TLV906xS 10-MHz, RRIO, CMOS Operational Amplifiers for Cost-Sensitive Systems

1 Features

- Rail-to-Rail Input and Output
- Low Input Offset Voltage: ±0.3 mV
- Unity-Gain Bandwidth: 10 MHz
- Low Broadband Noise: 10 nV/√Hz
- Low Input Bias Current: 0.5 pA
- Low Quiescent Current: 538 µA
- Unity-Gain Stable
- Internal RFI and EMI Filter
- Operational at Supply Voltages as Low as 1.8 V
- Easier to Stabilize With Higher Capacitive Load Due to Resistive Open-Loop Output Impedance
- Shutdown Version: TLV906xS
- Extended Temperature Range: –40°C to +125°C

2 Applications

- E-Bikes
- Smoke Detectors
- HVAC: Heating, Ventilating, and Air Conditioning
- Motor Control: AC Induction
- Refrigerators
- Wearable Devices
- Laptop Computers
- Washing Machines
- Sensor Signal Conditioning
- Power Modules
- Barcode Scanners
- Active Filters
- Low-Side Current Sensing

3 Description

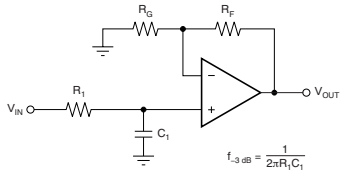
The TLV9061 (single), TLV9062 (dual), and TLV9064 (quad) are single-, dual-, and quad- low-voltage (1.8 V to 5.5 V) operational amplifiers (op amps) with rail-to-rail input- and output-swing capabilities. These devices are highly cost-effective solutions for applications where low-voltage operation, a small footprint, and high capacitive load drive are required. Although the capacitive load drive of the TLV906x is 100 pF, the resistive open-loop output impedance makes stabilizing with higher capacitive loads simpler. These op amps are designed specifically for low-voltage operation (1.8 V to 5.5 V) with performance specifications similar to the OPAx316 and TLVx316 devices.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TLV9061	SOT-23 (5)	1.60 mm × 2.90 mm
	SC70 (5)	1.25 mm × 2.00 mm
	SOT553 (5)	1.65 mm × 1.20 mm
	X2SON (5)	0.80 mm × 0.80 mm
TLV9061S	SOT-23 (6)	1.60 mm × 2.90 mm
TLV9062	SOIC (8)	3.91 mm × 4.90 mm
	TSSOP (8)	3.00 mm × 4.40 mm
	VSSOP (8)	3.00 mm × 3.00 mm
	WSON (8)	2.00 mm × 2.00 mm
TLV9062S	VSSOP (10)	3.00 mm × 3.00 mm
	X2QFN (10)	1.50 mm × 2.00 mm
TLV9064	SOIC (14)	8.65 mm × 3.91 mm
	TSSOP (14)	4.40 mm × 5.00 mm
	WQFN (16)	3.00 mm × 3.00 mm
	WQFN (14)	2.00 mm × 2.00 mm
TLV9064S	WQFN (16)	3.00 mm × 3.00 mm

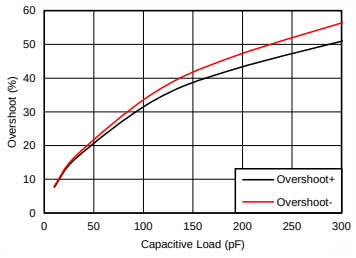
(1) For all available packages, see the orderable addendum at the end of the data sheet.

Single-Pole, Low-Pass Filter



$$\frac{V_{OUT}}{V_{IN}} = \left(1 + \frac{R_F}{R_G}\right)\left(\frac{1}{1 + sR_1C_1}\right)$$

Small-Signal Overshoot vs Load Capacitance



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

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4 Revision History

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

Changes from Revision E (July 2018) to Revision F — **Page**

- Deleted Shutdown part numbers from datasheet header ... 1
- Deleted X2QFN (10) package from TLV9062 Device Information table ... 1
- Added references to shutdown part numbers in Description section ... 4
- Changed TLV906xS series to TLV906xS family throughout datasheet ... 4
- Added Shutdown devices to Device Comparison Table ... 4
- Changed pin namings for all pinout drawings to reflect updated nomenclature ... 5
- Added TLV9061S Thermal Information Table ... 11
- Added TLV9064S Thermal Information Table ... 12
- Deleted Partial Shutdown Amplifer Enable Time ... 14
- Added clarification on selecting resistors for a current sensing application in the Typical Applications Section ... 24
- Changed wording of third bullet in Layout Guidelines ... 28

Changes from Revision D (June 2018) to Revision E — **Page**

- Added TLV9061S device to *Device Information* table ... 1
- Added TLV9064S device to *Device Information* table ... 1
- Added RUC and RUG packages to the *Device Comparison* table ... 4
- Added TLV9061S DBV (SOT-23) pinout drawing to *Pin Configuration and Functions* section ... 6
- Added TLV9061S DBV (SOT-23) package pinout information to *Pin Functions: TLV9061S* table ... 6
- Added TLV9062S RUG (VSSOP) package pinout drawing to *Pin Configuration and Functions* section ... 7
- Added TLV9062S RUG (VSSOP) package pinout information to *Pin Functions: TLV9062S* table ... 7
- Added TLV9064 RTE (WQFN) pinout drawing to *Pin Configuration and Functions* section ... 8
- Added TLV9064 RTE pinout information to *Pin Functions: TLV9064* table ... 8

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- Added TLV9064S RTE (WQFN) pinout drawing to *Pin Configuration and Functions* section 9

Changes from Revision C (March 2018) to Revision D **Page**

- Added shutdown suffix to "TLV906x" to document title 1
- Added "Shutdown Version" bullet to *Features* list 1
- Added TLV9062S device to *Device Information* table 1
- Added shutdown text to *Description (continued)* section 4
- Added "(V_S = [V+] – [V–]) supply voltage parameter in *Absolute Maximum Ratings* table 10
- Added "input voltage range" and "output voltage range" parameters and values to *Recommended Operating Conditions* table 10
- Added shutdown pin recommended operating conditions in *Recommended Operating Conditions* table 10
- Added "T_A" symbol to "specified temperature" parameter to *Recommended Operating Conditions* table 10
- Added *Thermal Information: TLV9062S* thermal table data 12
- Added *Thermal Information: TLV9062S* thermal table data 12
- Added shutdown section to *Electrical Characteristics: V_S (Total Supply Voltage) = (V+) – (V–) = 1.8 V to 5.5 V* table 14
- Added *Shutdown Function* section 22
- Added *Typical Comparator Application* section 25

Changes from Revision B (October 2017) to Revision C **Page**

- Changed device status from Production Data/Mixed Status to Production Data 1
- Deleted package preview note from TLV9061 DPW (X2SON) package in *Device Information* table 1
- Deleted package preview note from TLV9061 DPW (X2SON) package pinout drawing 5
- Changed formatting of *ESD Ratings* table to show different results for all packages 10
- Deleted package preview note from DPW (X2SON) package in *Thermal Information: TLV9061* table 11
- Deleted package preview note from DPW (X2SON) package in *Thermal Information: TLV9061* table 11

Changes from Revision A (June 2017) to Revision B **Page**

- Added 8-pin PW package to *Pin Configuration and Functions* section 6
- Added DSG (WSON) package to *Thermal Information* table 11
- Added PW (TSSOP) to TLV9062 *Thermal Information* table 11
- Changed maximum input offset voltage value from ±1.6 mV to 2 mV 13
- Changed maximum input offset voltage value from ±1.5 to ±1.6 mV 13
- Changed minimum common-mode rejection ratio input voltage range from 86 dB to 80 dB 13
- Changed typical input current noise density value from 10 to 23 fA/$\sqrt{\text{Hz}}$ 13
- Changed THD + N test conditions from V_S = 5 V to V_S = 5.5 V 13
- Added V_{CM} = 2.5 V test condition to THD + N parameter in *Electrical Characteristics* table 13
- Added maximum output voltage swing value from 25 mV to 60 mV 13
- Changed maximum output voltage swing value from 15 mV to 20 mV 13

Changes from Original (March 2017) to Revision A **Page**

- Changed device status from Advance Information to Production Data 1

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5 Description (continued)

The TLV906xS devices include a shutdown mode that allow the amplifiers to switch into standby mode with typical current consumption less than 1 µA.

The TLV906xS family helps simplify system design, because the family is unity-gain stable, integrates the RFI and EMI rejection filter, and provides no phase reversal in overdrive condition.

Micro size packages, such as SOT-553 and WSON, are offered for all the channel variants (single, dual and quad), along with industry-standard packages, such as SOIC, MSOP, SOT-23 and TSSOP.

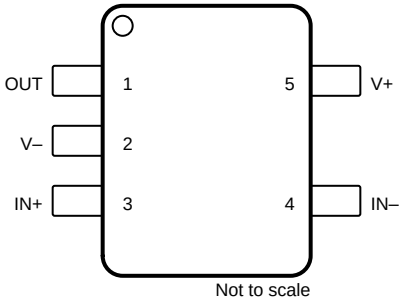
6 Device Comparison Table

DEVICE	NO. OF CHANNELS	PACKAGE LEADS											
		D	DBV	DCK	DGK	DGS	DPW	DRL	DSG	PW	RTE	RUC	RUG
TLV9061	1	8	5	5	—	—	5	5	—	—	—	—	—
TLV9061S	1	—	6	—	—	—	—	—	—	—	—	—	—
TLV9062	2	8	—	—	8	10	—	—	8	8	—	—	—
TLV9062S	2	—	—	—	—	10	—	—	—	—	—	—	10
TLV9064	4	14	—	—	—	—	—	—	—	14	16	14	—
TLV9064S	4	—	—	—	—	—	—	—	—	—	16	—	—

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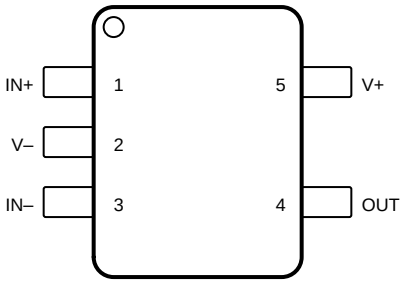
7 Pin Configuration and Functions

TLV9061 DBV and DRL Packages
5-Pin SOT-23 and SOT-553
Top View



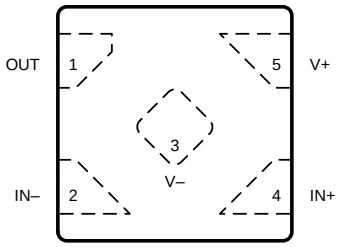
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TLV9061 DCK Package
5-Pin SC70
Top View



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TLV9061 DPW Package
5-Pin X2SON
Top View



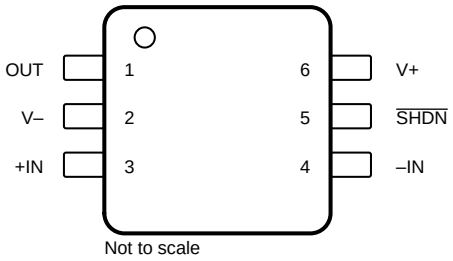
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Pin Functions: TLV9061

PIN				I/O	DESCRIPTION
NAME	NO.				
	SOT-23, SOT-553	SC70	X2SON		
IN–	4	3	2	I	Inverting input
IN+	3	1	4	I	Noninverting input
OUT	1	4	1	O	Output
V–	2	2	3	I or —	Negative (low) supply or ground (for single-supply operation)
V+	5	5	5	I	Positive (high) supply

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TLV9061S DBV Package
6-Pin SOT-23
Top View

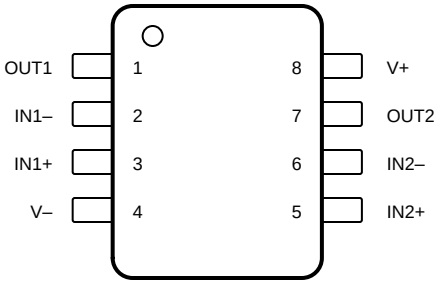


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Pin Functions: TLV9061S

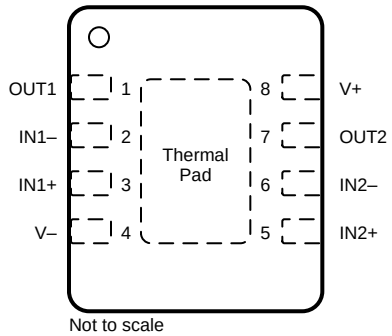
PIN		I/O	DESCRIPTION
NAME	NO.		
IN–	4	I	Inverting input
IN+	3	I	Noninverting input
OUT	1	O	Output
$\overline{\text{SHDN}}$	5	I	Shutdown active low
V–	2	I or —	Negative (low) supply or ground (for single-supply operation)
V+	6	I	Positive (high) supply

TLV9062 D, DGK, PW Packages
8-Pin SOIC, VSSOP, TSSOP
Top View



Not to scale

TLV9062 DSG Package
8-Pin WSON With Exposed Thermal Pad
Top View



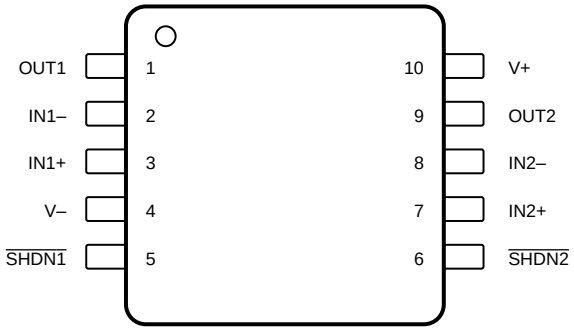
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Pin Functions: TLV9062

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

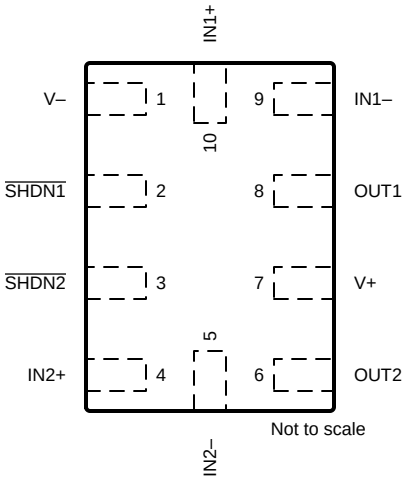
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TLV9062S DGS Package
10-Pin VSSOP
Top View



Not to scale

TLV9062S RUG Package
10-Pin X2QFN
Top View



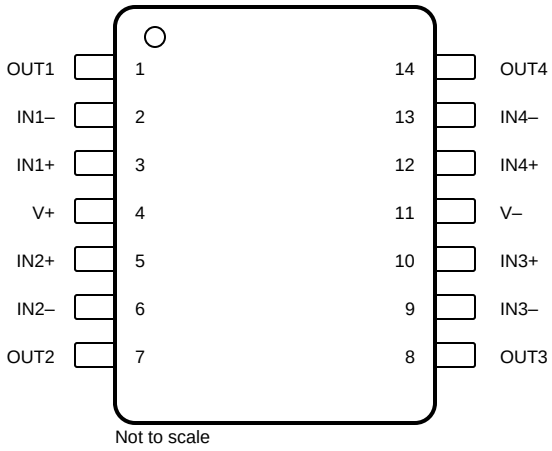
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Pin Functions: TLV9062S

PIN			I/O	DESCRIPTION
NAME	NO.			
	VSSOP	X2QFN		
IN1–	2	9	I	Inverting input, channel 1
IN1+	3	10	I	Noninverting input, channel 1
IN2–	8	5	I	Inverting input, channel 2
IN2+	7	4	I	Noninverting input, channel 2
OUT1	1	8	O	Output, channel 1
OUT2	9	6	O	Output, channel 2
$\overline{\text{SHDN1}}$	5	2	I	Shutdown low = disabled, high = enabled, channel 1
$\overline{\text{SHDN2}}$	6	3	I	Shutdown low = disabled, high = enabled, channel 2
V–	4	1	I or —	Negative (low) supply or ground (for single-supply operation)
V+	10	7	I	Positive (high) supply

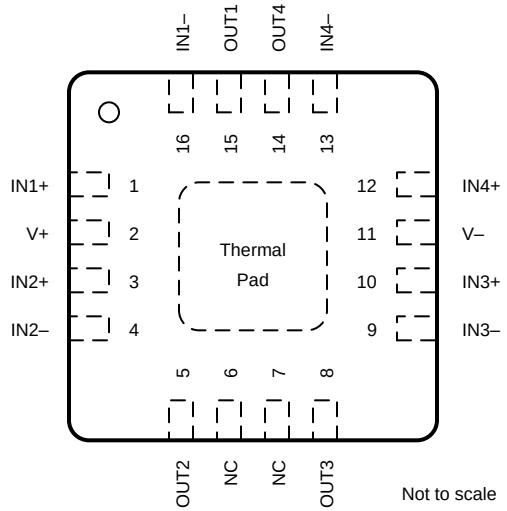
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TLV9064 D, PW Packages
14-Pin SOIC, TSSOP
Top View



Not to scale

TLV9064 RTE Package
16-Pin WQFN With Exposed Thermal Pad
Top View



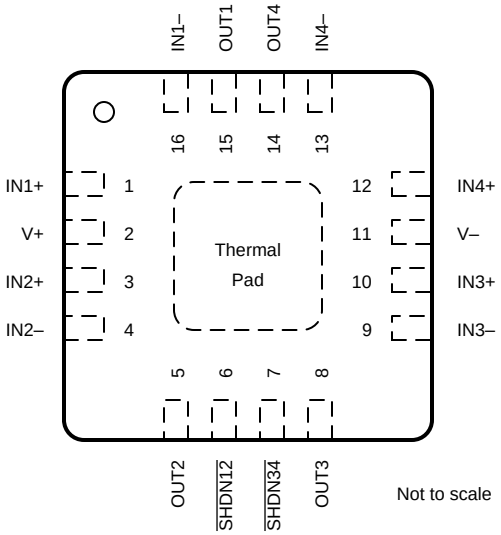
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Pin Functions: TLV9064

PIN			I/O	DESCRIPTION
NAME	NO.			
	SOIC, TSSOP	WQFN		
IN1–	2	16	I	Inverting input, channel 1
IN1+	3	1	I	Noninverting input, channel 1
IN2–	6	4	I	Inverting input, channel 2
IN2+	5	3	I	Noninverting input, channel 2
IN3–	9	9	I	Inverting input, channel 3
IN3+	10	10	I	Noninverting input, channel 3
IN4–	13	13	I	Inverting input, channel 4
IN4+	12	12	I	Noninverting input, channel 4
NC	—	6, 7	—	No internal connection
OUT1	1	15	O	Output, channel 1
OUT2	7	5	O	Output, channel 2
OUT3	8	8	O	Output, channel 3
OUT4	14	14	O	Output, channel 4
V–	11	11	I or —	Negative (low) supply or ground (for single-supply operation)
V+	4	2	I	Positive (high) supply

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TLV9064S RTE Package
16-Pin WQFN With Exposed Thermal Pad
Top View



Pin Functions: TLV9064S

PIN		I/O	DESCRIPTION
NAME	NO.		
IN1–	16	I	Inverting input, channel 1
IN1+	1	I	Noninverting input, channel 1
IN2–	4	I	Inverting input, channel 2
IN2+	3	I	Noninverting input, channel 2
IN3–	9	I	Inverting input, channel 3
IN3+	10	I	Noninverting input, channel 3
IN4–	13	I	Inverting input, channel 4
IN4+	12	I	Noninverting input, channel 4
OUT1	15	O	Output, channel 1
OUT2	5	O	Output, channel 2
OUT3	8	O	Output, channel 3
OUT4	14	O	Output, channel 4
$\overline{\text{SHDN12}}$	6	I	Shutdown – low = disabled, high = enabled, channels 1 and 2
$\overline{\text{SHDN34}}$	7	I	Shutdown – low = disabled, high = enabled, channels 3 and 4
V–	11	I or —	Negative (low) supply or ground (for single-supply operation)
V+	2	I	Positive (high) supply

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8 Specifications

8.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
Supply voltage [(V+) – (V–)]			0	6	V
Signal input pins	Voltage(2)	Common-mode	(V–) – 0.5	(V+) + 0.5	V
		Differential		(V+) – (V–) + 0.2	
	Current(2)		–10	10	mA
Output short-circuit(3)			Continuous		mA
Temperature	Specified, T_A		–40	125	°C
	Junction, T_J			150	
	Storage, T_{stg}		–65	150	

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

8.2 ESD Ratings

			VALUE	UNIT
TLV9061 PACKAGES				
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±2500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±1500	
ALL OTHER PACKAGES				
$V_{(ESD)}$	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)	±1500	

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

8.3 Recommended Operating Conditions

over operating ambient temperature range (unless otherwise noted)

		MIN	MAX	UNIT
V_S	Supply voltage (V_S = [V+] – [V–])	1.8	5.5	V
V_I	Input voltage range	(V–) – 0.1	(V+) + 0.1	V
V_O	Output voltage range	V–	V+	V
V_{SHDN_IH}	High level input voltage at shutdown pin (amplifier enabled)	1.1	V+	V
V_{SHDN_IL}	Low level input voltage at shutdown pin (amplifier disabled)	V–	0.2	V
T_A	Specified temperature	–40	125	°C

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8.4 Thermal Information: TLV9061

THERMAL METRIC(1)		TLV9061			UNIT
		DBV (SOT-23)	DCK (SC70)	DPW (X2SON)	
		5 PINS	5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	221.7	263.3	467	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	144.7	75.5	211.6	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	49.7	51	332.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter	26.1	1	29.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	49	50.3	330.6	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	125	°C/W

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

8.5 Thermal Information: TLV9061S

THERMAL METRIC(1)		TLV9061S	UNIT
		DBV (SOT-23)	
		6 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	216.5	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	155.1	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	96.2	°C/W
ψ_{JT}	Junction-to-top characterization parameter	80.3	°C/W
ψ_{JB}	Junction-to-board characterization parameter	95.9	°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.

