5	V
		Differential	(V+) - (V-) + 0.2		V
	Current <sup>(2)</sup>	- 10	10	mA	
Output short-circuit <sup>(3)</sup>		Continuous			
Operating, T <sub>A</sub>		- 55	125	°C	
Operating junction temperature, T <sub>J</sub>			150	°C	
Storage temperature, T <sub>stg</sub>		- 65	150	°C	

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) Input pins are diode-clamped to the power-supply rails. Input signals that may swing more than 0.5 V beyond the supply rails must be current limited to 10 mA or less.
- (3) Short-circuit to ground, one amplifier per package.

### 6.2 ESD Ratings

		VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	±2000
		Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>	±1000

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating junction temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V <sub>S</sub>	Supply voltage [(V+) - (V-)]	2.7	5.5	V
V <sub>IN</sub>	Input-pin voltage range	(V-) - 0.1	(V+) - 1	V
T <sub>A</sub>	Specified temperature	- 40	125	°C

### 6.4 Thermal Information: LM2904LV

THERMAL METRIC <sup>(1)</sup>	LM2904LV				UNIT	
	D (SOIC)	DGK (VSSOP)	PW (TSSOP)	DDF (SOT-23)		
	8 PINS	8 PINS	8 PINS	8 PINS		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	207.9	201.2	200.7	183.7	°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	92.8	85.7	95.4	112.5	°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	129.7	122.9	128.6	98.2	°C/W
ψ <sub>JT</sub>	Junction-to-top characterization parameter	26	21.2	27.2	18.8	°C/W
ψ <sub>JB</sub>	Junction-to-board characterization parameter	127.9	121.4	127.2	97.6	°C/W

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

## 6.5 Thermal Information: LM2902LV

THERMAL METRIC <sup>(1)</sup>		LM2902LV			UNIT
		D (SOIC)	PW (TSSOP)	DYY (SOT-23)	
		14 PINS	14 PINS	14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	102.1	148.3	154.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	56.8	68.1	86.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	58.5	92.7	67.3	°C/W
$\psi_{JT}$	Junction-to-top characterization parameter	20.5	16.9	9.8	°C/W
$\psi_{JB}$	Junction-to-board characterization parameter	58.1	91.8	67.1	°C/W

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

## 6.6 Electrical Characteristics

For  $V_S = (V_+) - (V_-) = 2.7\text{ V to }5.5\text{ V}$  ( $\pm 1.35\text{ V to } \pm 2.75\text{ V}$ ),  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>OFFSET VOLTAGE</b>						
$V_{OS}$	Input offset voltage	$V_S = 5\text{ V}$		$\pm 1$	$\pm 3$	mV
		$V_S = 5\text{ V}, T_A = -40^\circ\text{C to }125^\circ\text{C}$			$\pm 5$	
$dV_{OS}/dT$	$V_{OS}$ vs temperature	$T_A = -40^\circ\text{C to }125^\circ\text{C}$		$\pm 4$		$\mu\text{V}/^\circ\text{C}$
PSRR	Power-supply rejection ratio	$V_S = 2.7\text{ V to }5.5\text{ V}, V_{CM} = (V_-)$	80	100		dB
<b>INPUT VOLTAGE RANGE</b>						
$V_{CM}$	Common-mode voltage range	No phase reversal	$(V_-) - 0.1$		$(V_+) - 1$	V
CMRR	Common-mode rejection ratio	$V_S = 2.7\text{ V}, (V_-) - 0.1\text{ V} < V_{CM} < (V_+) - 1\text{ V}$ $T_A = -40^\circ\text{C to }125^\circ\text{C}$		84		dB
		$V_S = 5.5\text{ V}, (V_-) - 0.1\text{ V} < V_{CM} < (V_+) - 1\text{ V}$ $T_A = -40^\circ\text{C to }125^\circ\text{C}$	63	92		
<b>INPUT BIAS CURRENT</b>						
$I_B$	Input bias current	$V_S = 5\text{ V}$		$\pm 15$		pA
$I_{OS}$	Input offset current			$\pm 5$		pA
<b>NOISE</b>						
$E_n$	Input voltage noise (peak-to-peak)	$f = 0.1\text{ Hz to }10\text{ Hz}, V_S = 5\text{ V}$		5.1		$\mu\text{V}_{PP}$
$e_n$	Input voltage noise density	$f = 1\text{ kHz}, V_S = 5\text{ V}$		40		$\text{nV}/\sqrt{\text{Hz}}$
<b>INPUT CAPACITANCE</b>						
$C_{ID}$	Differential			2		pF
$C_{IC}$	Common-mode			5.5		pF
<b>OPEN-LOOP GAIN</b>						
$A_{OL}$	Open-loop voltage gain	$V_S = 2.7\text{ V}, (V_-) + 0.15\text{ V} < V_O < (V_+) - 0.15\text{ V}, R_L = 2\text{ k}\Omega$		110		dB
		$V_S = 5.5\text{ V}, (V_-) + 0.15\text{ V} < V_O < (V_+) - 0.15\text{ V}, R_L = 2\text{ k}\Omega$		125		
<b>FREQUENCY RESPONSE</b>						
GBW	Gain-bandwidth product	$V_S = 5\text{ V}$		1		MHz
$\phi_m$	Phase margin	$V_S = 5.5\text{ V}, G = 1$		75		°
SR	Slew rate	$V_S = 5\text{ V}$		1.5		V/ $\mu\text{s}$
$t_s$	Settling time	To 0.1%, $V_S = 5\text{ V}, 2\text{-V step}, G = 1, C_L = 100\text{ pF}$		4		$\mu\text{s}$
		To 0.01%, $V_S = 5\text{ V}, 2\text{-V step}, G = 1, C_L = 100\text{ pF}$		5		
$t_{OR}$	Overload recovery time	$V_S = 5\text{ V}, V_{IN} \times \text{gain} > V_S$		1		$\mu\text{s}$
THD+N	Total harmonic distortion + noise	$V_S = 5.5\text{ V}, V_{CM} = 2.5\text{ V}, V_O = 1\text{ V}_{RMS}, G = 1, f = 1\text{ kHz}, 80\text{-kHz measurement BW}$		0.005%		
<b>OUTPUT</b>						
$V_{OH}$	Voltage output swing from positive supply	$R_L \geq 2\text{ k}\Omega, T_A = -40^\circ\text{C to }125^\circ\text{C}$	1			V
$V_{OL}$	Voltage output swing from negative supply	$R_L \leq 10\text{ k}\Omega, T_A = -40^\circ\text{C to }125^\circ\text{C}$		40	75	mV
$I_{SC}$	Short-circuit current	$V_S = 5.5\text{ V}$		$\pm 40$		mA
$Z_O$	Open-loop output impedance	$V_S = 5\text{ V}, f = 1\text{ MHz}$		1200		$\Omega$

## 6.6 Electrical Characteristics (continued)

For  $V_S = (V+) - (V-) = 2.7\text{ V to }5.5\text{ V}$  ( $\pm 1.35\text{ V to } \pm 2.75\text{ V}$ ),  $T_A = 25^\circ\text{C}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ , and  $V_{CM} = V_{OUT} = V_S / 2$  (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
<b>POWER SUPPLY</b>						
$V_S$	Specified voltage range		2.7 ( $\pm 1.35$ )		5.5 ( $\pm 2.75$ )	V
$I_Q$	Quiescent current per amplifier	$I_O = 0\text{ mA}$ , $V_S = 5.5\text{ V}$		90	150	$\mu\text{A}$
		$I_O = 0\text{ mA}$ , $V_S = 5.5\text{ V}$ , $T_A = -40^\circ\text{C to }125^\circ\text{C}$			160	

## 6.7 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_+ = 2.75\text{ V}$ ,  $V_- = -2.75\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_S / 2$ , and  $V_{OUT} = V_S / 2$  (unless otherwise noted)

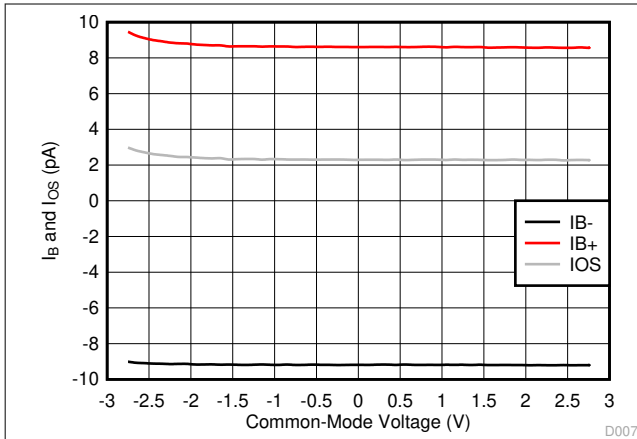


图 6-1.  $I_B$  and  $I_{OS}$  vs Common-Mode Voltage

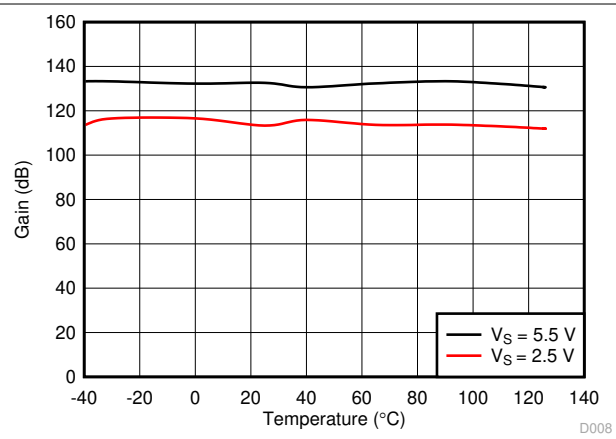


图 6-2. Open-Loop Gain vs Temperature

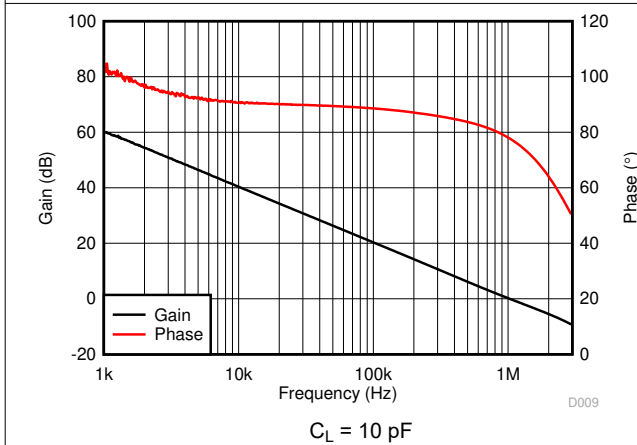


图 6-3. Open-Loop Gain and Phase vs Frequency

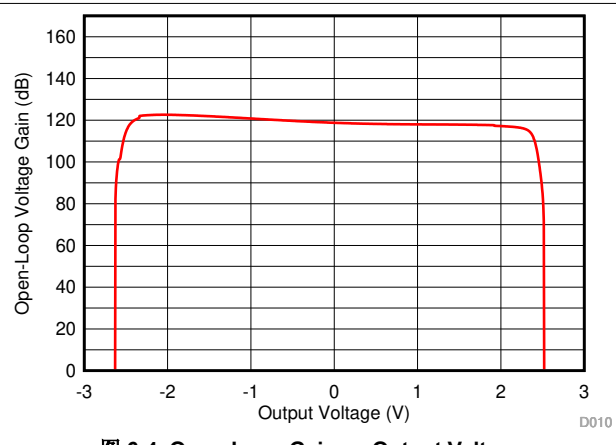


图 6-4. Open-Loop Gain vs Output Voltage

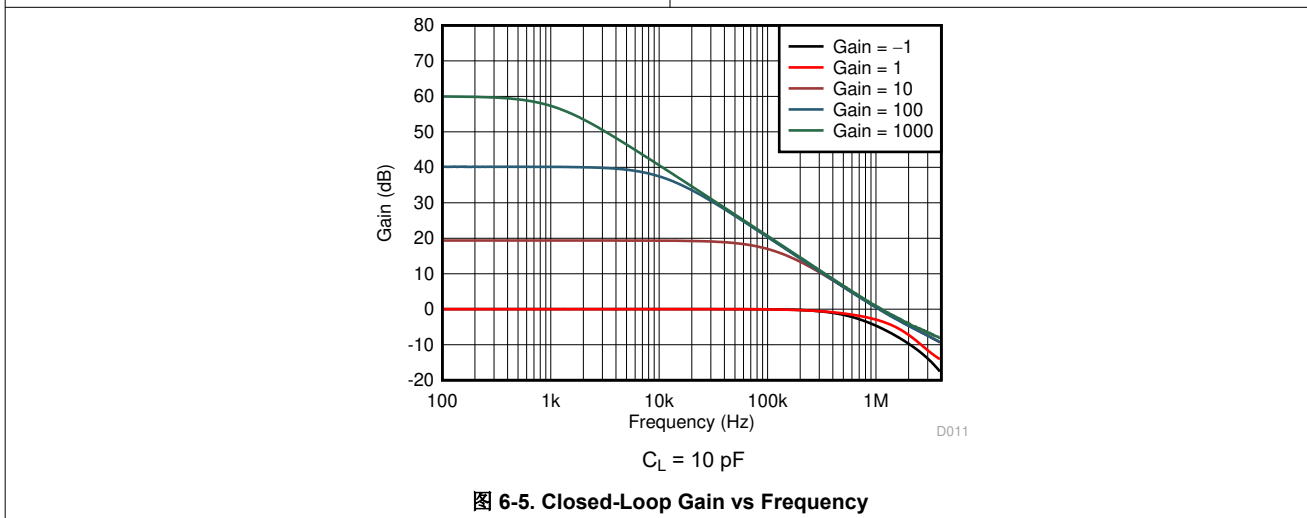


图 6-5. Closed-Loop Gain vs Frequency

## 6.7 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_+ = 2.75\text{ V}$ ,  $V_- = -2.75\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_S / 2$ , and  $V_{OUT} = V_S / 2$  (unless otherwise noted)

