TLVx313 Low-Power, Rail-to-Rail In/Out, 500-µV Typical Offset, 1-MHz Operational Amplifier for Cost-Sensitive Systems

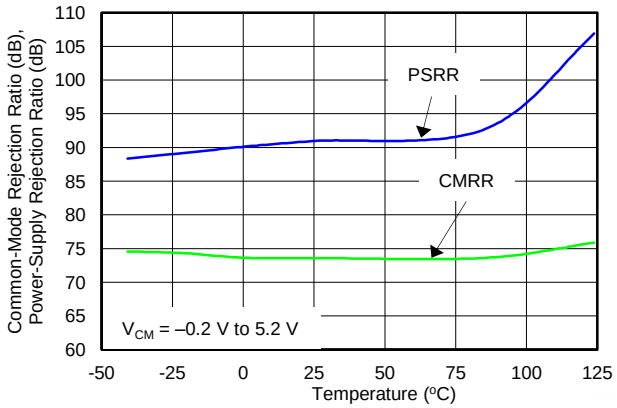
1 Features

- Precision Amplifier for Cost-Sensitive Systems
- Low I_Q: 65 µA/ch
- Wide Supply Range: 1.8 V to 5.5 V
- Low Noise: 26 nV/√Hz at 1 kHz
- Gain Bandwidth: 1 MHz
- Rail-to-Rail Input/Output
- Low Input Bias Current: 1 pA
- Low Offset Voltage: 0.75 mV
- Unity-Gain Stable
- Internal RF/EMI Filter
- Extended Temperature Range: –40°C to +125°C

2 Applications

- Medical and Healthcare
- Fitness and Wearable Electronics
- Utility Metering (Heat, Water, Energy)
- Building Automation Equipment
- Currency Counters

CMRR and PSRR vs Temperature



3 Description

The TLV313 family of single-, dual-, and quad-channel precision operational amplifiers combine low power consumption with good performance. This makes them suitable for a wide range of applications, such as wearables, utility metering, building automation, currency counters and more. The family features rail-to-rail input and output (RRIO) swings, low quiescent current (65 µA, typical), wide bandwidth (1 MHz) and very low noise (26 nV/√Hz at 1 kHz), making it attractive for a variety of battery-powered applications that require a good balance between cost and performance. Further, low-input-bias current enables these devices to be used in applications with megaohm source impedances.

The robust design of the TLV313 devices provides ease-of-use to the circuit designer: unity-gain stability with capacitive loads of up to 150 pF, integrated RF/EMI rejection filter, no phase reversal in overdrive conditions, and high electrostatic discharge (ESD) protection (4-kV HBM).

The devices are optimized for operation at voltages as low as +1.8 V (±0.9 V) and up to +5.5 V (±2.75 V), and are specified over the extended temperature range of –40°C to +125°C.

The single-channel TLV313 device is available in both SC70-5 and SOT23-5 packages. The dual-channel TLV2313 device is offered in SOIC-8 and VSSOP-8 packages, and the quad-channel TLV4313 device is offered in a TSSOP-14 package.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TLV313	SC70 (5)	2.00 mm × 1.25 mm
	SOT23 (5)	2.90 mm × 1.60 mm
TLV2313	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (8)	3.00 mm × 3.00 mm
TLV4313	TSSOP (14)	5.00 mm × 4.40 mm

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

Table of Contents

4 Revision History

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

Changes from Revision A (June 2016) to Revision B	Page
• Changed pin assignment for DCK package	3

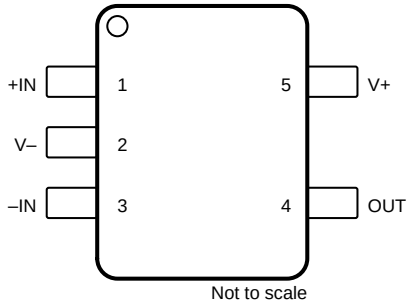
Changes from Original (June 2016) to Revision A	Page
• Changed Product Status from Product Preview to Production Data	1
• Changed the formatting of the *Related Documentation* section	23
• Changed wording in the *Receiving Notification of Documentation Updates* section	23

5 Device Comparison Table

DEVICE	NO. OF CHANNELS	PACKAGE LEADS				
		SC70	SOT23	SOIC	VSSOP	TSSOP
TLV313	1	5	5	—	—	—
TLV2313	2	—	—	8	8	—
TLV4313	4	—	—	—	—	14

6 Pin Configuration and Functions

DCK Package
5-Pin SC70
TLV313 Top View



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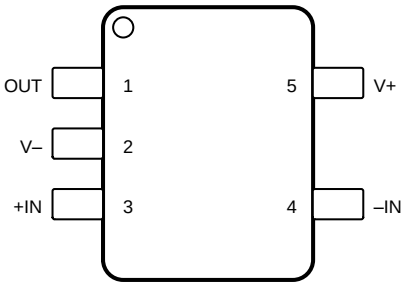
DBV Package
5-Pin SOT23
TLV313 Top View



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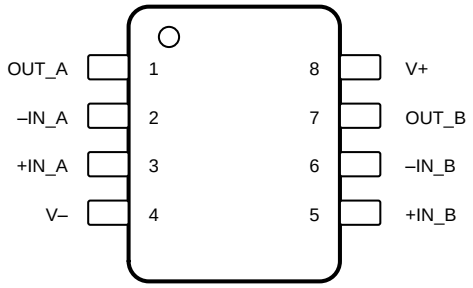
Pin Functions: TLV313

PIN			I/O	DESCRIPTION
NAME	DCK (SC70)	DBV (SOT23)		
+IN	1	3	I	Noninverting input
–IN	3	4	I	Inverting input
OUT	4	1	O	Output
V+	5	5	—	Positive (highest) power supply
V–	2	2	—	Negative (lowest) power supply

D, DGK Packages
8-Pin SOIC, 8-Pin VSSOP
TLV2313 Top View



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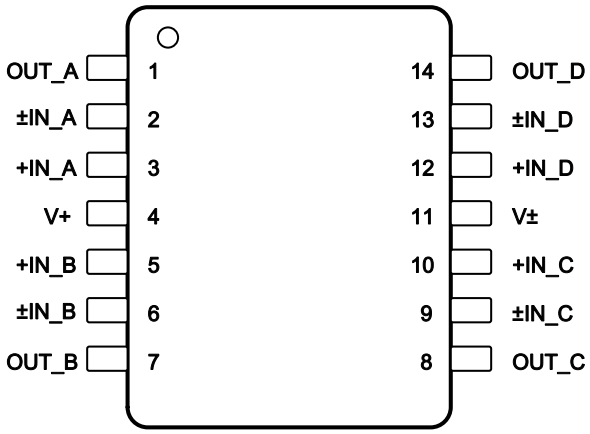
Pin Functions: TLV2313

PIN			I/O	DESCRIPTION
NAME	D (SOIC)	DGK (VSSOP)		
V–	4	4	—	Negative (lowest) power supply
V+	8	8	—	Positive (highest) power supply
OUT A	1	1	O	Output, channel A
OUT B	7	7	O	Output, channel B
–IN A	2	2	I	Inverting input, channel A
+IN A	3	3	I	Noninverting input, channel A
–IN B	6	6	I	Inverting input, channel B
+IN B	5	5	I	Noninverting input, channel B

PW Package
14-Pin TSSOP
TLV4313 Top View



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Pin Functions: TLV4313

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

7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
Voltage	Supply voltage		7	V
	Signal input terminals(2)	(V−) − (0.5)	(V+) + 0.5	V
Current	Signal input terminals(2)	–10	10	mA
	Output short circuit(3)	Continuous		
Temperature	Operating, T_A	–40	150	°C
	Junction, T_J		150	°C
	Storage, T_{stg}	–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.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±4000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±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.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V_S	Supply voltage	1.8	5.5	V
T_A	Specified temperature range	–40	125	°C

7.4 Thermal Information: TLV313

THERMAL METRIC(1)		TLV313		UNIT
		DBV (SOT23)	DCK (SC70)	
		5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	228.5	281.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	99.1	91.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	54.6	59.6	°C/W
ψ_{JT}	Junction-to-top characterization parameter	7.7	1.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	53.8	58.8	°C/W
$R_{\theta JC(bot)}$	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.

7.5 Thermal Information: TLV2313

THERMAL METRIC(1)		TLV2313		UNIT
		D (SOIC)	DGK (VSSOP)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	138.4	191.2	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	89.5	61.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	78.6	111.9	°C/W
ψ_{JT}	Junction-to-top characterization parameter	29.9	5.1	°C/W
ψ_{JB}	Junction-to-board characterization parameter	78.1	110.2	°C/W
$R_{\theta JC(bot)}$	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.

7.6 Thermal Information: TLV4313

THERMAL METRIC(1)		TLV4313	UNIT
		PW (TSSOP)	
		14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	121.0	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	49.4	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	62.8	°C/W
ψ_{JT}	Junction-to-top characterization parameter	5.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	62.2	°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.

7.7 Electrical Characteristics: 5.5 V

At T_A = 25°C, R_L = 10 kΩ connected to V_S / 2, and V_{CM} = V_{OUT} = V_S / 2, unless otherwise noted.(1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage			0.75	3	mV
dV_{OS}/dT	Input offset voltage vs temperature	T_A = –40°C to 125°C		2		µV/°C
PSRR	Power-supply rejection ratio		74	90		dB
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	No phase reversal, rail-to-rail input	(V–) – 0.2		(V+) + 0.2	V
CMRR	Common-mode rejection ratio	(V_S–) – 0.2 V < V_{CM} < (V_S+) – 1.3 V		85		dB
		V_{CM} = –0.2 V to 5.7 V	64	80		dB
INPUT BIAS CURRENT						
I_B	Input bias current			±1		pA
I_{OS}	Input offset current			±1		pA
NOISE						
	Input voltage noise (peak-to-peak)	f = 0.1 Hz to 10 Hz		6		μV_{PP}
e_n	Input voltage noise density	f = 10 kHz		22		nV/√Hz
		f = 1 kHz		26		nV/√Hz
i_n	Input current noise density	f = 1 kHz		5		fA/√Hz
INPUT CAPACITANCE						
C_{IN}	Differential			1		pF
	Common-mode			5		pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	0.05 V < V_O < (V+) – 0.05 V, R_L = 100 kΩ		104		dB
		0.3 V < V_O < (V+) – 0.3 V, R_L = 2 kΩ	100	110		dB
	Phase margin	V_S = 5.0 V, G = +1		65		°

(1) Parameters with minimum or maximum specification limits are 100% production tested at 25ºC, unless otherwise noted. Over-temperature limits are based on characterization and statistical analysis.

Electrical Characteristics: 5.5 V (continued)

At T_A = 25°C, R_L = 10 kΩ connected to V_S / 2, and V_{CM} = V_{OUT} = V_S / 2, unless otherwise noted.(1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product	V_S = 5.0 V, C_L = 10 pF		1		MHz
SR	Slew rate	V_S = 5.0 V, G = +1		0.5		V/µs
t_S	Settling time	To 0.01%, V_S = 5.0 V, 2-V step , G = +1		6		µs
	Overload recovery time	V_S = 5.0 V, V_{IN} × Gain > V_S		3		µs
OUTPUT						
V_O	Voltage output swing from supply rails	R_L = 100 kΩ(2)		5	20	mV
		R_L = 2 kΩ(2)		75	100	mV
I_{SC}	Short-circuit current			±15		mA
R_O	Open-loop output impedance			2300		Ω
POWER SUPPLY						
V_S	Specified voltage range		1.8 (±0.9)		5.5 (±2.75)	V
I_Q	Quiescent current per amplifier	T_A = –40°C to 125°C, V_S = 5.0 V, I_O = 0 mA		65	90	µA
	Power-on time	V_S = 0 V to 5 V, to 90% I_Q level		10		µs

(2) Specified by design and characterization; not production tested.