8.6 Thermal Information: TLV9062

THERMAL METRIC(1)		TLV9062					UNIT
		D (SOIC)	DGK (VSSOP)	DSG (WSON)	PW (TSSOP)	RUG (X2QFN)	
		8 PINS	8 PINS	8 PINS	8 PINS	10 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	157.6	201.2	94.4	205.8	TBD	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	104.6	85.7	116.5	106.7	TBD	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	99.7	122.9	61.3	133.9	TBD	°C/W
ψ_{JT}	Junction-to-top characterization parameter	55.6	21.2	13	34.4	TBD	°C/W
ψ_{JB}	Junction-to-board characterization parameter	99.2	121.4	61.7	132.6	TBD	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	34.4	N/A	TBD	°C/W

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

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8.7 Thermal Information: TLV9062S

THERMAL METRIC(1)		TLV9062S		UNIT
		DGS (VSSOP)	RUG (X2QFN)	
		10 PINS	10 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	170.4	TBD	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	84.9	TBD	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	113.5	TBD	°C/W
ψ_{JT}	Junction-to-top characterization parameter	16.4	TBD	°C/W
ψ_{JB}	Junction-to-board characterization parameter	112.3	TBD	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	TBD	°C/W

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

8.8 Thermal Information: TLV9064

THERMAL METRIC(1)		TLV9064				UNIT
		PW (TSSOP)	D (SOIC)	RTE (WQFN)	RUC (WQFN)	
		14 PINS	14 PINS	16 PINS	14 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	135.8	106.9	65.1	TBD	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	64	64	67.9	TBD	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	79	63	40.4	TBD	°C/W
ψ_{JT}	Junction-to-top characterization parameter	15.7	25.9	5.5	TBD	°C/W
ψ_{JB}	Junction-to-board characterization parameter	78.4	62.7	40.2	TBD	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	23.8	TBD	°C/W

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

8.9 Thermal Information: TLV9064S

THERMAL METRIC(1)		TLV9064S	UNIT
		RTE (WQFN)	
		16 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	65.1	°C/W
$R_{\theta JC(top)}$	Junction-to-case(top) thermal resistance	67.9	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	40.4	°C/W
ψ_{JT}	Junction-to-top characterization parameter	5.5	°C/W
ψ_{JB}	Junction-to-board characterization parameter	40.2	°C/W
$R_{\theta JC(bot)}$	Junction-to-case(bottom) thermal resistance	23.8	°C/W

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

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8.10 Electrical Characteristics:

For V_S (Total Supply Voltage) = (V+) – (V–) = 1.8 V to 5.5 Vat T_A = 25°C, R_L = 10 kΩ 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_S = 5 V		±0.3	±1.6	mV
		V_S = 5 V, T_A = –40°C to 125°C			±2	
dV_{OS}/dT	Drift	V_S = 5 V, T_A = –40°C to 125°C		±0.53		µV/°C
PSRR	Power-supply rejection ratio	V_S = 1.8 V – 5.5 V, V_{CM} = (V–)		±7	±80	µV/V
	Channel separation, dc	At dc		100		dB
INPUT VOLTAGE RANGE						
V_{CM}	Common-mode voltage range	V_S = 1.8 V to 5.5 V	(V–) – 0.1		(V+) + 0.1	V
CMRR	Common-mode rejection ratio	V_S = 5.5 V, (V–) – 0.1 V < V_{CM} < (V+) – 1.4 V T_A = –40°C to 125°C	80	103		dB
		V_S = 5.5 V, V_{CM} = –0.1 V to 5.6 V T_A = –40°C to 125°C	57	87		
		V_S = 1.8 V, (V–) – 0.1 V < V_{CM} < (V+) – 1.4 V, T_A = –40°C to 125°C		88		
		V_S = 1.8 V, V_{CM} = –0.1 V to 1.9 V T_A = –40°C to 125°C		81		
INPUT BIAS CURRENT						
I_B	Input bias current			±0.5		pA
I_{OS}	Input offset current			±0.05		pA
NOISE						
E_n	Input voltage noise (peak-to-peak)	V_S = 5 V, f = 0.1 Hz to 10 Hz		4.77		μV_{PP}
e_n	Input voltage noise density	V_S = 5 V, f = 10 kHz		10		$nV/\sqrt{Hz}$
		V_S = 5 V, f = 1 kHz		16		
i_n	Input current noise density	f = 1 kHz		23		$fA/\sqrt{Hz}$
INPUT CAPACITANCE						
C_{ID}	Differential			2		pF
C_{IC}	Common-mode			4		pF
OPEN-LOOP GAIN						
A_{OL}	Open-loop voltage gain	V_S = 1.8 V, (V–) + 0.04 V < V_O < (V+) – 0.04 V, R_L = 10 kΩ		100		dB
		V_S = 5.5 V, (V–) + 0.05 V < V_O < (V+) – 0.05 V, R_L = 10 kΩ	104	130		
		V_S = 1.8 V, (V–) + 0.06 V < V_O < (V+) – 0.06 V, R_L = 2 kΩ		100		
		V_S = 5.5 V, (V–) + 0.15 V < V_O < (V+) – 0.15 V, R_L = 2 kΩ		130		
FREQUENCY RESPONSE						
GBP	Gain bandwidth product	V_S = 5 V, G = +1		10		MHz
φ_m	Phase margin	V_S = 5 V, G = +1		55		°
SR	Slew rate	V_S = 5 V, G = +1		6.5		V/µs
t_S	Settling time	To 0.1%, V_S = 5 V, 2-V step , G = +1, C_L = 100 pF		0.5		µs
		To 0.01%, V_S = 5 V, 2-V step, G = +1, C_L = 100 pF		1		
t_{OR}	Overload recovery time	V_S = 5 V, V_{IN} × gain > V_S		0.2		µs
THD + N	Total harmonic distortion + noise(1)	V_S = 5.5 V, V_{CM} = 2.5 V, V_O = 1 V_{RMS}, G = +1, f = 1 kHz		0.0008%		
OUTPUT						
V_O	Voltage output swing from supply rails	V_S = 5.5 V, R_L = 10 kΩ			20	mV
		V_S = 5.5 V, R_L = 2 kΩ			60	
I_{SC}	Short-circuit current	V_S = 5 V		±50		mA
Z_O	Open-loop output impedance	V_S = 5 V, f = 10 MHz		100		Ω

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

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Electrical Characteristics: (continued)

For V_S (Total Supply Voltage) = (V+) – (V–) = 1.8 V to 5.5 Vat T_A = 25°C, R_L = 10 kΩ 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
POWER SUPPLY						
I_Q	Quiescent current per amplifier	V_S = 5.5 V, I_O = 0 mA		538	750	µA
		V_S = 5.5 V, I_O = 0 mA T_A = –40°C to +125°C			800	
SHUTDOWN						
I_{QSD}	Quiescent current per amplifier	V_S = 1.8 V to 5.5 V, all amplifiers disabled, $\overline{SHDN}$ = Low		0.5	1.5	µA
Z_{SHDN}	Output impedance during shutdown	V_S = 1.8 V to 5.5 V, amplifier disabled		10 || 8		GΩ || pF
$V_{SHDN_THR_HI}$	High level voltage shutdown threshold (amplifier enabled)	V_S = 1.8 V to 5.5 V		(V–) + 0.9 V	(V–) + 1.1 V	V
$V_{SDHN_THR_LO}$	Low level voltage shutdown threshold (amplifier disabled)	V_S = 1.8 V to 5.5 V	(V–) + 0.2V	(V–) + 0.7 V		V
t_{ON}	Amplifier enable time (shutdown)(2)	V_S = 1.8 V to 5.5 V, full shutdown; G = 1, V_{OUT} = 0.9 × V_S/2, R_L connected to V–		10		µs
t_{OFF}	Amplifier disable time(2)	V_S = 1.8 V to 5.5 V, G = 1, V_{OUT} = 0.1 × V_S/2, R_L connected to V–		0.6		µs
	$\overline{SHDN}$ pin input bias current (per pin)	V_S = 1.8 V to 5.5 V, V+ ≥ $\overline{SHDN}$ ≥ (V+) - 0.8V		130		pA
		V_S = 1.8 V to 5.5 V, V- ≤ $\overline{SHDN}$ ≤ V- + 0.8V		40		

(2) Disable time (t_{OFF}) and enable time (t_{ON}) are defined as the time interval between the 50% point of the signal applied to the $\overline{SHDN}$ pin and the point at which the output voltage reaches the 10% (disable) or 90% (enable) level.

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8.11 Typical Characteristics

at T_A = 25°C, V_S = 5.5 V, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

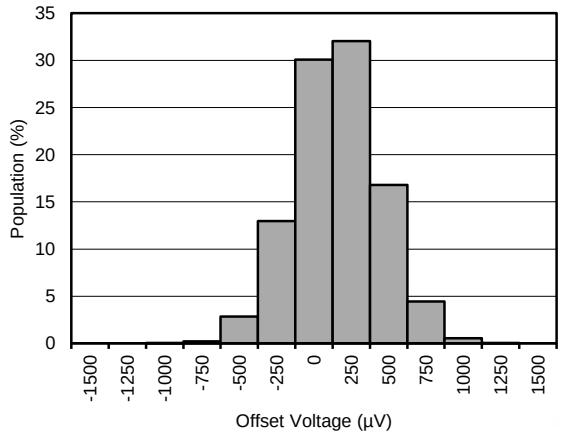
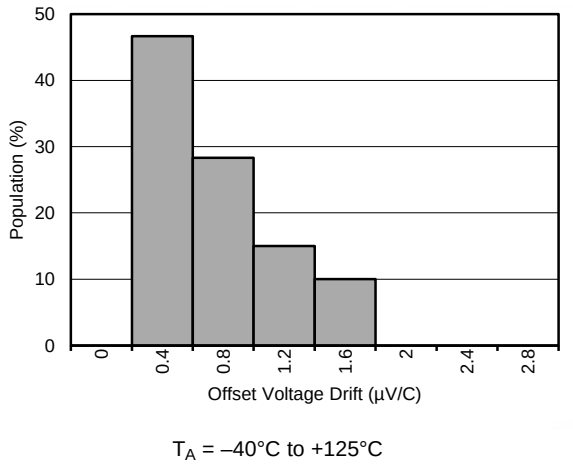


Figure 1. Offset Voltage Production Distribution



T_A = –40°C to +125°C

Figure 2. Offset Voltage Drift Distribution

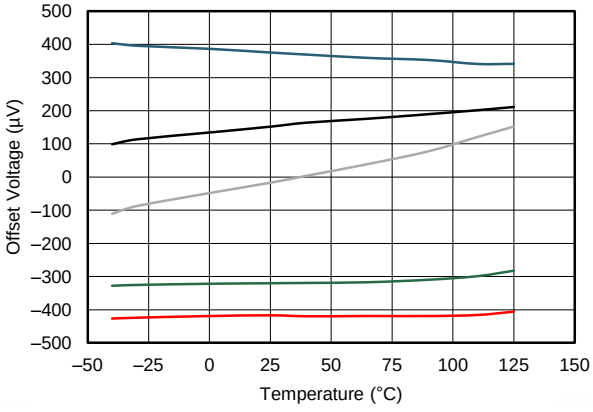
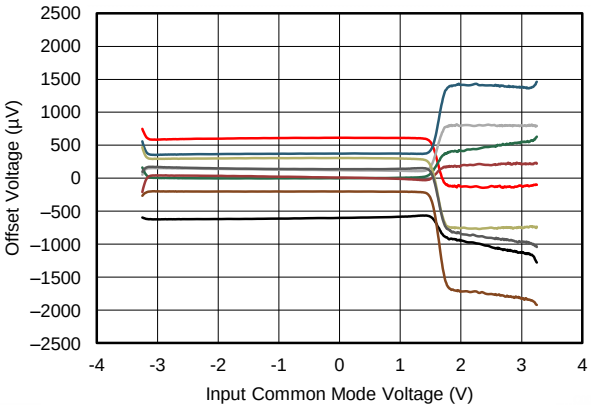
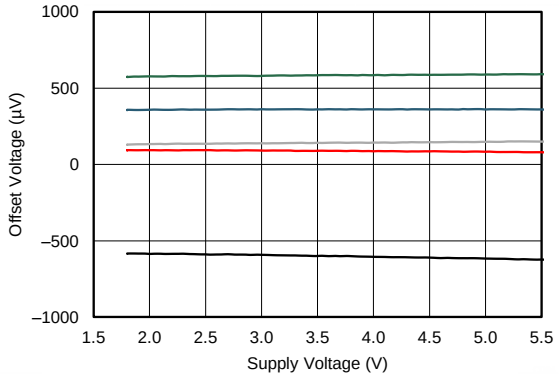


Figure 3. Offset Voltage vs Temperature



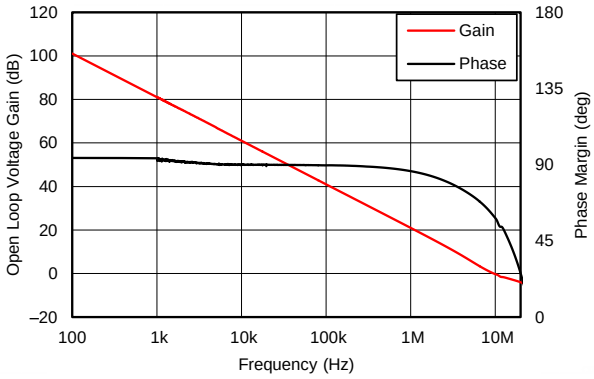
V+ = 2.75 V V– = –2.75 V

Figure 4. Offset Voltage vs Common-Mode Voltage



V_S = 1.8 V to 5.5 V

Figure 5. Offset Voltage vs Power Supply



C_L = 10 pF

Figure 6. Open-Loop Gain and Phase vs Frequency

Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5 V, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

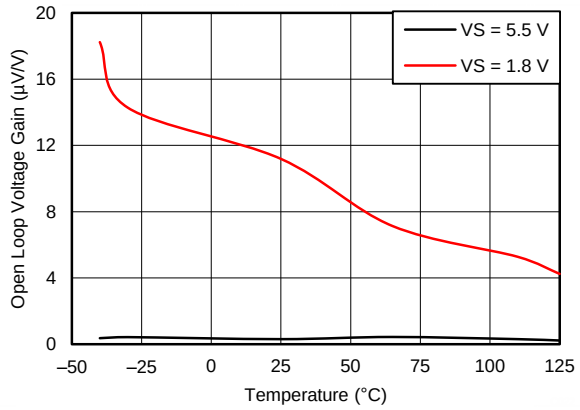


Figure 7. Open-Loop Gain vs Temperature

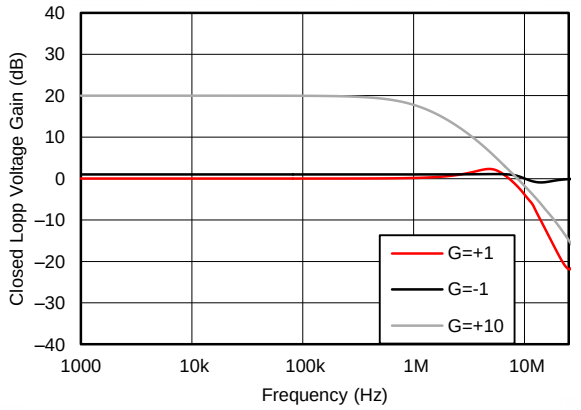


Figure 8. Closed-Loop Gain vs Frequency

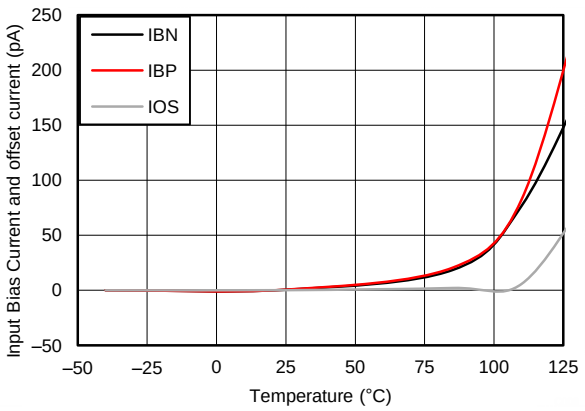


Figure 9. Input Bias Current vs Temperature

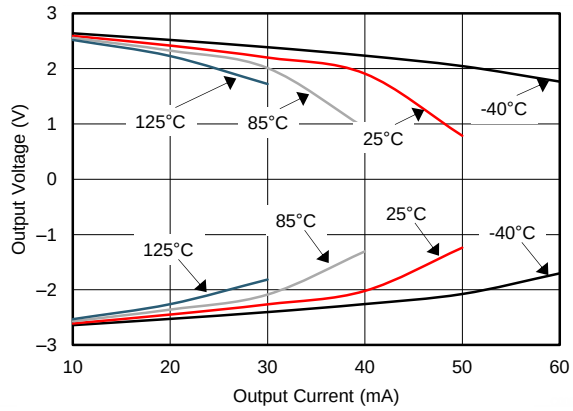


Figure 10. Output Voltage Swing vs Output Current

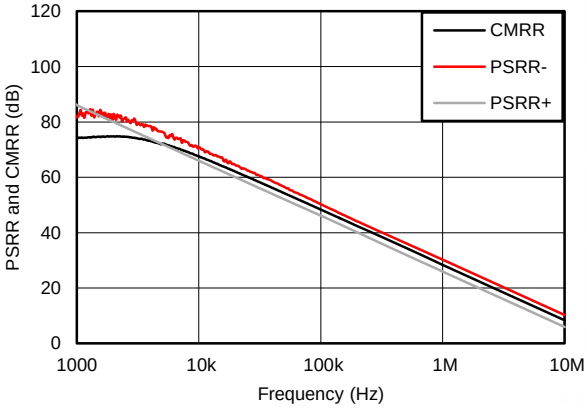


Figure 11. CMRR and PSRR vs Frequency (Referred to Input)

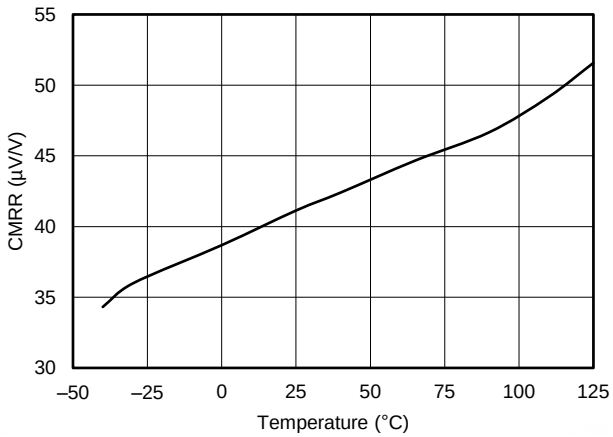
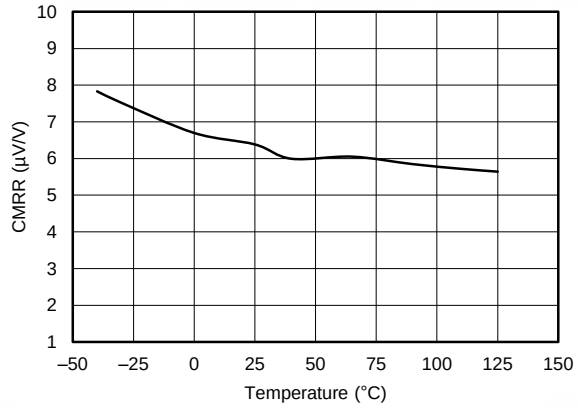


Figure 12. CMRR vs Temperature

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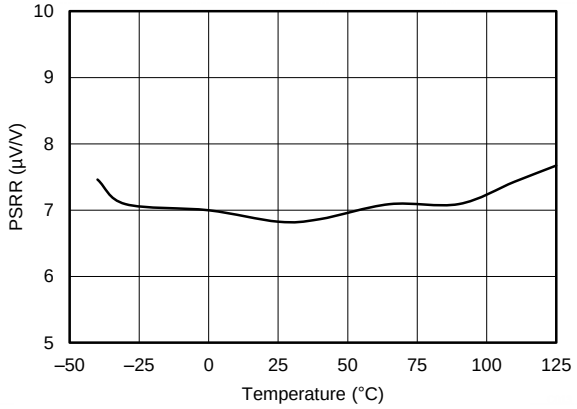
Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5 V, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



