TS321 Low-Power Single Operational Amplifier

1 Features

- Wide Power-Supply Range
  - Single Supply from 3 V to 30 V
  - Dual Supply from ±1.5 V to ±15 V
- Large Output Voltage Swing from 0 V to 3.5 V (Minimum) (V_{CC} = 5 V)
- Low Supply Current at 500 μA (Typical)
- Low Input Bias Current at 20 nA (Typical)
- Stable With High Capacitive Loads

2 Applications

- Desktop PCs
- HVAC: Heating, Ventilating, and Air Conditioning
- Portable Media Players
- Refrigerators
- Washing Machines: High-End and Low-End

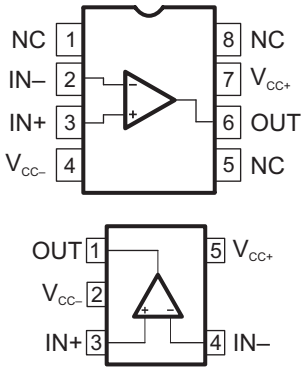
3 Description

The TS321 is a bipolar operational amplifier for cost-sensitive applications in which space savings are important.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TS321	SOIC (8)	4.90 mm × 3.90 mm
	SOT-23 (5)	2.90 mm × 1.60 mm

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



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

Changes from Revision C (April 2015) to Revision D **Page**

- Corrected SOIC package pinout quantity from "SOIC (14)" to "SOIC (8)" in *Device Information* table ... 1

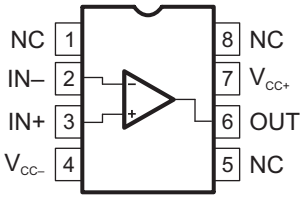
Changes from Revision B (December 2013) to Revision C **Page**

- Added *Pin Configuration and Functions* section, *ESD Ratings* table, *Feature Description* section, *Device Functional Modes*, *Application and Implementation* section, *Power Supply Recommendations* section, *Layout* section, *Device and Documentation Support* section, and *Mechanical, Packaging, and Orderable Information* section ... 1

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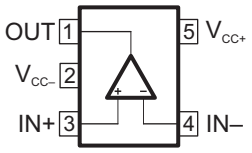
5 Pin Configuration and Functions

D Package
8-Pin SOIC
(Top View)



NC - no internal connection

DBV Package
5-Pin SOT-23
(Top View)



Pin Functions

PIN			I/O	DESCRIPTION
NAME	SOIC	SOT-23		
IN–	2	4	I	Negative input
IN+	3	3	I	Positive input
NC	1	—	—	Do not connect
	5			
	8			
OUT	6	1	O	Output
V_{CC-}	4	2	—	Negative supply
V_{CC+}	7	5	—	Positive supply

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6 Specifications

6.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
	Supply voltage, V_{CC}	Single supply		32	V
		Dual supplies		±16	
	Differential input voltage(2), V_{ID}			±32	V
	Input voltage range (3), V_I		–0.3	32	V
	Input current, I_{IK}			50	mA
	Duration of output short circuit to ground, t_{short}			Unlimited	
	Operating virtual junction temperature, T_J			150	°C
	Storage temperature, T_{stg}		–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, 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) Differential voltages are at IN+ with respect to IN–.
(3) Input voltages are at IN with respect to $V_{CC–}$.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	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	

(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_{CC}	Supply voltage	Single supply	3	30	V
		Dual supply	±1.5	±15	
T_A	Operating free-air temperature		–40	125	°C

6.4 Thermal Information: TS321

THERMAL METRIC(1) (2)(3)		TS321		UNIT
		D (SOIC)	DBV (SOT-23)	
		5 PINS	5 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	97	206	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.
(2) Maximum power dissipation is a function of TJ(max), qJA, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is PD = [TJ(max) – TA] / qJA. Selecting the maximum of 150°C can effect reliability.
(3) The package thermal impedance is calculated in accordance with JESD 51-7.

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6.5 Electrical Characteristics

V_{CC+} = 5 V, V_{CC-} = GND, V_O = 1.4 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{IO}	Input offset voltage	R_S = 0, 5 V < V_{CC+} < 30 V 0 < V_{IC} < (V_{CC+} – 1.5 V)	T_A = 25°C		0.5	4	mV
			T_A = Full range			5	
I_{IO}	Input offset current	T_A = 25°C			2	30	nA
		T_A = Full range				50	
I_{IB}	Input bias current(1)	T_A = 25°C			20	150	nA
		T_A = Full range				200	
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, R_L = 2 kΩ V_O = 1.4 V to 11.4 V	T_A = 25°C	50	100		V/mV
			T_A = Full range	25			
V_{ICR}	Common-mode input voltage(2)	V_{CC} = 30 V	T_A = 25°C	0		V_{CC+} – 1.5	V
			T_A = Full range	0		V_{CC+} – 2	
V_{OH}	High-level output voltage	V_{CC} = 30 V R_L = 2 kΩ	T_A = 25°C	26	27		V
			T_A = Full range	25.5			
		V_{CC} = 30 V R_L = 10 kΩ	T_A = 25°C	27	28		
			T_A = Full range	26.5			
		V_{CC} = 5 V R_L = 2 kΩ	T_A = 25°C	3.5			
			T_A = Full range	3			
V_{OL}	Low-level output voltage	R_L = 10 kΩ	T_A = 25°C		5	15	mV
			T_A = Full range			20	
GBP	Gain bandwidth product	V_{CC} = 30 V, V_I = 10 mV, R_L = 2 kΩ f = 100 kHz, C_L = 100 pF T_A = 25°C			0.8		MHz
SR	Slew rate	V_{CC} = 15 V, V_I = 0.5 V to 3 V, R_L = 2 kΩ, C_L = 100 pF, unity gain, T_A = 25°C			0.4		V/µs
φ_m	Phase margin	T_A = 25°C			60		°
CMRR	Common-mode rejection ratio	R_S ≤ 10 kΩ T_A = 25°C		65	85		dB
I_{SOURCE}	Output source current	V_{CC} = 15 V, V_O = 2 V, V_{ID} = 1 V T_A = 25°C		20	40		mA
I_{SINK}	Output sink current	V_{CC} = 15 V, V_{ID} = 1 V V_O = 2 V T_A = 25°C		10	20		mA
		V_{CC} = 15 V, V_{ID} = 1 V V_O = 0.2 V T_A = 25°C		12	50		µA
I_O	Short-circuit to GND	V_{CC} = 15 V, T_A = 25°C			40	60	mA
SVR	Supply-voltage rejection ratio	V_{CC} = 5 V to 30 V, T_A = 25°C		65	110		dB
I_{CC}	Total supply current	V_{CC} = 5 V T_A = 25°C, no load			500	800	µA
		V_{CC} = 30 V T_A = 25°C, no load			600	900	
		V_{CC} = 5 V T_A = full range, no load			600	900	
		V_{CC} = 30 V T_A = full range, no load				1000	
THD	Total harmonic distortion	V_{CC} = 30 V, V_O = 2 V_{pp}, A_V = 20 dB R_L = 2 k, f = 1 kHz, C_L = 100 pF, T_A = 25°C			0.015%		

