

适用于成本敏感型系统的 TLV935x-Q1 3.5MHz、40V、RRO、支持多路复用器的汽车类运算放大器

1 特性

- 低失调电压：±350μV
- 低失调电压漂移：±1.5μV/°C
- 低噪声：1 kHz 时为 15nV/√Hz
- 高共模抑制：110dB
- 低偏置电流：±10pA
- 轨到轨输出
- 支持多路复用器/比较器的输入
 - 放大器以最高达到电源轨的差分输入工作
 - 放大器可用于开环中，也可用作比较器
- 高带宽：3.5MHz GBW
- 高压摆率：20V/μs
- 低静态电流：每个放大器 600μA
- 宽电源电压：±2.25V 至 ±20V，4.5V 至 40V
- 强大的 EMIRR 性能：输入引脚上采用 EMI/RFI 滤波器

2 应用

- 针对 AEC-Q100 1 级应用进行了优化
- 信息娱乐系统与仪表组
- 被动安全
- 车身电子装置和照明
- 混合动力汽车/电动汽车逆变器和电机控制
- 板载 (OBC) 和无线充电器
- 动力总成电流传感器
- 高级驾驶辅助系统 (ADAS)
- 单电源低侧电流检测

3 说明

TLV935x-Q1 系列 (TLV9351-Q1、TLV9352-Q1 和 TLV9354-Q1) 是 40V 成本优化型汽车类运算放大器系列。

这些器件具有出色的直流和交流规格，包括轨到轨输出、低失调电压 (典型值为 ±350μV)、低温漂 (典型值为 ±1.5μV/°C) 和 3.5MHz 带宽。

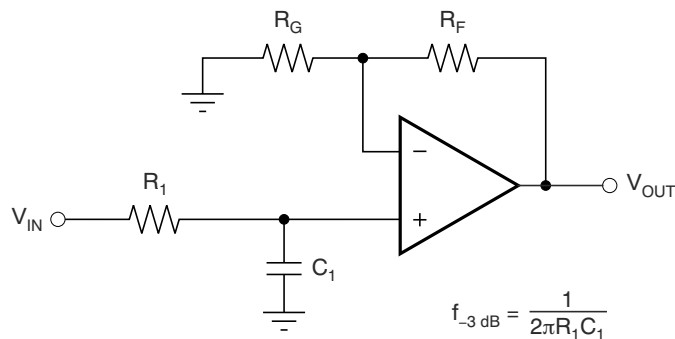
TLV935x-Q1 具有独特的特性，例如电源轨的差分输入电压范围、高输出电流 (±60mA) 以及高压摆率 (20V/μs)，是一款稳定可靠的运算放大器，适用于高电压成本敏感型应用。

TLV935x-Q1 系列运算放大器采用标准封装，额定工作温度范围为 -40°C 至 125°C。

器件信息

器件型号 ⁽¹⁾	封装	封装尺寸 (标称值)
TLV9351-Q1	SOT-23 (5)	2.90mm × 1.60mm
TLV9352-Q1	SOIC (8)	4.90mm × 3.90mm
	VSSOP (8)	3.00mm × 3.00mm
TLV9354-Q1	SOIC (14)	8.65mm × 3.90mm
	SOT-23 (14)	4.20mm × 1.90mm
	TSSOP (14)	5.00mm × 4.40mm

(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。



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

单极低通滤波器中的 TLV935x-Q1



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4 Revision History

注：以前版本的页码可能与当前版本的页码不同

Changes from Revision B (May 2021) to Revision C (September 2021)	Page
• 删除了整个数据表中 SOIC (14) 封装的预发布说明.....	1
• 删除了整个数据表中 SOT-23 (14) 封装的预发布说明.....	1
• 删除了整个数据表中 SOIC (8) 封装的预发布说明.....	1
• 删除了整个数据表中 SOT-23 (5) 封装的预发布说明.....	1
Changes from Revision A (March 2021) to Revision B (May 2021)	Page
• 删除了整个数据表中 TSSOP (14) 封装的预发布说明.....	1
• Deleted preview note from PW package in Thermal Information for Quad Channel table.....	7
Changes from Revision * (January 2021) to Revision A (March 2021)	Page
• 将器件状态从 <i>预告信息</i> 更改为 <i>量产数据</i>	1

5 Pin Configuration and Functions

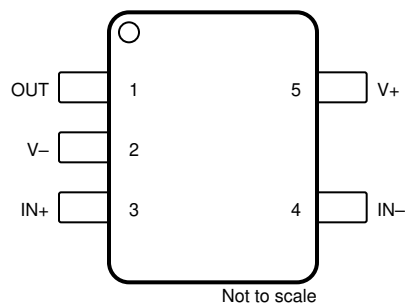


图 5-1. TLV9351-Q1 DBV Package
5-Pin SOT-23
Top View

表 5-1. Pin Functions: TLV9351-Q1

PIN		I/O	DESCRIPTION
NAME	NO.		
IN+	3	I	Noninverting input
IN -	4	I	Inverting input
OUT	1	O	Output
V+	5	—	Positive (highest) power supply
V -	2	—	Negative (lowest) power supply

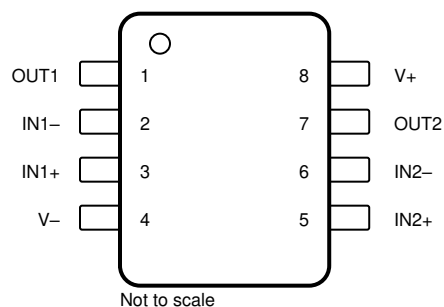


**图 5-2. TLV9352-Q1 D and DGK Package
8-Pin SOIC and VSSOP
Top View**

表 5-2. Pin Functions: TLV9352-Q1

PIN		I/O	DESCRIPTION
NAME	NO.		
IN1+	3	I	Noninverting input, channel 1
IN2+	5	I	Noninverting input, channel 1
IN1 -	2	I	Inverting input, channel 1
IN2 -	6	I	Inverting input, channel 2
OUT1	1	O	Output, channel 1
OUT2	7	O	Output, channel 2
V+	8	—	Positive (highest) power supply
V -	4	—	Negative (lowest) power supply

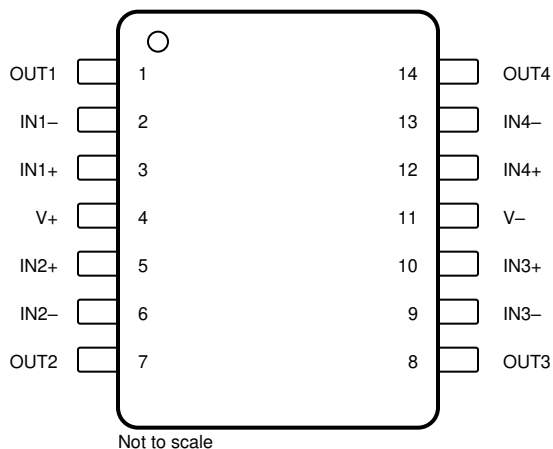


**图 5-3. TLV9354-Q1 D, DYY, and PW Package
14-Pin SOIC, SOT-23, and TSSOP
Top View**

表 5-3. Pin Functions: TLV9354-Q1

PIN		I/O	DESCRIPTION
NAME	NO.		
IN1+	3	I	Noninverting input, channel 1
IN2+	5	I	Noninverting input, channel 2
IN3+	10	I	Noninverting input, channel 3
IN4+	12	I	Noninverting input, channel 4
IN1 -	2	I	Inverting input, channel 1
IN2 -	6	I	Inverting input, channel 2
IN3 -	9	I	Inverting input, channel 3
IN4 -	13	I	Inverting 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+	4	—	Positive (highest) power supply
V -	11	—	Negative (lowest) power supply

6 Specifications

6.1 Absolute Maximum Ratings

over operating ambient temperature range (unless otherwise noted) ⁽¹⁾

		MIN	MAX	UNIT
Supply voltage, $V_S = (V+) - (V-)$		0	42	V
Signal input pins	Common-mode voltage ⁽³⁾	$(V-) - 0.5$	$(V+) + 0.5$	V
	Differential voltage ⁽³⁾		$V_S + 0.2$	V
	Current ⁽³⁾	- 10	10	mA
Output short-circuit ⁽²⁾		Continuous		
Operating ambient temperature, T_A		- 55	150	°C
Junction temperature, T_J			150	°C
Storage temperature, T_{slg}		- 65	150	°C

- (1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) Short-circuit to ground, one amplifier per package.
- (3) 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.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per AEC Q100-002 ⁽¹⁾	±2000	V
		Charged-device model (CDM), per AEC Q100-011	±1000	

- (1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification.

6.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_S	Supply voltage, $(V+) - (V-)$	4.5	40	V
V_I	Input voltage range	$(V-) - 0.1$	$(V+) - 2$	V
T_A	Specified ambient temperature	- 40	125	°C

6.4 Thermal Information for Single Channel

THERMAL METRIC ⁽¹⁾		TLV9351-Q1	UNIT
		DBV (SOT-23)	
		5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	187.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	86.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	54.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	27.8	°C/W
ψ_{JB}	Junction-to-board characterization parameter	54.3	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

- (1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

6.5 Thermal Information for Dual Channel

THERMAL METRIC ⁽¹⁾		TLV9352-Q1		UNIT
		D (SOIC)	DGK (VSSOP)	
		8 PINS	8 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	132.6	176.5	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	73.4	68.1	°C/W
R _{θJB}	Junction-to-board thermal resistance	76.1	98.2	°C/W
ψ _{JT}	Junction-to-top characterization parameter	24.0	12.0	°C/W
ψ _{JB}	Junction-to-board characterization parameter	75.4	96.7	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

6.6 Thermal Information for Quad Channel

THERMAL METRIC ⁽¹⁾		TLV9354-Q1			UNIT
		D (SOIC)	DYY (SOT-23)	PW (TSSOP)	
		14 PINS	14 PINS	14 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	101.4	110.7	118	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	57.6	55.9	47.6	°C/W
R _{θJB}	Junction-to-board thermal resistance	57.3	35.3	60.9	°C/W
ψ _{JT}	Junction-to-top characterization parameter	18.5	2.3	6	°C/W
ψ _{JB}	Junction-to-board characterization parameter	56.9	35.1	60.4	°C/W
R _{θJC(bot)}	Junction-to-case (bottom) thermal resistance	N/A	N/A	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application report, [SPRA953](#).

6.7 Electrical Characteristics

For $V_S = (V^+) - (V^-) = 4.5 \text{ V to } 40 \text{ V}$ ($\pm 2.25 \text{ V to } \pm 20 \text{ V}$) at $T_A = 25^\circ\text{C}$, $R_L = 10 \text{ k}\Omega$ connected to $V_S / 2$, $V_{CM} = V_S / 2$, and $V_{OUT} = V_S / 2$, unless otherwise noted.

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OFFSET VOLTAGE							
V _{OS}	Input offset voltage	V _{CM} = V -		±0.35		±1.8	mV
			T _A = - 40°C to 125°C			±2	
dV _{OS} /dT	Input offset voltage drift		T _A = - 40°C to 125°C		±1.5		µV/°C
PSRR	Input offset voltage versus power supply	V _{CM} = V -	T _A = - 40°C to 125°C		±2	±5	µ V/V
	Channel separation	f = 0 Hz			5		µV/V
INPUT BIAS CURRENT							
I _B	Input bias current				±10		pA
I _{OS}	Input offset current				±10		pA
NOISE							
E _N	Input voltage noise	f = 0.1 Hz to 10 Hz		2			µ V _{PP}
				0.33			µV _{RMS}
e _N	Input voltage noise density	f = 1 kHz		15			nV/ √ Hz
		f = 10 kHz		14			
i _N	Input current noise	f = 1 kHz		2			fA/ √ Hz
INPUT VOLTAGE RANGE							
V _{CM}	Common-mode voltage range			(V -) - 0.2		(V+) - 2	V
CMRR	Common-mode rejection ratio	V _S = 40 V, (V -) - 0.1 V < V _{CM} < (V+) - 2 V (Main input pair)	T _A = - 40°C to 125°C	95	110		dB
		V _S = 4.5 V, (V -) - 0.1 V < V _{CM} < (V+) - 2 V (Main input pair)		82	90		
INPUT CAPACITANCE							
Z _{ID}	Differential				100 3		M Ω pF
Z _{ICM}	Common-mode				6 1		T Ω pF
OPEN-LOOP GAIN							
A _{OL}	Open-loop voltage gain	V _S = 40 V, V _{CM} = V - (V -) + 0.1 V < V _O < (V+) - 0.1 V		120	130		dB
			T _A = - 40°C to 125°C		127		

6.7 Electrical Characteristics (continued)

For $V_S = (V_+ - (V_-)) = 4.5\text{ V to }40\text{ V}$ ($\pm 2.25\text{ V to } \pm 20\text{ V}$) at $T_A = 25^\circ\text{C}$, $R_L = 10\text{ k}\Omega$ connected to $V_S / 2$, $V_{CM} = V_S / 2$, and $V_{OUT} = V_S / 2$, unless otherwise noted.

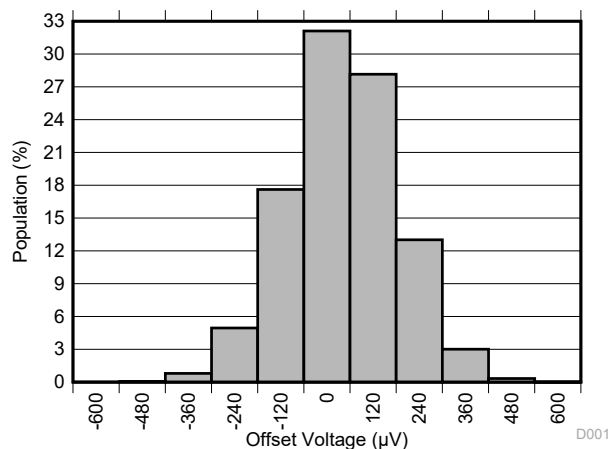
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product			3.5		MHz
SR	Slew rate	$V_S = 40\text{ V}$, $G = +1$, $C_L = 20\text{ pF}$		20		V/ $\mu\text{ s}$
t_S	Settling time	To 0.01%, $V_S = 40\text{ V}$, $V_{STEP} = 10\text{ V}$, $G = +1$, $C_L = 20\text{ pF}$		5		$\mu\text{ s}$
		To 0.01%, $V_S = 40\text{ V}$, $V_{STEP} = 2\text{ V}$, $G = +1$, $C_L = 20\text{ pF}$		4		
		To 0.1%, $V_S = 40\text{ V}$, $V_{STEP} = 10\text{ V}$, $G = +1$, $C_L = 20\text{ pF}$		4		
		To 0.1%, $V_S = 40\text{ V}$, $V_{STEP} = 2\text{ V}$, $G = +1$, $C_L = 20\text{ pF}$		3		
	Phase margin	$G = +1$, $R_L = 10\text{ k}\Omega$		60		°
	Overload recovery time	$V_{IN} \times \text{gain} > V_S$		600		ns
THD+N	Total harmonic distortion + noise ⁽¹⁾	$V_S = 40\text{ V}$, $V_O = 1\text{ V}_{RMS}$, $G = 1$, $f = 1\text{ kHz}$		0.001%		
OUTPUT						
	Voltage output swing from rail	Positive and negative rail headroom	$V_S = 40\text{ V}$, $R_L = \text{no load}$ ⁽²⁾	5	10	mV
			$V_S = 40\text{ V}$, $R_L = 10\text{ k}\Omega$	50	55	
			$V_S = 40\text{ V}$, $R_L = 2\text{ k}\Omega$	200	250	
			$V_S = 4.5\text{ V}$, $R_L = \text{no load}$ ⁽²⁾	1		
			$V_S = 4.5\text{ V}$, $R_L = 10\text{ k}\Omega$	20	30	
			$V_S = 4.5\text{ V}$, $R_L = 2\text{ k}\Omega$	40	75	
I_{SC}	Short-circuit current			± 60		mA
C_{LOAD}	Capacitive load drive			300		pF
Z_O	Open-loop output impedance	$f = 1\text{ MHz}$, $I_O = 0\text{ A}$		600		Ω
POWER SUPPLY						
I_Q	Quiescent current per amplifier	$V_{CM} = V_-$, $I_O = 0\text{ A}$		650	800	μA
			$T_A = -40^\circ\text{C to }125^\circ\text{C}$		850	

(1) Third-order filter; bandwidth = 80 kHz at -3 dB.

(2) Specified by characterization only.