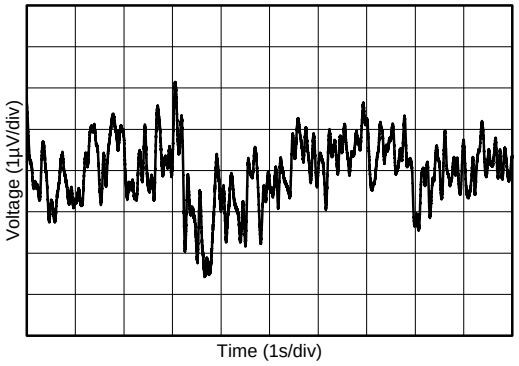
V_{CM} = (V–) – 0.1 V to (V+) – 1.4 V
T_A = –40°C to 125°C R_L = 10 kΩ V_S = 5.5 V

Figure 13. CMRR vs Temperature



V_S = 1.8 V to 5.5 V

Figure 14. PSRR vs Temperature



V_S = 1.8 V to 5.5 V

Figure 15. 0.1-Hz to 10-Hz Input Voltage Noise

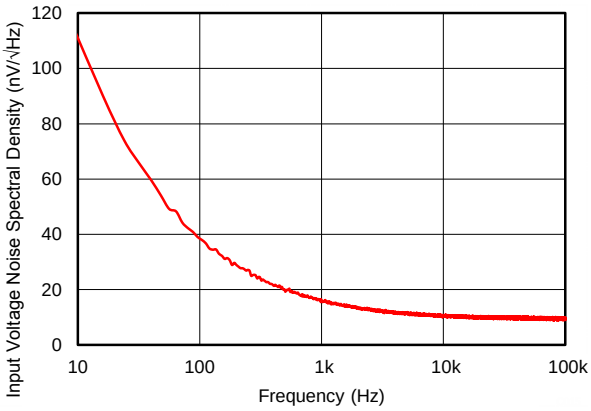
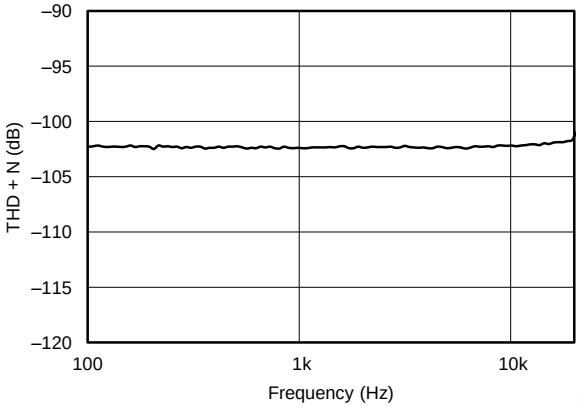
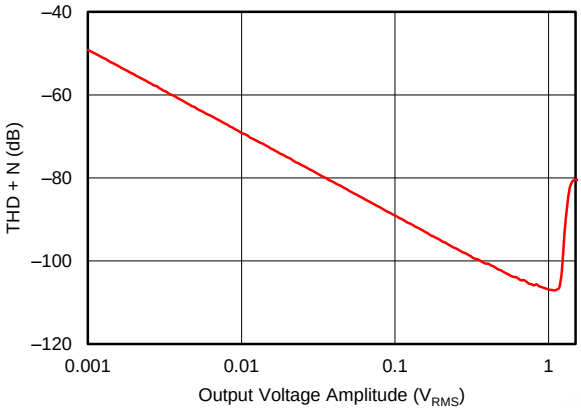


Figure 16. Input Voltage Noise Spectral Density vs Frequency



V_S = 5.5 V V_{CM} = 2.5 V R_L = 2 kΩ
V_{OUT} = 0.5 V_{RMS} BW = 80 kHz G = +1

Figure 17. THD + N vs Frequency



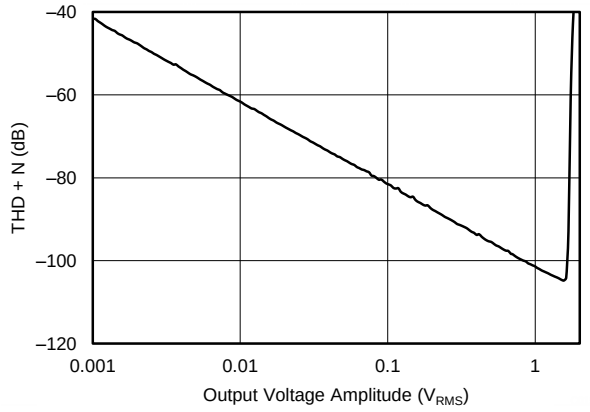
V_S = 5.5 V R_L = 2 kΩ G = +1
V_{CM} = 2.5 V BW = 80 kHz, f = 1 kHz

Figure 18. THD + N vs Amplitude

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Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5 V, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



V_S = 5.5 V V_{CM} = 2.5 V R_L = 2 kΩ
G = –1 BW = 80 kHz, f = 1 kHz

Figure 19. THD + N vs Amplitude

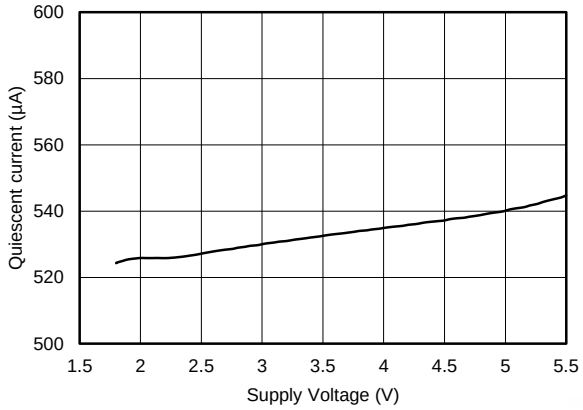


Figure 20. Quiescent Current vs Supply Voltage

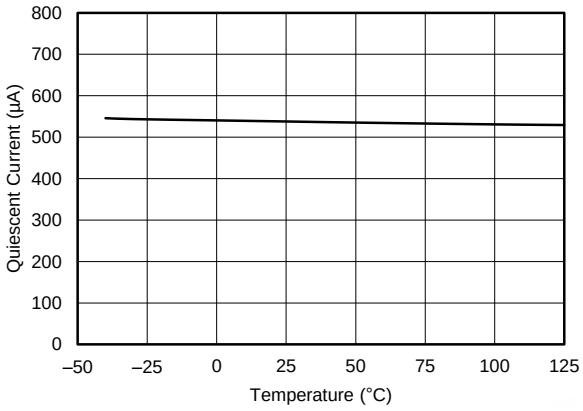


Figure 21. Quiescent Current vs Temperature

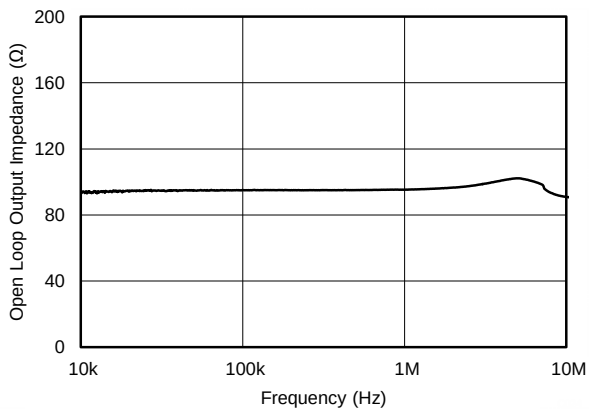
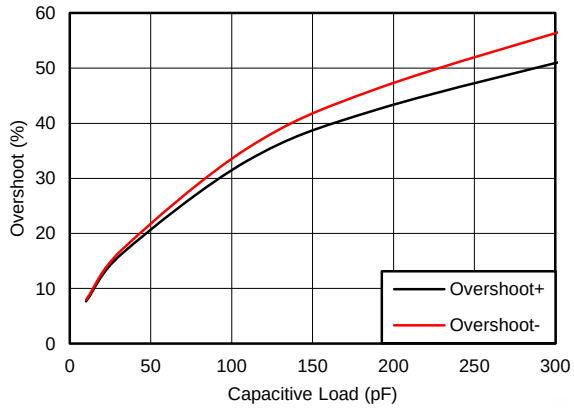
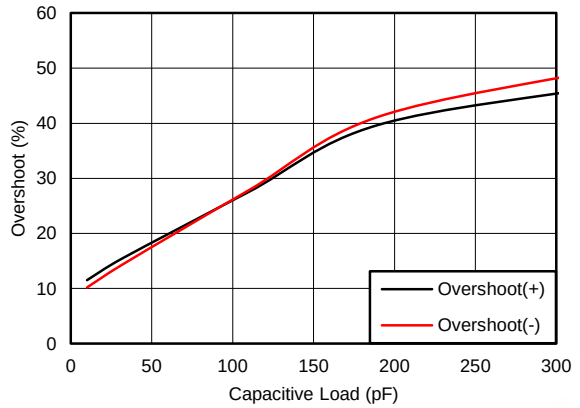


Figure 22. Open-Loop Output Impedance vs Frequency



V+ = 2.75 V V– = –2.75 V G = +1 V/V
V_{OUT} step = 100 mV_{p-p} R_L = 10 kΩ

Figure 23. Small-Signal Overshoot vs Load Capacitance



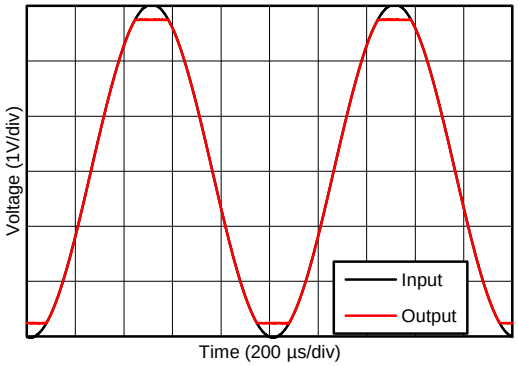
V+ = 2.75 V V– = –2.75 V G = –1 V/V
V_{OUT} step = 100 mV_{p-p} R_L = 10 kΩ

Figure 24. Small-Signal Overshoot vs Load Capacitance

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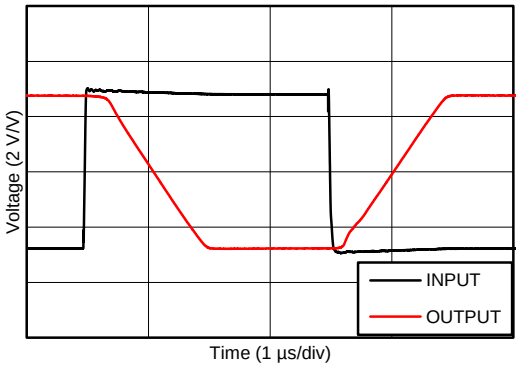
Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5 V, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)



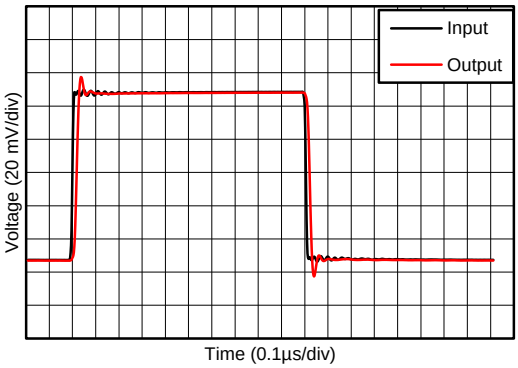
V+ = 2.75 V V– = –2.75 V

Figure 25. No Phase Reversal



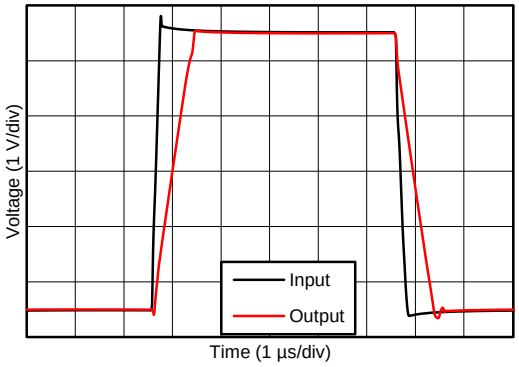
V+ = 2.75 V V– = –2.75 V G = –10 V/V

Figure 26. Overload Recovery



V+ = 2.75 V V– = –2.75 V G = 1 V/V

Figure 27. Small-Signal Step Response



V+ = 2.75 V V– = –2.75 V C_L = 100 pF
G = 1 V/V

Figure 28. Large-Signal Step Response

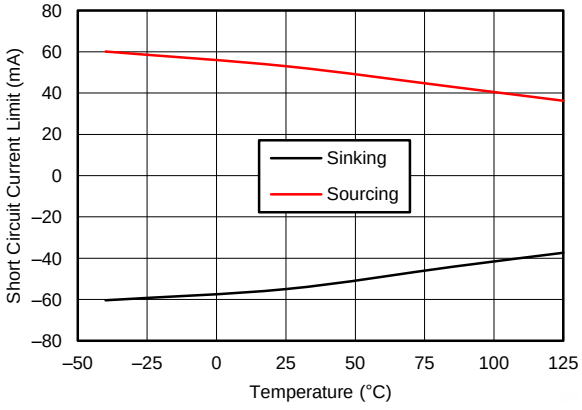
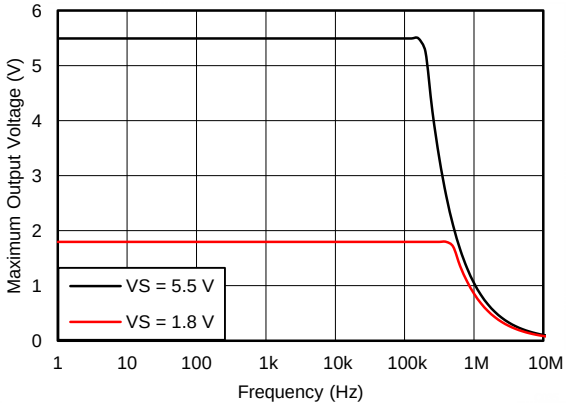


Figure 29. Short-Circuit Current vs Temperature



R_L = 10 kΩ C_L = 10 pF

Figure 30. Maximum Output Voltage vs Frequency and Supply Voltage

Typical Characteristics (continued)

at T_A = 25°C, V_S = 5.5 V, R_L = 10 kΩ connected to V_S / 2, V_{CM} = V_S / 2, and V_{OUT} = V_S / 2 (unless otherwise noted)

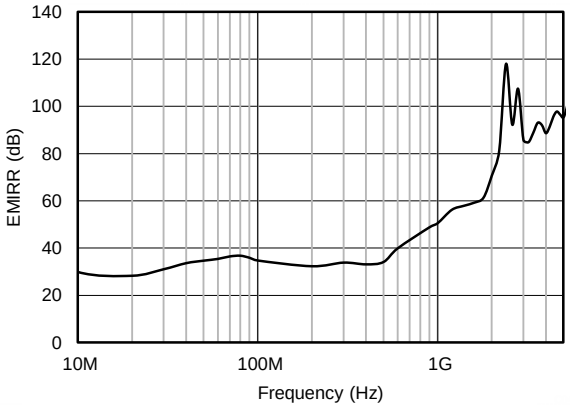


Figure 31. Electromagnetic Interference Rejection Ratio Referred to Noninverting Input (EMIRR+) vs Frequency

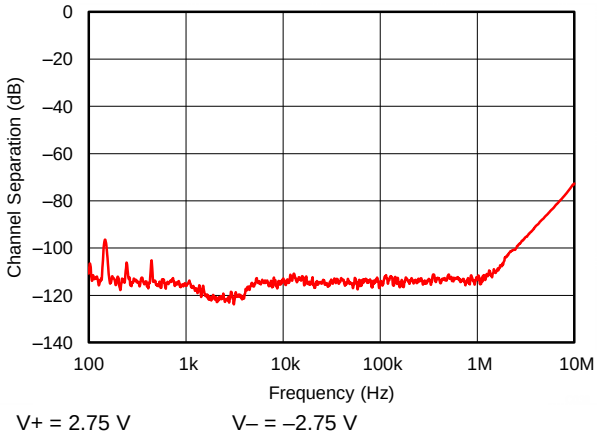


Figure 32. Channel Separation vs Frequency

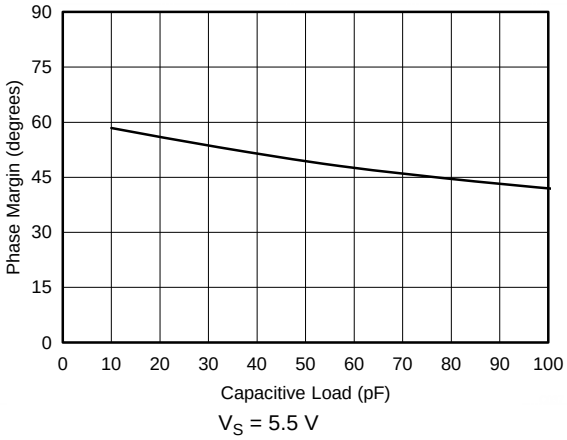


Figure 33. Phase Margin vs Capacitive Load

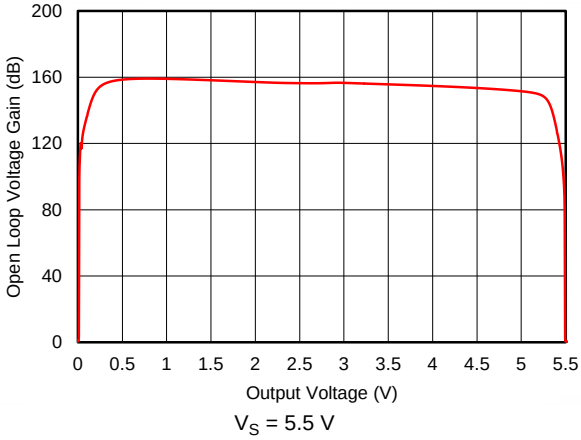


Figure 34. Open Loop Voltage Gain vs Output Voltage

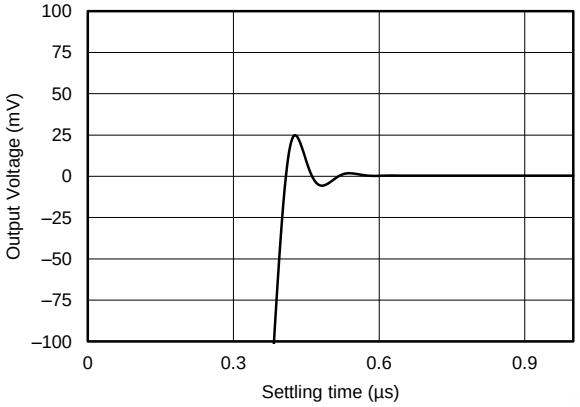


Figure 35. Large Signal Settling Time (Positive)

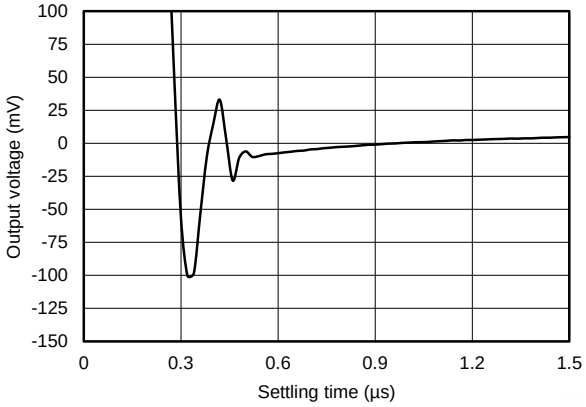


Figure 36. Large Signal Settling Time (Negative)

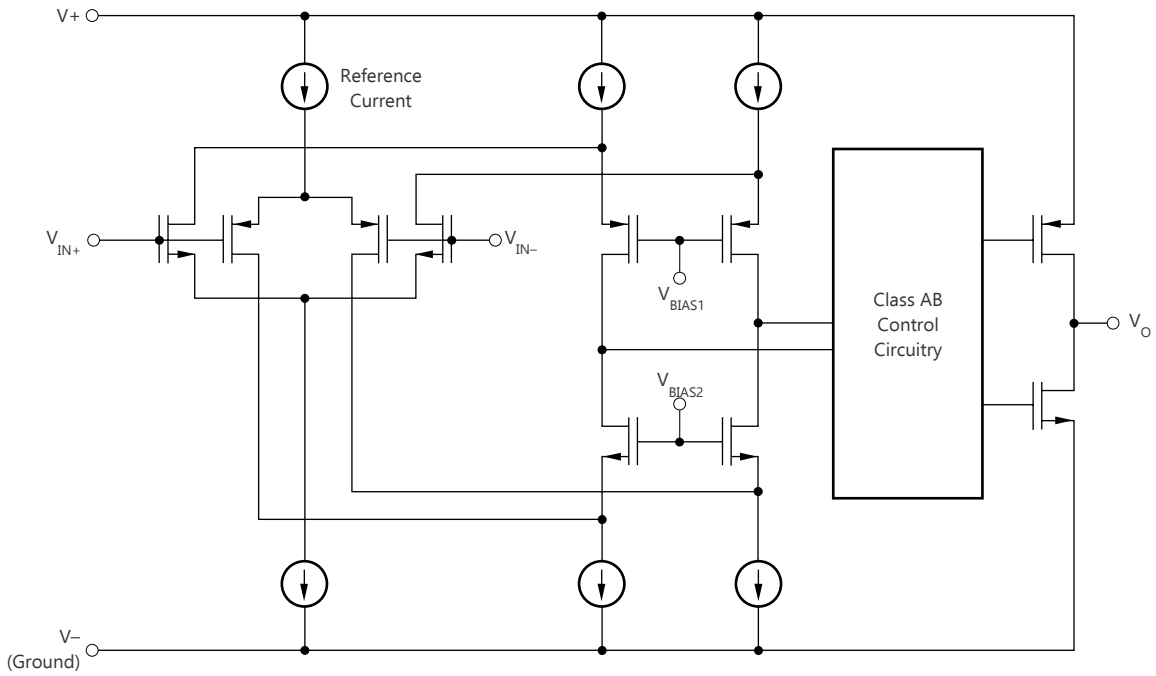
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9 Detailed Description

9.1 Overview

The TLV906x devices are a family of low-power, rail-to-rail input and output op amps. These devices operate from 1.8 V to 5.5 V, are unity-gain stable, and are designed for a wide range of general-purpose applications. The input common-mode voltage range includes both rails and allows the TLV906x series to be used in virtually any single-supply application. Rail-to-rail input and output swing significantly increases dynamic range, especially in low-supply applications. The high bandwidth enables this family to drive the sample-hold circuitry of analog-to-digital converters (ADCs).