(1) The direction of the input current is out of the device. This current essentially is constant, independent of the state of the output, so no loading change exists on the input lines.
(2) The input common-mode voltage of either input signal should not be allowed to go negative by more than 0.3 V. The upper end of the common-mode voltage range is V_{CC+} – 1.5 V, but either or both inputs can go to 32 V without damage.

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Electrical Characteristics (continued)

V_{CC+} = 5 V, V_{CC-} = GND, V_O = 1.4 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
e_N	Equivalent input noise voltage	V_{CC} = 30 V, f = 1 kHz, R_S = 100 Ω T_A = 25°C		50		

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6.6 Typical Characteristics

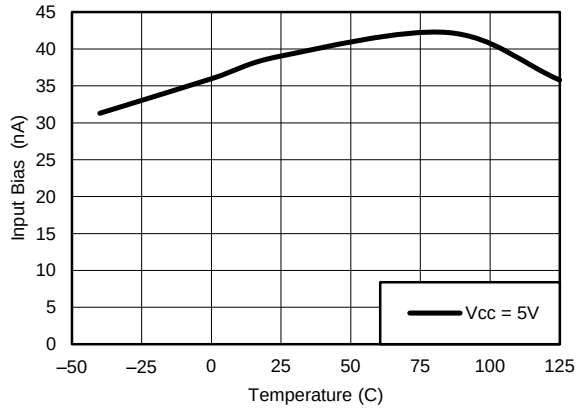


Figure 1. Input Current vs Temperature

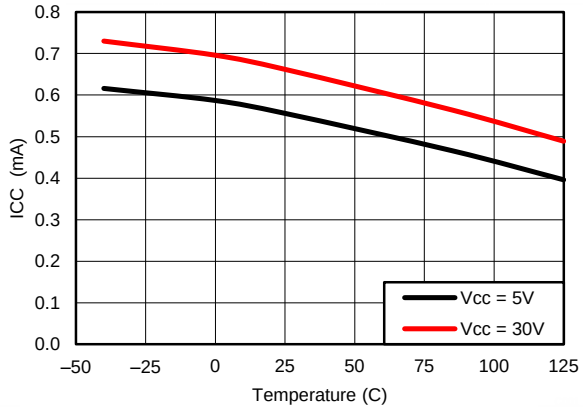


Figure 2. Supply Current vs Temperature

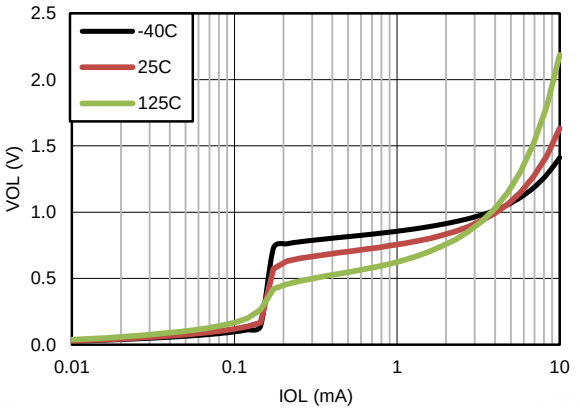


Figure 3. Output Sinking Characteristics

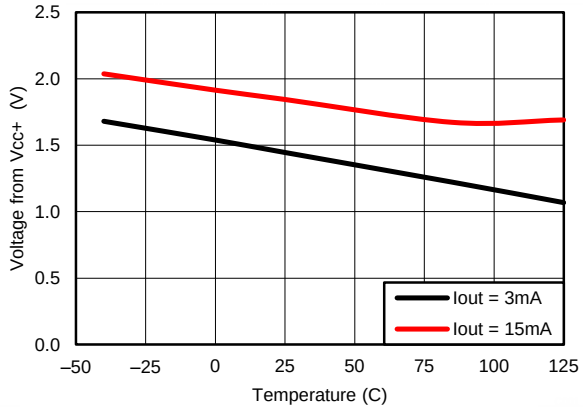


Figure 4. Output Sourcing Characteristics

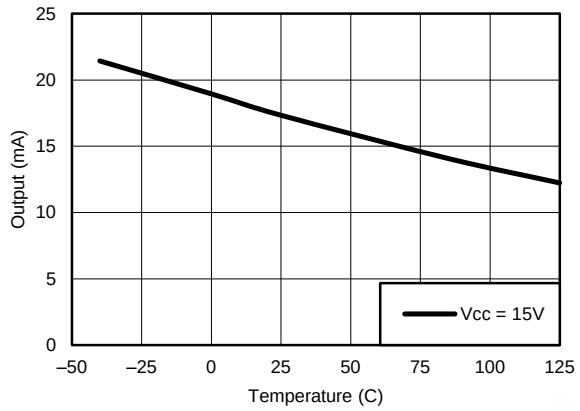


Figure 5. Short-Circuit Current to Supply (1)