7.8 Electrical Characteristics: 1.8 V

At T_A = 25°C, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_{S+} – 1.3 V, and V_{OUT} = V_S / 2, unless otherwise noted.(1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
OFFSET VOLTAGE						
V_{OS}	Input offset voltage			0.75	3	mV
dV_{OS}/dT	Input offset voltage vs temperature	T_A = –40°C to 125°C		2		µV/°C
PSRR	Power-supply rejection ratio		74	90		dB
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	No phase reversal, rail-to-rail input	(V–) – 0.2		(V+) + 0.2	V
CMRR	Common-mode rejection ratio	(V_S–) – 0.2 V < V_{CM} < (V_S+) – 1.3 V		85		dB
		V_{CM} = –0.2 V to +1.8 V		73		dB
INPUT BIAS CURRENT						
I_B	Input bias current			±1		pA
I_{OS}	Input offset current			±1		pA
NOISE						
	Input voltage noise (peak-to-peak)	f = 0.1 Hz to 10 Hz		6		μV_{PP}
e_n	Input voltage noise density	f = 10 kHz		22		nV/√Hz
		f = 1 kHz		26		nV/√Hz
i_n	Input current noise density	f = 1 kHz		5		fA/√Hz
INPUT CAPACITANCE						
C_{IN}	Differential			1		pF
	Common-mode			5		pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	0.1 V < V_O < (V+) – 0.1 V, R_L = 10 kΩ		110		dB
		0.05 V < V_O < (V+) – 0.05 V, R_L = 100 kΩ		110		dB

(1) Parameters with minimum or maximum specification limits are 100% production tested at 25ºC, unless otherwise noted. Over-temperature limits are based on characterization and statistical analysis.

Electrical Characteristics: 1.8 V (continued)

At T_A = 25°C, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_{S+} – 1.3 V, and V_{OUT} = V_S / 2, unless otherwise noted.(1)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
FREQUENCY RESPONSE						
GBW	Gain-bandwidth product	C_L = 10 pF		0.9		MHz
SR	Slew rate	G = +1		0.45		V/µs
t_S	Settling time	To 0.01%, V_S = 5.0 V, 2-V step , G = +1		6		µs
	Overload recovery time	V_S = 5.0 V, V_{IN} × Gain > V_S		3		µs
OUTPUT						
V_O	Voltage output swing from supply rails	R_L = 100 kΩ(2)		5		mV
		R_L = 2 kΩ(2)		25		mV
I_{SC}	Short-circuit current			±6		mA
R_O	Open-loop output impedance			2300		Ω
POWER SUPPLY						
V_S	Specified voltage range		1.8 (±0.9)		5.5 (±2.75)	V
I_Q	Quiescent current per amplifier	T_A = –40°C to 125°C, V_S = 5.0 V, I_O = 0 mA		65	90	µA
	Power-on time	V_S = 0 V to 5 V, to 90% I_Q level		10		µs

(2) Specified by design and characterization; not production tested.

7.9 Typical Characteristics: Table of Graphs

Table 1. Table of Graphs

TITLE	FIGURE
Open-Loop Gain and Phase vs Frequency	Figure 1
Quiescent Current vs Supply Voltage	Figure 2
Offset Voltage Production Distribution	Figure 3
Offset Voltage vs Common-Mode Voltage (Maximum Supply)	Figure 4
CMRR and PSRR vs Frequency (RTI)	Figure 5
0.1-Hz to 10-Hz Input Voltage Noise (5.5 V)	Figure 6
Input Voltage Noise Spectral Density vs Frequency (1.8 V, 5.5 V)	Figure 7
Input Bias and Offset Current vs Temperature	Figure 8
Open-Loop Output Impedance vs Frequency	Figure 9
Maximum Output Voltage vs Frequency and Supply Voltage	Figure 10
Output Voltage Swing vs Output Current (over Temperature)	Figure 11
Closed-Loop Gain vs Frequency, G = 1, –1, 10 (1.8 V)	Figure 12
Small-Signal Step Response, Noninverting (1.8 V)	Figure 13
Small-Signal Step Response, Noninverting (5.5 V)	Figure 14
Large-Signal Step Response, Noninverting (1.8 V)	Figure 15
Large-Signal Step Response, Noninverting (5.5 V)	Figure 16
No Phase Reversal	Figure 17
EMIRR IN+ vs Frequency	Figure 18

7.10 Typical Characteristics

At T_A = 25°C, V_S = 5 V, R_L = 10 kΩ connected to V_S / 2, and V_{CM} = V_{OUT} = V_S / 2, unless otherwise noted.

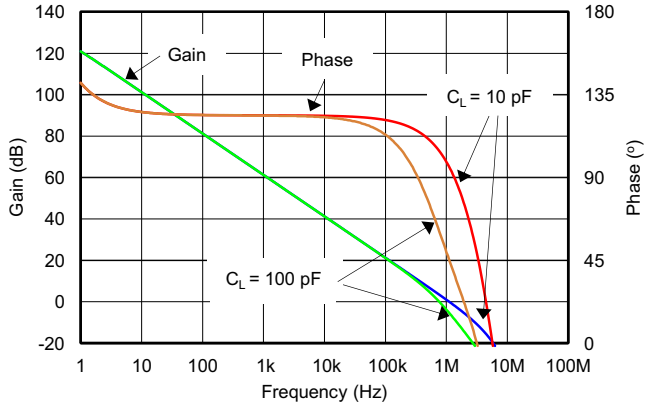


Figure 1. Open-Loop Gain and Phase vs Frequency

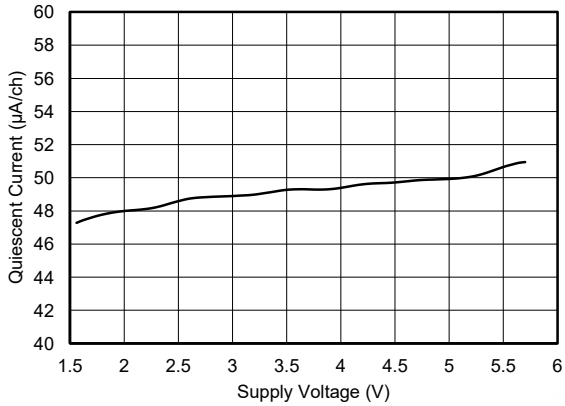


Figure 2. Quiescent Current vs Supply

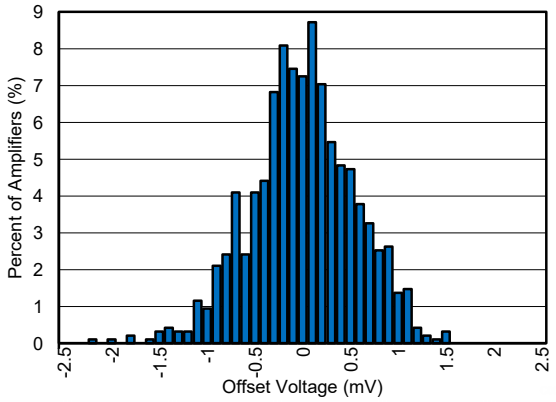


Figure 3. Offset Voltage Production Distribution

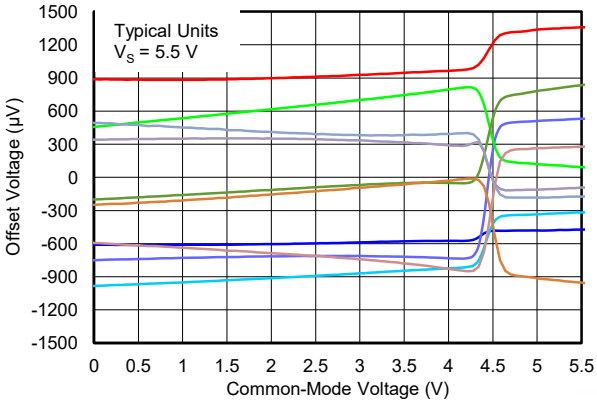


Figure 4. Offset Voltage vs Common-Mode Voltage

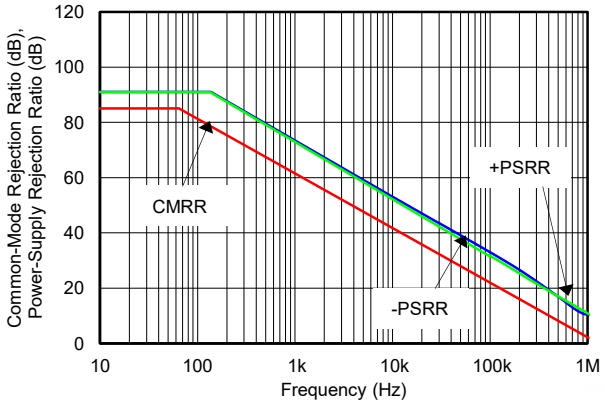


Figure 5. CMRR and PSRR vs Frequency (Referred-to-Input)

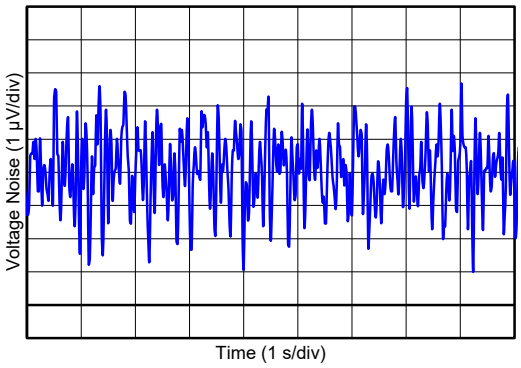


Figure 6. 0.1-Hz to 10-Hz Input Voltage Noise

Typical Characteristics (continued)

At T_A = 25°C, V_S = 5 V, R_L = 10 kΩ connected to V_S / 2, and V_{CM} = V_{OUT} = V_S / 2, unless otherwise noted.