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Rail-to-Rail Input

The input common-mode voltage range of the TLV906x family extends 100 mV beyond the supply rails for the full supply voltage range of 1.8 V to 5.5 V. 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*. The N-channel pair is active for input voltages close to the positive rail, typically (V+) – 1.4 V to 200 mV above the positive supply, whereas the P-channel pair is active for inputs from 200 mV below the negative supply to approximately (V+) – 1.4 V. There is a small transition region, typically (V+) – 1.2 V to (V+) – 1 V, in which both pairs are on. This 200-mV transition region can vary up to 200 mV with process variation. Thus, the transition region (with both stages on) can range from (V+) – 1.4 V to (V+) – 1.2 V on the low end, and up to (V+) – 1 V to (V+) – 0.8 V on the high end. Within this transition region, PSRR, CMRR, offset voltage, offset drift, and THD can degrade compared to device operation outside this region.

9.3.2 Rail-to-Rail Output

Designed as a low-power, low-voltage operational amplifier, the TLV906x series delivers a robust output drive capability. A class AB output stage with common-source transistors achieves full rail-to-rail output swing capability. For resistive loads of 10-kΩ, the output swings to within 15 mV of either supply rail, regardless of the applied power-supply voltage. Different load conditions change the ability of the amplifier to swing close to the rails.

9.3.3 Overload Recovery

Overload recovery is defined as the time required for the operational amplifier output to recover from a saturated state to a linear state. The output devices of the operational amplifier enter a saturation region when the output voltage exceeds the rated operating voltage, because of the high input voltage or the high gain. After the device enters the saturation region, the charge carriers in the output devices require time to return to the linear state. After the charge carriers return to the linear state, the device begins to slew at the specified slew rate. Therefore, the propagation delay (in case of an overload condition) is the sum of the overload recovery time and the slew time. The overload recovery time for the TLV906x family is approximately 200 ns.

9.3.4 Shutdown Function

The TLV906xS devices feature $\overline{\text{SHDN}}$ pins that disable the op amp, placing it into a low-power standby mode. In this mode, the op amp typically consumes less than 1 µA. The $\overline{\text{SHDN}}$ pins are active-low, meaning that shutdown mode is enabled when the input to the $\overline{\text{SHDN}}$ pin is a valid logic low.

The $\overline{\text{SHDN}}$ pins are referenced to the negative supply voltage of the op amp. The threshold of the shutdown feature lies around 800 mV (typical) and does not change with respect to the supply voltage. Hysteresis has been included in the switching threshold to ensure smooth switching characteristics. To ensure optimal shutdown behavior, the $\overline{\text{SHDN}}$ pins should be driven with valid logic signals. A valid logic low is defined as a voltage between V– and V– + 0.2V. A valid logic high is defined as a voltage between V– + 1.2 V and V+. The shutdown pin must either be connected to a valid high or a low voltage or driven, and not left as an open circuit.

The $\overline{\text{SHDN}}$ pins are high-impedance CMOS inputs. Dual op amp versions are independently controlled, and quad op amp versions are controlled in pairs with logic inputs. For battery-operated applications, this feature may be used to greatly reduce the average current and extend battery life. The enable time is 10 µs for full shutdown of all channels; disable time is 3 µs. When disabled, the output assumes a high-impedance state. This architecture allows the TLV906xS to be operated as a gated amplifier (or to have the device output multiplexed onto a common analog output bus). Shutdown time (t_{OFF}) depends on loading conditions and increases as load resistance increases. To ensure shutdown (disable) within a specific shutdown time, the specified 10-kΩ load to midsupply (V_S/2) is required. If using the TLV906xS without a load, the resulting turnoff time is significantly increased.

9.4 Device Functional Modes

The TLV906x family are operational when the power-supply voltage is between 1.8 V (±0.9 V) and 5.5 V (±2.75 V). The TLV906xS devices feature a shutdown mode and are shut down when a valid logic low is applied to the shutdown pin.

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10 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.

10.1 Application Information

The TLV906x family features 10-MHz bandwidth and 6.5-V/µs slew rate with only 538-µA of supply current per channel, providing good ac performance at very low power consumption. DC applications are well served with a very low input noise voltage of 10 nV/√Hz at 10 kHz, low input bias current, and a typical input offset voltage of 0.3 mV.

10.2 Typical Applications

10.2.1 Typical Low-Side Current Sense Application

Figure 37 shows the TLV906x configured in a low-side current-sensing application.

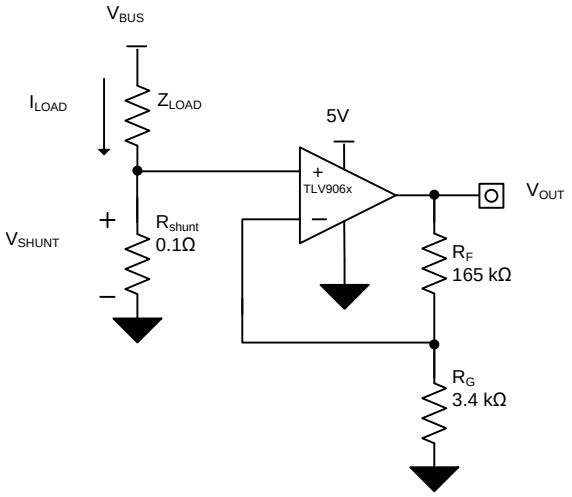


Figure 37. TLV906x in a Low-Side, Current-Sensing Application

10.2.1.1 Design Requirements

The design requirements for this design are:

- Load current: 0 A to 1 A
- Output voltage: 4.95 V
- Maximum shunt voltage: 100 mV

Typical Applications (continued)

10.2.1.2 Detailed Design Procedure

The transfer function of the circuit in Figure 37 is given in Equation 1.

$$V_{OUT} = I_{LOAD} \times R_{SHUNT} \times Gain \tag{1}$$

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

$$R_{SHUNT} = \frac{V_{SHUNT_MAX}}{I_{LOAD_MAX}} = \frac{100mV}{1A} = 100m\Omega \tag{2}$$

Using Equation 2, R_{SHUNT} equals 100 mΩ. The voltage drop produced by I_{LOAD} and R_{SHUNT} is amplified by the TLV906x to produce an output voltage of approximately 0 V to 4.95 V. Equation 3 calculates the gain required for the TLV906x to produce the required output voltage.

$$Gain = \frac{\left(V_{OUT_MAX} - V_{OUT_MIN}\right)}{\left(V_{IN_MAX} - V_{IN_MIN}\right)} \tag{3}$$

Using Equation 3, the required gain equals 49.5 V/V, which is set with the R_F and R_G resistors. Equation 4 sizes the R_F and R_G, resistors to set the gain of the TLV906x to 49.5 V/V.

$$Gain = 1 + \frac{\left(R_F\right)}{\left(R_G\right)} \tag{4}$$

Selecting R_F to equal 165 kΩ and R_G to equal 3.4 kΩ provides a combination that equals approximately 49.5 V/V. Figure 38 shows the measured transfer function of the circuit shown in Figure 37. Notice that the gain is only a function of the feedback and gain resistors. This gain is adjusted by varying the ratio of the resistors and the actual resistor values are determined by the impedance levels that the designer wants to establish. The impedance level determines the current drain, the effect that stray capacitance has, and a few other behaviors. There is no optimal impedance selection that works for every system, you must choose an impedance that is ideal for your system parameters.

10.2.1.3 Application Curve

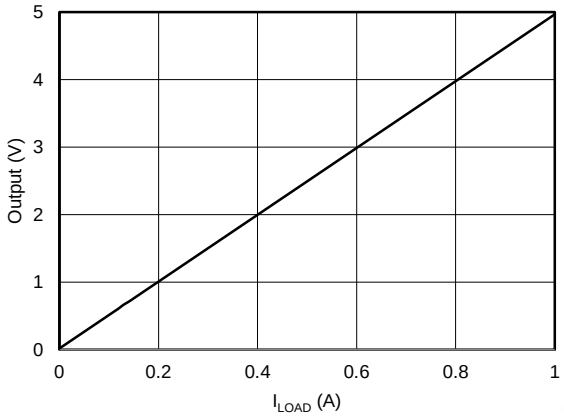


Figure 38. Low-Side, Current-Sense, Transfer Function

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Typical Applications (continued)

10.2.2 Typical Comparator Application

Comparators are used to differentiate between two different signal levels. For example, a comparator can be used to differentiate between an overvoltage situation and normal operation. The TLV9062 can be used as a comparator by applying the two voltages being compared to each input without any feedback from output to inverting input.

The TLV9062 features a rail-to-rail input and output stage with an input common-mode range that exceeds the supply rails by 100 mV. The TLV9062 is designed to prevent phase reversal over the entire input common-mode range. The propagation delay for the TLV9062 used as a comparator is equal to the overload recovery time plus the slew rate. Overdrive voltages less than 100 mV result in longer propagation delays because the overload recovery time increases and the slew rate decreases.

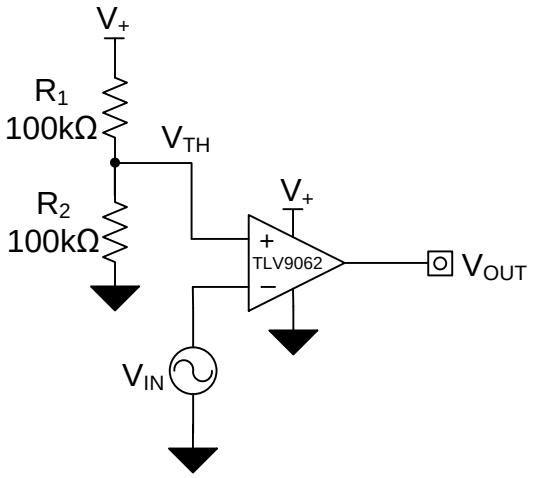


Figure 39. Typical Comparator Application

10.2.2.1 Design Requirements

The design requirements for this design are:

- Supply voltage (V_+): 5 V
- Input (V_{IN}): 0 V–5 V
- Threshold voltage (V_{TH}) = 2.5 V

10.2.2.2 Detailed Design Procedure

The inverting comparator circuit applies the input voltage (V_{IN}) to the inverting terminal of the op amp. Two resistors (R1 and R2) divide the supply voltage (V_{CC}) to create a midsupply threshold voltage (V_{TH}) as calculated in Equation 1. The circuit is shown in Figure 39. When V_{IN} is less then V_{TH}, the output voltage transitions to the positive supply and equals the high-level output voltage. When V_{IN} is greater than V_{TH}, the output voltage transitions to the negative supply and equals the low-level output voltage, V_{TH}.

$$V_{TH} = \frac{R_2}{R_1 + R_2} \times V_+ = 2.5V \tag{5}$$

Typical Applications (continued)

10.2.2.3 Application Curves

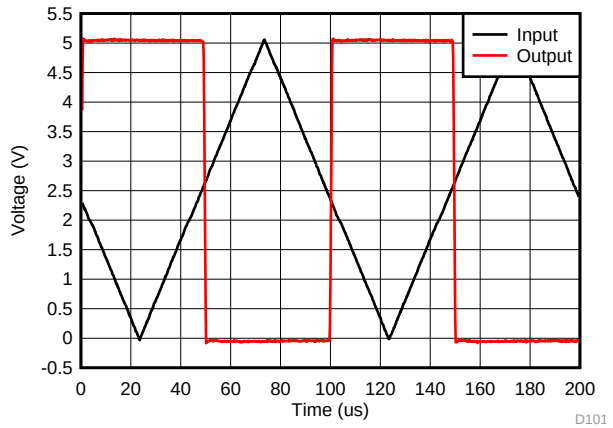


Figure 40. Comparator Response to Input Voltage (Propagation Delay Included)

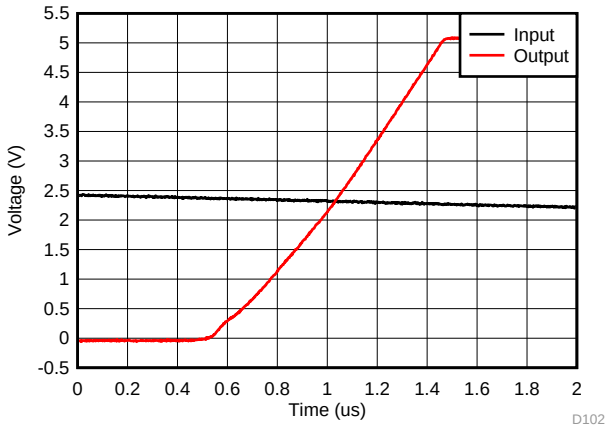


Figure 41. Rising Edge

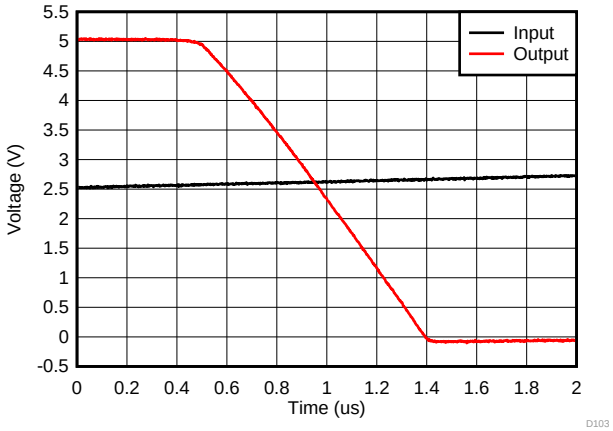


Figure 42. Falling Edge

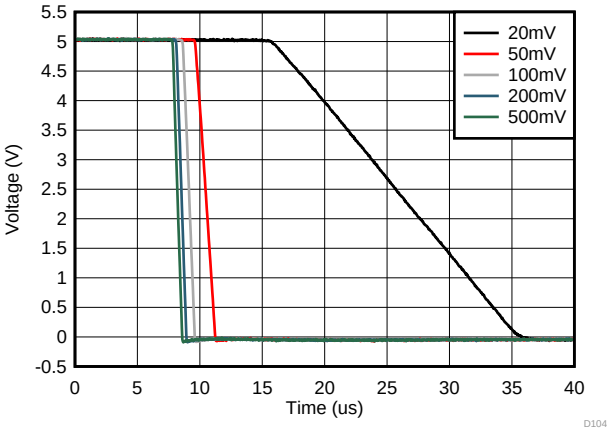


Figure 43. Falling Edge Propagation Delay vs. Input Overdrive Voltage

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11 Power Supply Recommendations

The TLV906x series 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 can exhibit significant variance with regard to operating voltage or temperature.

CAUTION

Supply voltages larger than 6 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, see the section.

11.1 Input and ESD Protection

The TLV906x series incorporates internal ESD protection circuits on all pins. For input and output pins, this protection primarily consists of current-steering diodes connected between the input and power-supply pins. These ESD protection diodes provide in-circuit, input overdrive protection, as long as the current is limited to 10 mA, as shown in the *Absolute Maximum Ratings* table. Figure 44 shows how a series input resistor can be added to the driven input to limit the input current. The added resistor contributes thermal noise at the amplifier input and the value must be kept to a minimum in noise-sensitive applications.

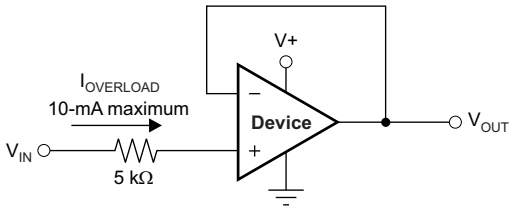


Figure 44. Input Current Protection

12 Layout

12.1 Layout Guidelines

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

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and of the op amp itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-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 adequate for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces electromagnetic interference (EMI) noise pickup. Take care to physically separate digital and analog grounds, paying attention to the flow of the ground current. For more detailed information, see *Circuit Board Layout Techniques*.
- 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 at a 90 degree angle is much better as opposed to running the traces in parallel with the noisy trace.
- Place the external components as close to the device as possible. As illustrated in Figure 46, keeping R_F and R_G close to the inverting input minimizes parasitic capacitance on the inverting input.
- 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 can experience performance shifts resulting from moisture ingress into the plastic package. Following any aqueous PCB cleaning process, baking the PCB assembly is recommended to remove moisture introduced into the device packaging during the cleaning process. A low-temperature, post-cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

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12.2 Layout Example

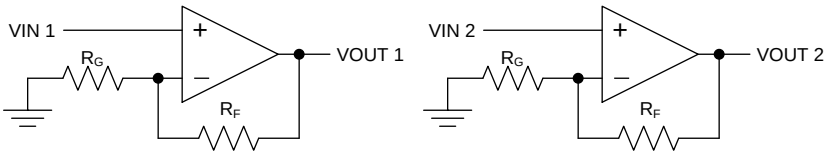


Figure 45. Schematic Representation for Figure 46

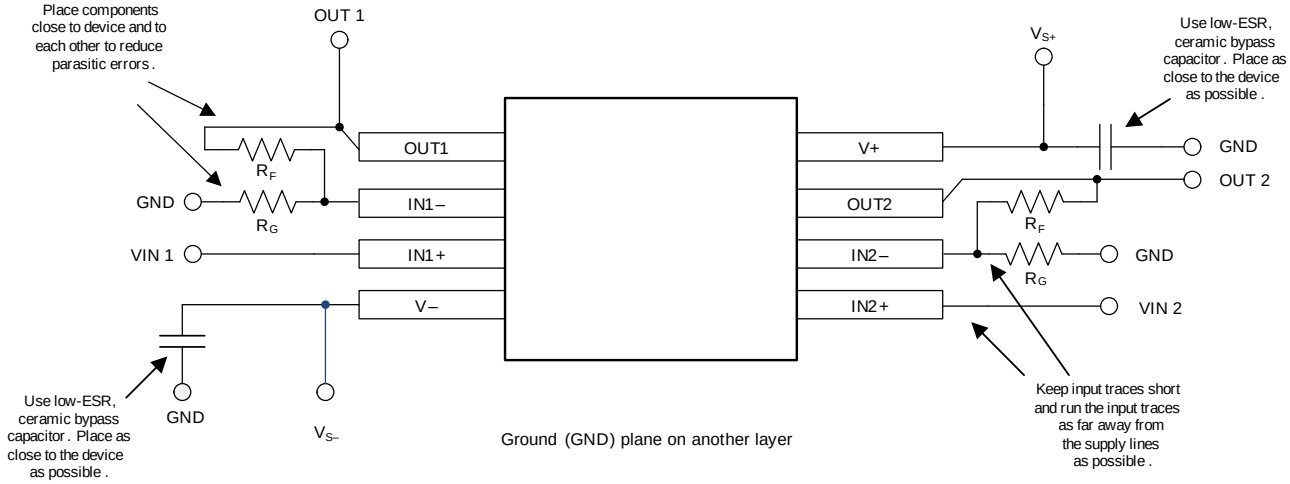


Figure 46. Layout Example

13 Device and Documentation Support

13.1 Documentation Support

13.1.1 Related Documentation

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

Texas Instruments, *TLVx314 3-MHz, Low-Power, Internal EMI Filter, RRIO, Operational Amplifier*.

