THS402x 2GHz、10V/V 稳定增益、低噪声高速放大器

1 特性

- 超低 1.2nV/√Hz 电压噪声
- 高速：
  - 2GHz 增益带宽积
  - 470V/μs 压摆率
  - 30ns 稳定时间 (0.1%)
- 在增益 ≥10V/V 时保持稳定
- 输出驱动，I_O = 200mA（典型值）
- 极低失真：
  - THD = -68dBc（f = 1MHz，R_L = 150Ω）
- 宽电压范围的电源：
  - V_{CC} = ±4.5V 至 ±16V
- THS4021 上的失调电压归零引脚

2 应用

- 超声波扫描仪
- 源测量单元 (SMU)
- 电源品质测定器

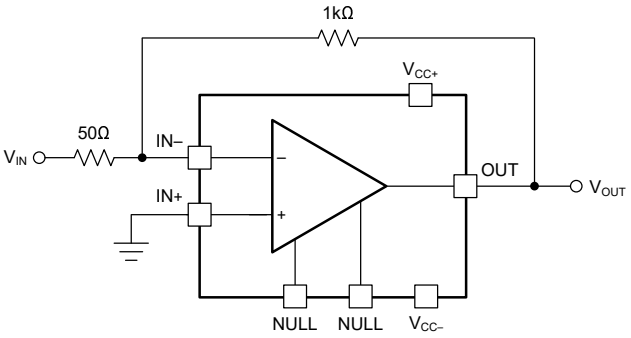
3 说明

THS4021 和 THS4022 (THS402x) 是超低电压噪声、高速电压反馈放大器，非常适合需要低电压噪声的应用（包括通信和成像）。单通道放大器 THS4021 和双通道放大器 THS4022 可提供卓越的交流性能，闭环带宽为 290MHz，压摆率为 470V/μs，稳定时间为 30ns (0.1%)，增益为 10V/V。THS402x 在增益为 10V/V 或更高以及 –9V/V 或更低时保持稳定。这些放大器具有 200mA 的高驱动能力，每个放大器只消耗 7.5mA 的电源电流。THS402x 在 f = 1MHz 时总谐波失真 (THD) 为 –68dBc，专为需要低失真的应用而设计。

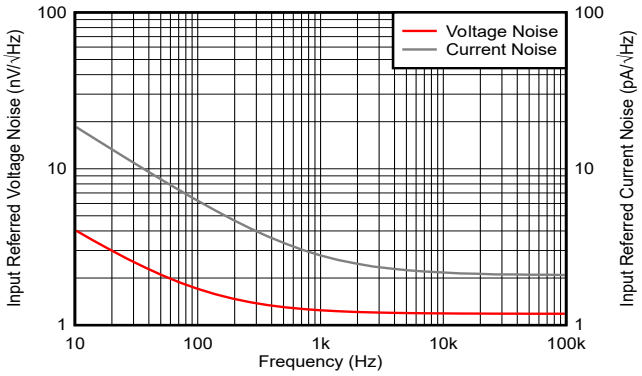
器件信息

器件型号	放大器	封装(1)
THS4021	一个	D（SOIC，8）
		DGN（HVSSOP，8）
THS4022	两个	DGN（HVSSOP，8）

(1) 有关更多信息，请参阅节 10。



简化版应用



电压噪声和电流噪声与频率间的关系

本资源的原文使用英文撰写。 为方便起见，TI 提供了译文；由于翻译过程中可能使用了自动化工具，TI 不保证译文的准确性。 为确认准确性，请务必访问 ti.com 参考最新的英文版本（控制文档）。

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4 Pin Configuration and Functions

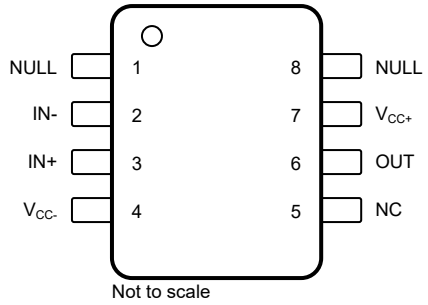


图 4-1. THS4021: D Package, 8-Pin SOIC, or DGN Package, 8-pin HVSSOP (Top View)

表 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

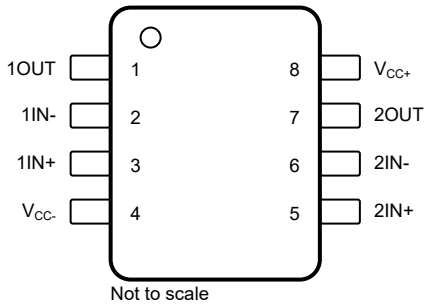


图 4-2. THS4022: DGN Package, 8-pin HVSSOP (Top View)

表 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			±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（续）

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 节 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（续）

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

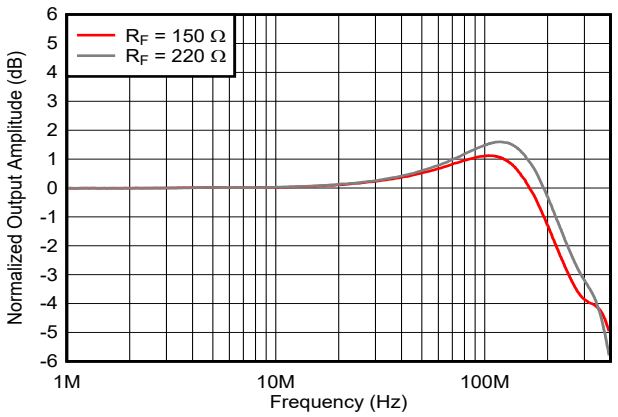
PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS							
V_{ICR}	Common-mode input voltage	V_{CC} = ±15 V		±13.8	±14.3		V
		V_{CC} = ±5 V		±3.8	±4.3		
CMRR	Common-mode rejection ratio	V_{CC} = ±15 V, V_{ICR} = ±12 V, T_A = full range		74	95		dB
r_i	Input resistance				1		MΩ
C_i	Input 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 / 2 π $V_{O(Peak)}$.
(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 节 5.1.

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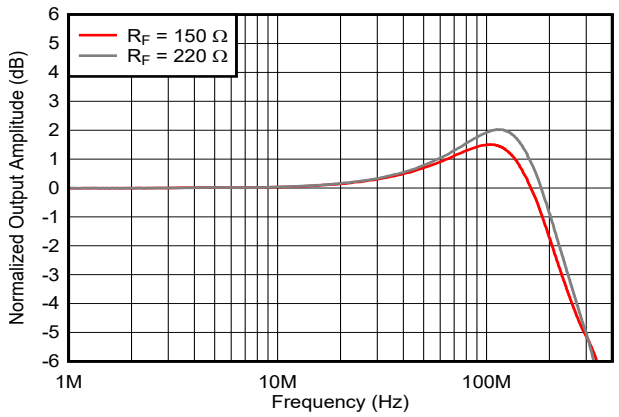
5.8 Typical Characteristics: THS4021D and THS4022DGN

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)



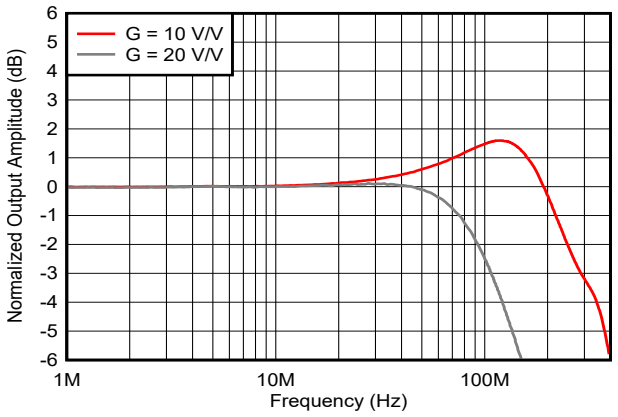
V_{CC} = ±15 V, V_{OUT} = 100 mV_{PP}

图 5-1. Frequency Response vs Feedback Resistance



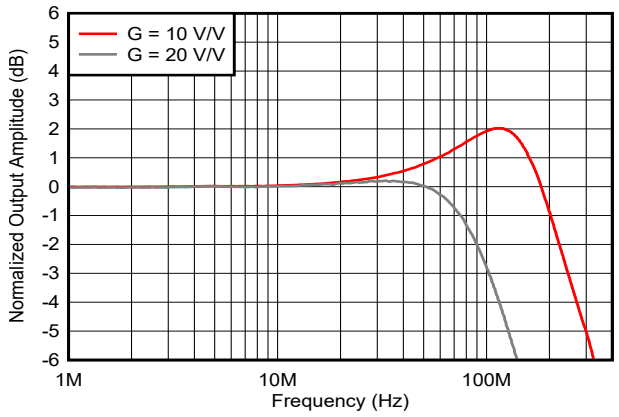
V_{CC} = ±5 V, V_{OUT} = 100 mV_{PP}

图 5-2. Frequency Response vs Feedback Resistance



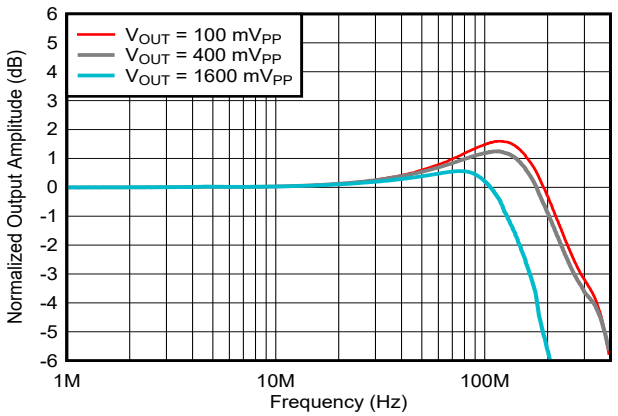
V_{CC} = ±15 V, V_{OUT} = 100 mV_{PP}

图 5-3. Frequency Response vs Gain



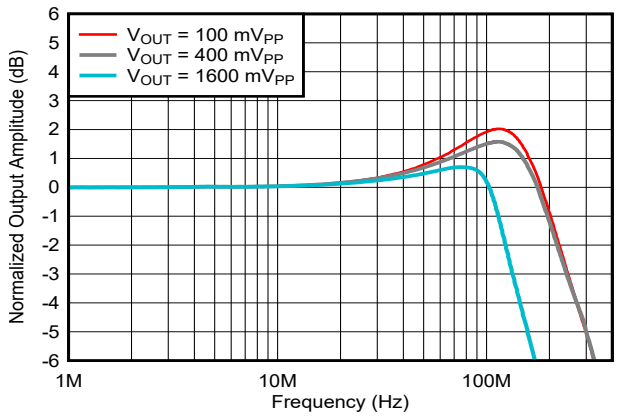
V_{CC} = ±5 V, V_{OUT} = 100 mV_{PP}

图 5-4. Frequency Response vs Gain



V_{CC} = ±15 V

图 5-5. Large-Signal Frequency Response



V_{CC} = ±5 V

图 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)

