THS402x 2GHz, 10V/V Stable, Low-Noise, High-Speed Amplifiers

1 Features

- Ultra-low 1.2nV/√Hz voltage noise
- High speed:
  - 2GHz gain-bandwidth product
  - 470V/µs slew rate
  - 30ns settling time (0.1%)
- Stable at gains ≥10V/V
- Output drive, I_O = 200mA (typical)
- Very low distortion:
  - THD = –68dBc (f = 1MHz, R_L = 150Ω)
- Wide range of power supplies:
  - V_{CC} = ±4.5V to ±16V
- Offset nulling pins on the THS4021

2 Applications

- Ultrasound scanner
- Source measurement unit (SMU)
- Power quality meter

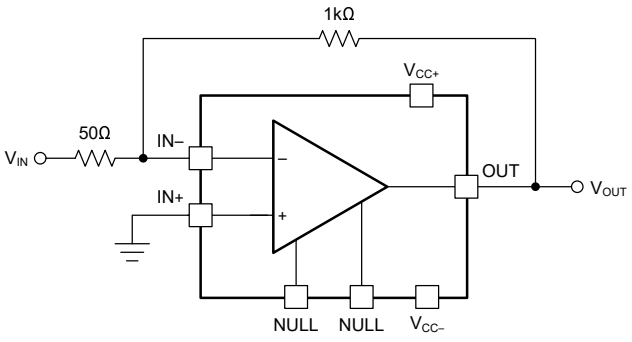
3 Description

The THS4021 and THS4022 (THS402x) are ultra-low voltage noise, high-speed voltage-feedback amplifiers that are an excellent choice for applications requiring low voltage noise, including communication and imaging. The single-amplifier THS4021 and the dual-amplifier THS4022 offer very good ac performance with a 290MHz closed-loop bandwidth, 470V/µs slew rate, and 30ns settling time (0.1%) for a gain of 10V/V. The THS402x are stable at gains of 10V/V or greater and –9V/V or less. These amplifiers have a high drive capability of 200mA and draw only 7.5mA of supply current per amplifier. With a total harmonic distortion (THD) of –68dBc at f = 1MHz, the THS402x are designed for applications requiring low distortion.

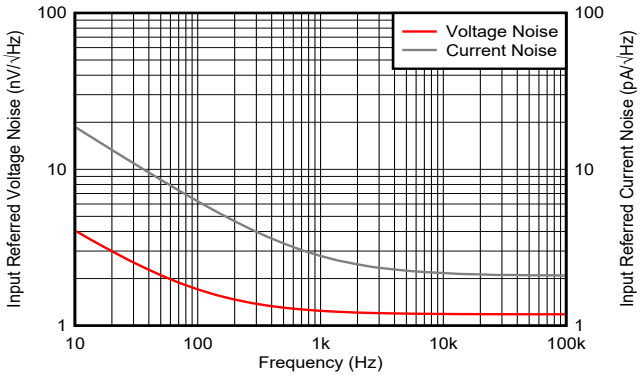
Device Information

PART NUMBER	AMPLIFIERS	PACKAGE(1)
THS4021	One	D (SOIC, 8)
		DGN (HVSSOP, 8)
THS4022	Two	DGN (HVSSOP, 8)

(1) For more information, see Section 10.



Simplified Application



Voltage and Current Noise vs Frequency

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Table of Contents

1 Features....1
2 Applications....1
3 Description....1
4 Pin Configuration and Functions....3
5 Specifications....4
5.1 Absolute Maximum Ratings....4
5.2 ESD Ratings....4
5.3 Recommended Operating Conditions....4
5.4 Thermal Information - THS4021....5
5.5 Thermal Information - THS4022....5
5.6 Electrical Characteristics - THS4021D and THS4022DGN....6
5.7 Electrical Characteristics - THS4021DGN....8
5.8 Typical Characteristics: THS4021D and THS4022DGN....10
5.9 Typical Characteristics: THS4021DGN....16
6 Detailed Description....21
6.1 Overview....21
6.2 Functional Block Diagram....21
6.3 Feature Description....22
6.4 Device Functional Modes....22
7 Application and Implementation....23
7.1 Application Information....23
7.2 Power Supply Recommendations....24
7.3 Layout....24
8 Device and Documentation Support....27
8.1 Documentation Support....27
8.2 Receiving Notification of Documentation Updates....27
8.3 Support Resources....27
8.4 Trademarks....27
8.5 Electrostatic Discharge Caution....27
8.6 Glossary....27
9 Revision History....27
10 Mechanical, Packaging, and Orderable Information....28

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4 Pin Configuration and Functions

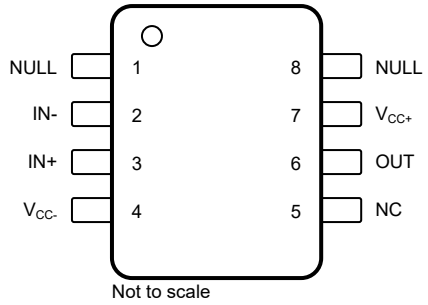

Figure 4-1. THS4021: D Package, 8-Pin SOIC, or DGN Package, 8-pin HVSSOP (Top View)

Table 4-1. Pin Functions: THS4021

PIN		TYPE	DESCRIPTION
NAME	NO.		
IN–	2	Input	Inverting input
IN+	3	Input	Noninverting input
NC	5	—	No connection
NULL	1, 8	Input	Voltage offset adjust
OUT	6	Output	Output of amplifier
$V_{CC–}$	4	—	Negative power supply
V_{CC+}	7	—	Positive power supply

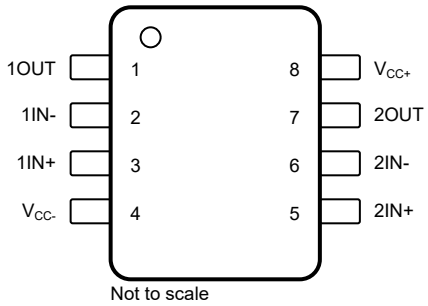

Figure 4-2. THS4022: DGN Package, 8-pin HVSSOP (Top View)

Table 4-2. Pin Functions: THS4022

PIN		TYPE	DESCRIPTION
NAME	NO.		
1IN–	2	Input	Channel 1 inverting input
1IN+	3	Input	Channel 1 noninverting input
1OUT	1	Output	Channel 1 output
2IN–	6	Input	Channel 2 inverting input
2IN+	5	Input	Channel 2 noninverting input
2OUT	7	Output	Channel 2 output
$V_{CC–}$	4	—	Negative power supply
V_{CC+}	8	—	Positive power supply

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5 Specifications

5.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
$V_{CC–}$ to V_{CC+}	Supply voltage			33	V
V_I	Input voltage			$\pm V_{CC}$	V
I_O	Output current(2)			240	mA
V_{IO}	Differential input voltage			±1.5	V
I_{IN}	Continuous input current			10	mA
T_J	Maximum junction temperature	Maximum junction temperature		150	°C
T_A	Operating free-air temperature	C-suffix	0	70	°C
		I-suffix	–40	85	
T_{stg}	Storage temperature		–65	150	°C
	Lead temperature 1.6 mm (1/16 inch) from case for 10 seconds			300	°C

(1) Operation outside the *Absolute Maximum Ratings* may cause permanent device damage. *Absolute Maximum Ratings* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Conditions*. If used outside the *Recommended Operating Conditions* but within the *Absolute Maximum Ratings*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
(2) When continuously operating at any output current, do not exceed the maximum junction temperature. Keep the output current less than the absolute maximum rating regardless of time interval.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001, all pins(1)	±1000	V
		Charged device model (CDM), per JEDEC specification JESD22-C101(2)	±1000	

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

5.3 Recommended Operating Conditions

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

			MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage	Dual-supply	±4.5	±15	±16	V
		Single-supply	9	30	32	
T_A	Operating free-air temperature	C-suffix	0	25	70	°C
		I-suffix	–40	25	85	

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5.4 Thermal Information - THS4021

THERMAL METRIC[1]		THS4021		UNIT
		D (SOIC)	DGN (HVSSOP)	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	124.5	58.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	65.0	4.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	72.2	N/A	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	13.6	N/A	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	71.4	N/A	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	N/A	°C/W

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

5.5 Thermal Information - THS4022

THERMAL METRIC[1]		THS4022	UNIT
		DGN (HVSSOP)	
		8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	52	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	75.2	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	24.5	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	4	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	24.5	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	9.1	°C/W

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

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5.6 Electrical Characteristics - THS4021D and THS4022DGN

at T_A = 25°C, V_{CC} = ±15 V, and R_L = 150 Ω (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
DYNAMIC PERFORMANCE							
BW	Small-signal bandwidth (–3 dB)	Gain = 10	V_{CC} = ±15 V		290		MHz
			V_{CC} = ±5 V		250		
		Gain = 20	V_{CC} = ±15 V		110		
			V_{CC} = ±5 V		100		
	Bandwidth for 0.1-dB flatness	Gain = 10	V_{CC} = ±15 V		17		
			V_{CC} = ±5 V		17		
	Full-power bandwidth(1)	$V_{O(pp)}$ = 20 V, V_{CC} = ±15 V			7.5		
		$V_{O(pp)}$ = 5 V, V_{CC} = ±5 V			23.6		
SR	Slew rate(2)	Gain = 10	V_{CC} = ±15 V, 20-V step		470		V/µs
			V_{CC} = ±5 V, 5-V step		370		
t_s	Settling time to 0.1%	Gain = –10	V_{CC} = ±15 V, 5-V step		30		ns
			V_{CC} = ±5 V, 2-V step		30		
	Settling time to 0.01%	Gain = –10	V_{CC} = ±15 V, 5-V step		160		
			V_{CC} = ±5 V, 2-V step		160		
NOISE AND DISTORTION PERFORMANCE							
THD	Total harmonic distortion	$V_{O(pp)}$ = 2 V, f = 1 MHz, gain = 10, V_{CC} = ±15 V			–68		dBc
			R_L = 1 kΩ		–77		
		$V_{O(pp)}$ = 2 V, f = 1 MHz, gain = 10, V_{CC} = ±5 V			–69		
			R_L = 1 kΩ		–78		
V_n	Input voltage noise	V_{CC} = ±5 V or ±15 V, f > 10 kHz			1.2		nV/√Hz
I_n	Input current noise	V_{CC} = ±5 V or ±15 V, f > 10 kHz			2.3		pA/√Hz
	Differential gain error	Gain = 10, NTSC, 40 IRE modulation, ±100 IRE ramp	V_{CC} = ±15		0.02		%
			V_{CC} = ±5 V		0.02		
	Differential phase error	Gain = 10, NTSC, 40 IRE modulation, ±100 IRE ramp	V_{CC} = ±15		0.08		°
			V_{CC} = ±5 V		0.06		
X_T	Channel-to-channel crosstalk (THS4022 only)	V_{CC} = ±5 V or ±15 V, f = 1 MHz			–54		dBc
DC PERFORMANCE							
	Open-loop gain	V_{CC} = ±15 V, V_O = ±10 V, R_L = 1 kΩ	T_A = 25°C	92	100		dB
			T_A = full range	91			
		V_{CC} = ±5 V, V_O = ±2.5 V, R_L = 1 kΩ	T_A = 25°C	86	98		
			T_A = full range	84			
V_{OS}	Input offset voltage	V_{CC} = ±5 V or ±15 V	T_A = 25°C		0.3	2	mV
			T_A = full range			3	
	Offset voltage drift	V_{CC} = ±5 V or ±15 V, T_A = full range			2		µV/°C
I_{IB}	Input bias current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		9	20	µA
			T_A = full range			33	µA
I_{OS}	Input offset current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		30	250	nA
			T_A = full range			400	nA
	Input offset current drift	V_{CC} = ±5 V or ±15 V, T_A = full range			0.2		nA/°C

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5.6 Electrical Characteristics - THS4021D and THS4022DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, and R_L = 150 Ω (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS							
V_{ICR}	Common-mode input voltage	V_{CC} = ±15 V		±13.8	±14.3		V
		V_{CC} = ±5 V		±3.8	±4.3		
CMRR	Common-mode rejection ratio	V_{CC} = ±15 V, V_{ICR} = ±12 V	T_A = 25 °C		95		dB
			T_A = full range	74			
		V_{CC} = ±5 V, V_{ICR} = ±2.5 V	T_A = 25 °C		100		
			T_A = full range	85			
r_i	Input resistance				1		MΩ
C_i	Input capacitance				1.5		pF
OUTPUT CHARACTERISTICS							
V_O	Output voltage swing	V_{CC} = ±15 V, R_L = 250 Ω		±12	±12.9		V
		V_{CC} = ±5 V, R_L = 150 Ω		±3	±3.5		
		V_{CC} = ±15 V, R_L = 1 kΩ		±13	±13.6		
		V_{CC} = ±5 V, R_L = 1 kΩ		±3.4	±3.8		
I_O	Output current	V_{CC} = ±15 V, R_L = 10 Ω		80	200		mA
		V_{CC} = ±5 V, R_L = 10 Ω		50	160		
R_O	Output resistance(3)	Open-loop			5		Ω
POWER SUPPLY							
V_{CC}	Supply voltage	Dual supply		±4.5		±16.5	V
		Single supply		9		33	
I_{CC}	Supply current (per amplifier)	V_{CC} = ±15 V	T_A = 25°C		7.5	10	mA
			T_A = full range			11	
		V_{CC} = ±5 V	T_A = 25°C		6.5	9	
			T_A = full range			10.5	
PSRR	Power-supply rejection ratio	V_{CC} = ±5 V or ±15 V	T_A = 25 °C		95		dB
			T_A = full range	80			

(1) Full-power bandwidth = slew rate / [π $V_{O(P-P)}$].
(2) Slew rate is measured from an output level range of 25% to 75%.
(3) Keep junction temperature less than the absolute maximum rating when the output is heavily loaded or shorted; see also Section 5.1.

