



TLV34xx Low-Voltage Rail-to-Rail Output CMOS Operational Amplifiers With Shutdown

1 Features

- 1.8-V and 5-V Performance
- Low Offset (A Grade)
 - 1.25 mV Maximum (25°C)
 - 1.7 mV Maximum (–40°C to 125°C)
- Rail-to-Rail Output Swing
- Wide Common-Mode Input Voltage Range: –0.2 V to ($V_+ - 0.5$ V)
- Input Bias Current: 1 pA (Typical)
- Input Offset Voltage: 0.3 mV (Typical)
- Low Supply Current: 70 μ A/Channel
- Low Shutdown Current: 10 pA (Typical) Per Channel
- Gain Bandwidth: 2.3 MHz (Typical)
- Slew Rate: 0.9 V/ μ s (Typical)
- Turnon Time From Shutdown: 5 μ s (Typical)
- Input Referred Voltage Noise (at 10 kHz): 20 nV/ $\sqrt{\text{Hz}}$
- ESD Protection Exceeds JESD 22
 - 2000-V Human-Body Model (HBM)
 - 750-V Charged-device model (CDM)

2 Applications

- Cellular Phones
- Consumer Electronics (Laptops)
- Audio Preamplifier for Voice
- Portable and Battery-Powered Electronic Equipment
- Supply Current Monitoring
- Battery Monitoring
- Buffers
- Filters

3 Description

The TLV34xx devices are single and dual CMOS operational amplifiers, respectively, with low-voltage, low-power, and rail-to-rail output swing capabilities. The PMOS input stage offers an ultra-low input bias current of 1 pA (typical) and an offset voltage of 0.3 mV (typical). For applications requiring excellent dc precision, the A grade (TLV34xA) has a low offset voltage of 1.25 mV (maximum) at 25°C.

These single-supply amplifiers are designed specifically for ultra-low-voltage (1.5 V to 5 V) operation, with a common-mode input voltage range that typically extends from –0.2 V to 0.5 V from the positive supply rail.

The TLV341 (single) and TLV342 (dual) in the RUG package also offer a shutdown (SHDN) pin that can be used to disable the device. In shutdown mode, the supply current is reduced to 45 pA (typical). Offered in both the SOT-23 and smaller SC70 packages, the TLV341 is suitable for the most space-constrained applications. The dual TLV342 is offered in the standard SOIC, VSSOP, and X2QFN packages.

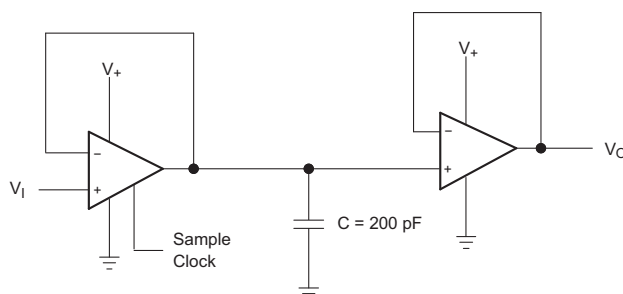
An extended industrial temperature range from –40°C to 125°C makes the TLV34xx suitable in a wide variety of commercial and industrial applications.

Device Information⁽¹⁾

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TLV341	SOT-23 (6)	2.90 mm × 1.60 mm
	SC70 (6)	2.00 mm × 1.25 mm
	SOT (6)	1.60 mm × 1.20 mm
TLV342	SOIC (8)	4.90 mm × 3.91 mm
	VSSOP (8)	3.00 mm × 3.00 mm
	X2QFN (10)	1.50 mm × 2.00 mm
TLV342S	X2QFN (10)	1.50 mm × 2.00 mm

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

Sample and Hold Circuit Using Two TLV341



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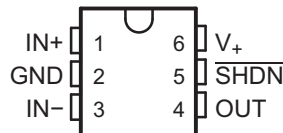
4 Revision History

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

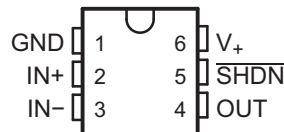
Changes from Revision C (November 2007) to Revision D	Page
Added <i>ESD Ratings</i> table, <i>Feature Description</i> section, <i>Device Functional Modes</i>, <i>Application and Implementation</i> section, <i>Power Supply Recommendations</i> section, <i>Layout</i> section, <i>Device and Documentation Support</i> section, and <i>Mechanical, Packaging, and Orderable Information</i> section	1
Removed DPK package and TLV344 part from the <i>Pin Configuration and Functions</i> table	3

5 Pin Configuration and Functions

TLV341 DBV or DCK Package
6-Pin SOT-23 or SC70
Top View



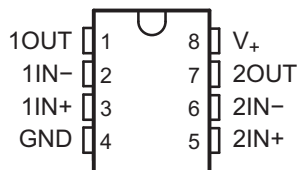
TLV341 DRL Package
6-Pin SOT
Top View



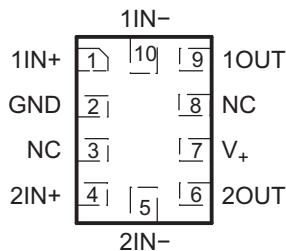
Pin Functions: TLV341

PIN			I/O	DESCRIPTION
NAME	SOT-23, SC70	SOT		
1IN+	1	2	I	Noninverting input on channel 1
1IN–	3	3	I	Inverting input on channel 1
1OUT	4	4	O	Output on channel 1
GND	2	1	—	Ground
SHDN	5	5	I	Shutdown active low
V+	6	6	—	Positive power supply

TLV342 D or DGK Package
10-Pin SOIC or VSSOP
Top View



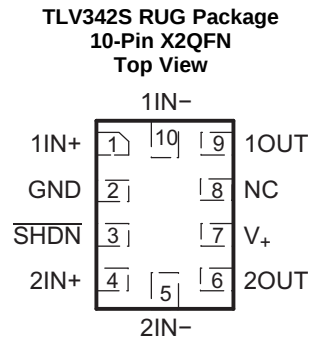
TLV342 RUG Package
10-Pin X2QFN
Top View



Pin Functions: TLV342

PIN			I/O	DESCRIPTION
NAME	SOIC, VSSOP	X2QFN		
1IN+	3	1	I	Noninverting input on channel 1
1IN–	2	10	I	Inverting input on channel 1
1OUT	1	9	O	Output on channel 1
2IN+	5	4	I	Noninverting input on channel 2
2IN–	6	5	I	Inverting input on channel 2
2OUT	7	6	O	Output on channel 2
GND	4	2	—	Ground
NC ⁽¹⁾	—	3, 8	—	Not connected
V+	8	7	—	Positive power supply

(1) NC – No internal connection


Pin Functions: TLV342S

PIN		I/O	DESCRIPTION
NAME	NO.		
1IN+	1	I	Noninverting input on channel 1
1IN–	10	I	Inverting input on channel 1
1OUT	9	O	Output on channel 1
2IN+	4	I	Noninverting input on channel 2
2IN–	5	I	Inverting input on channel 2
2OUT	6	O	Output on channel 2
GND	2	—	Ground
NC ⁽¹⁾	8	—	Not connected
SHDN	3	I	Shutdown active low
V+	7	—	Positive power supply

(1) NC – No internal connection

6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
V ₊	Supply voltage ⁽²⁾	–0.3	5.5	V
V _{ID}	Differential input voltage ⁽³⁾		±5.5	V
V _I	Input voltage (either input or shutdown)	–0.3	5.5	V
V _O	Output voltage	–0.3	V _{CC} + 0.3	V
T _J	Operating virtual-junction temperature		150	°C
T _{stg}	Storage temperature	–65	150	°C

- (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) All voltage values (except differential voltages) are with respect to the network GND.
- (3) Differential voltages are at IN+ with respect to IN–.

6.2 ESD Ratings

		VALUE	UNIT
V _(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2000
		Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±750

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

6.3 Recommended Operating Conditions

		MIN	MAX	UNIT
V ₊	Supply voltage (single-supply operation)	1.5	5.5	V
T _A	Operating free-air temperature	–40	125	°C

6.4 Thermal Information: TLV341

THERMAL METRIC ⁽¹⁾		TLV341			UNIT
		DBV (SOT-23)	DCK (SC70)	DRL (SOT)	
		6 PINS	6 PINS	6 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	193.4	196.8	221.1	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	145.6	82.4	109.1	°C/W
R _{θJB}	Junction-to-board thermal resistance	44.1	95.2	111.4	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	34.1	1.8	6.2	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	43.4	93.2	109.8	°C/W

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

6.5 Thermal Information: TLV342

THERMAL METRIC ⁽¹⁾		TLV342			UNIT
		D (SOIC)	DGK (MSOP)	RUG (X2QFN)	
		8 PINS	8 PINS	10 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	123.6	192.3	167	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	69.8	78.2	56.5	°C/W
R _{θJB}	Junction-to-board thermal resistance	63.9	112.6	94.3	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	24.4	15.2	4.1	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	63.4	111.2	94	°C/W

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

6.6 Thermal Information: TLV342S

THERMAL METRIC ⁽¹⁾		TLV342S	UNIT
		RUG (X2QFN)	
		10 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	158.3	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	52.6	°C/W
R _{θJB}	Junction-to-board thermal resistance	87.9	°C/W
Ψ _{JT}	Junction-to-top characterization parameter	1	°C/W
Ψ _{JB}	Junction-to-board characterization parameter	87	°C/W

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

6.7 Electrical Characteristics: $V_+ = 1.8\text{ V}$

$V_+ = 1.8\text{ V}$, $\text{GND} = 0\text{ V}$, $V_{\text{IC}} = V_{\text{O}} = V_+/2$, $R_{\text{L}} > 1\text{ M}\Omega$ (unless otherwise noted). See [Shutdown Characteristics: \$V_+ = 1.8\text{ V}\$](#) .

PARAMETER		TEST CONDITIONS	T_{A}	MIN	TYP ⁽¹⁾	MAX	UNIT
V_{IO}	Input offset voltage	Standard grade	25°C		0.3	4	mV
			Full range			4.5	
	A grade		25°C		0.3	1.25	
			0°C to 125°C		0.3	1.5	
			–40°C to 125°C		0.3	1.7	
α_{VIO}	Average temperature coefficient of input offset voltage		Full range		1.9		$\mu\text{V}/^\circ\text{C}$
I_{IB}	Input bias current		25°C		1	100	pA
			–40°C to 85°C			375	
			–40°C to 125°C			3000	
I_{IO}	Input offset current		25°C		6.6		fA
CMRR	Common-mode rejection ratio	$0 \leq V_{\text{ICR}} \leq 1.2\text{ V}$	25°C	60	85		dB
			Full range	50			
k_{SVR}	Supply-voltage rejection ratio	$1.8\text{ V} \leq V_+ \leq 5\text{ V}$	25°C	75	95		dB
			Full range	65			
V_{ICR}	Common-mode input voltage range	CMRR $\geq 60\text{ dB}$	25°C	0		1.2	V
A_{V}	Large-signal voltage gain ⁽²⁾	$R_{\text{L}} = 10\text{ k}\Omega$ to 1.35 V	25°C	70	110		dB
			Full range	60			
		$R_{\text{L}} = 2\text{ k}\Omega$ to 1.35 V	25°C	65	100		
			Full range	55			
V_{O}	Output swing (delta from supply rails)	$R_{\text{L}} = 2\text{ k}\Omega$ to 1.35 V	Low level	25°C	22	50	mV
				Full range		75	
			High level	25°C	25	50	
				Full range		75	
		$R_{\text{L}} = 10\text{ k}\Omega$ to 1.35 V	Low level	25°C	14	20	
				Full range		25	
			High level	25°C	7	20	
				Full range		25	
I_{CC}	Supply current (per channel)		25°C		70	150	μA
			Full range			200	
I_{OS}	Output short-circuit current	Sourcing	25°C	6	12		mA
		Sinking		10	20		
SR	Slew rate	$R_{\text{L}} = 10\text{ k}\Omega$ ⁽³⁾	25°C		0.9		V/ μs
GBW	Unity-gain bandwidth	$R_{\text{L}} = 10\text{ k}\Omega$, $C_{\text{L}} = 200\text{ pF}$	25°C		2.2		MHz
ϕ_{m}	Phase margin	$R_{\text{L}} = 100\text{ k}\Omega$, $C_{\text{L}} = 200\text{ pF}$	25°C		55		°
G_{m}	Gain margin	$R_{\text{L}} = 100\text{ k}\Omega$, $C_{\text{L}} = 200\text{ pF}$	25°C		15		dB
V_{n}	Equivalent input noise voltage	$f = 1\text{ kHz}$	25°C		33		$\text{nV}/\sqrt{\text{Hz}}$
I_{n}	Equivalent input noise current	$f = 1\text{ kHz}$	25°C		0.001		$\text{pA}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion	$f = 1\text{ kHz}$, $A_{\text{V}} = 1$, $R_{\text{L}} = 600\text{ }\Omega$, $V_{\text{I}} = 1\text{ V}_{\text{PP}}$	25°C		0.015%		

(1) Typical values represent the most likely parametric norm.