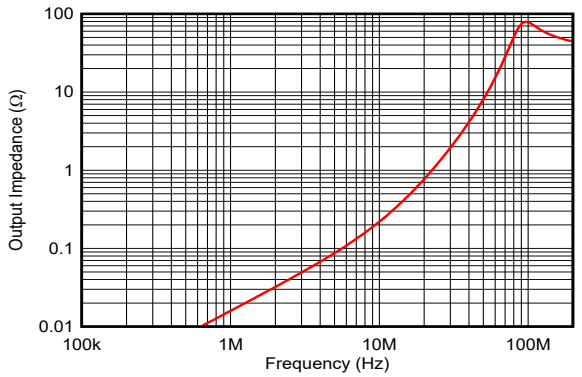


图 5-7. Closed-Loop Output Impedance

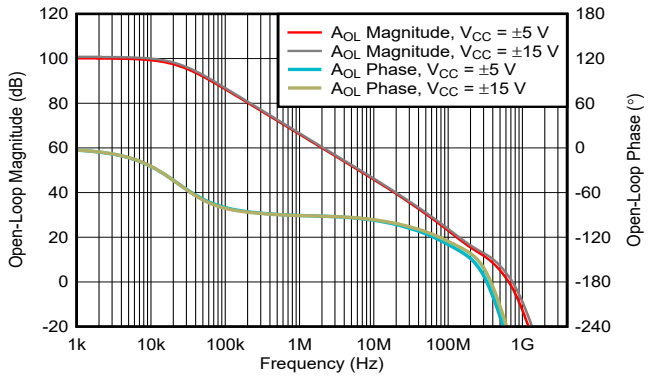


图 5-8. Open-loop Gain and Phase Response

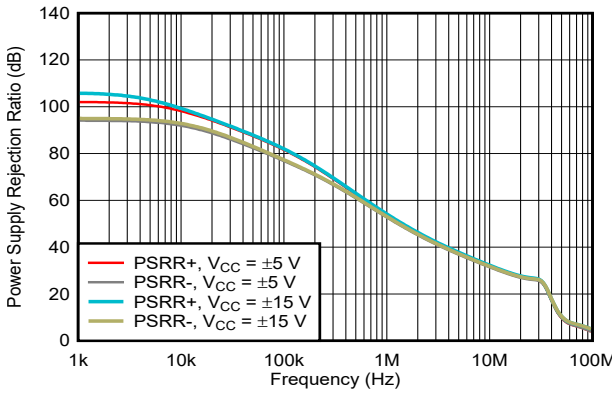


图 5-9. Power-Supply Rejection Ratio vs Frequency

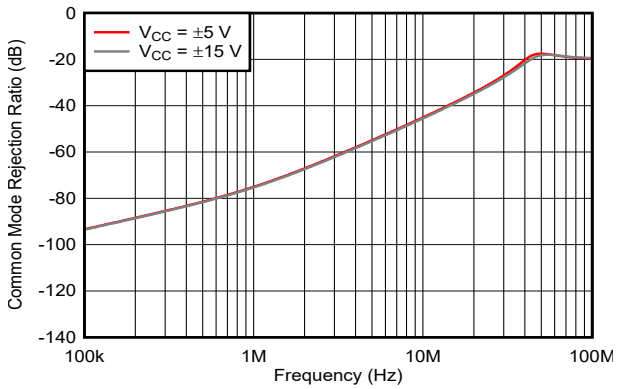
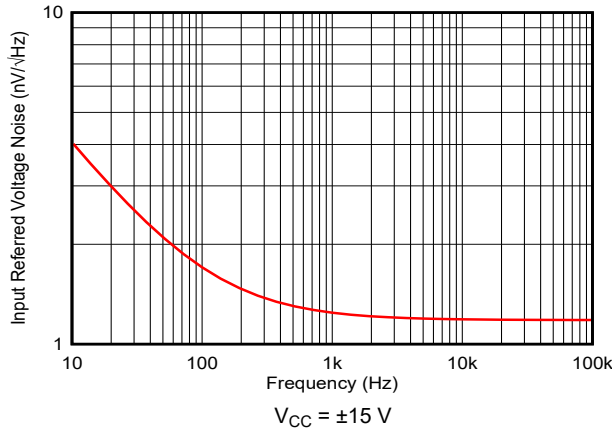
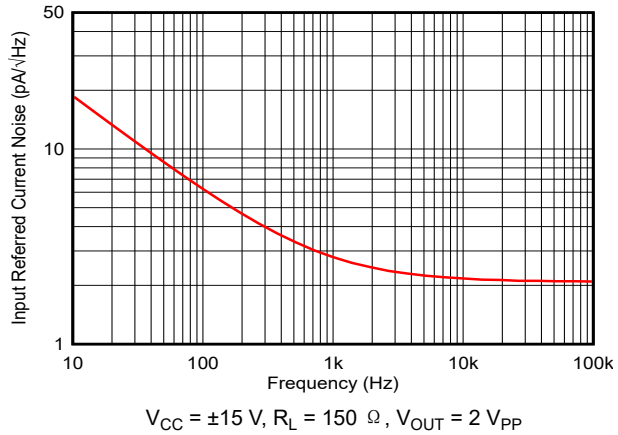


图 5-10. Common-Mode Rejection Ratio vs Frequency



V_{CC} = ±15 V

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



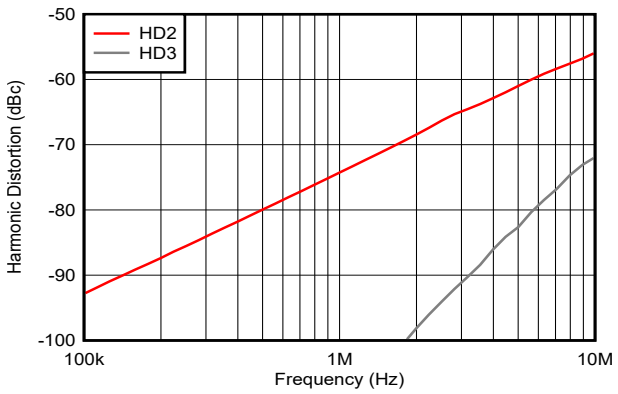
V_{CC} = ±15 V, R_L = 150 Ω, V_{OUT} = 2 V_{PP}

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

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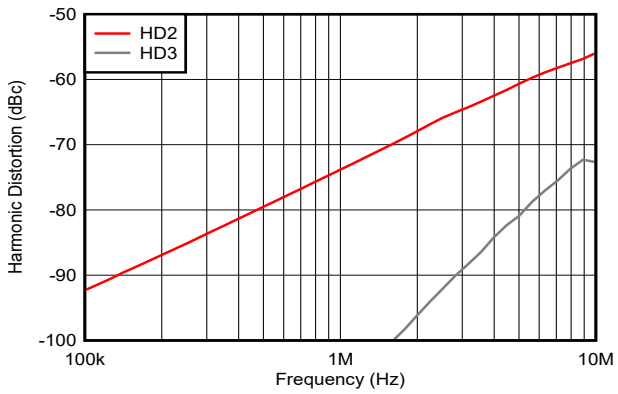
5.8 Typical Characteristics: THS4021D and THS4022DGN (continued)

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)



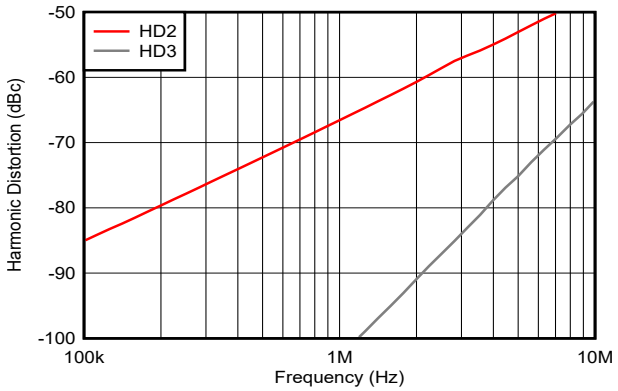
V_{CC} = ±15 V, R_L = 1 kΩ, V_{OUT} = 2 V_{PP}

图 5-13. Harmonic Distortion vs Frequency



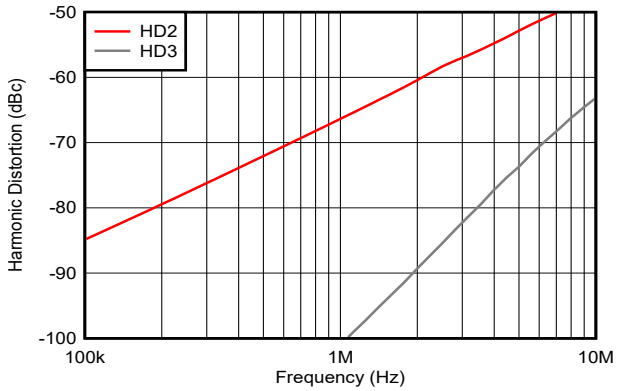
V_{CC} = ±5 V, R_L = 1 kΩ, V_{OUT} = 2 V_{PP}