Texas Instruments, *EMI Rejection Ratio of Operational Amplifiers*.

Texas Instruments, *QFN/SON PCB Attachment*.

Texas Instruments, *Quad Flatpack No-Lead Logic Packages*.

Texas Instruments, *Circuit Board Layout Techniques*.

Texas Instruments, *Single-Ended Input to Differential Output Conversion Circuit Reference Design*.

13.2 Related Links

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

Table 1. Related Links

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TLV9061	Click here	Click here	Click here	Click here	Click here
TLV9062	Click here	Click here	Click here	Click here	Click here
TLV9064	Click here	Click here	Click here	Click here	Click here

13.3 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.

13.4 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.

13.5 Trademarks

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

13.6 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.

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13.7 Glossary

SLYZ022 — *TI Glossary*.

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

14 Mechanical, Packaging, and Orderable Information

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

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PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
PTLV9061IDBVR	ACTIVE	SOT-23	DBV	5	2500	TBD	Call TI	Call TI	-40 to 125		Samples
PTLV9061IDCKR	ACTIVE	SC70	DCK	5	3000	TBD	Call TI	Call TI	-40 to 125		Samples
PTLV9061SIDBVR	ACTIVE	SOT-23	DBV	6	2500	TBD	Call TI	Call TI	-40 to 125		Samples
PTLV9062SIDGST	ACTIVE	VSSOP	DGS	10	250	TBD	Call TI	Call TI	-40 to 125		Samples
TLV9061IDBVR	PREVIEW	SOT-23	DBV	5	3000	TBD	Call TI	Call TI	-40 to 125		
TLV9061IDCKR	PREVIEW	SC70	DCK	5	3000	TBD	Call TI	Call TI	-40 to 125		
TLV9061IDPWR	ACTIVE	X2SON	DPW	5	3000	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	CG	Samples
TLV9062IDGKR	ACTIVE	VSSOP	DGK	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	T062	Samples
TLV9062IDGKT	ACTIVE	VSSOP	DGK	8	250	Green (RoHS & no Sb/Br)	CU NIPDAUAG	Level-2-260C-1 YEAR	-40 to 125	T062	Samples
TLV9062IDR	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-40 to 125	TL9062	Samples
TLV9062IDSGR	ACTIVE	WSON	DSG	8	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T062	Samples
TLV9062IDSGT	ACTIVE	WSON	DSG	8	250	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T062	Samples
TLV9062IPWR	ACTIVE	TSSOP	PW	8	2000	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-40 to 125	TL9062	Samples
TLV9064IDR	ACTIVE	SOIC	D	14	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	TLV9064D	Samples
TLV9064IPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-40 to 125	TLV9064	Samples
TLV9064IPWT	ACTIVE	TSSOP	PW	14	250	Green (RoHS & no Sb/Br)	CU SN	Level-2-260C-1 YEAR	-40 to 125	TLV9064	Samples
TLV9064IRTER	ACTIVE	WQFN	RTE	16	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T9064	Samples
TLV9064SIRTER	ACTIVE	WQFN	RTE	16	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	T9064S	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.

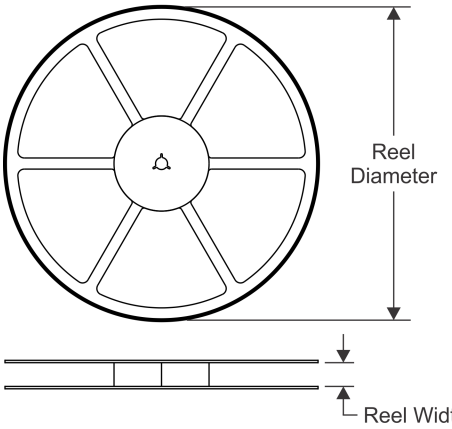
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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

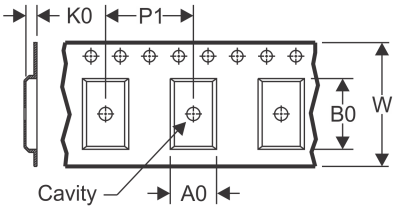
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

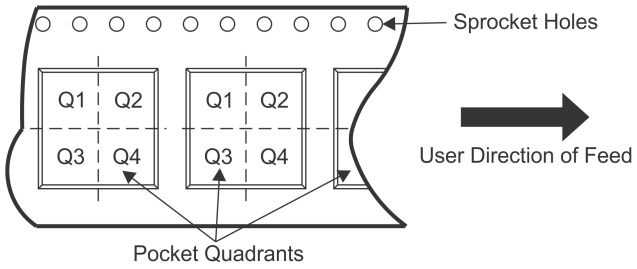


TAPE DIMENSIONS



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

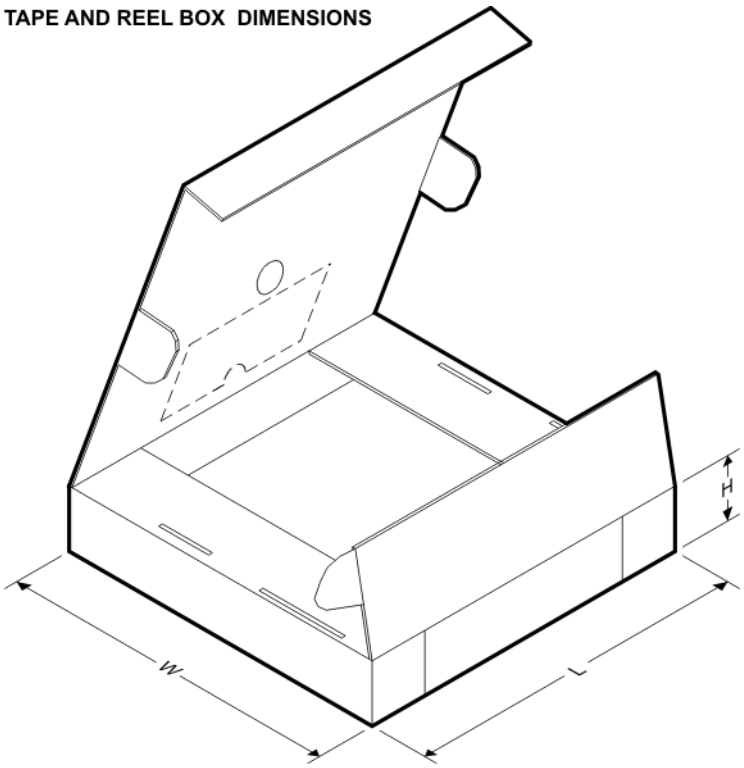
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TLV9061IDPWR	X2SON	DPW	5	3000	178.0	8.4	0.91	0.91	0.5	2.0	8.0	Q2
TLV9062IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV9062IDGKT	VSSOP	DGK	8	250	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
TLV9062IDR	SOIC	D	8	2500	330.0	15.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV9062IDSGR	WSON	DSG	8	3000	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TLV9062IDSGT	WSON	DSG	8	250	180.0	8.4	2.3	2.3	1.15	4.0	8.0	Q2
TLV9062IPWR	TSSOP	PW	8	2000	330.0	12.4	7.0	3.6	1.6	8.0	12.0	Q1
TLV9064IDR	SOIC	D	14	2500	330.0	15.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV9064IPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TLV9064IPWT	TSSOP	PW	14	250	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
TLV9064IRTER	WQFN	RTE	16	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2
TLV9064SIRTER	WQFN	RTE	16	3000	330.0	12.4	3.3	3.3	1.1	8.0	12.0	Q2

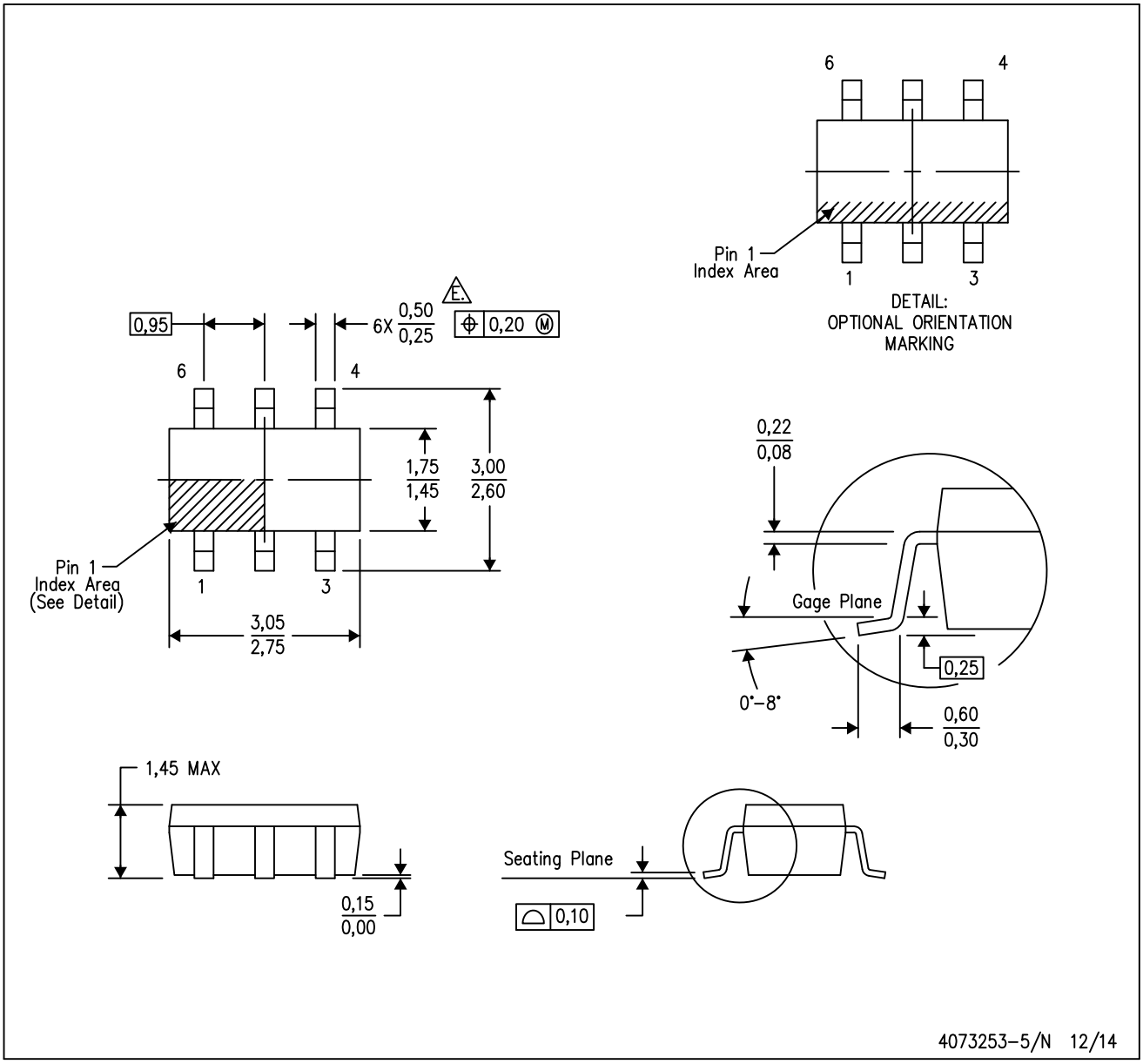
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV9061IDPWR	X2SON	DPW	5	3000	205.0	200.0	33.0
TLV9062IDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
TLV9062IDGKT	VSSOP	DGK	8	250	366.0	364.0	50.0
TLV9062IDR	SOIC	D	8	2500	336.6	336.6	41.3
TLV9062IDSGR	WSON	DSG	8	3000	210.0	185.0	35.0
TLV9062IDSGT	WSON	DSG	8	250	210.0	185.0	35.0
TLV9062IPWR	TSSOP	PW	8	2000	366.0	364.0	50.0
TLV9064IDR	SOIC	D	14	2500	336.6	336.6	41.3
TLV9064IPWR	TSSOP	PW	14	2000	366.0	364.0	50.0
TLV9064IPWT	TSSOP	PW	14	250	366.0	364.0	50.0
TLV9064IRTER	WQFN	RTE	16	3000	367.0	367.0	35.0
TLV9064SIRTER	WQFN	RTE	16	3000	367.0	367.0	35.0

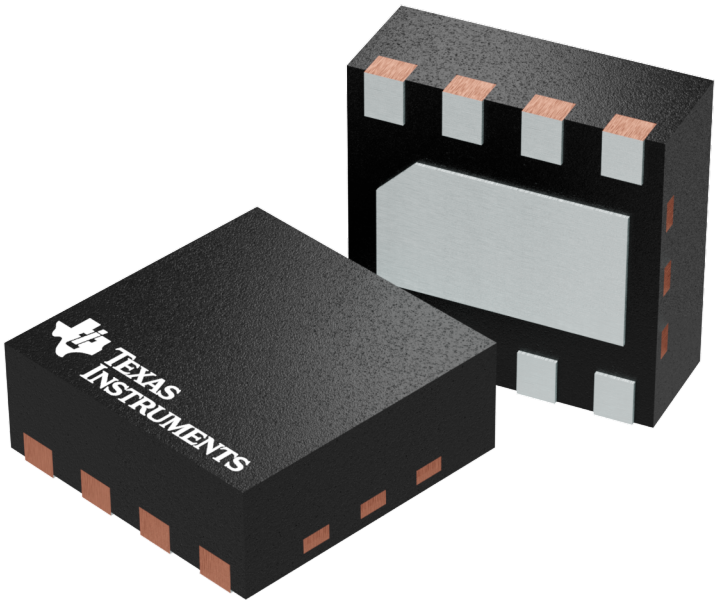
DBV (R–PDSO–G6) PLASTIC SMALL–OUTLINE PACKAGE



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. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
E. Falls within JEDEC MO–178 Variation AB, except minimum lead width.

DSG 8 WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



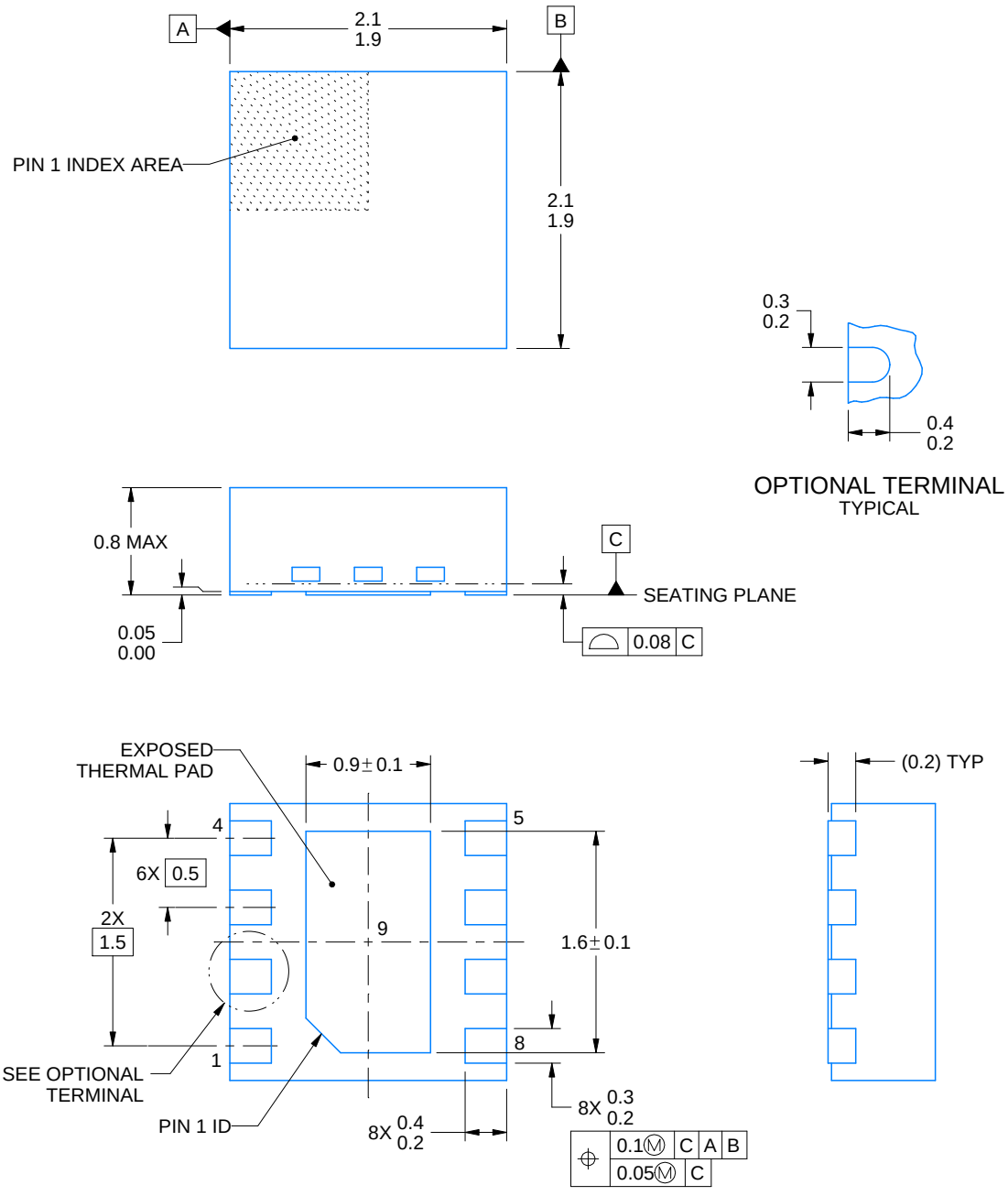
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

PACKAGE OUTLINE

DSG0008A

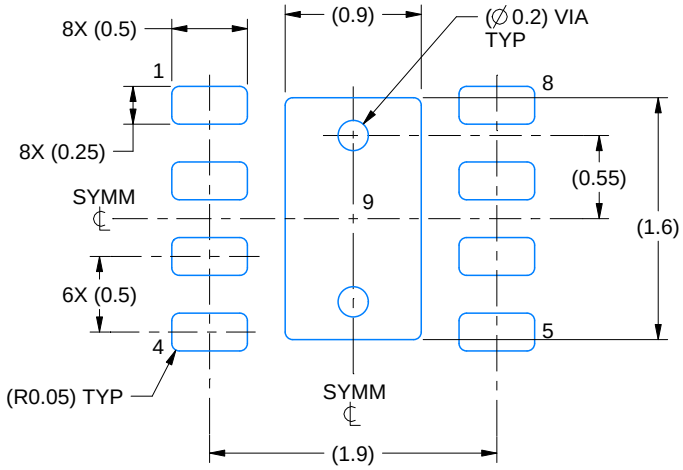
WSON - 0.8 mm max height

PLASTIC SMALL OUTLINE - NO LEAD

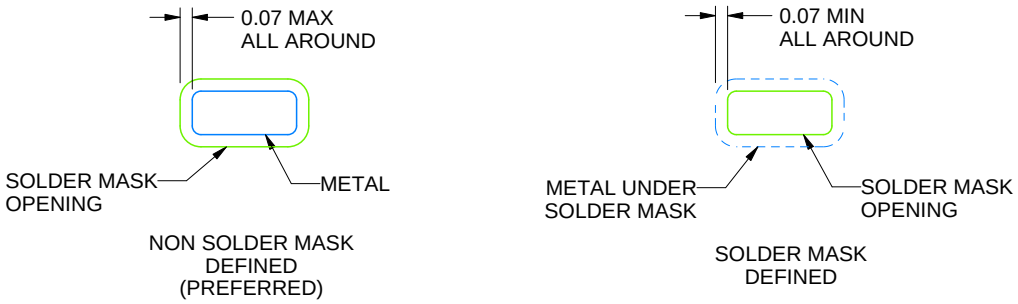


NOTES:

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. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
SCALE:20X

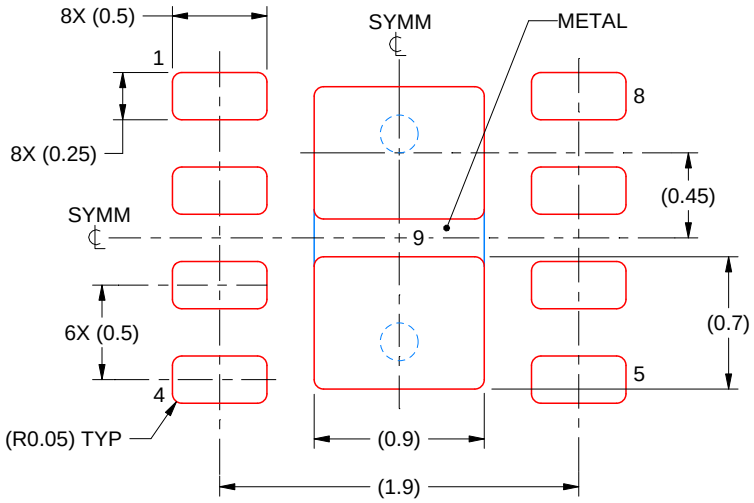


SOLDER MASK DETAILS

4218900/B 09/2017

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).
5. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD 9:
87% PRINTED SOLDER COVERAGE BY AREA UNDER PACKAGE
SCALE:25X