(2) $\text{GND} + 0.2\text{ V} \leq V_{\text{O}} \leq V_+ - 0.2\text{ V}$

(3) Connected as voltage follower with 2- V_{PP} step input. Number specified is the slower of the positive and negative slew rates.

6.8 Electrical Characteristics: $V_+ = 5\text{ V}$

$V_+ = 5\text{ V}$, $\text{GND} = 0\text{ V}$, $V_{\text{IC}} = V_{\text{O}} = V_+/2$, $R_{\text{L}} > 1\text{ M}\Omega$ (unless otherwise noted). See [Shutdown Characteristics: \$V_+ = 5\text{ V}\$](#) .

PARAMETER		TEST CONDITIONS	T_{A}	MIN	TYP ⁽¹⁾	MAX	UNIT
V_{IO}	Input offset voltage	Standard grade	25°C		0.3	4	mV
			Full range			4.5	
	A grade		25°C		0.3	1.25	
			0°C to 125°C		0.3	1.5	
			–40°C to 125°C		0.3	1.7	
α_{VIO}	Average temperature coefficient of input offset voltage		Full range		1.9		$\mu\text{V}/^\circ\text{C}$
I_{IB}	Input bias current		25°C		1	200	pA
			–40°C to 85°C			375	
			–40°C to 125°C			3000	
I_{IO}	Input offset current		25°C		6.6		fA
CMRR	Common-mode rejection ratio	$0 \leq V_{\text{ICR}} \leq 4.4\text{ V}$	25°C	75	90		dB
			Full range	70			
k_{SVR}	Supply-voltage rejection ratio	$1.8\text{ V} \leq V_+ \leq 5\text{ V}$	25°C	75	95		dB
			Full range	65			
V_{ICR}	Common-mode input voltage range	CMRR $\geq 70\text{ dB}$	25°C	0		4.4	V
A_{V}	Large-signal voltage gain ⁽²⁾	$R_{\text{L}} = 10\text{ k}\Omega$ to 2.5 V	25°C	80	110		dB
			Full range	70			
		$R_{\text{L}} = 2\text{ k}\Omega$ to 2.5 V	25°C	75	105		
			Full range	60			
V_{O}	Output swing (delta from supply rails)	$R_{\text{L}} = 2\text{ k}\Omega$ to 2.5 V	Low level	25°C	40	60	mV
				Full range		85	
			High level	25°C	25	60	
				Full range		85	
		$R_{\text{L}} = 10\text{ k}\Omega$ to 2.5 V	Low level	25°C	18	30	
				Full range		40	
			High level	25°C	7	15	
				Full range		20	
I_{CC}	Supply current (per channel)		25°C		75	150	μA
			Full range			200	
I_{OS}	Output short-circuit current	Sourcing	25°C	60	113		mA
		Sinking		80	115		
SR	Slew rate	$R_{\text{L}} = 10\text{ k}\Omega$ ⁽³⁾	25°C		1		V/ μs
GBW	Unity-gain bandwidth	$R_{\text{L}} = 10\text{ k}\Omega$, $C_{\text{L}} = 200\text{ pF}$	25°C		2.3		MHz
ϕ_{m}	Phase margin	$R_{\text{L}} = 100\text{ k}\Omega$, $C_{\text{L}} = 200\text{ pF}$	25°C		55		°
G_{m}	Gain margin	$R_{\text{L}} = 100\text{ k}\Omega$, $C_{\text{L}} = 200\text{ pF}$	25°C		15		dB
V_{n}	Equivalent input noise voltage	$f = 1\text{ kHz}$	25°C		33		$\text{nV}/\sqrt{\text{Hz}}$
I_{n}	Equivalent input noise current	$f = 1\text{ kHz}$	25°C		0.001		$\text{pA}/\sqrt{\text{Hz}}$
THD	Total harmonic distortion	$f = 1\text{ kHz}$, $A_{\text{V}} = 1$, $R_{\text{L}} = 600\text{ }\Omega$, $V_{\text{I}} = 1\text{ V}_{\text{PP}}$	25°C		0.012%		

(1) Typical values represent the most likely parametric norm.

(2) $\text{GND} + 0.2\text{ V} \leq V_{\text{O}} \leq V_+ - 0.2\text{ V}$

(3) Connected as voltage follower with 2- V_{PP} step input. Number specified is the slower of the positive and negative slew rates.

6.9 Shutdown Characteristics: $V_+ = 1.8\text{ V}$

 $V_+ = 1.8\text{ V}$, $\text{GND} = 0\text{ V}$, $V_{\text{IC}} = V_{\text{O}} = V_+/2$, $R_{\text{L}} > 1\text{ M}\Omega$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_{A}	MIN	TYP	MAX	UNIT
$I_{\text{CC(SHDN)}}$	Supply current in shutdown mode	$V_{\text{SD}} = 0\text{ V}$	25°C		0.01	1	μA
			Full range			1.5	
$t_{\text{(on)}}$	Amplifier turnon time		25°C		5		μs
V_{SD}	Recommended shutdown pin voltage range	On mode	25°C	1.5		1.8	V
		Shutdown mode		0		0.5	

6.10 Shutdown Characteristics: $V_+ = 5\text{ V}$

 $V_+ = 5\text{ V}$, $\text{GND} = 0\text{ V}$, $V_{\text{IC}} = V_{\text{O}} = V_+/2$, $R_{\text{L}} > 1\text{ M}\Omega$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_{A}	MIN	TYP	MAX	UNIT
$I_{\text{CC(SHDN)}}$	Supply current in shutdown mode	$V_{\text{SD}} = 0\text{ V}$	25°C		0.01	1	μA
			Full range			1.5	
$t_{\text{(on)}}$	Amplifier turnon time		25°C		5		μs
V_{SD}	Recommended shutdown pin voltage range	On mode	25°C	4.5		5	V
		Shutdown mode		0		0.8	