图 5-14. Harmonic Distortion vs Frequency



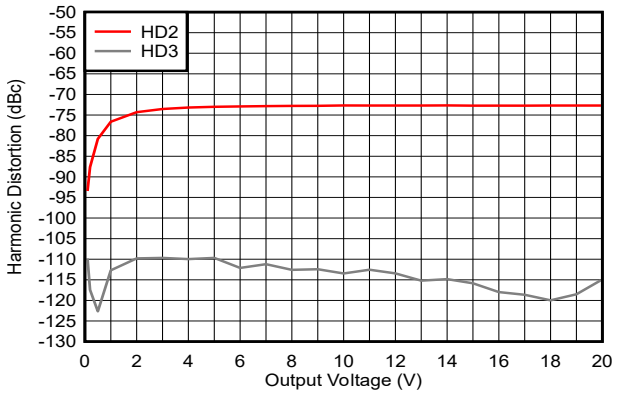
V_{CC} = ±15 V, R_L = 150 Ω, V_{OUT} = 2 V_{PP}

图 5-15. Harmonic Distortion vs Frequency



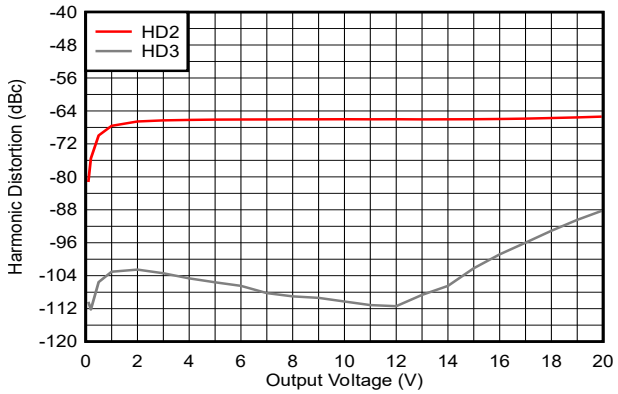
V_{CC} = ±5 V, R_L = 150 Ω, V_{OUT} = 2 V_{PP}

图 5-16. Harmonic Distortion vs Frequency



V_{CC} = ±15 V, R_L = 1 kΩ, f = 1 MHz

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



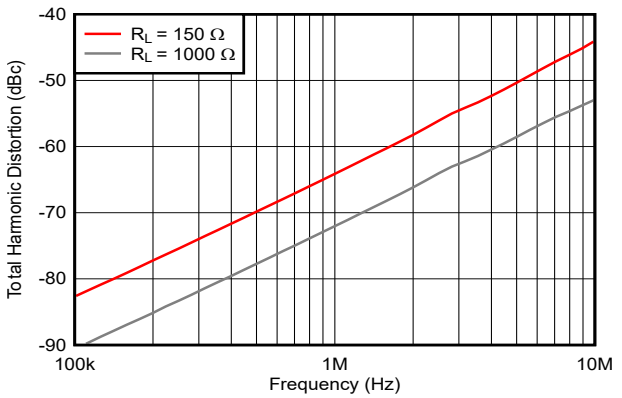
V_{CC} = ±15 V, R_L = 150 Ω, f = 1 MHz

图 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}

图 5-19. Total Harmonic Distortion vs Frequency

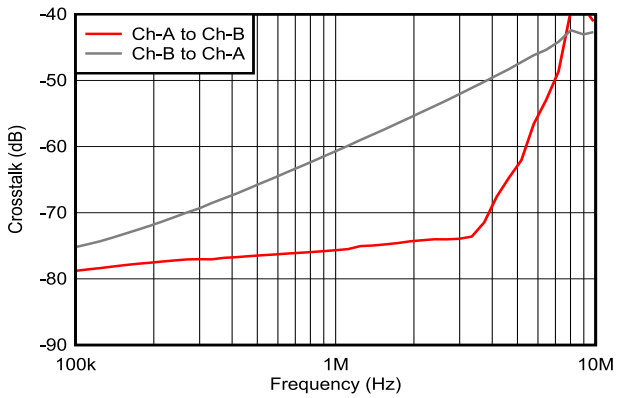


图 5-20. Crosstalk vs Frequency

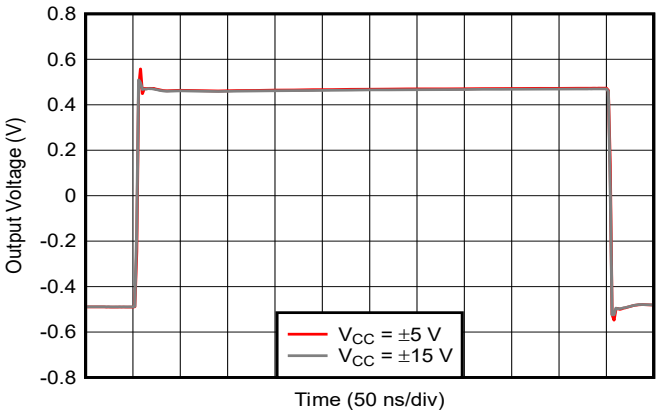
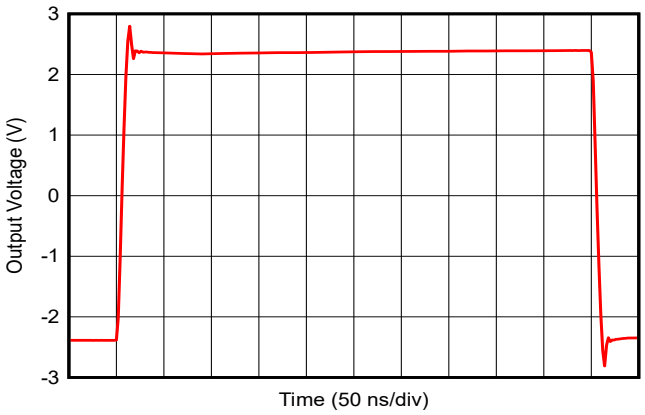
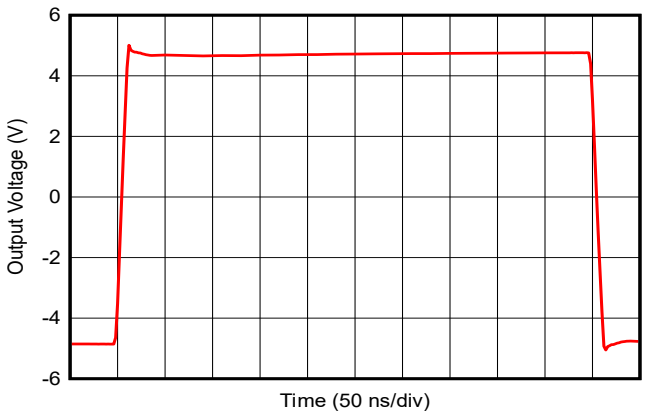


图 5-21. 1-V Step Response



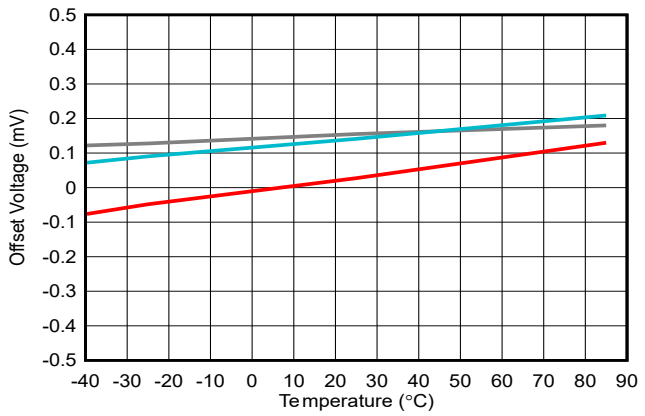
V_{CC} = ±5 V

图 5-22. 5-V Step Response



V_{CC} = ±15 V

图 5-23. 10-V Step Response



3 typical units

图 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)