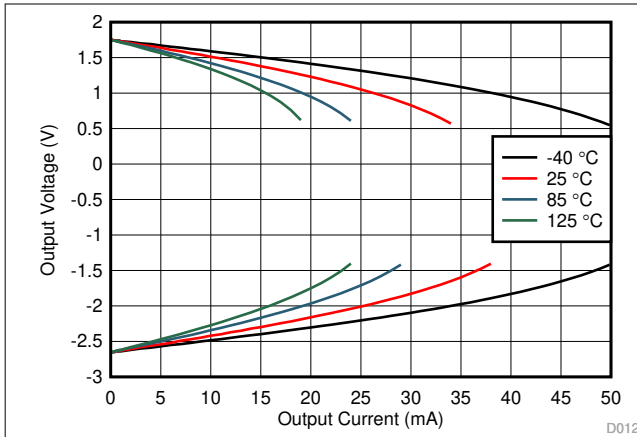


图 6-6. Output Voltage vs Output Current (Claw)

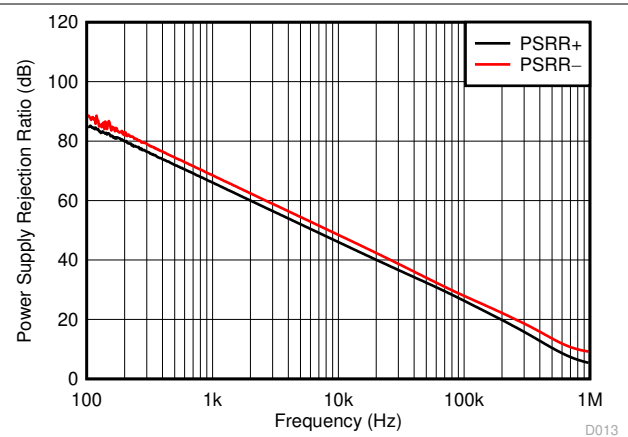


图 6-7. PSRR vs Frequency

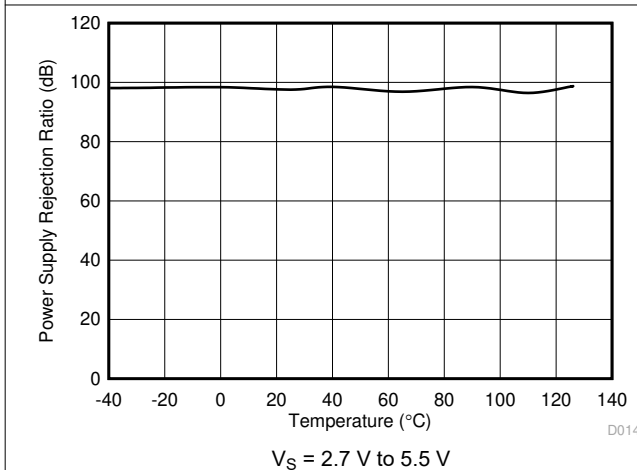


图 6-8. DC PSRR vs Temperature

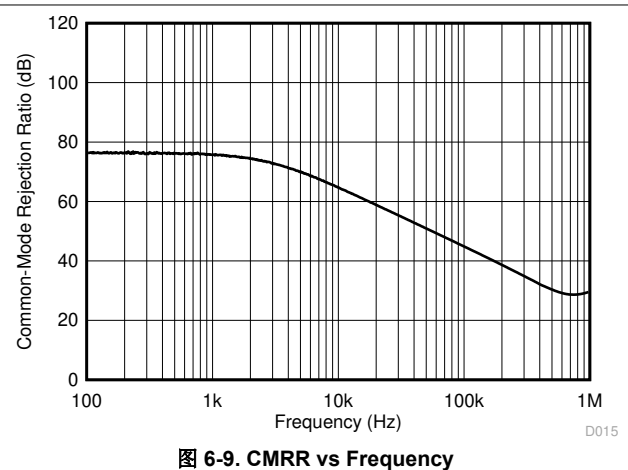


图 6-9. CMRR vs Frequency

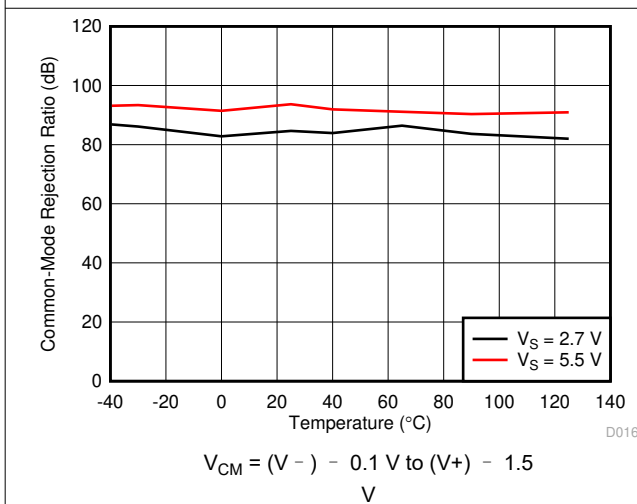


图 6-10. DC CMRR vs Temperature

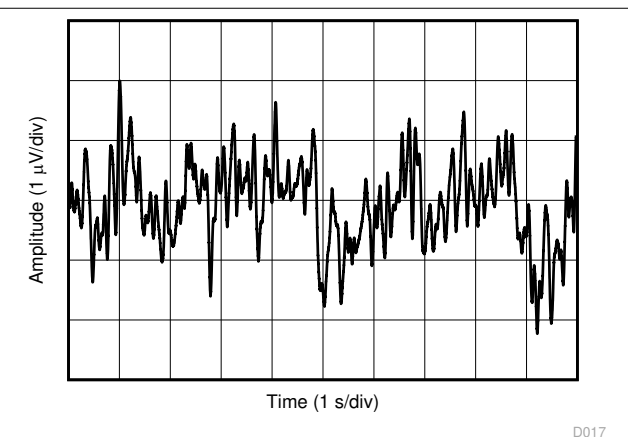


图 6-11. 0.1-Hz to 10-Hz Integrated Voltage Noise

### 6.7 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_+ = 2.75\text{ V}$ ,  $V_- = -2.75\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_S / 2$ , and  $V_{OUT} = V_S / 2$  (unless otherwise noted)

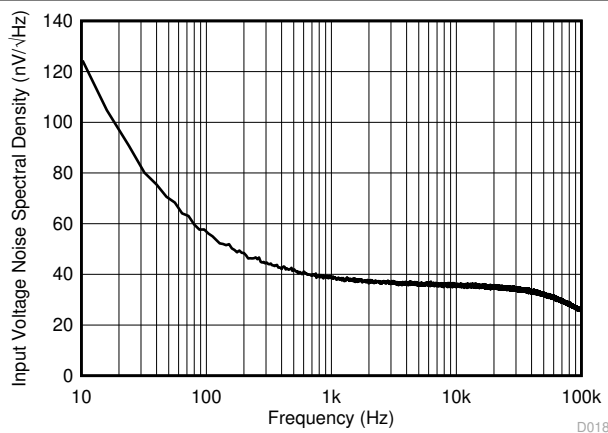
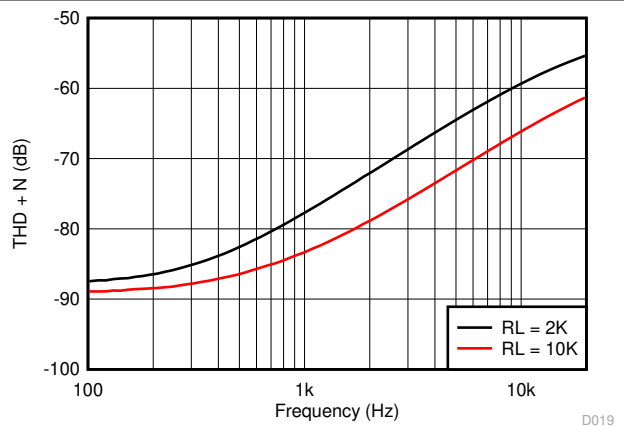
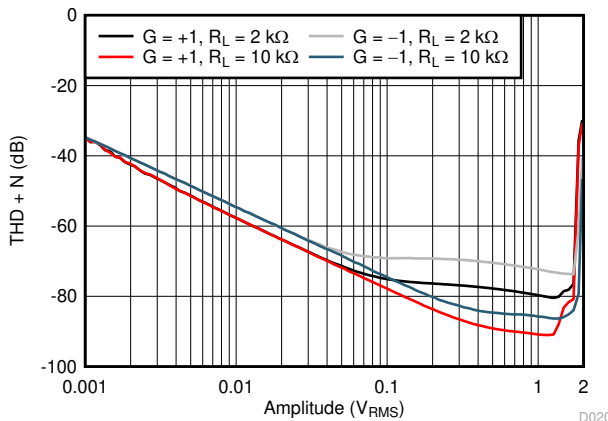


图 6-12. Input Voltage Noise Spectral Density



$V_S = 5.5\text{ V}$        $V_{CM} = 2.5\text{ V}$        $G = 1$   
 $BW = 80\text{ kHz}$        $V_{OUT} = 0.5\text{ V}_{RMS}$

图 6-13. THD + N vs Frequency



$V_S = 5.5\text{ V}$        $V_{CM} = 2.5\text{ V}$        $f = 1\text{ kHz}$   
 $G = 1$        $BW = 80\text{ kHz}$