6.11 Typical Characteristics

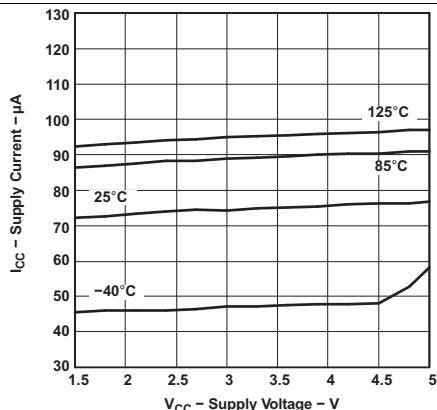


Figure 1. Supply Current vs Supply Voltage

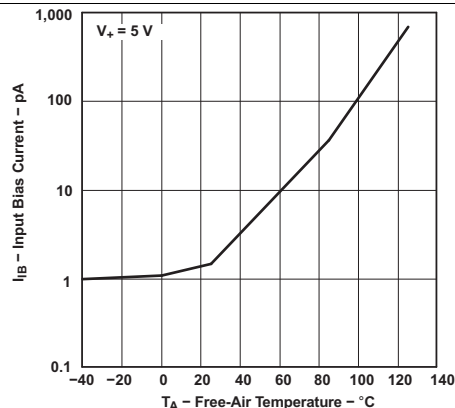


Figure 2. Input Bias Current vs Temperature

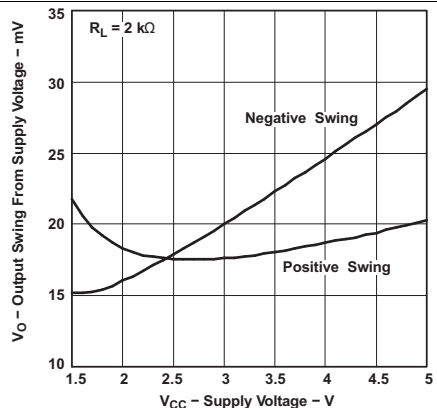


Figure 3. Output Voltage Swing vs Supply Voltage

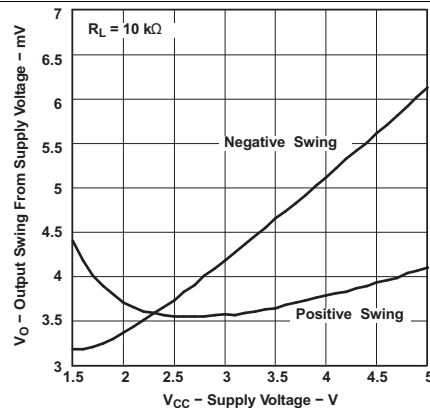


Figure 4. Output Voltage Swing vs Supply Voltage

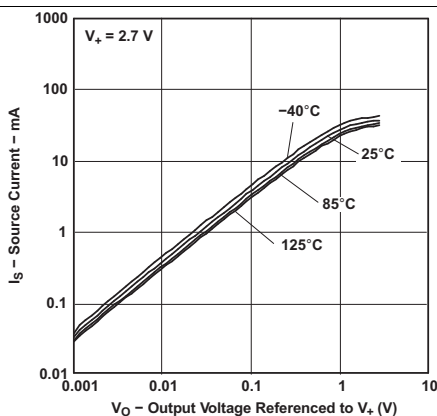


Figure 5. Source Current vs Output Voltage

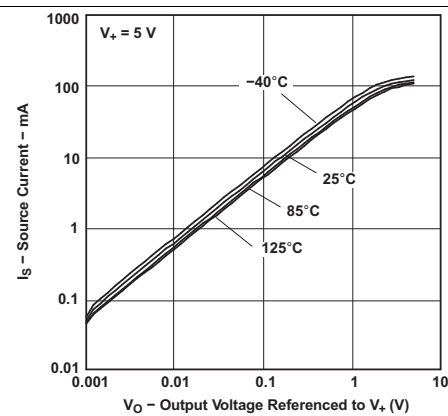
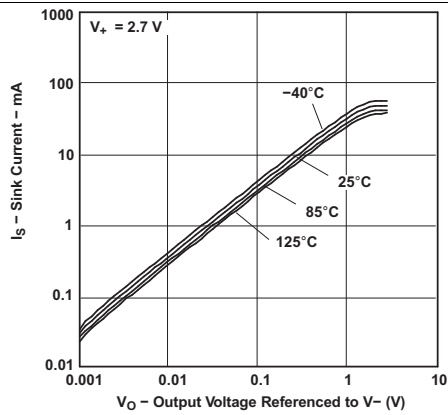
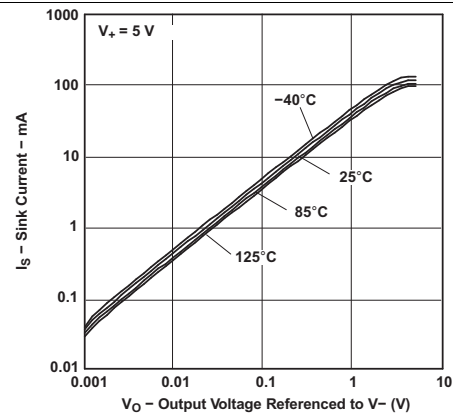
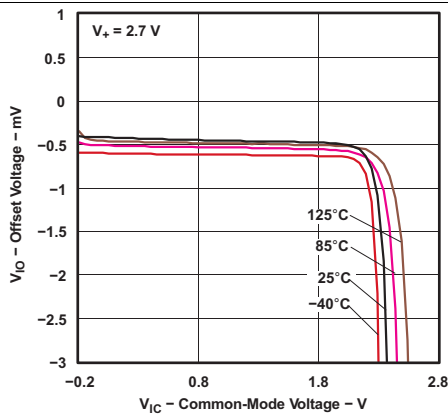
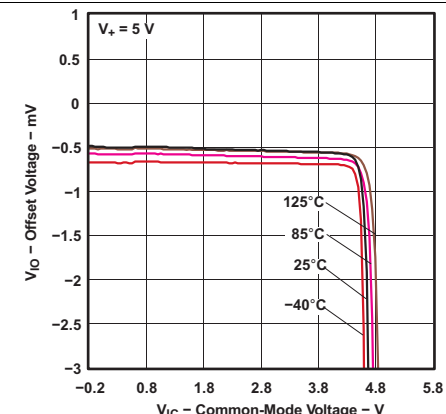
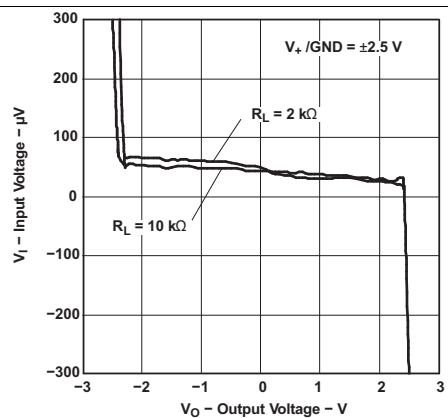
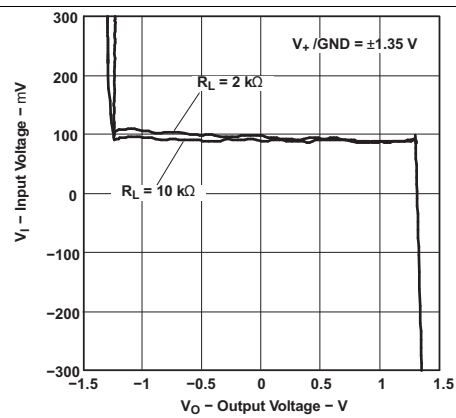


Figure 6. Source Current vs Output Voltage

Typical Characteristics (continued)

Figure 7. Sink Current vs Output Voltage

Figure 8. Sink Current vs Output Voltage

Figure 9. Offset Voltage vs Common-Mode Voltage

Figure 10. Offset Voltage vs Common-Mode Voltage

Figure 11. Input Voltage vs Output Voltage

Figure 12. Input Voltage vs Output Voltage

Typical Characteristics (continued)

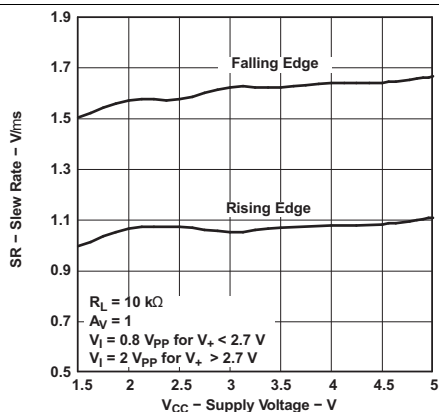


Figure 13. Slew Rate vs Supply Voltage

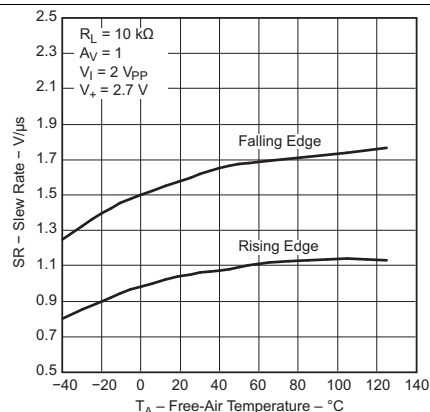


Figure 14. Slew Rate vs Temperature

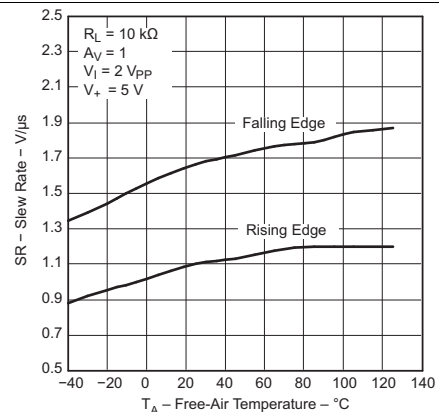


Figure 15. Slew Rate vs Temperature

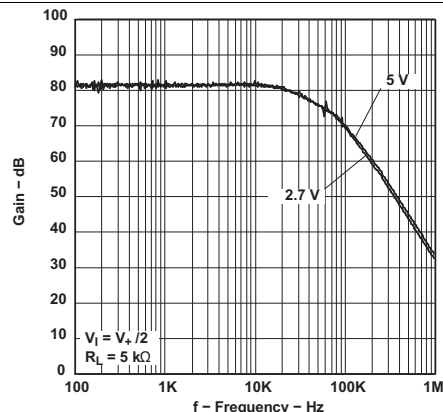


Figure 16. CMRR vs Frequency

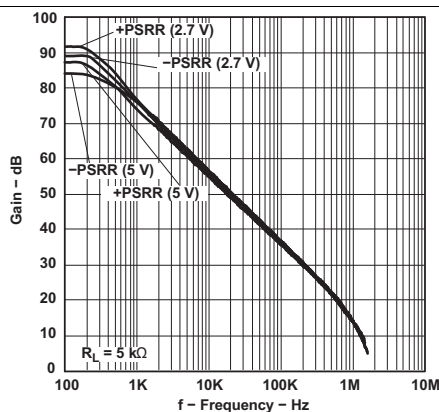


Figure 17. PSRR vs Frequency

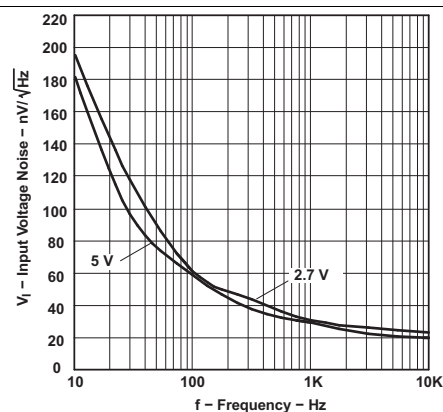
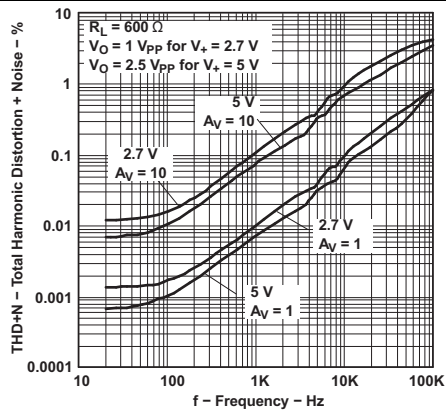
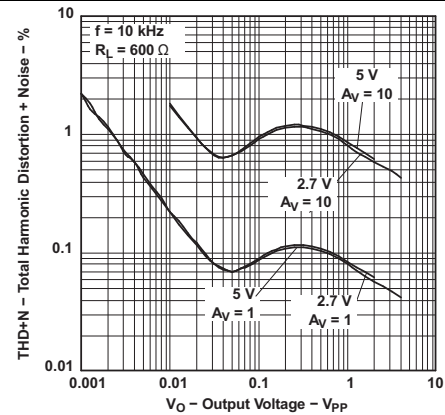
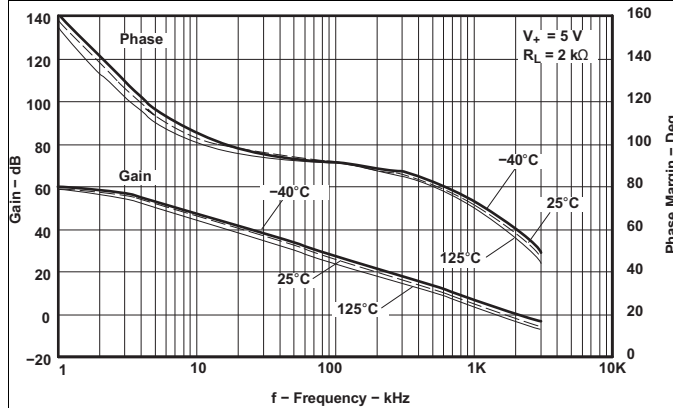
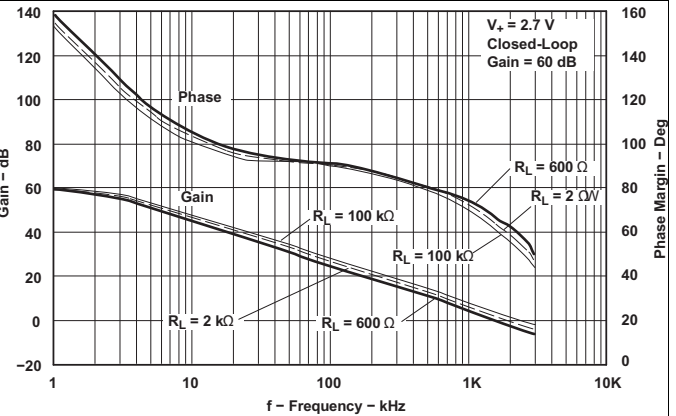
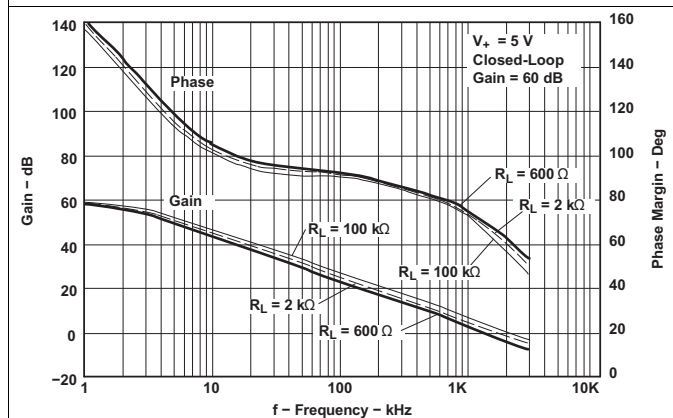
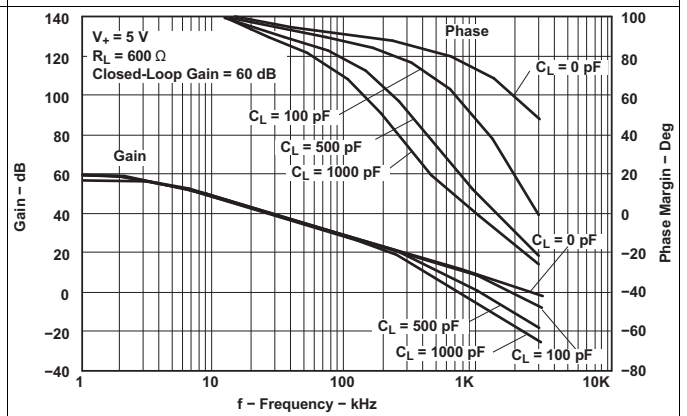