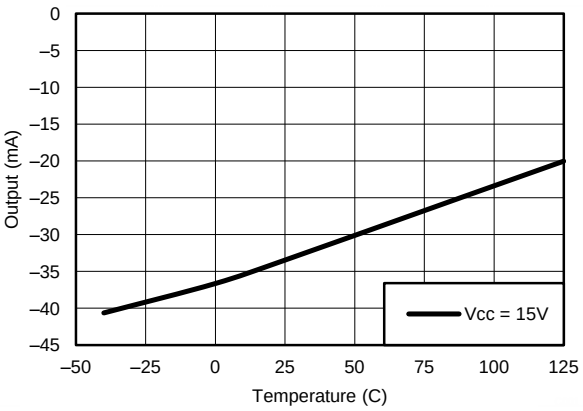


Figure 6. Short-Circuit Current to Ground

(1) Short circuits from outputs to VCC can cause excessive heating and eventual destruction.

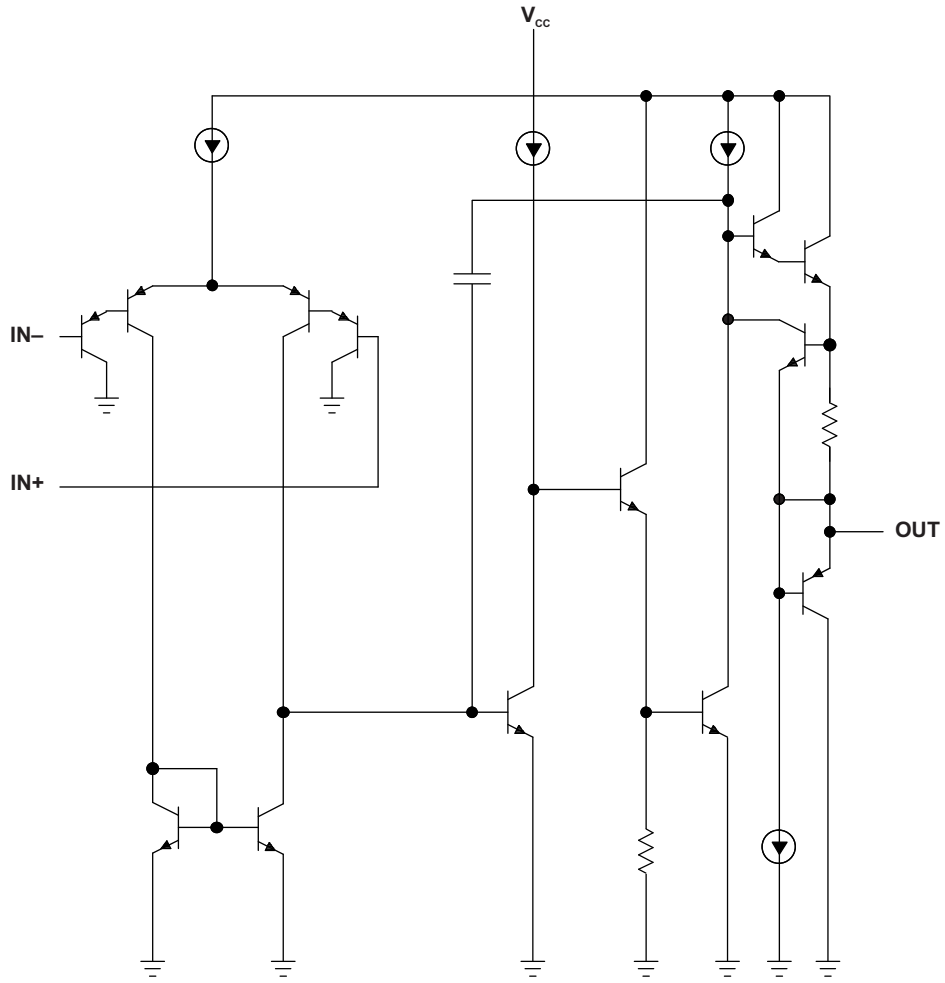
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7 Detailed Description

7.1 Overview

The TS321 is a single-channel operational amplifier. The device can handle a single supply between 3 V and 30 V or a dual-supply between ±1.5 V and ±15 V. Available in the small SOT-23 package, the TS321 is great for saving space in any application.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 Operating Voltage

The TS321 can be powered from a single supply between 3 V and 30 V or a dual-supply between ±1.5 V and ±15 V.

7.3.2 Gain Bandwidth Product

Gain bandwidth product is found by multiplying a measured bandwidth of the amplifier by the gain at which that bandwidth was measured. The TS321 has a gain bandwidth of 0.8 MHz.

7.3.3 Slew Rate

The slew rate is the rate at which an operational amplifier can change the output when there is a change on the input. The TS321 has a 0.4-V/μs slew rate.

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Feature Description (continued)

7.3.4 Input Common-Mode Range

The valid common-mode range is from device ground pin to VCC – 1.5 V (VCC – 2 V across temperature). Inputs may exceed VCC up to the maximum VCC without device damage. At least one input must be in the valid input common-mode range for output to be correct phase. If both inputs exceed valid range then output phase is undefined. If either input is less than –0.3 V then input current must be limited to 1 mA and output phase is undefined.

7.3.5 Stability With High Capacitive Loads

Operational amplifiers have reduced phase margin when there is a direct capacitance on the output. The stability is affected most when the amplifier is set to unity gain. Small signal response to a step input of 100 mV reveals the loop stability with a range of capacitors. See SLVA381 to correlate response waveform to phase margin. The responses at 1 nF or less indicate acceptable phase margin. The responses at 1 uF and above indicate good phase margin.