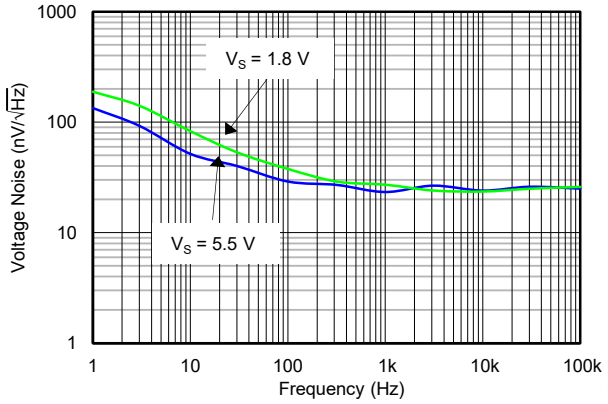


Figure 7. Input Voltage Noise Spectral Density vs Frequency

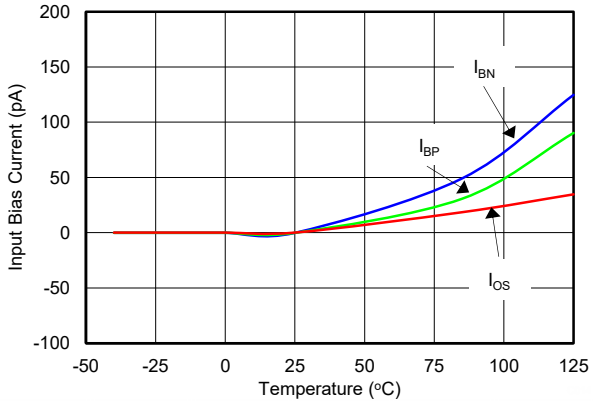


Figure 8. Input Bias and Offset Current vs Temperature

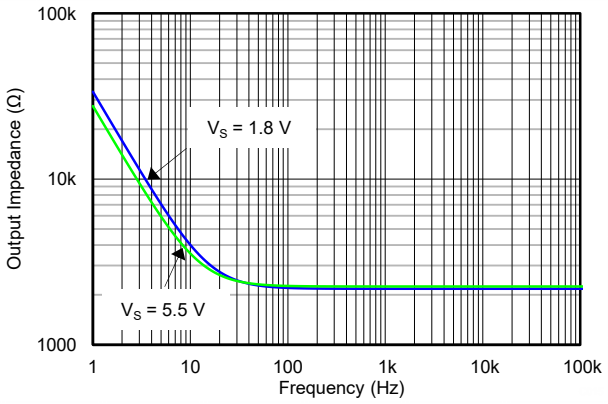


Figure 9. Open-Loop Output Impedance vs Frequency

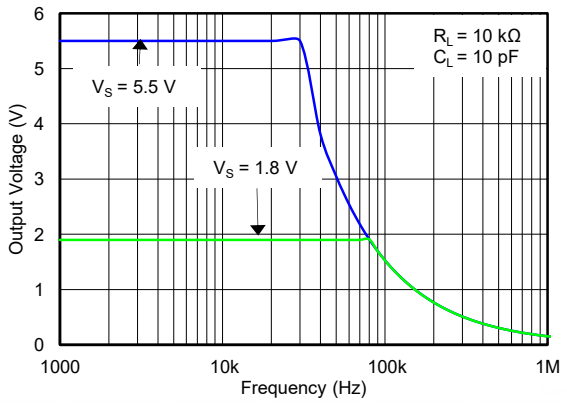


Figure 10. Maximum Output Voltage vs Frequency and Supply Voltage

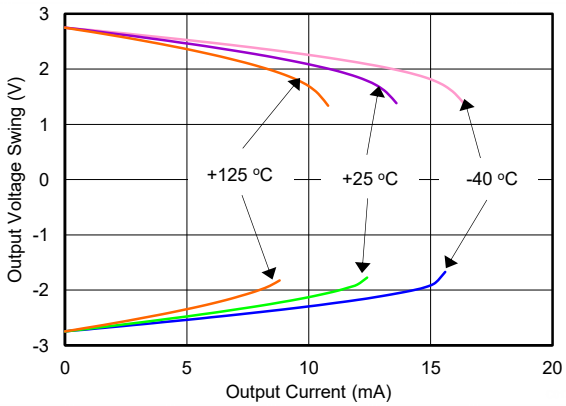


Figure 11. Output Voltage Swing vs Output Current (Over Temperature)

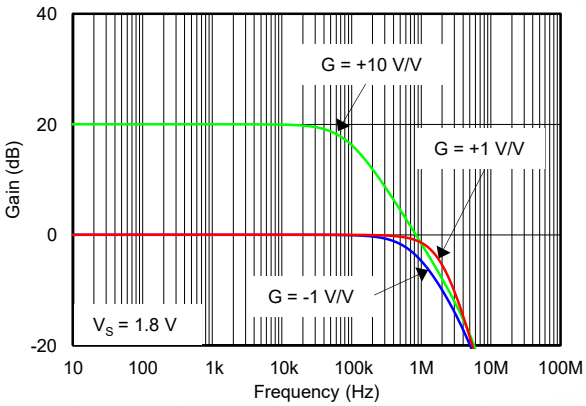


Figure 12. Closed-Loop Gain vs Frequency (Minimum Supply)

Typical Characteristics (continued)

At T_A = 25°C, V_S = 5 V, R_L = 10 kΩ connected to V_S / 2, and V_{CM} = V_{OUT} = V_S / 2, unless otherwise noted.

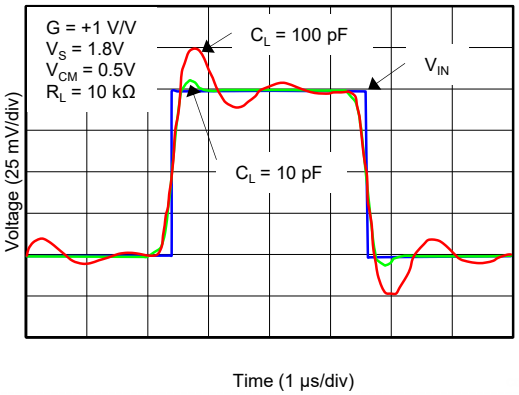


Figure 13. Small-Signal Pulse Response (Minimum Supply)

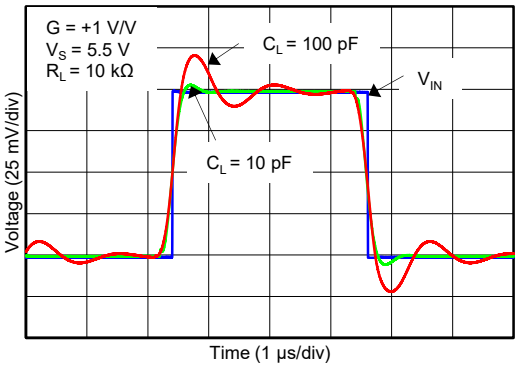


Figure 14. Small-Signal Pulse Response (Maximum Supply)

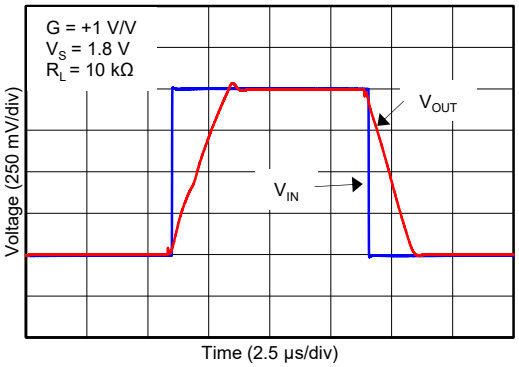


Figure 15. Large-Signal Pulse Response (Minimum Supply)

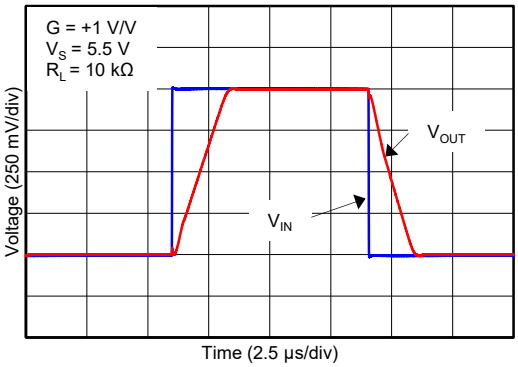


Figure 16. Large-Signal Pulse Response (Maximum Supply)

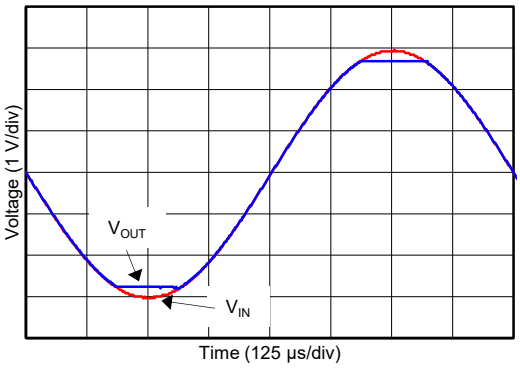


Figure 17. No Phase Reversal

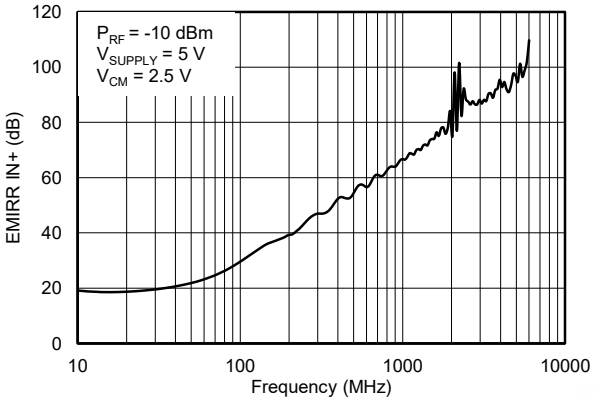


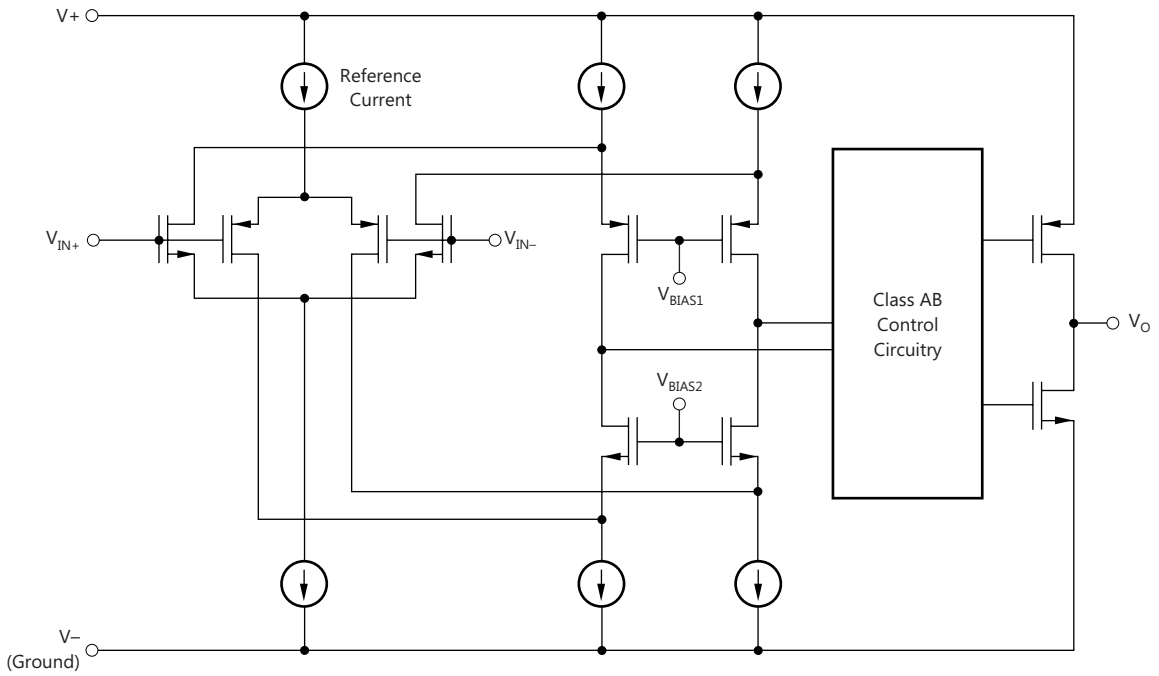
Figure 18. EMIRR IN+ vs Frequency

8 Detailed Description

8.1 Overview

The TLVx313 family of operational amplifiers are general-purpose devices that are ideal for a wide range of portable, low-cost applications. Rail-to-rail input and output swings, low quiescent current, and wide dynamic range make the op amps well-suited for driving sampling analog-to-digital converters (ADCs) as well as other single-supply applications.

8.2 Functional Block Diagram



8.3 Feature Description

8.3.1 Operating Voltage

The TLV313 series is fully specified and tested from 1.8 V to 5.5 V (±0.9 V to ±2.75 V). Parameters that vary with supply voltage are illustrated in the *Typical Characteristics* section.

8.3.2 Rail-to-Rail Input

The input common-mode voltage range of the TLV313 series extends 200 mV beyond the supply rails. This performance is achieved with a complementary input stage: an N-channel input differential pair in parallel with a P-channel differential pair, as shown in the *Functional Block Diagram* section. The N-channel pair is active for input voltages close to the positive rail, typically (V+) – 1.3 V to 200 mV above the positive supply, while the P-channel pair is on for inputs from 200 mV below the negative supply to approximately (V+) – 1.3 V. There is a small transition region, typically (V+) – 1.4 V to (V+) – 1.2 V, in which both pairs are on. This 200-mV transition region may vary up to 300 mV with process variation. Thus, the transition region (both stages on) may range from (V+) – 1.7 V to (V+) – 1.5 V on the low end, up to (V+) – 1.1 V to (V+) – 0.9 V on the high end. Within this transition region, PSRR, CMRR, offset voltage, offset drift, and THD may be degraded compared to device operation outside this region.