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5.7 Electrical Characteristics - THS4021DGN

at T_A = 25°C, V_{CC} = ±15 V, R_L = 150 Ω (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
DYNAMIC PERFORMANCE							
BW	Small-signal bandwidth (–3 dB)	Gain = 10	V_{CC} = ±15 V		350		MHz
			V_{CC} = ±5 V		280		
		Gain = 20	V_{CC} = ±15 V		80		
			V_{CC} = ±5 V		70		
	Bandwidth for 0.1-dB flatness	Gain = 10	V_{CC} = ±15 V		17		
			V_{CC} = ±5 V		17		
	Full-power bandwidth(1)	$V_{O(pp)}$ = 20 V, V_{CC} = ±15 V			3.7		
		$V_{O(pp)}$ = 5 V, V_{CC} = ±5 V			11.8		
SR	Slew rate(2)	Gain = 10	V_{CC} = ±15 V, 10-V step		470		V/µs
			V_{CC} = ±5 V, 5-V step		370		
t_s	Settling time to 0.1%	Gain = –10	V_{CC} = ±15 V, 5-V step		40		ns
			V_{CC} = ±5 V, 2-V step		50		
	Settling time to 0.01%	Gain = –10	V_{CC} = ±15 V, 5-V step		145		
			V_{CC} = ±5 V, 2-V step		150		
NOISE/DISTORTION PERFORMANCE							
THD	Total harmonic distortion	$V_{O(pp)}$ = 2 V, f = 1 MHz, gain = 2, V_{CC} = ±15 V			–68		dBc
			R_L = 1 kΩ		–77		
		$V_{O(pp)}$ = 2 V, f = 1 MHz, gain = 2, V_{CC} = ±5 V			–69		
			R_L = 1 kΩ		–78		
V_n	Input voltage noise	V_{CC} = ±5 V or ±15 V, f > 10 kHz			1.5		nV/√Hz
I_n	Input current noise	V_{CC} = ±5 V or ±15 V, f > 10 kHz			2		pA/√Hz
	Differential gain error	Gain = 2, NTSC, 40 IRE modulation, ±100 IRE ramp	V_{CC} = ±15		0.02		%
			V_{CC} = ±5 V		0.02		
	Differential phase error	Gain = 2, NTSC, 40 IRE modulation, ±100 IRE ramp	V_{CC} = ±15		0.08		°
			V_{CC} = ±5 V		0.06		
DC PERFORMANCE							
	Open-loop gain	V_{CC} = ±15 V, V_O = ±10 V, R_L = 1 kΩ	T_A = 25°C	40	60		V/mV
			T_A = full range	35			
		V_{CC} = ±5 V, V_O = ±2.5 V, R_L = 250 Ω	T_A = 25°C	20	35		
			T_A = full range	15			
V_{OS}	Input offset voltage	V_{CC} = ±5 V or ±15 V	T_A = 25°C		0.5	2	mV
			T_A = full range			3	
	Offset voltage drift	V_{CC} = ±5 V or ±15 V	T_A = full range		15		µV/°C
I_{IB}	Input bias current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		3	6	µA
			T_A = full range			6	
I_{OS}	Input offset current	V_{CC} = ±5 V or ±15 V	T_A = 25°C		30	250	nA
			T_A = full range			400	
	Input offset current drift	T_A = full range			0.3		nA/°C

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5.7 Electrical Characteristics - THS4021DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, R_L = 150 Ω (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS							
V_{ICR}	Common-mode input voltage	V_{CC} = ±15 V		±13.8	±14.3		V
		V_{CC} = ±5 V		±3.8	±4.3		
CMRR	Common-mode rejection ratio	V_{CC} = ±15 V, V_{ICR} = ±12 V, T_A = full range		74	95		dB
r_i	Input resistance				1		MΩ
C_i	Input capacitance				1.5		pF
OUTPUT CHARACTERISTICS							
V_O	Output voltage swing	V_{CC} = ±15 V, R_L = 250 Ω		±12	±12.5		V
		V_{CC} = ±5 V, R_L = 150 Ω		±3	±3.3		
		V_{CC} = ±15 V, R_L = 150 Ω		±13	±13.5		
		V_{CC} = ±5 V, R_L = 150 Ω		±3.4	±3.8		
I_O	Output current	R_L = 20 Ω	V_{CC} = ±15 V	80	100		mA
			V_{CC} = ±5 V	50	75		
I_{SC}	Short-circuit current(3)	V_{CC} = ±15 V			150		mA
R_O	Output resistance(3)	Open loop			13		Ω
POWER SUPPLY							
V_{CC}	Supply voltage	Dual supply		±4.5		±16.5	V
		Single supply		9		33	
I_{CC}	Supply current (per amplifier)	V_{CC} = ±15 V	T_A = 25°C		7.8	10	mA
			T_A = full range			11	
		V_{CC} = ±5 V	T_A = 25°C		6.7	9	
			T_A = full range			10.5	
PSRR	Power-supply rejection ratio	V_{CC} = ±5 V or ±15 V, T_A = full range		80	95		dB

(1) Full-power bandwidth = slew rate / 2π $V_{O(Peak)}$.
(2) Slew rate is measured from an output level range of 25% to 75%.
(3) Keep junction temperature less than the absolute maximum rating when the output is heavily loaded or shorted; see also Section 5.1.

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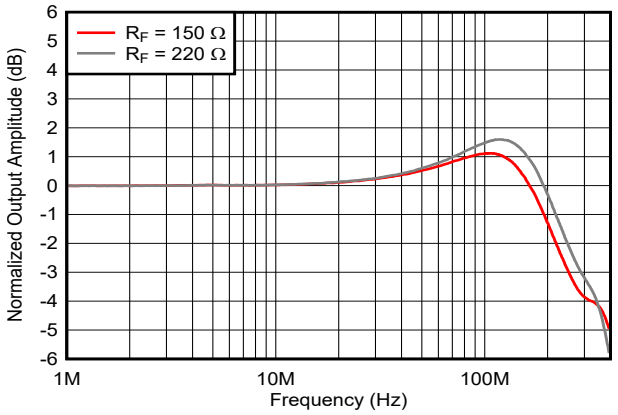
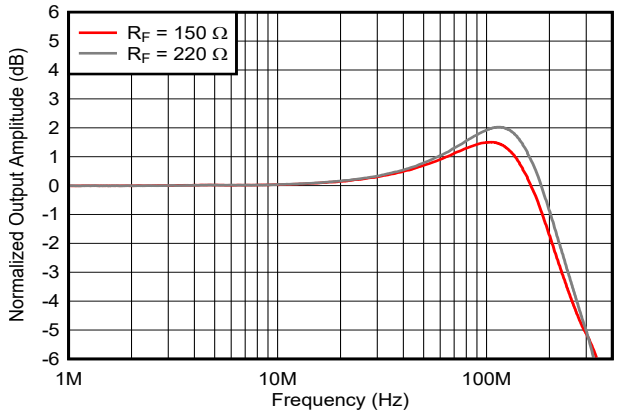
5.8 Typical Characteristics: THS4021D and THS4022DGN

at T_A = 25°C, V_{CC} = ±15 V, gain = +10 V/V, R_L = 150 Ω, and R_F = 220 Ω (unless otherwise noted)



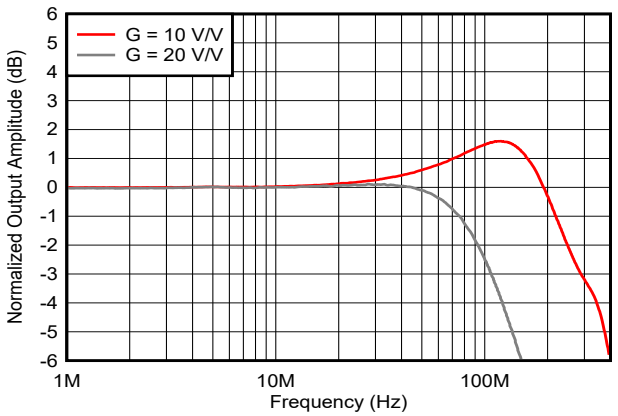
V_{CC} = ±15 V, V_{OUT} = 100 mV_{PP}

Figure 5-1. Frequency Response vs Feedback Resistance



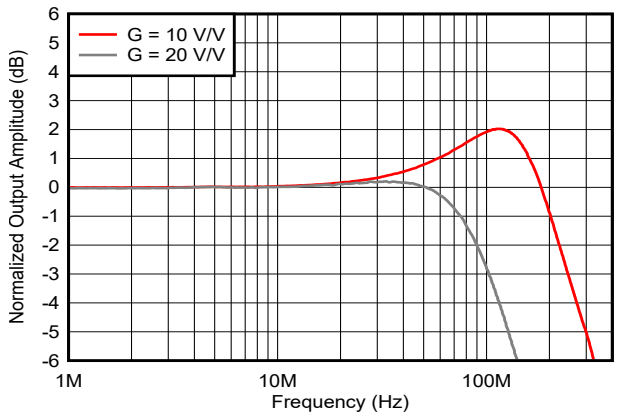
V_{CC} = ±5 V, V_{OUT} = 100 mV_{PP}

Figure 5-2. Frequency Response vs Feedback Resistance



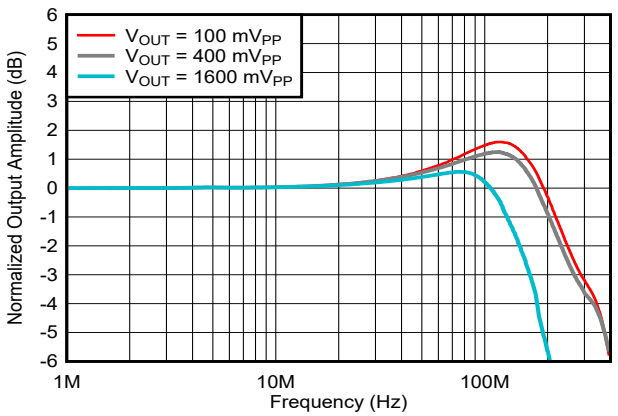
V_{CC} = ±15 V, V_{OUT} = 100 mV_{PP}

Figure 5-3. Frequency Response vs Gain



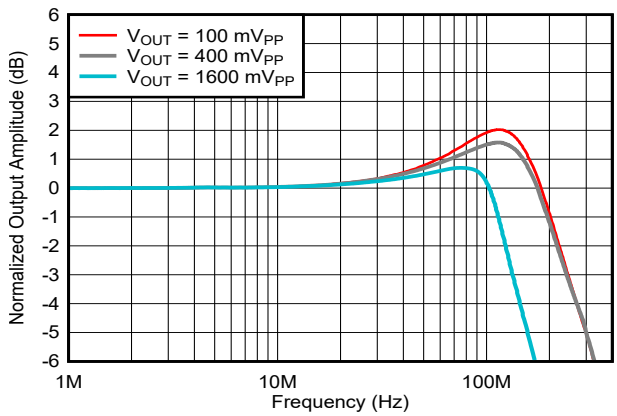
V_{CC} = ±5 V, V_{OUT} = 100 mV_{PP}

Figure 5-4. Frequency Response vs Gain



V_{CC} = ±15 V

Figure 5-5. Large-Signal Frequency Response



V_{CC} = ±5 V

Figure 5-6. Large-Signal Frequency Response

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5.8 Typical Characteristics: THS4021D and THS4022DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, gain = +10 V/V, R_L = 150 Ω, and R_F = 220 Ω (unless otherwise noted)

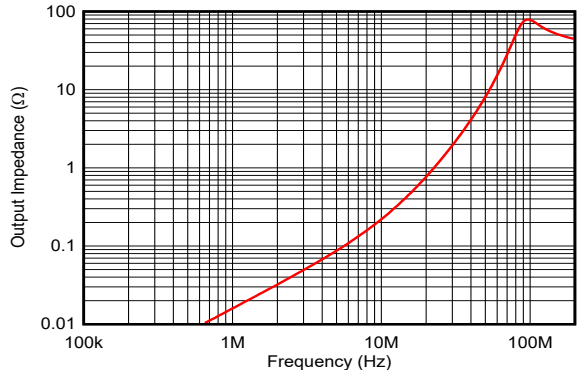


Figure 5-7. Closed-Loop Output Impedance

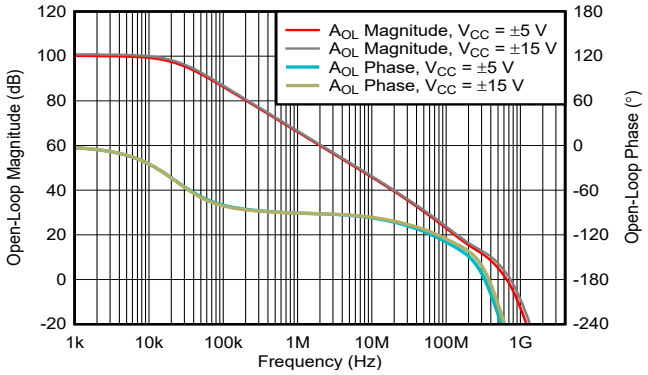


Figure 5-8. Open-loop Gain and Phase Response

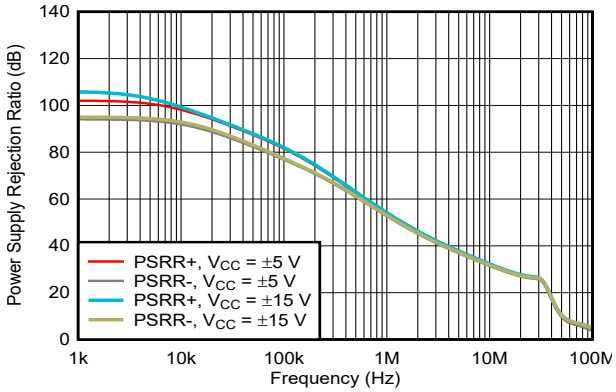


Figure 5-9. Power-Supply Rejection Ratio vs Frequency

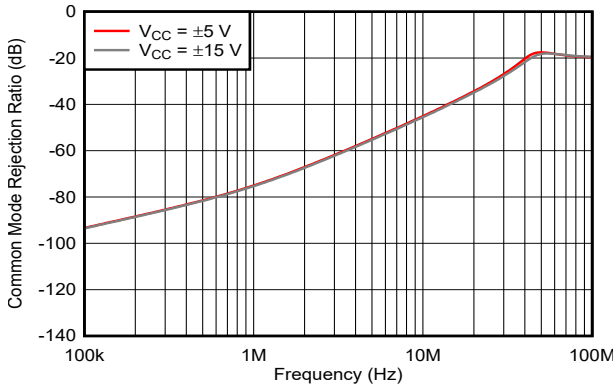
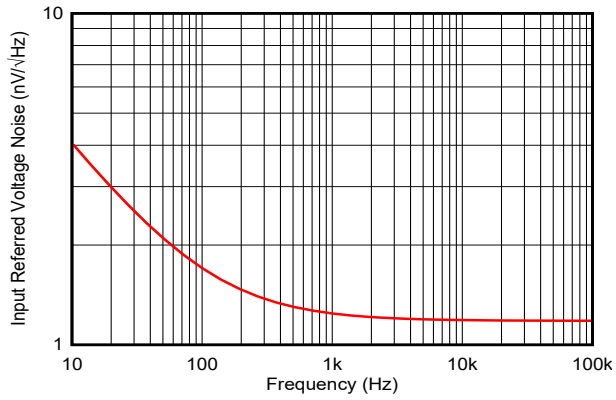
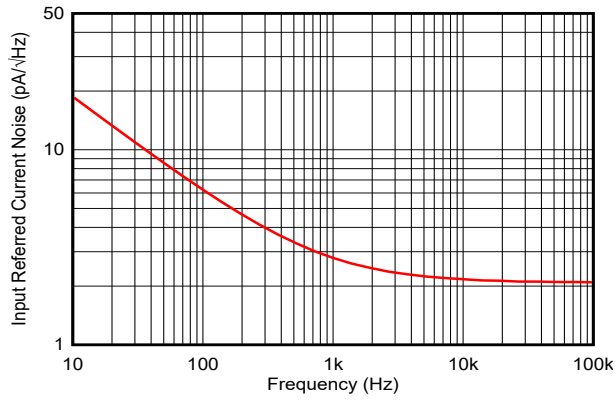