Figure 18. Input Voltage Noise vs Frequency

Typical Characteristics (continued)

Figure 19. Total Harmonic Distortion +Noise vs Frequency

Figure 20. Total Harmonic Distortion +Noise vs Output Voltage

Figure 21. Frequency Response vs Temperature

Figure 22. Frequency Response vs R_L

Figure 23. Frequency Response vs R_L

Figure 24. Frequency Response vs C_L

Typical Characteristics (continued)

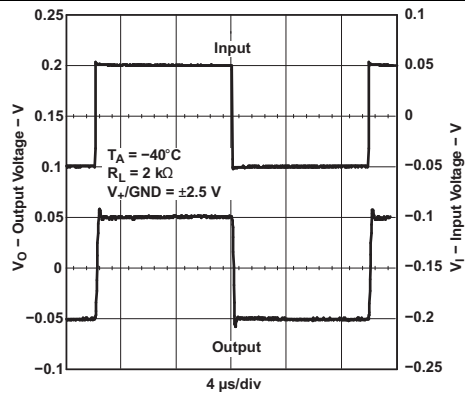


Figure 25. Small-Signal Noninverting Response

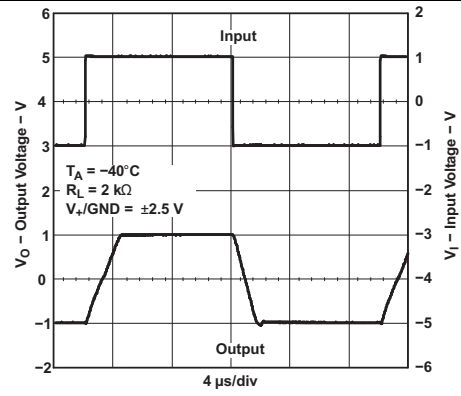


Figure 26. Large-Signal Noninverting Response

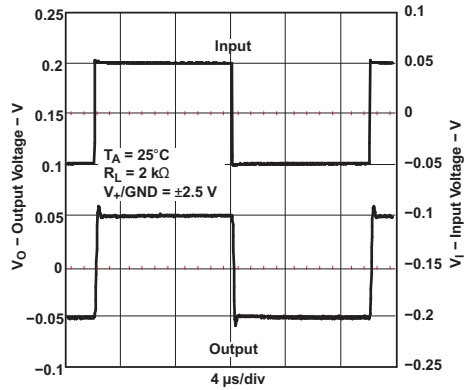


Figure 27. Small-Signal Noninverting Response

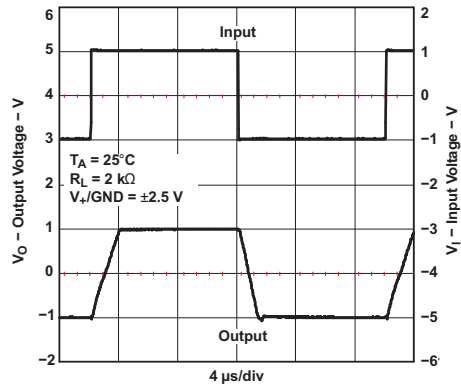


Figure 28. Large-Signal Noninverting Response

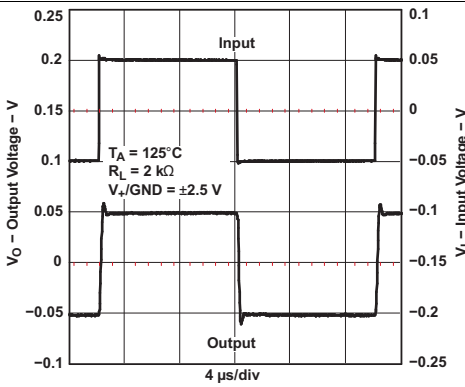


Figure 29. Small-Signal Noninverting Response

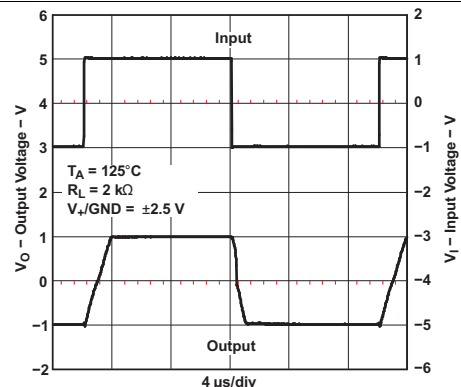
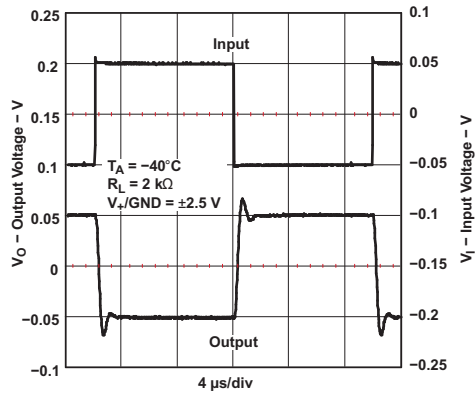
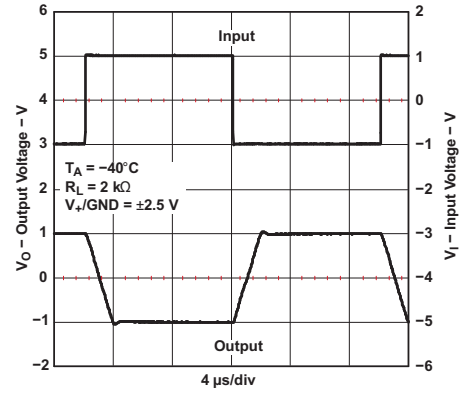
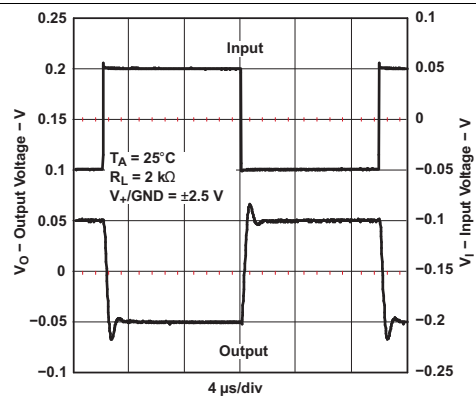
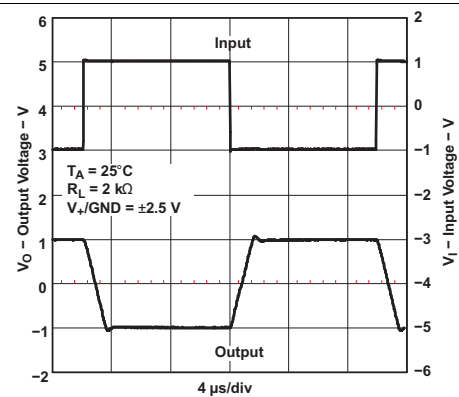
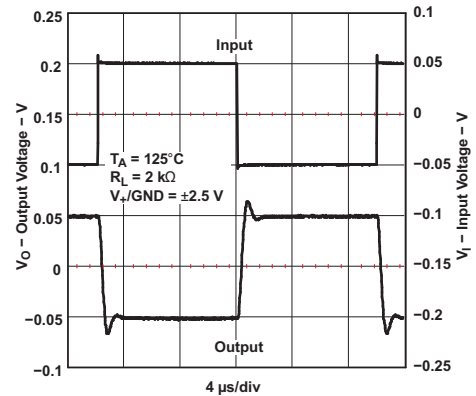
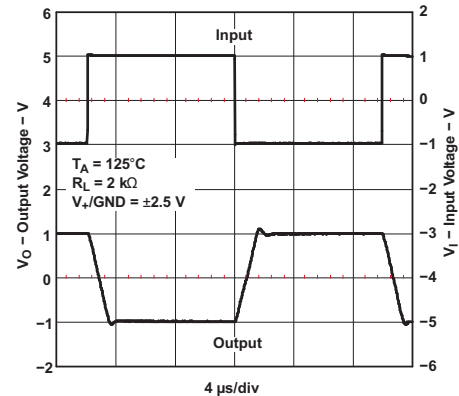


Figure 30. Large-Signal Noninverting Response

Typical Characteristics (continued)

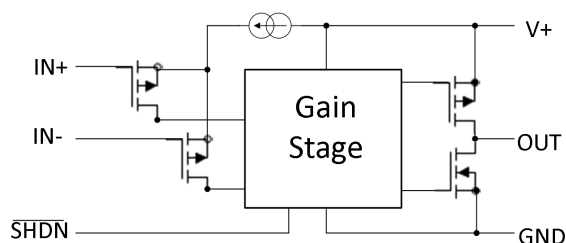

Figure 31. Small-Signal Noninverting Response

Figure 32. Large-Signal Inverting Response

Figure 33. Small-Signal Inverting Response

Figure 34. Large-Signal Inverting Response

Figure 35. Small-Signal Inverting Response

Figure 36. Large-Signal Inverting Response

7 Detailed Description

7.1 Overview

The TLV34xx devices are precision operational amplifiers with CMOS inputs for very low input bias current. Grade A devices offer lower V_{IO} for high accuracy in direct-coupled applications. Output is rail to rail and input common mode includes ground. TLV341 and TLV342S have shutdown mode for very low supply current.

7.2 Functional Block Diagram



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7.3 Feature Description

7.3.1 PMOS Input Stage

PMOS Input Stage supports a lower input range that includes ground. Upper range limit is $V_{CC} - 0.6\text{ V}$.

7.3.2 CMOS Output Stage

The CMOS drain output topology allows rail-to-rail output swing.

7.3.3 Shutdown

TLV341 and TLV342S include a shutdown pin. During shutdown, I_{CC} is nearly zero and the output becomes high impedance. The typical turnon time coming out of shutdown is 5 μs .

7.4 Device Functional Modes

The TLV34xx devices have two operation modes:

- Normal operation when $\overline{\text{SHDN}}$ pin is at V_+ level or the $\overline{\text{SHDN}}$ pin is not present
- Shutdown mode when $\overline{\text{SHDN}}$ is at GND level; I_{CC} is very low and output is high impedance.