8.3.3 Rail-to-Rail Output

Designed as a micro-power, low-noise operational amplifier, the TLV313 device delivers a robust output drive capability. A class AB output stage with common-source transistors is used to achieve full rail-to-rail output swing capability. For resistive loads up to 100 kΩ, the output swings typically to within 5 mV of either supply rail regardless of the power-supply voltage applied. Different load conditions change the ability of the amplifier to swing close to the rails, as shown in Figure 12.

8.3.4 Common-Mode Rejection Ratio (CMRR)

CMRR for the TLV313 device is specified in several ways so the best match for a given application may be used; see the *Electrical Characteristics*. First, the CMRR of the device in the common-mode range below the transition region [V_{CM} < (V+) – 1.3 V] is given. This specification is the best indicator of the capability of the device when the application requires use of one of the differential input pairs. Second, the CMRR over the entire common-mode range is specified at (V_{CM} = –0.2 V to 5.7 V). This last value includes the variations seen through the transition region, as shown in Figure 4.

8.3.5 Capacitive Load and Stability

The TLV313 device is designed to be used in applications where driving a capacitive load is required. As with all op amps, there may be specific instances where the TLV313 device may become unstable. The particular op amp circuit configuration, layout, gain, and output loading are some of the factors to consider when establishing whether or not an amplifier is stable in operation. An op amp in the unity-gain (+1-V/V) buffer configuration that drives a capacitive load exhibits a greater tendency to be unstable than an amplifier operated at a higher noise gain. The capacitive load, in conjunction with the op amp output resistance, creates a pole within the feedback loop that degrades the phase margin. The degradation of the phase margin increases as the capacitive loading increases. When operating in the unity-gain configuration, the TLV313 device remains stable with a pure capacitive load up to approximately 1 nF. The equivalent series resistance (ESR) of some capacitors (C_L greater than 1 μF) is sufficient to alter the phase characteristics in the feedback loop such that the amplifier remains stable. Increasing the amplifier closed-loop gain allows the amplifier to drive increasingly larger capacitance. This increased capability is evident when observing the overshoot response of the amplifier at higher voltage gains.

Feature Description (continued)

One technique for increasing the capacitive load drive capability of the amplifier when it operates in a unity-gain configuration is to insert a small resistor, typically 10 Ω to 20 Ω, in series with the output, as shown in Figure 19. This resistor significantly reduces the overshoot and ringing associated with large capacitive loads. One possible problem with this technique is that a voltage divider is created with the added series resistor and any resistor connected in parallel with the capacitive load. The voltage divider introduces a gain error at the output that reduces the output swing.

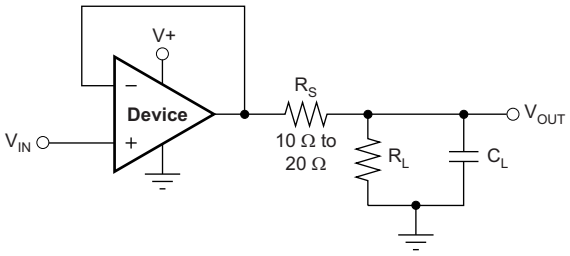


Figure 19. Improving Capacitive Load Drive

8.3.6 EMI Susceptibility and Input Filtering

Operational amplifiers vary with regard to the susceptibility of the device to electromagnetic interference (EMI). If conducted EMI enters the op amp, the dc offset observed at the amplifier output may shift from the nominal value while EMI is present. This shift is a result of signal rectification associated with the internal semiconductor junctions. While all op amp pin functions may be affected by EMI, the signal input pins are likely to be the most susceptible. The TLV313 family incorporates an internal input low-pass filter that reduces the amplifiers response to EMI. Both common-mode and differential mode filtering are provided by this filter. The filter is designed for a cutoff frequency of approximately 35 MHz (–3 dB), with a roll-off of 20 dB per decade.

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 EMI rejection ratio (EMIRR) metric allows op amps to be directly compared by the EMI immunity. Figure 18 illustrates the results of this testing on the TLV313 family. Detailed information may be found in *EMI Rejection Ratio of Operational Amplifiers* (SBOA128), available for download from www.ti.com.

8.4 Device Functional Modes

The TLV313 devices have a single functional mode. The devices are powered on as long as the power-supply voltage is between 1.8 V (±0.9 V) and 5.5 V (±2.75 V).

9 Application and Implementation

NOTE

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

9.1 Application Information

The TLVx313 devices are a family of low-power, rail-to-rail input and output operational amplifiers specifically designed for portable applications. The devices operate from 1.8 V to 5.5 V, are unity-gain stable, and are suitable for a wide range of general-purpose applications. The class AB output stage is capable of driving ≤ 10-kΩ loads connected to any point between V+ and ground. The input common-mode voltage range includes both rails, and allows the TLV313 family to be used in virtually any single-supply application.

9.2 Typical Application

A typical application for an operational amplifier is an inverting amplifier, as shown in Figure 20. An inverting amplifier takes a positive voltage on the input and outputs a signal inverted to the input, making a negative voltage of the same magnitude. In the same manner, the amplifier also makes negative input voltages positive on the output. In addition, amplification may be added by selecting the input resistor R_I and the feedback resistor R_F.

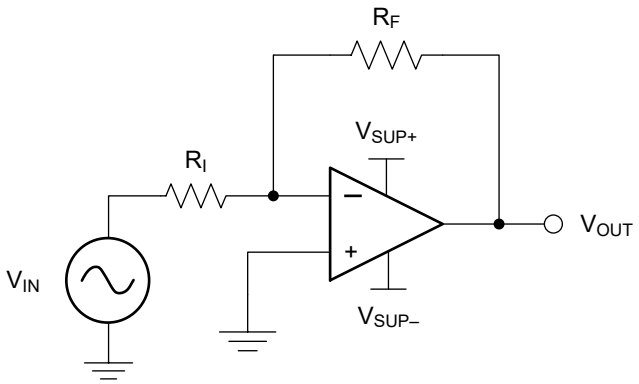


Figure 20. Application Schematic

9.2.1 Design Requirements

The supply voltage must be chosen to be larger than the input voltage range and the desired output range. The limits of the input common-mode range (V_{CM}) and the output voltage swing to the rails (V_O) must also be considered. For instance, this application scales a signal of ±0.5 V (1 V) to ±1.8 V (3.6 V). Setting the supply at ±2.5 V is sufficient to accommodate this application.

9.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using Equation 1 and Equation 2:

$$A_V \quad \frac{V_{OUT}}{V_{IN}} \tag{1}$$

$$A_V \quad \frac{1.8}{-0.5} \quad -3.6 \tag{2}$$

Typical Application (continued)

When the desired gain is determined, choose a value for R_I or R_F. Choosing a value in the kilohm range is desirable for general-purpose applications because the amplifier circuit uses currents in the milliamp range. This milliamp current range ensures the device does not draw too much current. The trade-off is that very large resistors (100s of kilohms) draw the smallest current but generate the highest noise. Small resistors (100s of ohms) generate low noise but draw high current. This example uses 10 kΩ for R_I, meaning 36 kΩ is used for R_F. The values are determined by Equation 3:

$$A_V = -\frac{R_F}{R_I} \tag{3}$$

9.2.3 Application Curve

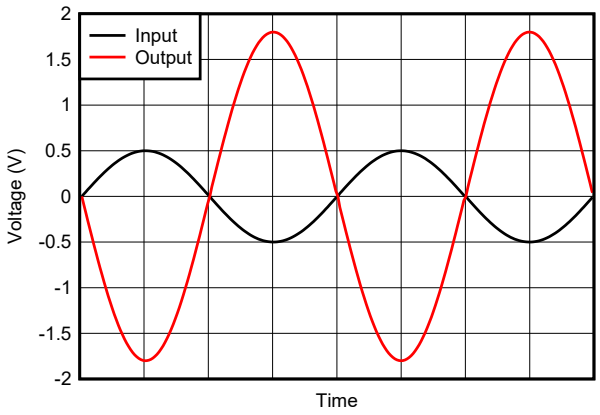


Figure 21. Inverting Amplifier Input and Output

9.3 System Examples

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. The simplest way to establish this limited bandwidth is to place an RC filter at the noninverting terminal of the amplifier, as shown in Figure 22.

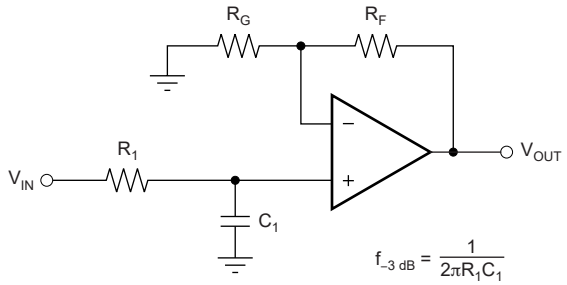


Figure 22. Single-Pole Low-Pass Filter

System Examples (continued)

If even more attenuation is needed, a multiple pole filter is required. The Sallen-Key filter may be used for this task, as shown in Figure 23. For best results, the amplifier must have a bandwidth that is eight to 10 times the filter frequency bandwidth. Failure to follow this guideline may result in phase shift of the amplifier.

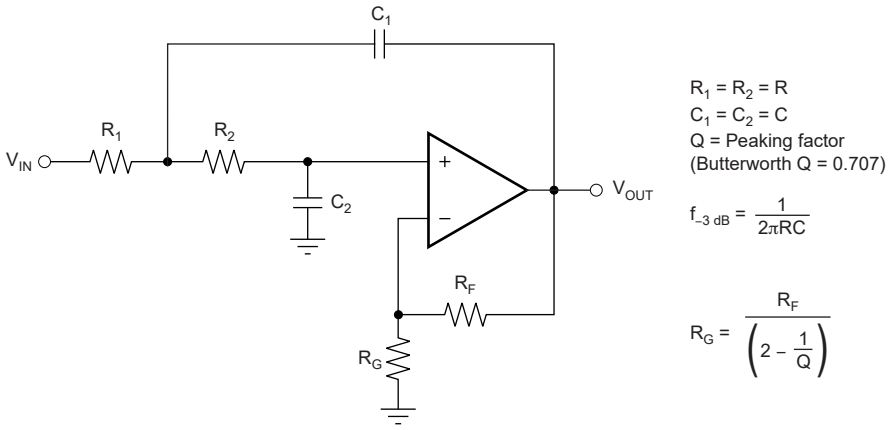


Figure 23. Two-Pole, Low-Pass, Sallen-Key Filter

10 Power Supply Recommendations

The TLVx313 family is specified for operation from 1.8 V to 5.5 V (±0.9 V to ±2.75 V); many specifications apply from –40°C to +125°C. The *Typical Characteristics* section presents parameters that may exhibit significant variance with regard to operating voltage or temperature.

CAUTION

Supply voltages larger than 7 V can permanently damage the device (see the *Absolute Maximum Ratings* table).

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

10.1 Input and ESD Protection

The TLV313 family incorporates internal electrostatic discharge (ESD) protection circuits on all pins. In the case of input and output pins, this protection primarily consists of current-steering diodes connected between the input and power-supply pins. The ESD protection diodes also provide in-circuit, input overdrive protection, as long as the current is limited to 10 mA as stated in the *Absolute Maximum Ratings*. Figure 24 shows how a series input resistor may 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.