图 6-14. THD + N vs Amplitude

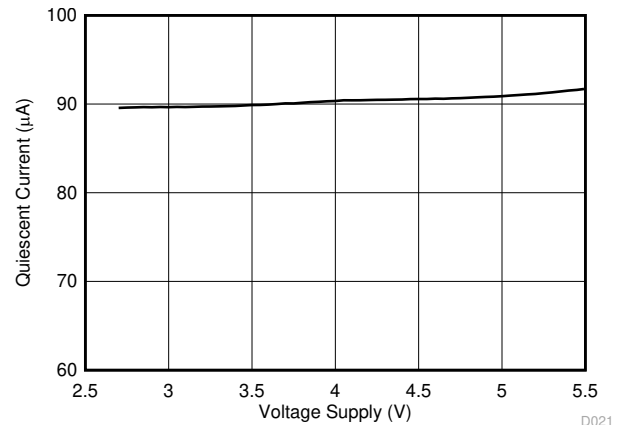


图 6-15. Quiescent Current vs Supply Voltage

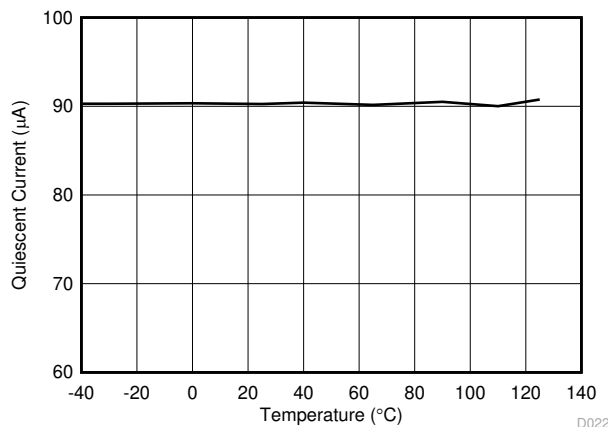


图 6-16. Quiescent Current vs Temperature

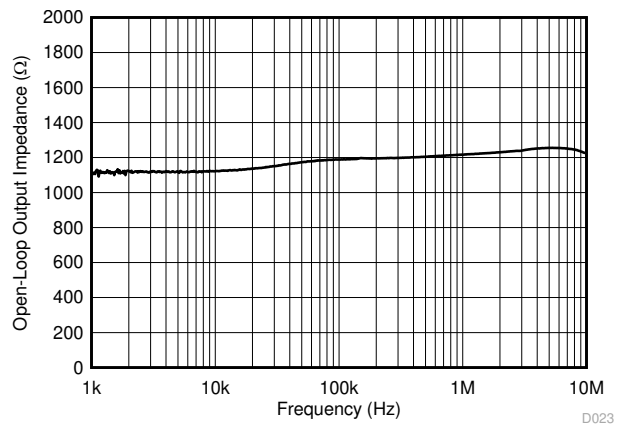


图 6-17. Open-Loop Output Impedance vs Frequency

## 6.7 Typical Characteristics

at  $T_A = 25^\circ\text{C}$ ,  $V_+ = 2.75\text{ V}$ ,  $V_- = -2.75\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_S / 2$ , and  $V_{OUT} = V_S / 2$  (unless otherwise noted)

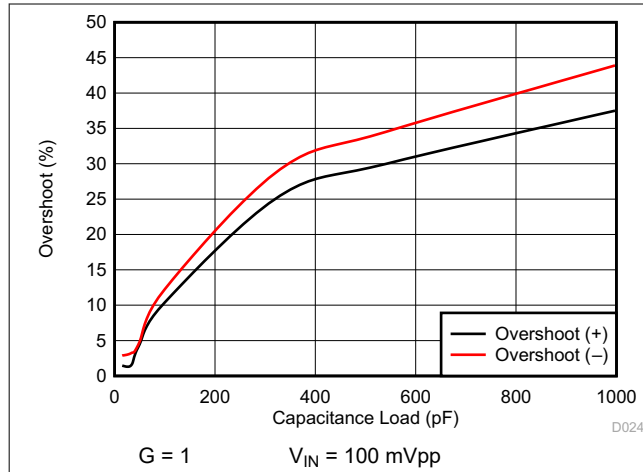


图 6-18. Small Signal Overshoot vs Capacitive Load

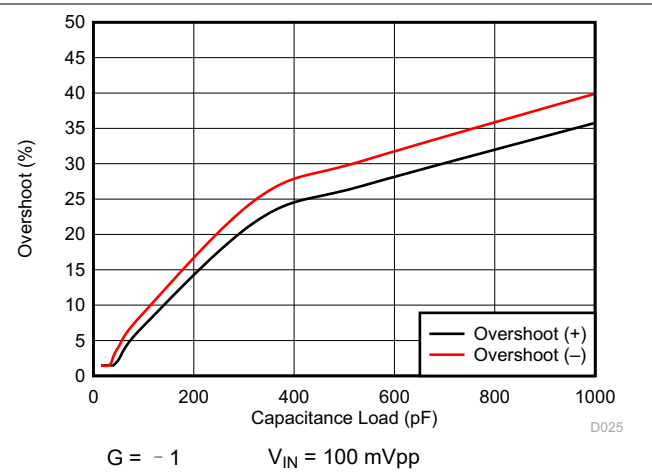


图 6-19. Small Signal Overshoot vs Capacitive Load

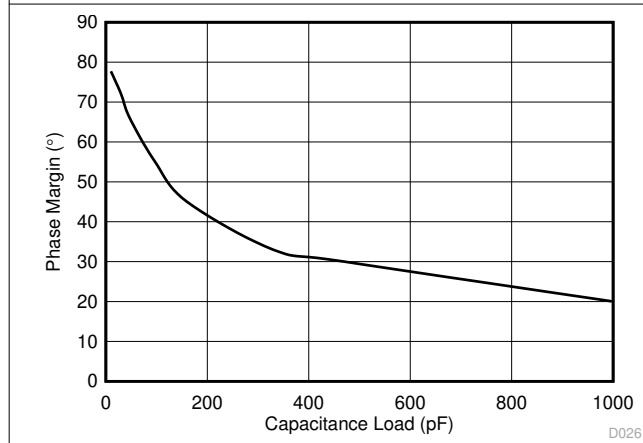


图 6-20. Phase Margin vs Capacitive Load

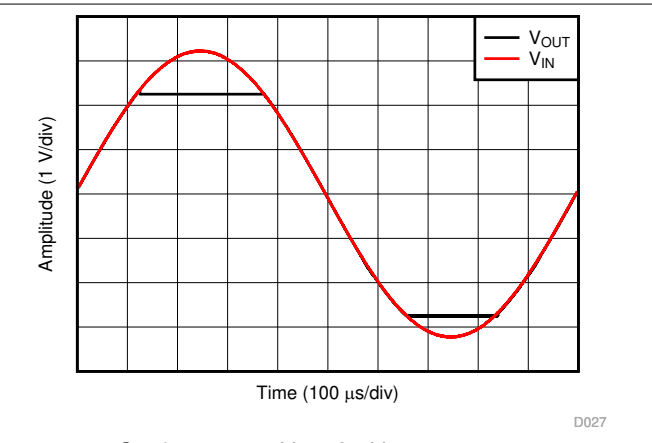


图 6-21. No Phase Reversal

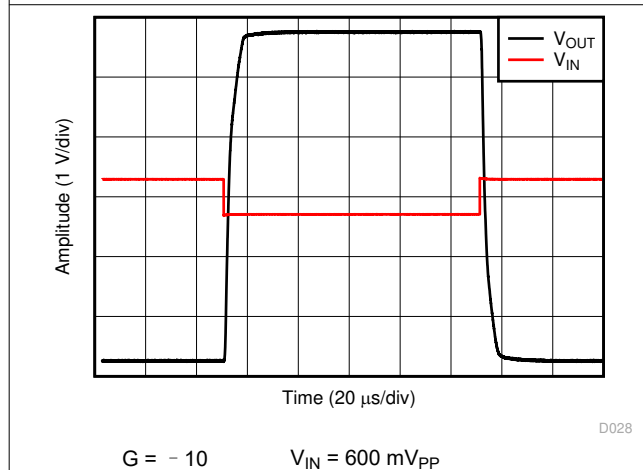


图 6-22. Overload Recovery

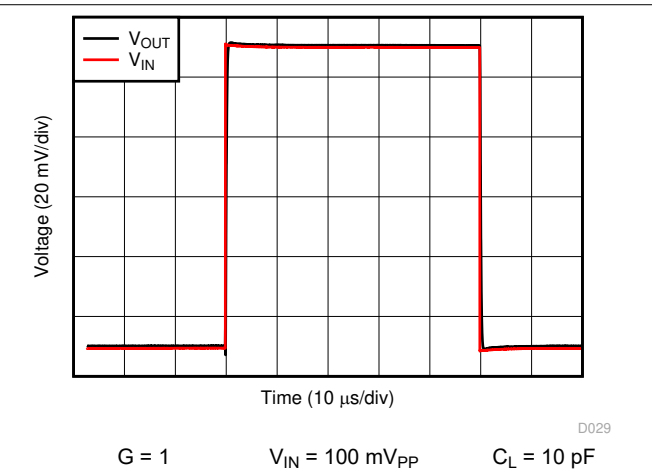
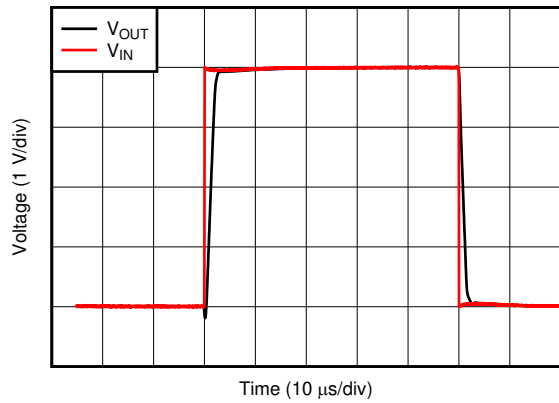


图 6-23. Small-Signal Step Response

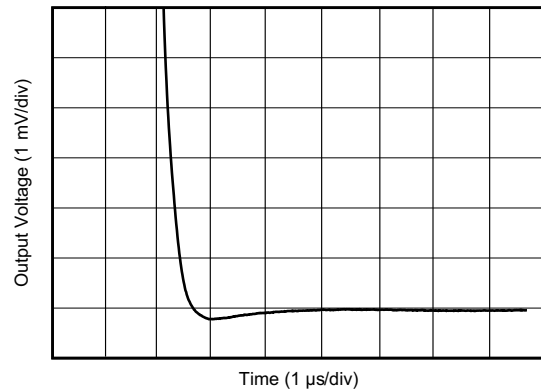
### 6.7 Typical Characteristics (continued)

at  $T_A = 25^\circ\text{C}$ ,  $V_+ = 2.75\text{ V}$ ,  $V_- = -2.75\text{ V}$ ,  $R_L = 10\text{ k}\Omega$  connected to  $V_S / 2$ ,  $V_{CM} = V_S / 2$ , and  $V_{OUT} = V_S / 2$  (unless otherwise noted)



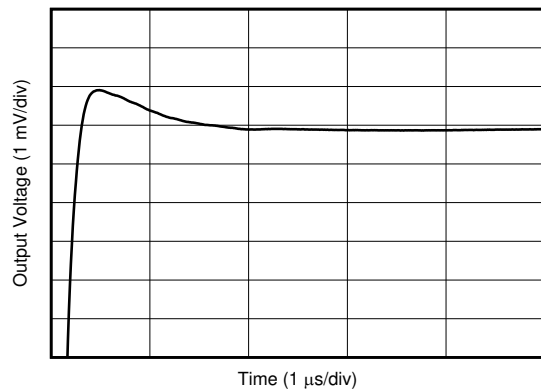
D030  
G = 1       $C_L = 10\text{ pF}$        $V_{IN} = 4\text{ V}_{PP}$

图 6-24. Large-Signal Step Response



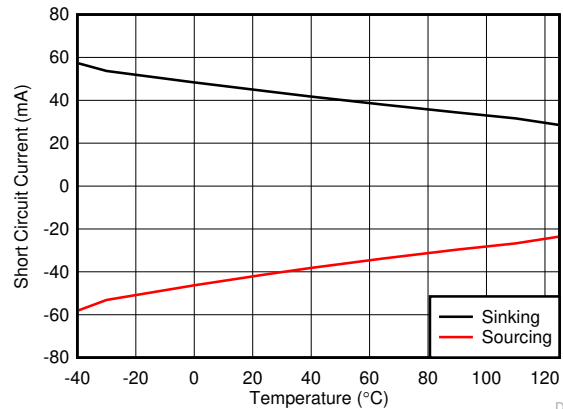
D031  
G = 1       $C_L = 100\text{ pF}$       2-V step

图 6-25. Large-Signal Settling Time (Negative)