Figure 5-10. Common-Mode Rejection Ratio vs Frequency



V_{CC} = ±15 V

Figure 5-11. Input-Referred Voltage Noise vs Frequency



V_{CC} = ±15 V, R_L = 150 Ω, V_{OUT} = 2 V_{PP}

Figure 5-12. Input-Referred Current Noise vs Frequency

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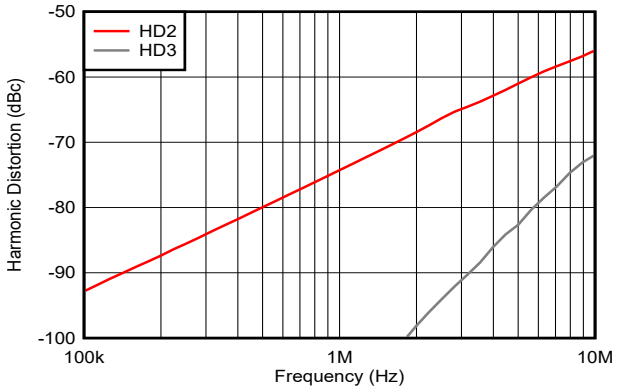
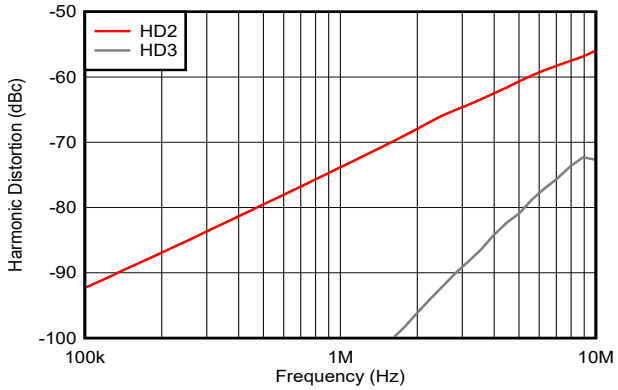
5.8 Typical Characteristics: THS4021D and THS4022DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, gain = +10 V/V, R_L = 150 Ω, and R_F = 220 Ω (unless otherwise noted)



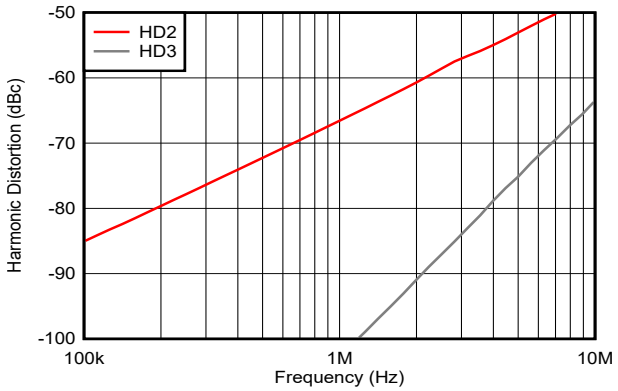
V_{CC} = ±15 V, R_L = 1 kΩ, V_{OUT} = 2 V_{PP}

Figure 5-13. Harmonic Distortion vs Frequency



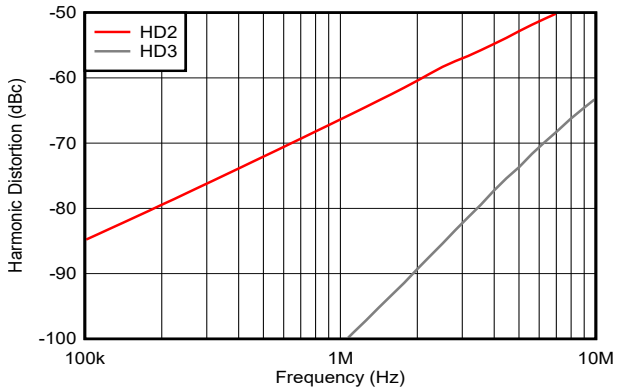
V_{CC} = ±5 V, R_L = 1 kΩ, V_{OUT} = 2 V_{PP}

Figure 5-14. Harmonic Distortion vs Frequency



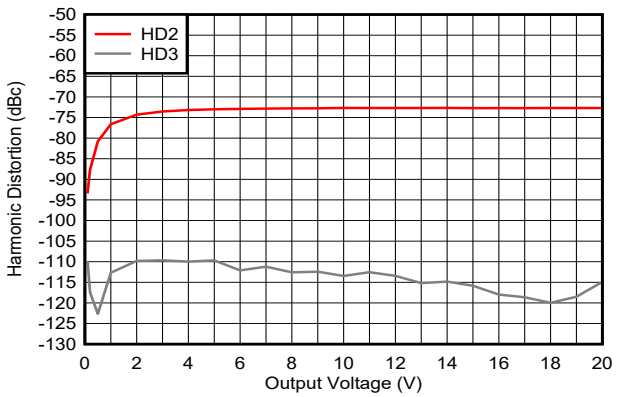
V_{CC} = ±15 V, R_L = 150 Ω, V_{OUT} = 2 V_{PP}

Figure 5-15. Harmonic Distortion vs Frequency



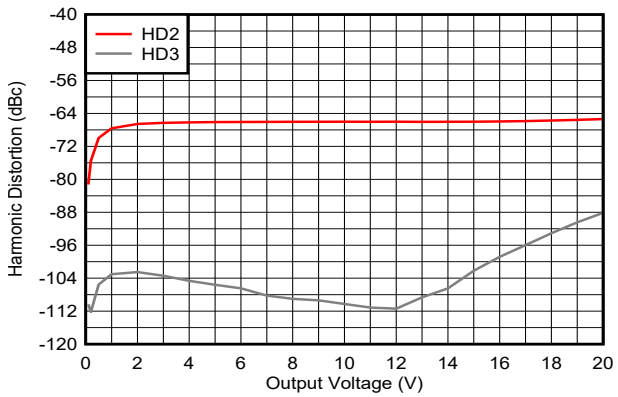
V_{CC} = ±5 V, R_L = 150 Ω, V_{OUT} = 2 V_{PP}

Figure 5-16. Harmonic Distortion vs Frequency



V_{CC} = ±15 V, R_L = 1 kΩ, f = 1 MHz

Figure 5-17. Harmonic Distortion vs Peak-to-Peak Output Voltage



V_{CC} = ±15 V, R_L = 150 Ω, f = 1 MHz

Figure 5-18. Harmonic Distortion vs Peak-to-Peak Output Voltage

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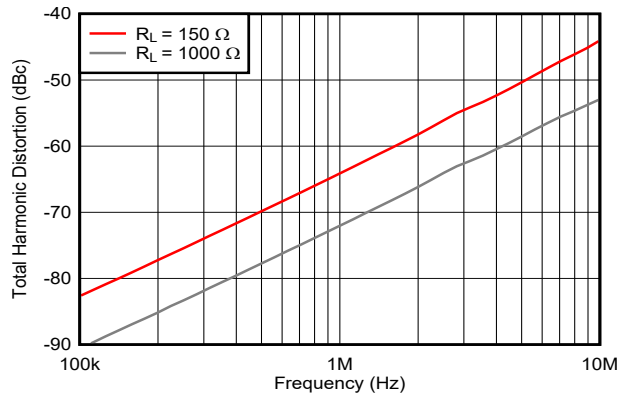
5.8 Typical Characteristics: THS4021D and THS4022DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, gain = +10 V/V, R_L = 150 Ω, and R_F = 220 Ω (unless otherwise noted)



V_{CC} = ±15 V, V_{OUT} = 2 V_{PP}

Figure 5-19. Total Harmonic Distortion vs Frequency

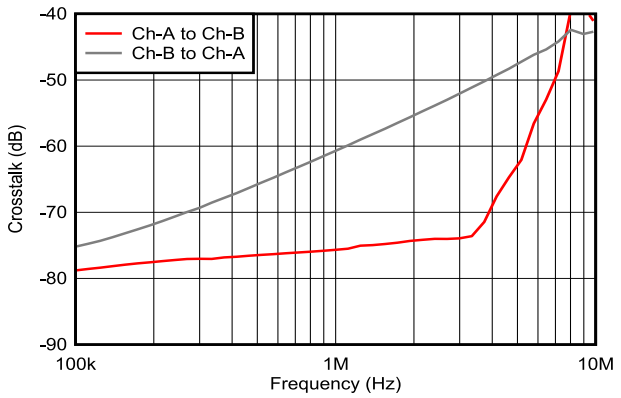


Figure 5-20. Crosstalk vs Frequency

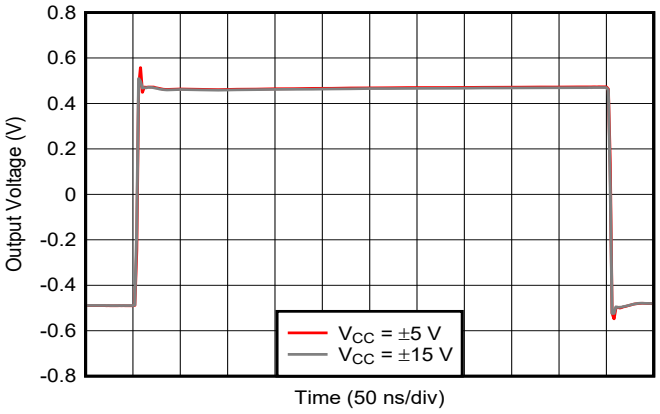
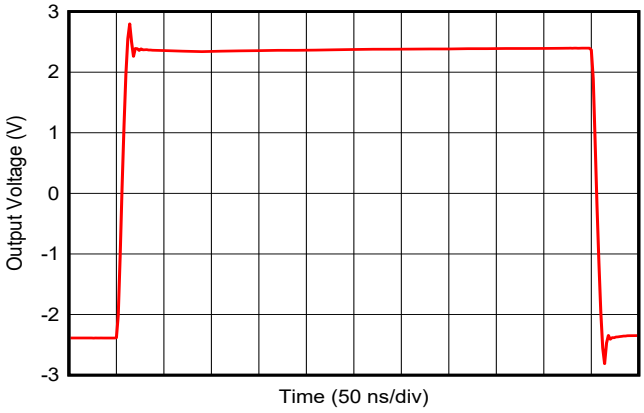
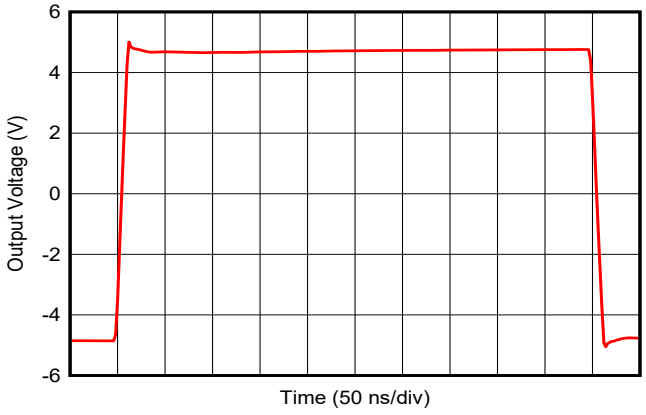


Figure 5-21. 1-V Step Response



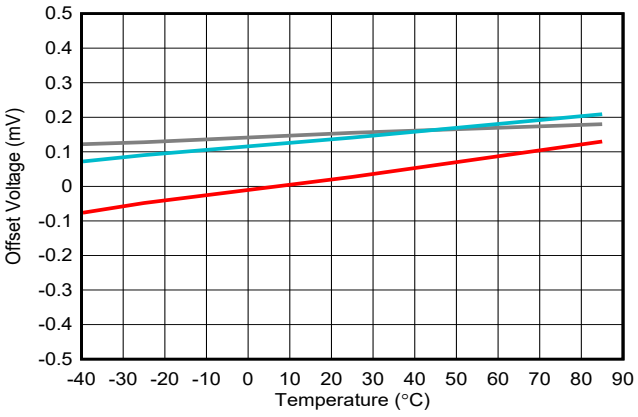
V_{CC} = ±5 V

Figure 5-22. 5-V Step Response



V_{CC} = ±15 V

Figure 5-23. 10-V Step Response



3 typical units

Figure 5-24. Input Offset Voltage vs Ambient Temperature

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5.8 Typical Characteristics: THS4021D and THS4022DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, gain = +10 V/V, R_L = 150 Ω, and R_F = 220 Ω (unless otherwise noted)

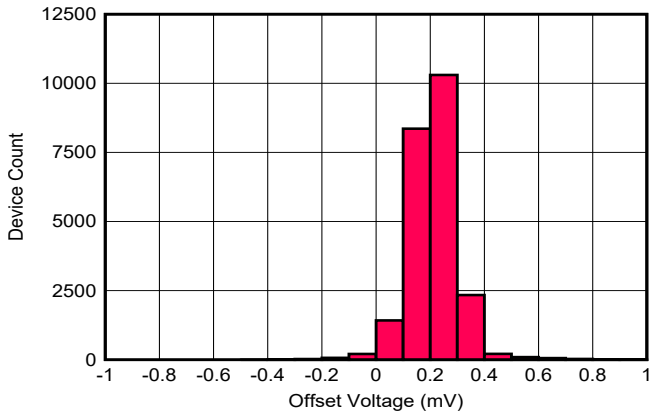

Figure 5-25. Voltage Offset Distribution

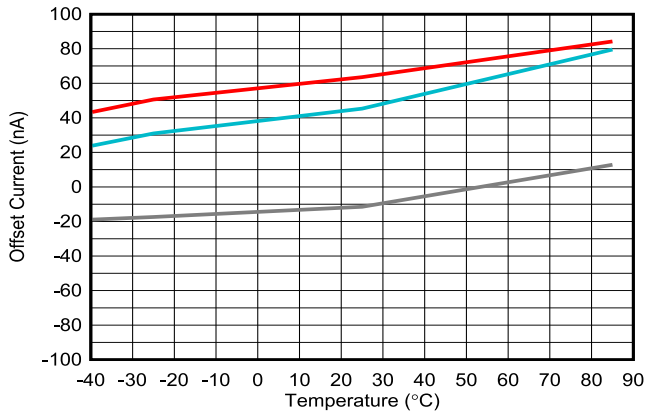

Figure 5-26. Input Offset Current vs Ambient Temperature

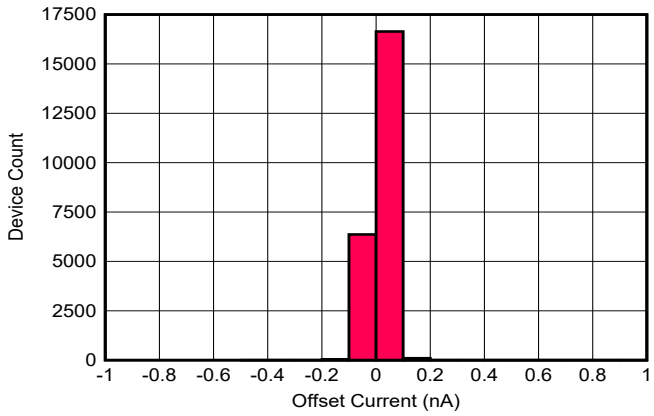

Figure 5-27. Input Offset Current vs Ambient Temperature

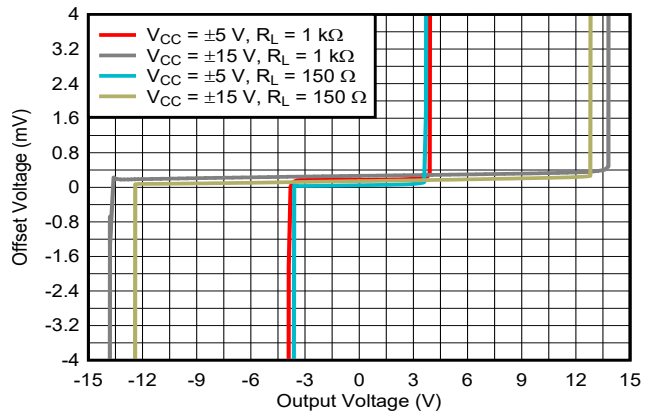

Figure 5-28. Offset Voltage vs Output Voltage

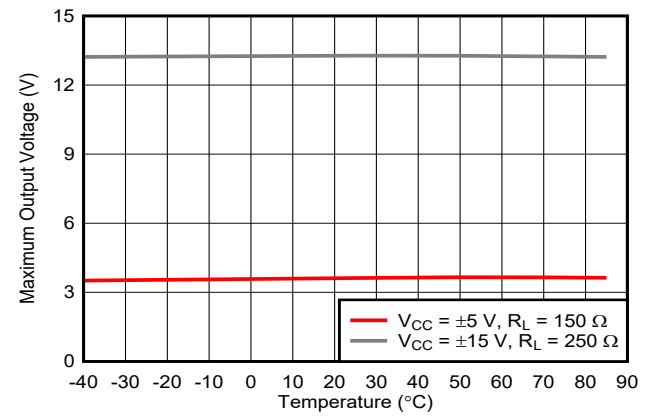

Figure 5-29. Maximum Output Voltage Swing vs Ambient Temperature

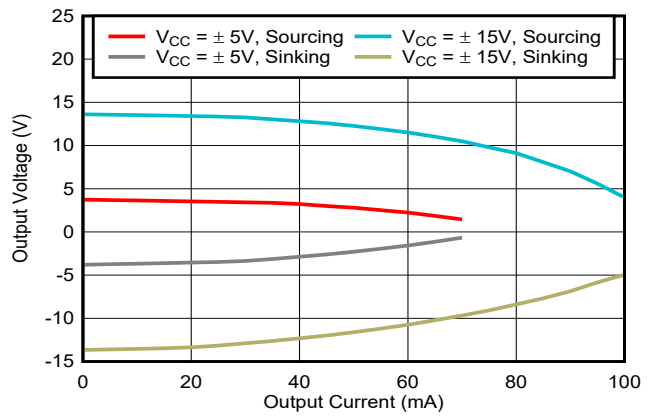

Figure 5-30. Output Swing vs Load Current

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5.8 Typical Characteristics: THS4021D and THS4022DGN (continued)

at T_A = 25°C, V_{CC} = ±15 V, gain = +10 V/V, R_L = 150 Ω, and R_F = 220 Ω (unless otherwise noted)