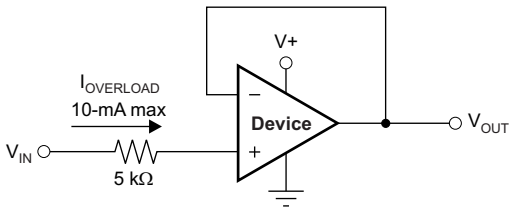


Figure 24. Input Current Protection

11 Layout

11.1 Layout Guidelines

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

- Noise may propagate into analog circuitry through the power pins of the circuit and the operational amplifier. Use bypass capacitors 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 the 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. Take care to physically separate digital and analog grounds, paying attention to the flow of the ground current. For more detailed information, refer to *Circuit Board Layout Techniques*, (SLOA089).
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If the traces cannot be kept separate, crossing the sensitive trace perpendicularly is much better than crossing in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keep R_F and R_G close to the inverting input in order to minimize parasitic capacitance, as shown in Figure 25.
- 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.

11.2 Layout Example

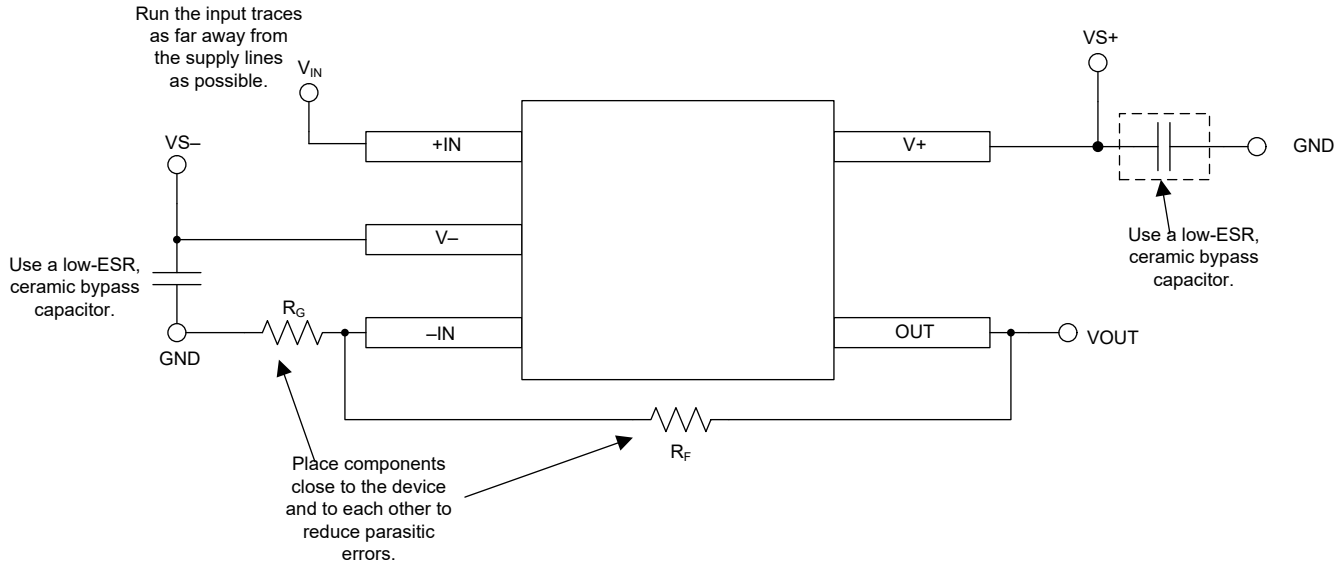


Figure 25. Operational Amplifier Board Layout for Noninverting Configuration

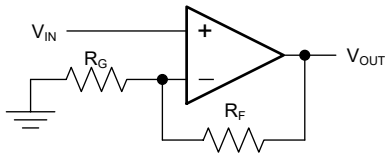


Figure 26. Schematic Representation of Figure 25

12 Device and Documentation Support

12.1 Documentation Support

12.1.1 Related Documentation

For related documentation, see the following:

- *EMI Rejection Ratio of Operational Amplifiers*.
- *Circuit Board Layout Techniques*.

12.2 Receiving Notification of Documentation Updates

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

12.3 Related Links

Table 2 lists quick access links. Categories include technical documents, support and community resources, tools and software, and quick access to sample or buy.

Table 2. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TLV313	Click here	Click here	Click here	Click here	Click here
TLV2313	Click here	Click here	Click here	Click here	Click here
TLV4313	Click here	Click here	Click here	Click here	Click here

12.4 Community Resources

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

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

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

12.5 Trademarks

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

12.6 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.

12.7 Glossary

SLYZ022 — *TI Glossary*.

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

13 Mechanical, Packaging, and Orderable Information

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

PACKAGE OPTION ADDENDUM

27-Jul-2022

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
TLV2313IDGKR	ACTIVE	VSSOP	DGK	8	2500	RoHS & Green	NIPDAUAG | SN	Level-2-260C-1 YEAR	-40 to 125	13AV	Samples
TLV2313IDGKT	ACTIVE	VSSOP	DGK	8	250	RoHS & Green	NIPDAUAG | SN	Level-2-260C-1 YEAR	-40 to 125	13AV	Samples
TLV2313IDR	ACTIVE	SOIC	D	8	2500	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	V2313	Samples
TLV313IDBVR	ACTIVE	SOT-23	DBV	5	3000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	15F2	Samples
TLV313IDBVT	ACTIVE	SOT-23	DBV	5	250	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	15F2	Samples
TLV313IDCKR	ACTIVE	SC70	DCK	5	3000	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	14E	Samples
TLV313IDCKT	ACTIVE	SC70	DCK	5	250	RoHS & Green	NIPDAU	Level-1-260C-UNLIM	-40 to 125	14E	Samples
TLV4313IPWR	ACTIVE	TSSOP	PW	14	2000	RoHS & Green	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	TLV4313	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.

OTHER QUALIFIED VERSIONS OF TLV2313, TLV313 :

- Automotive : TLV2313-Q1, TLV313-Q1

NOTE: Qualified Version Definitions:

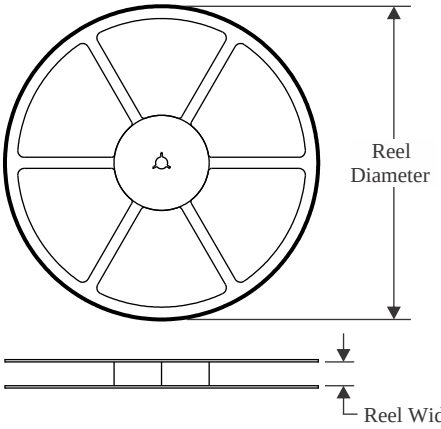
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

PACKAGE MATERIALS INFORMATION

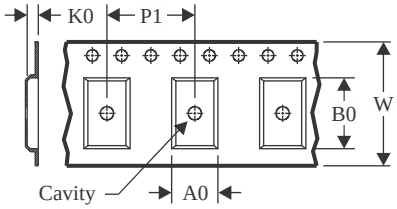
9-Aug-2022

TAPE AND REEL INFORMATION

REEL DIMENSIONS

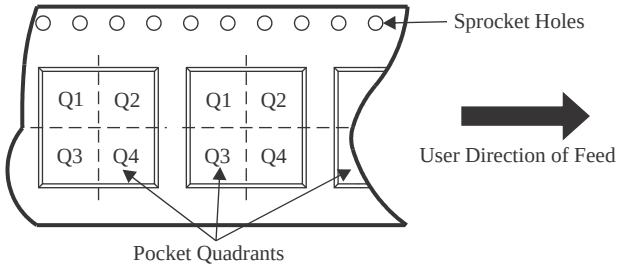


TAPE DIMENSIONS



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

QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



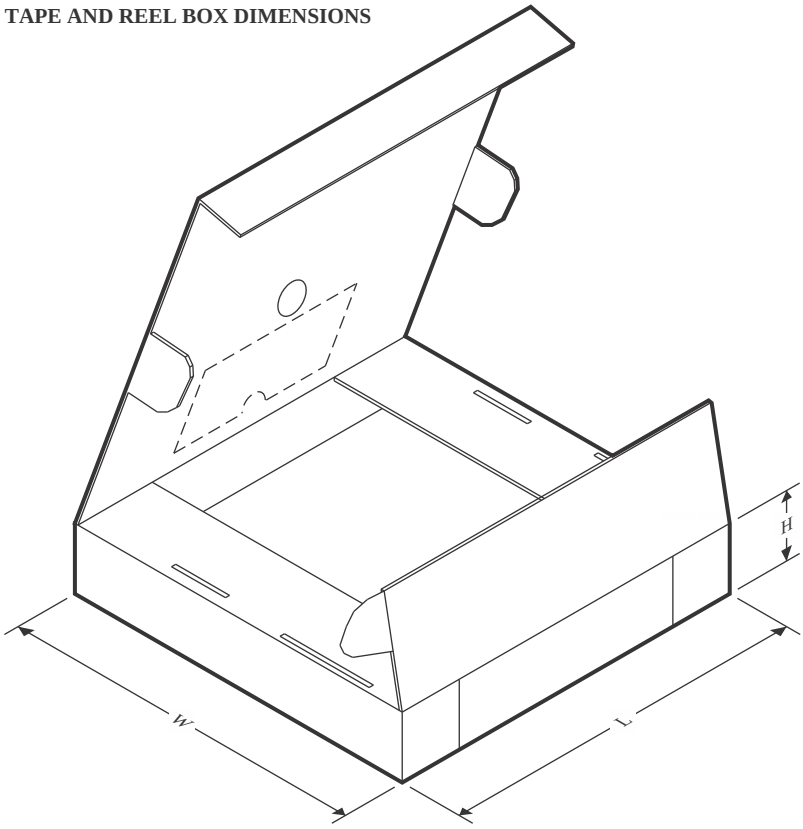
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV2313IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV2313IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV2313IDGKT	VSSOP	DGK	8	250	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV2313IDGKT	VSSOP	DGK	8	250	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV2313IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV313IDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
TLV313IDBVT	SOT-23	DBV	5	250	178.0	9.0	3.3	3.2	1.4	4.0	8.0	Q3
TLV313IDCKR	SC70	DCK	5	3000	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
TLV313IDCKT	SC70	DCK	5	250	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
TLV4313IPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1

PACKAGE MATERIALS INFORMATION

9-Aug-2022

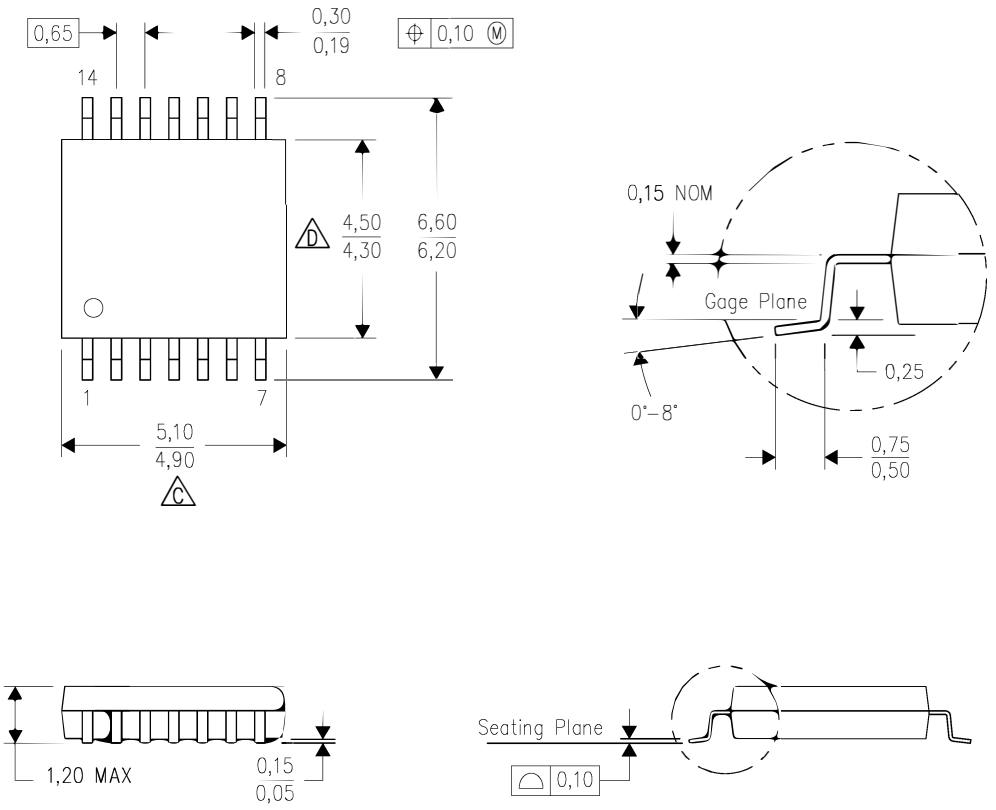
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV2313IDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
TLV2313IDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
TLV2313IDGKT	VSSOP	DGK	8	250	366.0	364.0	50.0
TLV2313IDGKT	VSSOP	DGK	8	250	366.0	364.0	50.0
TLV2313IDR	SOIC	D	8	2500	340.5	336.1	25.0
TLV313IDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
TLV313IDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
TLV313IDCKR	SC70	DCK	5	3000	180.0	180.0	18.0
TLV313IDCKT	SC70	DCK	5	250	180.0	180.0	18.0
TLV4313IPWR	TSSOP	PW	14	2000	356.0	356.0	35.0