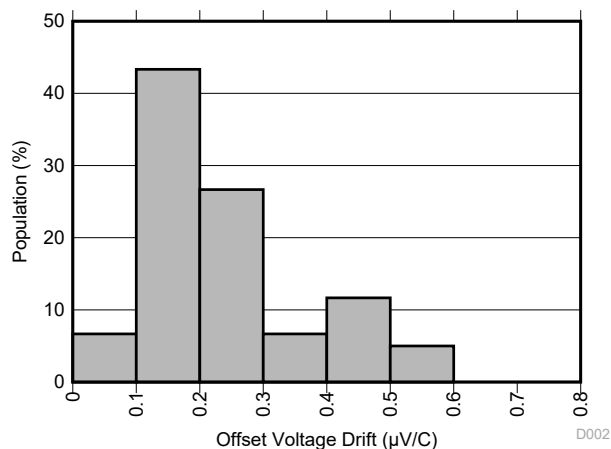
6.8 Typical Characteristics

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)



Distribution from 15462 amplifiers, $T_A = 25^\circ\text{C}$

图 6-1. Offset Voltage Production Distribution



Distribution from 60 amplifiers

图 6-2. Offset Voltage Drift Distribution

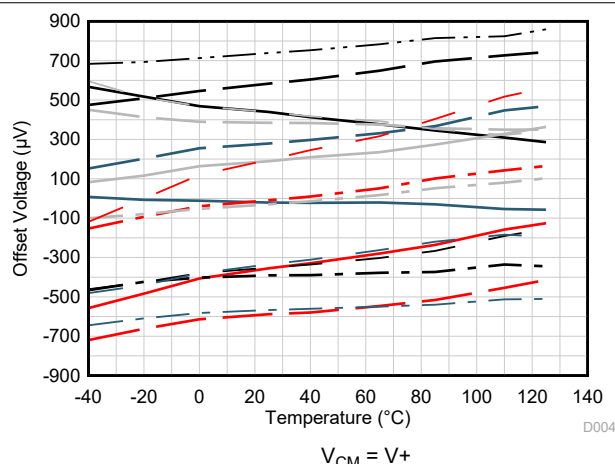


图 6-3. Offset Voltage vs Temperature

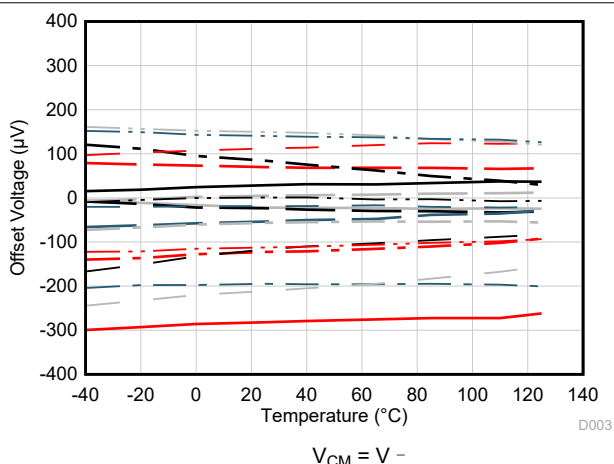


图 6-4. Offset Voltage vs Temperature

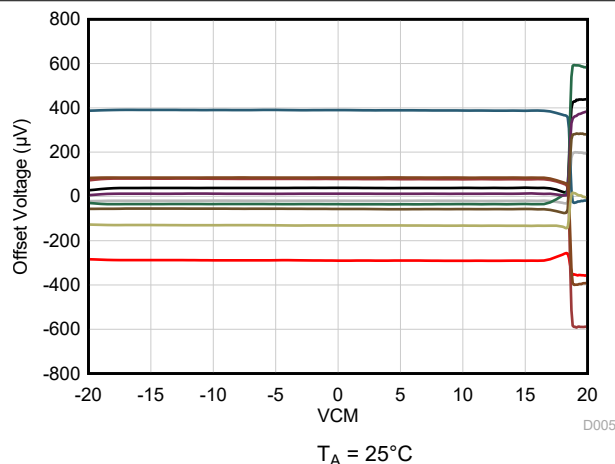


图 6-5. Offset Voltage vs Common-Mode Voltage

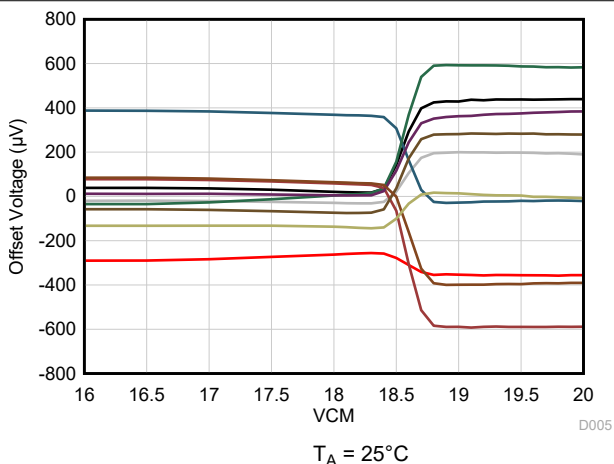


图 6-6. Offset Voltage vs Common-Mode Voltage (Transition Region)

6.8 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)

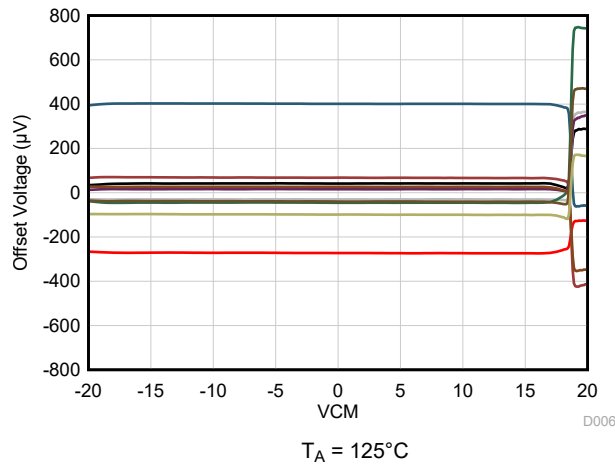


图 6-7. Offset Voltage vs Common-Mode Voltage

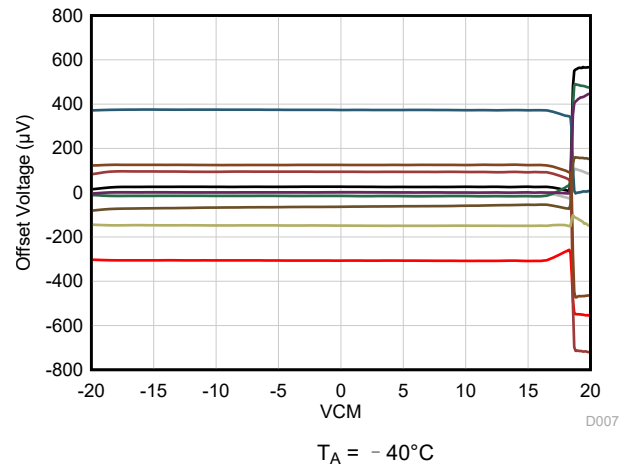


图 6-8. Offset Voltage vs Common-Mode Voltage

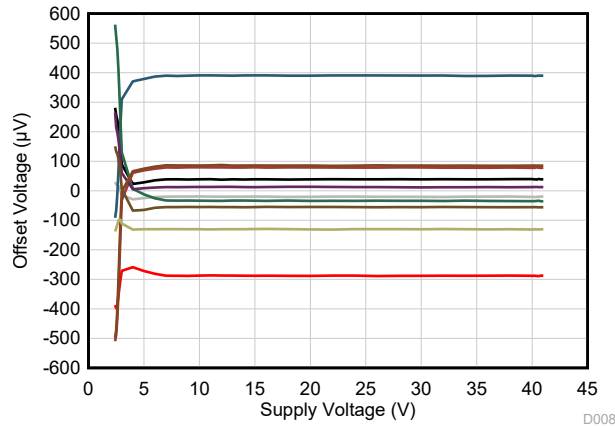


图 6-9. Offset Voltage vs Power Supply

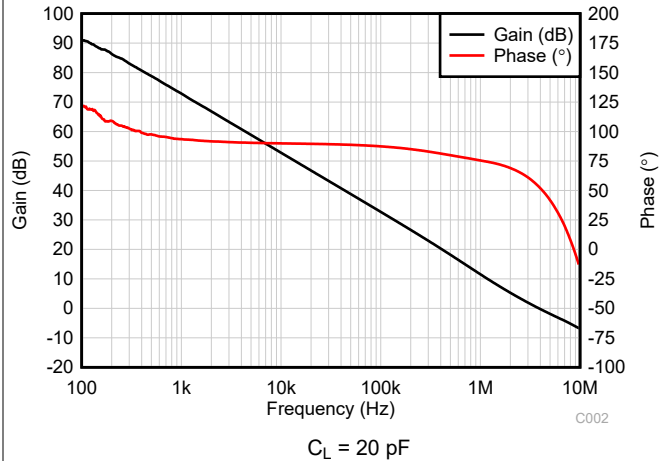


图 6-10. Open-Loop Gain and Phase vs Frequency

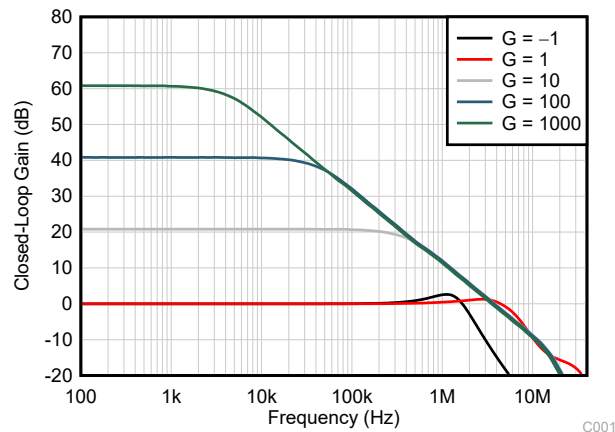


图 6-11. Closed-Loop Gain vs Frequency

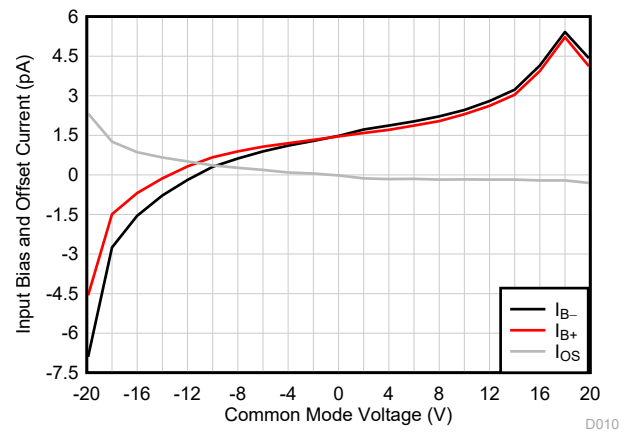


图 6-12. Input Bias Current vs Common-Mode Voltage

6.8 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)

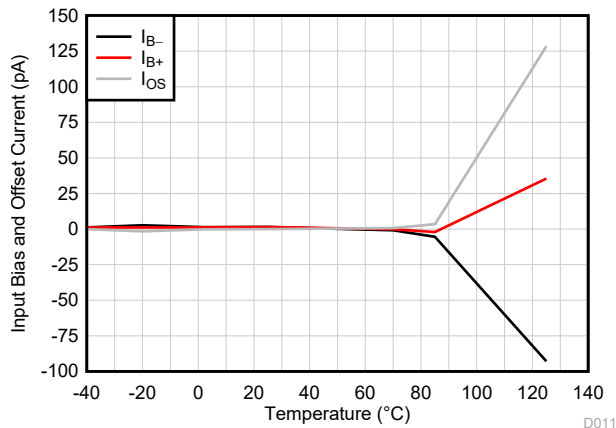


图 6-13. Input Bias Current vs Temperature

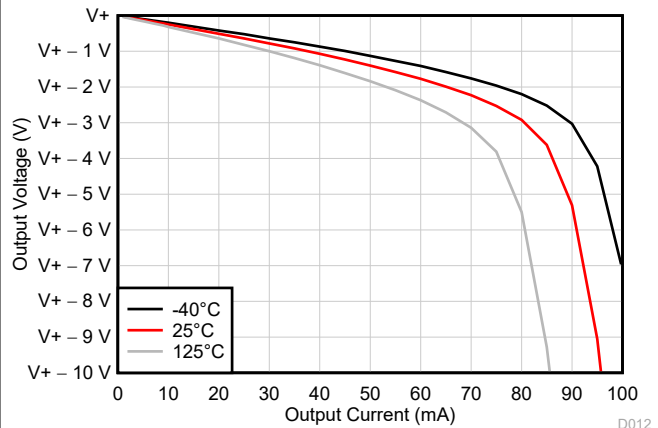


图 6-14. Output Voltage Swing vs Output Current (Sourcing)

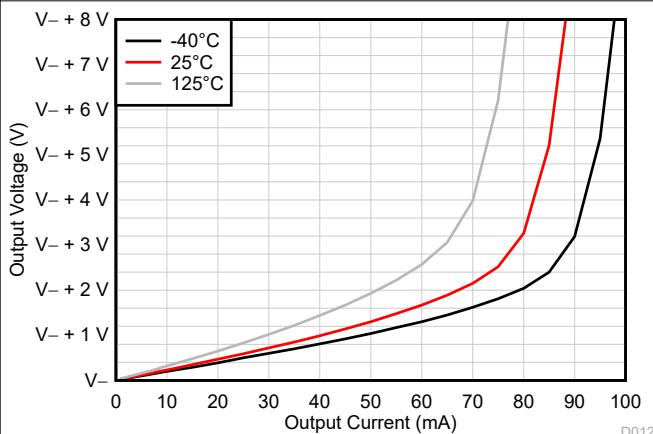


图 6-15. Output Voltage Swing vs Output Current (Sinking)

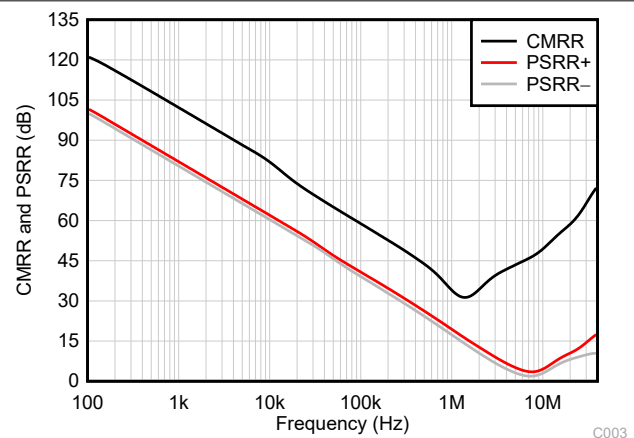


图 6-16. CMRR and PSRR vs Frequency

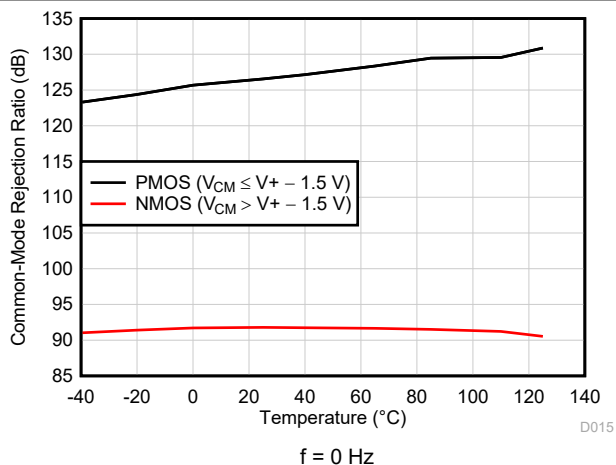


图 6-17. CMRR vs Temperature (dB)

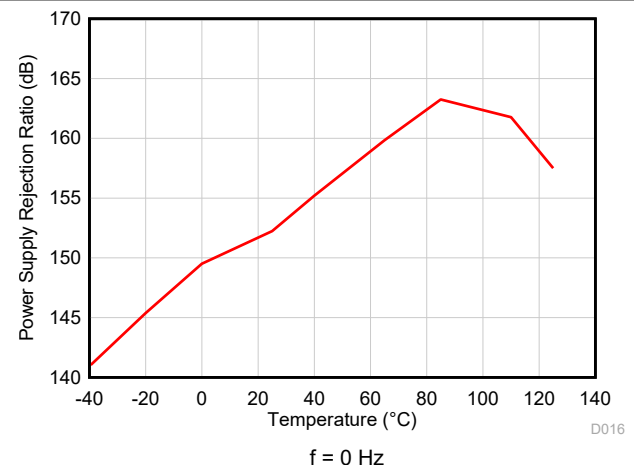


图 6-18. PSRR vs Temperature (dB)

6.8 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)

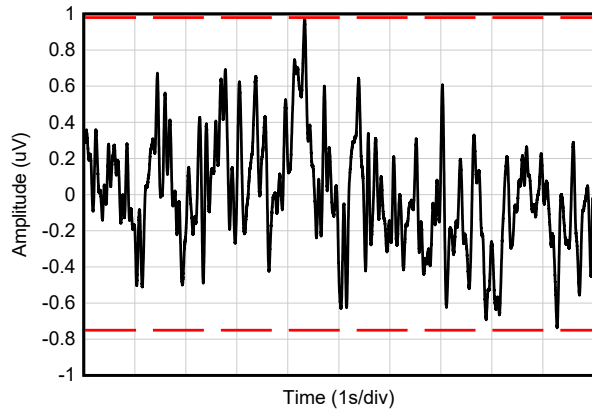


图 6-19. 0.1-Hz to 10-Hz Noise

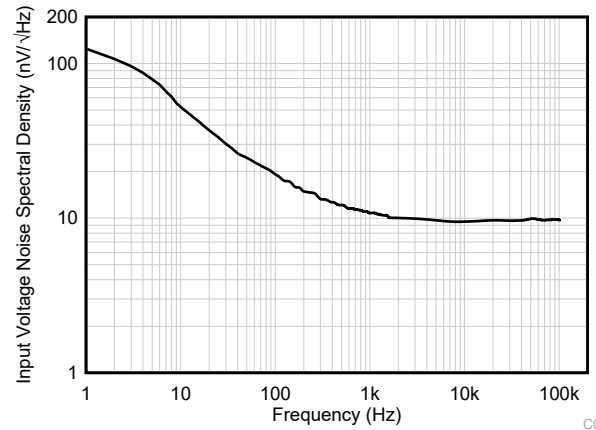


图 6-20. Input Voltage Noise Spectral Density vs Frequency

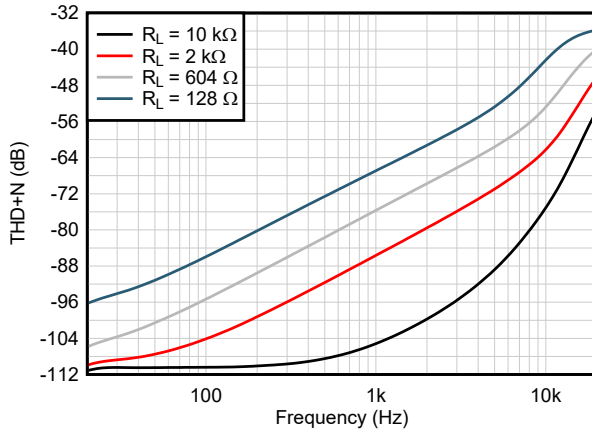


图 6-21. THD+N Ratio vs Frequency

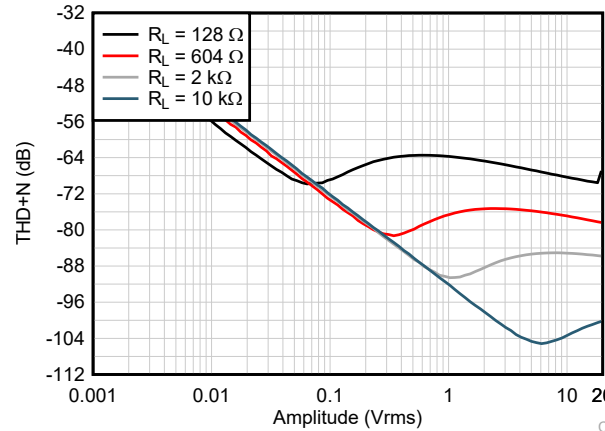


图 6-22. THD+N vs Output Amplitude

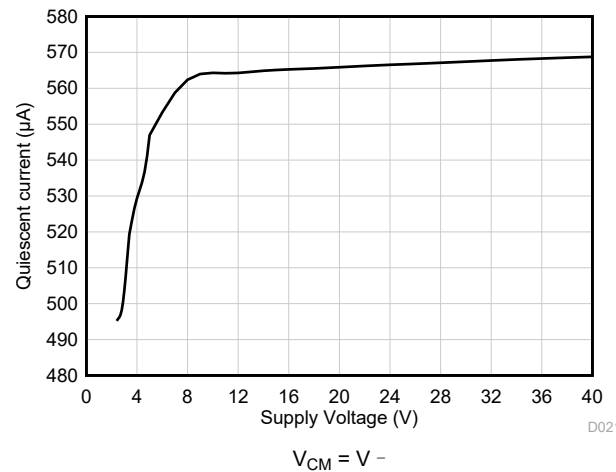


图 6-23. Quiescent Current vs Supply Voltage

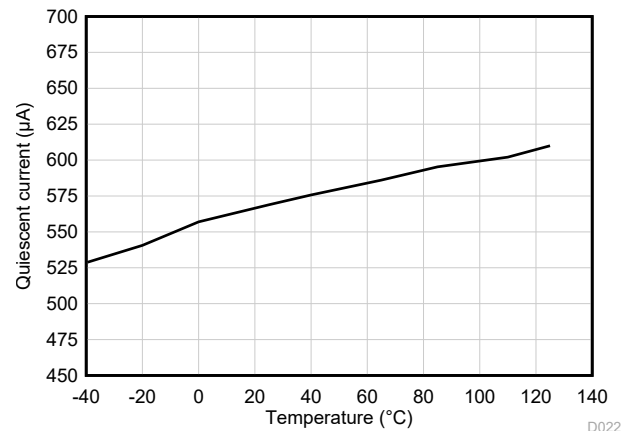


图 6-24. Quiescent Current vs Temperature

6.8 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)