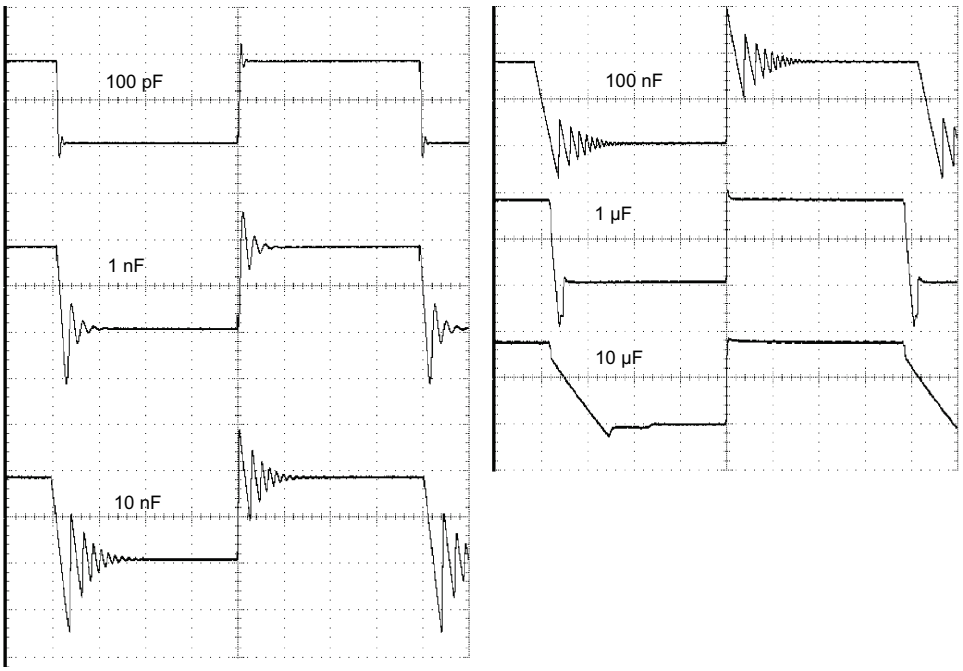


Figure 7. Small-Signal Response

7.4 Device Functional Modes

The TS321 is powered on when the supply is connected. This device can operate as a single-supply operational amplifier or dual-supply amplifier depending on the application.

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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 TS321 operational amplifier is useful in a wide range of signal conditioning applications. Inputs can be powered before VCC for flexibility in multiple supply circuits.

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 the voltage a negative voltage of the same magnitude. In the same manner, the amplifier makes negative voltages positive.

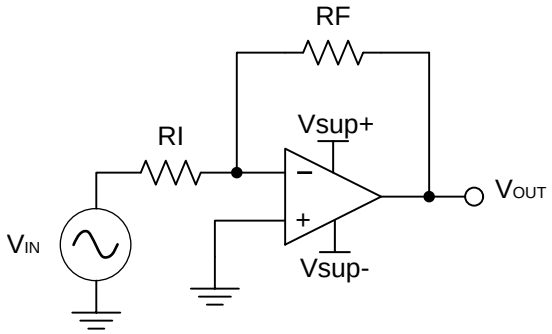


Figure 8. Typical Application Schematic

8.2.1 Design Requirements

The supply voltage must be selected such that the supply voltage is larger than the input voltage range and output range. For instance, this application scales a signal of ±0.5 V to ±1.8 V. Setting the supply at ±12 V is sufficient to accommodate this application.

8.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier:

$$A_V = \frac{VOUT}{VIN} \quad (1)$$

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

Once the desired gain is determined, select a value for RI or RF. Selecting a value in the kilohm range is desirable because the amplifier circuit uses currents in the milliamp range. This ensures the part does not draw too much current. This example selects 10 kΩ for RI which means 36 kΩ is be used for RF. This is determined by Equation 3.

$$A_V = -\frac{RF}{RI} \quad (3)$$

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Typical Application (continued)

8.2.3 Application Curve

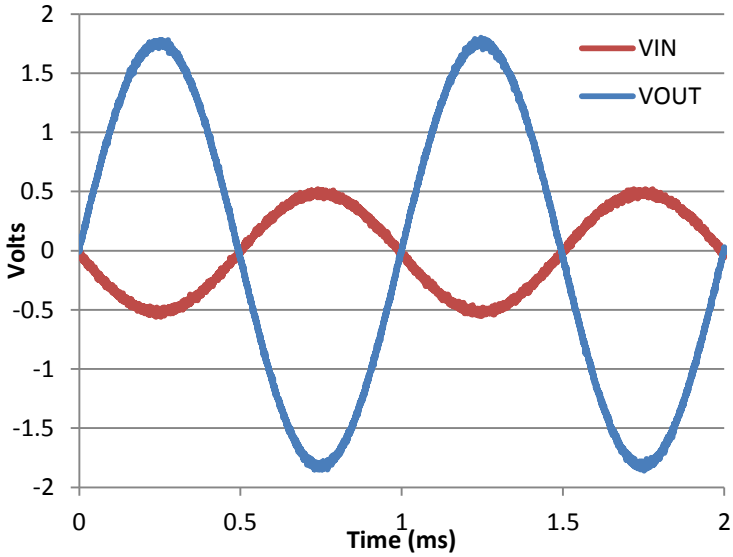


Figure 9. Input and Output Voltages of the Inverting Amplifier

9 Power Supply Recommendations

The TS321 is specified to operate between 3 V and 30 V or a dual supply between ±1.5 V and ±15 V.

CAUTION

Supply voltages larger than 32 V for a single supply, or outside the range of ±16 V for a dual supply can permanently damage the device (see the *Absolute Maximum Ratings*).

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 *Layout* section.