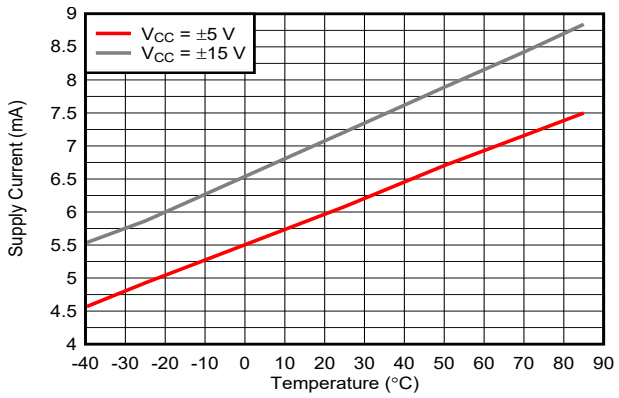

Figure 5-31. Supply Current vs Ambient Temperature

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5.9 Typical Characteristics: THS4021DGN

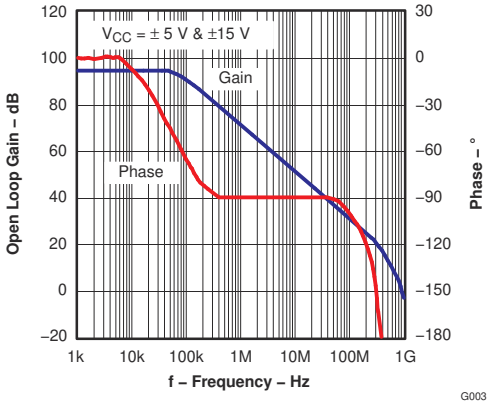

Figure 5-32. Open Loop Gain and Phase Response vs Frequency

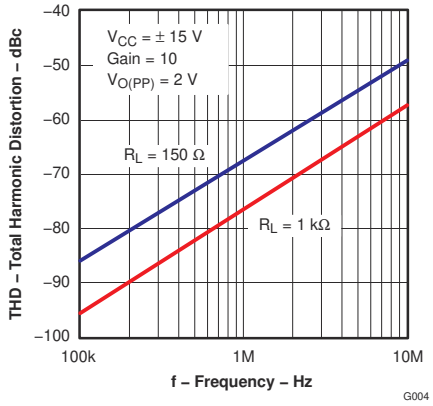

Figure 5-33. Total Harmonic Distortion vs Frequency

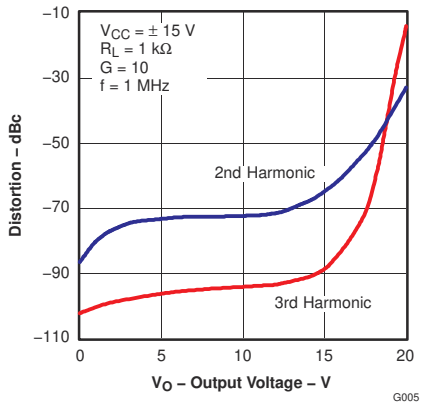

Figure 5-34. Distortion vs Output Voltage

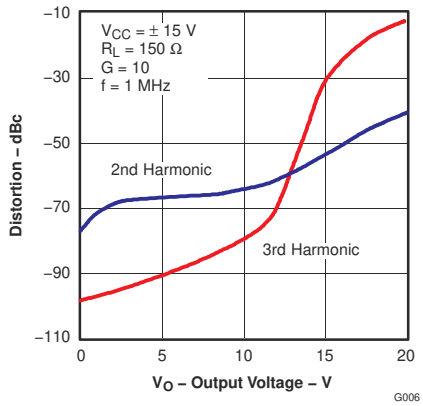

Figure 5-35. Distortion vs Output Voltage

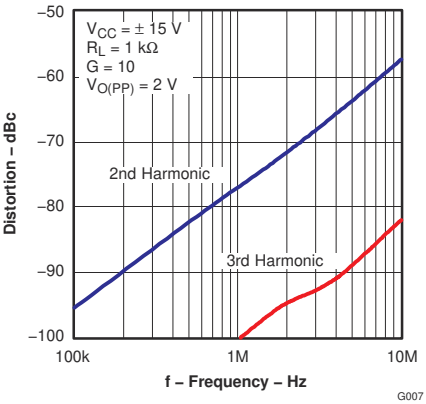

Figure 5-36. Distortion vs Frequency

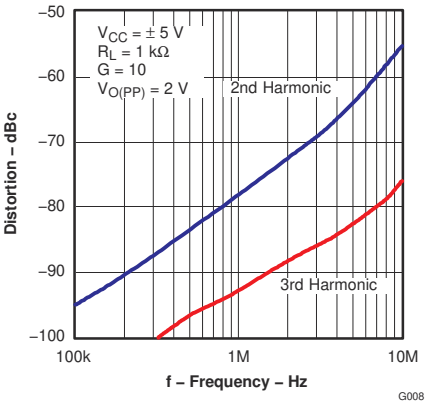

Figure 5-37. Distortion vs Frequency

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5.9 Typical Characteristics: THS4021DGN (continued)

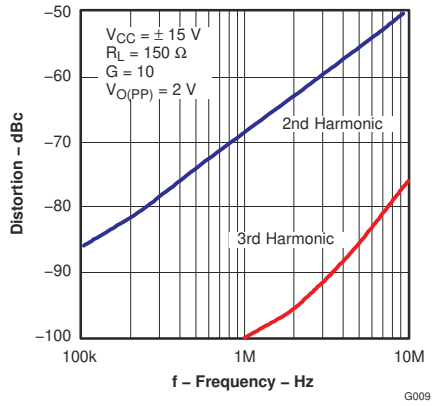

Figure 5-38. Distortion vs Frequency

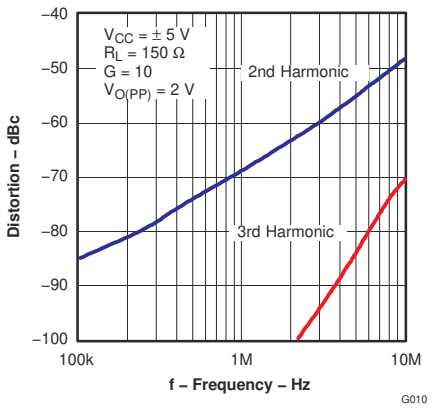

Figure 5-39. Distortion vs Frequency

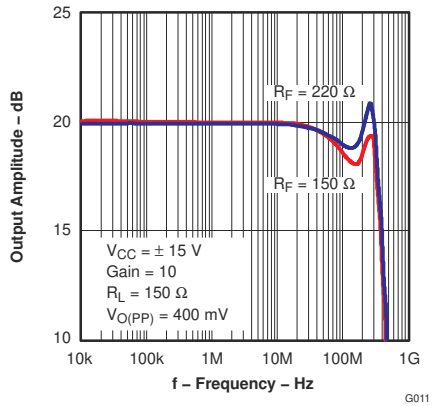

Figure 5-40. Output Amplitude vs Frequency

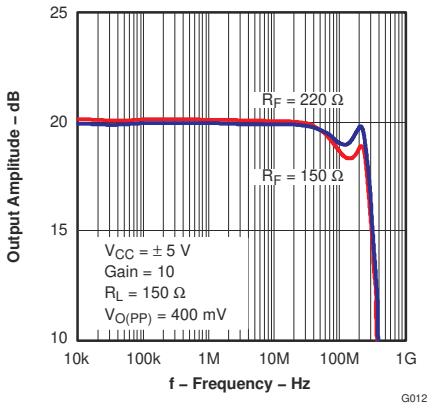

Figure 5-41. Output Amplitude vs Frequency

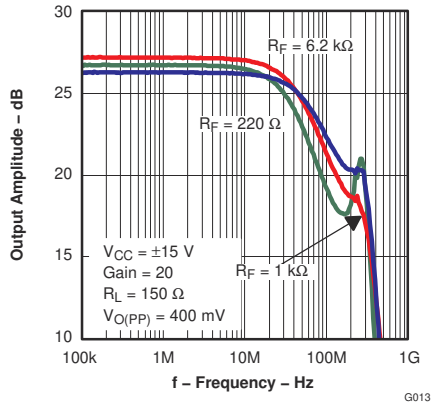

Figure 5-42. Output Amplitude vs Frequency

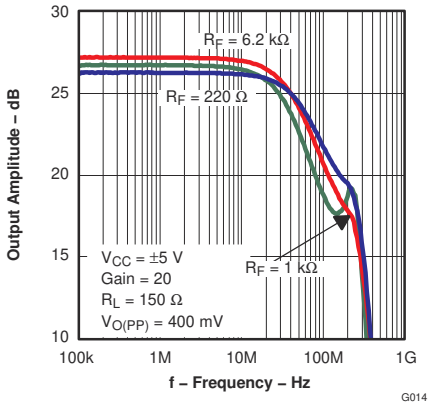

Figure 5-43. Output Amplitude vs Frequency

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5.9 Typical Characteristics: THS4021DGN (continued)

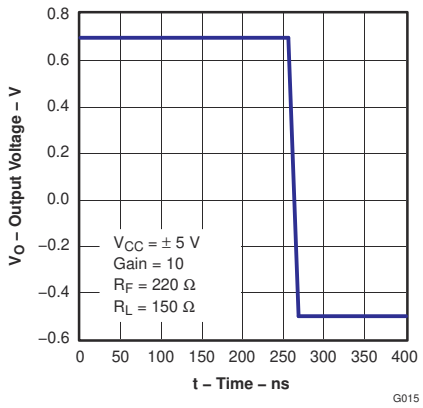

Figure 5-44. 1-V Step Response

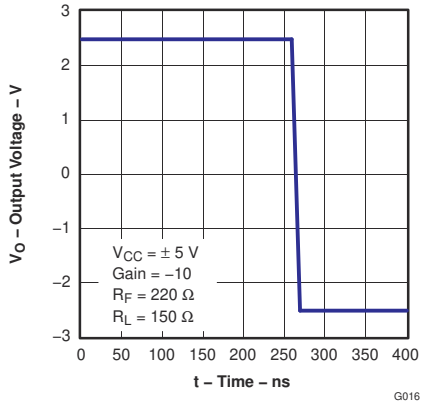

Figure 5-45. 5-V Step Response

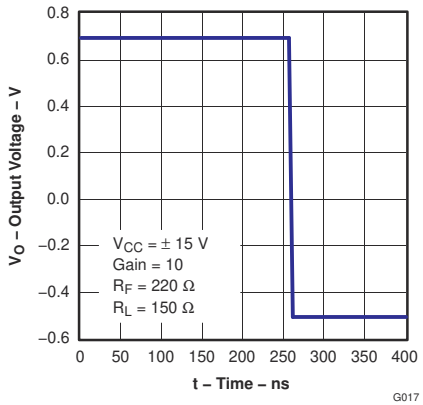

Figure 5-46. 1-V Step Response

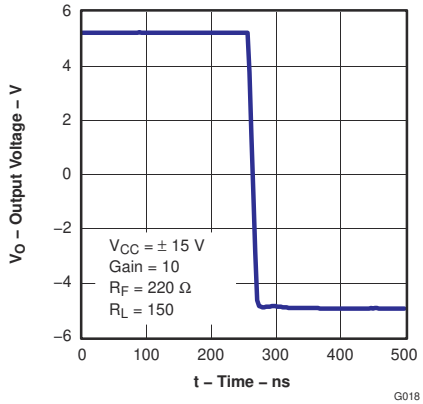

Figure 5-47. 10-V Step Response

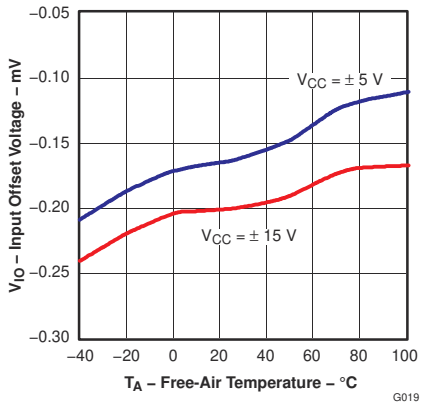

Figure 5-48. Input Offset Voltage vs Free-air Temperature

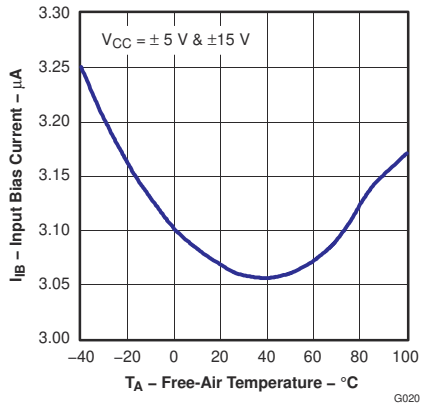

Figure 5-49. Input Bias Current vs Free-air Temperature

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5.9 Typical Characteristics: THS4021DGN (continued)