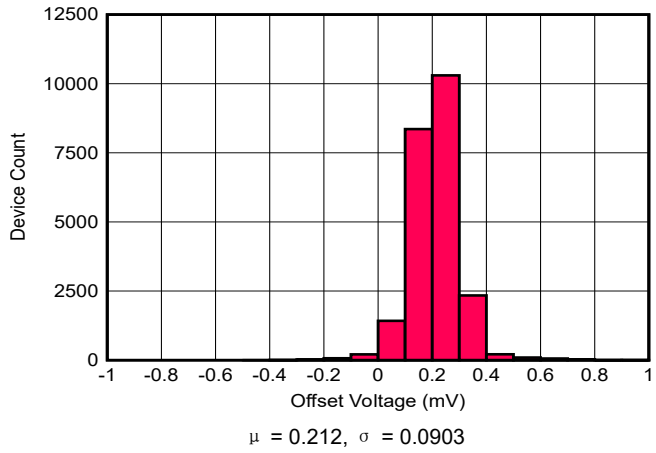


图 5-25. Voltage Offset Distribution

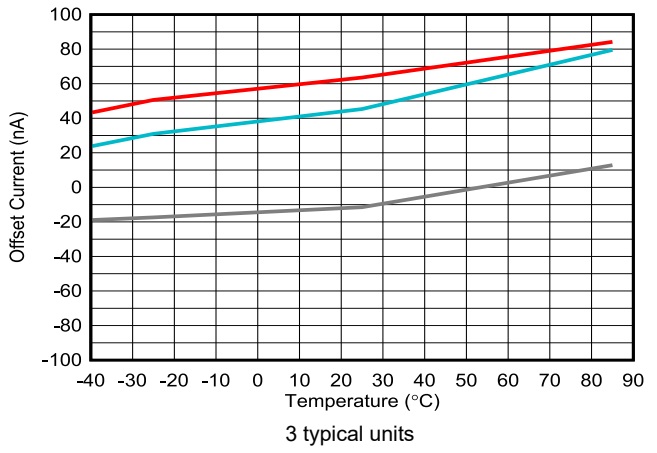


图 5-26. Input Offset Current vs Ambient Temperature

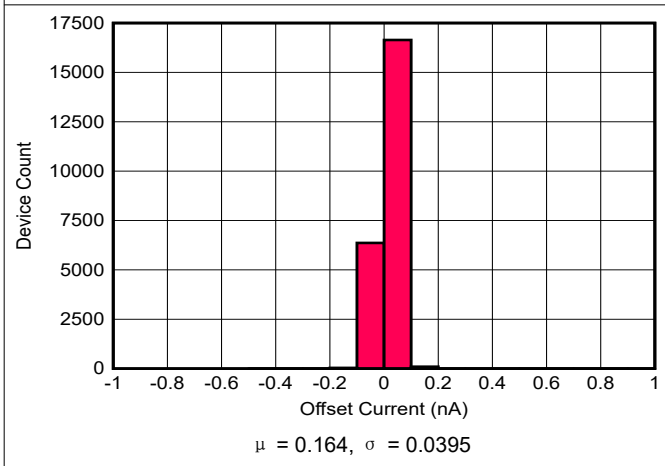


图 5-27. Input Offset Current vs Ambient Temperature

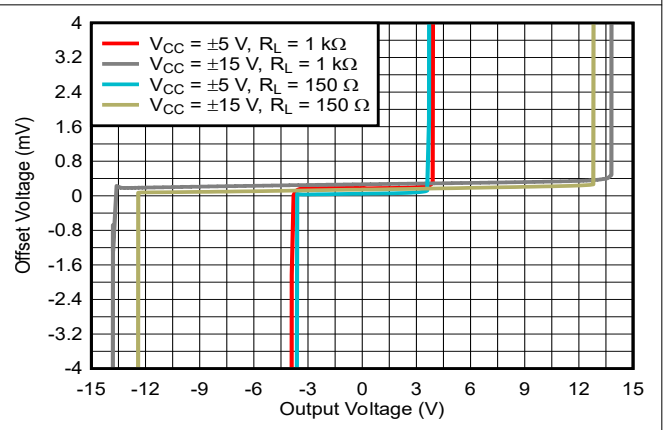


图 5-28. Offset Voltage vs Output Voltage

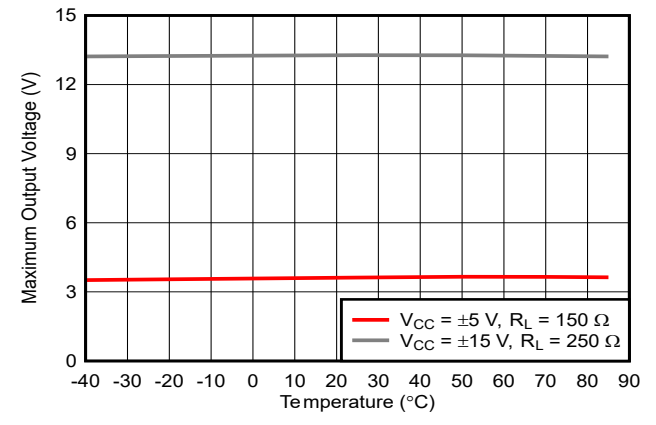


图 5-29. Maximum Output Voltage Swing vs Ambient Temperature

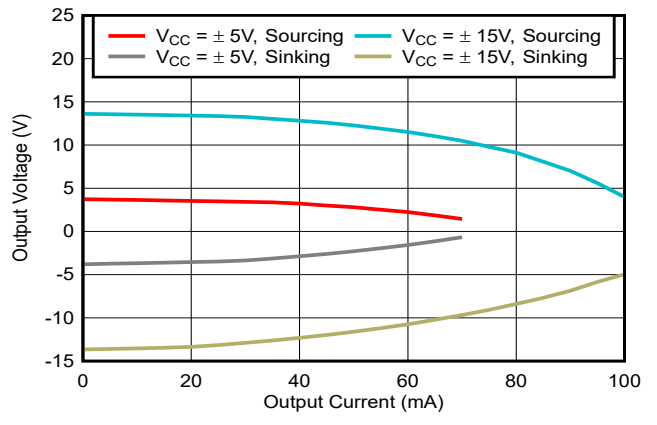


图 5-30. Output Swing vs Load Current

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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)

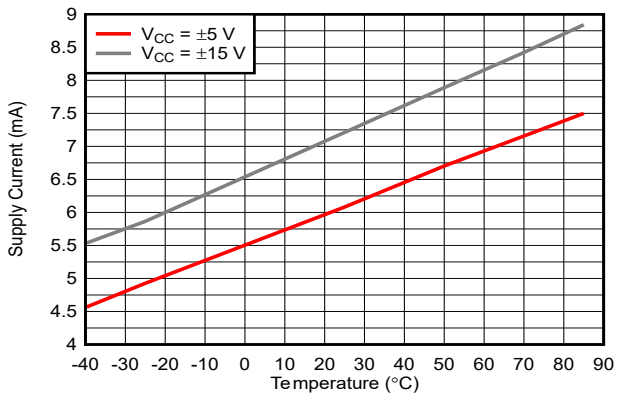


图 5-31. Supply Current vs Ambient Temperature

5.9 Typical Characteristics: THS4021DGN

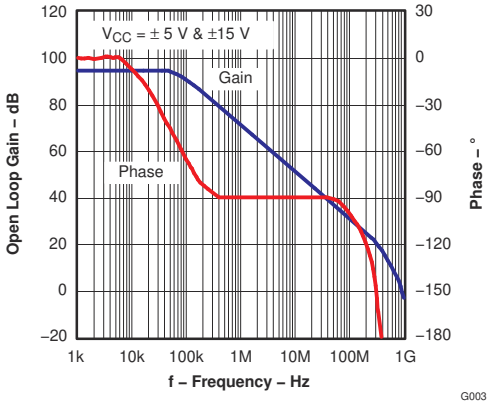


图 5-32. Open Loop Gain and Phase Response vs Frequency

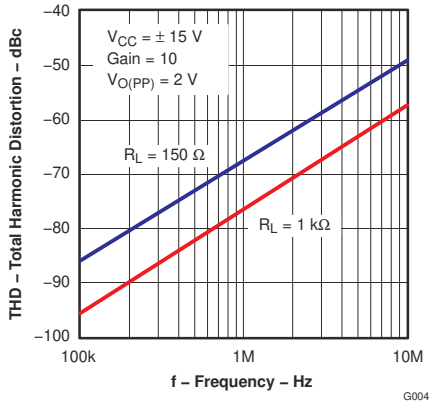


图 5-33. Total Harmonic Distortion vs Frequency

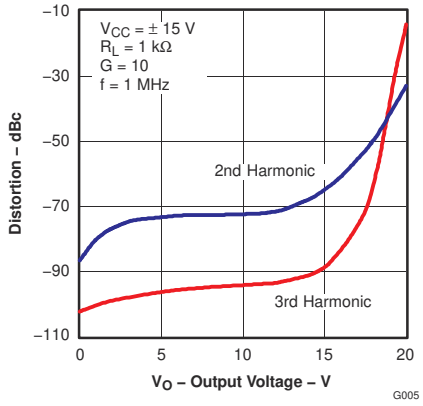


图 5-34. Distortion vs Output Voltage

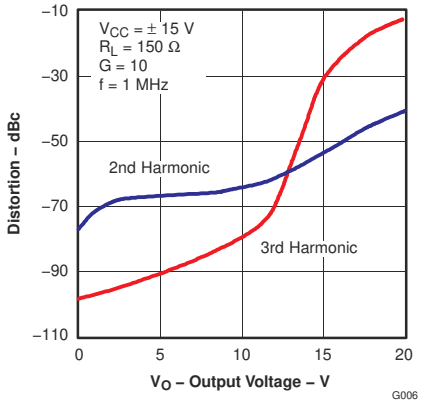


图 5-35. Distortion vs Output Voltage

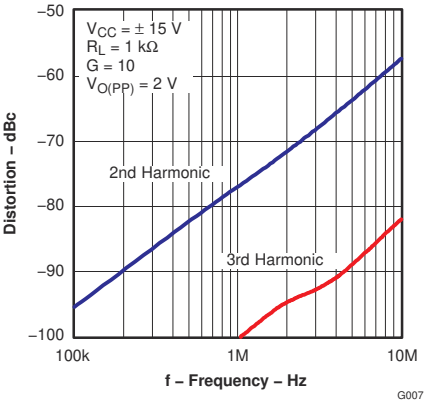


图 5-36. Distortion vs Frequency

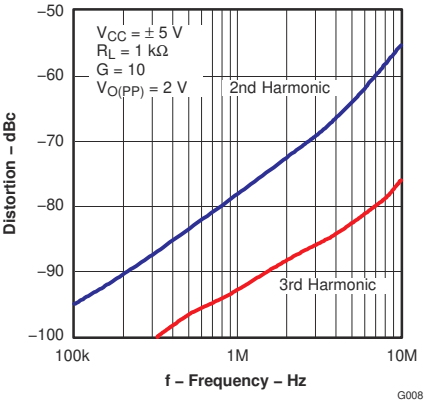


图 5-37. Distortion vs Frequency

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5.9 Typical Characteristics: THS4021DGN (continued)