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-μF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effective methods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds, paying attention to the flow of the ground current. For more detailed information, see SLOA089.
- 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 RF and RG close to the inverting input minimizes parasitic capacitance, as shown in *Layout Example*.
- 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

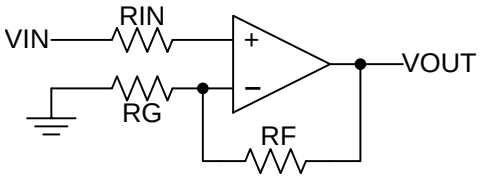


Figure 10. Operational Amplifier Schematic for Noninverting Configuration

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Layout Example (continued)

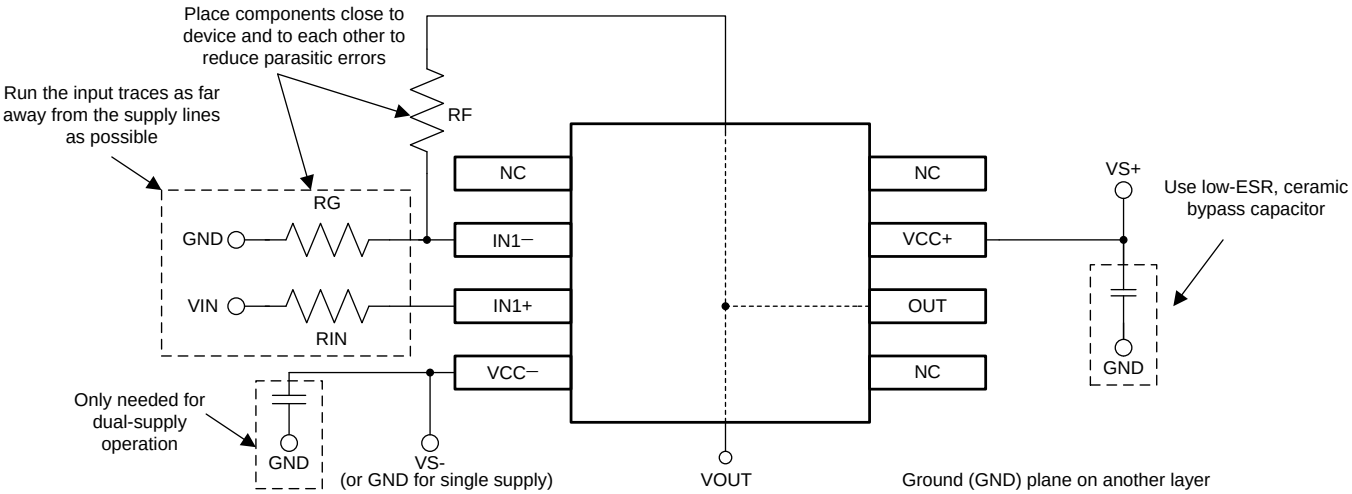


Figure 11. Operational Amplifier Board Layout for Noninverting Configuration

11 Device and Documentation Support

11.1 Documentation Support

11.1.1 Related Documentation

For more information, see the following:

- *Simplifying Stability Checks*
- *Circuit Board Layout Techniques*

11.2 Trademarks

All trademarks are the property of their respective owners.

11.3 Electrostatic Discharge Caution



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

11.4 Glossary

SLYZ022 — *TI Glossary*.

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

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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)
TS321ID	Obsolete	Production	SOIC (D) | 8	-	-	Call TI	Call TI	-40 to 125	SR321I
TS321IDBVR	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU | SN	Level-1-260C-UNLIM	-40 to 125	(9C1A, 9C1G, 9C1M, 9C1S)
TS321IDBVR.A	Active	Production	SOT-23 (DBV) | 5	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	(9C1A, 9C1G, 9C1M, 9C1S)
TS321IDBVRG4	Obsolete	Production	SOT-23 (DBV) | 5	-	-	Call TI	Call TI	-40 to 125	9C1G
TS321IDBVT	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU | SN	Level-1-260C-UNLIM	-40 to 125	(9C1G, 9C1S)
TS321IDBVT.A	Active	Production	SOT-23 (DBV) | 5	250 | SMALL T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	(9C1G, 9C1S)
TS321IDR	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SR321I
TS321IDR.A	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SR321I

(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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and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

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

OTHER QUALIFIED VERSIONS OF TS321 :

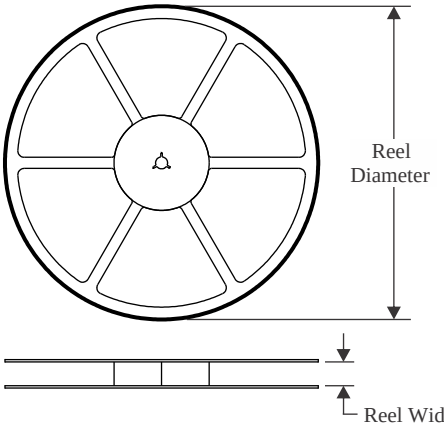
- Automotive : TS321-Q1

NOTE: Qualified Version Definitions:

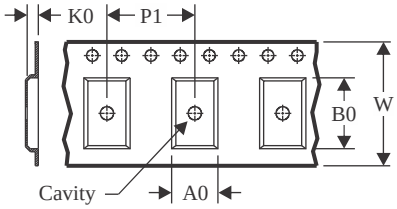
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