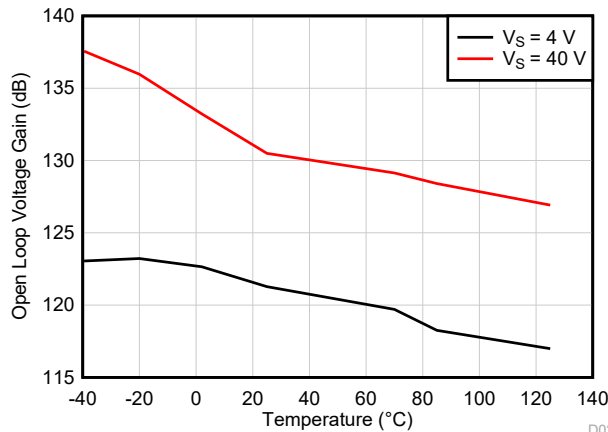


图 6-25. Open-Loop Voltage Gain vs Temperature (dB)

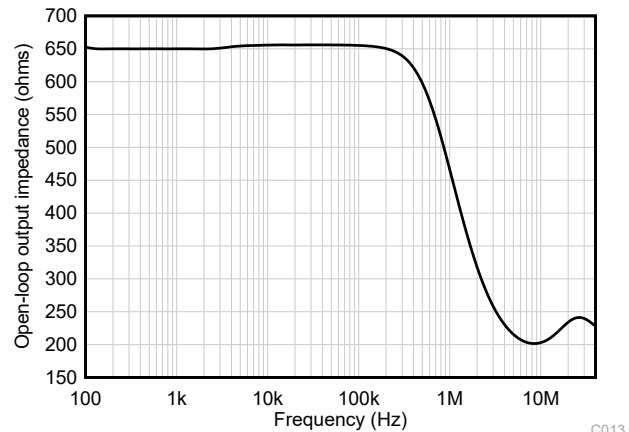
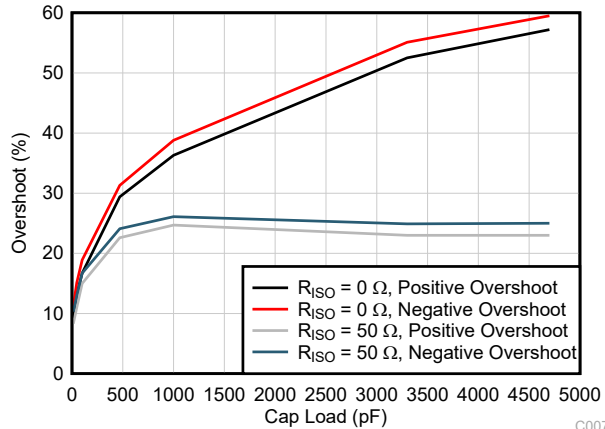
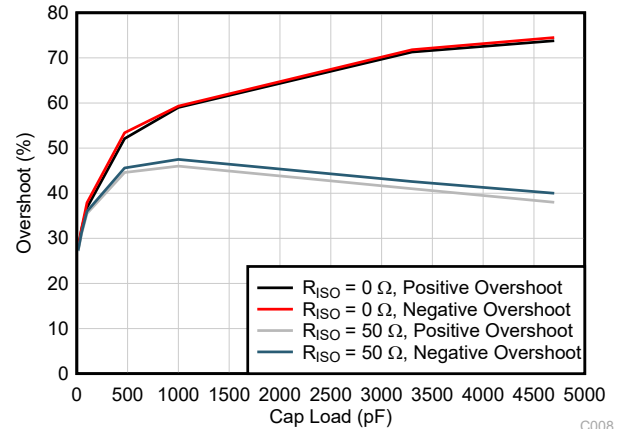


图 6-26. Open-Loop Output Impedance vs Frequency



$G = -1$, 10-mV output step

图 6-27. Small-Signal Overshoot vs Capacitive Load



$G = 1$, 10-mV output step

图 6-28. Small-Signal Overshoot vs Capacitive Load

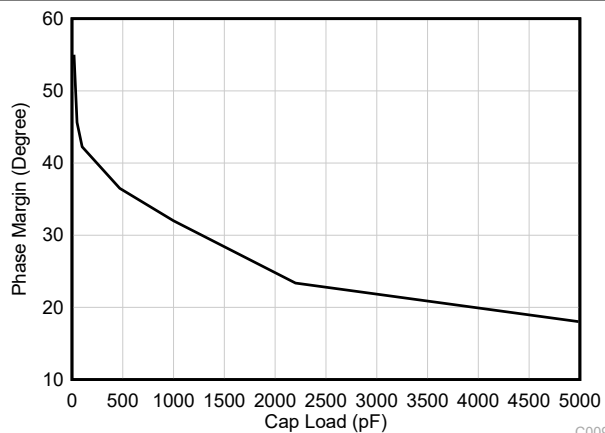
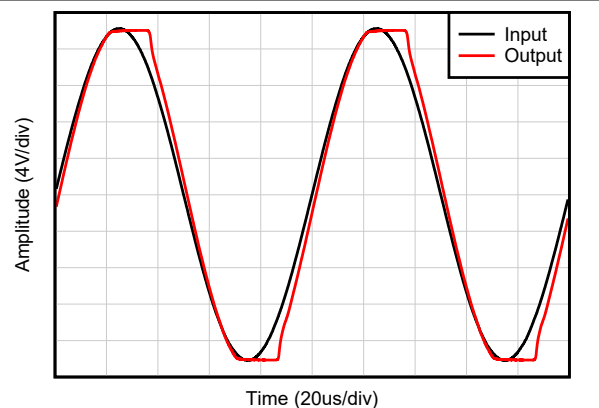


图 6-29. Phase Margin vs Capacitive Load

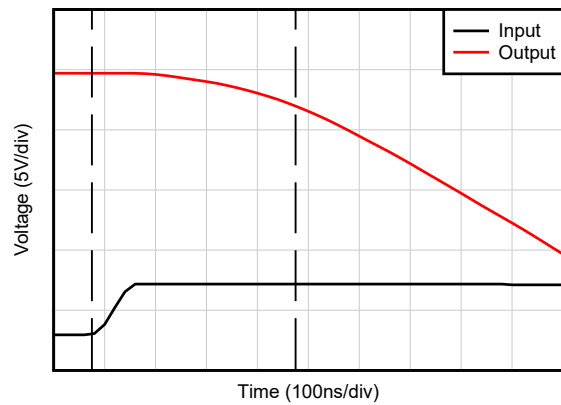


$V_{IN} = \pm 20\text{ V}$; $V_S = V_{OUT} = \pm 17\text{ V}$

图 6-30. No Phase Reversal

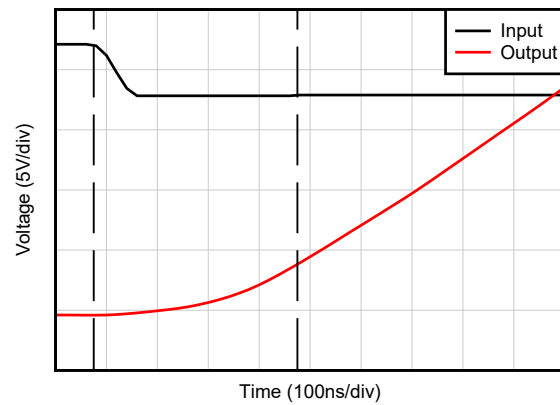
6.8 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)



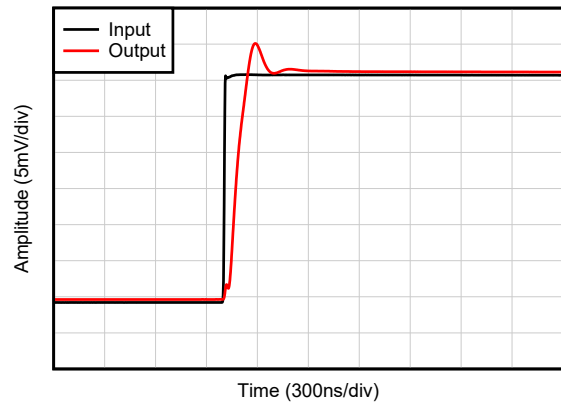
$G = -10$

图 6-31. Positive Overload Recovery



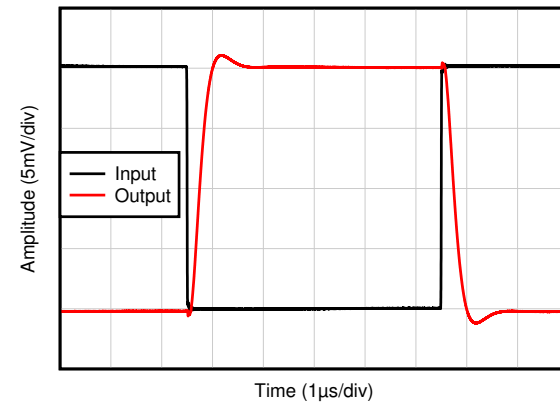
$G = -10$

图 6-32. Negative Overload Recovery



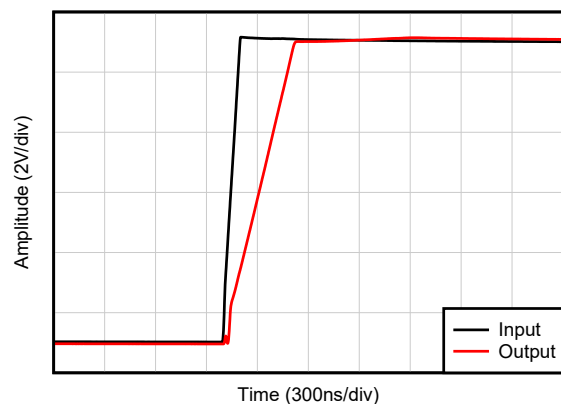
$C_L = 20\text{ pF}$, $G = 1$, 20-mV step response

图 6-33. Small-Signal Step Response, Rising



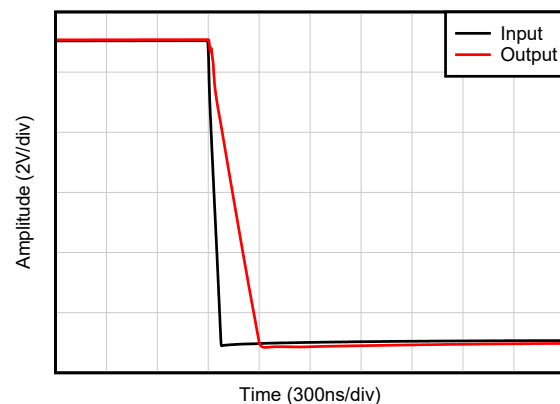
$C_L = 20\text{ pF}$, $G = -1$, 20-mV step response

图 6-34. Small-Signal Step Response



$C_L = 20\text{ pF}$, $G = 1$

图 6-35. Large-Signal Step Response (Rising)

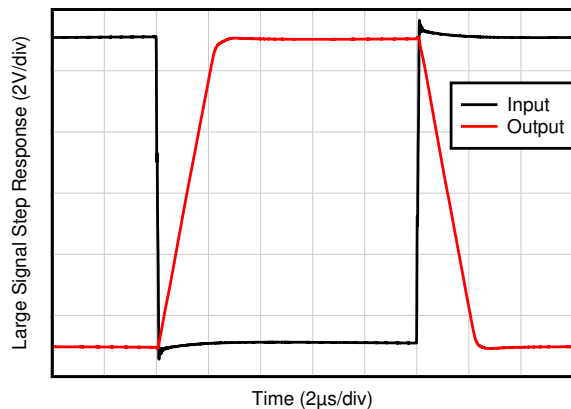


$C_L = 20\text{ pF}$, $G = 1$

图 6-36. Large-Signal Step Response (Falling)

6.8 Typical Characteristics (continued)

at $T_A = 25^\circ\text{C}$, $V_S = \pm 20\text{ V}$, $V_{CM} = V_S / 2$, $R_{LOAD} = 10\text{ k}\Omega$ connected to $V_S / 2$, and $C_L = 10\text{ pF}$ (unless otherwise noted)



$C_L = 20\text{ pF}$, $G = -1$

图 6-37. Large-Signal Step Response

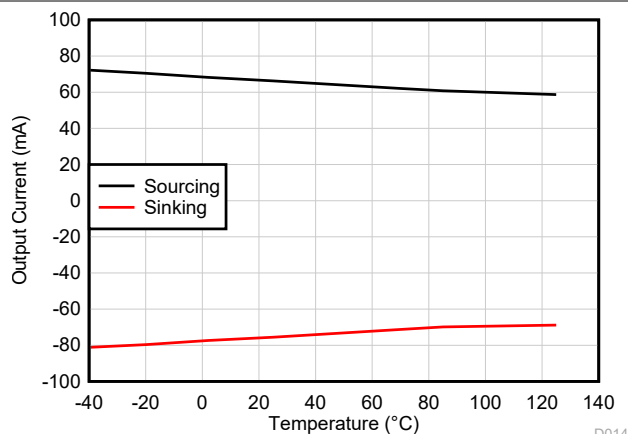


图 6-38. Short-Circuit Current vs Temperature

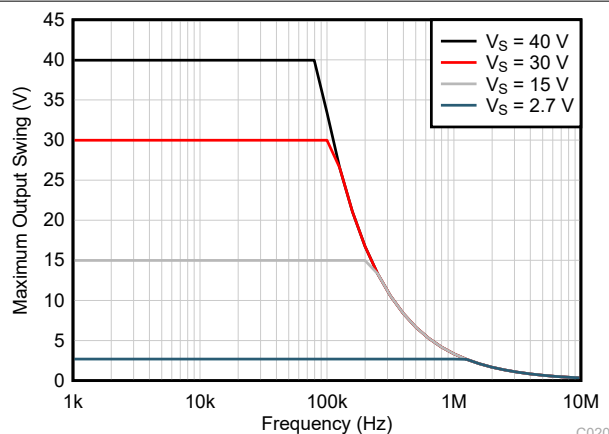


图 6-39. Maximum Output Voltage vs Frequency

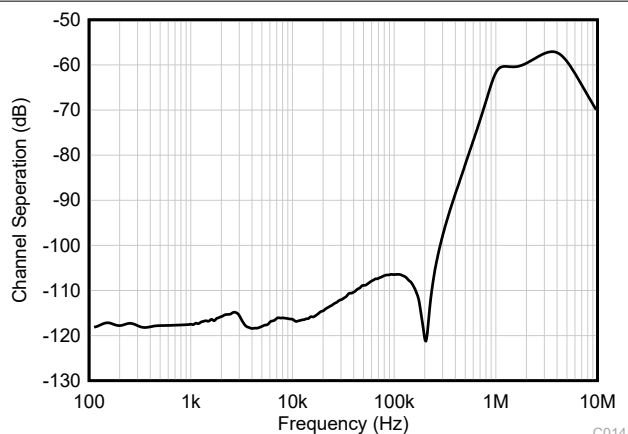


图 6-40. Channel Separation vs Frequency

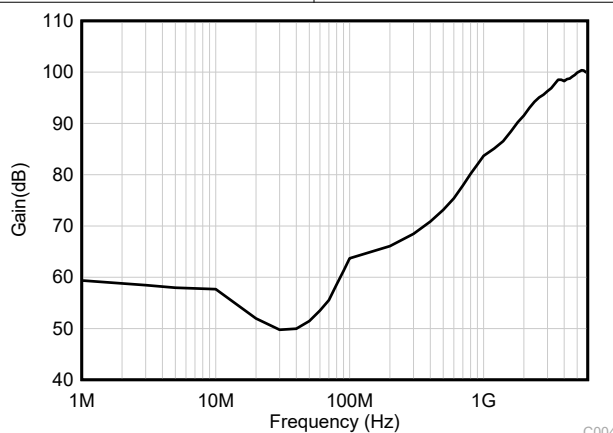


图 6-41. EMIRR (Electromagnetic Interference Rejection Ratio) at Inputs vs Frequency

7 Detailed Description

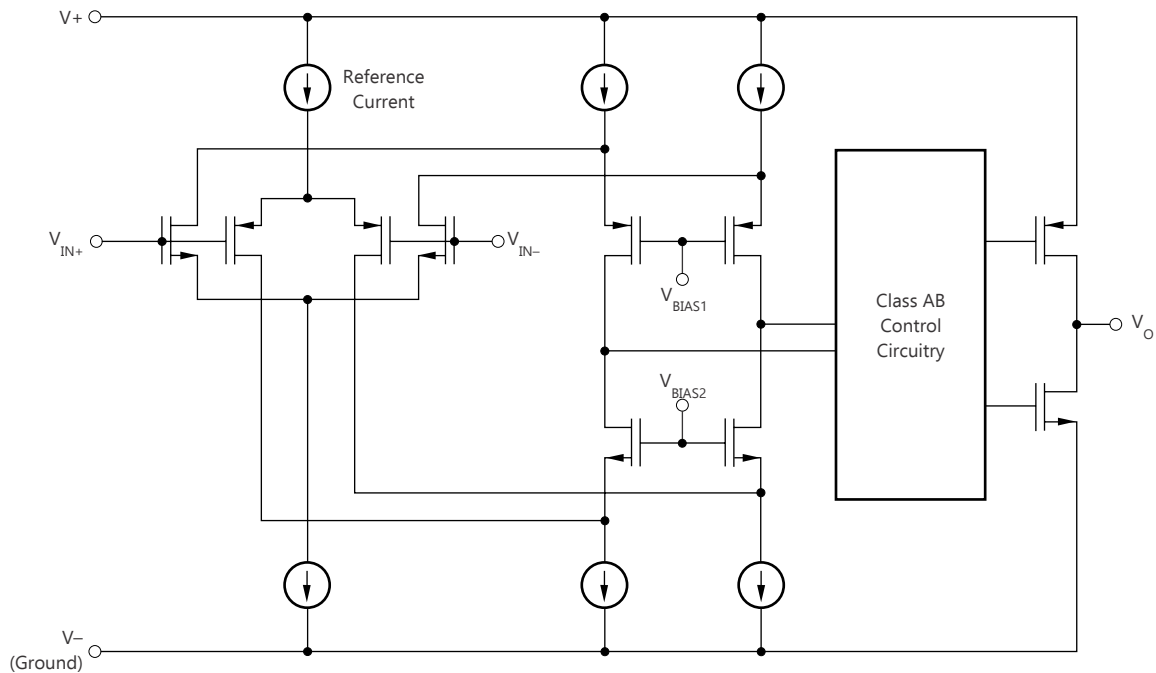
7.1 Overview

The TLV935x-Q1 family (TLV9351-Q1, TLV9352-Q1, and TLV9354-Q1) is a family of 40-V, cost-optimized automotive operational amplifiers. These devices offer strong general-purpose DC and AC specifications, including rail-to-rail output, low offset ($\pm 350 \mu\text{V}$, typ), low offset drift ($\pm 1.5 \mu\text{V}/^\circ\text{C}$, typ), and 3.5-MHz bandwidth.