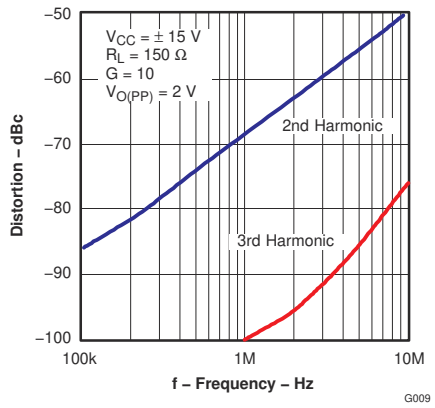


图 5-38. Distortion vs Frequency

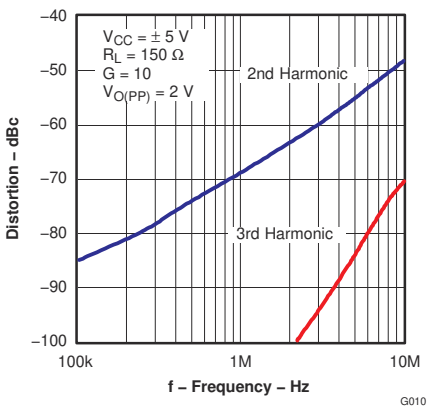


图 5-39. Distortion vs Frequency

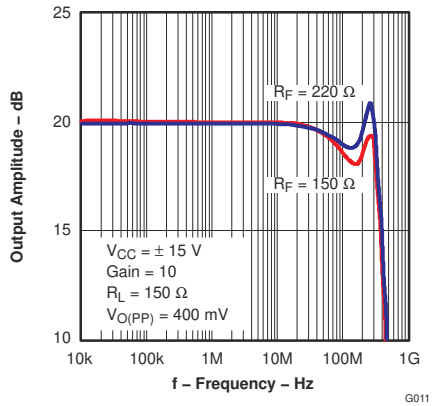


图 5-40. Output Amplitude vs Frequency

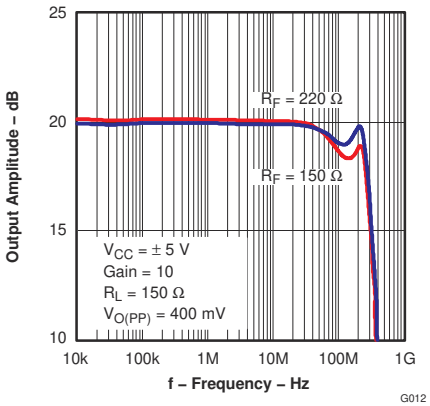


图 5-41. Output Amplitude vs Frequency

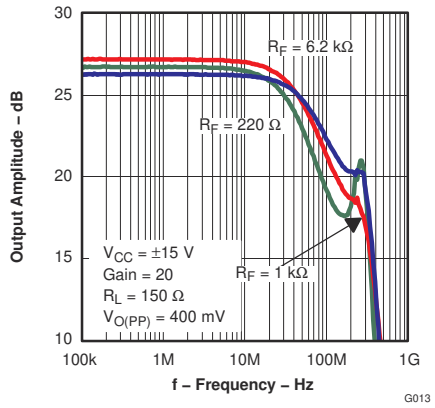


图 5-42. Output Amplitude vs Frequency

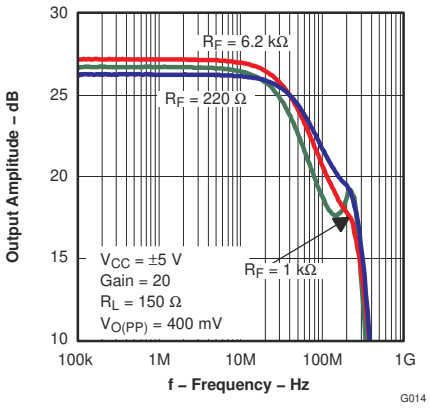


图 5-43. Output Amplitude vs Frequency

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5.9 Typical Characteristics: THS4021DGN (continued)

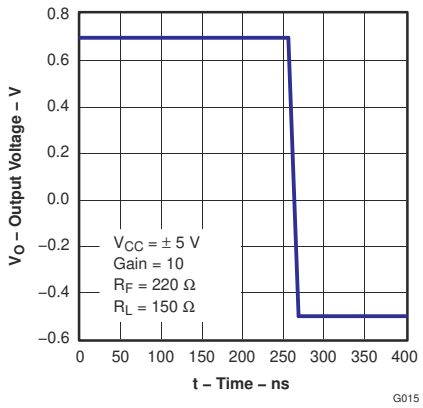


图 5-44. 1-V Step Response

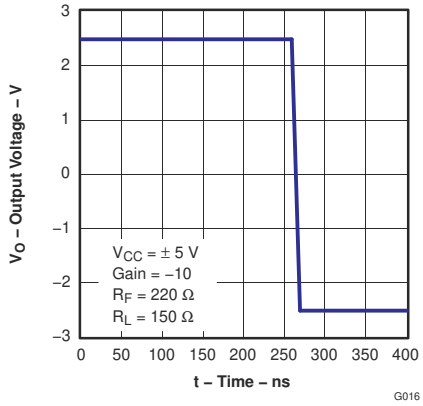


图 5-45. 5-V Step Response

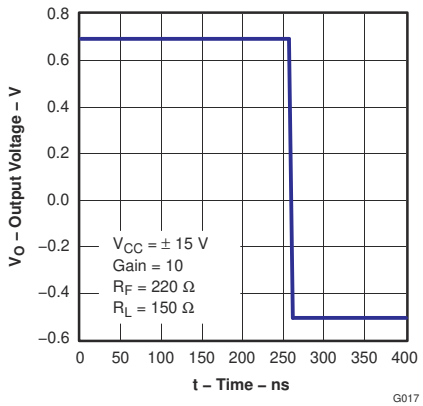


图 5-46. 1-V Step Response

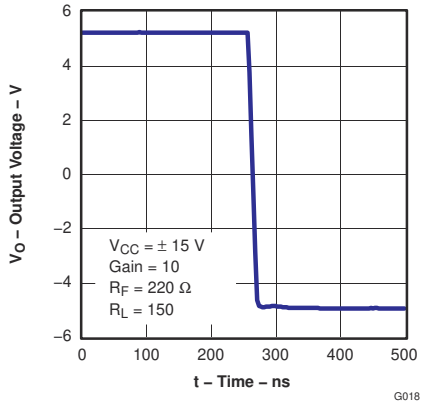


图 5-47. 10-V Step Response

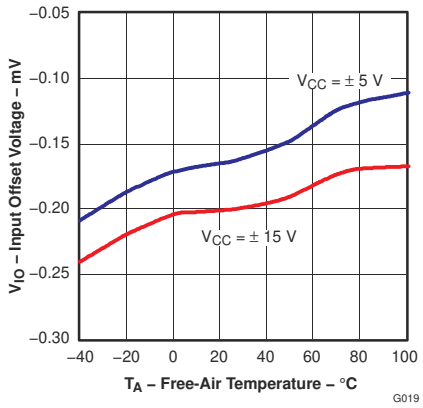


图 5-48. Input Offset Voltage vs Free-air Temperature

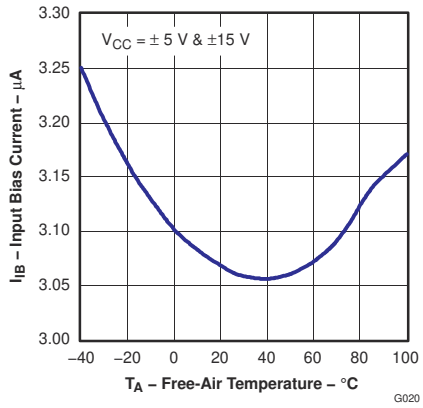


图 5-49. Input Bias Current vs Free-air Temperature

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5.9 Typical Characteristics: THS4021DGN (continued)

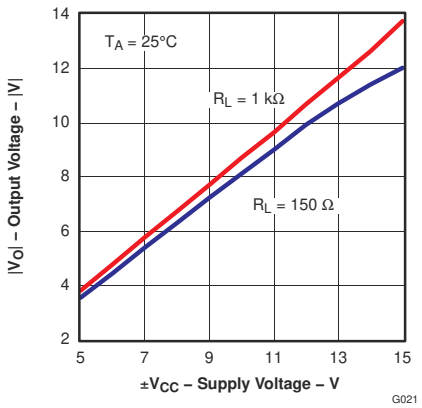


图 5-50. Output Voltage vs Supply Voltage

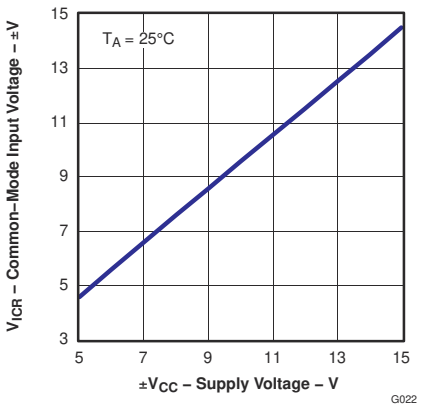


图 5-51. Common-mode Input Voltage vs Supply Voltage

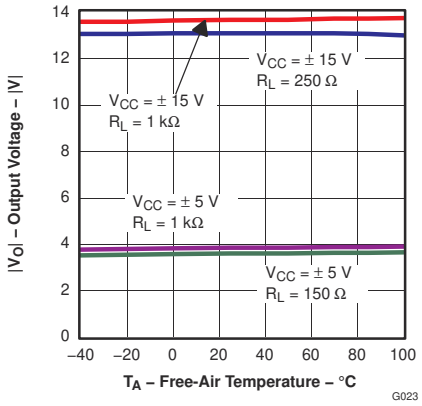


图 5-52. Output Voltage vs Free-air Temperature

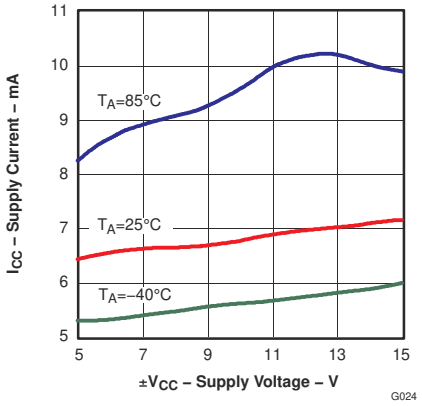


图 5-53. Supply Current vs Supply Voltage

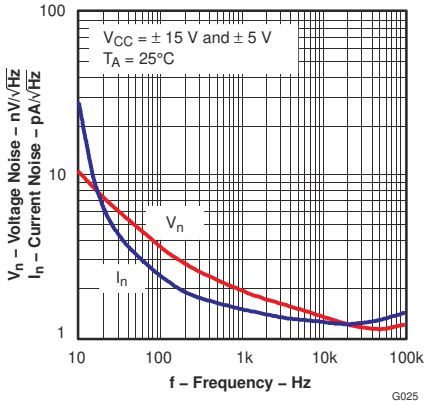


图 5-54. Voltage and Current Noise vs Frequency

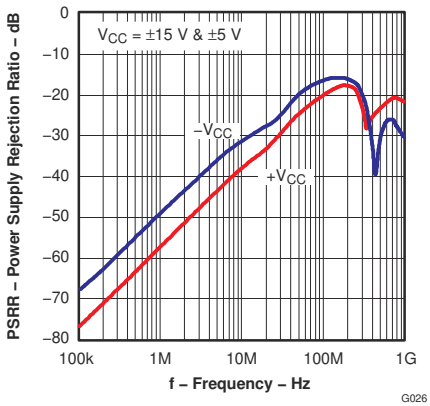


图 5-55. Power Supply Rejection Ratio vs Frequency

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5.9 Typical Characteristics: THS4021DGN (continued)