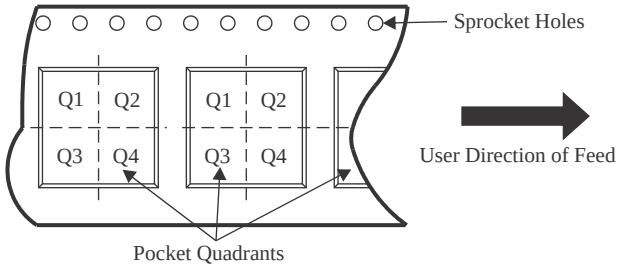


TAPE DIMENSIONS



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

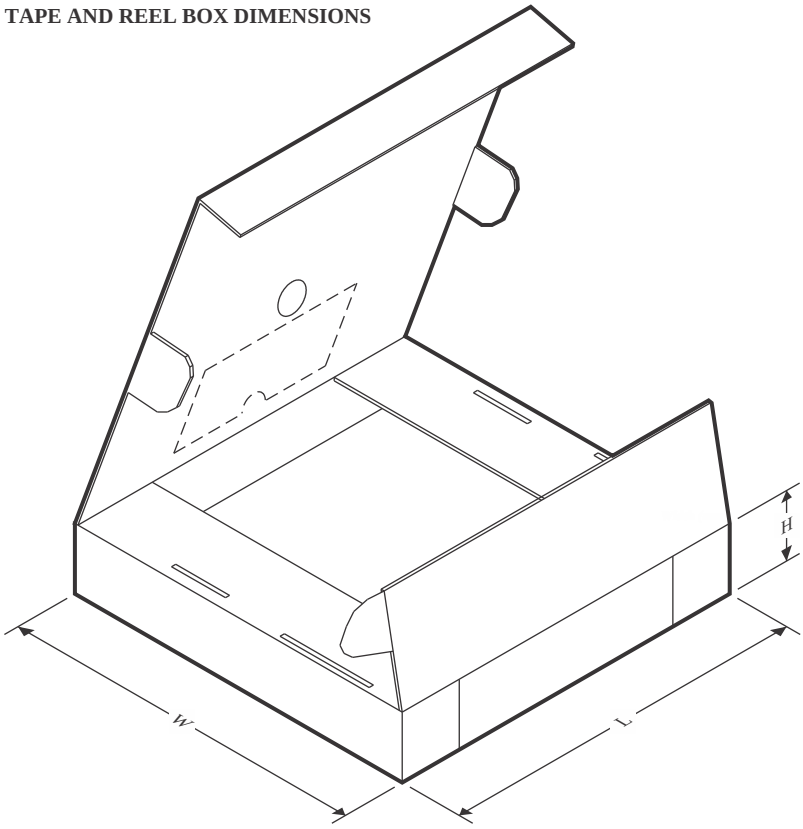
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

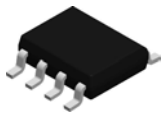
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TS321IDBVR	SOT-23	DBV	5	3000	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TS321IDBVR	SOT-23	DBV	5	3000	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
TS321IDBVT	SOT-23	DBV	5	250	180.0	8.4	3.23	3.17	1.37	4.0	8.0	Q3
TS321IDBVT	SOT-23	DBV	5	250	178.0	9.0	3.23	3.17	1.37	4.0	8.0	Q3
TS321IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TS321IDBVR	SOT-23	DBV	5	3000	202.0	201.0	28.0
TS321IDBVR	SOT-23	DBV	5	3000	180.0	180.0	18.0
TS321IDBVT	SOT-23	DBV	5	250	202.0	201.0	28.0
TS321IDBVT	SOT-23	DBV	5	250	180.0	180.0	18.0
TS321IDR	SOIC	D	8	2500	353.0	353.0	32.0