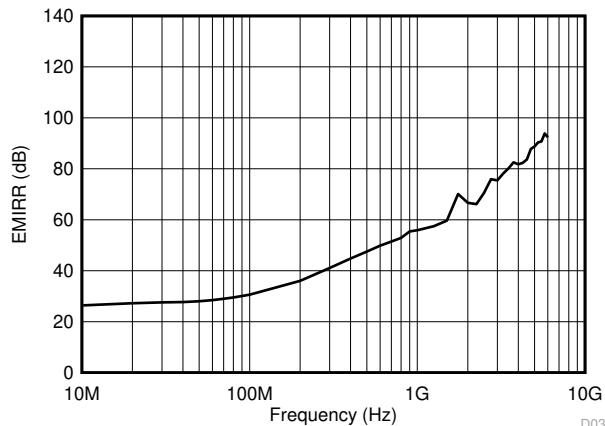


D032  
G = 1       $C_L = 100\text{ pF}$       2-V step

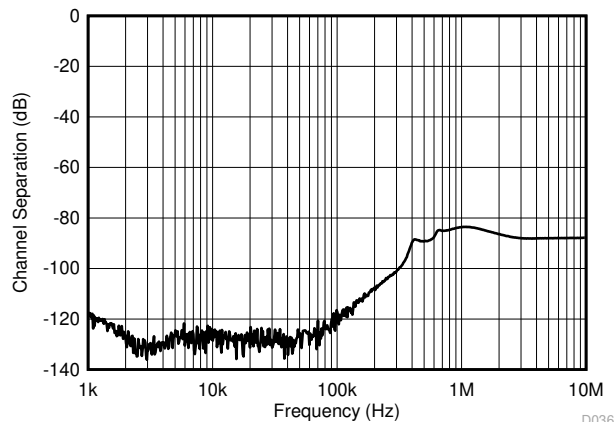
图 6-26. Large-Signal Settling Time (Positive)



D033  
图 6-27. Short-Circuit Current vs Temperature



D035  
图 6-28. Electromagnetic Interference Rejection Ratio Referred to Noninverting Input (EMIRR+) vs Frequency



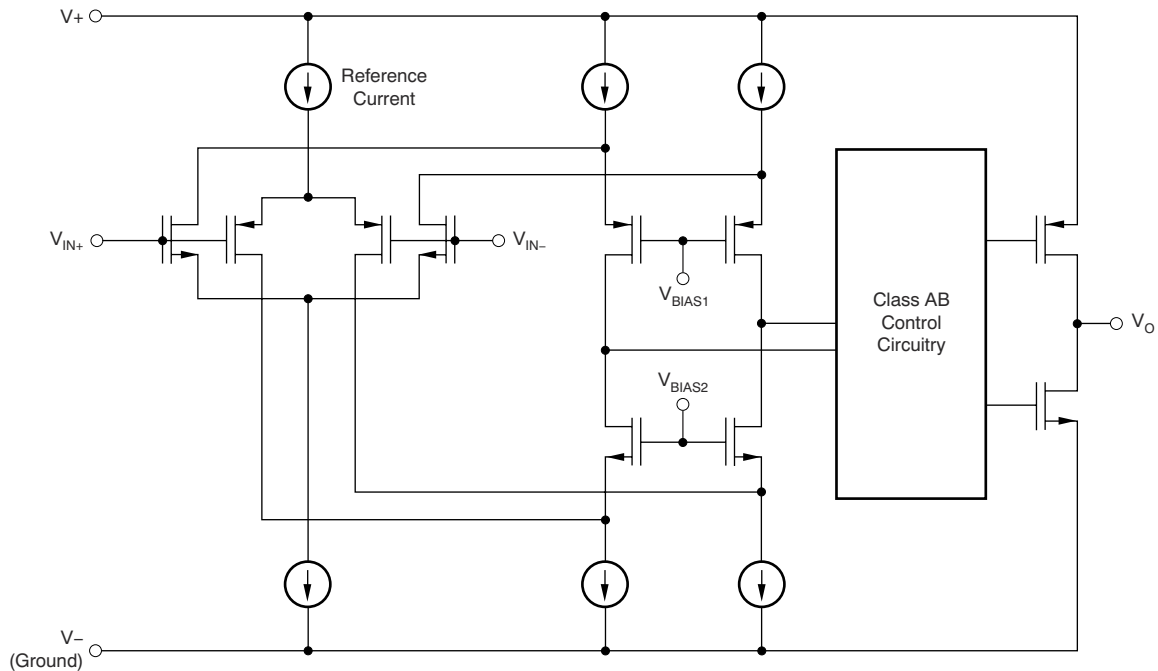
D036  
图 6-29. Channel Separation

## 7 Detailed Description

### 7.1 Overview

The LM290xLV family of low-power op amps is intended for cost-optimized systems. These devices operate from 2.7 V to 5.5 V, are unity-gain stable, and are designed for a wide range of general-purpose applications. The input common-mode voltage range includes the negative rail and allows the LM290xLV family to be used in many single-supply applications.

### 7.2 Functional Block Diagram



### 7.3 Feature Description

#### 7.3.1 Operating Voltage

The LM290xLV family of op amps is specified for operation from 2.7 V to 5.5 V. In addition, many specifications apply from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Parameters that vary significantly with operating voltages or temperature are shown in the section.

#### 7.3.2 Common-Mode Input Range Includes Ground

The input common-mode voltage range of the LM290xLV family extends to the negative supply rail and within 1 V below the positive rail for the full supply voltage range of 2.7 V to 5.5 V. This performance is achieved with a P-channel differential pair, as shown in the [Functional Block Diagram](#). Additionally, a complementary N-channel differential pair has been included in parallel to eliminate issues with phase reversal that are common with previous generations of op amps. However, the N-channel pair is not optimized for operation, and significant performance degradation occurs while this pair is operational. TI recommends limiting any voltage applied at the inputs to at least 1 V below the positive supply rail ( $V+$ ) to ensure that the op amp conforms to the specifications detailed in the section.

#### 7.3.3 Overload Recovery

Overload recovery is defined as the time required for the operational amplifier output to recover from a saturated state to a linear state. The output devices of the operational amplifier enter a saturation region when the output voltage exceeds the specified output voltage swing, because of the high input voltage or the high gain. After the device enters the saturation region, the charge carriers in the output devices require time to return to the linear state. After the charge carriers return to the linear state, the device begins to slew at the specified slew rate.

Therefore, the propagation delay (in case of an overload condition) is the sum of the overload recovery time and the slew time. The overload recovery time for the LM290xLV family is typically 1  $\mu$ s.

### 7.3.4 Electrical Overstress

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress. These questions tend to focus on the device inputs, but can also involve the supply voltage pins. Each of these different pin functions has electrical stress limits determined by the voltage breakdown characteristics of the particular semiconductor fabrication process and specific circuits connected to the pin. Additionally, internal electrostatic discharge (ESD) protection is built into these circuits to protect them from accidental ESD events both before and during product assembly.

Having a good understanding of this basic ESD circuitry and its relevance to an electrical overstress event is helpful. [Figure 7-1](#) shows the ESD circuits contained in the LM290xLV. The ESD protection circuitry involves several current-steering diodes connected from the input and output pins and routed back to the internal power supply lines, where they meet at an absorption device internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

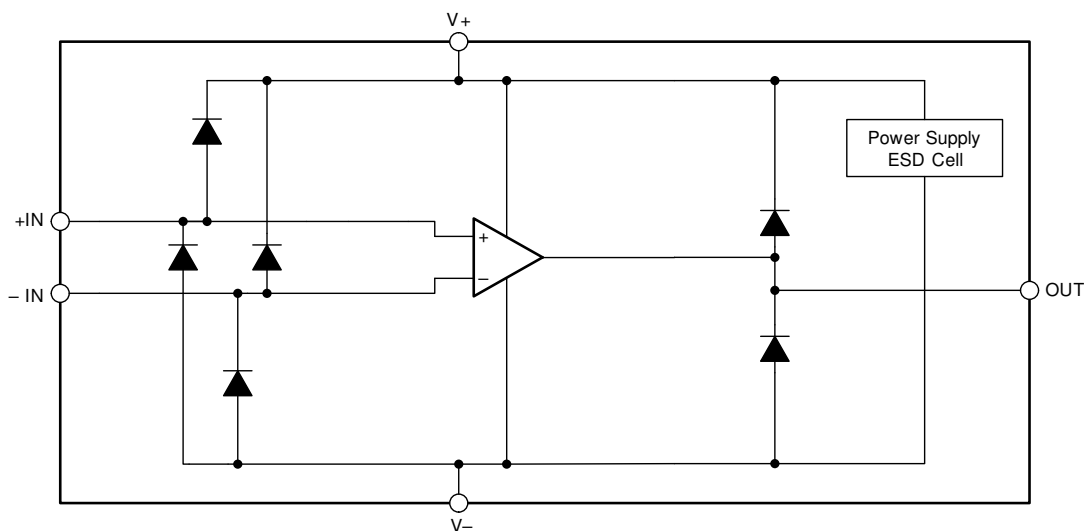


图 7-1. Equivalent Internal ESD Circuitry

### 7.3.5 EMI Susceptibility and Input Filtering

Texas Instruments has developed the ability to accurately measure and quantify the immunity of an operational amplifier over a broad frequency spectrum extending from 10 MHz to 6 GHz. The [Figure 6-28](#) plot illustrates the performance of the LM290xLV family's EMI filters across a wide range of frequencies. For more detailed information, see [EMI Rejection Ratio of Operational Amplifiers](#) available for download from [www.ti.com](http://www.ti.com).

## 7.4 Device Functional Modes

The LM290xLV family has a single functional mode. The devices are powered on as long as the power-supply voltage is between 2.7 V ( $\pm 1.35$  V) and 5.5 V ( $\pm 2.75$  V).

## 8 Application and Implementation

### 备注

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

### 8.1 Application Information

The LM290xLV devices are a family of low-power, cost-optimized operational amplifiers. The devices operate from 2.7 V to 5.5 V, are unity-gain stable, and are suitable for a wide range of general-purpose applications. The input common-mode voltage range includes the negative rail, and allows the LM290xLV to be used in any single-supply applications.

### 8.2 Typical Application

图 8-1 shows the LM290xLV device configured in a low-side current sensing application.

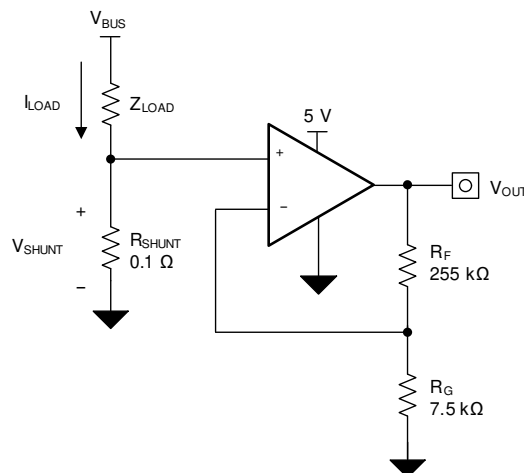


图 8-1. LM290xLV Device in a Low-Side, Current-Sensing Application

#### 8.2.1 Design Requirements

The design requirements for this design are:

- Load current: 0 A to 1 A
- Output voltage: 3.5 V
- Maximum shunt voltage: 100 mV

#### 8.2.2 Detailed Design Procedure

The transfer function of the circuit in 图 8-1 is given in 方程式 1:

$$V_{OUT} = I_{LOAD} \times R_{SHUNT} \times \text{Gain} \quad (1)$$

The load current ( $I_{LOAD}$ ) produces a voltage drop across the shunt resistor ( $R_{SHUNT}$ ). The load current is set from 0 A to 1 A. To keep the shunt voltage below 100 mV at maximum load current, the largest allowable shunt resistor is shown using 方程式 2:

$$R_{SHUNT} = \frac{V_{SHUNT\_MAX}}{I_{LOAD\_MAX}} = \frac{100\text{mV}}{1\text{A}} = 100\text{m}\Omega \quad (2)$$

Using 方程式 2,  $R_{SHUNT}$  is calculated to be  $100\text{ m}\Omega$ . The voltage drop produced by  $I_{LOAD}$  and  $R_{SHUNT}$  is amplified by the LM290xLV device to produce an output voltage of approximately 0 V to 3.5 V. The gain needed by the LM290xLV to produce the necessary output voltage is calculated using 方程式 3:

$$\text{Gain} = \frac{(V_{OUT\_MAX} - V_{OUT\_MIN})}{(V_{IN\_MAX} - V_{IN\_MIN})} \quad (3)$$

Using 方程式 3, the required gain is calculated to be 35 V/V, which is set with resistors  $R_F$  and  $R_G$ . 方程式 4 sizes the resistors  $R_F$  and  $R_G$ , to set the gain of the LM290xLV device to 35 V/V.

$$\text{Gain} = 1 + \frac{(R_F)}{(R_G)} \quad (4)$$

### 8.2.3 Application Curve

Selecting  $R_F$  as  $255\text{ k}\Omega$  and  $R_G$  as  $7.5\text{ k}\Omega$  provides a combination that equals 35 V/V. 图 8-2 shows the measured transfer function of the circuit shown in 图 8-1. Notice that the gain is only a function of the feedback and gain resistors. This gain is adjusted by varying the ratio of the resistors and the actual resistors values are determined by the impedance levels that the designer wants to establish. The impedance level determines the current drain, the effect that stray capacitance has, and a few other behaviors. There is no optimal impedance selection that works for every system, you must choose an impedance that is ideal for your system parameters.