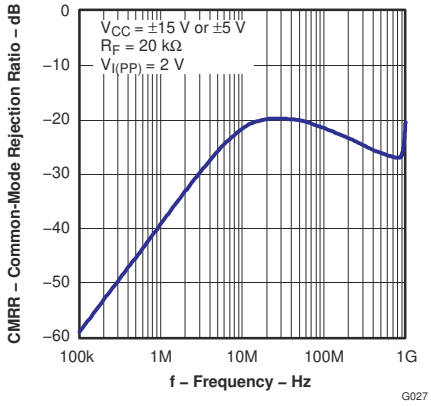


图 5-56. Common Mode Rejection Ratio vs Frequency

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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

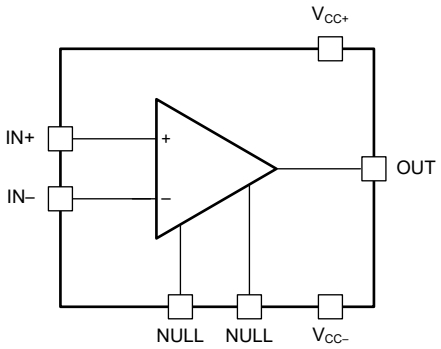


图 6-1. THS4021: Single Channel

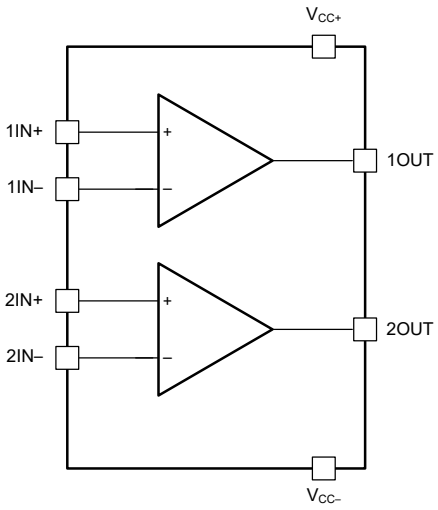


图 6-2. THS4022: Dual Channel

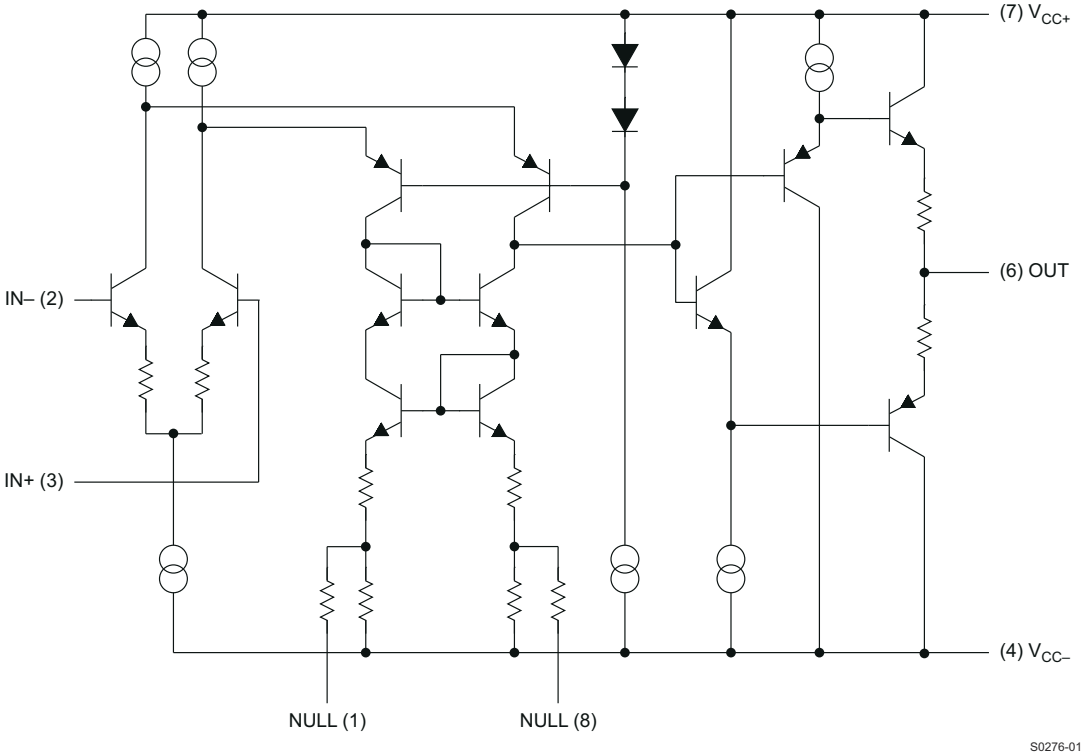


图 6-3. THS4021 Simplified Schematic

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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. 图 6-4 shows this feature.

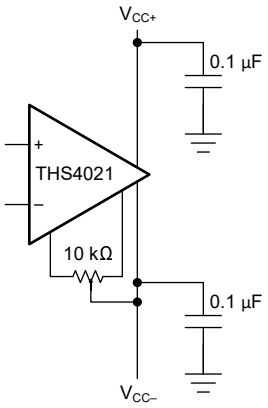


图 6-4. Offset Nulling Schematic

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

备注

以下应用部分中的信息不属于 TI 器件规格的范围，TI 不担保其准确性和完整性。TI 的客 户应负责确定器件是否适用于其应用。客户应验证并测试其设计，以确保系统功能。

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. 图 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.

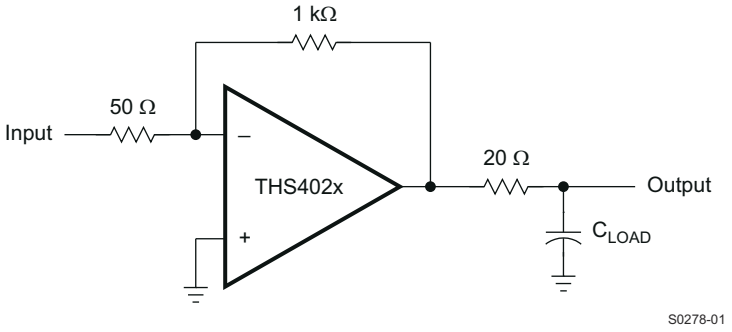


图 7-1. Driving a Capacitive Load

7.1.2 General Configuration

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

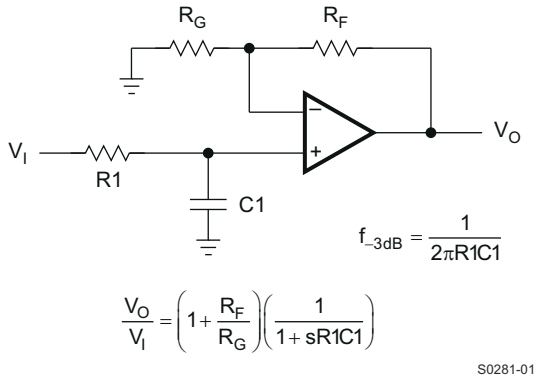


图 7-2. Single-Pole Low-Pass Filter

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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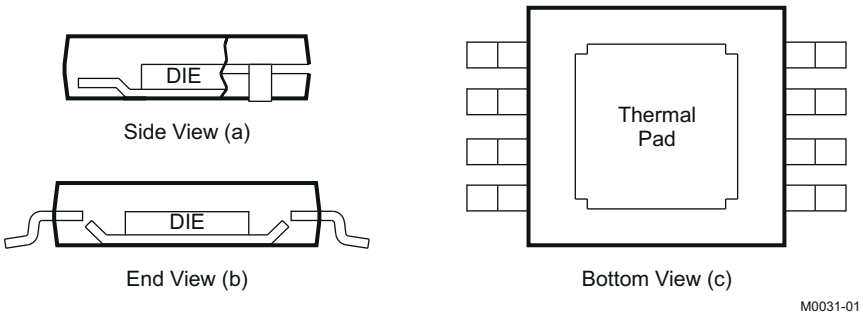
7.3.1.1 General PowerPAD™ Integrated Circuit Package Design Considerations

The THS402x is available in a thermally-enhanced DGN package, which is a member of the PowerPAD™ integrated circuit package family. 图 7-3 **a** and 图 7-3 **b** show that this package is constructed using a downset leadframe upon which the die is mounted. 图 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.