4218900/B 09/2017

NOTES: (continued)

6. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

GENERIC PACKAGE VIEW

DPW 5 X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

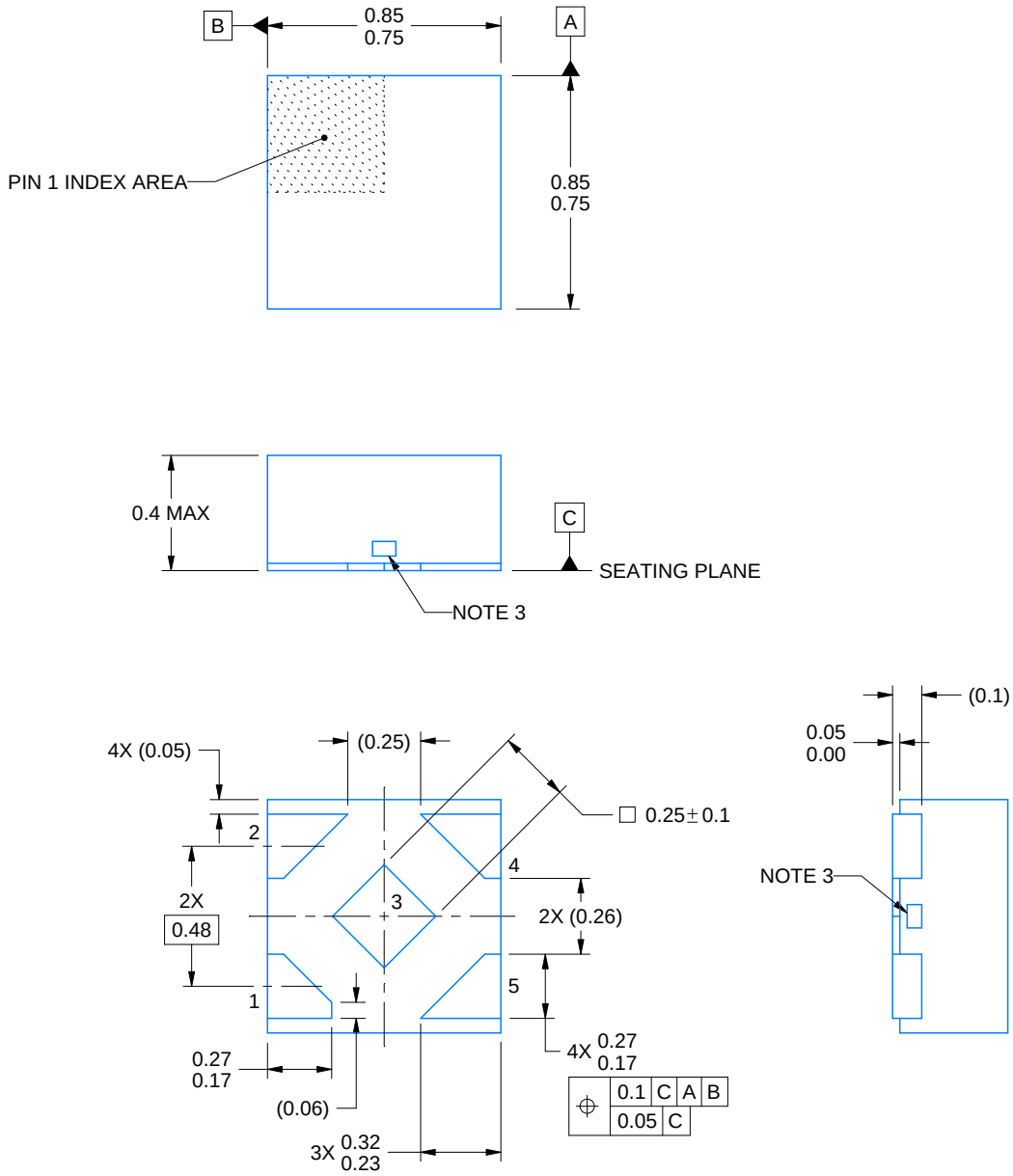
4211218-3/D

PACKAGE OUTLINE

DPW0005A

X2SON - 0.4 mm max height

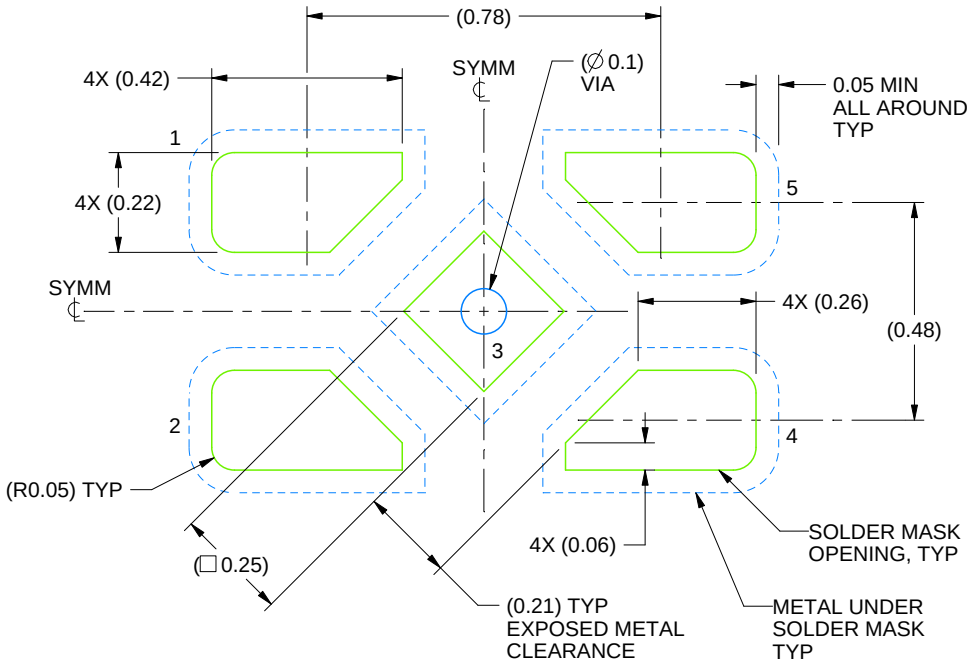
PLASTIC SMALL OUTLINE - NO LEAD



4223102/B 09/2017

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. The size and shape of this feature may vary.

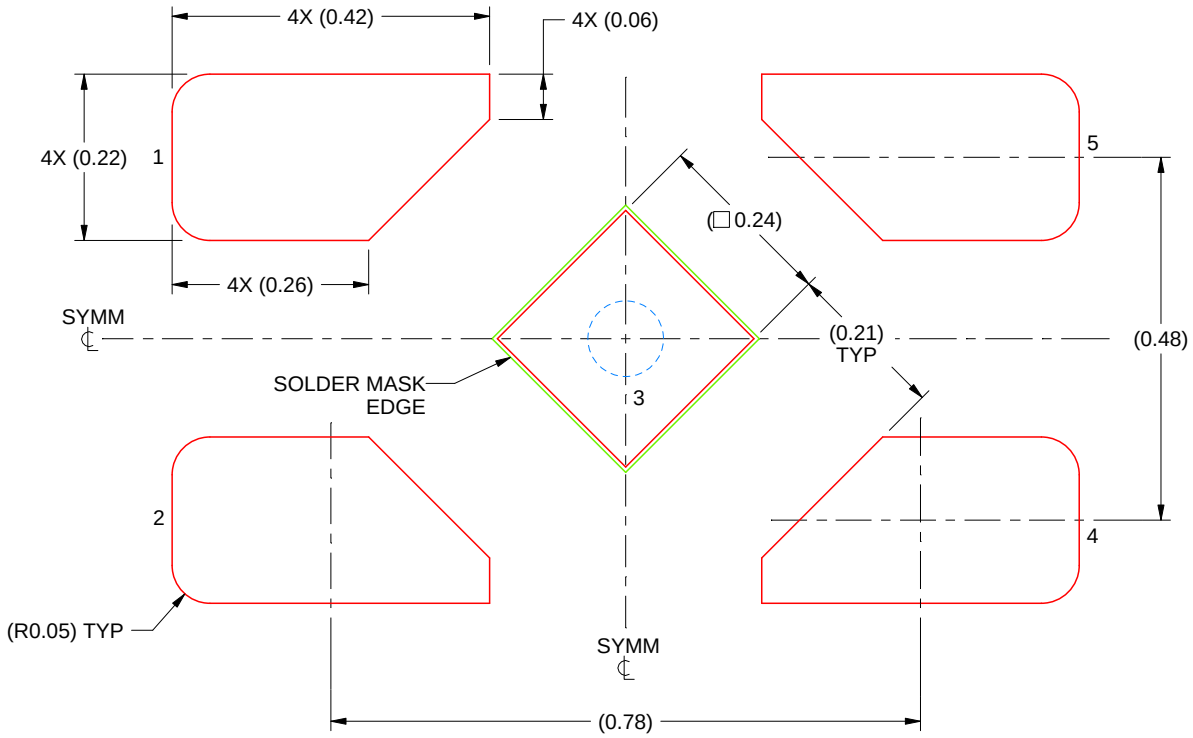


LAND PATTERN EXAMPLE
SOLDER MASK DEFINED
SCALE:60X

4223102/B 09/2017

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, refer to QFN/SON PCB application note in literature No. SLUA271 (www.ti.com/lit/slua271).



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

EXPOSED PAD
92% PRINTED SOLDER COVERAGE BY AREA
SCALE:100X

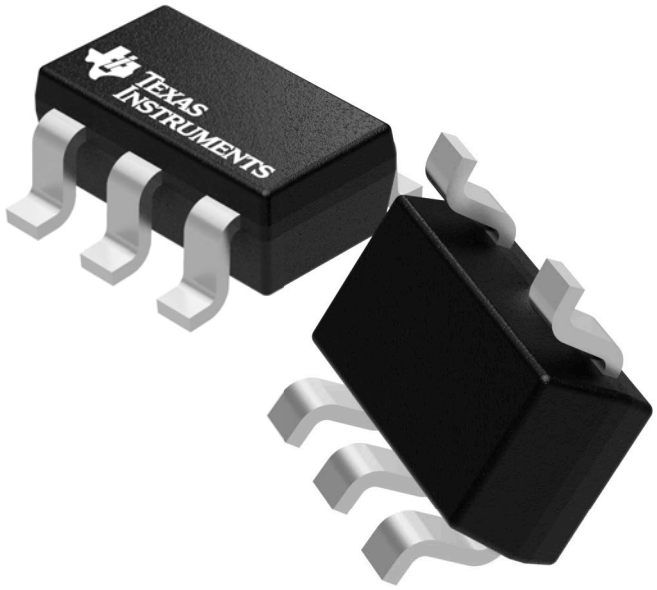
4223102/B 09/2017

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

DBV 5 SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



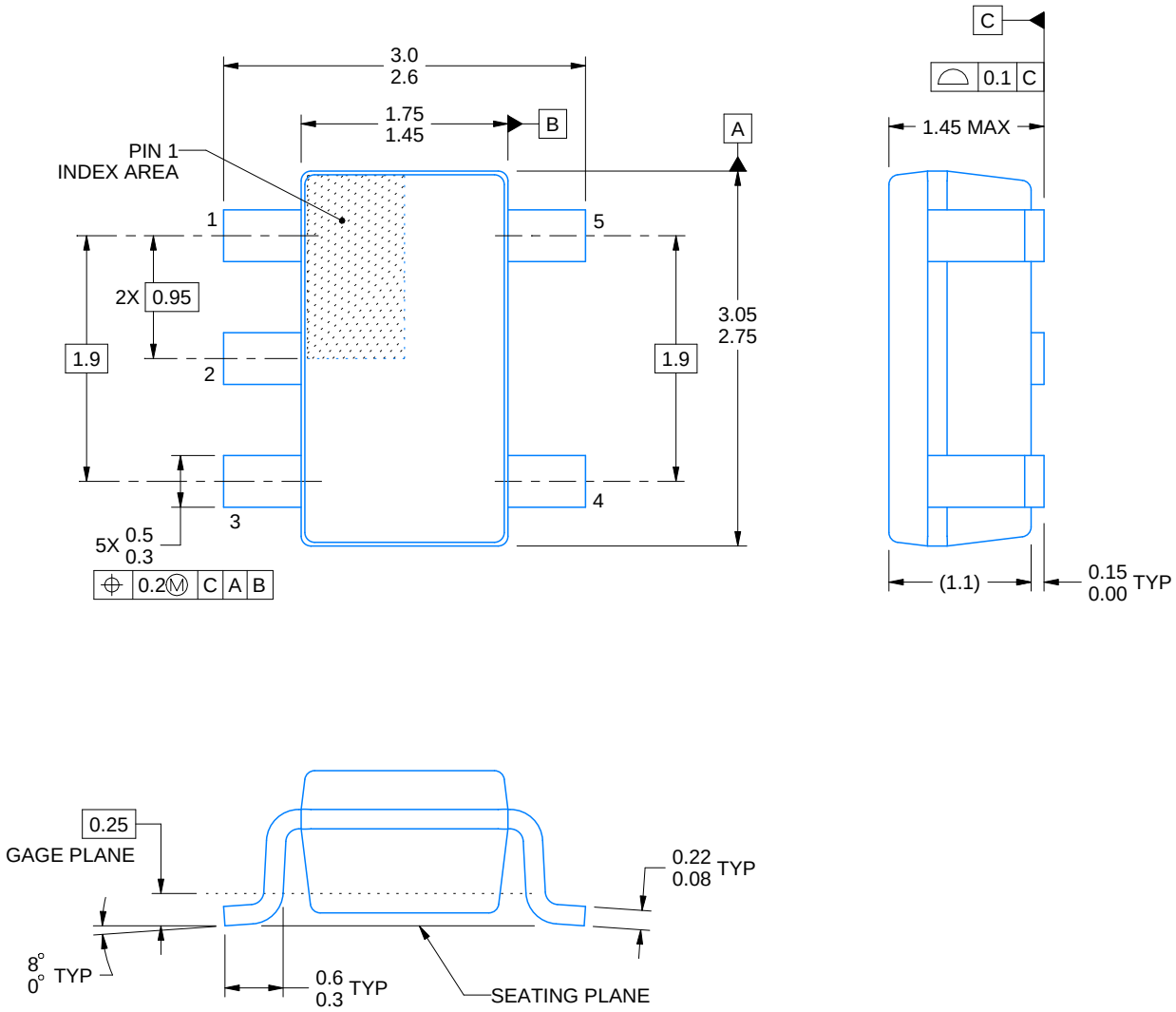
Images above are just a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

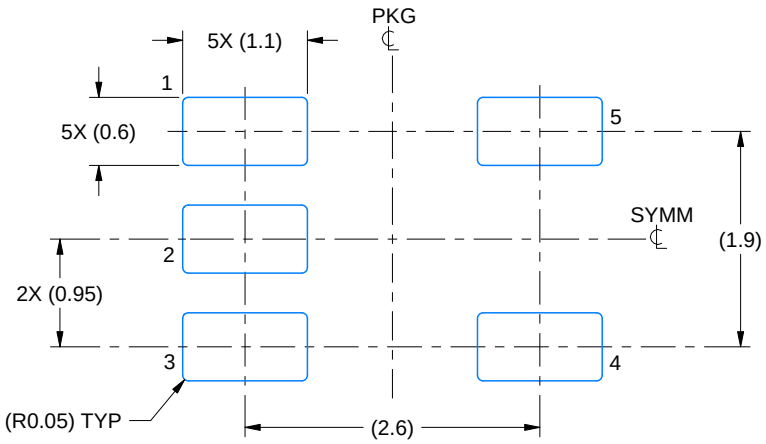
SMALL OUTLINE TRANSISTOR



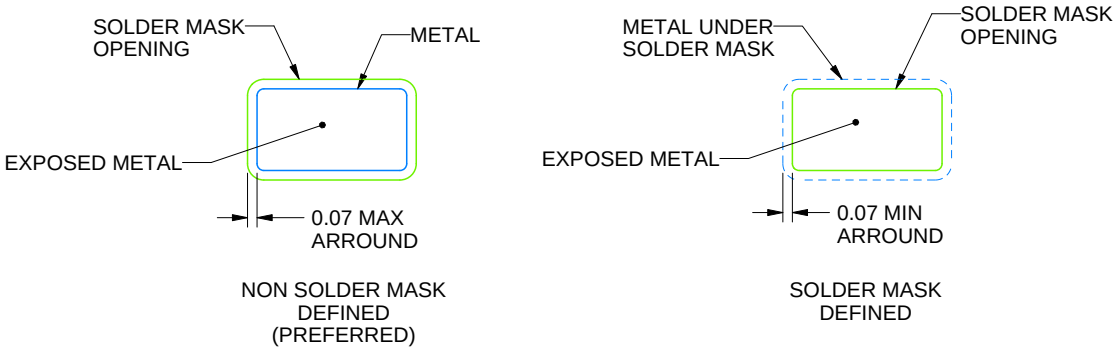
4214839/C 04/2017

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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

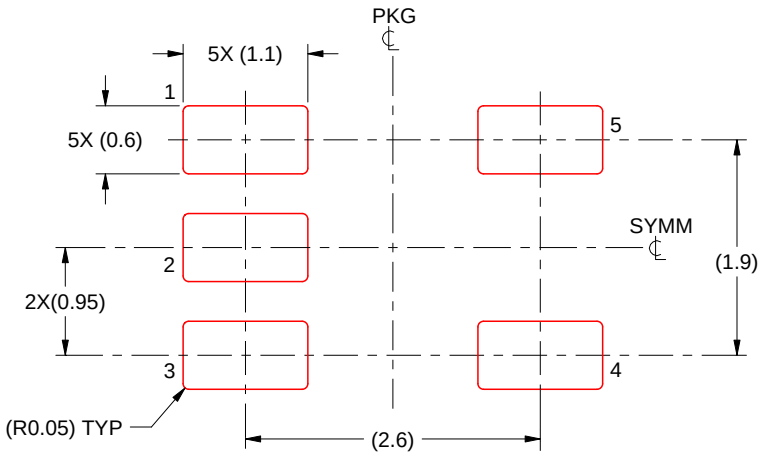


SOLDER MASK DETAILS

4214839/C 04/2017

NOTES: (continued)

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



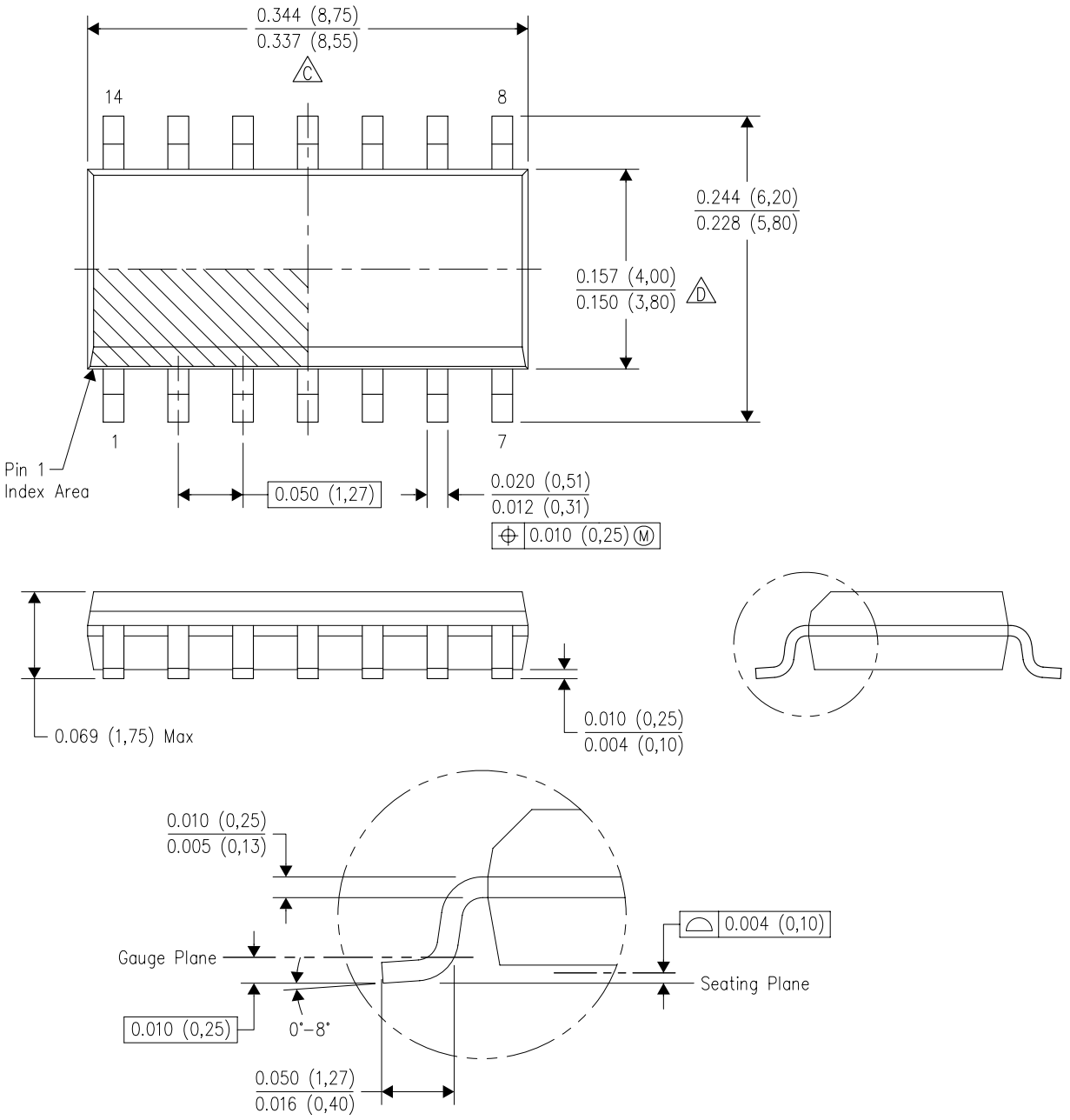
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:15X