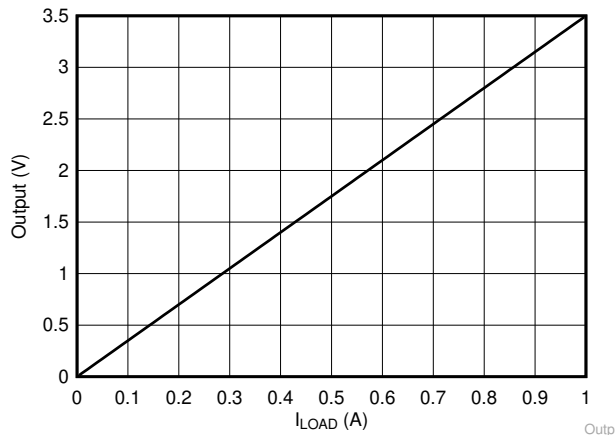


图 8-2. Low-Side, Current-Sense Transfer Function

## 9 Power Supply Recommendations

The LM290xLV family is specified for operation from 2.7 V to 5.5 V ( $\pm 1.35$  V to  $\pm 2.75$  V); many specifications apply from  $-40^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . 节 6.6 presents parameters that may exhibit significant variance with regard to operating voltage or temperature.

### CAUTION

Supply voltages larger than 6 V may permanently damage the device; see the 节 6.1.

Place 0.1- $\mu\text{F}$  bypass capacitors close to the power-supply pins to reduce coupling errors from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see 节 10.1.

### 9.1 Input and ESD Protection

The LM290xLV family incorporates internal ESD protection circuits on all pins. For input and output pins, this protection primarily consists of current-steering diodes connected between the input and power-supply pins. These ESD protection diodes provide in-circuit, input overdrive protection, as long as the current is limited to 10 mA, as stated in the section. 图 9-1 shows how a series input resistor can be added to the driven input to limit the input current. The added resistor contributes thermal noise at the amplifier input and the value must be kept to a minimum in noise-sensitive applications.

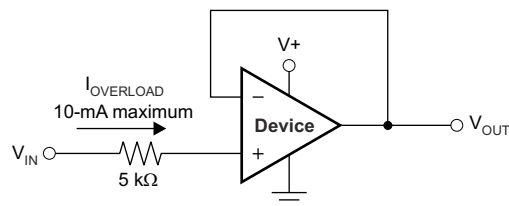


图 9-1. Input Current Protection

## 10 Layout

### 10.1 Layout Guidelines

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

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and of the op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1- $\mu\text{F}$  ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- 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 electromagnetic interference (EMI) noise pickup. Take care to physically separate digital and analog grounds. Use thermal signatures or EMI measurement techniques to determine where the majority of the ground current is flowing and be sure to route this path away from sensitive analog circuitry. For more detailed information, see [Circuit Board Layout Techniques](#).
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace at a 90° angle is much better as opposed to running the traces in parallel with the noisy trace.
- Place the external components as close to the device as possible, as shown in [图 10-2](#). Keeping  $R_F$  and  $R_G$  close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. 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 may significantly reduce leakage currents from nearby traces that are at different potentials.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit can experience performance shifts resulting from moisture ingress into the plastic package. Following any aqueous PCB cleaning process, baking the PCB assembly is recommended to remove moisture introduced into the device packaging during the cleaning process. A low-temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

### 10.2 Layout Example

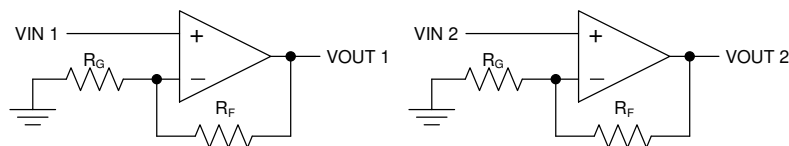
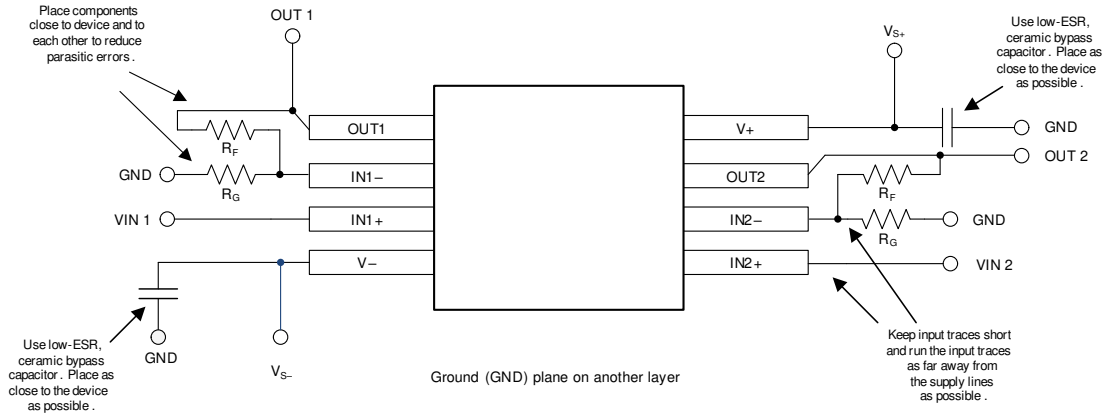


图 10-1. Schematic Representation for



**图 10-2. Layout Example**

## 11 Device and Documentation Support

### 11.1 Documentation Support

#### 11.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, [EMI Rejection Ratio of Operational Amplifiers](#)

#### 11.2 接收文档更新通知

要接收文档更新通知，请导航至 [ti.com](https://www.ti.com) 上的器件产品文件夹。点击 [订阅更新](#) 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

#### 11.3 支持资源

[TI E2E™ 支持论坛](#) 是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的《[使用条款](#)》。

#### 11.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

所有商标均为其各自所有者的财产。

#### 11.5 Electrostatic Discharge Caution



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

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

#### 11.6 术语表

[TI 术语表](#) 本术语表列出并解释了术语、首字母缩略词和定义。

## 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 without revision of this document. For browser-based versions of this data sheet, see the left-hand navigation pane.

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead finish/ Ball material (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LM2902LVIDR	ACTIVE	SOIC	D	14	2500	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LM2902LV	<a href="#">Samples</a>
LM2902LVIDYYR	ACTIVE	SOT-23-THIN	DYY	14	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LM2902I	<a href="#">Samples</a>
LM2902LVIPWR	ACTIVE	TSSOP	PW	14	2000	RoHS & Green	SN	Level-2-260C-1 YEAR	-40 to 125	LM2902LV	<a href="#">Samples</a>
LM2904LVIDDFR	ACTIVE	SOT-23-THIN	DDF	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	L904	<a href="#">Samples</a>
LM2904LVIDGKR	ACTIVE	VSSOP	DGK	8	2500	RoHS & Green	NIPDAUAG   SN	Level-2-260C-1 YEAR	-40 to 125	1SQX	<a href="#">Samples</a>
LM2904LVIDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	SN	Level-2-260C-1 YEAR	-40 to 125	2904LV	<a href="#">Samples</a>
LM2904LVIPWR	ACTIVE	TSSOP	PW	8	2000	RoHS & Green	NIPDAU   SN	Level-2-260C-1 YEAR	-40 to 125	2904	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSOLETE:** TI has discontinued the production of the device.

(2) **RoHS:** TI defines "RoHS" to mean semiconductor products that are compliant with the current EU RoHS requirements for all 10 RoHS substances, including the requirement that RoHS substance do not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, "RoHS" products are suitable for use in specified lead-free processes. TI may reference these types of products as "Pb-Free".

**RoHS Exempt:** TI defines "RoHS Exempt" to mean products that contain lead but are compliant with EU RoHS pursuant to a specific EU RoHS exemption.

**Green:** TI defines "Green" to mean the content of Chlorine (Cl) and Bromine (Br) based flame retardants meet JS709B low halogen requirements of <=1000ppm threshold. Antimony trioxide based flame retardants must also meet the <=1000ppm threshold requirement.

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

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

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

(6) Lead finish/Ball material - Orderable Devices 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.

**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 LM2902LV, LM2904LV :**

- Automotive : [LM2902LV-Q1](#), [LM2904LV-Q1](#)

NOTE: Qualified Version Definitions:

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

**TAPE AND REEL INFORMATION**

**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
LM2902LVIDR	SOIC	D	14	2500	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
LM2902LVIDYR	SOT-23-THIN	DYY	14	3000	330.0	12.4	4.8	3.6	1.6	8.0	12.0	Q3
LM2902LVIPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
LM2904LVIDDFR	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
LM2904LVIDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LM2904LVIDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
LM2904LVIDR	SOIC	D	8	2500	330.0	15.4	6.4	5.2	2.1	8.0	12.0	Q1
LM2904LVIPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
LM2904LVIPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1