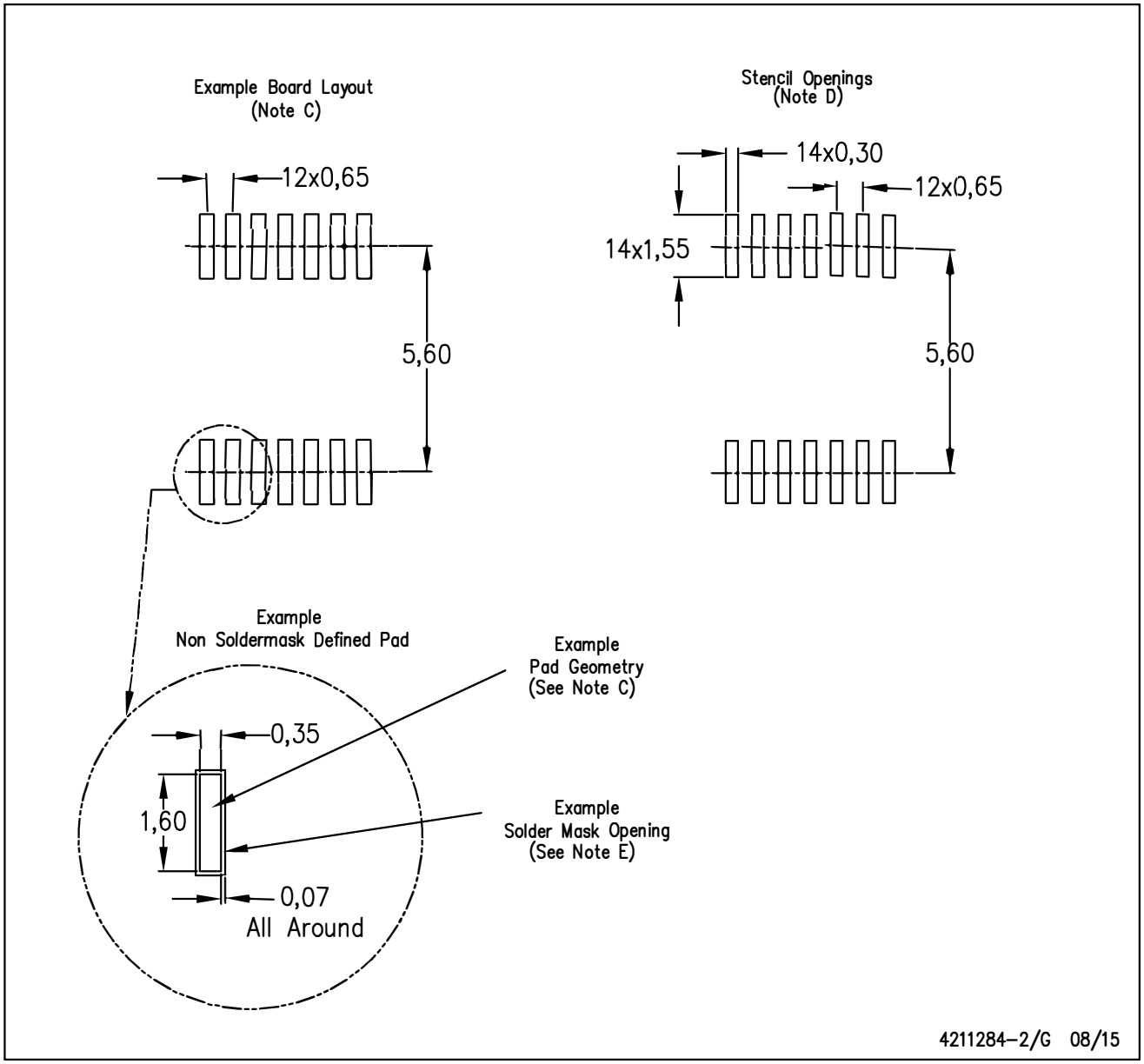
PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



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



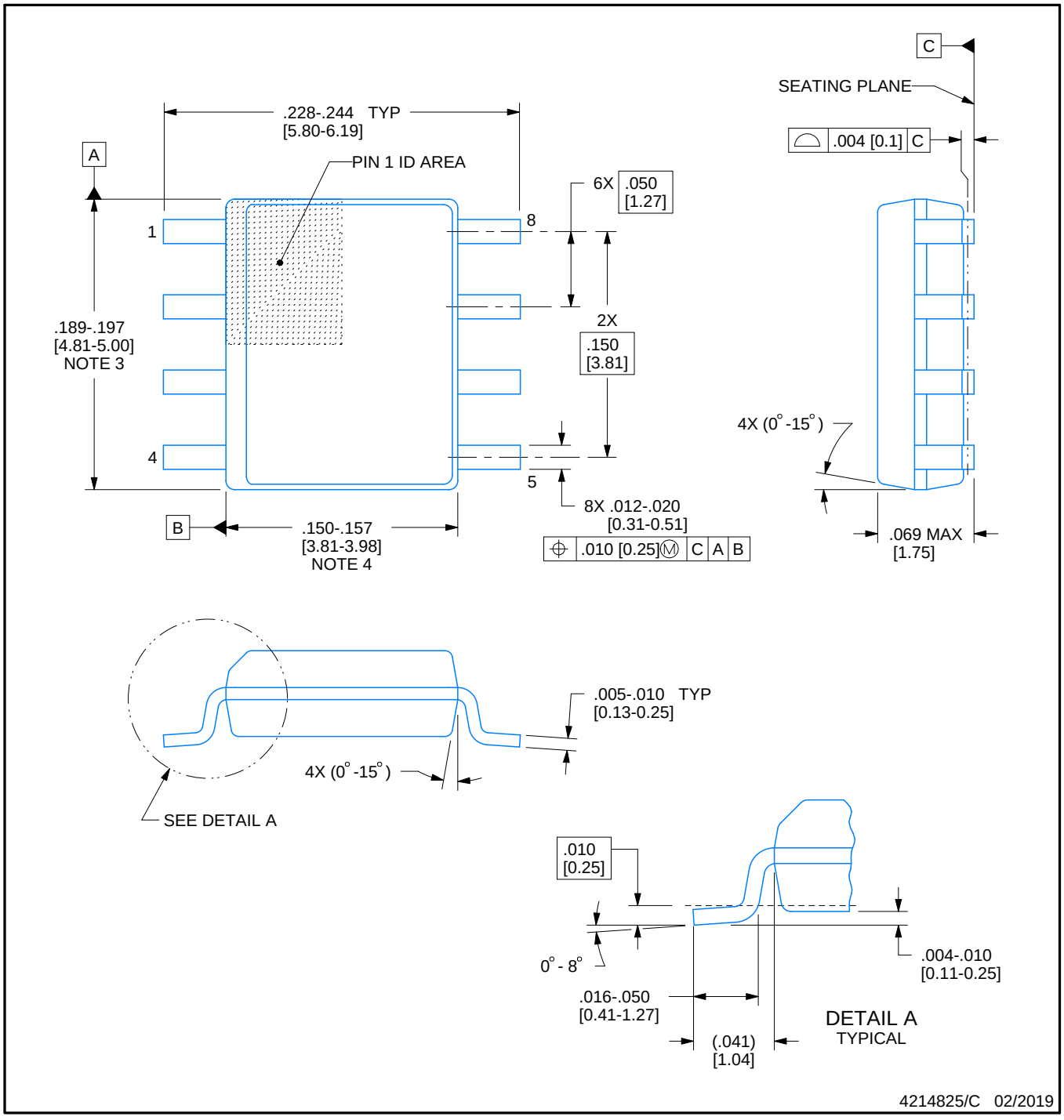
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact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

PACKAGE OUTLINE

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



NOTES:

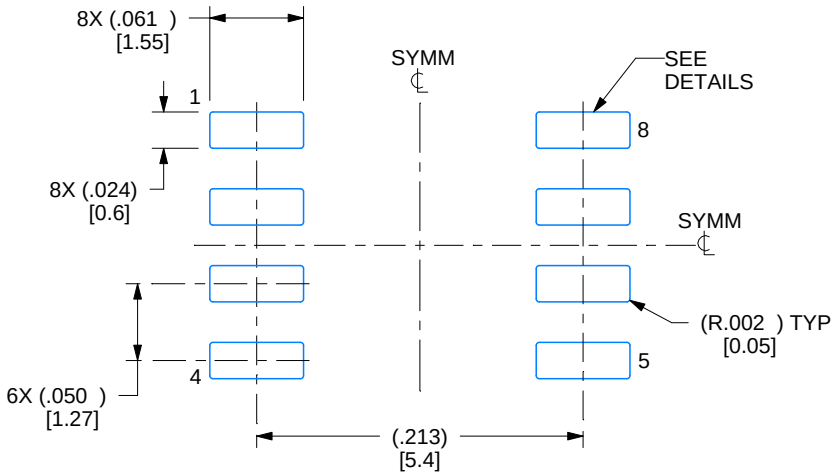
1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate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

EXAMPLE BOARD LAYOUT

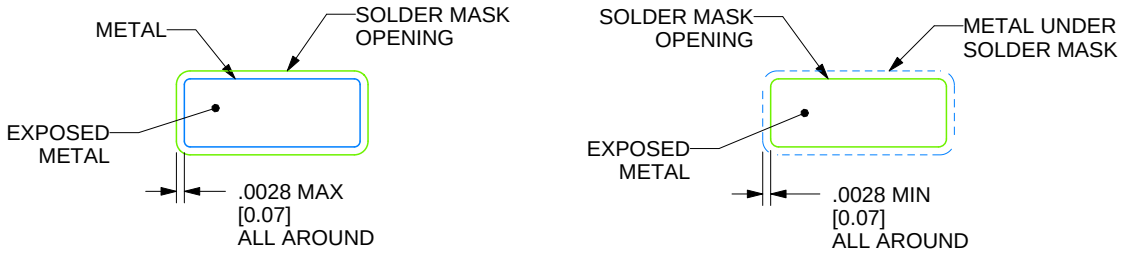
D0008A

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)