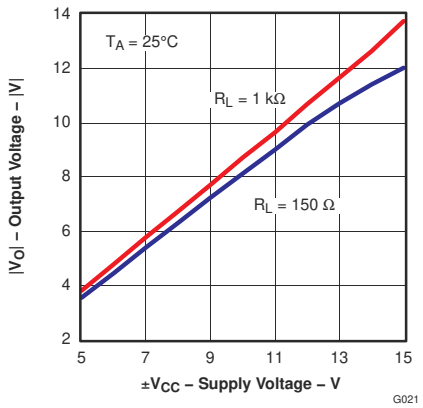

Figure 5-50. Output Voltage vs Supply Voltage

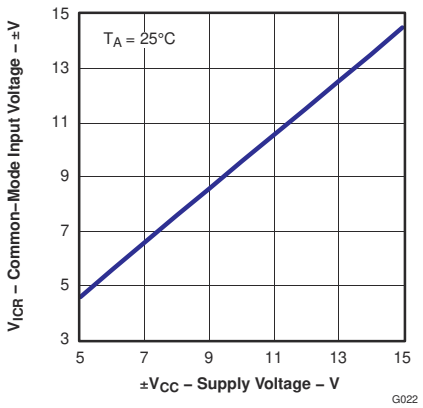

Figure 5-51. Common-mode Input Voltage vs Supply Voltage

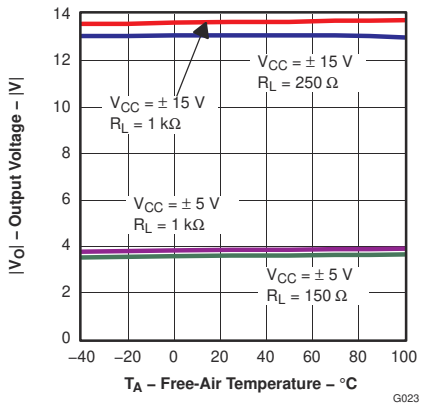

Figure 5-52. Output Voltage vs Free-air Temperature

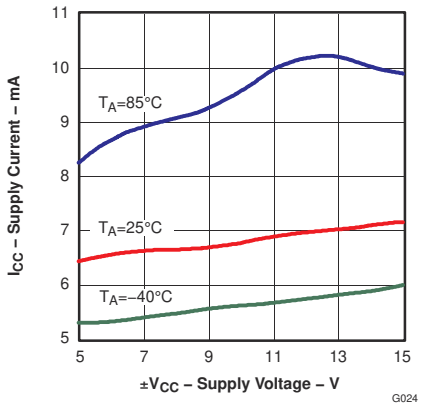

Figure 5-53. Supply Current vs Supply Voltage

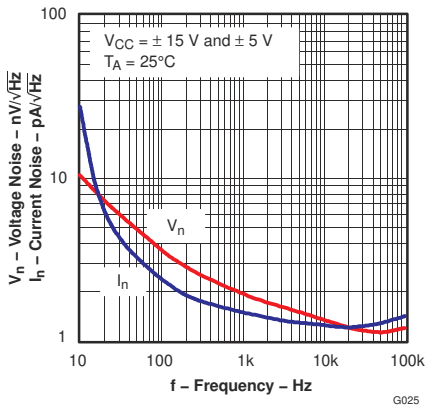

Figure 5-54. Voltage and Current Noise vs Frequency

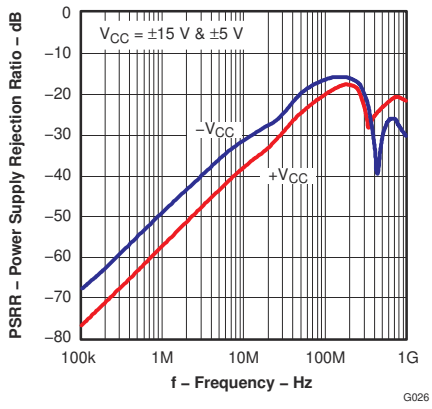

Figure 5-55. Power Supply Rejection Ratio vs Frequency

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5.9 Typical Characteristics: THS4021DGN (continued)

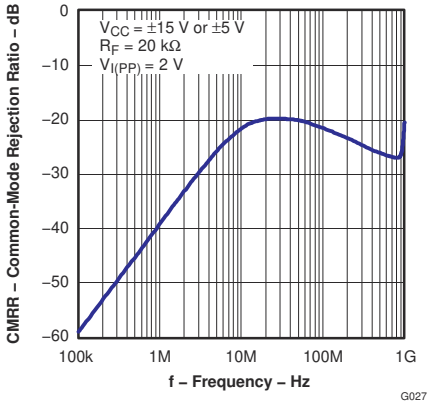

Figure 5-56. Common Mode Rejection Ratio vs Frequency

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6 Detailed Description

6.1 Overview

The THS402x are high-speed operational amplifiers configured in a decompensated voltage-feedback architecture. The THS402x are stable with gain configurations of 10 V/V or greater. These amplifiers is built using a greater than 30-V, complementary, bipolar process with NPN and PNP transistors possessing an f_T of several GHz. This configuration results in exceptionally high-performance amplifiers with wide bandwidth, high slew rate, fast settling time, and low distortion.

6.2 Functional Block Diagram

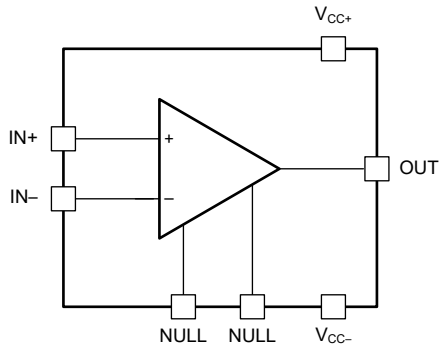

Figure 6-1. THS4021: Single Channel

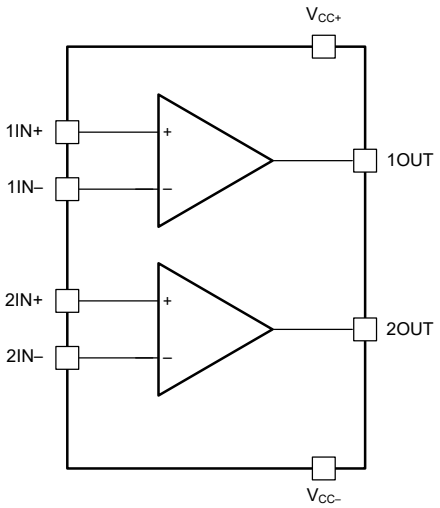

Figure 6-2. THS4022: Dual Channel

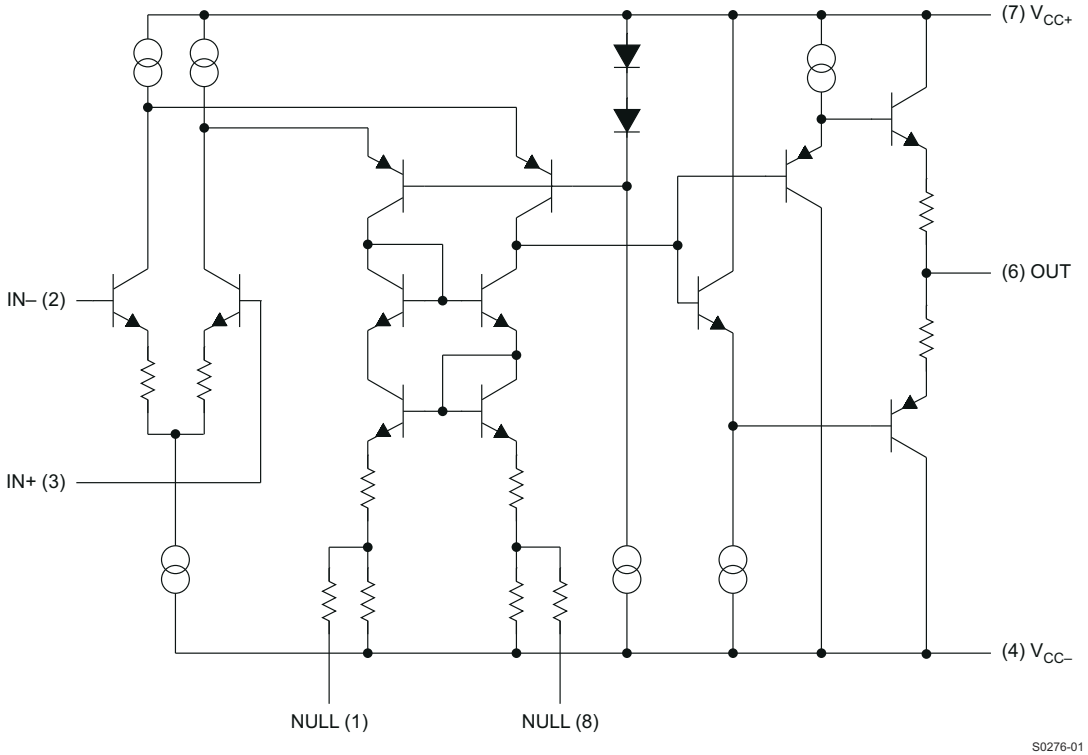

Figure 6-3. THS4021 Simplified Schematic

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6.3 Feature Description

6.3.1 Offset Nulling

The THS402x have a very low input offset voltage for high-speed amplifiers. However, if additional correction is required, an offset nulling function has been provided on the THS4021. To adjust the input offset voltage, place a potentiometer between pin 1 and pin 8 of the device, and tie the wiper to the negative supply. Figure 6-4 shows this feature.

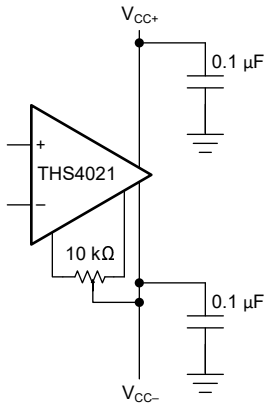

Figure 6-4. Offset Nulling Schematic

6.4 Device Functional Modes

The THS402x family has a single functional mode and can be used with both single-supply or split power-supply configurations. The power-supply voltage must be greater than 9 V (±4.5 V) and less than 33 V (±16.5 V).

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7 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, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

7.1.1 Driving a Capacitive Load

The THS402x are internally compensated to maximize bandwidth and slew-rate performance. To maintain stability, take additional precautions when driving capacitive loads with a high-performance amplifier. As a result of the internal compensation, significant capacitive loading directly on the output node decreases the device phase margin, and potentially lead to high-frequency ringing or oscillations. Therefore, for capacitive loads greater than 10 pF, place an isolation resistor in series with the output of the amplifier. Figure 7-1 shows this configuration. For most applications, a minimum resistance of 20 Ω is recommended. In 75-Ω transmission systems, setting the series resistor value to 75 Ω is a beneficial choice because this value isolates any capacitance loading and provides source impedance matching.

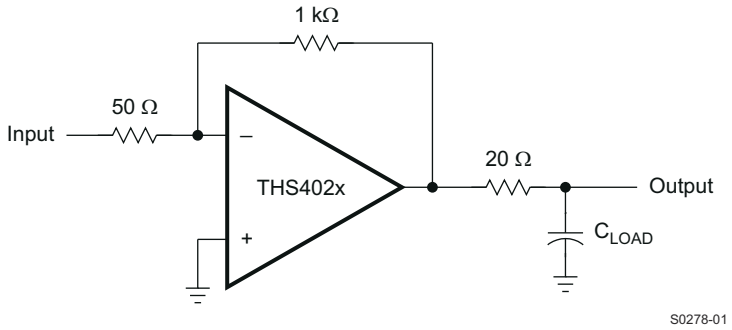

Figure 7-1. Driving a Capacitive Load

7.1.2 General Configuration

When receiving low-level signals, limiting the bandwidth of the incoming signals into the system is often required. Figure 7-2 shows how the simplest way to accomplish this limiting is to place an RC filter at the noninverting pin of the amplifier.

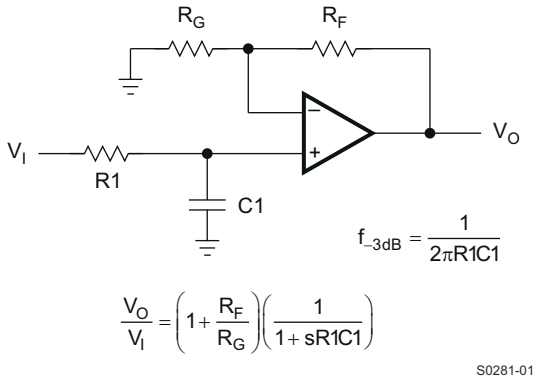

Figure 7-2. Single-Pole Low-Pass Filter

7.2 Power Supply Recommendations

The THS402x devices are designed to operate on power supplies ranging from ±4.5 V to ±16 V (single-ended supplies of 9 V to 32 V). Use a power-supply accuracy of 5% or better. When operated on a board with high-speed digital signals, make sure to provide isolation between digital signal noise and the analog input pins. The THS4021 and THS4022 are connected to the positive power supply (V_{CC+}) through pin 7 and pin 8, respectively. Both devices use pin 4 for the negative power supply (V_{CC-}). Decouple each supply pin to GND as close to the device as possible.

7.3 Layout

7.3.1 Layout Guidelines

To achieve the levels of high-frequency performance of the THS402x, follow proper printed-circuit board (PCB), high-frequency design techniques. The following is a general set of guidelines. In addition, a THS402x evaluation board is available to use as a guide for layout or for evaluating the device performance.

- **Ground planes**—make sure that the ground plane used on the board provides all components with a low-inductive ground connection. However, in the areas of the amplifier inputs and output, the ground plane can be removed to minimize stray capacitance.
- **Proper power-supply decoupling**—use a 6.8-µF tantalum capacitor in parallel with a 0.1-µF ceramic capacitor on each supply pin. Sharing the tantalum capacitor among several amplifiers is possible depending on the application, but always use a 0.1-µF ceramic capacitor on the supply pin of every amplifier. In addition, place the 0.1-µF capacitor as close as possible to the supply pin. As this distance increases, the inductance in the connecting trace makes the capacitor less effective. Strive for distances of less than 0.1 inch (2.54 mm) between the device power pins and the ceramic capacitors.
- **Short trace runs or compact part placements**—optimum high-frequency performance is achieved when stray series inductance has been minimized. To realize this, make the circuit layout as compact as possible, thereby minimizing the length of all trace runs. Pay particular attention to the inputs of the amplifier, keeping the trace lengths as short as possible. This layout helps to minimize stray capacitance at the input of the amplifier.

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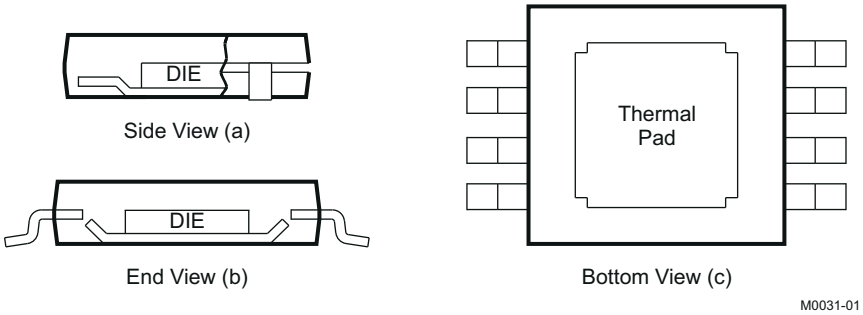
7.3.1.1 General PowerPAD™ Integrated Circuit Package Design Considerations

The THS402x is available in a thermally-enhanced DGN package, which is a member of the PowerPAD™ integrated circuit package family. Figure 7-3 **a** and Figure 7-3 **b** show that this package is constructed using a downset leadframe upon which the die is mounted. Figure 7-3 **c** that this arrangement results in the leadframe being exposed as a thermal pad on the underside of the package. Because this thermal pad has direct thermal contact with the die, excellent thermal performance can be achieved by providing a good thermal path away from the thermal pad.