Convenient features such as wide differential input-voltage range, high output current ($\pm 60 \text{ mA}$), and high slew rate ($20 \text{ V}/\mu\text{s}$) make the TLV935x-Q1 a robust operational amplifier for high-voltage, cost-sensitive applications.

The TLV935x-Q1 family of op amps is available in standard packages and is specified from -40°C to 125°C .

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Input Protection Circuitry

The TLV935x-Q1 uses a patented input architecture to eliminate the requirement for input protection diodes but still provides robust input protection under transient conditions. 图 7-1 shows conventional input diode protection schemes that are activated by fast transient step responses and introduce signal distortion and settling time delays because of alternate current paths, as shown in 图 7-2. For low-gain circuits, these fast-ramping input signals forward-bias back-to-back diodes, causing an increase in input current and resulting in extended settling time.

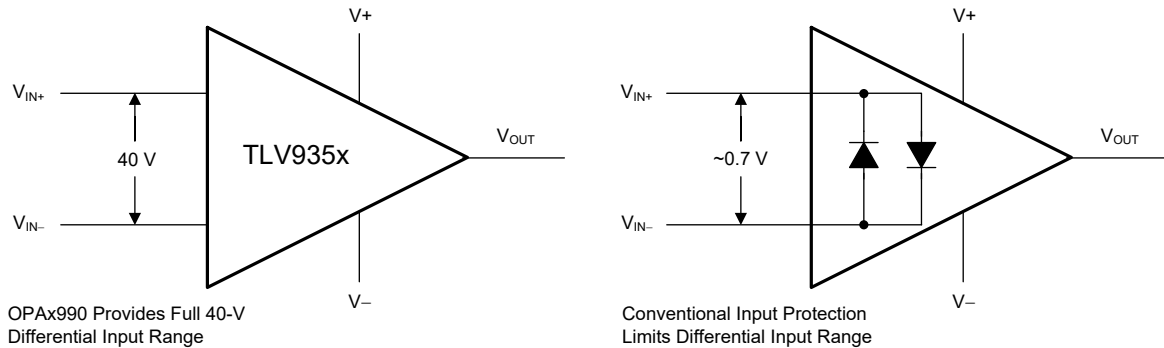


图 7-1. TLV935x-Q1 Input Protection Does Not Limit Differential Input Capability

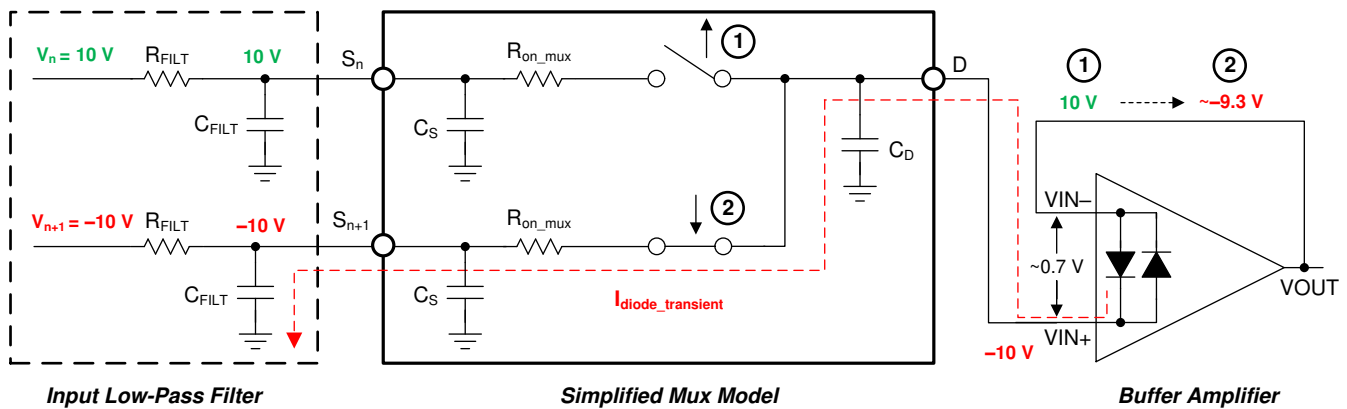


图 7-2. Back-to-Back Diodes Create Settling Issues

The TLV935x-Q1 family of operational amplifiers provides a true high-impedance differential input capability for high-voltage applications. This patented input protection architecture does not introduce additional signal distortion or delayed settling time, making the device an optimal op amp for multichannel, high-switched, input applications. The TLV935x-Q1 tolerates a maximum differential swing (voltage between inverting and noninverting pins of the op amp) of up to 40 V, making the device suitable for use as a comparator or in applications with fast-ramping input signals.

7.3.2 EMI Rejection

The TLV935x-Q1 uses integrated electromagnetic interference (EMI) filtering to reduce the effects of EMI from sources such as wireless communications and densely-populated boards with a mix of analog signal chain and digital components. EMI immunity can be improved with circuit design techniques; the TLV935x-Q1 benefits from these design improvements. 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. 图 7-3 shows the results of this testing on the TLV935x-Q1. 表 7-1 shows the EMIRR IN+ values for the TLV935x-Q1 at particular frequencies commonly encountered in real-world applications. 表 7-1 lists applications that may be centered on or operated near the particular frequency shown. The *EMI Rejection Ratio of Operational Amplifiers* (SBOA128) application report contains detailed information on the topic of EMIRR performance as it relates to op amps and is available for download from www.ti.com.

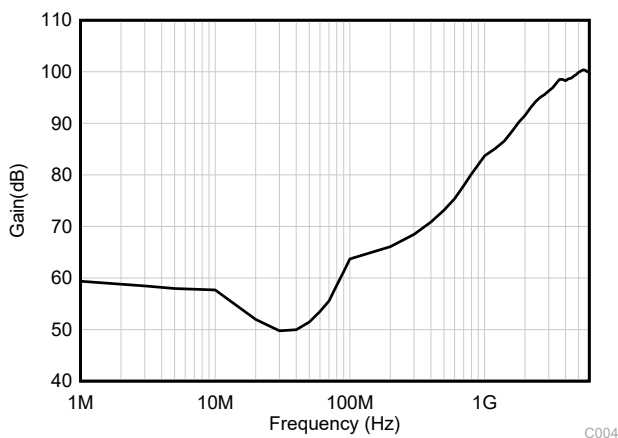


图 7-3. EMIRR Testing

表 7-1. TLV935x-Q1 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION OR ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite, space operation, weather, radar, ultra-high frequency (UHF) applications	71 dB
900 MHz	Global system for mobile communications (GSM) applications, radio communication, navigation, GPS (to 1.6 GHz), GSM, aeronautical mobile, UHF applications	80 dB
1.8 GHz	GSM applications, mobile personal communications, broadband, satellite, L-band (1 GHz to 2 GHz)	87 dB
2.4 GHz	802.11b, 802.11g, 802.11n, Bluetooth®, mobile personal communications, industrial, scientific and medical (ISM) radio band, amateur radio and satellite, S-band (2 GHz to 4 GHz)	90 dB
3.6 GHz	Radiolocation, aero communication and navigation, satellite, mobile, S-band	92 dB
5 GHz	802.11a, 802.11n, aero communication and navigation, mobile communication, space and satellite operation, C-band (4 GHz to 8 GHz)	94 dB

7.3.3 Phase Reversal Protection

The TLV935x-Q1 family has internal phase-reversal protection. Many op amps exhibit a phase reversal when the input is driven beyond its linear common-mode range. This condition is most often encountered in noninverting circuits when the input is driven beyond the specified common-mode voltage range, causing the output to reverse into the opposite rail. The TLV935x-Q1 is a rail-to-rail input op amp; therefore, the common-mode range can extend up to the rails. Input signals beyond the rails do not cause phase reversal; instead, the output limits into the appropriate rail.

7.3.4 Thermal Protection

The internal power dissipation of any amplifier causes its internal (junction) temperature to rise. This phenomenon is called *self heating*. The absolute maximum junction temperature of the TLV935x-Q1 is 150°C. Exceeding this temperature causes damage to the device. The TLV935x-Q1 has a thermal protection feature that prevents damage from self heating. The protection works by monitoring the temperature of the device and turning off the op amp output drive for temperatures above 140°C. 图 7-4 shows an application example for the TLV9351-Q1 that has significant self heating (159°C) because of its power dissipation (0.81 W). Thermal calculations indicate that for an ambient temperature of 65°C the device junction temperature will reach 187°C. The actual device, however, turns off the output drive to maintain a safe junction temperature. 图 7-4 shows how the circuit behaves during thermal protection. During normal operation, the device acts as a buffer so the output is 3 V. When self heating causes the device junction temperature to increase above 140°C, the thermal protection forces the output to a high-impedance state and the output is pulled to ground through resistor R_L .

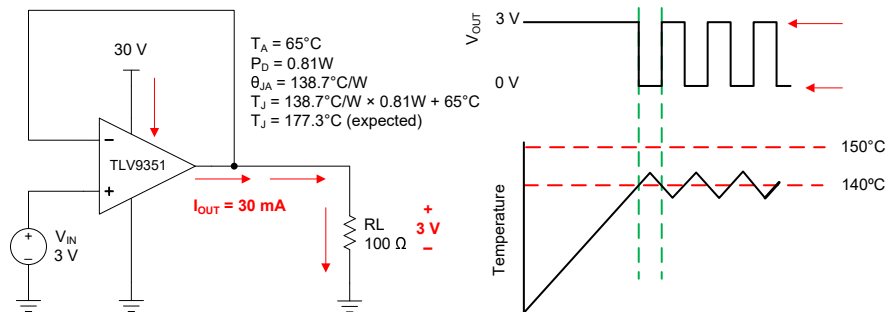


图 7-4. Thermal Protection

7.3.5 Capacitive Load and Stability

The TLV935x-Q1 features a resistive output stage capable of driving smaller capacitive loads, and by leveraging an isolation resistor, the device can easily be configured to drive large capacitive loads. Increasing the gain enhances the ability of the amplifier to drive greater capacitive loads; see 图 7-5 and 图 7-6. The particular op amp circuit configuration, layout, gain, and output loading are some of the factors to consider when establishing whether an amplifier is stable in operation.

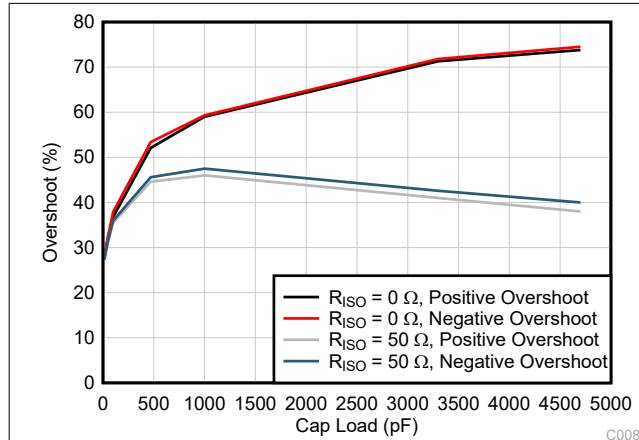


图 7-5. Small-Signal Overshoot vs Capacitive Load
(100-mV Output Step, $G = 1$)

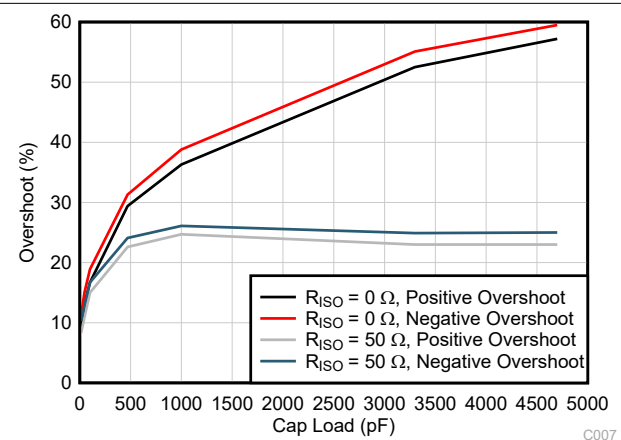


图 7-6. Small-Signal Overshoot vs Capacitive Load
(100-mV Output Step, $G = -1$)

For additional drive capability in unity-gain configurations, improve capacitive load drive by inserting a small ($10\ \Omega$ to $20\ \Omega$) resistor, R_{ISO} , in series with the output, as shown in 图 7-7. This resistor significantly reduces ringing and maintains DC performance for purely capacitive loads. However, if a resistive load is in parallel with the capacitive load, then a voltage divider is created, thus introducing a gain error at the output and slightly reducing the output swing. The error introduced is proportional to the ratio R_{ISO} / R_L , and is generally negligible at low output levels. A high capacitive load drive makes the TLV935x-Q1 well suited for applications such as reference buffers, MOSFET gate drives, and cable-shield drives. The circuit shown in 图 7-7 uses an isolation resistor, R_{ISO} , to stabilize the output of an op amp. R_{ISO} modifies the open-loop gain of the system for increased phase margin. For additional information on techniques to optimize and design using this circuit, TI Precision Design TIDU032 details complete design goals, simulation, and test results.

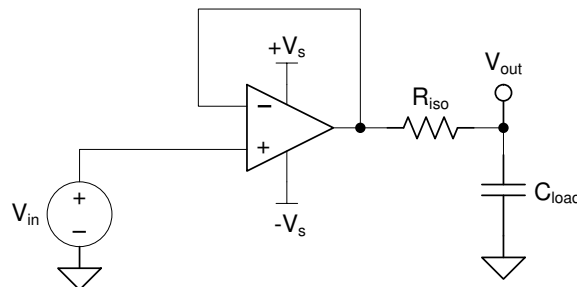


图 7-7. Extending Capacitive Load Drive With the TLV9351-Q1

7.3.6 Common-Mode Voltage Range

The TLV935x-Q1 is a 40-V, rail-to-rail output operational amplifier with an input common-mode range that extends 100 mV beyond V^- and within 2 V of V^+ for normal operation. The device accomplishes this performance through a complementary input stage, using a P-channel differential pair. Additionally, a complementary N-channel differential pair has been included in parallel with the P-channel pair to eliminate common undesirable op amp behaviors, such as phase reversal.

The TLV935x-Q1 can operate with common mode ranges beyond 100 mV of the top rail, but with reduced performance above $(V^+) - 2$ V. The N-channel pair is active for input voltages close to the positive rail, typically $(V^+) - 1$ V to 100 mV above the positive supply. The P-channel pair is active for inputs from 100 mV below the negative supply to approximately $(V^+) - 2$ V. There is a small transition region, typically $(V^+) - 2$ V to $(V^+) - 1$ V in which both input pairs are on. This transition region can vary modestly with process variation, and within the transition region and N-channel region, many specifications of the op amp, including PSRR, CMRR, offset voltage, offset drift, noise and THD performance may be degraded compared to operation within the P-channel region.

表 7-2. Typical Performance for Common-Mode Voltages Within 2 V of the Positive Supply

PARAMETER	MIN	TYP	MAX	UNIT
Input common-mode voltage	$(V^+) - 2$		$(V^+) + 0.1$	V
Offset voltage		1.5		mV
Offset voltage drift		2		$\mu\text{V}/^\circ\text{C}$
Common-mode rejection		75		dB
Open-loop gain		75		dB
Gain-bandwidth product		1.5		MHz

7.3.7 Electrical Overstress

Designers often ask questions about the capability of an operational amplifier to withstand electrical overstress (EOS). These questions tend to focus on the device inputs, but may involve the supply voltage pins or even the output pin. Each of these different pin functions have 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. 图 7-8 shows an illustration of the ESD circuits contained in the TLV935x-Q1 (indicated by the dashed line area). 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 the diodes meet at an absorption device or the power-supply ESD cell, internal to the operational amplifier. This protection circuitry is intended to remain inactive during normal circuit operation.