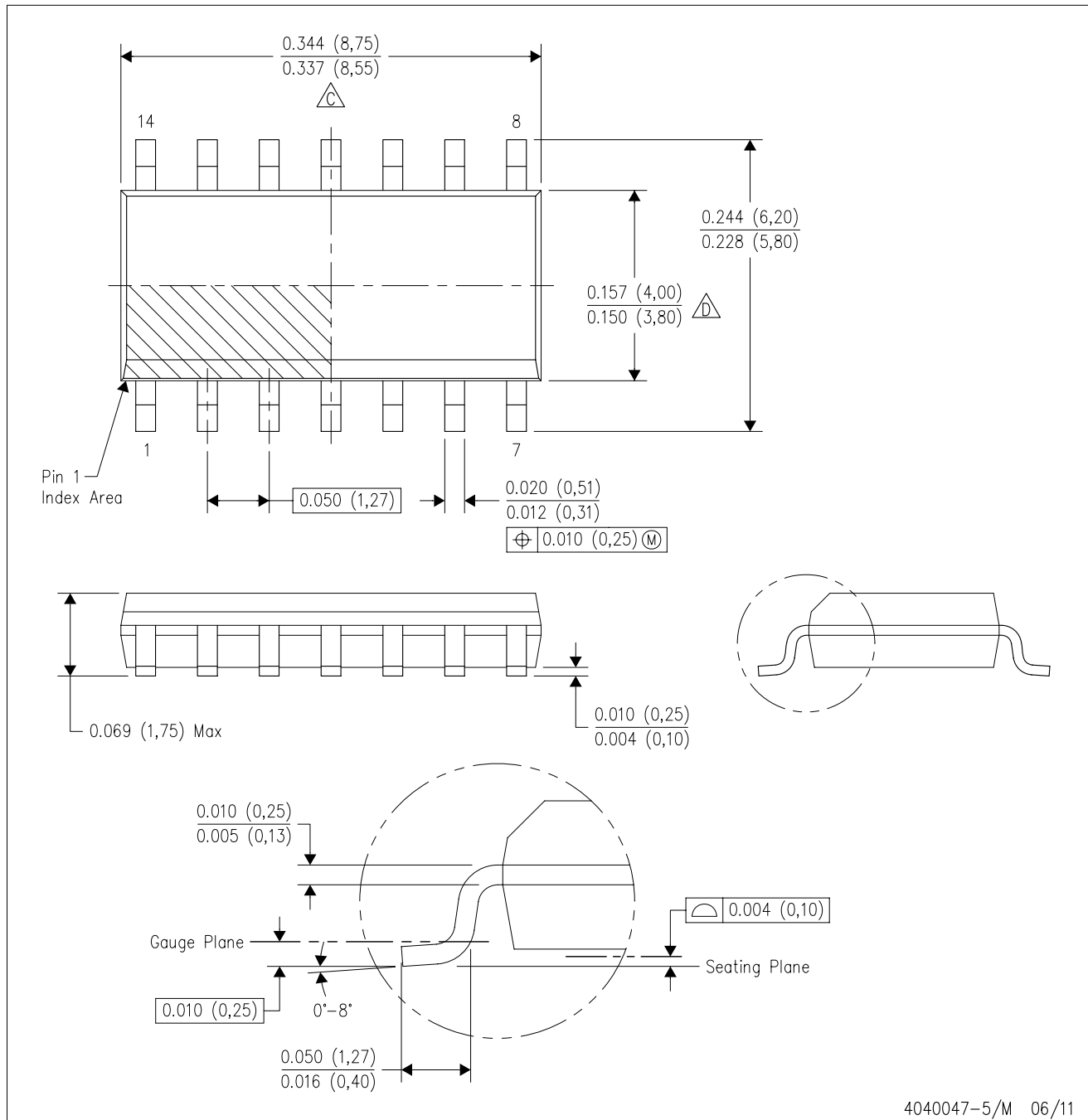
**TAPE AND REEL BOX DIMENSIONS**




\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM2902LVIDR	SOIC	D	14	2500	356.0	356.0	35.0
LM2902LVIDYYR	SOT-23-THIN	DYY	14	3000	336.6	336.6	31.8
LM2902LVIPWR	TSSOP	PW	14	2000	366.0	364.0	50.0
LM2904LVIDDFR	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
LM2904LVIDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
LM2904LVIDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
LM2904LVIDR	SOIC	D	8	2500	336.6	336.6	41.3
LM2904LVIPWR	TSSOP	PW	8	2000	356.0	356.0	35.0
LM2904LVIPWR	TSSOP	PW	8	2000	366.0	364.0	50.0

D (R-PDSO-G14)

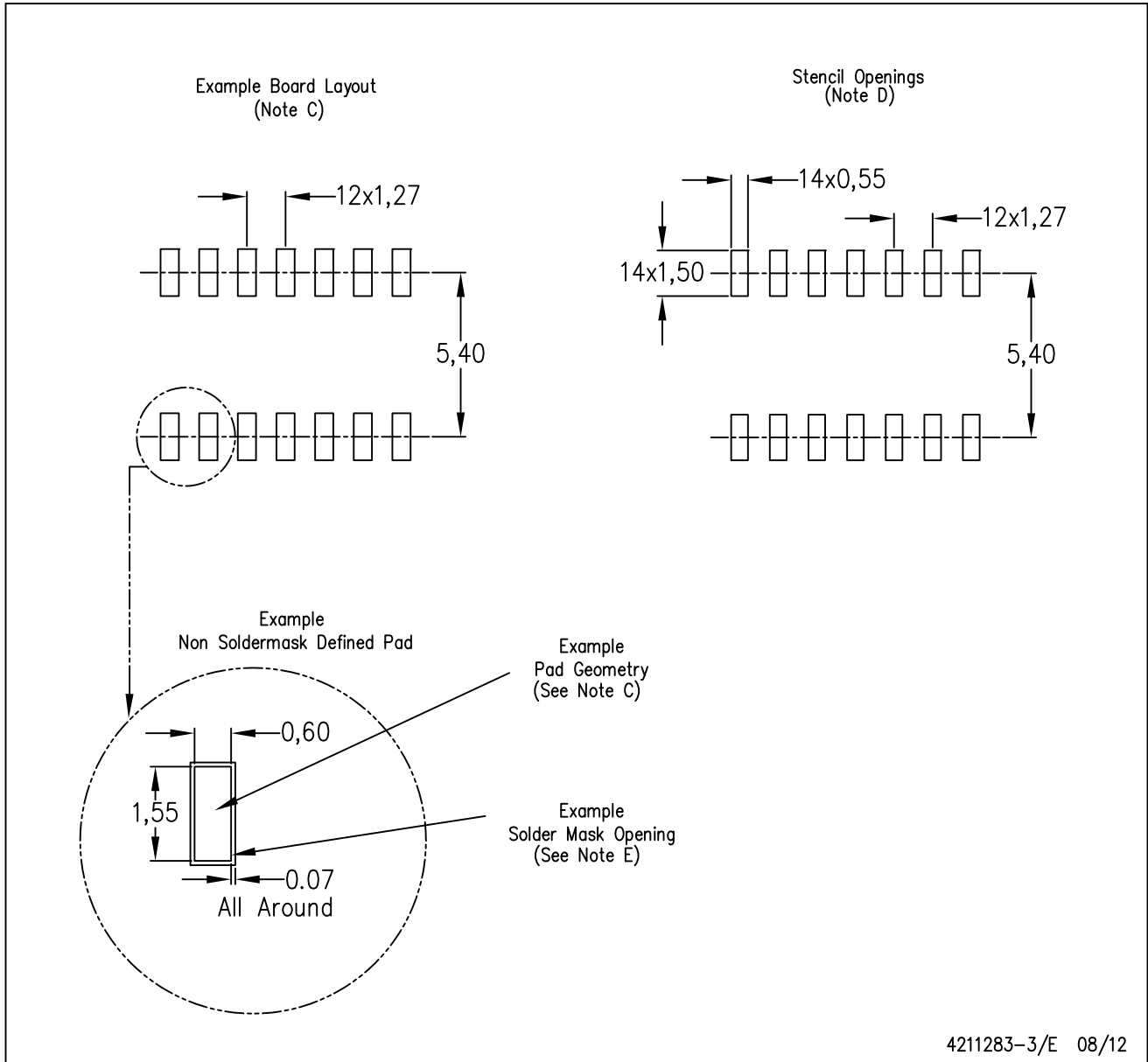
PLASTIC SMALL OUTLINE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  -  Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
  -  Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
  - E. Reference JEDEC MS-012 variation AB.

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



4211283-3/E 08/12

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

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE

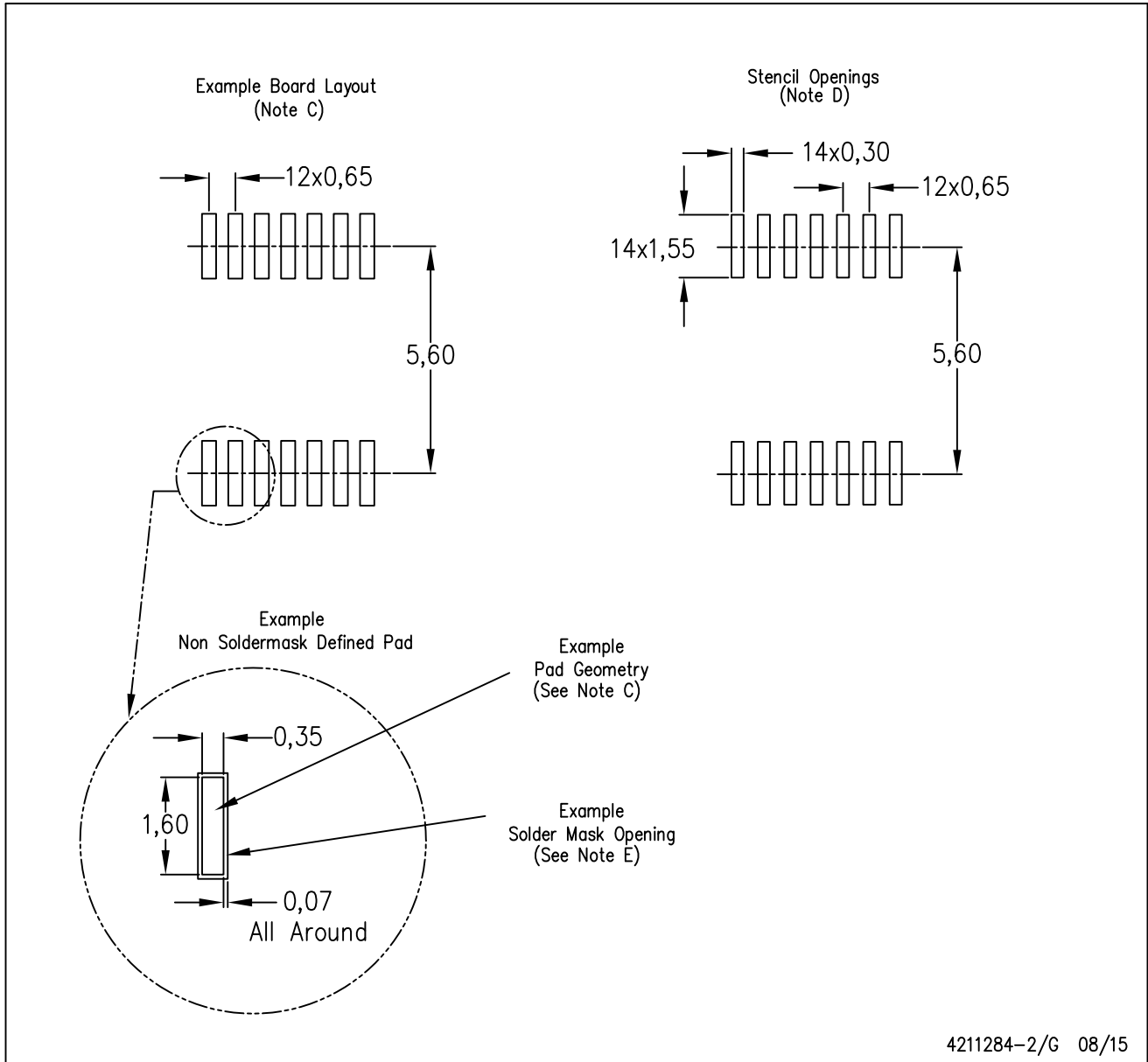


4040064-3/G 02/11

- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
  - B. This drawing is subject to change without notice.
  - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
  - D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
  - E. Falls within JEDEC MO-153

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE



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



D0008A

# PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES:

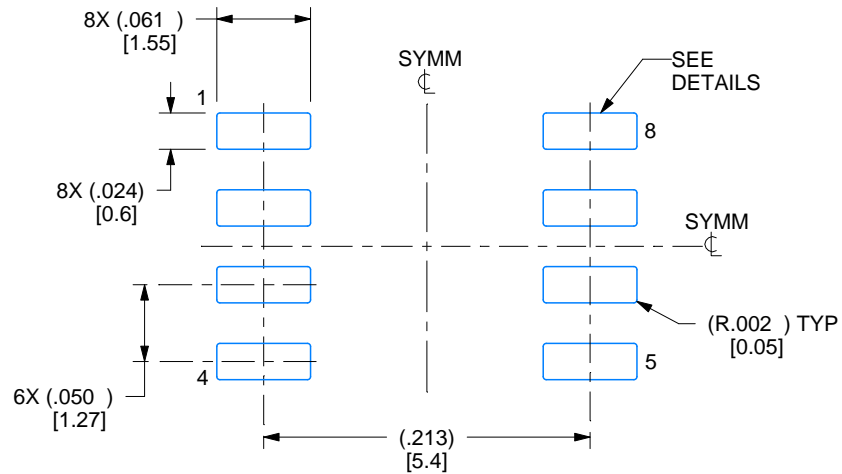
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate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

# EXAMPLE BOARD LAYOUT

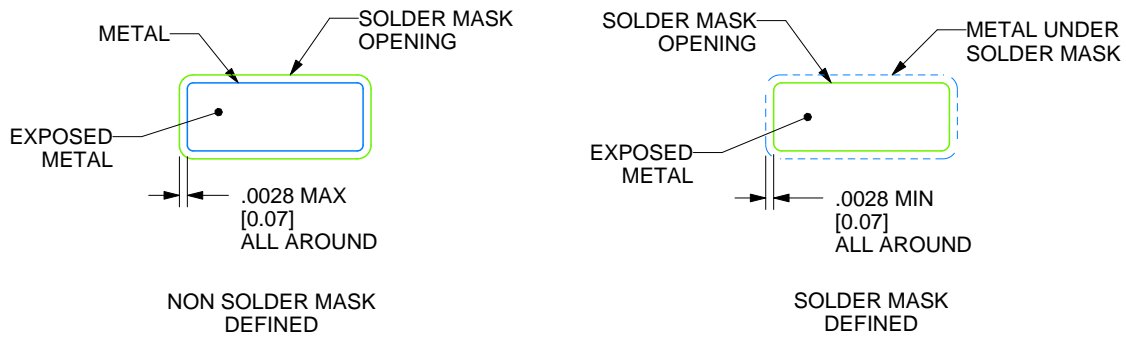
D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