The PowerPAD integrated circuit package allows for both assembly and thermal management in one manufacturing operation. During the surface-mount solder operation (when the leads are being soldered), the thermal pad can also be soldered to a copper area underneath the package. Through the use of thermal paths within this copper area, heat can be conducted away from the package into either a ground plane or other heat dissipating device.

The PowerPAD integrated circuit package represents a breakthrough in combining the small area and ease of assembly of the surface mount with the previously awkward mechanical methods of heat sinking.

More complete details of the PowerPAD installation process and thermal management techniques are found in *PowerPAD Thermally-Enhanced Package*. This document is found on the TI website (www.ti.com) by searching on the keyword PowerPAD. The document can also be ordered through your local TI sales office; refer to SLMA002 when ordering.



NOTE: The thermal pad (PowerPAD integrated circuit package) is electrically isolated from all other pins and can be connected to any potential from V_{CC-} to V_{CC+}. Typically, the thermal pad is connected to the ground plane because this plane tends to physically be the largest and is able to dissipate the most amount of heat.

Figure 7-3. Views of Thermally-enhanced DGN Package

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7.3.2 Layout Example

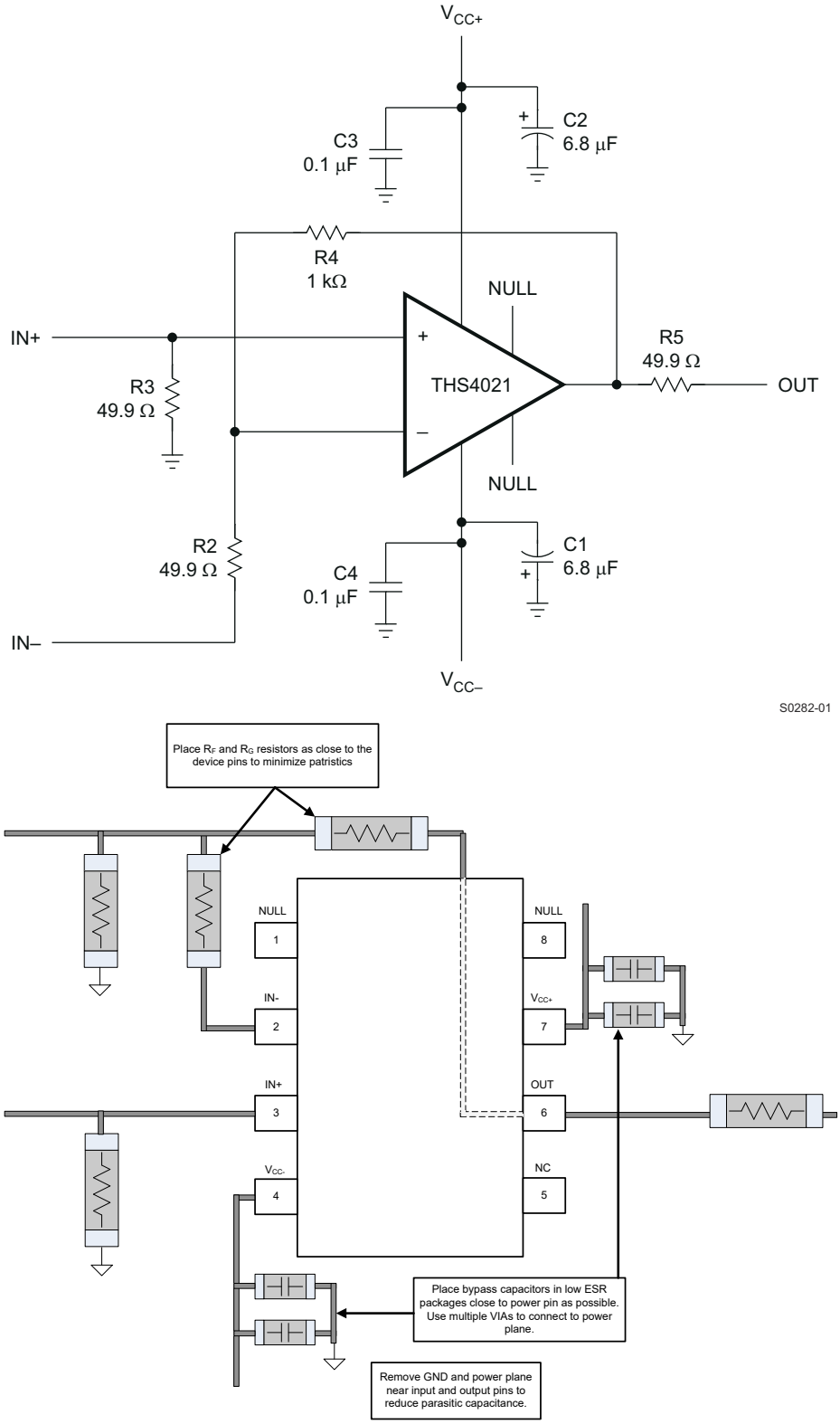

Figure 7-4. Layout Recommendations

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8 Device and Documentation Support

TI offers an extensive line of development tools. Tools and software to evaluate the performance of the device, generate code, and develop solutions are listed below.

8.1 Documentation Support

8.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *Noise Analysis in Operational Amplifier Circuits* application report
- Texas Instruments, *PowerPAD Thermally Enhanced Package* application report
- Texas Instruments, *THS4021 High-Speed Operational Amplifier Evaluation Module* user's guide
- Texas Instruments, *THS4022 Dual High-Speed Operational Amplifier Evaluation Module* user's guide

8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* 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.

8.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is 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.

8.4 Trademarks

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8.5 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.

8.6 Glossary

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

9 Revision History

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

Changes from Revision E (March 2024) to Revision F (July 2024)	Page
• Deleted Total harmonic distortion + noise and Intermodulation distortion specifications from *Electrical Characteristics: THS4021D and THS4022DGN*	6

Changes from Revision D (May 2023) to Revision E (March 2024)	Page
• Deleted THS4022 D package from the document	1
• Updated *Simplified Application* figure to show correct pin names	1
• Updated closed-loop bandwidth and supply current in *Description*	1
• Updated *Thermal Information: THS4022*	5

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- Changed title of *Electrical Characteristics: THS4021 (D Package)* to *Electrical Characteristics: THS4021D and THS4022DGN* 6
- Changed Channel-to-channel crosstalk from –60 dB to –54 dB in *Electrical Characteristics THS4021D and THS4022DGN*B 6
- Changed title of *Electrical Characteristics: THS4021 (DGN Package) and THS4022 (D and DGN Packages)* to *Electrical Characteristics: THS4021DGN* 8
- Changed title of *Typical Characteristics: THS4021 (D Package)* to *Typical Characteristics: THS4021D and THS4022DGN* 10
- Changed V_{CC} from ±5 V to ±15 V in *Typical Characteristics: THS4021D and THS4022DGN* 10
- Updated *Power-Supply Rejection Ratio vs Frequency* figure legend in *Typical Characteristics: THS4021D and THS4022DGN* 10
- Changed title of *Typical Characteristics:THS4021 (DGN Package) and THS4022 (D and DGN Packages)* to Typical Characteristics:THS4021DGN 16
- Updated *Crosstalk vs Frequency* figure and moved to *Typical Characteristics: THS4021D and THS4022DGN* 16

10 Mechanical, Packaging, and Orderable Information

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

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PACKAGING INFORMATION

Orderable 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)
THS4021CD	Obsolete	Production	SOIC (D) | 8	-	-	Call TI	Call TI	0 to 70	4021C
THS4021CDGN	Active	Production	HVSSOP (DGN) | 8	80 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	ACK
THS4021CDGN.A	Active	Production	HVSSOP (DGN) | 8	80 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	ACK
THS4021CDGNR	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	ACK
THS4021CDGNR.A	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	ACK
THS4021ID	Active	Production	SOIC (D) | 8	-	-	Call TI	Call TI	-40 to 85	4021I
THS4021IDGN	Active	Production	HVSSOP (DGN) | 8	80 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	ACL
THS4021IDGN.A	Active	Production	HVSSOP (DGN) | 8	80 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	ACL
THS4021IDGNR	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	ACL
THS4021IDGNR.A	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	ACL
THS4021IDR	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	4021I
THS4021IDR.B	Active	Production	SOIC (D) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	4021I
THS4022CD	Active	Production	SOIC (D) | 8	75 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	4022C
THS4022CD.A	Active	Production	SOIC (D) | 8	75 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	0 to 70	4022C
THS4022CDGN	Obsolete	Production	HVSSOP (DGN) | 8	-	-	Call TI	Call TI	0 to 70	ACA
THS4022CDGNR	Obsolete	Production	HVSSOP (DGN) | 8	-	-	Call TI	Call TI	0 to 70	ACA
THS4022ID	Active	Production	SOIC (D) | 8	75 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	4022I
THS4022ID.A	Active	Production	SOIC (D) | 8	75 | TUBE	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	4022I
THS4022IDGN	Obsolete	Production	HVSSOP (DGN) | 8	-	-	Call TI	Call TI	-40 to 85	ACB
THS4022IDGNR	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ACB
THS4022IDGNR.B	Active	Production	HVSSOP (DGN) | 8	2500 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	ACB

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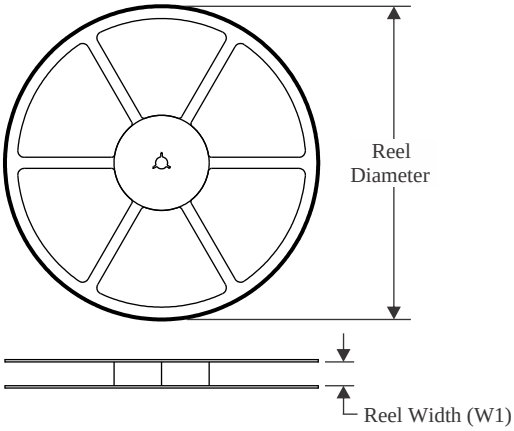
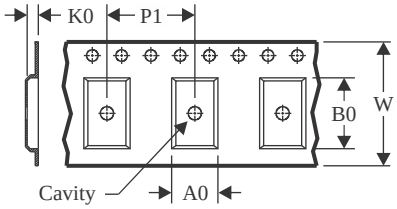
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

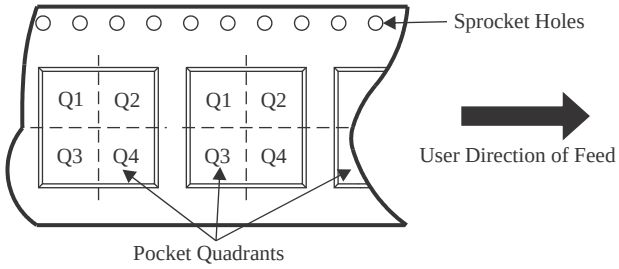


TAPE DIMENSIONS



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

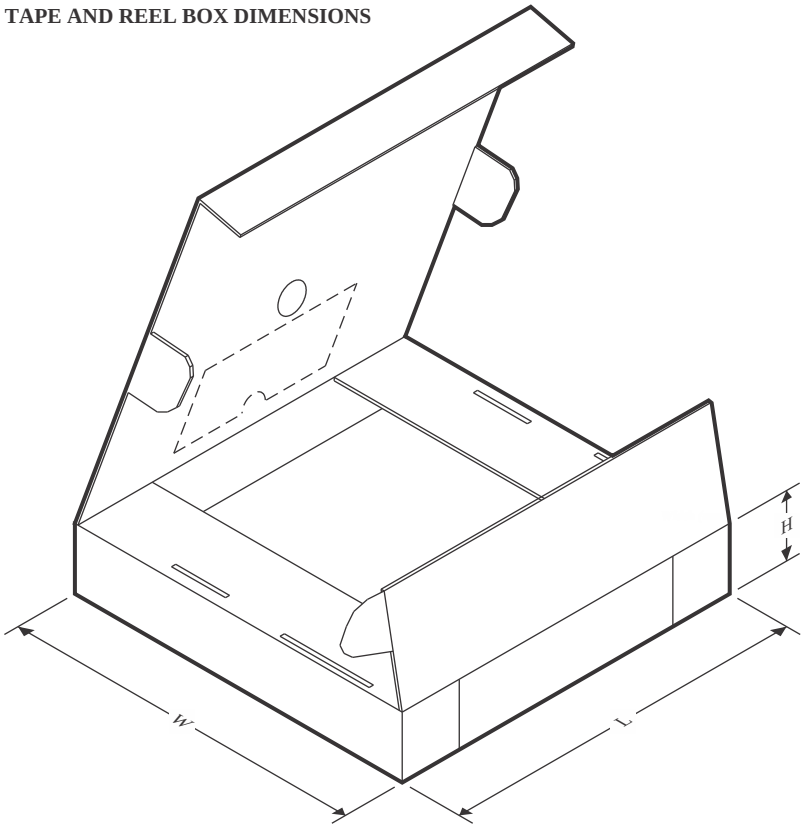
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
THS4021CDGNR	HVSSOP	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
THS4021IDGNR	HVSSOP	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
THS4021IDR	SOIC	D	8	2500	330.0	12.4	6.4	5.2	2.1	8.0	12.0	Q1
THS4022IDGNR	HVSSOP	DGN	8	2500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1

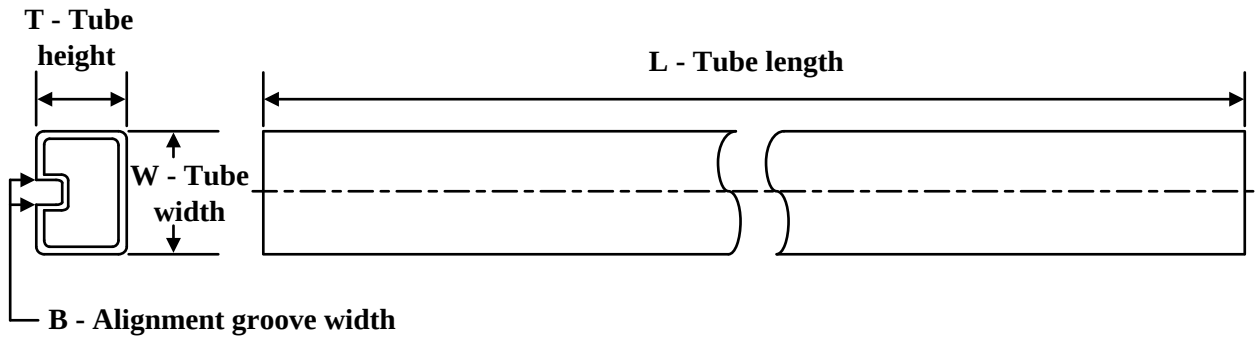
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
THS4021CDGNR	HVSSOP	DGN	8	2500	358.0	335.0	35.0
THS4021IDGNR	HVSSOP	DGN	8	2500	358.0	335.0	35.0
THS4021IDR	SOIC	D	8	2500	353.0	353.0	32.0
THS4022IDGNR	HVSSOP	DGN	8	2500	353.0	353.0	32.0