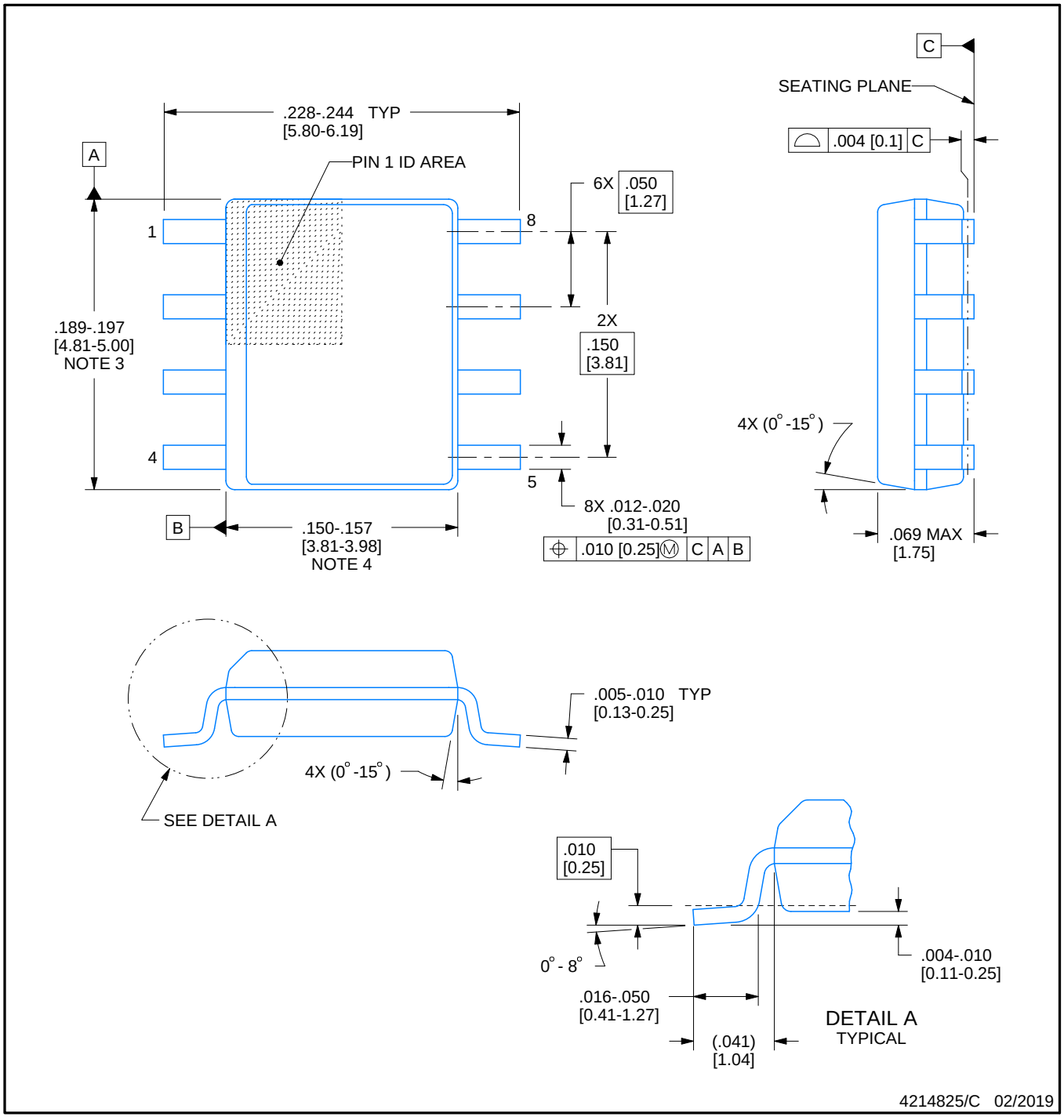


PACKAGE OUTLINE

D0008A

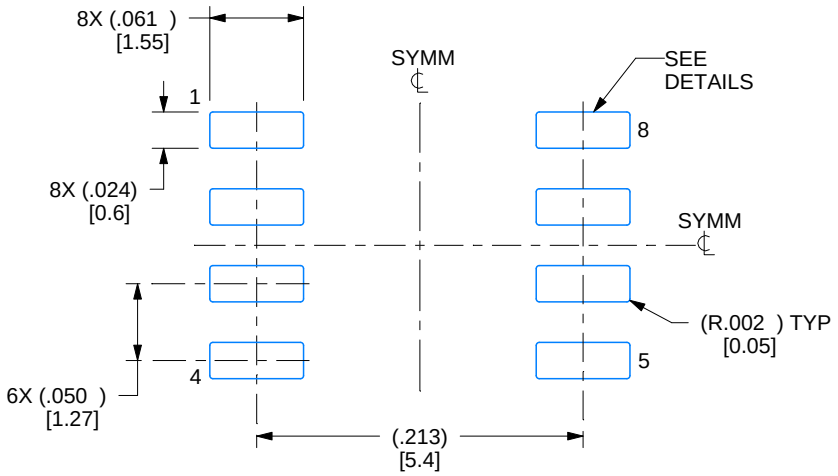
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

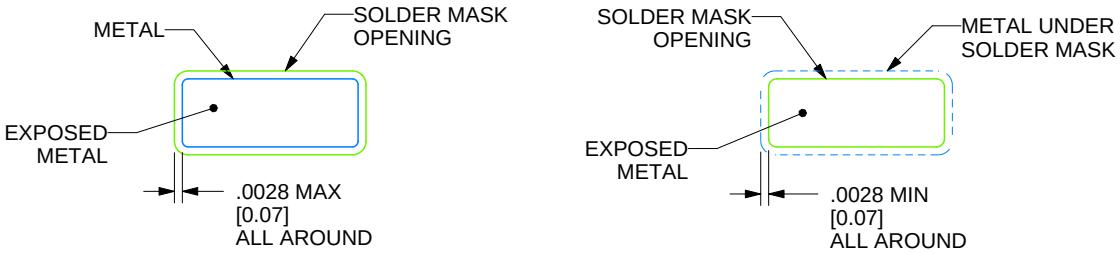


NOTES:

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



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



SOLDER MASK DETAILS

4214825/C 02/2019

NOTES: (continued)

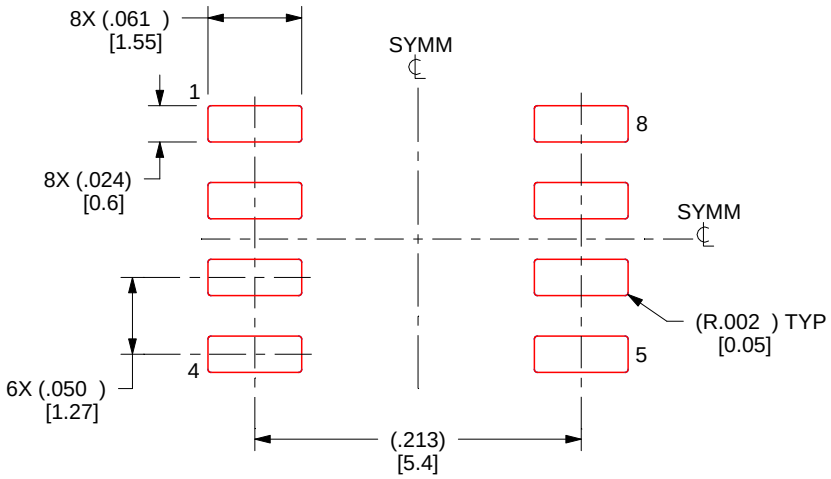
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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)