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

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7.3.2 Layout Example

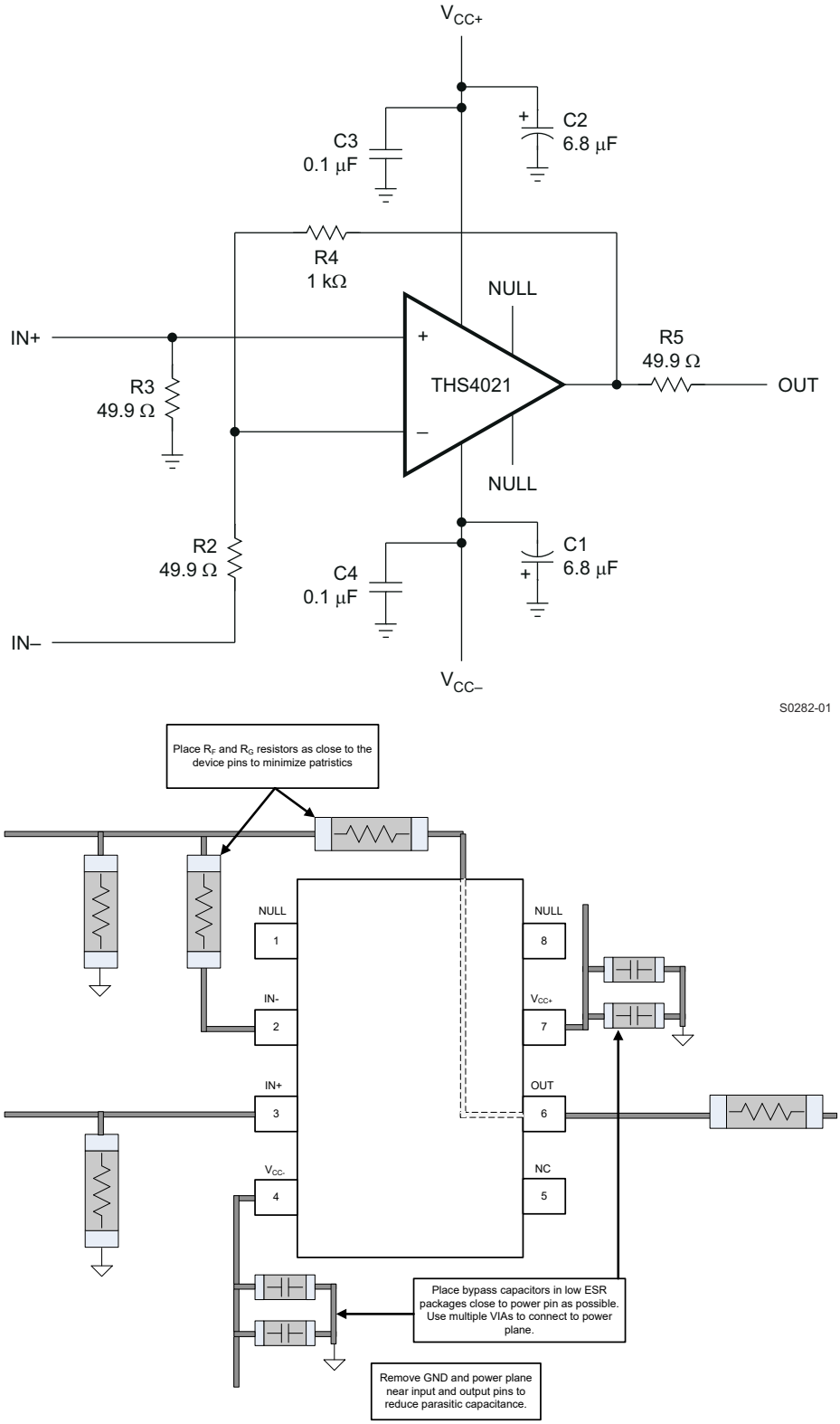


图 7-4. Layout Recommendations

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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 接收文档更新通知

要接收文档更新通知，请导航至 ti.com 上的器件产品文件夹。点击*通知* 进行注册，即可每周接收产品信息更改摘要。有关更改的详细信息，请查看任何已修订文档中包含的修订历史记录。

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链接的内容由各个贡献者“按原样”提供。这些内容并不构成 TI 技术规范，并且不一定反映 TI 的观点；请参阅 TI 的使用条款。

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ESD 的损坏小至导致微小的性能降级，大至整个器件故障。精密的集成电路可能更容易受到损坏，这是因为非常细微的参数更改都可能会导致器件与其发布的规格不相符。

8.6 术语表

TI 术语表　　本术语表列出并解释了术语、首字母缩略词和定义。

9 Revision History

注：以前版本的页码可能与当前版本的页码不同

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
• 从文档中删除了 THS4022 D 封装	1
• 更新了*简化版应用* 图以显示正确的引脚名称	1
• 更新了*说明* 中的闭环带宽和电源电流	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.

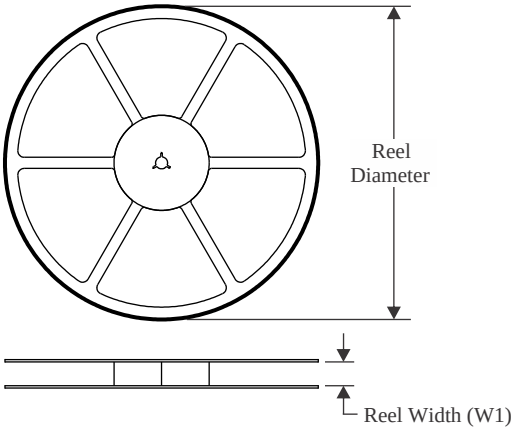
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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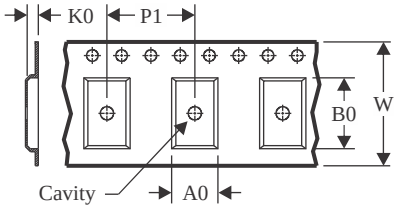
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

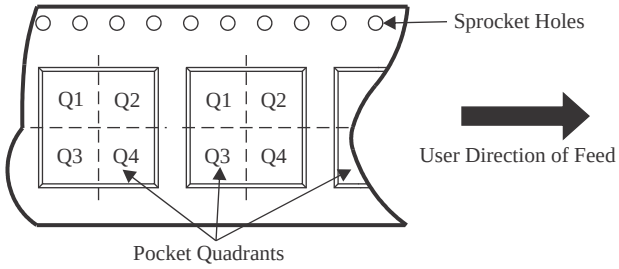


TAPE DIMENSIONS



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

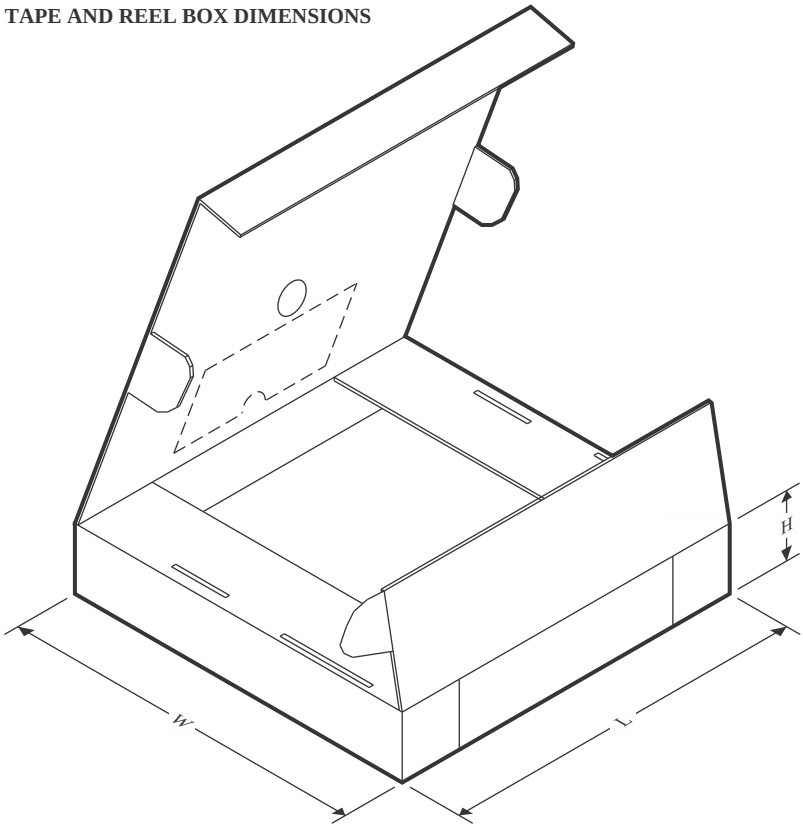
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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

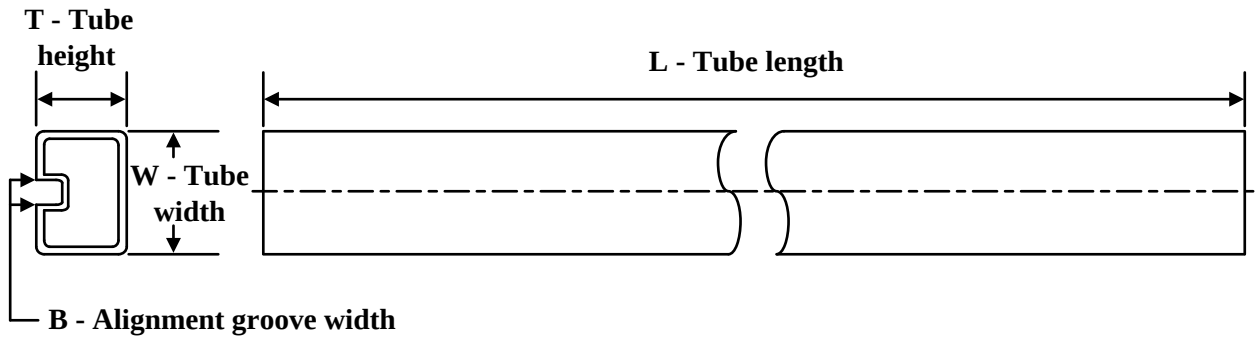
TAPE AND REEL BOX DIMENSIONS



*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

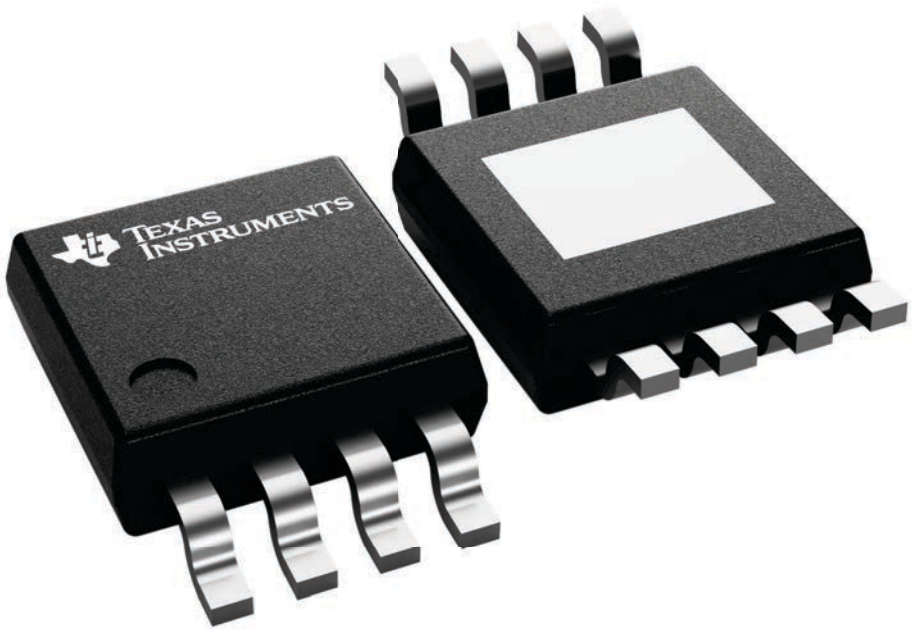
DGN 8

PowerPAD™ HVSSOP - 1.1 mm max height

3 x 3, 0.65 mm pitch

SMALL OUTLINE PACKAGE

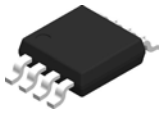
This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