TUBE



*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (µm)	B (mm)
THS4021CDGN	DGN	HVSSOP	8	80	274	6.2	2540	2.5
THS4021CDGN.A	DGN	HVSSOP	8	80	274	6.2	2540	2.5
THS4021IDGN	DGN	HVSSOP	8	80	274	6.2	2540	2.5
THS4021IDGN.A	DGN	HVSSOP	8	80	274	6.2	2540	2.5
THS4022CD	D	SOIC	8	75	505.46	6.76	3810	4
THS4022CD.A	D	SOIC	8	75	505.46	6.76	3810	4
THS4022ID	D	SOIC	8	75	505.46	6.76	3810	4
THS4022ID.A	D	SOIC	8	75	505.46	6.76	3810	4

GENERIC PACKAGE VIEW

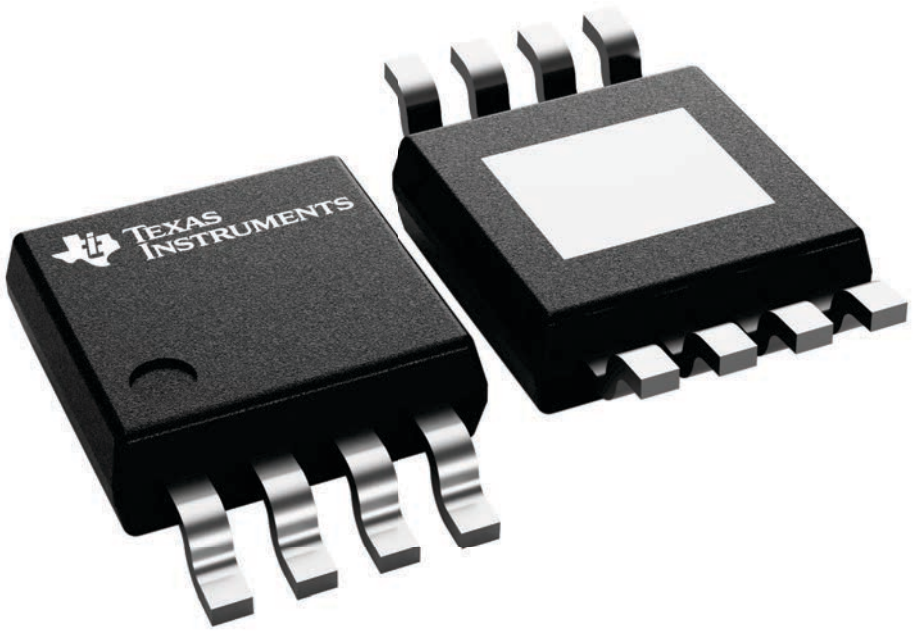
DGN 8

PowerPAD™ HVSSOP - 1.1 mm max height

3 x 3, 0.65 mm pitch

SMALL OUTLINE PACKAGE

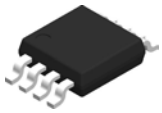
This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4225482/B

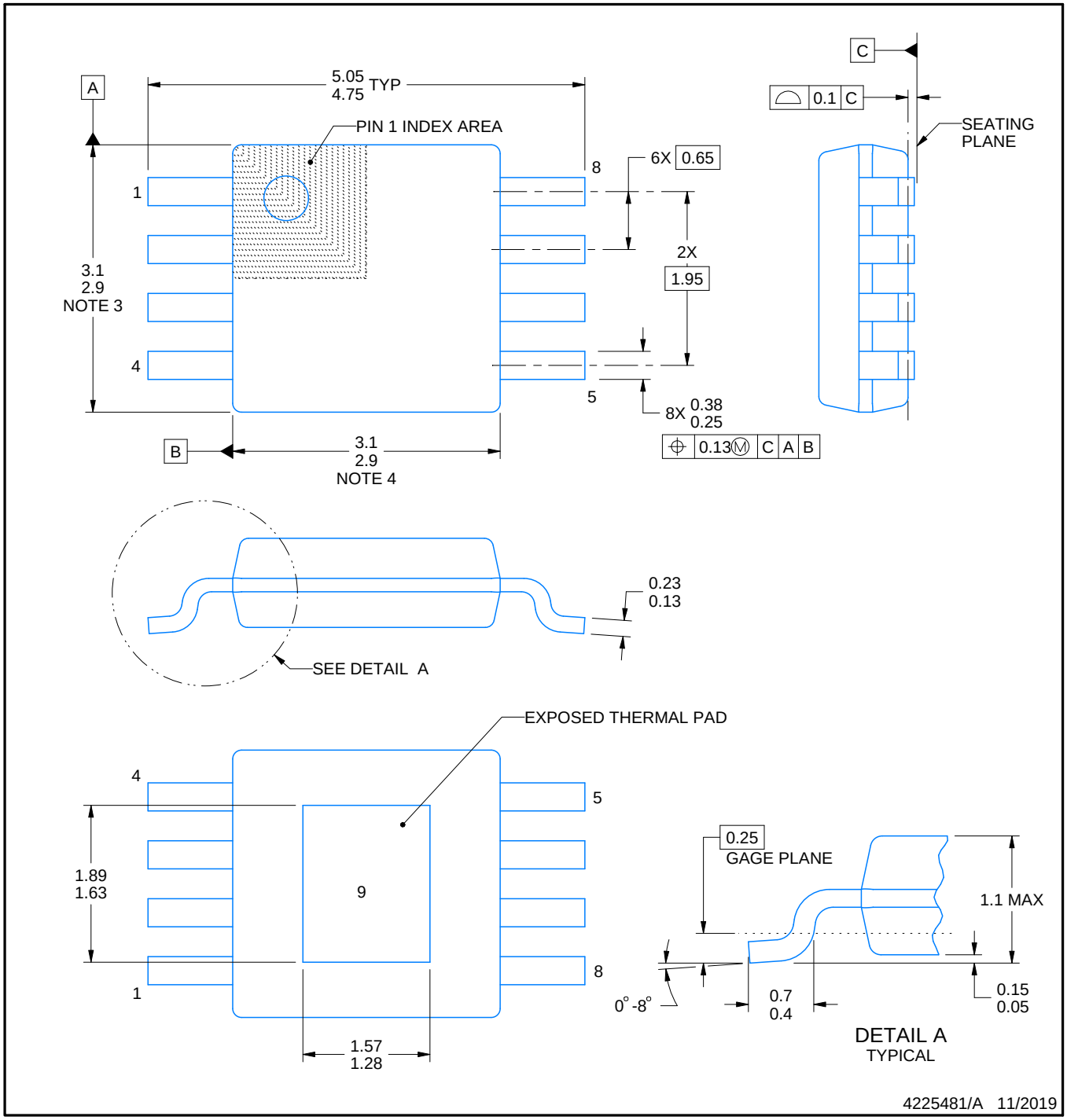
PACKAGE OUTLINE

DGN0008D



PowerPAD™ VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE



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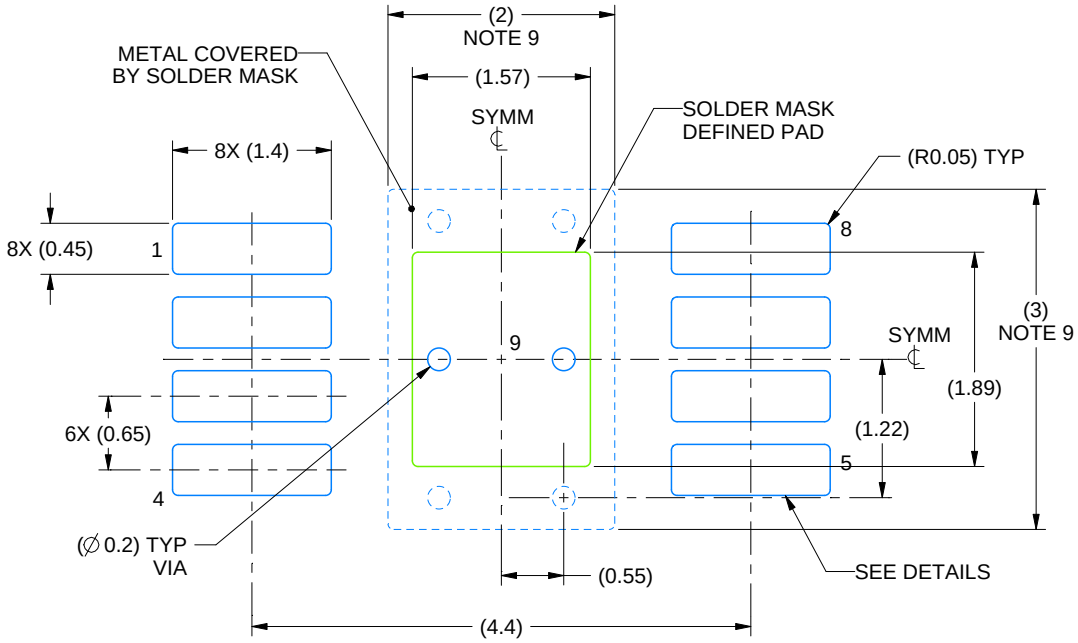
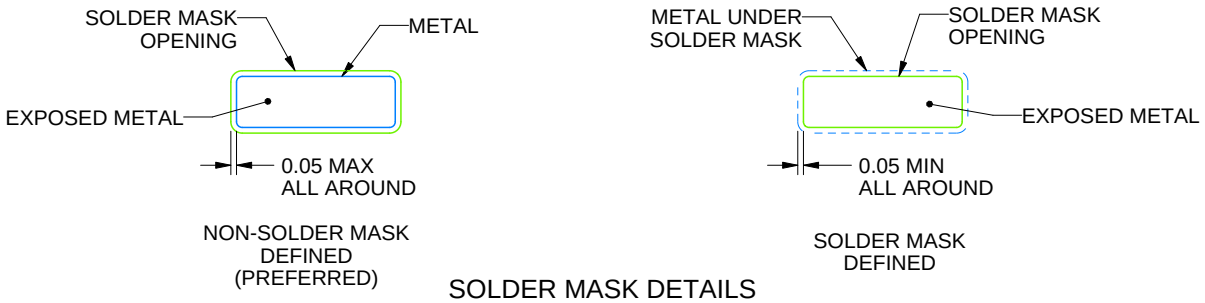
NOTES:

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-187.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

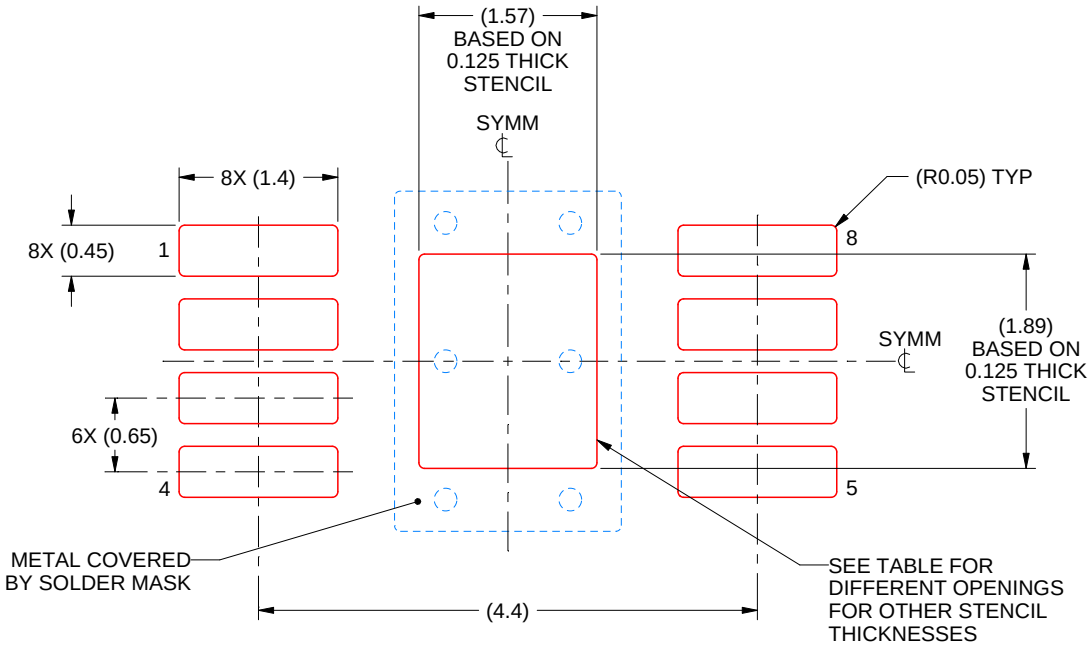


SOLDER MASK DETAILS

4225481/A 11/2019

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.
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.



SOLDER PASTE EXAMPLE
EXPOSED PAD 9:
100% PRINTED SOLDER COVERAGE BY AREA
SCALE: 15X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	1.76 X 2.11
0.125	1.57 X 1.89 (SHOWN)
0.15	1.43 X 1.73
0.175	1.33 X 1.60

4225481/A 11/2019

NOTES: (continued)

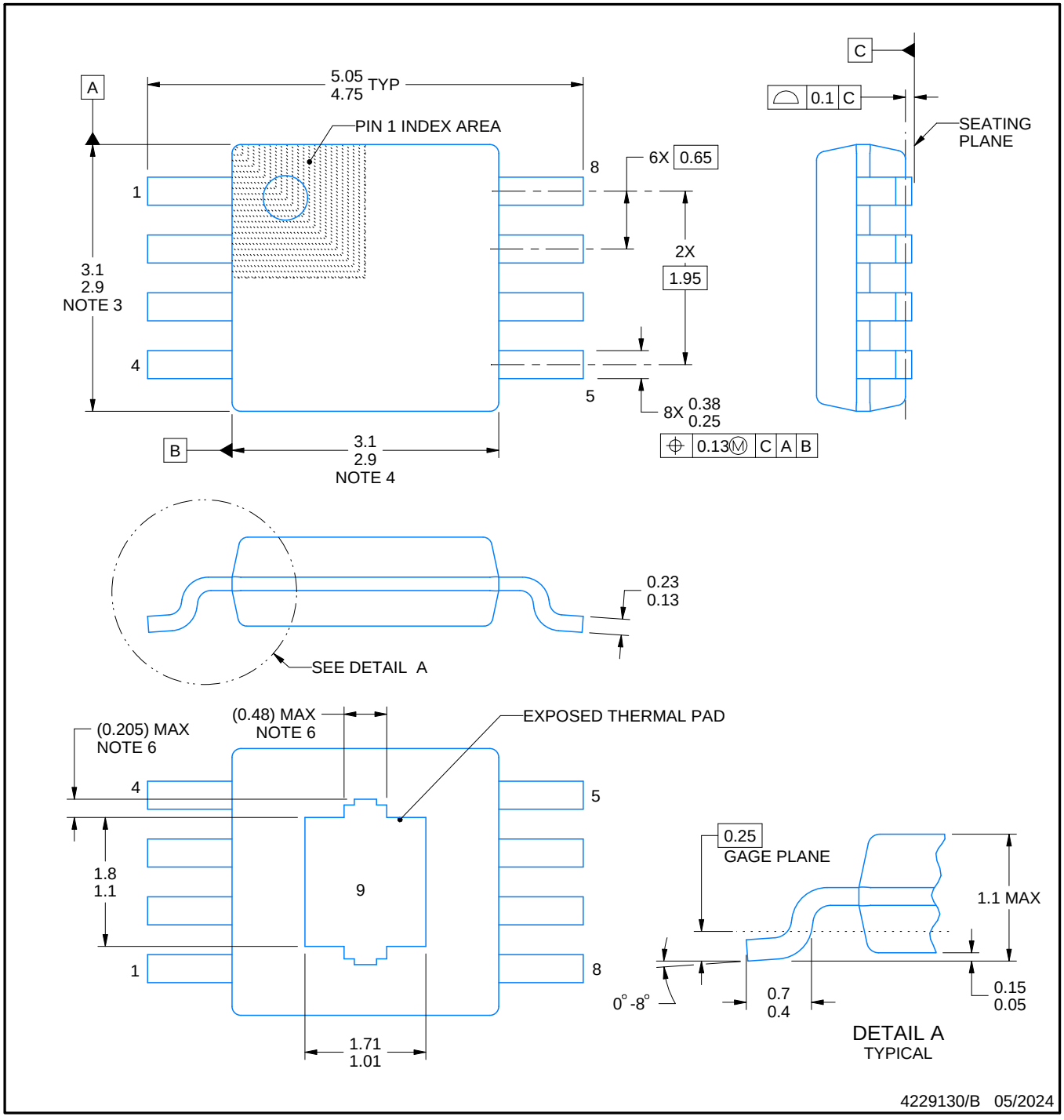
10. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
11. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DGN0008H