4214839/C 04/2017

NOTES: (continued)

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

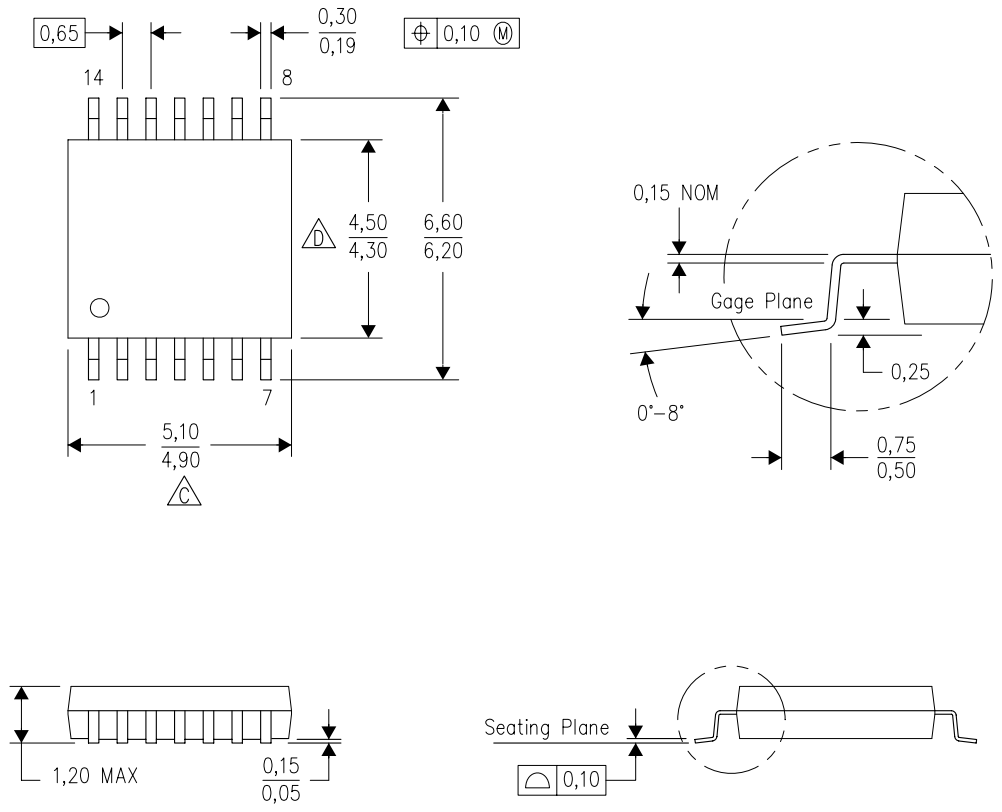
D (R–PDSO–G14) PLASTIC SMALL OUTLINE



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.

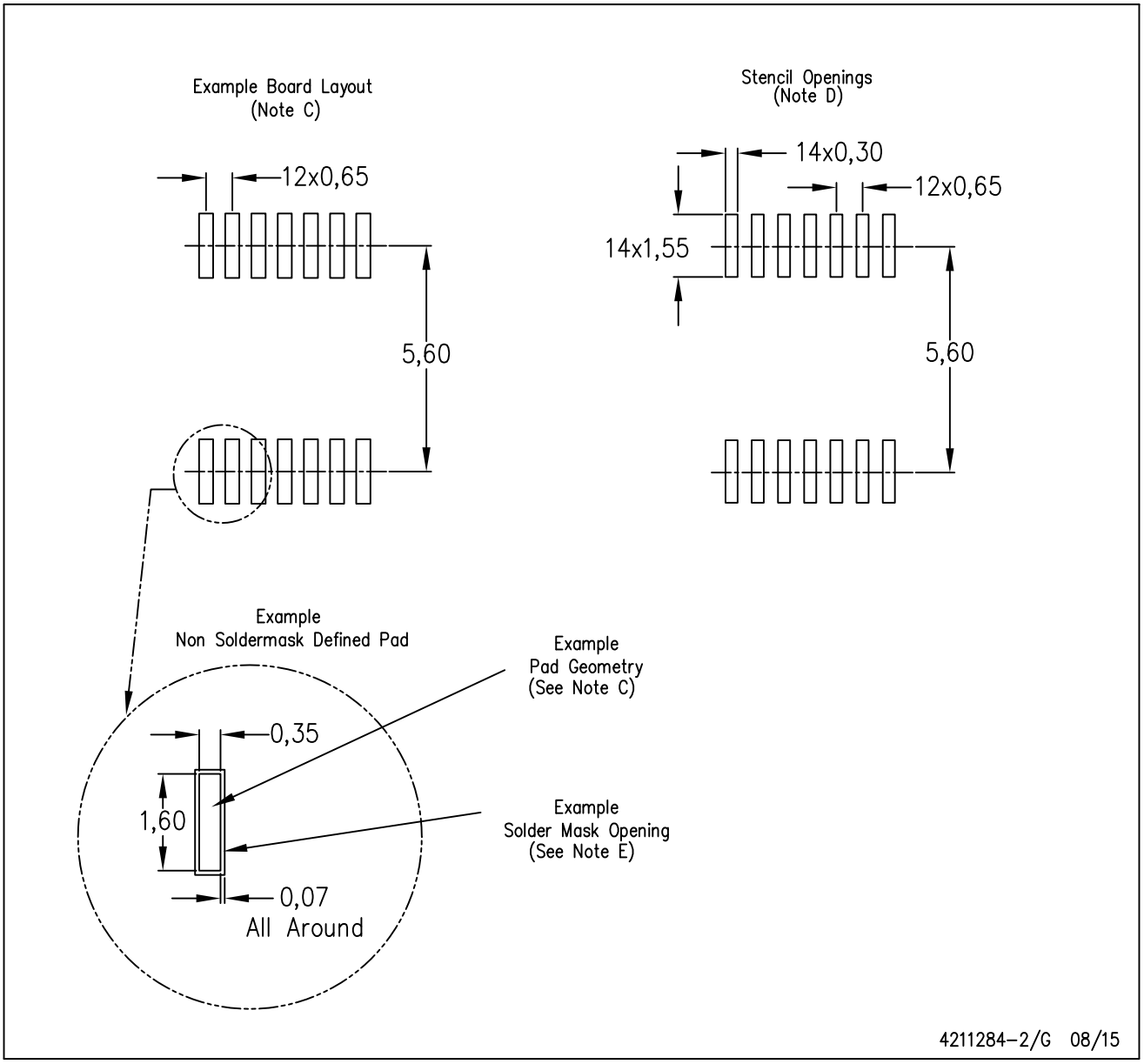
PW (R–PDSO–G14) PLASTIC SMALL OUTLINE



4040064–3/G 02/11

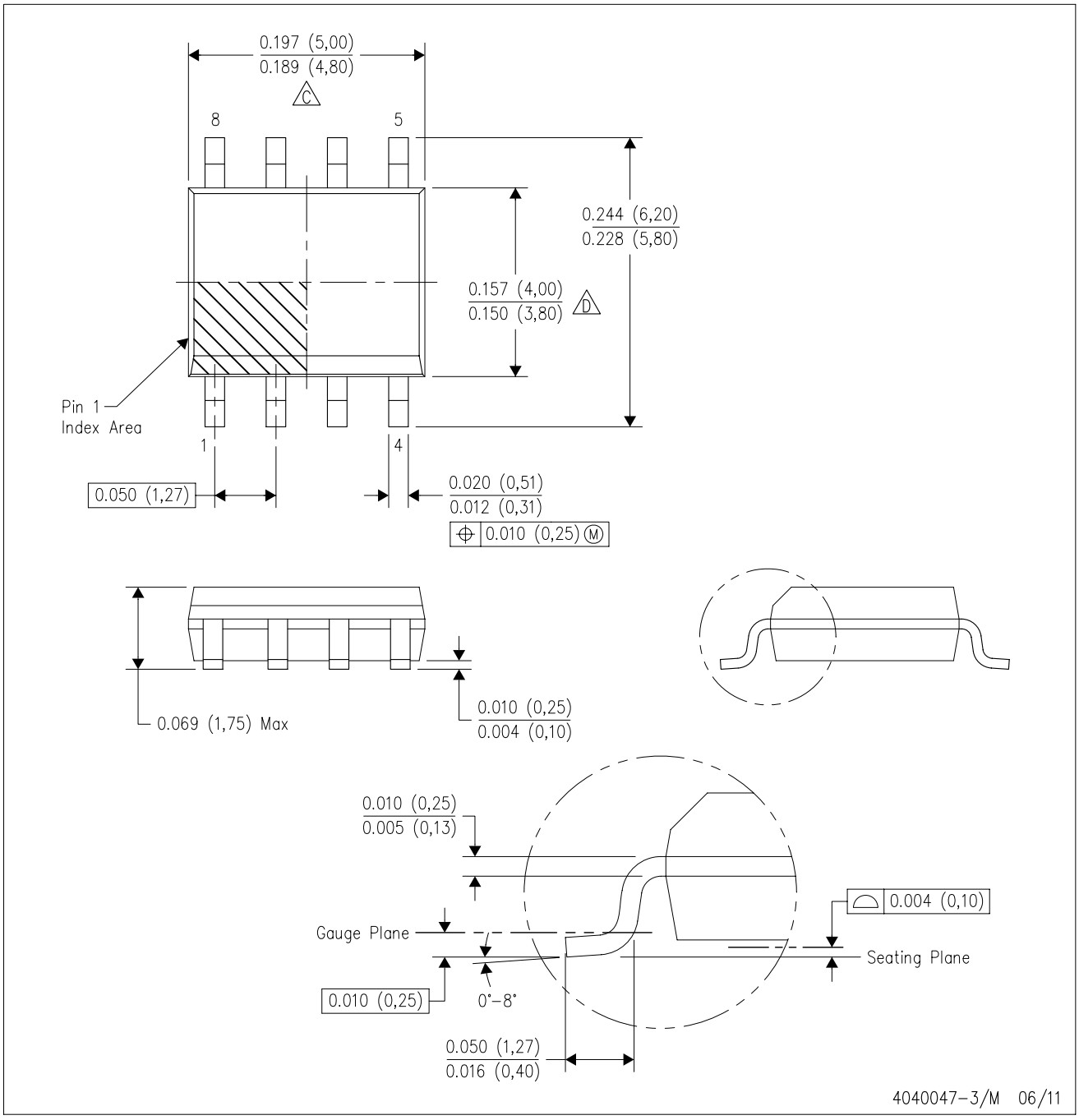
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D.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



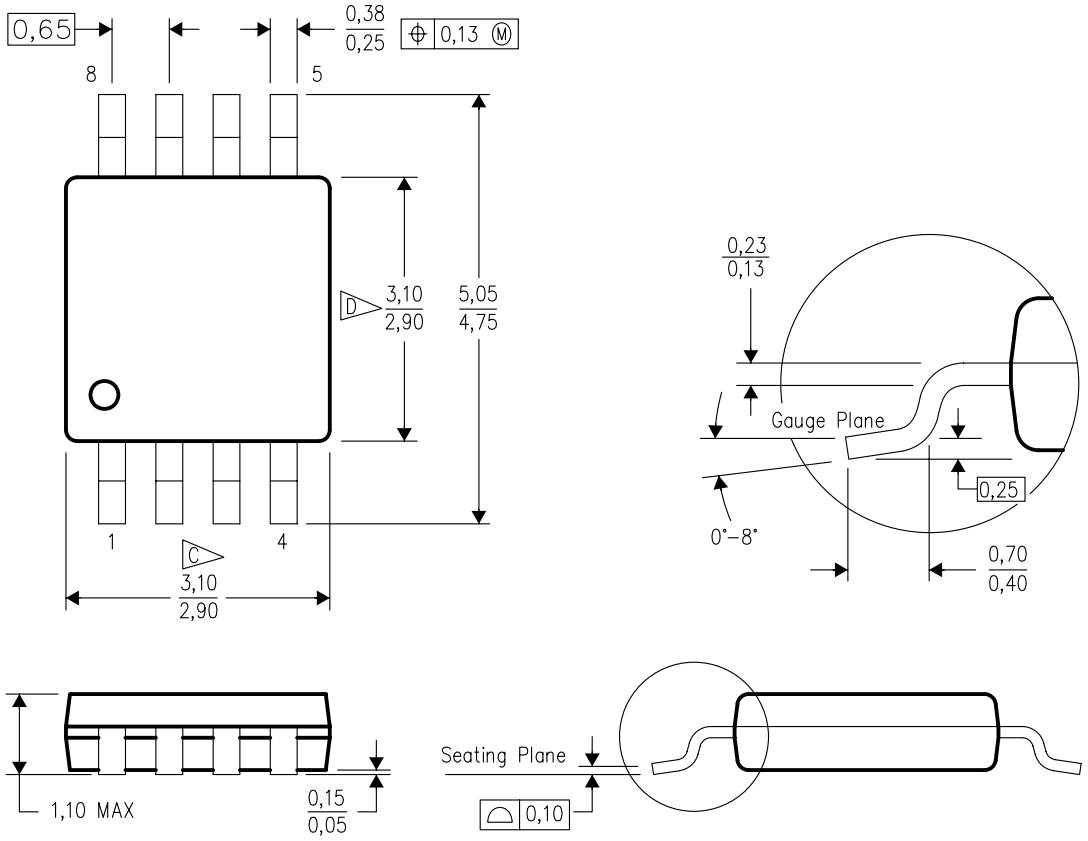
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact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

D (R–PDSO–G8) PLASTIC SMALL OUTLINE



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 AA.

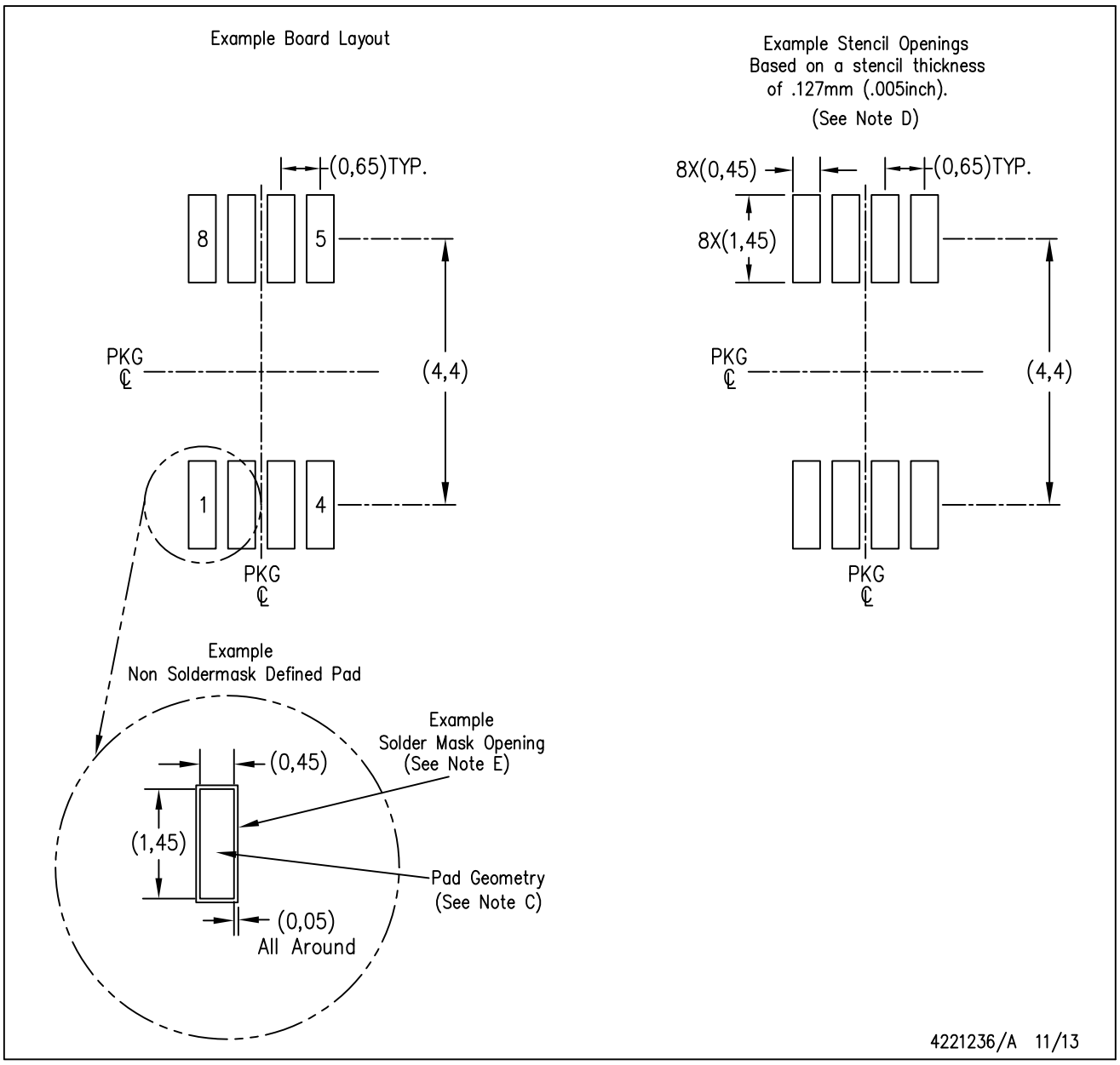
DGK (S–PDSO–G8) PLASTIC SMALL–OUTLINE PACKAGE



4073329/E 05/06

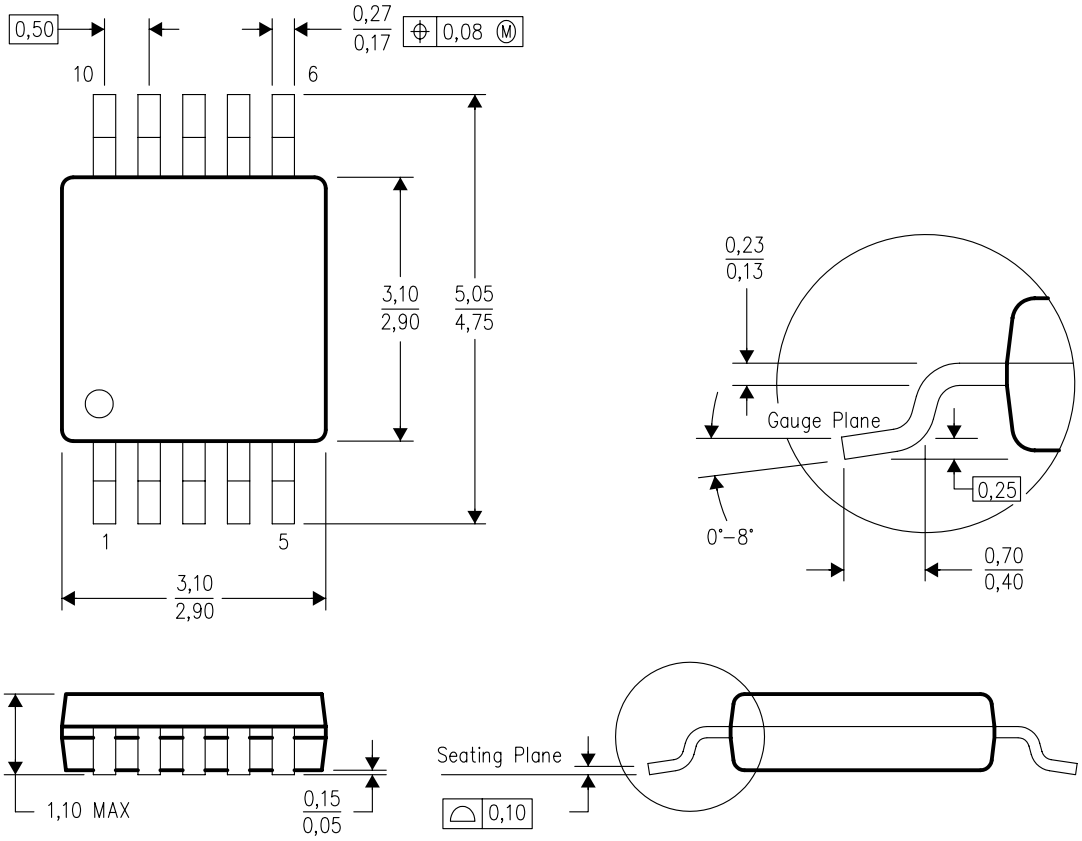
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 per end.
D. Body width does not include interlead flash. Interlead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