8 Application and Implementation

NOTE

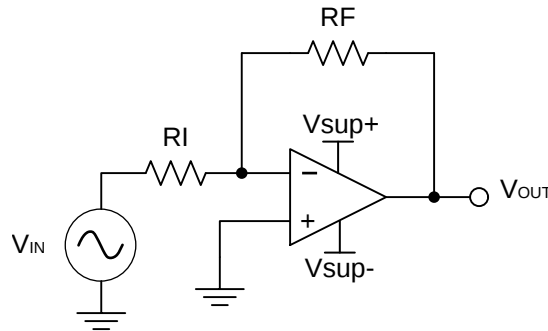
Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation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

8.1 Application Information

The TLV34xx devices have rail-to-rail output and input range from ground to VCC – 0.6 V. CMOS inputs provide very low input current. Shutdown capability is an option in dual amplifier version. Operation from 1.5 V to 5.5 V is possible.

8.2 Typical Application

A typical application for an operational amplifier in an inverting amplifier. This amplifier takes a positive voltage on the input, and makes it a negative voltage of the same magnitude. In the same manner, it also makes negative voltages positive.



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Figure 37. Application Schematic

8.2.1 Design Requirements

The supply voltage must be chosen such that it is larger than the input voltage range and output voltage range. For instance, this application scales a signal of ± 0.5 V to ± 1.8 V. Setting the supply at ± 2 V is sufficient to accommodate this application. The supplies can power up in any order; however, neither supply can be of opposite polarity relative to ground at any time; otherwise, a large current can flow through the input ESD diodes. TI highly recommends adding a series resistor to the grounded input to limit current in such an occurrence. V_{sup+} must be more positive than V_{sup-} at all times; otherwise, a large reverse supply current may flow.

8.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using [Equation 1](#) and [Equation 2](#):

$$A_v = \frac{V_{OUT}}{V_{IN}} \quad (1)$$

$$A_v = \frac{1.8}{-0.5} = -3.6 \quad (2)$$

Once the desired gain is determined, choose a value for R_I or R_F. Choosing a value in the k Ω range is desirable because the amplifier circuit uses currents in the mA range. This ensures the part does not draw too much current. For this example, choose 10 k Ω for R_I, which means 36 k Ω is used for R_F. This was determined by [Equation 3](#).

$$A_v = -\frac{R_F}{R_I} \quad (3)$$

Typical Application (continued)

8.2.3 Application Curve

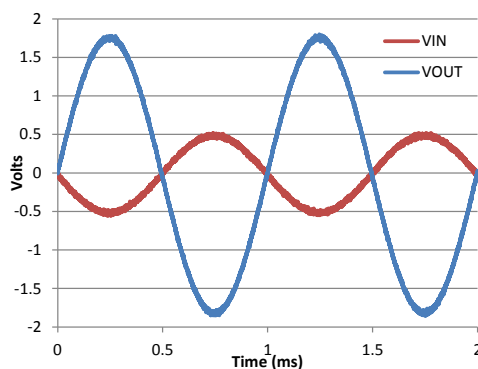


Figure 38. Input and Output Voltages of the Inverting Amplifier

9 Power Supply Recommendations

CAUTION

Supply voltages larger than 5.5 V for a single supply can permanently damage the device (see the [Absolute Maximum Ratings](#)).

Place 0.1- μ F bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies.

10 Layout

10.1 Layout Guidelines

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

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole, as well as the operational amplifier. 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- μ F ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V_+ to ground is applicable for single-supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds while paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping R_F and R_G close to the inverting input minimizes parasitic capacitance, as shown in [Layout Guidelines](#).
- 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.

10.2 Layout Example

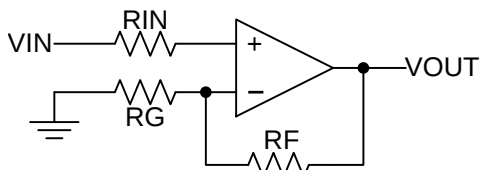


Figure 39. Layout Schematic

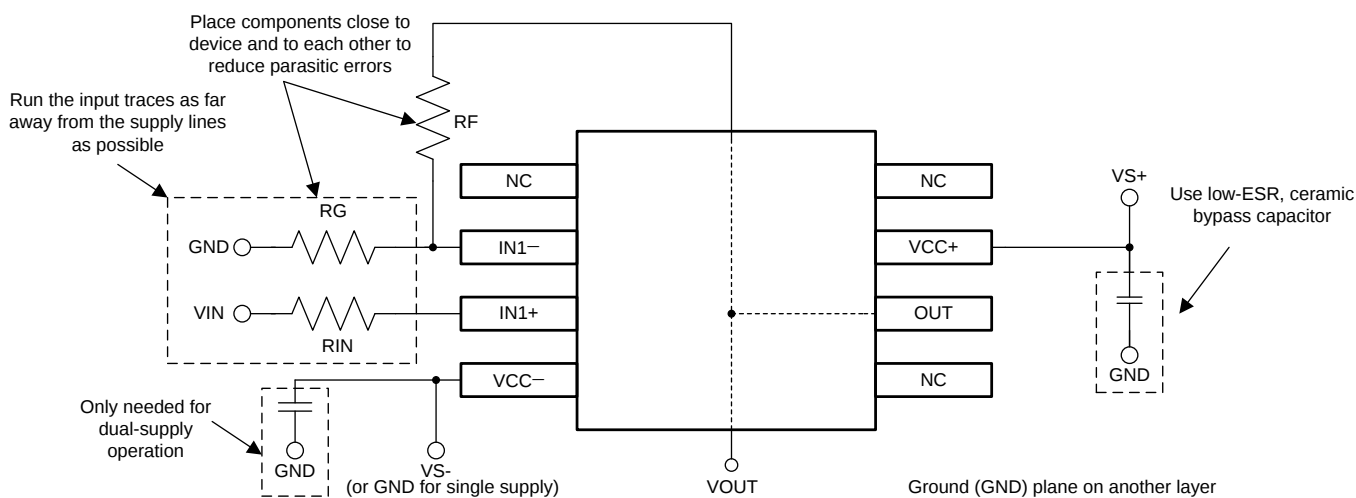


Figure 40. Operational Amplifier Schematic for Noninverting Configuration

11 Device and Documentation Support

11.1 Related Links

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

Table 1. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TLV341	Click here	Click here	Click here	Click here	Click here
TLV341A	Click here	Click here	Click here	Click here	Click here
TLV342	Click here	Click here	Click here	Click here	Click here
TLV342S	Click here	Click here	Click here	Click here	Click here

11.2 Community Resource

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

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

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

11.3 Trademarks

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

11.4 Electrostatic Discharge Caution



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

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

11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

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

12 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package Pins	Package qty Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TLV341AIDBVR	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	YCGE
TLV341AIDBVR.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	YCGE
TLV341AIDBVT	Obsolete	Production	SOT-23 (DBV) 6	-	-	Call TI	Call TI	-40 to 125	YCGE
TLV341AIDCKR	Active	Production	SC70 (DCK) 6	3000 LARGE T&R	Yes	Call TI Nipdau	Level-1-260C-UNLIM	-40 to 125	Y5E
TLV341AIDCKR.A	Active	Production	SC70 (DCK) 6	3000 LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 125	Y5E
TLV341AIDCKT	Obsolete	Production	SC70 (DCK) 6	-	-	Call TI	Call TI	-40 to 125	Y5E
TLV341IDBVR	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	YC9E
TLV341IDBVR.A	Active	Production	SOT-23 (DBV) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	YC9E
TLV341IDCKR	Active	Production	SC70 (DCK) 6	3000 LARGE T&R	Yes	Call TI Nipdau	Level-1-260C-UNLIM	-40 to 125	Y4E
TLV341IDCKR.A	Active	Production	SC70 (DCK) 6	3000 LARGE T&R	Yes	Call TI	Level-1-260C-UNLIM	-40 to 125	Y4E
TLV341IDCKRG4	Active	Production	SC70 (DCK) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	Y4E
TLV341IDCKRG4.A	Active	Production	SC70 (DCK) 6	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	Y4E
TLV341IDCKT	Obsolete	Production	SC70 (DCK) 6	-	-	Call TI	Call TI	-40 to 125	Y4E
TLV341IDRLR	Active	Production	SOT-5X3 (DRL) 6	4000 LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	(Y4A, Y4W)
TLV341IDRLR.A	Active	Production	SOT-5X3 (DRL) 6	4000 LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	(Y4A, Y4W)
TLV342AID	Obsolete	Production	SOIC (D) 8	-	-	Call TI	Call TI	-40 to 125	TY342A
TLV342AIDR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TY342A
TLV342AIDR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TY342A
TLV342ID	Obsolete	Production	SOIC (D) 8	-	-	Call TI	Call TI	-40 to 125	TY342
TLV342IDGKR	Active	Production	VSSOP (DGK) 8	2500 LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	Y6A
TLV342IDGKR.A	Active	Production	VSSOP (DGK) 8	2500 LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	Y6A
TLV342IDR	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TY342
TLV342IDR.A	Active	Production	SOIC (D) 8	2500 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	TY342
TLV342IRUGR	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	(1S8, Y6E)
TLV342IRUGR.A	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	(1S8, Y6E)
TLV342IRUGRG4.A	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	1S8
TLV342SIRUGR	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	(10A, 2YE)
TLV342SIRUGR.A	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	(10A, 2YE)
TLV342SIRUGRG4.A	Active	Production	X2QFN (RUG) 10	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	10A

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

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

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

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

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

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

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

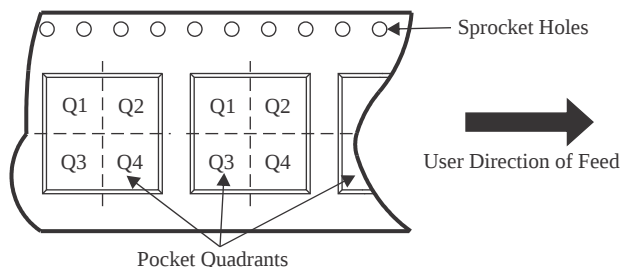
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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION



QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TLV341AIDBVR	SOT-23	DBV	6	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV341AIDCKR	SC70	DCK	6	3000	179.0	8.4	2.2	2.5	1.2	4.0	8.0	Q3
TLV341AIDCKR	SC70	DCK	6	3000	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
TLV341IDBVR	SOT-23	DBV	6	3000	179.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TLV341IDCKR	SC70	DCK	6	3000	179.0	8.4	2.2	2.5	1.2	4.0	8.0	Q3
TLV341IDCKR	SC70	DCK	6	3000	178.0	9.0	2.4	2.5	1.2	4.0	8.0	Q3
TLV341IDCKRG4	SC70	DCK	6	3000	179.0	8.4	2.2	2.5	1.2	4.0	8.0	Q3
TLV341IDRLR	SOT-5X3	DRL	6	4000	180.0	8.4	1.98	1.78	0.69	4.0	8.0	Q3
TLV342AIDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV342IDGKR	VSSOP	DGK	8	2500	330.0	12.4	5.25	3.35	1.25	8.0	12.0	Q1
TLV342IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
TLV342IRUGR	X2QFN	RUG	10	3000	180.0	8.4	1.75	2.25	0.55	4.0	8.0	Q1
TLV342SIRUGR	X2QFN	RUG	10	3000	180.0	8.4	1.75	2.25	0.55	4.0	8.0	Q1