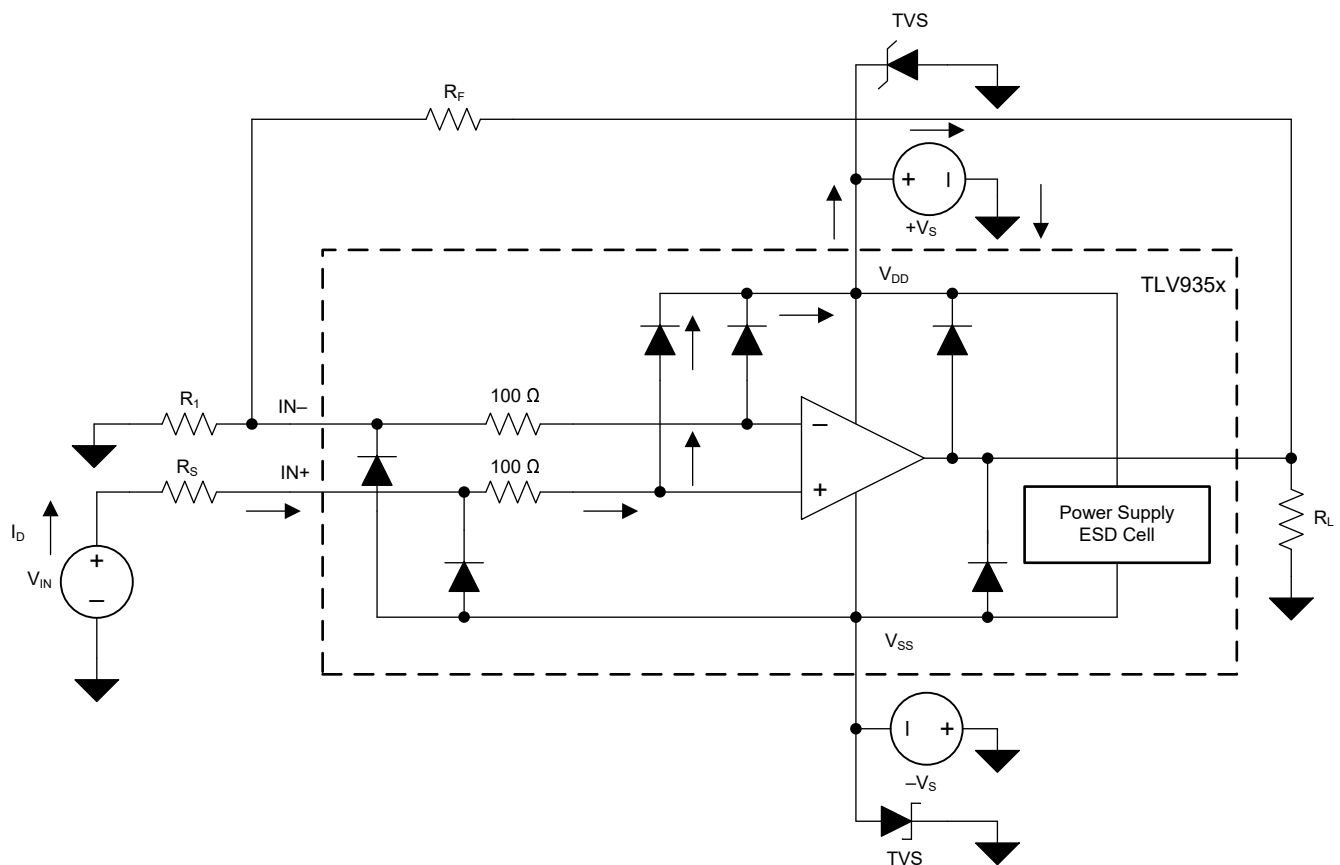


图 7-8. Equivalent Internal ESD Circuitry Relative to a Typical Circuit Application

An ESD event is very short in duration and very high voltage (for example, 1 kV, 100 ns), whereas an EOS event is long duration and lower voltage (for example, 50 V, 100 ms). The ESD diodes are designed for out-of-circuit ESD protection (that is, during assembly, test, and storage of the device before being soldered to the PCB). During an ESD event, the ESD signal is passed through the ESD steering diodes to an absorption circuit (labeled ESD power-supply circuit). The ESD absorption circuit clamps the supplies to a safe level.

Although this behavior is necessary for out-of-circuit protection, excessive current and damage is caused if activated in-circuit. A transient voltage suppressors (TVS) can be used to prevent against damage caused by turning on the ESD absorption circuit during an in-circuit ESD event. Using the appropriate current limiting resistors and TVS diodes allows for the use of device ESD diodes to protect against EOS events.

7.3.8 Overload Recovery

Overload recovery is defined as the time required for the op amp output to recover from a saturated state to a linear state. The output devices of the op amp enter a saturation region when the output voltage exceeds the rated operating voltage, either due to 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 back to the linear state. After the charge carriers return back to the linear state, the device begins to slew at the specified slew rate. Thus, 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 TLV935x-Q1 is approximately 600 ns.

7.3.9 Typical Specifications and Distributions

Designers often have questions about a typical specification of an amplifier in order to design a more robust circuit. Due to natural variation in process technology and manufacturing procedures, every specification of an amplifier will exhibit some amount of deviation from the ideal value, like an amplifier's input offset voltage. These deviations often follow *Gaussian* ("bell curve"), or *normal* distributions, and circuit designers can leverage this information to guardband their system, even when there is not a minimum or maximum specification in [节 6.7](#).

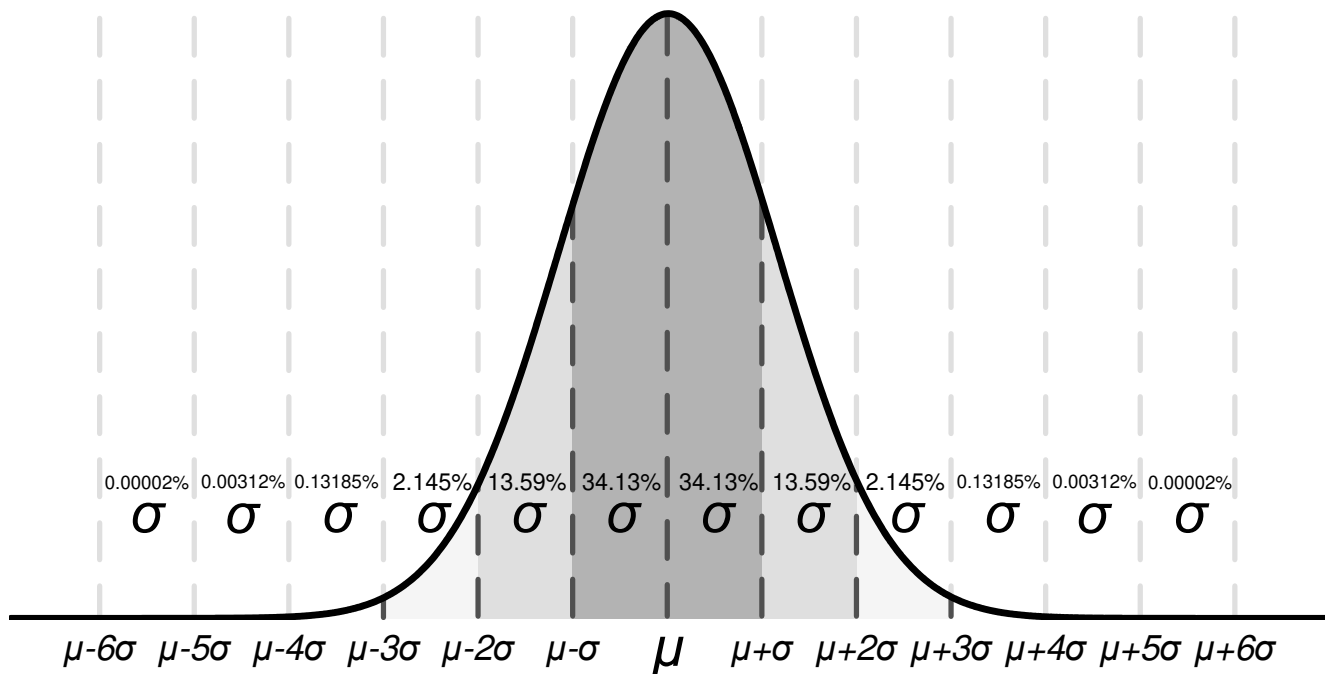


图 7-9. Ideal Gaussian Distribution

图 7-9 shows an example distribution, where μ , or *mu*, is the mean of the distribution, and where σ , or *sigma*, is the standard deviation of a system. For a specification that exhibits this kind of distribution, approximately two-thirds (68.26%) of all units can be expected to have a value within one standard deviation, or one sigma, of the mean (from $\mu - \sigma$ to $\mu + \sigma$).

Depending on the specification, values listed in the *typical* column of [节 6.7](#) are represented in different ways. As a general rule of thumb, if a specification naturally has a nonzero mean (for example, like gain bandwidth), then the typical value is equal to the mean (μ). However, if a specification naturally has a mean near zero (like input offset voltage), then the typical value is equal to the mean plus one standard deviation ($\mu + \sigma$) in order to most accurately represent the typical value.

You can use this chart to calculate approximate probability of a specification in a unit; for example, for TLV935x-Q1, the typical input voltage offset is 350 μ V, so 68.2% of all TLV935x-Q1 devices are expected to have an offset from -350 μ V to 350 μ V. At 4 σ (± 1400 μ V), 99.9937% of the distribution has an offset voltage less than ± 1400 μ V.

μV , which means 0.0063% of the population is outside of these limits, which corresponds to about 1 in 15,873 units.

Specifications with a value in the minimum or maximum column are assured by TI, and units outside these limits will be removed from production material. For example, the TLV935x-Q1 family has a maximum offset voltage of 1.8 mV at 125°C, and even though this corresponds to about 5 σ (≈ 1 in 1.7 million units), which is extremely unlikely, TI assures that any unit with larger offset than 1.8 mV will be removed from production material.

For specifications with no value in the minimum or maximum column, consider selecting a sigma value of sufficient guardband for your application, and design worst-case conditions using this value. For example, the 6- σ value corresponds to about 1 in 500 million units, which is an extremely unlikely chance, and could be an option as a wide guardband to design a system around. In this case, the TLV935x-Q1 family does not have a maximum or minimum for offset voltage drift, but based on the typical value of 1.5 $\mu\text{V}/^\circ\text{C}$ in [节 6.7](#), it can be calculated that the 6- σ value for offset voltage drift is about 9 $\mu\text{V}/^\circ\text{C}$. When designing for worst-case system conditions, this value can be used to estimate the worst possible offset across temperature without having an actual minimum or maximum value.

However, process variation and adjustments over time can shift typical means and standard deviations, and unless there is a value in the minimum or maximum specification column, TI cannot assure the performance of a device. This information should be used only to estimate the performance of a device.

7.4 Device Functional Modes

The TLV935x-Q1 has a single functional mode and is operational when the power-supply voltage is greater than 4.5 V (± 2.25 V). The maximum power supply voltage for the TLV935x-Q1 is 40 V (± 20 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 TLV935x-Q1 family offers excellent DC precision and DC performance. These devices operate up to 40-V supply rails and offer true rail-to-rail output, low offset voltage and offset voltage drift, as well as 3.5-MHz bandwidth and high output drive. These features make the TLV935x-Q1 a robust, high-performance operational amplifier for high-voltage cost-sensitive applications.

8.2 Typical Applications

8.2.1 High Voltage Precision Comparator

Many different systems require controlled voltages across numerous system nodes to ensure robust operation. A comparator can be used to monitor and control voltages by comparing a reference threshold voltage with an input voltage and providing an output when the input crosses this threshold.

The TLV935x-Q1 family of op amps make excellent high voltage comparators due to their MUX-friendly input stage (see 节 7.3.1). Previous generation high-voltage op amps often use back-to-back diodes across the inputs to prevent damage to the op amp which greatly limits these op amps to be used as comparators, but the TLV935x-Q1's patented input stage allows the device to have a wide differential voltage between the inputs.

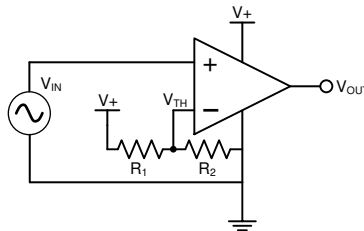


图 8-1. Typical Comparator Application

8.2.1.1 Design Requirements

The primary objective is to design a 40-V precision comparator.

- System supply voltage (V_+): 40 V
- Resistor 1 value: 100 k Ω
- Resistor 2 value: 100 k Ω
- Reference threshold voltage (V_{TH}): 20 V
- Input voltage range (V_{IN}): 0 V - 40 V
- Output voltage range (V_{OUT}): 0 V - 40 V

8.2.1.2 Detailed Design Procedure

This noninverting comparator circuit applies the input voltage (V_{IN}) to the noninverting terminal of the op amp. Two resistors (R_1 and R_2) divide the supply voltage (V_+) to create a mid-supply threshold voltage (V_{TH}) as calculated in 方程式 1. The circuit is shown in 图 8-1. When V_{IN} is less than V_{TH} , the output voltage transitions to the negative supply and equals the low-level output voltage. When V_{IN} is greater than V_{TH} , the output voltage transitions to the positive supply and equals the high-level output voltage.

In this example, resistor 1 and 2 have been selected to be 100 k Ω , which sets the reference threshold at 20 V. However, resistor 1 and 2 can be adjusted to modify the threshold using 方程式 1. Resistor 1 and 2's values have also been selected to reduce power consumption, but these values can be further increased to reduce power consumption, or reduced to improve noise performance.

$$V_{TH} = \frac{R_2}{R_1 + R_2} \times V_+ \quad (1)$$

8.2.1.3 Application Curve

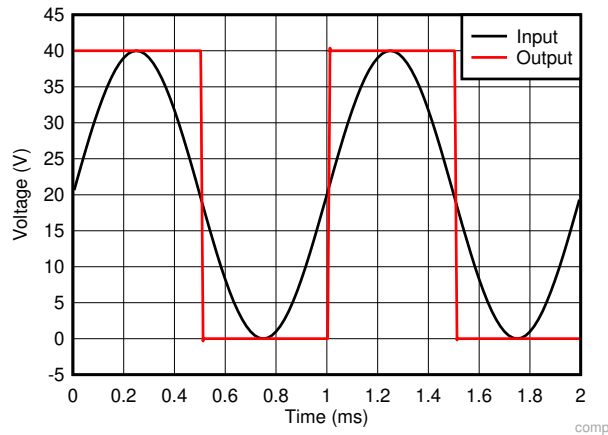


图 8-2. Comparator Output Response to Input Voltage

9 Power Supply Recommendations

The TLV935x-Q1 is specified for operation from 4.5 V to 40 V (± 2.25 V to ± 20 V); many specifications apply from -40°C to 125°C .

CAUTION

Supply voltages larger than 40 V can permanently damage the device; see [节 6.1](#).

Place 0.1- μF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, refer to [节 10](#).

10 Layout

10.1 Layout Guidelines

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

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and 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- μF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- In order to reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. As illustrated in [图 10-2](#), keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit may experience performance shifts due to 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

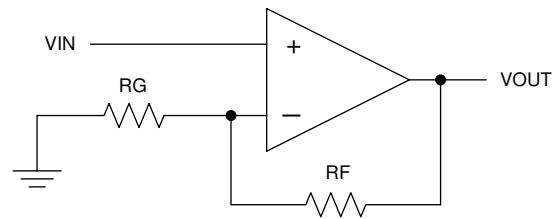


图 10-1. Schematic Representation

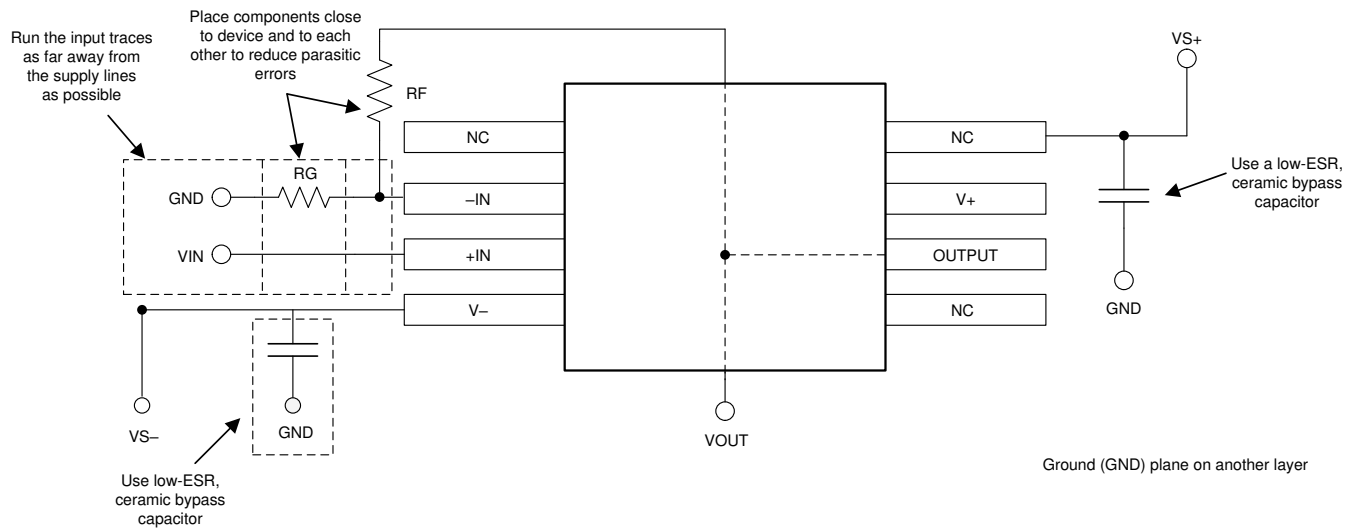


图 10-2. Operational Amplifier Board Layout for Noninverting Configuration

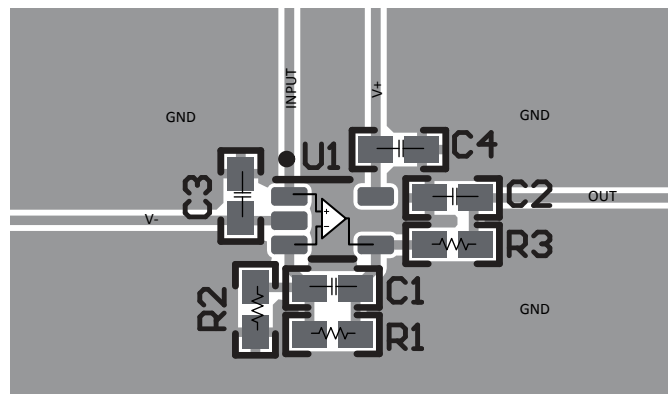


图 10-3. Example Layout for SC70 (DCK) Package

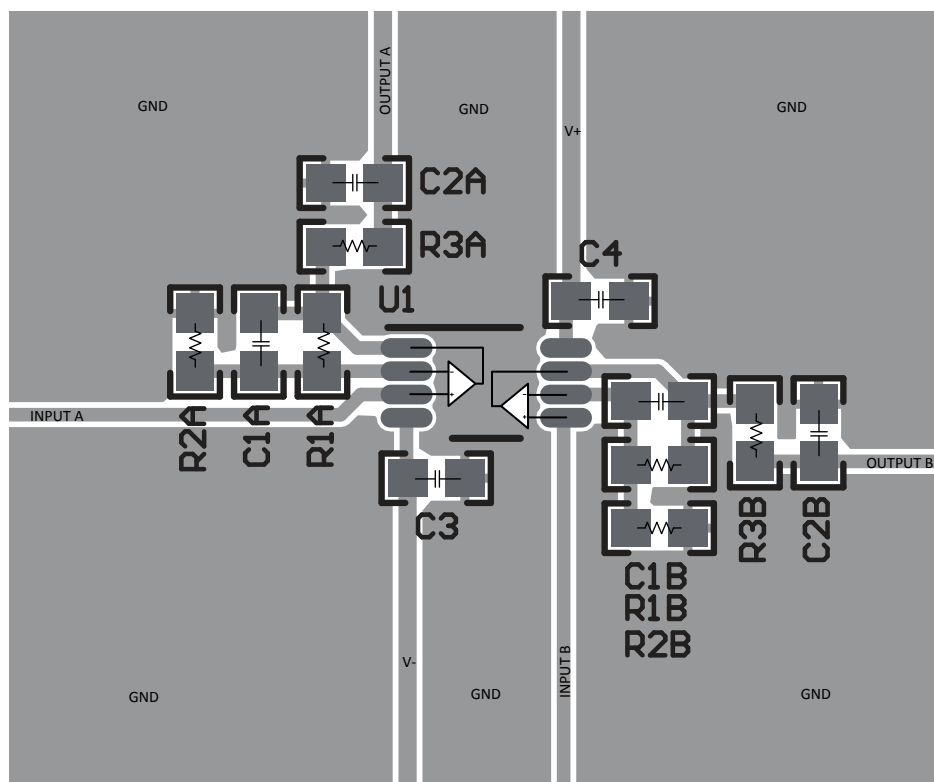


图 10-4. Example Layout for VSSOP-8 (DGK) Package

11 Device and Documentation Support

11.1 Device Support

11.1.1 Development Support

11.1.1.1 TINA-TI™ (Free Software Download)

TINA™ is a simple, powerful, and easy-to-use circuit simulation program based on a SPICE engine. TINA-TI is a free, fully-functional version of the TINA software, preloaded with a library of macro models in addition to a range of both passive and active models. TINA-TI provides all the conventional dc, transient, and frequency domain analysis of SPICE, as well as additional design capabilities.