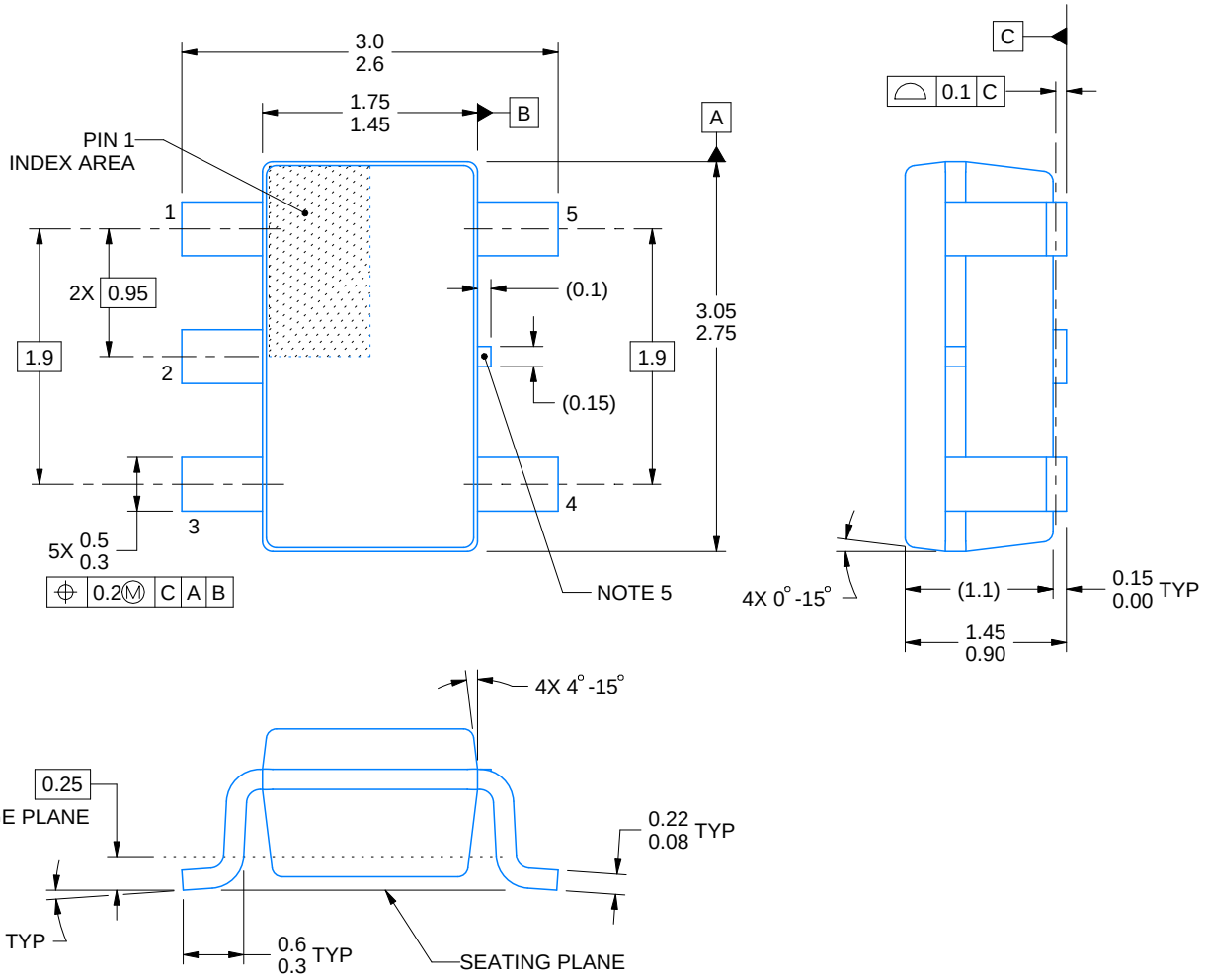
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DBV0005A

SOT-23 - 1.45 mm max height

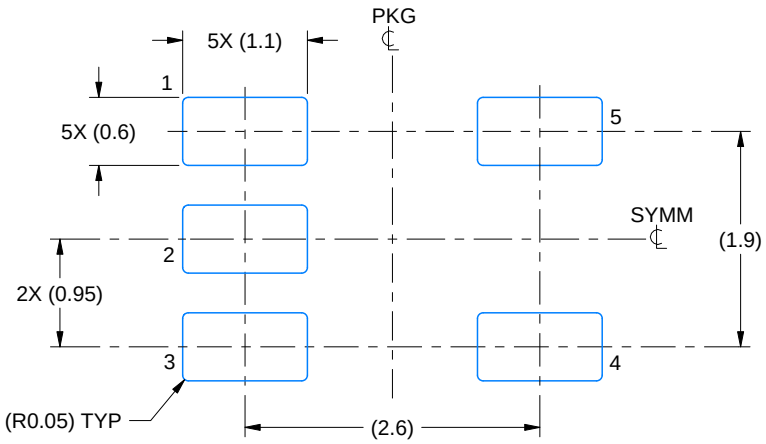
SMALL OUTLINE TRANSISTOR



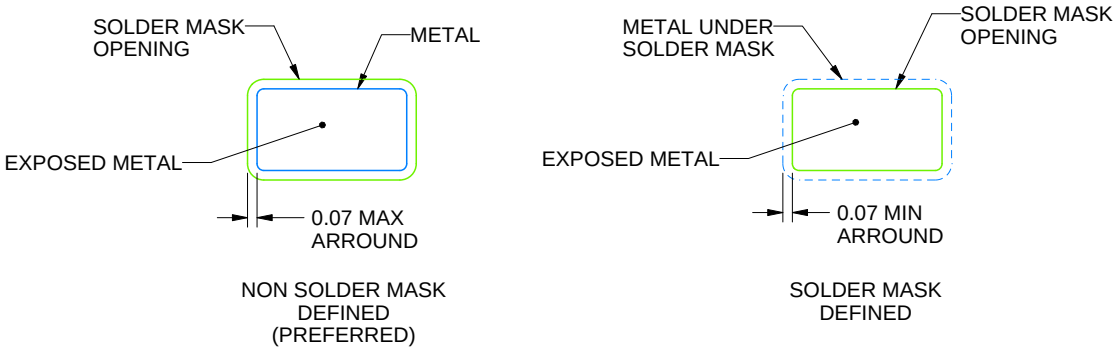
4214839/K 08/2024

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. Refernce JEDEC MO-178.
4. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25 mm per side.
5. Support pin may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:15X

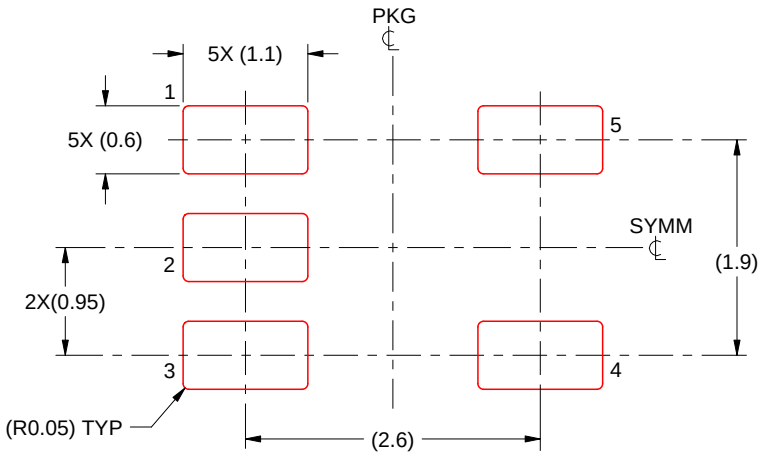


SOLDER MASK DETAILS

4214839/K 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.



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

4214839/K 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.

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Last updated 10/2025