TAPE AND REEL BOX DIMENSIONS



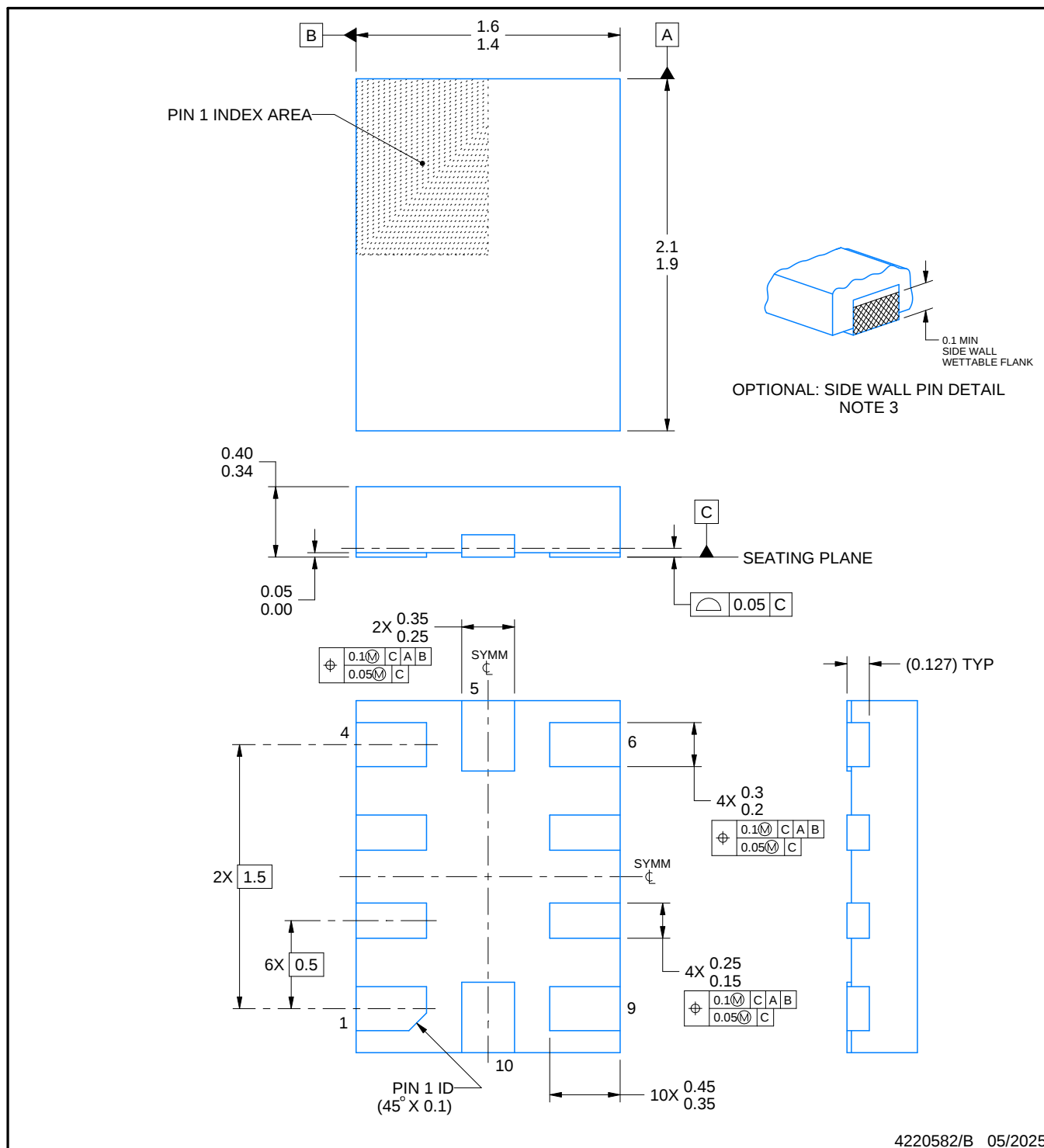
*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TLV341AIDBVR	SOT-23	DBV	6	3000	200.0	183.0	25.0
TLV341AIDCKR	SC70	DCK	6	3000	200.0	183.0	25.0
TLV341AIDCKR	SC70	DCK	6	3000	180.0	180.0	18.0
TLV341IDBVR	SOT-23	DBV	6	3000	200.0	183.0	25.0
TLV341IDCKR	SC70	DCK	6	3000	200.0	183.0	25.0
TLV341IDCKR	SC70	DCK	6	3000	180.0	180.0	18.0
TLV341IDCKRG4	SC70	DCK	6	3000	200.0	183.0	25.0
TLV341IDRLR	SOT-5X3	DRL	6	4000	202.0	201.0	28.0
TLV342AIDR	SOIC	D	8	2500	367.0	367.0	35.0
TLV342IDGKR	VSSOP	DGK	8	2500	366.0	364.0	50.0
TLV342IDR	SOIC	D	8	2500	367.0	367.0	35.0
TLV342IRUGR	X2QFN	RUG	10	3000	210.0	185.0	35.0
TLV342SIRUGR	X2QFN	RUG	10	3000	210.0	185.0	35.0



X2QFN - 0.4 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



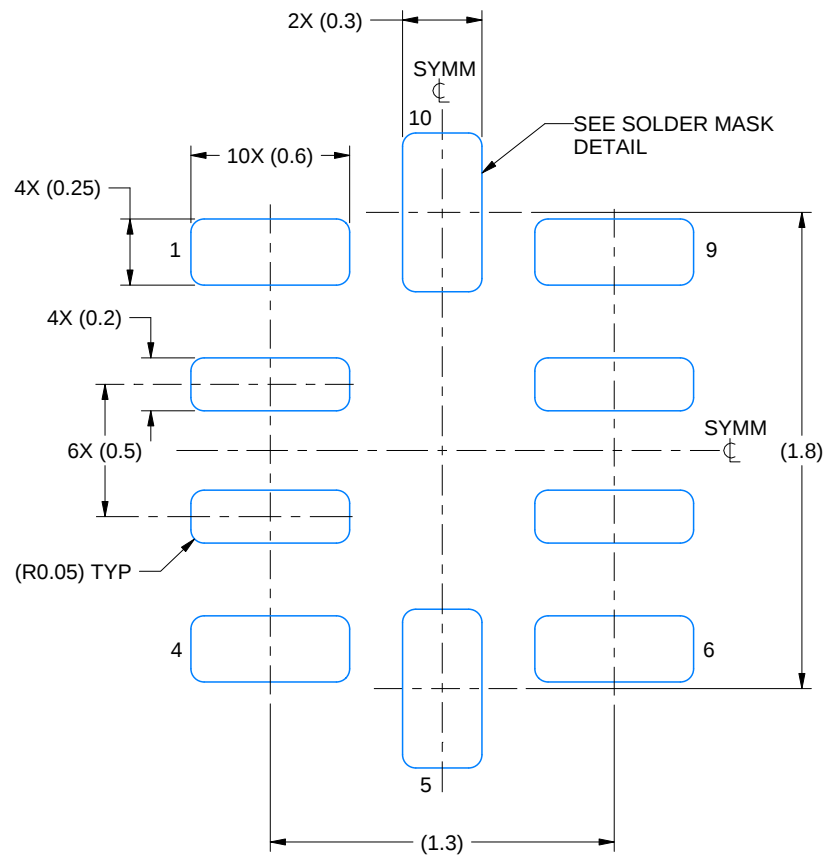
NOTES:

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. Minimum 0.1 mm solder wetting on pin side wall. Available for wettable flank version only.

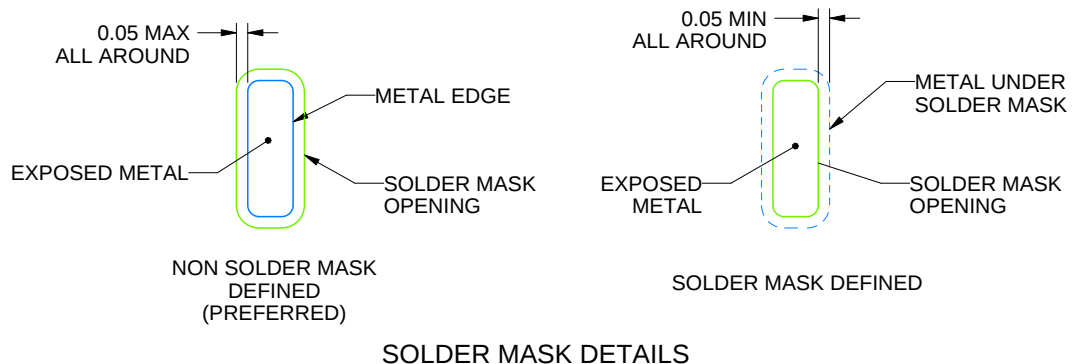
RUG0010B

X2QFN - 0.4 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 35X



4220582/B 05/2025

NOTES: (continued)

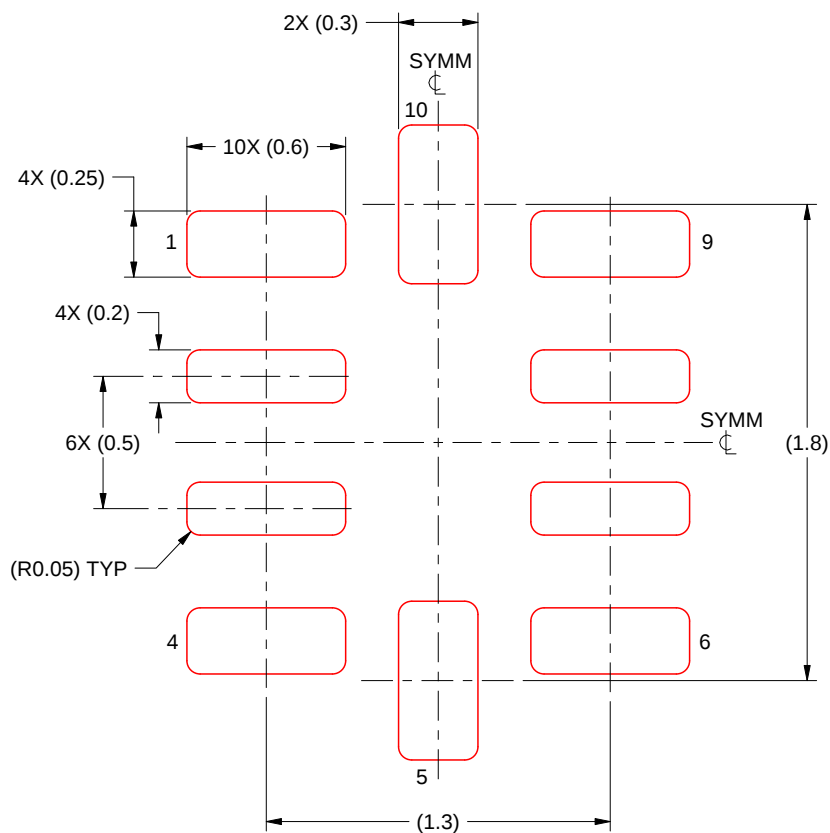
4. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sl原因271).