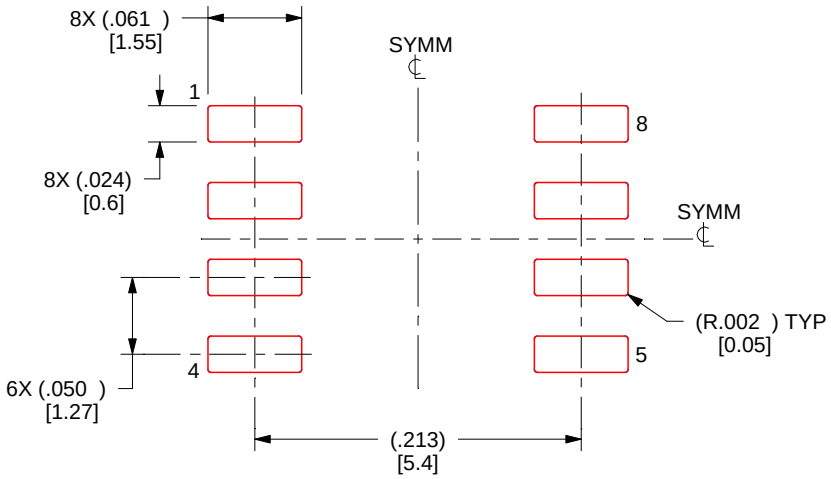
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

D0008A

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



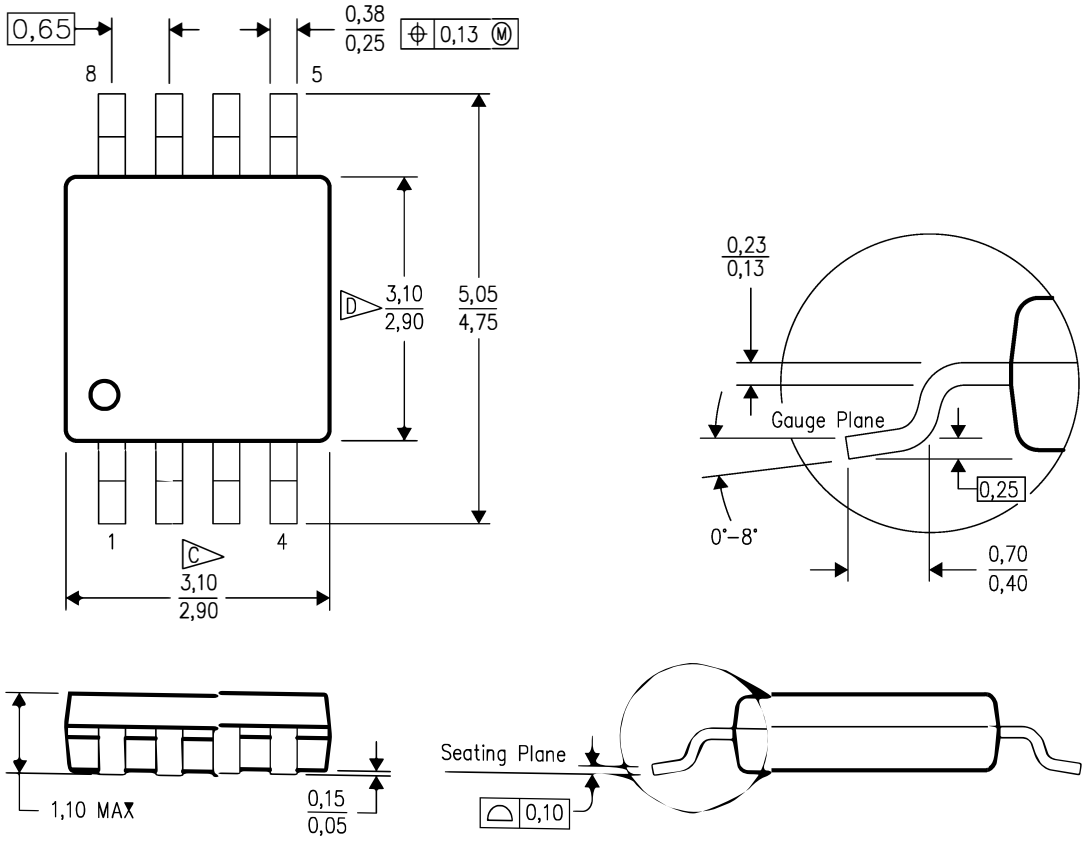
SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

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.

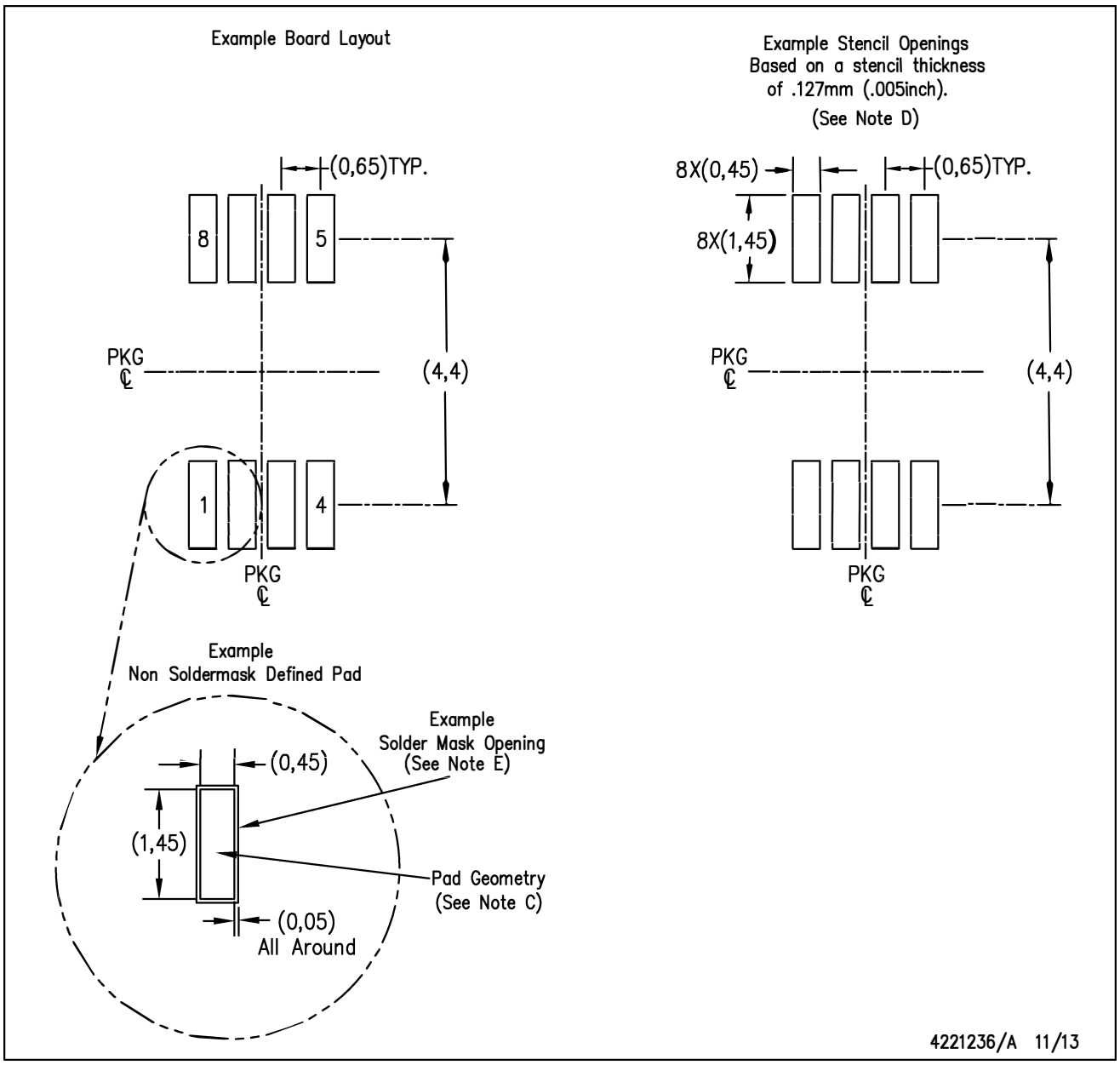
DGK (S–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



4073329/E 05/06

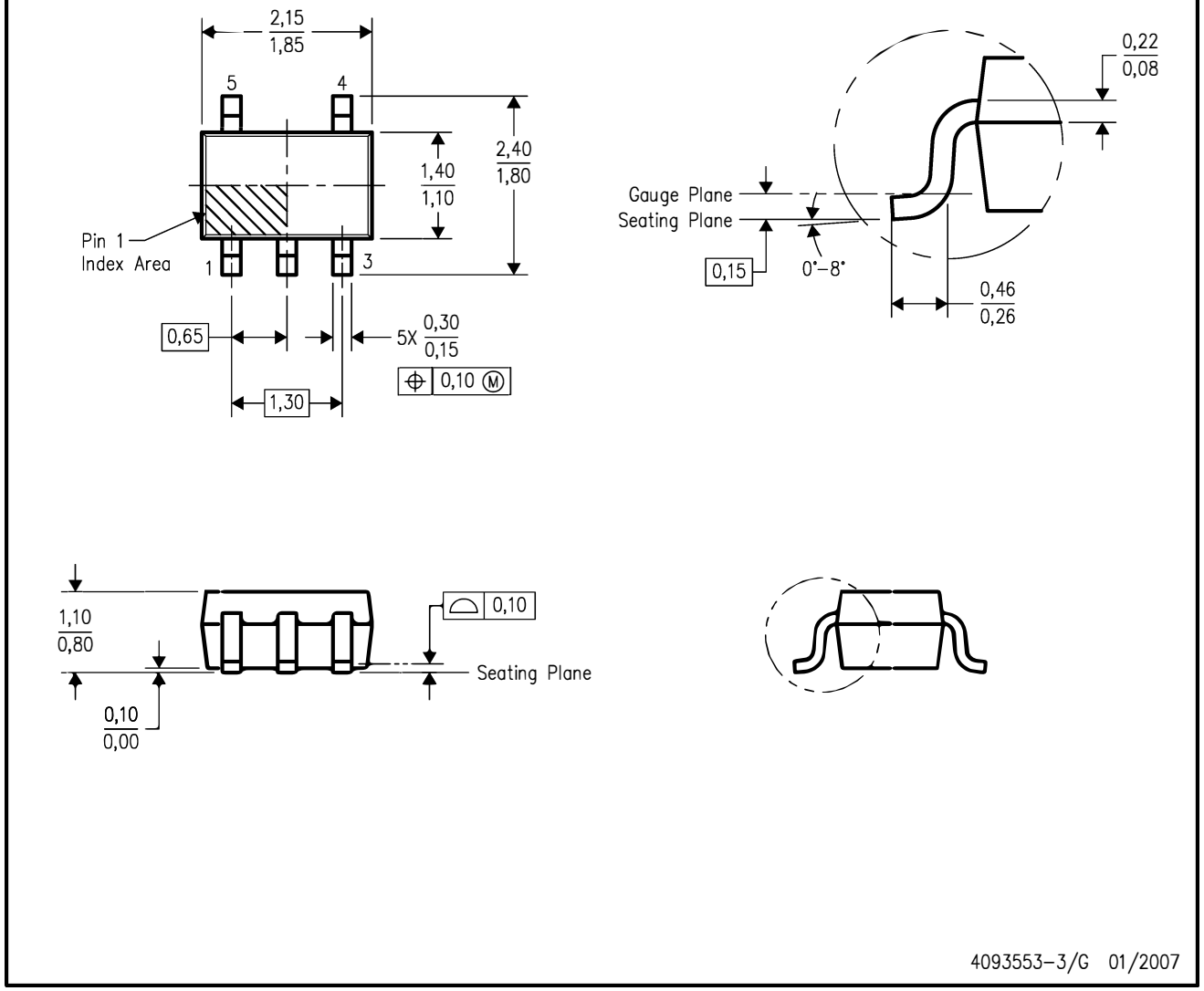
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead 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