PowerPAD™ VSSOP - 1.1 mm max height

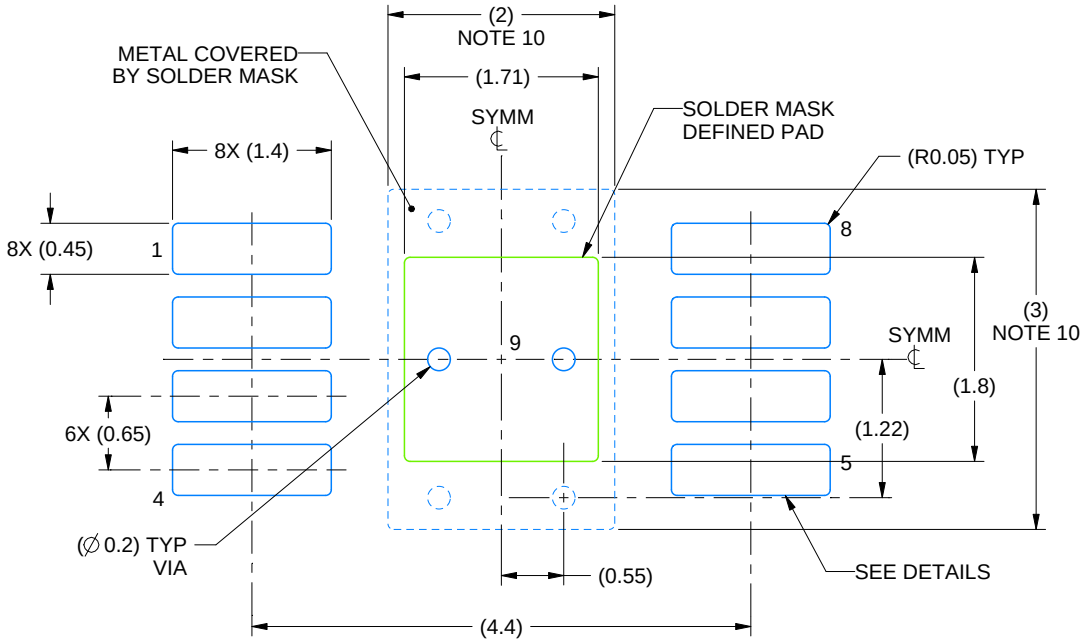
SMALL OUTLINE PACKAGE



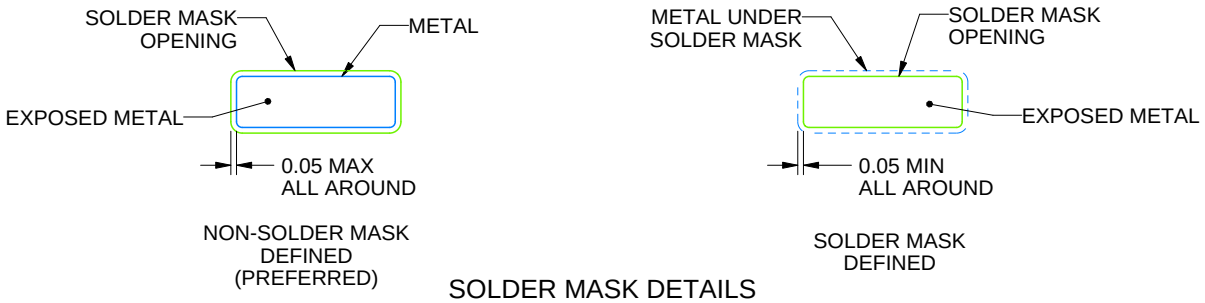
PowerPAD is a trademark of Texas Instruments.

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-187.
6. Features may differ or may not be present.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

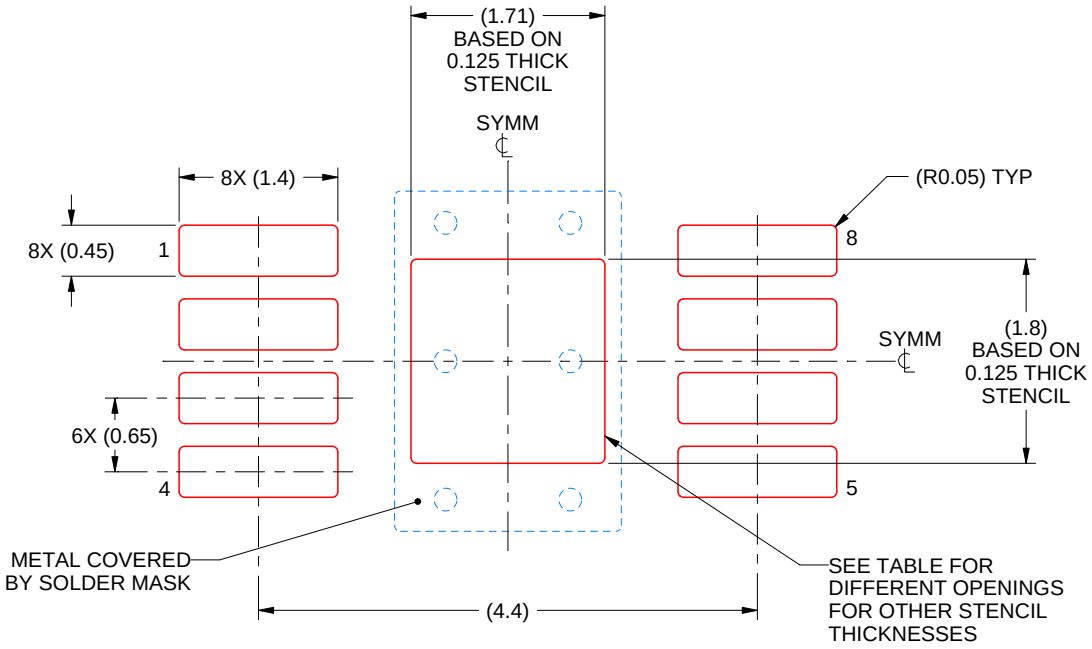


SOLDER MASK DETAILS

4229130/B 05/2024

NOTES: (continued)

7. Publication IPC-7351 may have alternate designs.
8. Solder mask tolerances between and around signal pads can vary based on board fabrication site.
9. 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.
10. Size of metal pad may vary due to creepage requirement.



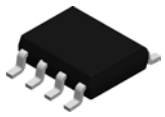
SOLDER PASTE EXAMPLE
EXPOSED PAD 9:
100% PRINTED SOLDER COVERAGE BY AREA
SCALE: 15X

STENCIL THICKNESS	SOLDER STENCIL OPENING
0.1	1.91 X 2.01
0.125	1.71 X 1.80 (SHOWN)
0.15	1.56 X 1.64
0.175	1.45 X 1.52

4229130/B 05/2024

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.

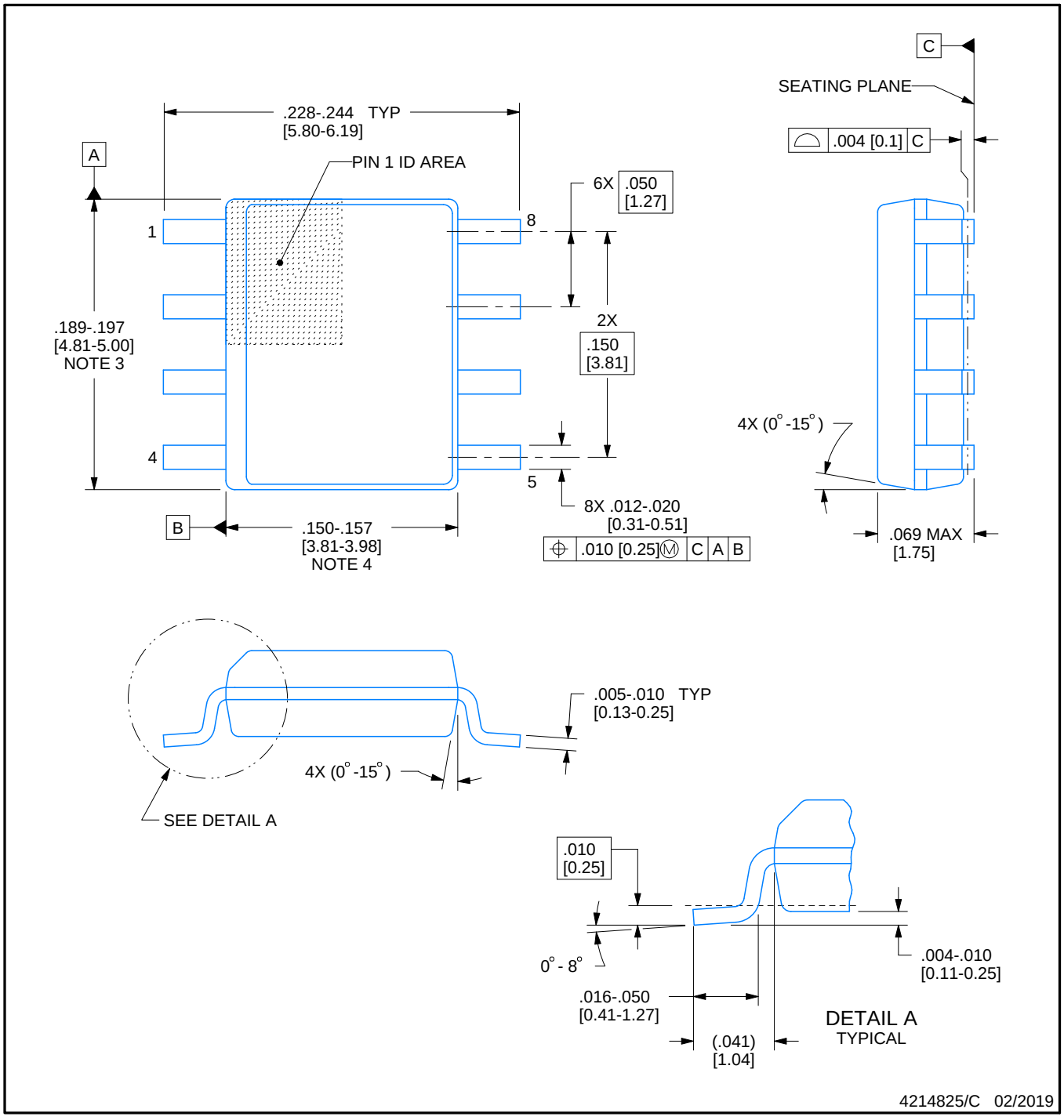


PACKAGE OUTLINE

D0008A

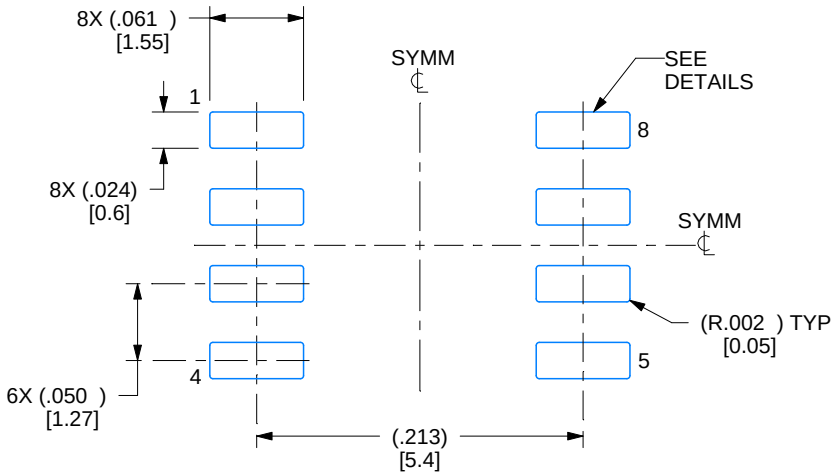
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

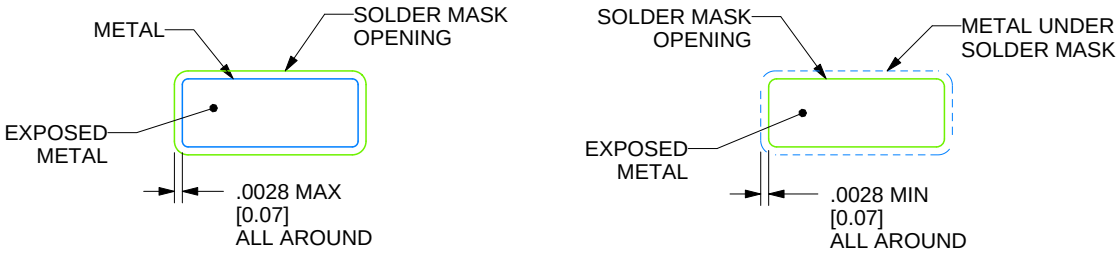


NOTES:

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)

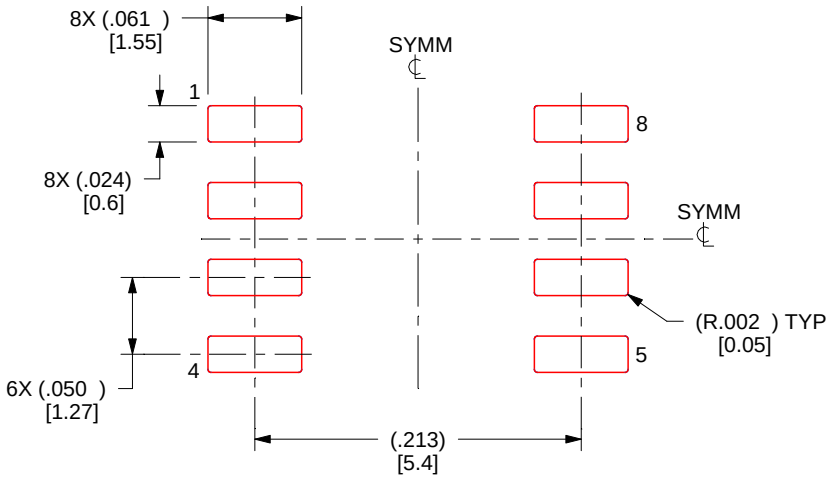
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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.

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