EXAMPLE STENCIL DESIGN

RUG0010B

X2QFN - 0.4 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 35X

4220582/B 05/2025

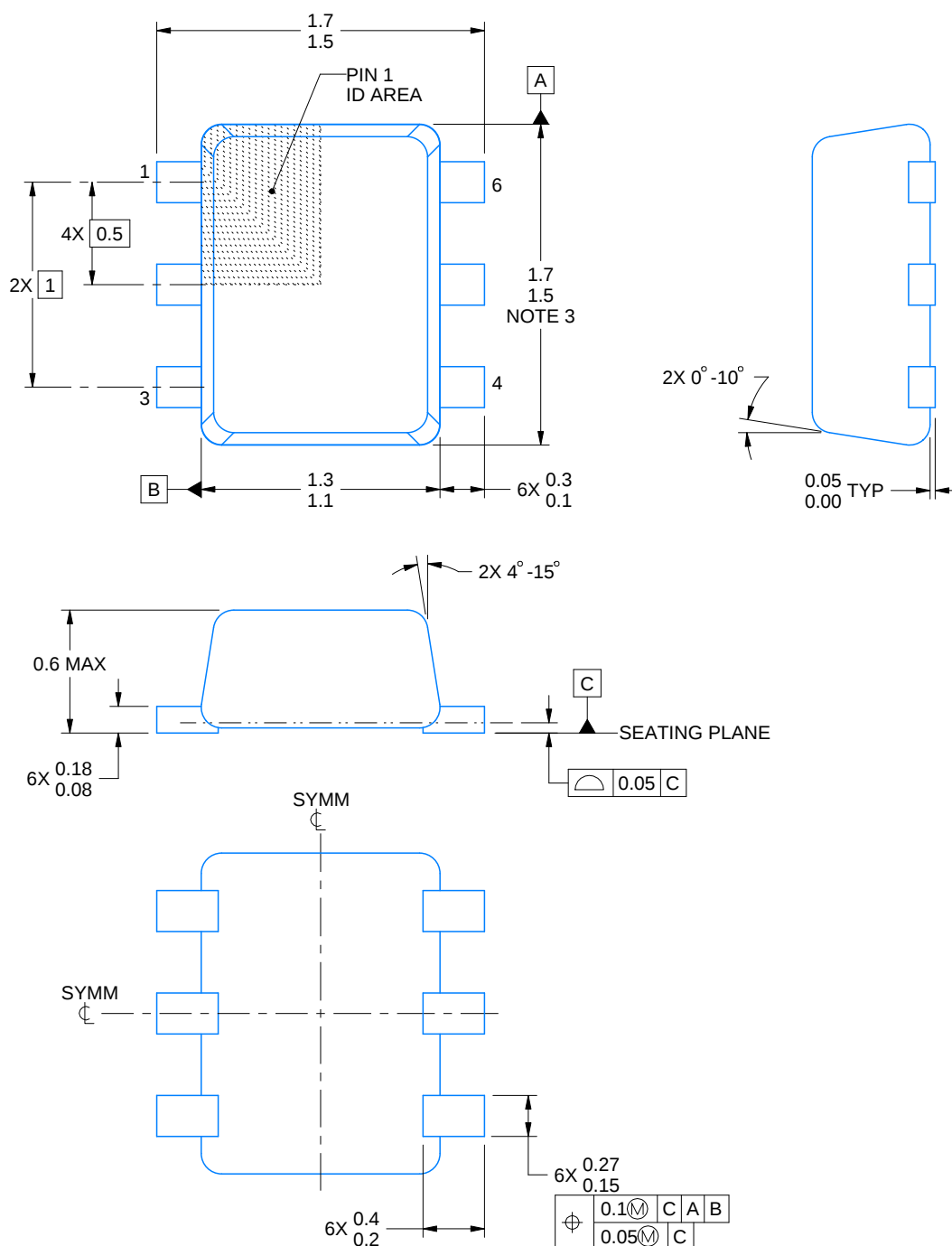
NOTES: (continued)

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



SOT - 0.6 mm max height

PLASTIC SMALL OUTLINE



4223266/F 11/2024

NOTES:

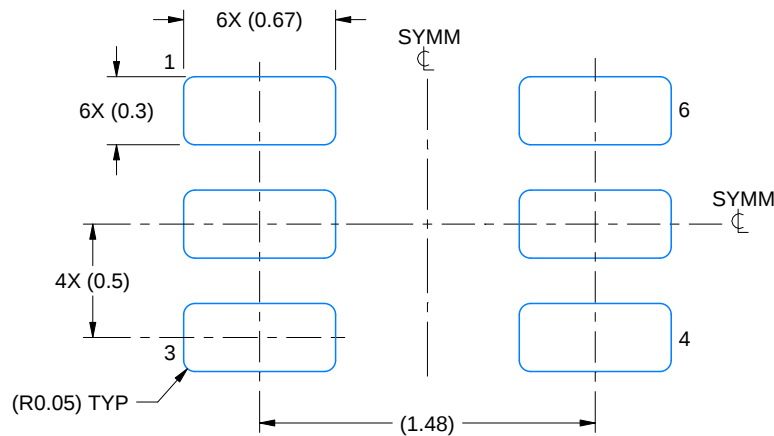
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. Reference JEDEC registration MO-293 Variation UAAD

EXAMPLE BOARD LAYOUT

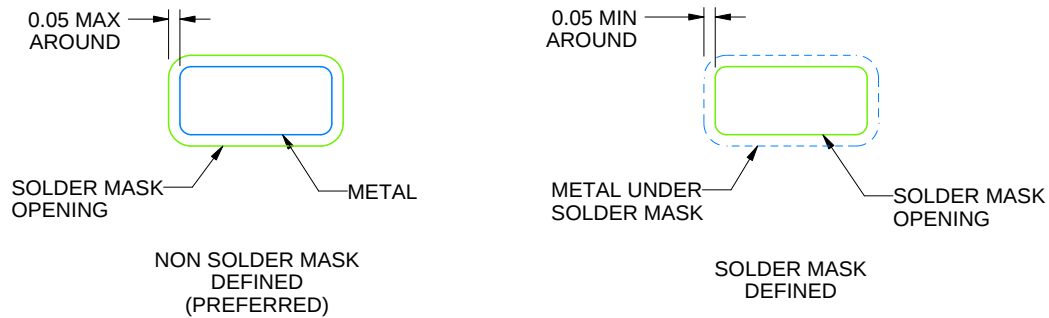
DRL0006A

SOT - 0.6 mm max height

PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE
SCALE:30X



SOLDERMASK DETAILS

4223266/F 11/2024

NOTES: (continued)

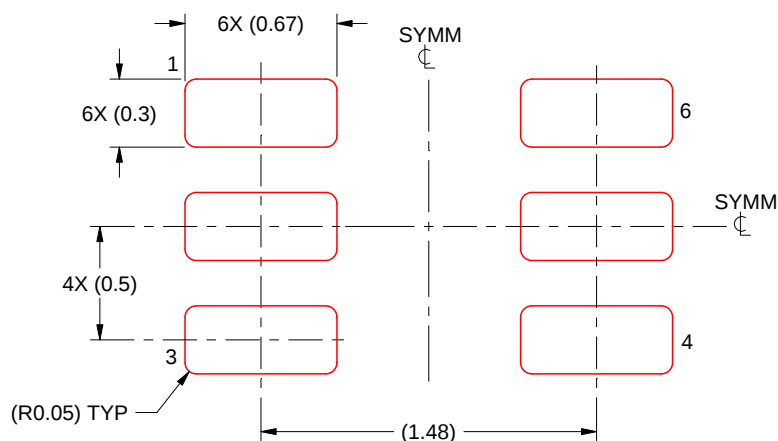
5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
7. Land pattern design aligns to IPC-610, Bottom Termination Component (BTC) solder joint inspection criteria.

EXAMPLE STENCIL DESIGN

DRL0006A

SOT - 0.6 mm max height

PLASTIC SMALL OUTLINE



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE:30X

4223266/F 11/2024

NOTES: (continued)

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



PACKAGE OUTLINE

SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT



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

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

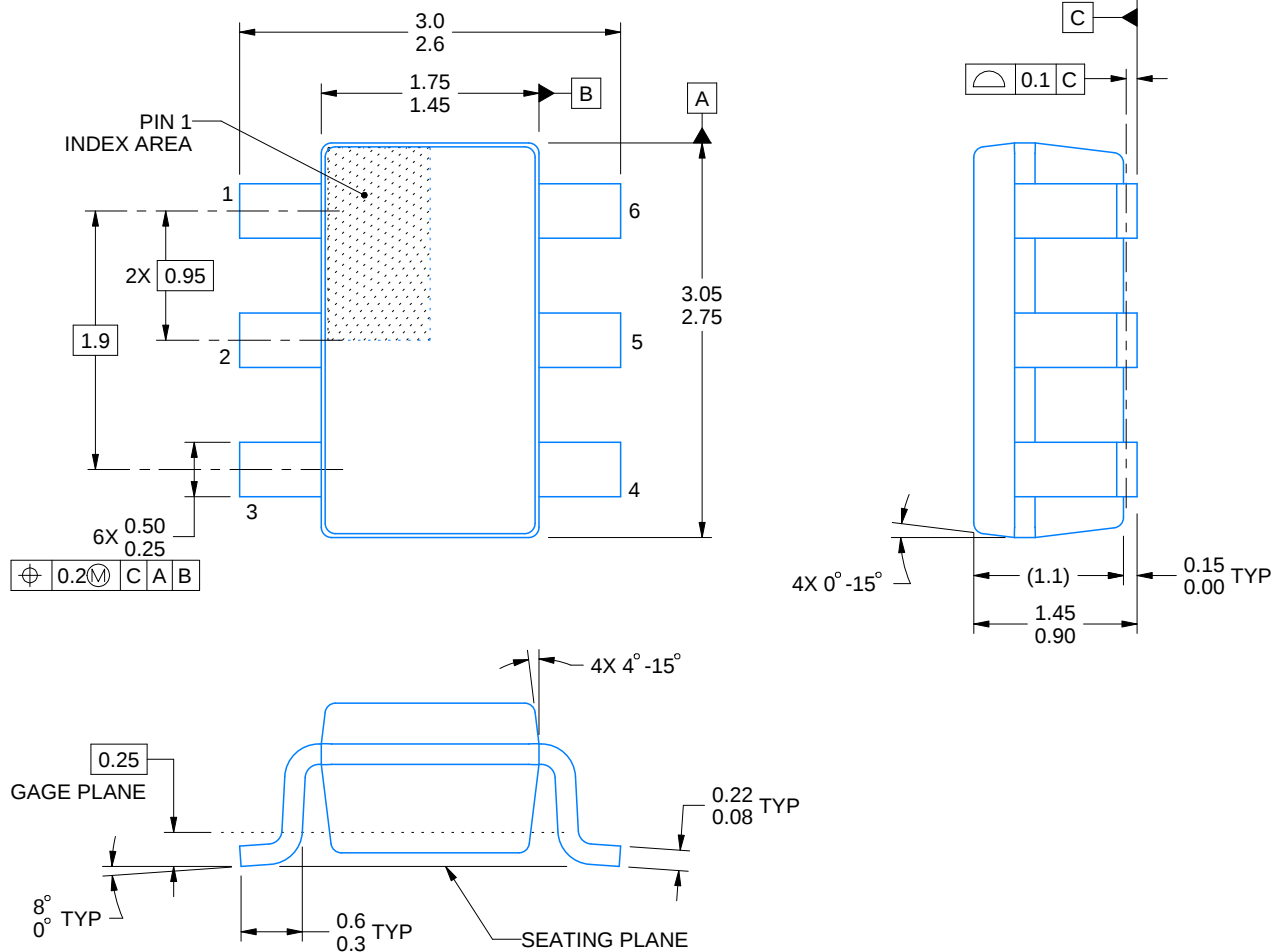
4214825/C 02/2019

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.