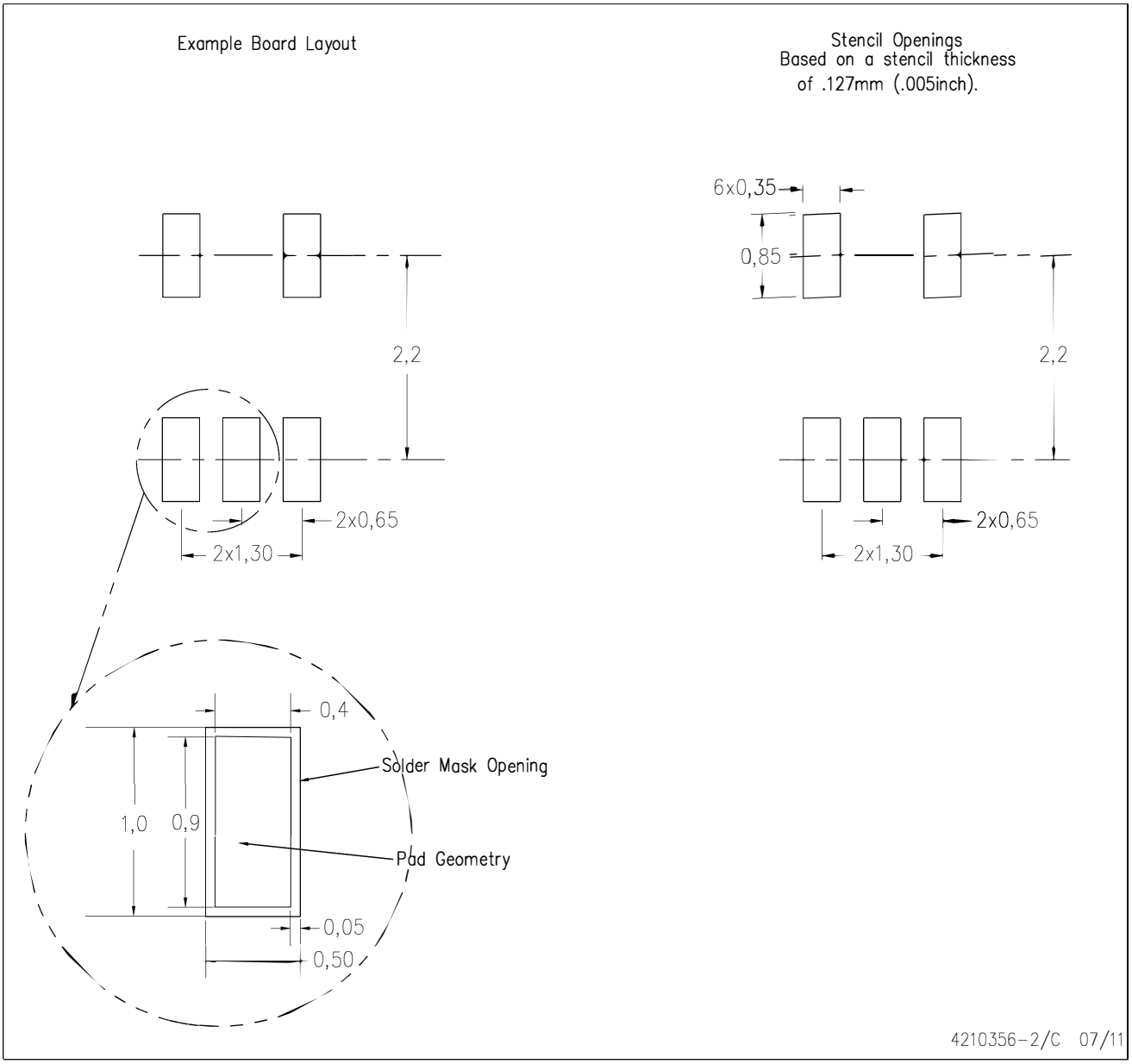
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact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

DCK (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
D. Falls within JEDEC MO–203 variation AA.

DCK (R–PDSO–G5) PLASTIC SMALL OUTLINE



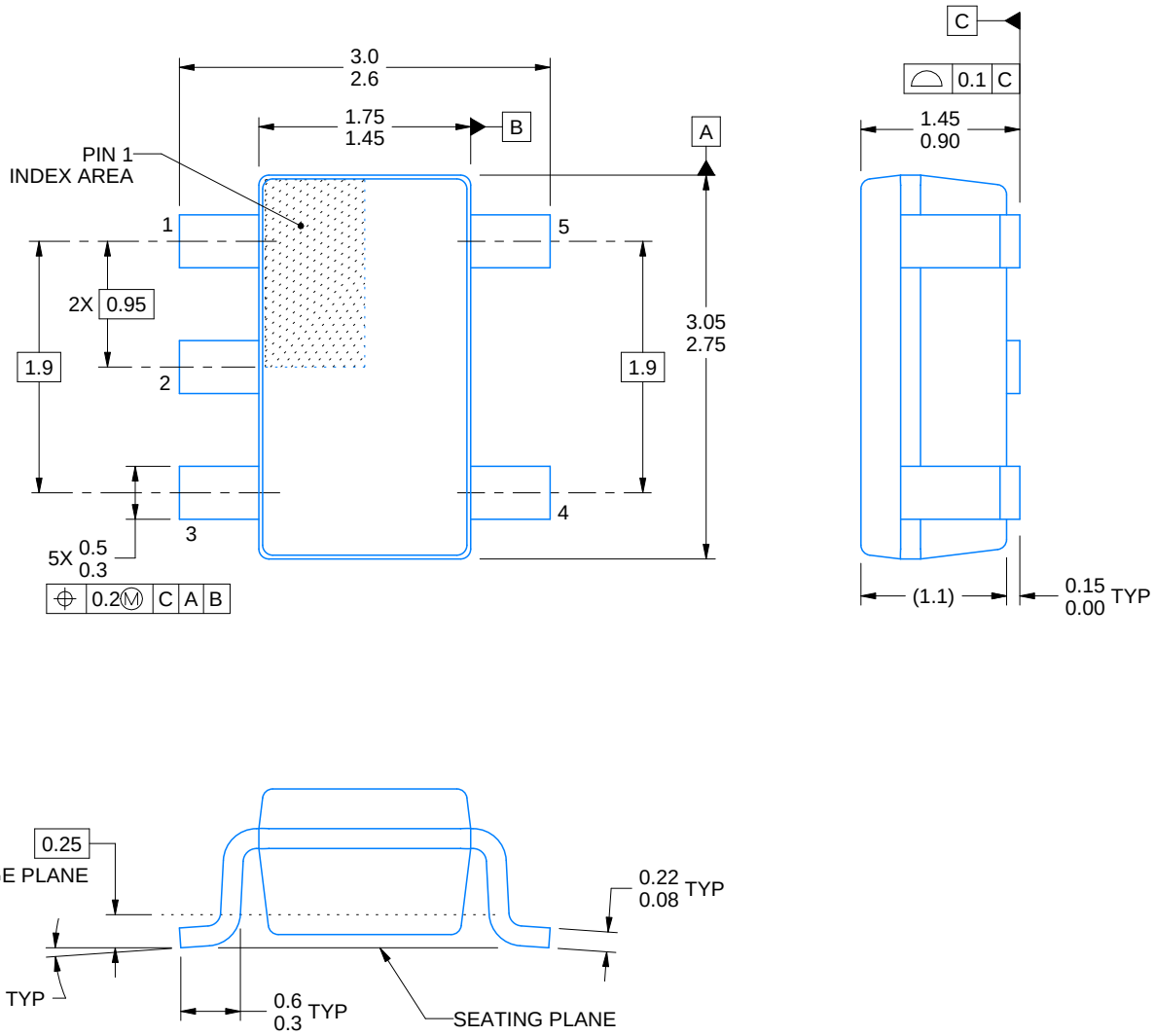
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Customers should place a note on the circuit board fabrication drawing not to alter the center solder mask defined pad.
D. Publication IPC–7351 is recommended for alternate designs.
E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Example stencil design based on a 50% volumetric metal load solder paste. Refer to IPC–7525 for other stencil recommendations.

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



4214839/F 06/2021

NOTES:

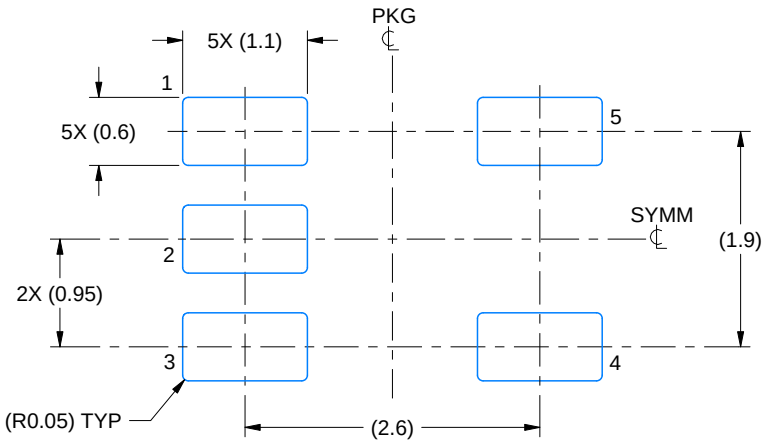
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold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

EXAMPLE BOARD LAYOUT

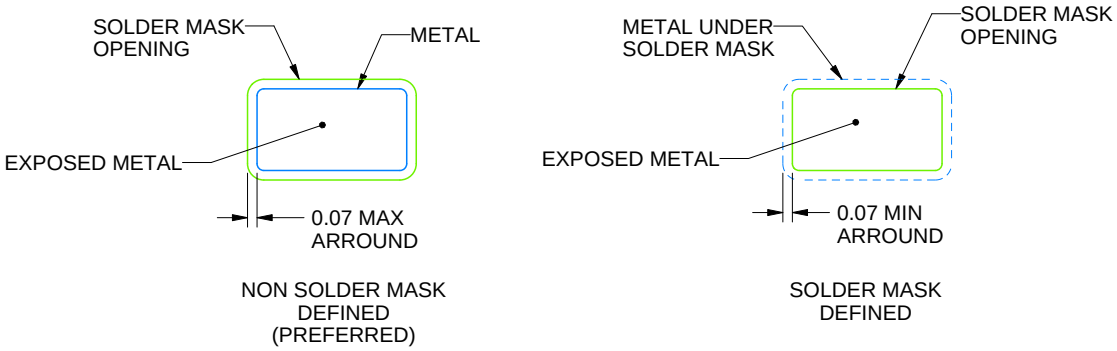
DBV0005A

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)

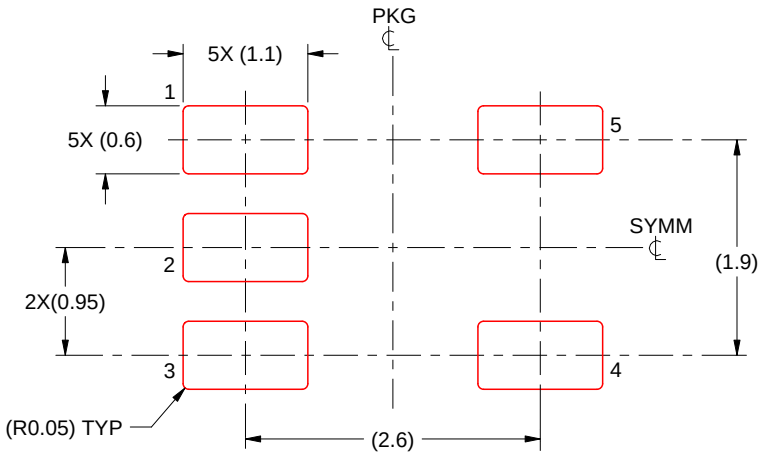
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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.