DGS (S–PDSO–G10) PLASTIC SMALL–OUTLINE PACKAGE



4073272/C 02/04

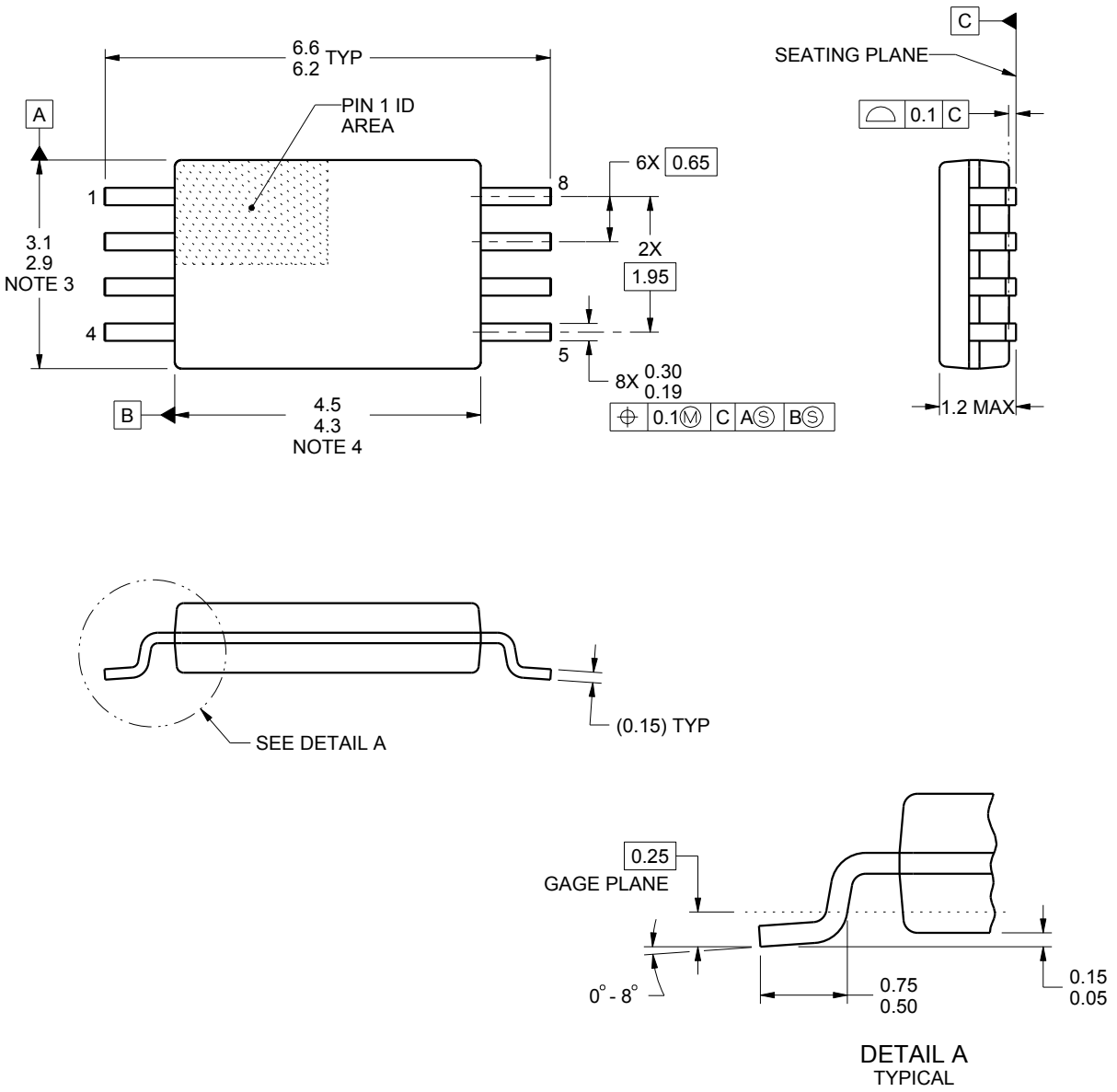
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion.
D. Falls within JEDEC MO–187 variation BA.

PACKAGE OUTLINE

PW0008A

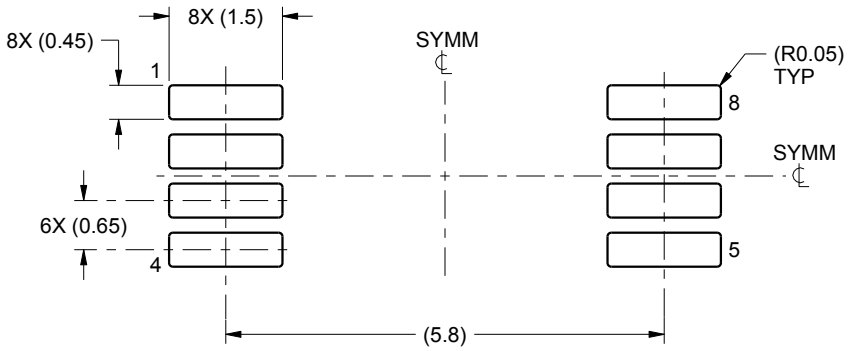
TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE

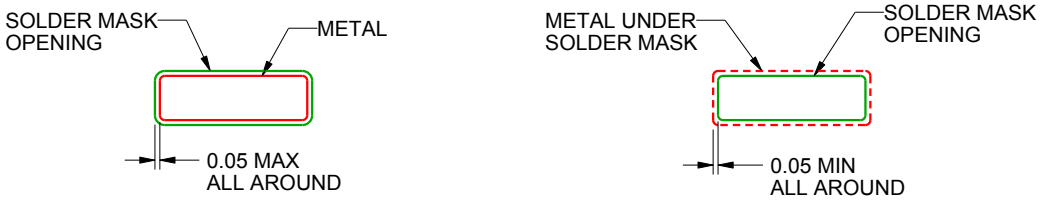


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-153, variation AA.



LAND PATTERN EXAMPLE
SCALE:10X

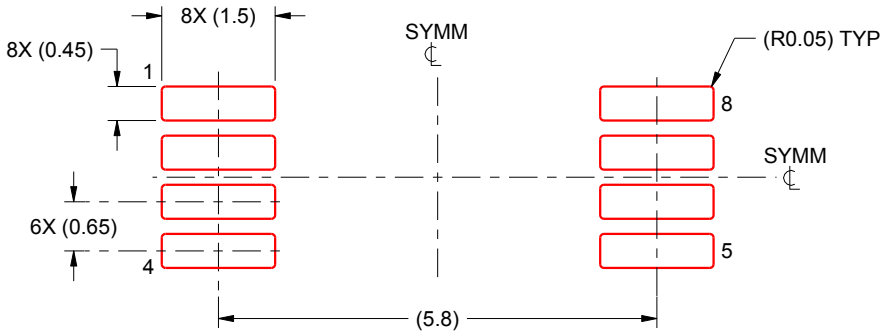


SOLDER MASK DETAILS
NOT TO SCALE

4221848/A 02/2015

NOTES: (continued)

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



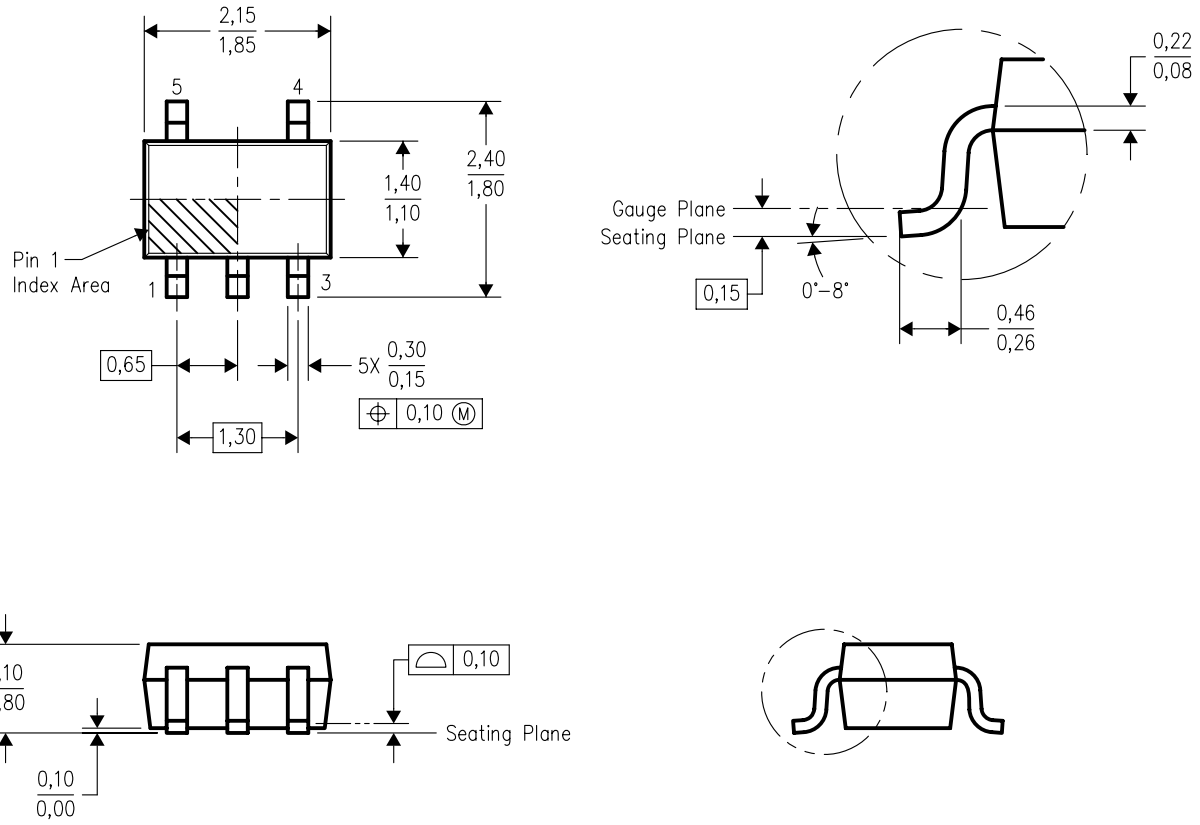
SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

4221848/A 02/2015

NOTES: (continued)

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

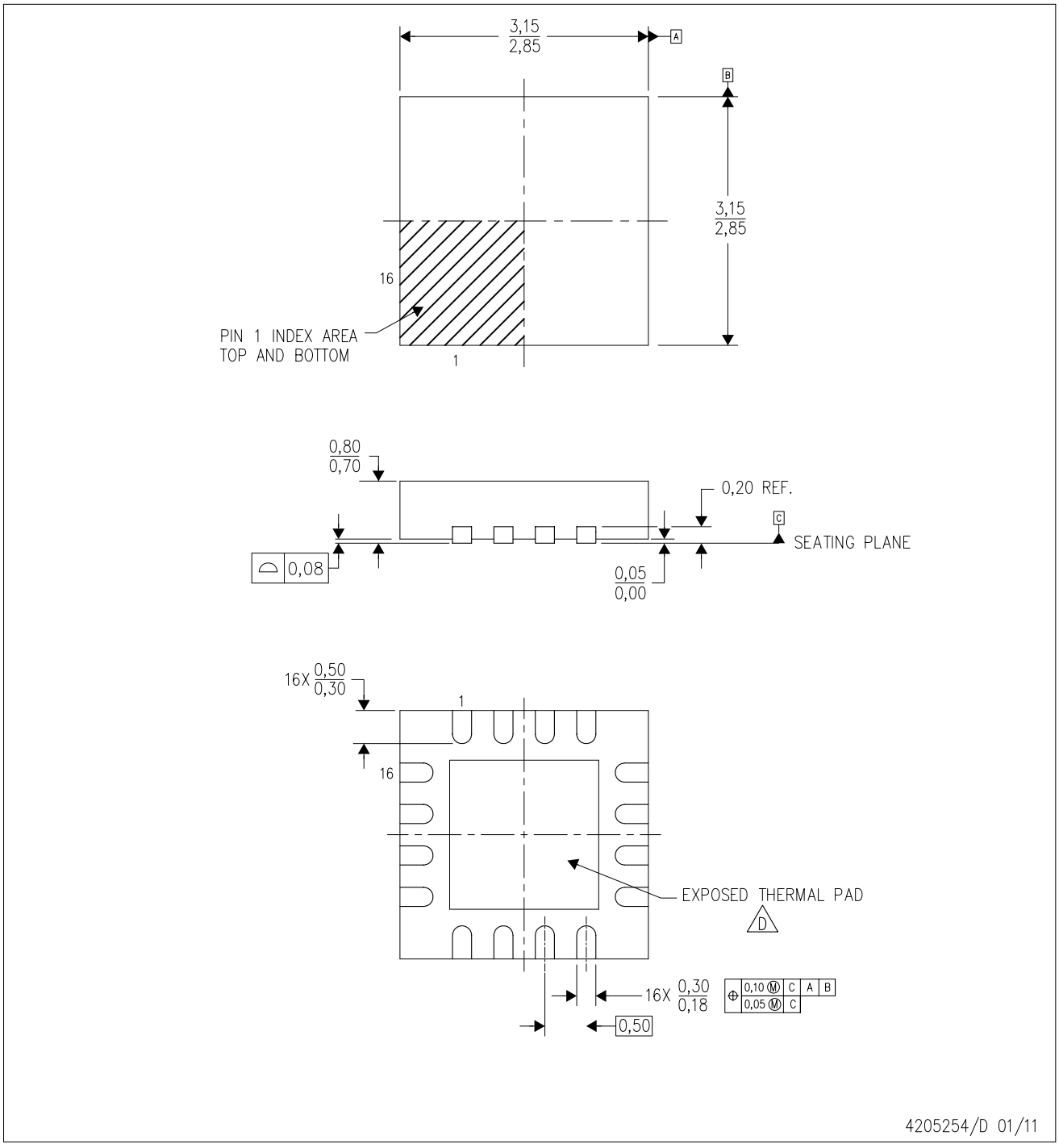
DCK (R–PDSO–G5) PLASTIC SMALL–OUTLINE PACKAGE



4093553–3/G 01/2007

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.

RTE (S–PWQFN–N16) PLASTIC QUAD FLATPACK NO–LEAD



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. Quad Flatpack, No–leads (QFN) package configuration.
D. The package thermal pad must be soldered to the board for thermal and mechanical performance. See the Product Data Sheet for details regarding the exposed thermal pad dimensions.
E. Falls within JEDEC MO–220.

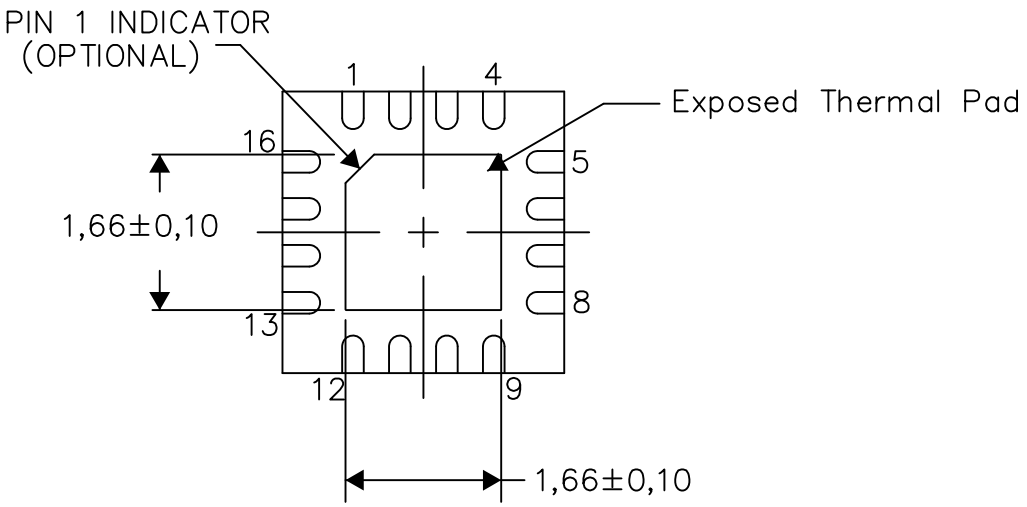
RTE (S–PWQFN–N16) PLASTIC QUAD FLATPACK NO–LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No–Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.



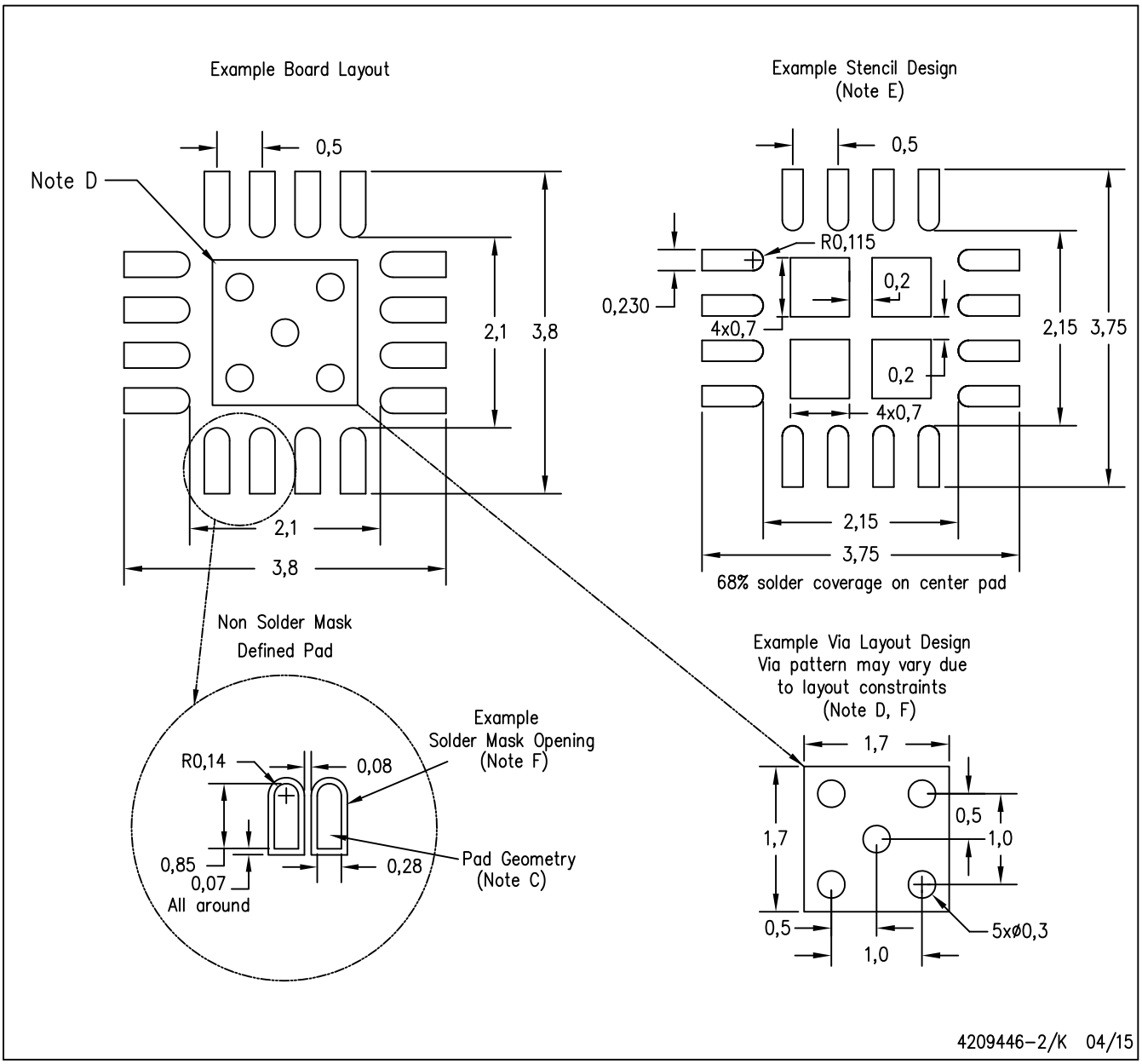
Bottom View

Exposed Thermal Pad Dimensions

4206446–8/U 08/15

NOTE: A. All linear dimensions are in millimeters

RTE (S–PWQFN–N16) PLASTIC QUAD FLATPACK NO–LEAD



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. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat–Pack Packages, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
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. Refer to IPC 7525 for stencil design considerations.
F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

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