Available as a [free download](#) from the Analog eLab Design Center, TINA-TI offers extensive post-processing capability that allows users to format results in a variety of ways. Virtual instruments offer the ability to select input waveforms and probe circuit nodes, voltages, and waveforms, creating a dynamic quick-start tool.

备注

These files require that either the TINA software (from DesignSoft™) or TINA-TI software be installed. Download the free TINA-TI software from the [TINA-TI folder](#).

11.1.1.2 TI Precision Designs

The TLV935x-Q1 is featured in several TI Precision Designs, available online at <http://www.ti.com/ww/en/analog/precision-designs/>. TI Precision Designs are analog solutions created by TI's precision analog applications experts and offer the theory of operation, component selection, simulation, complete PCB schematic and layout, bill of materials, and measured performance of many useful circuits.

11.2 Documentation Support

11.2.1 Related Documentation

- Texas Instruments, [EMI Rejection Ratio of Operational Amplifiers](#)
- Texas Instruments, [Capacitive Load Drive Solution using an Isolation Resistor](#)
- Texas Instruments, [Analog Engineer's Circuit Cookbook: Amplifiers](#)
- Texas Instruments, [AN31 amplifier circuit collection](#)

11.3 接收文档更新通知

要接收文档更新通知，请导航至 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。

11.4 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》](#)。

11.5 Trademarks

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11.6 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.

11.7 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 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 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
PTLV9354QDRQ1	ACTIVE	SOIC	D	14	3000	TBD	Call TI	Call TI	-40 to 125		Samples
TLV9351QDBVRQ1	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2JMF	Samples
TLV9352QDGKRQ1	ACTIVE	VSSOP	DGK	8	2500	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	27ST	Samples
TLV9352QDRQ1	ACTIVE	SOIC	D	8	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T9352Q	Samples
TLV9354QDRQ1	ACTIVE	SOIC	D	14	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TL9354QD	Samples
TLV9354QDYRQ1	ACTIVE	SOT-23-THIN	DYY	14	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TLV9354Q	Samples
TLV9354QPWRQ1	ACTIVE	TSSOP	PW	14	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	T9354Q	Samples

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

ACTIVE: Product device recommended for new designs.

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

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

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

OBSOLETE: TI has discontinued the production of the device.

(2) **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.

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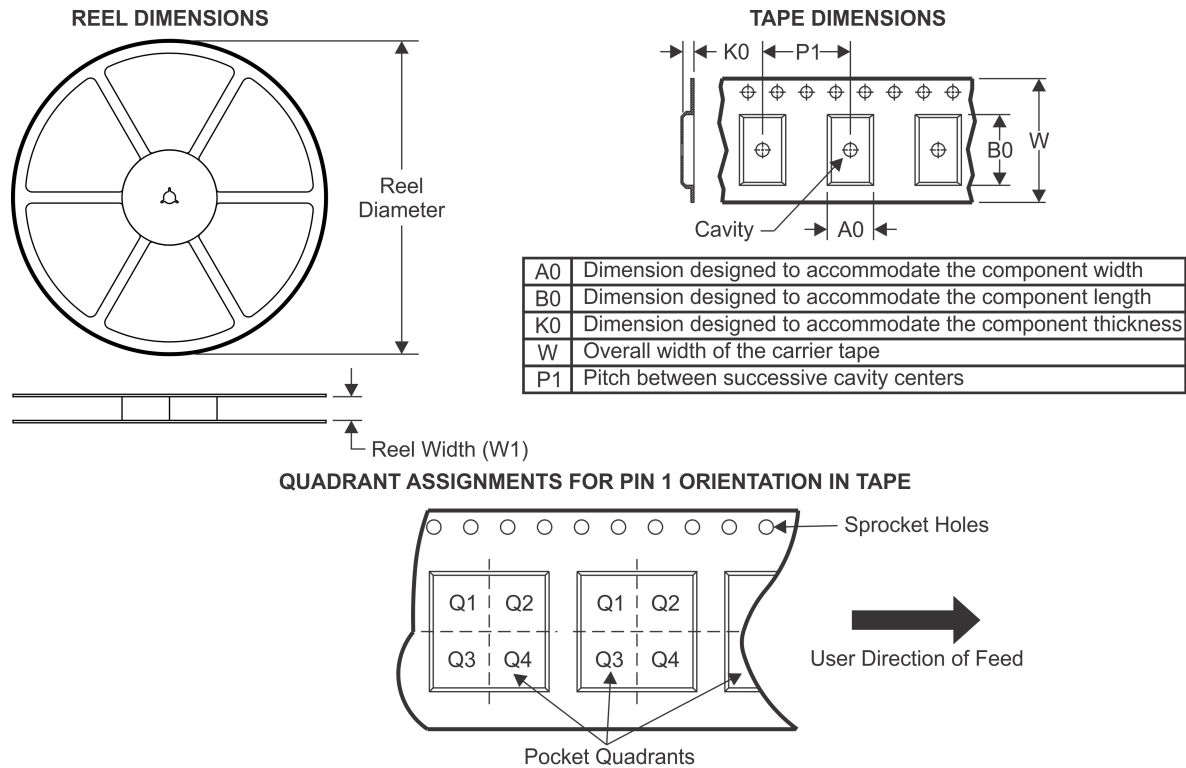
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TLV9351-Q1, TLV9352-Q1, TLV9354-Q1 :

- Catalog : [TLV9351](#), [TLV9352](#), [TLV9354](#)

NOTE: Qualified Version Definitions:

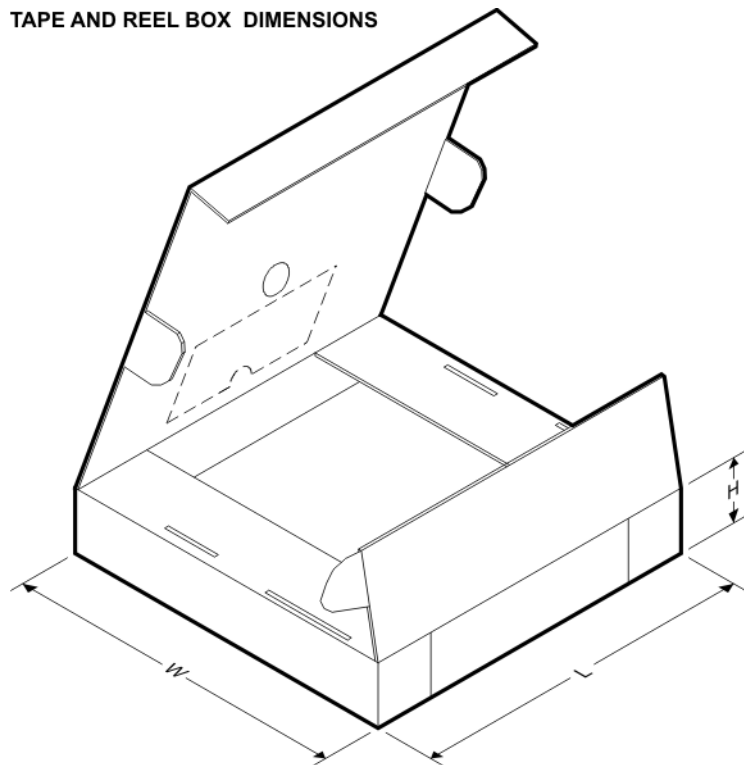
- Catalog - TI's standard catalog product

TAPE AND REEL INFORMATION


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV9351QDBVRQ1	SOT-23	DBV	5	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV9352QDGKRQ1	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV9352QDRQ1	SOIC	D	8	3000	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV9354QDRQ1	SOIC	D	14	3000	330.0	16.4	6.5	9.0	2.1	8.0	16.0	Q1
TLV9354QPWRQ1	TSSOP	PW	14	3000	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)
TLV9351QDBVRQ1	SOT-23	DBV	5	3000	210.0	185.0	35.0
TLV9352QDGKRQ1	VSSOP	DGK	8	2500	366.0	364.0	50.0
TLV9352QDRQ1	SOIC	D	8	3000	853.0	449.0	35.0
TLV9354QDRQ1	SOIC	D	14	3000	853.0	449.0	35.0
TLV9354QPWRQ1	TSSOP	PW	14	3000	853.0	449.0	35.0

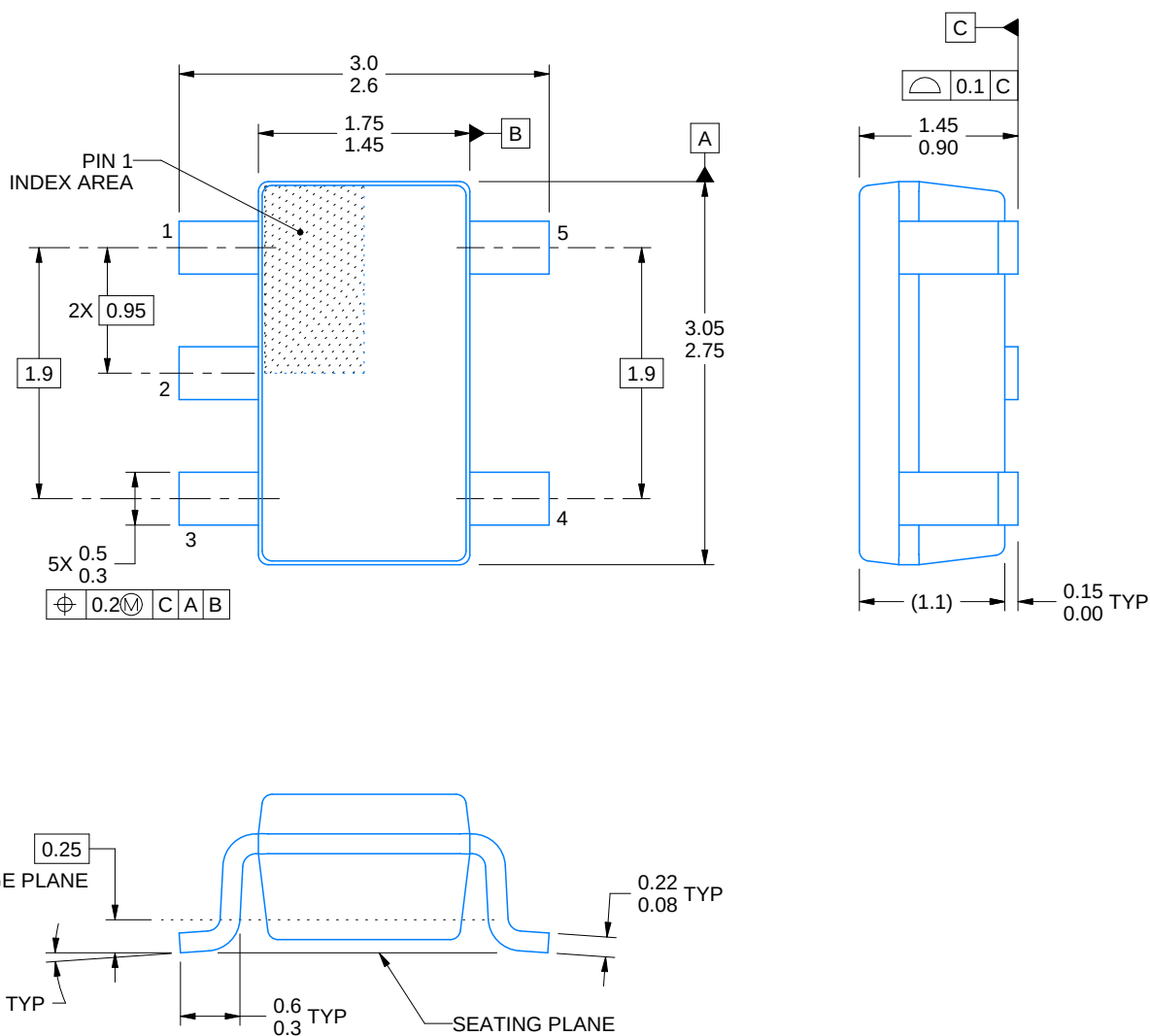


DBV0005A

PACKAGE OUTLINE

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



4214839/F 06/2021

NOTES:

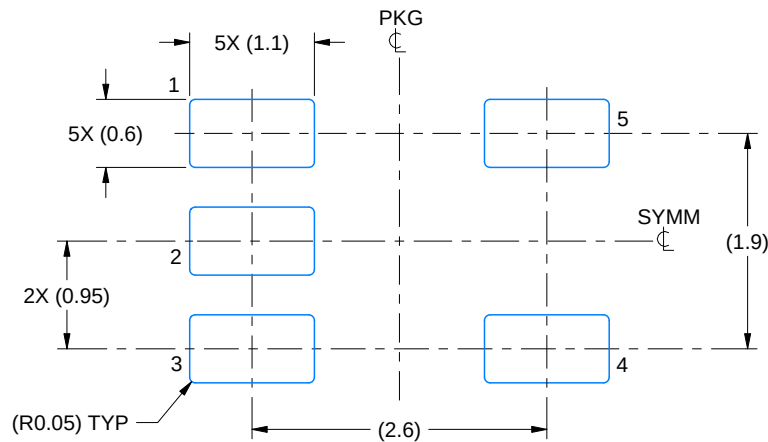
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Reference JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold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

EXAMPLE BOARD LAYOUT

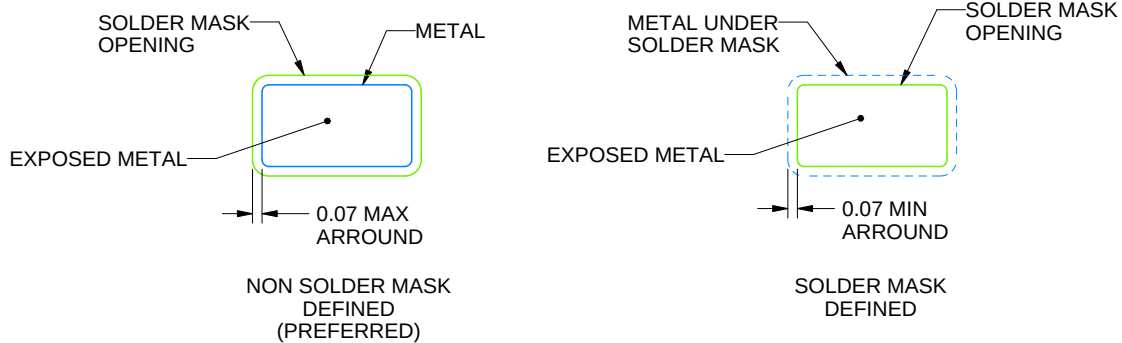
DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214839/F 06/2021

NOTES: (continued)

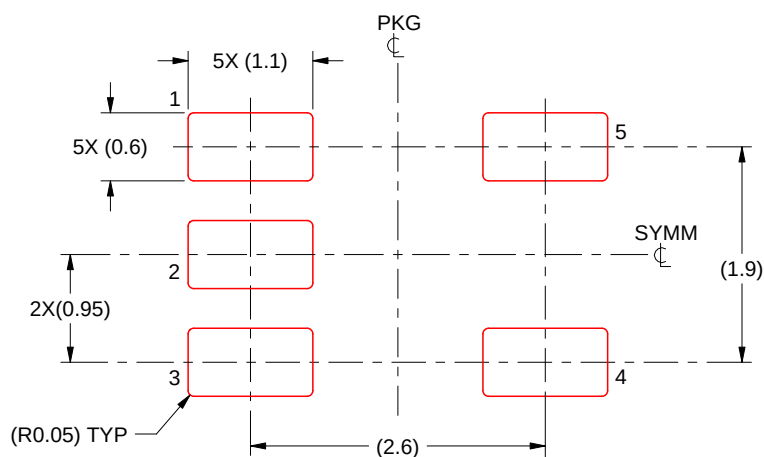
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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