DBV0006A**PACKAGE OUTLINE****SOT-23 - 1.45 mm max height**

SMALL OUTLINE TRANSISTOR



4214840/G 08/2024

NOTES:

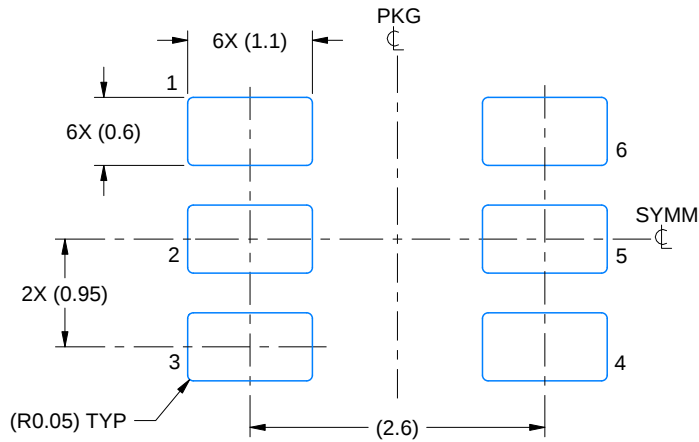
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.25 per side.
4. Leads 1,2,3 may be wider than leads 4,5,6 for package orientation.
5. Reference JEDEC MO-178.

EXAMPLE BOARD LAYOUT

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X



SOLDER MASK DETAILS

4214840/G 08/2024

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

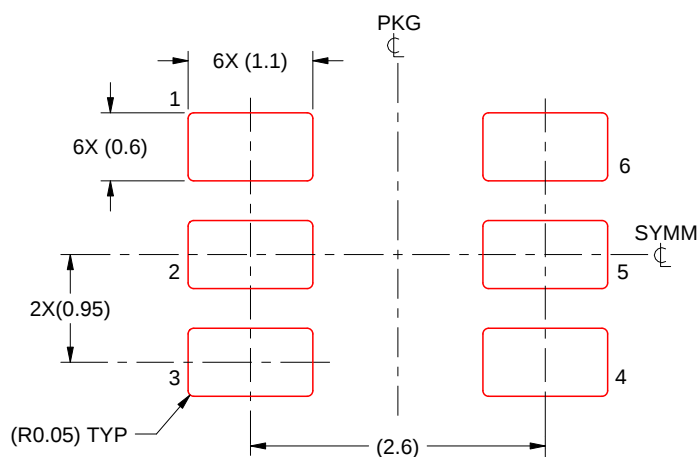
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

DBV0006A

SOT-23 - 1.45 mm max height

SMALL OUTLINE TRANSISTOR



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

4214840/G 08/2024

NOTES: (continued)

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

DGK0008A



PACKAGE OUTLINE

VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



4214862/A 04/2023

NOTES:

PowerPAD is a trademark of Texas Instruments.

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187.

EXAMPLE BOARD LAYOUT

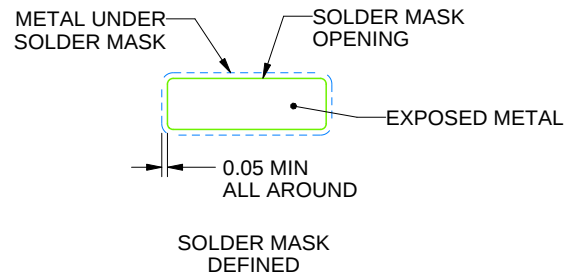
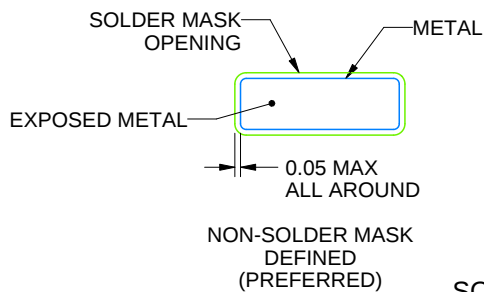
DGK0008A

TM VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X



SOLDER MASK DETAILS

4214862/A 04/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
8. Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.
9. Size of metal pad may vary due to creepage requirement.

EXAMPLE STENCIL DESIGN

DGK0008A

TM VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE

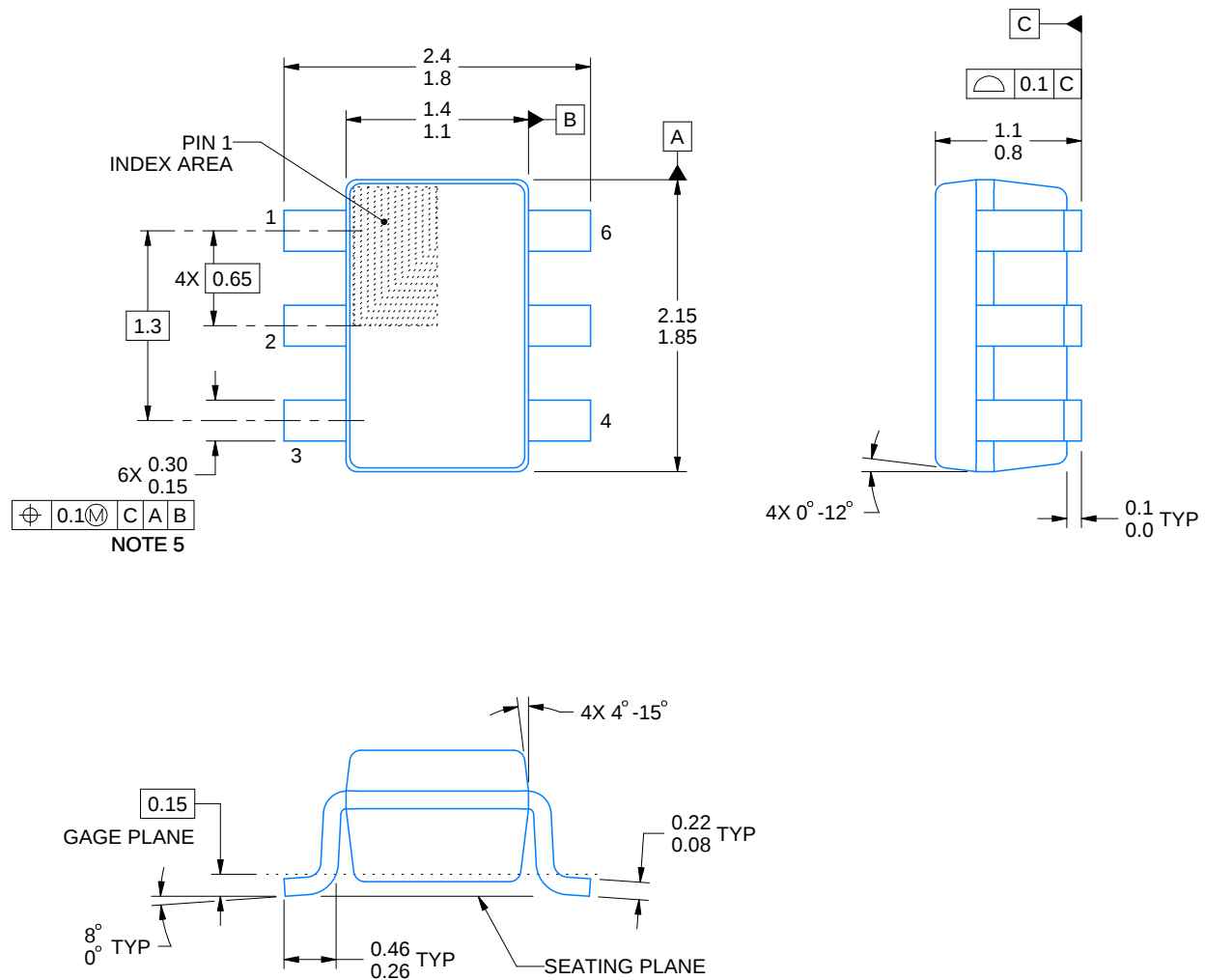


SOLDER PASTE EXAMPLE
SCALE: 15X

4214862/A 04/2023

NOTES: (continued)

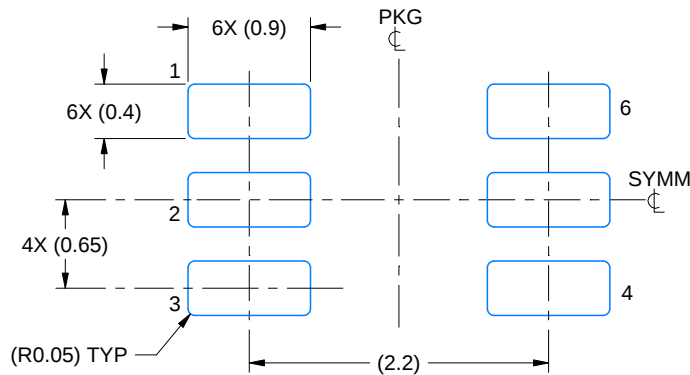
11. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
12. Board assembly site may have different recommendations for stencil design.



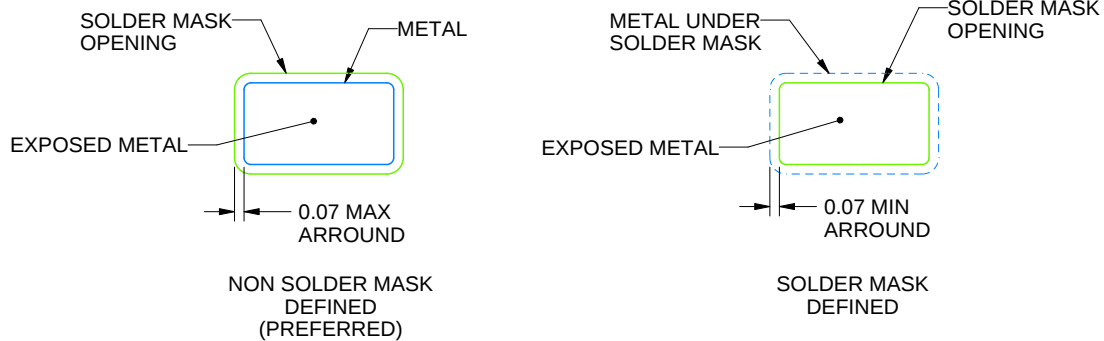
4214835/D 11/2024

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.15 per side.
4. Falls within JEDEC MO-203 variation AB.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:18X

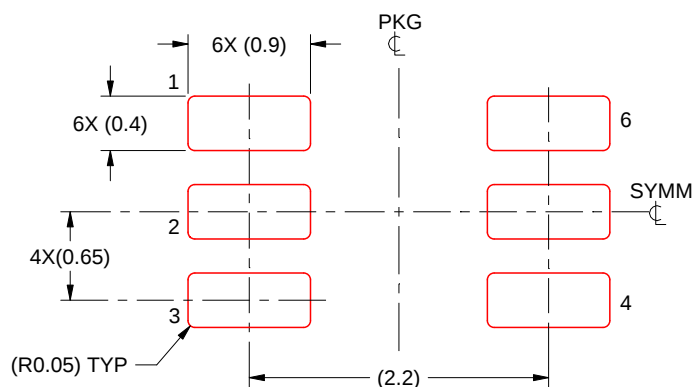


SOLDER MASK DETAILS

4214835/D 11/2024

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.



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

4214835/D 11/2024

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.

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