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

# EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



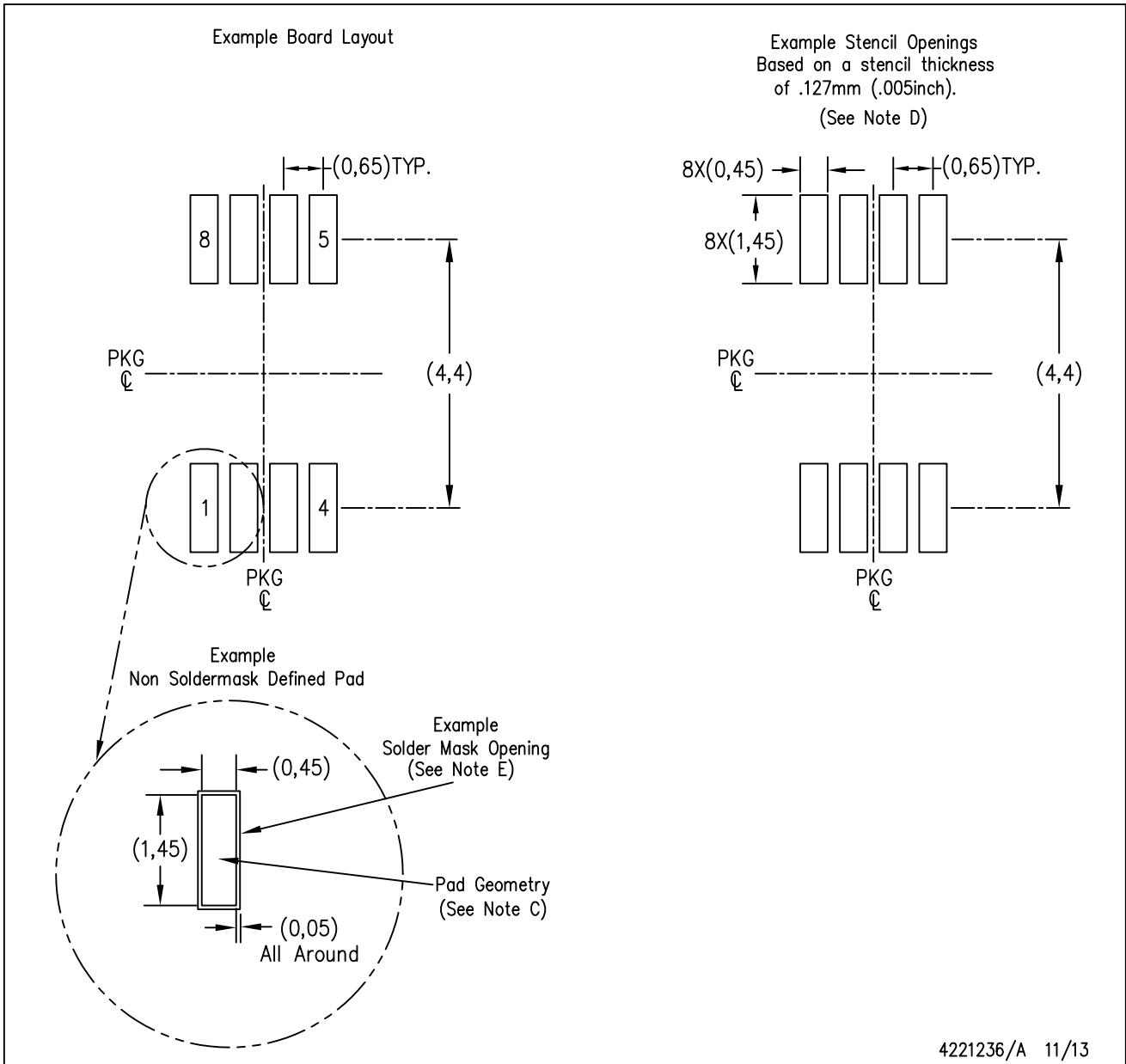
SOLDER PASTE EXAMPLE  
BASED ON .005 INCH [0.125 MM] THICK STENCIL  
SCALE:8X

4214825/C 02/2019

NOTES: (continued)

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





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



# 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.

# EXAMPLE STENCIL DESIGN

PW0008A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



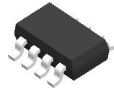
SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:10X

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.

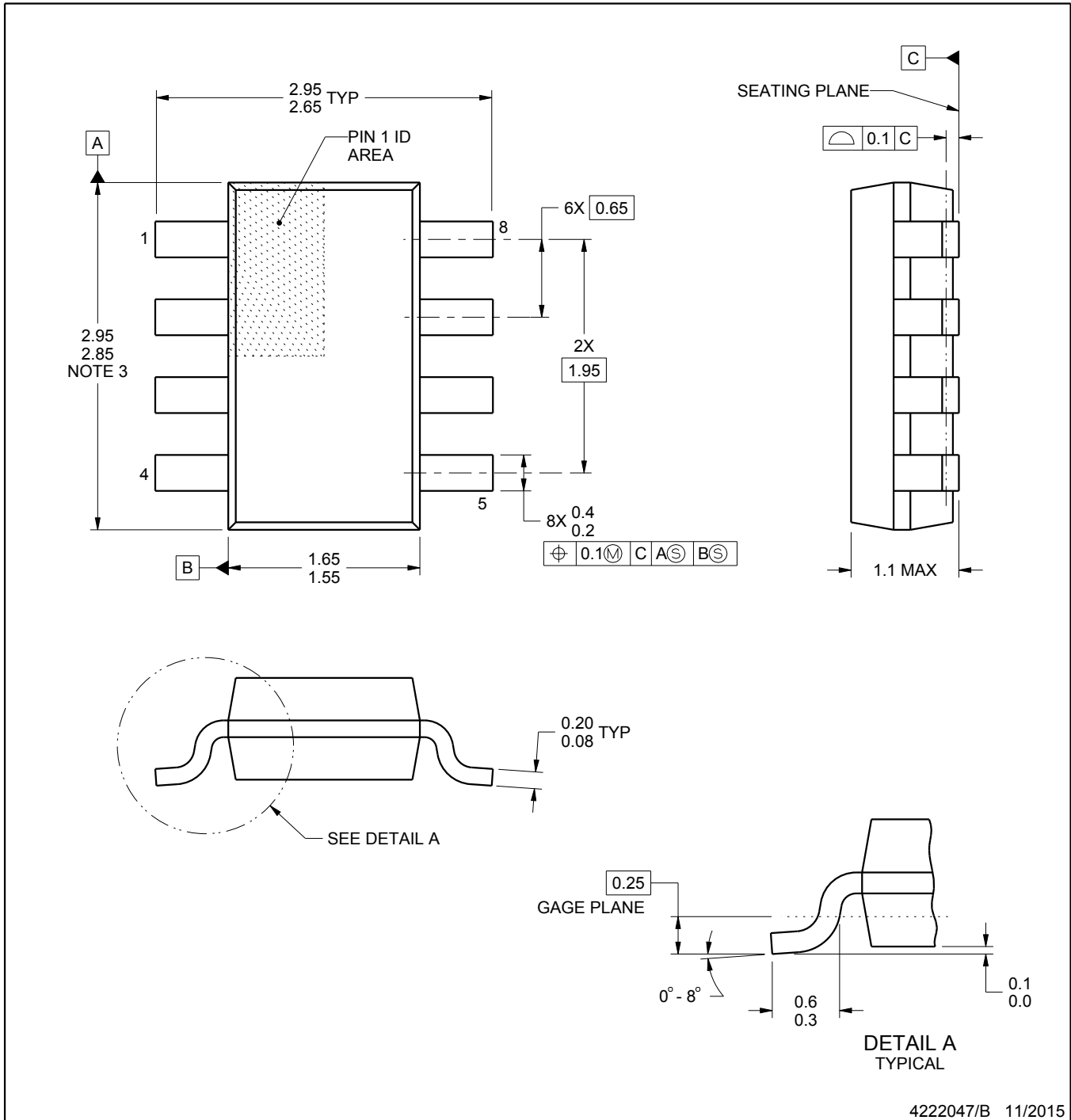
# DDF0008A



# PACKAGE OUTLINE

## SOT-23 - 1.1 mm max height

PLASTIC SMALL OUTLINE



**NOTES:**

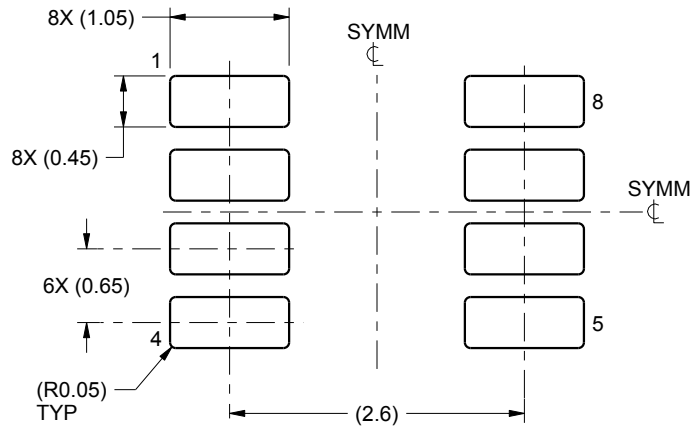
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or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

# EXAMPLE BOARD LAYOUT

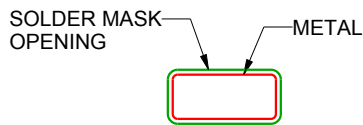
DDF0008A

SOT-23 - 1.1 mm max height

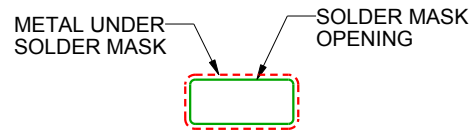
PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE  
SCALE:15X



NON SOLDER MASK  
DEFINED



SOLDER MASK  
DEFINED

SOLDER MASK DETAILS

4222047/B 11/2015

NOTES: (continued)

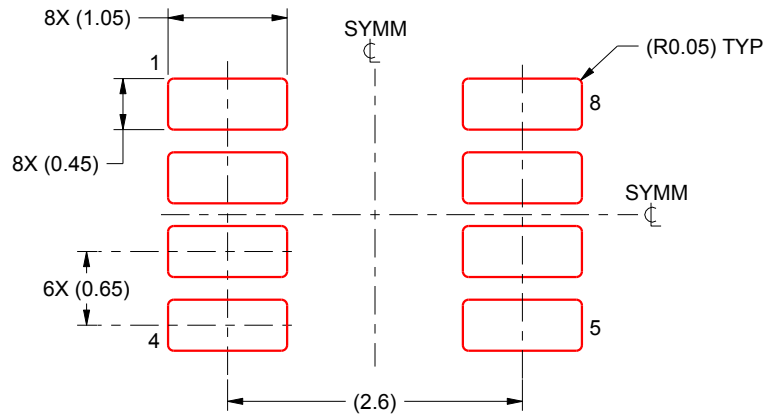
4. Publication IPC-7351 may have alternate designs.
5. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