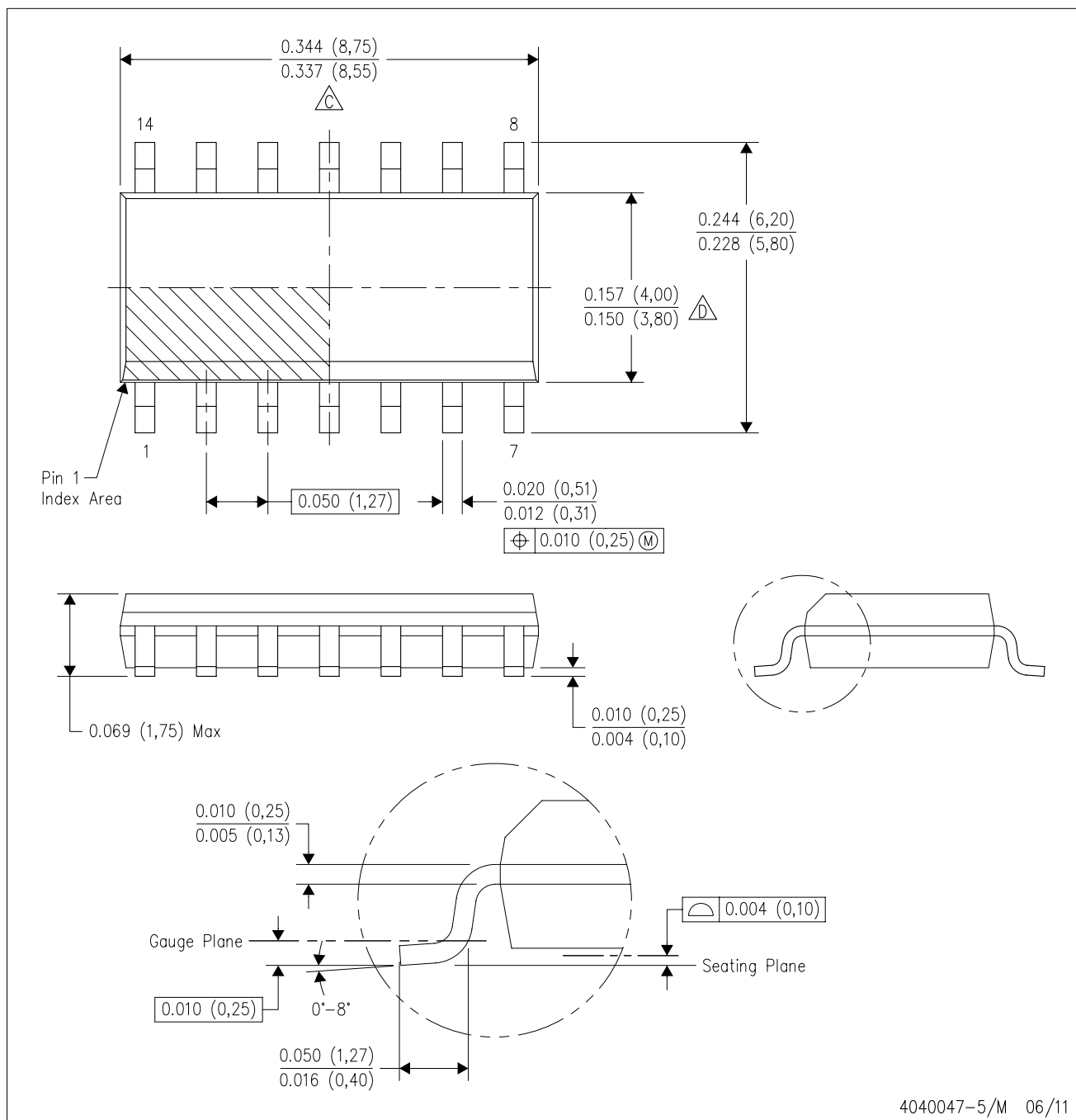
4214839/F 06/2021

NOTES: (continued)

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

D (R-PDSO-G14)

PLASTIC SMALL OUTLINE



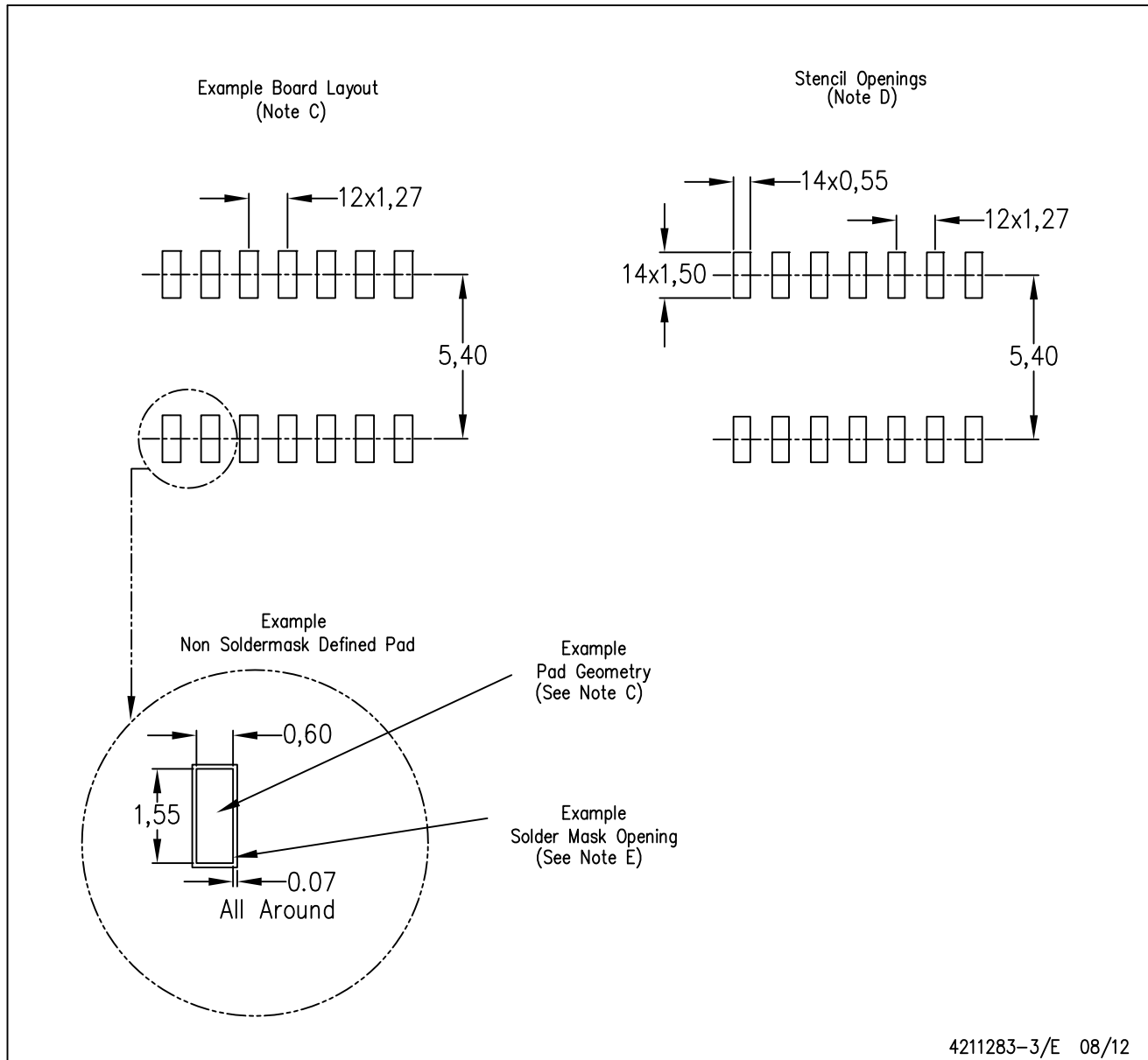
4040047-5/M 06/11

NOTES:

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

D (R-PDSO-G14)

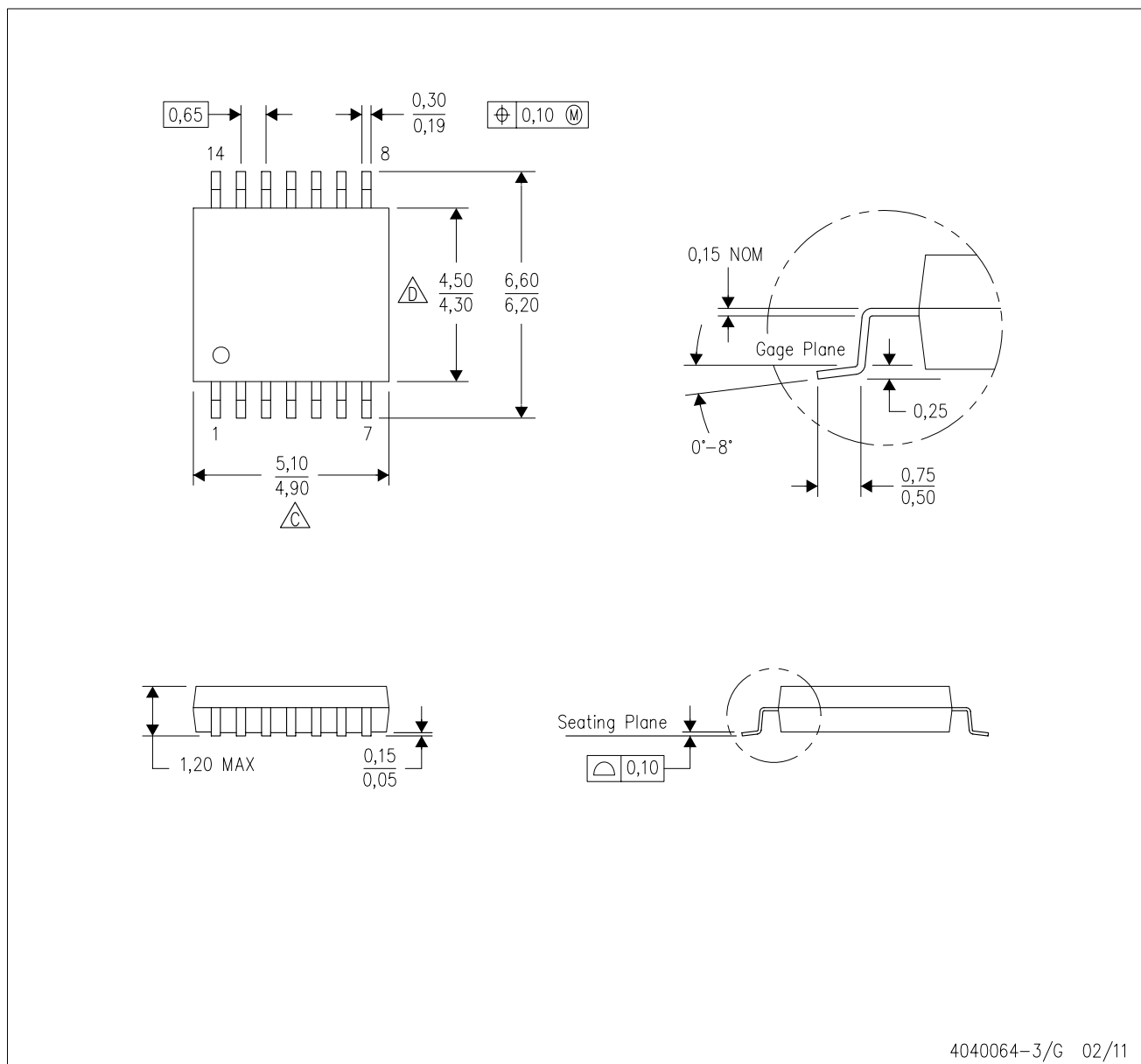
PLASTIC SMALL OUTLINE



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

PW (R-PDSO-G14)

PLASTIC SMALL OUTLINE

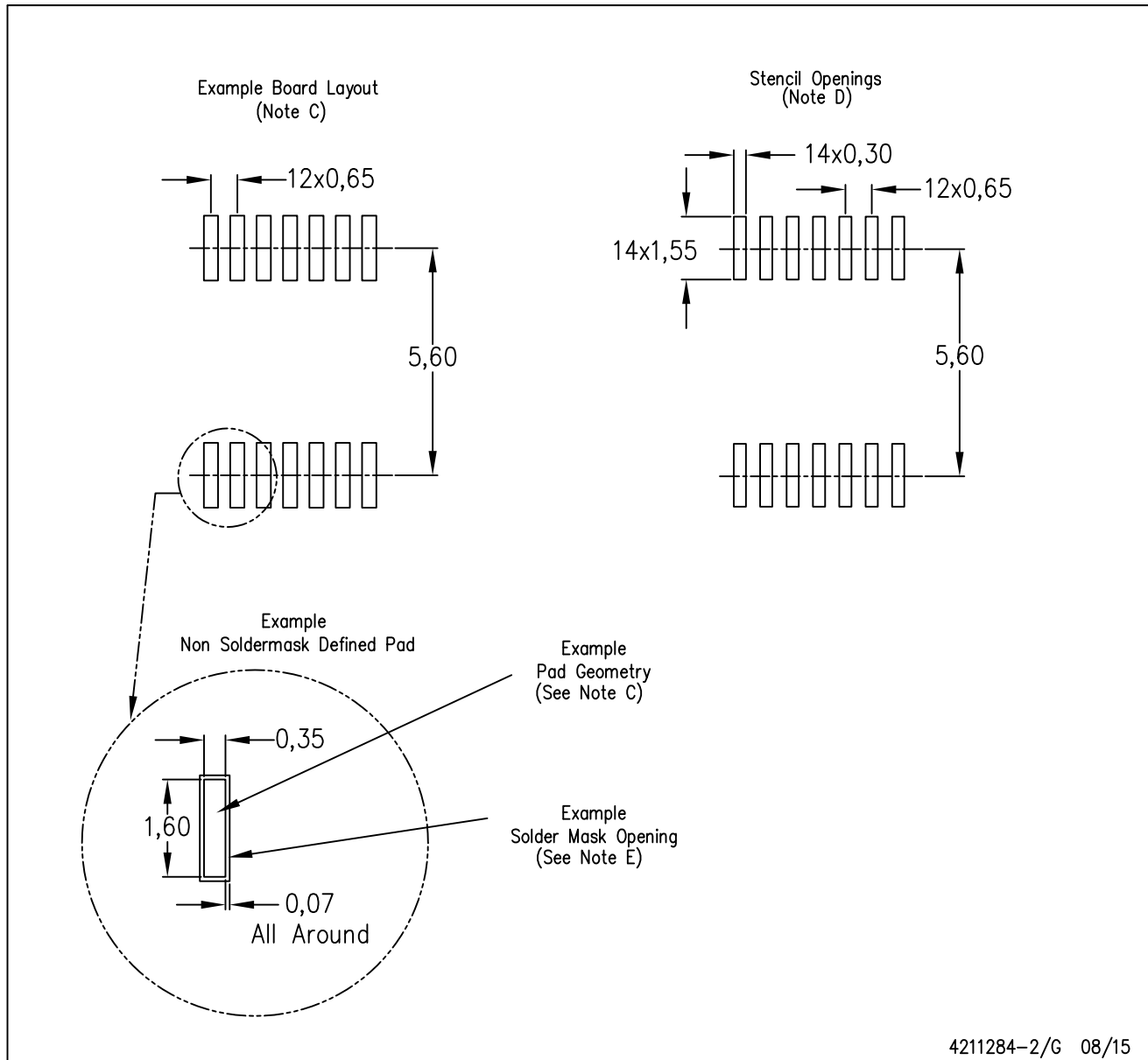


4040064-3/G 02/11

- 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.



PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



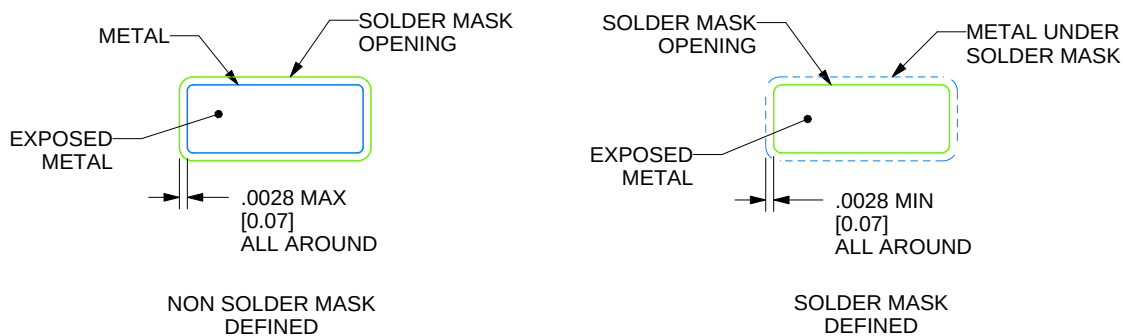
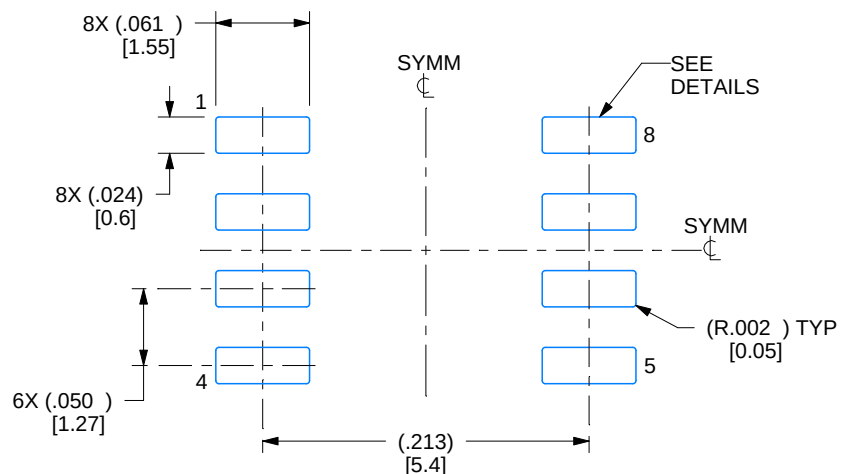
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate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