# EXAMPLE STENCIL DESIGN

DDF0008A

SOT-23 - 1.1 mm max height

PLASTIC SMALL OUTLINE

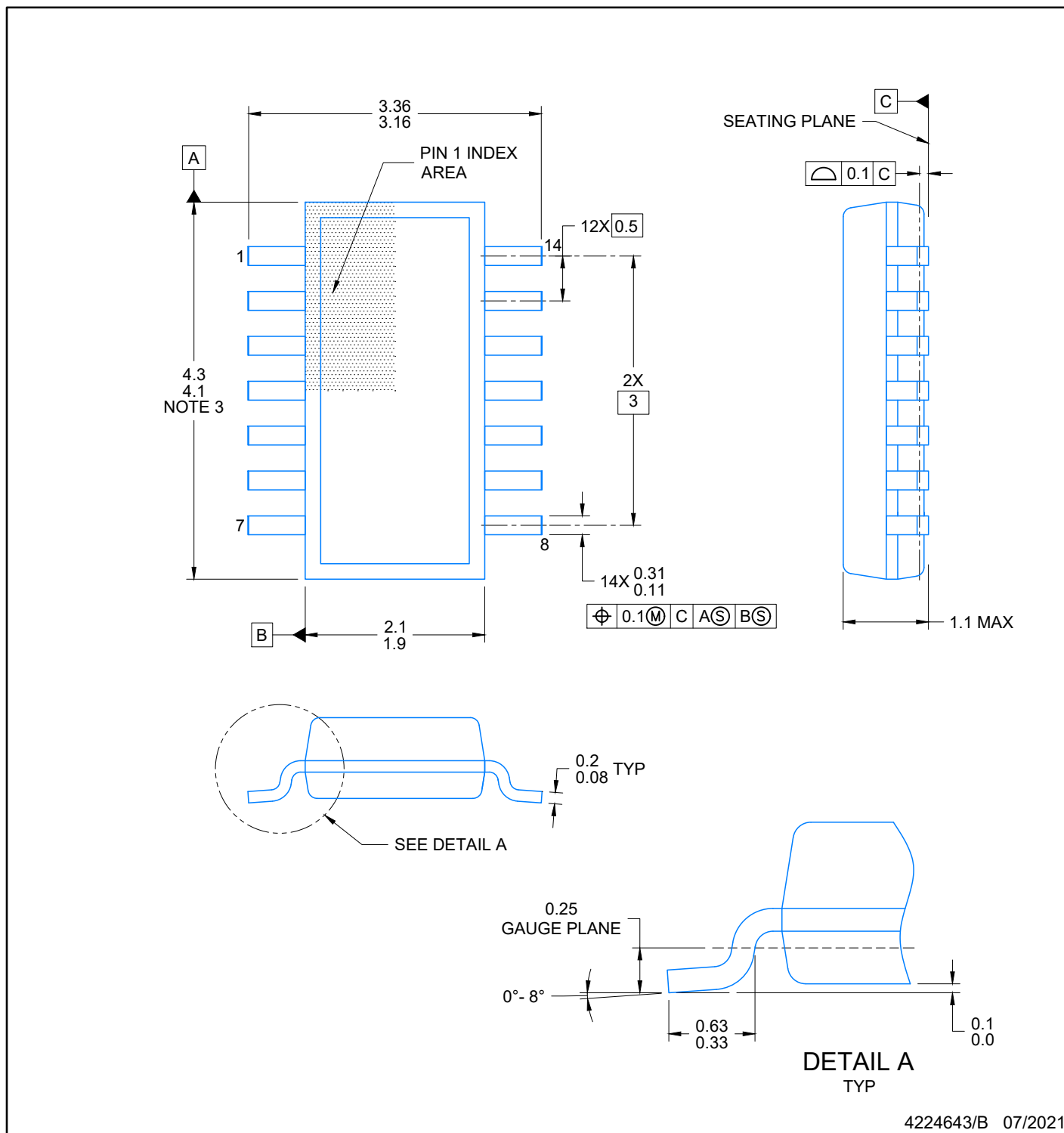


SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

4222047/B 11/2015

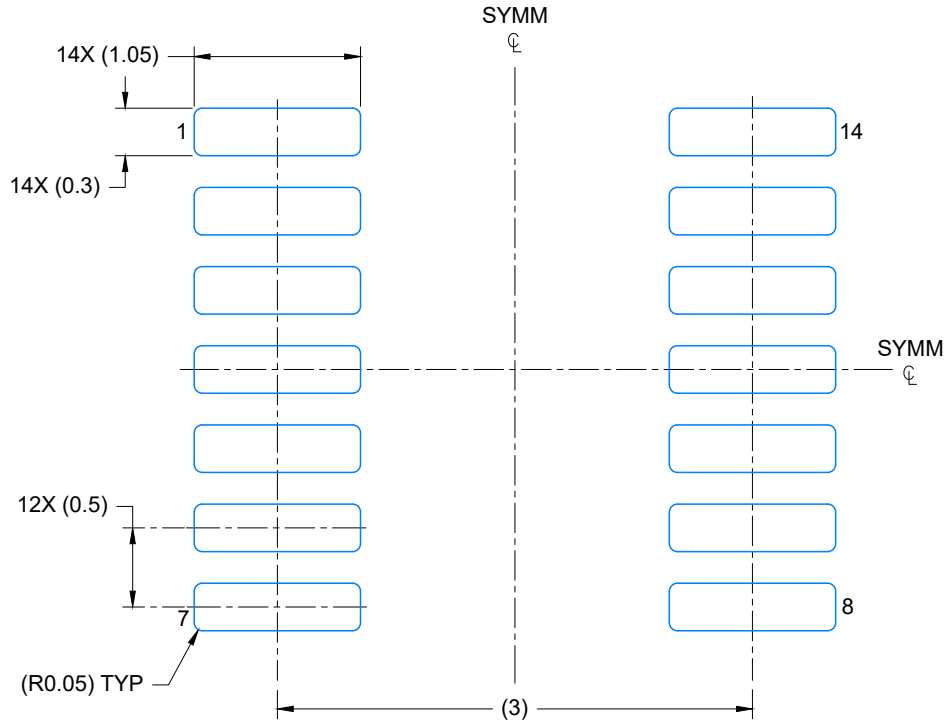
NOTES: (continued)

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

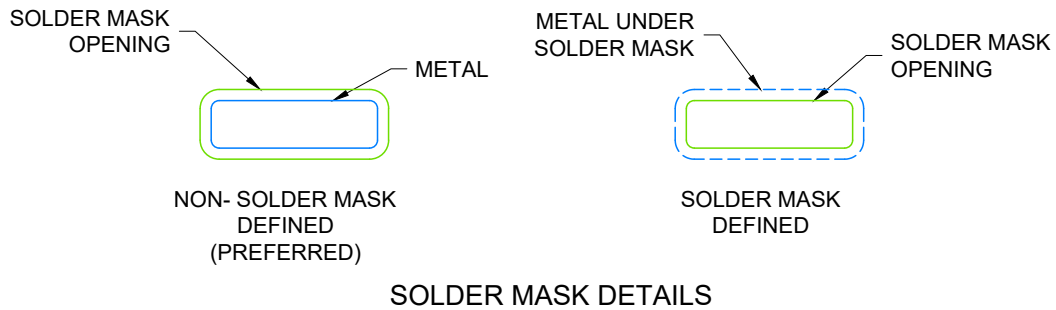


**NOTES:**

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 per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
5. Reference JEDEC Registration MO-345, Variation AB



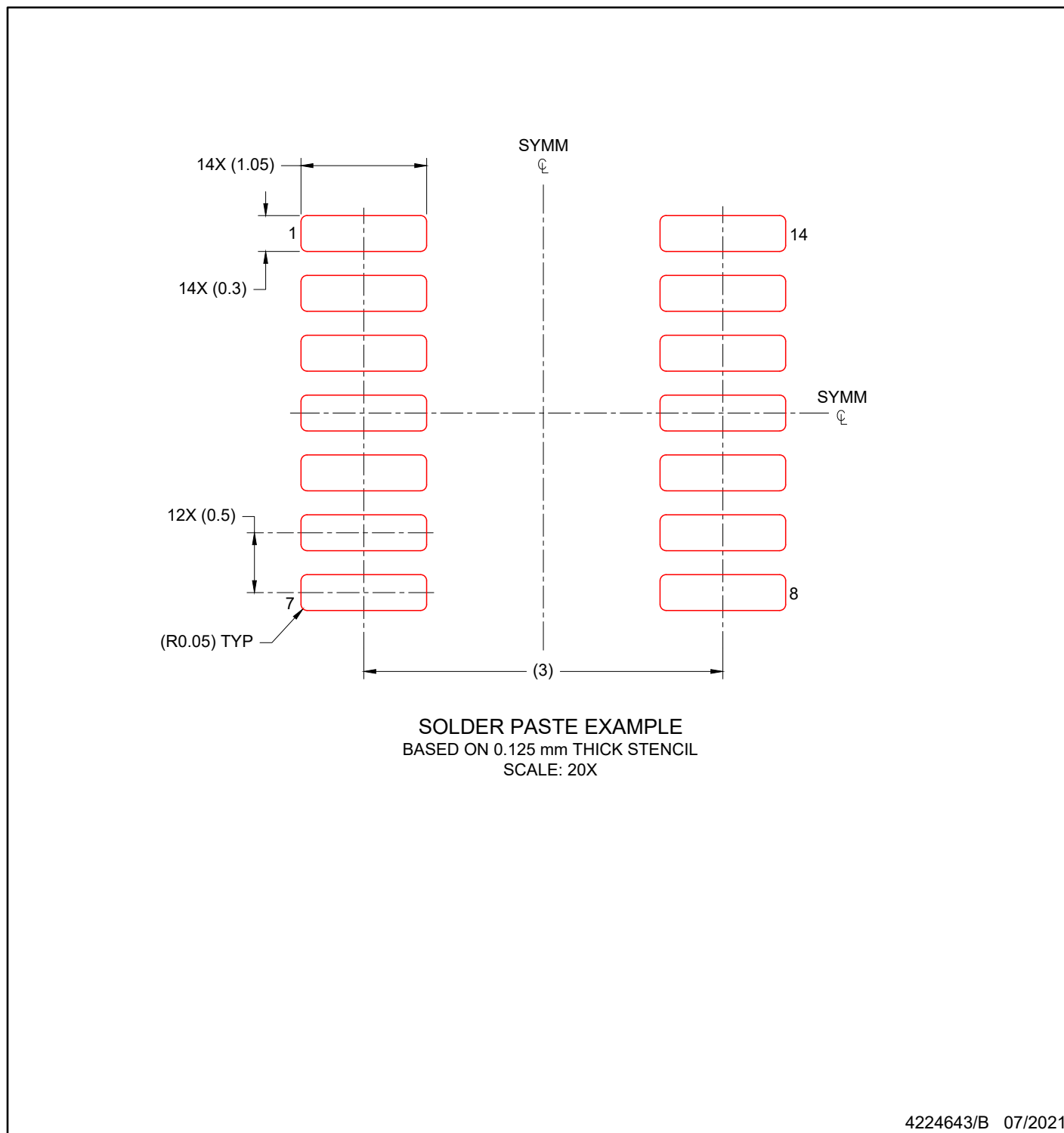
LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE: 20X



4224643/B 07/2021

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.



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.

## 重要声明和免责声明

TI“按原样”提供技术和可靠性数据（包括数据表）、设计资源（包括参考设计）、应用或其他设计建议、网络工具、安全信息和其他资源，不保证没有瑕疵且不做任何明示或暗示的担保，包括但不限于对适销性、某特定用途方面的适用性或不侵犯任何第三方知识产权的暗示担保。

这些资源可供使用 TI 产品进行设计的熟练开发人员使用。您将自行承担以下全部责任：(1) 针对您的应用选择合适的 TI 产品，(2) 设计、验证并测试您的应用，(3) 确保您的应用满足相应标准以及任何其他功能安全、信息安全、监管或其他要求。

这些资源如有变更，恕不另行通知。TI 授权您仅可将这些资源用于研发本资源所述的 TI 产品的应用。严禁对这些资源进行其他复制或展示。您无权使用任何其他 TI 知识产权或任何第三方知识产权。您应全额赔偿因在这些资源的使用中对 TI 及其代表造成的任何索赔、损害、成本、损失和债务，TI 对此概不负责。

TI 提供的产品受 [TI 的销售条款](#) 或 [ti.com](#) 上其他适用条款/TI 产品随附的其他适用条款的约束。TI 提供这些资源并不会扩展或以其他方式更改 TI 针对 TI 产品发布的适用的担保或担保免责声明。

TI 反对并拒绝您可能提出的任何其他或不同的条款。

邮寄地址：Texas Instruments, Post Office Box 655303, Dallas, Texas 75265

Copyright © 2022，德州仪器 (TI) 公司