EXAMPLE BOARD LAYOUT

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



4214825/C 02/2019

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

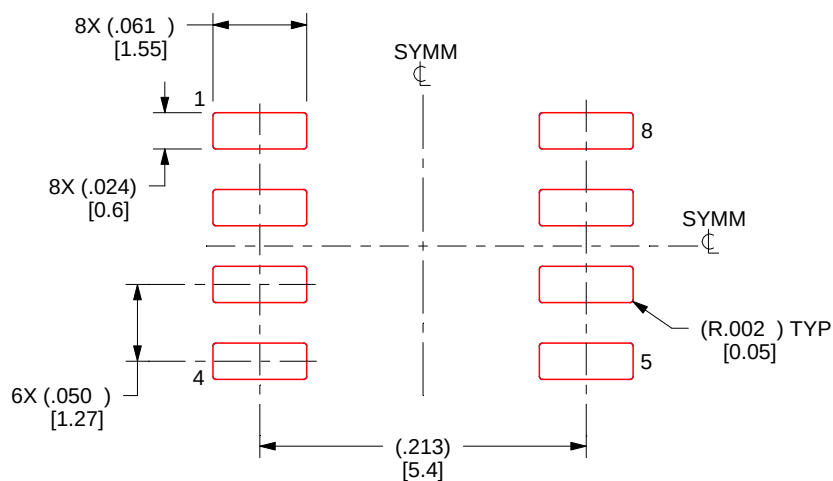
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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

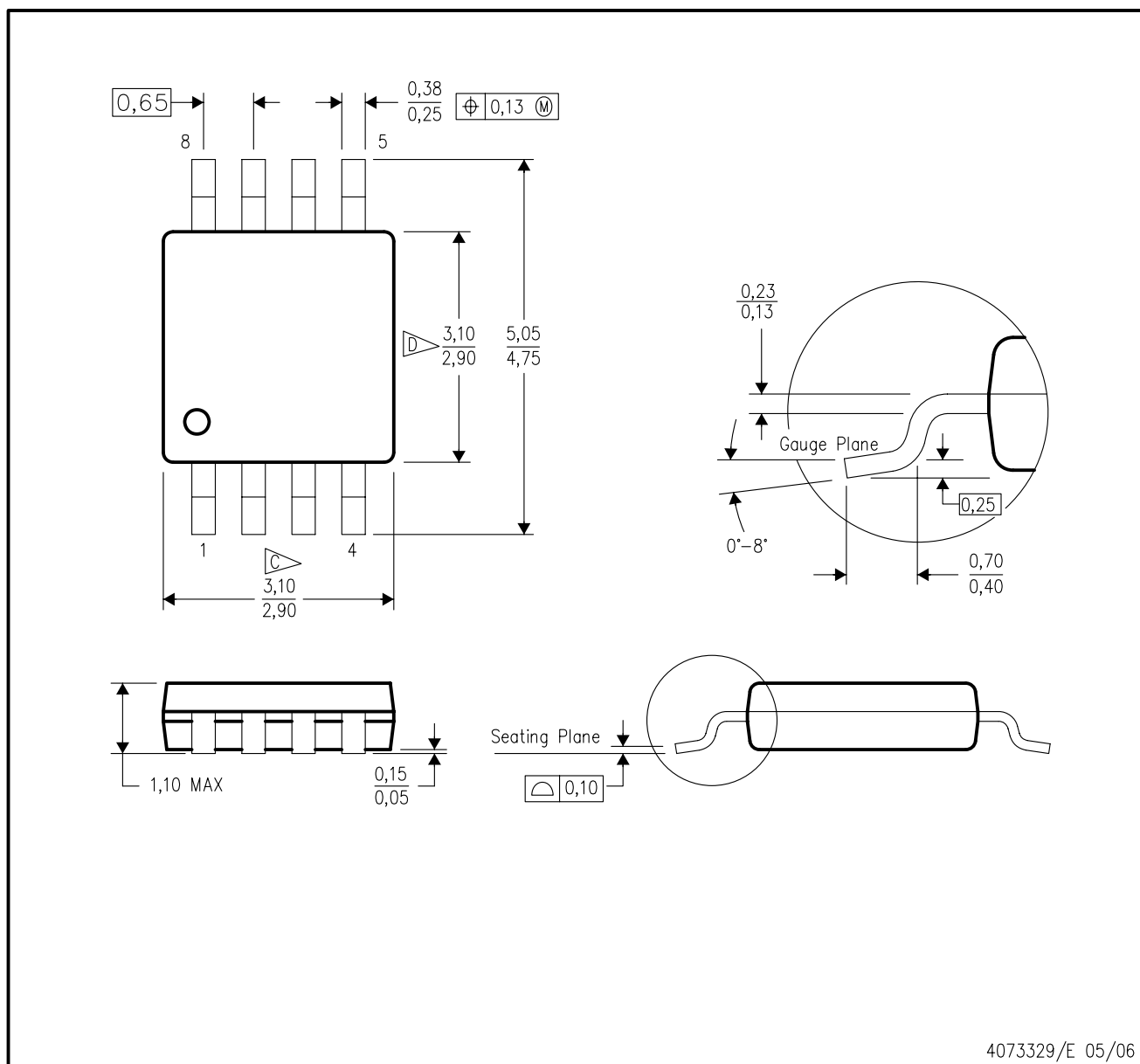
4214825/C 02/2019

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.

DGK (S-PDSO-G8)

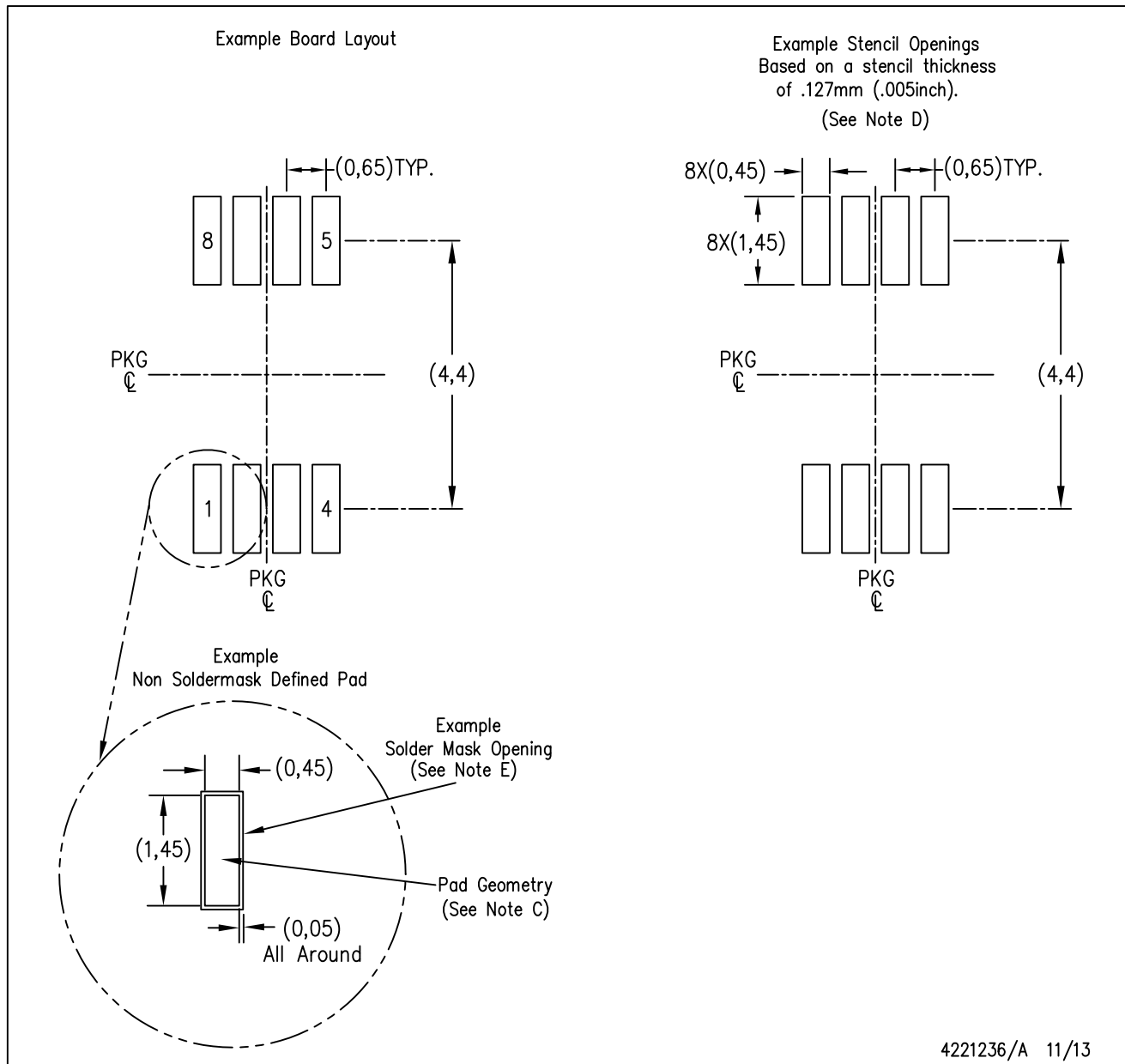
PLASTIC SMALL-OUTLINE PACKAGE



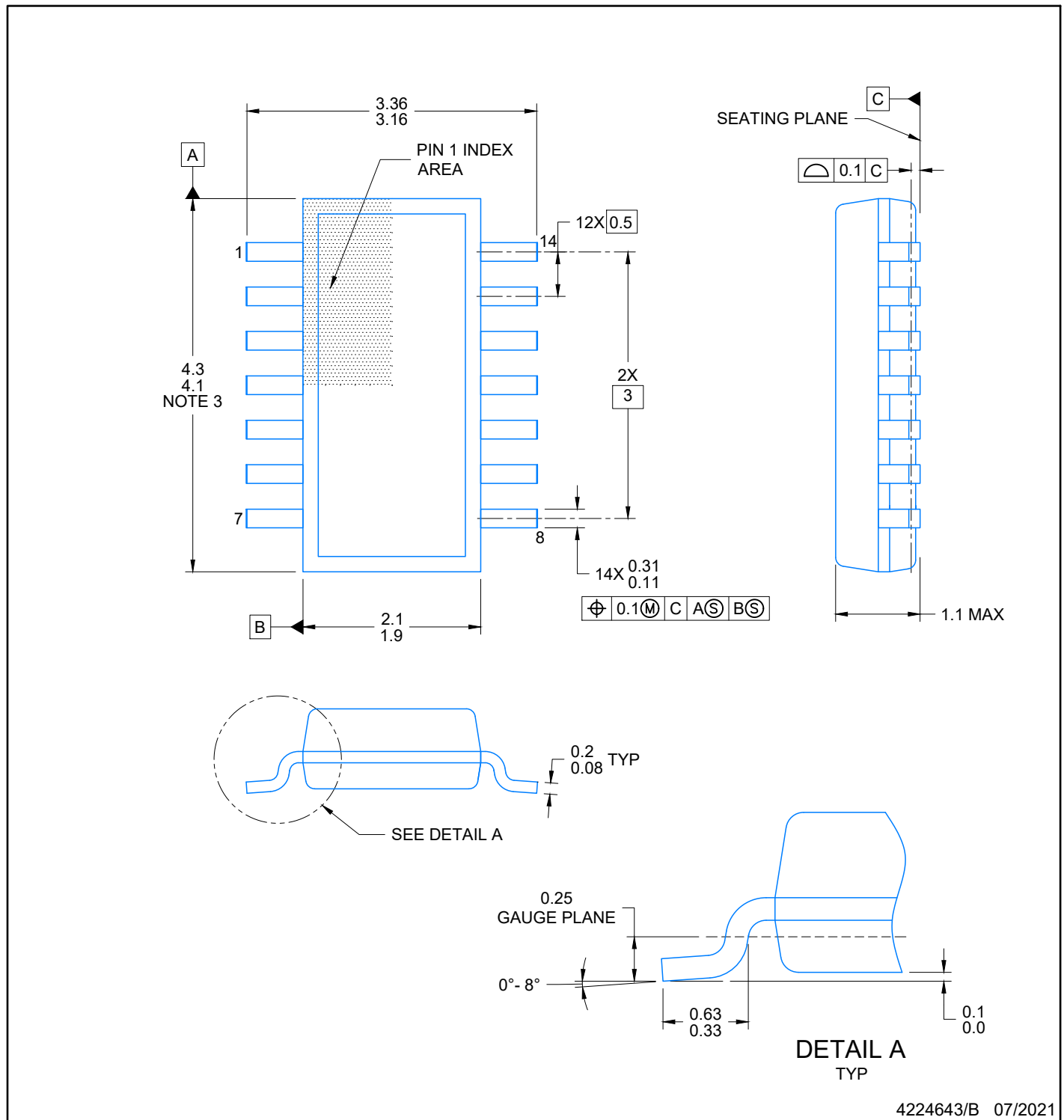
- NOTES:
- A. All linear dimensions are in millimeters.
 - B. This drawing is subject to change without notice.
 - C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
 - D. Body width does not include interlead flash. Interlead flash shall not exceed 0.50 per side.
 - E. Falls within JEDEC MO-187 variation AA, except interlead flash.

DGK (S-PDSO-G8)

PLASTIC SMALL OUTLINE PACKAGE



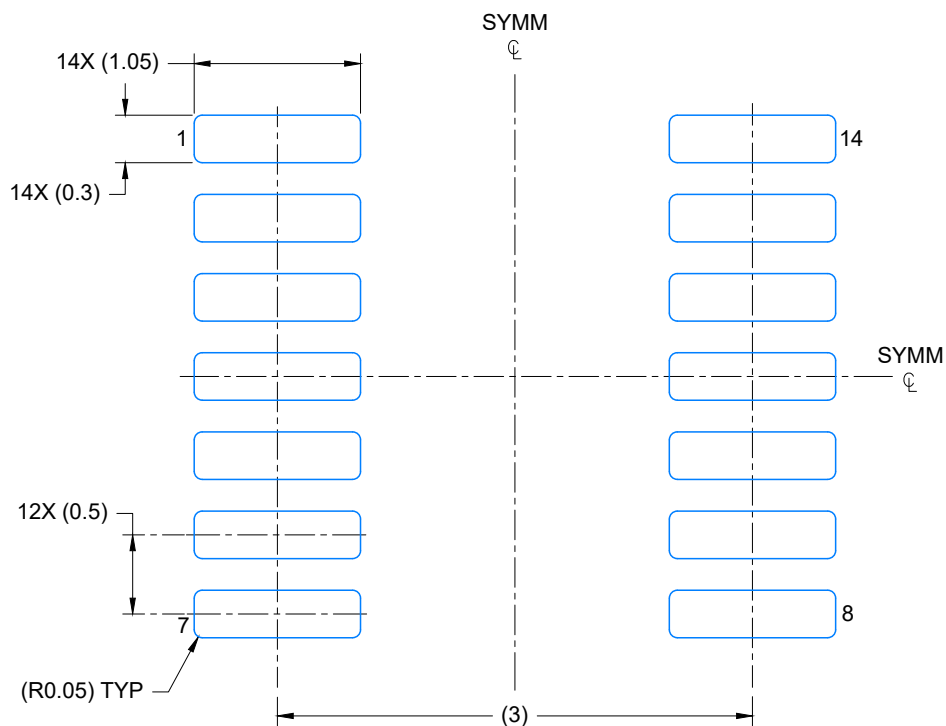
- NOTES:
- All linear dimensions are in millimeters.
 - This drawing is subject to change without notice.
 - Publication IPC-7351 is recommended for alternate designs.
 - Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact 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.



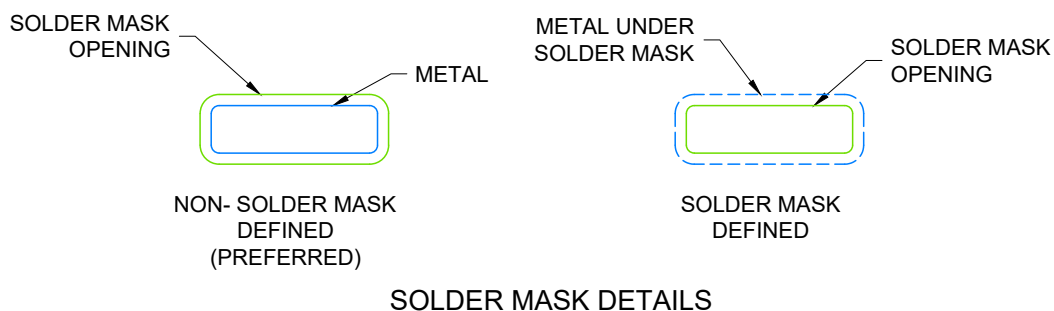
4224643/B 07/2021

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



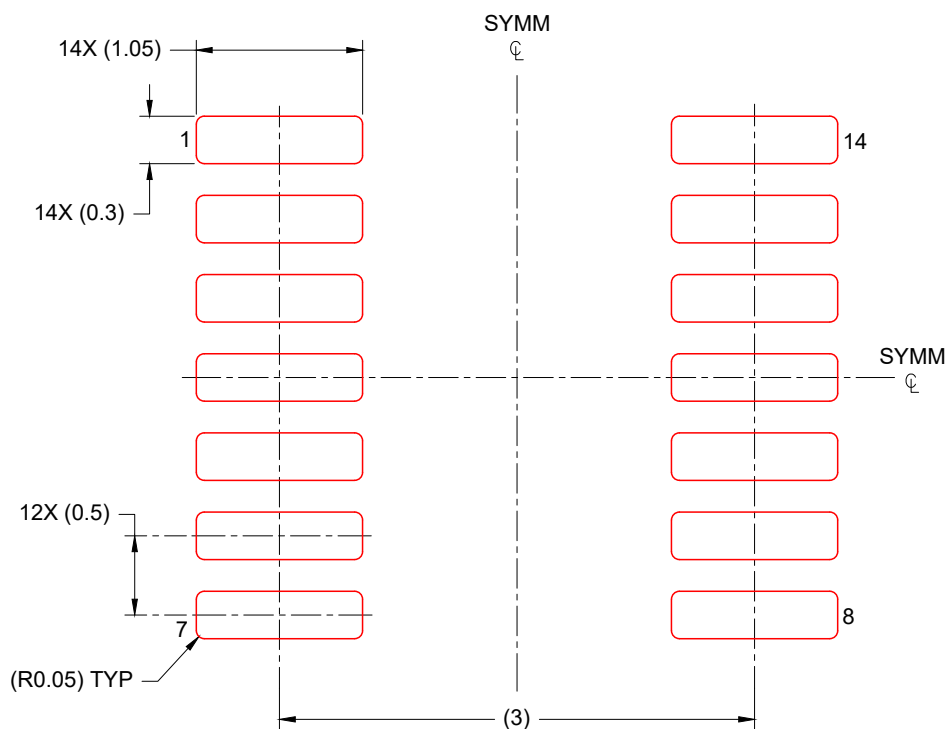
LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 20X



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NOTES: (continued)

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



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE: 20X

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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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