4225482/B

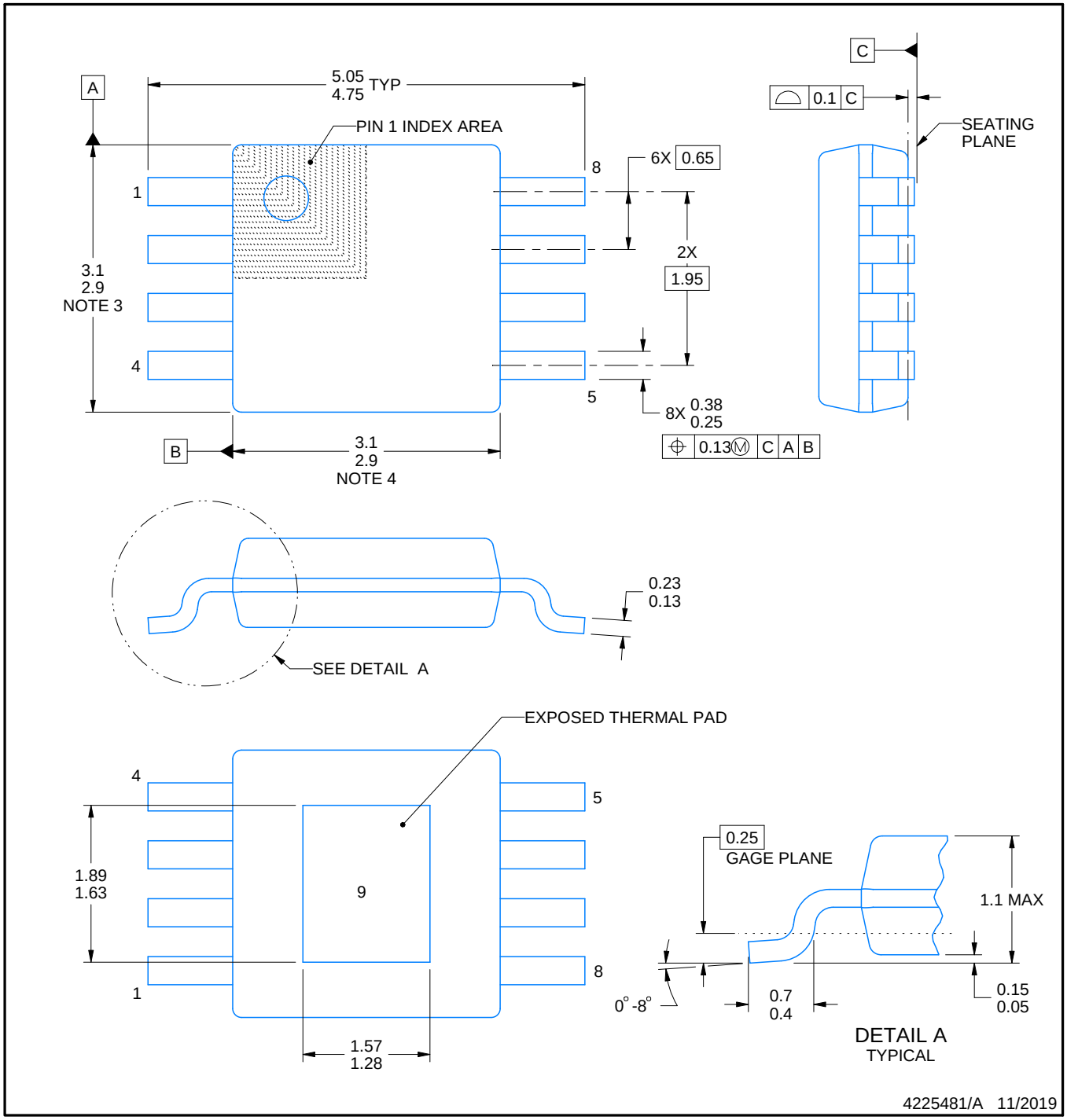
PACKAGE OUTLINE

DGN0008D



PowerPAD™ VSSOP - 1.1 mm max height

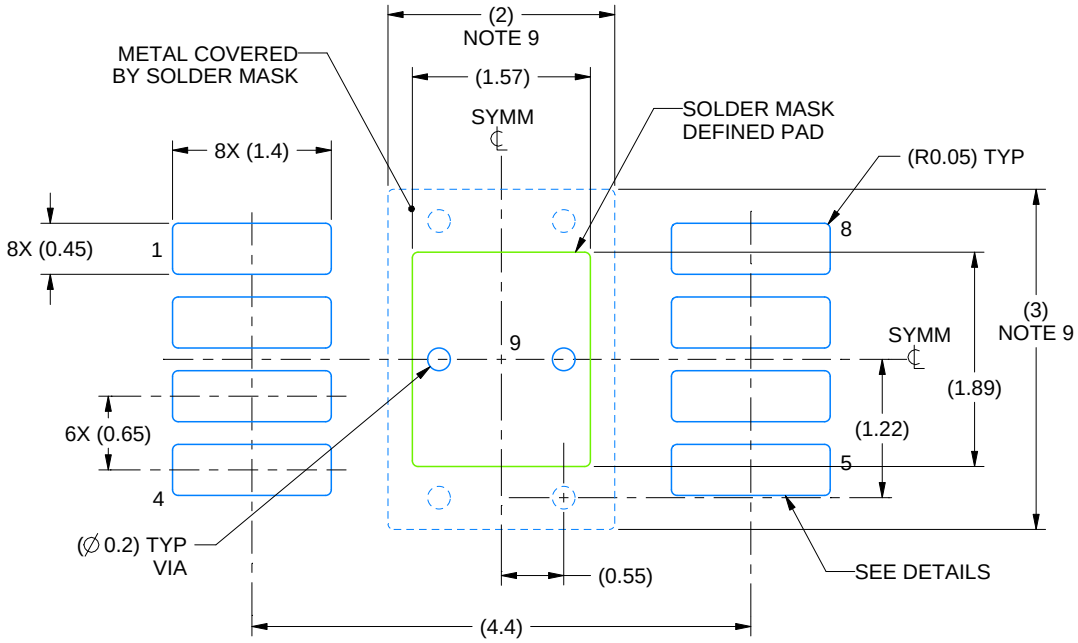
SMALL OUTLINE PACKAGE



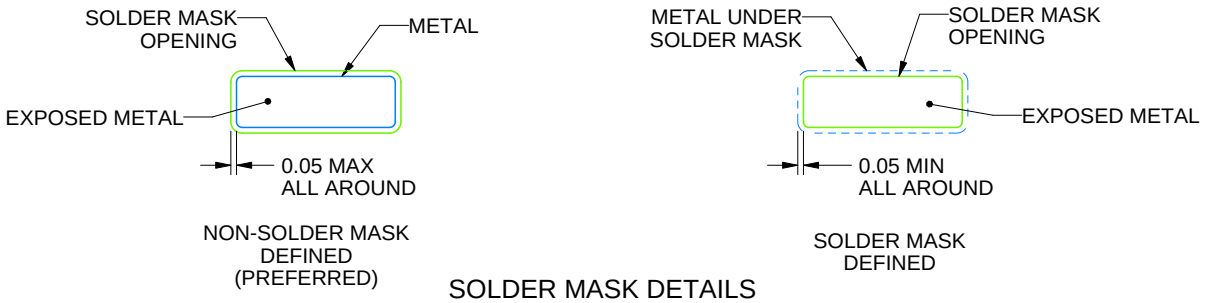
PowerPAD is a trademark of Texas Instruments.

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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 15X

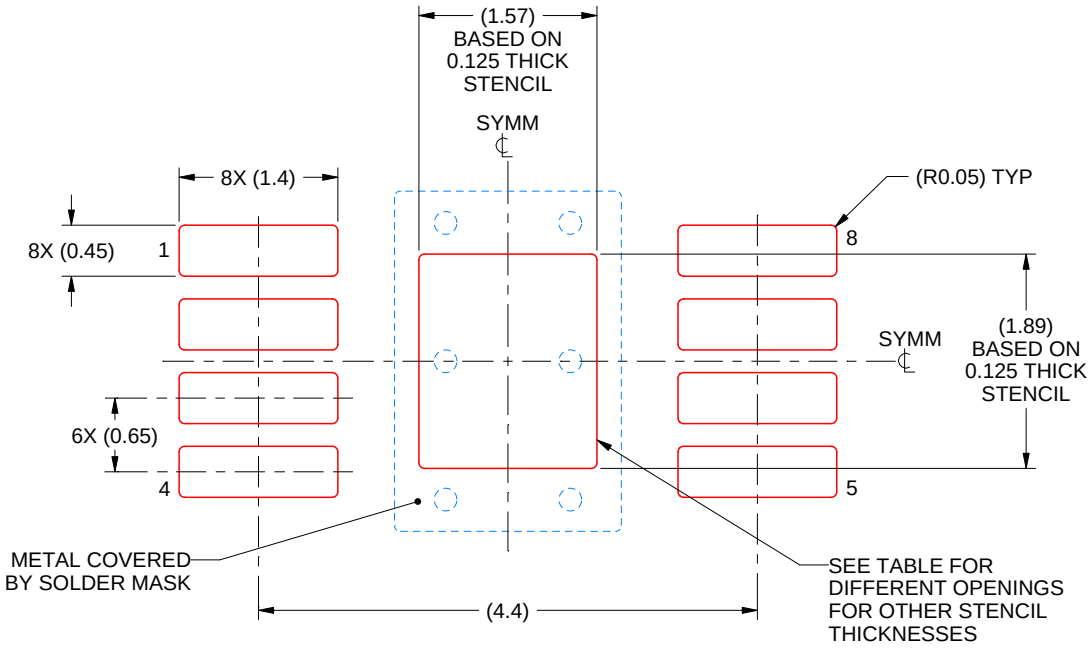


SOLDER MASK DETAILS

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)

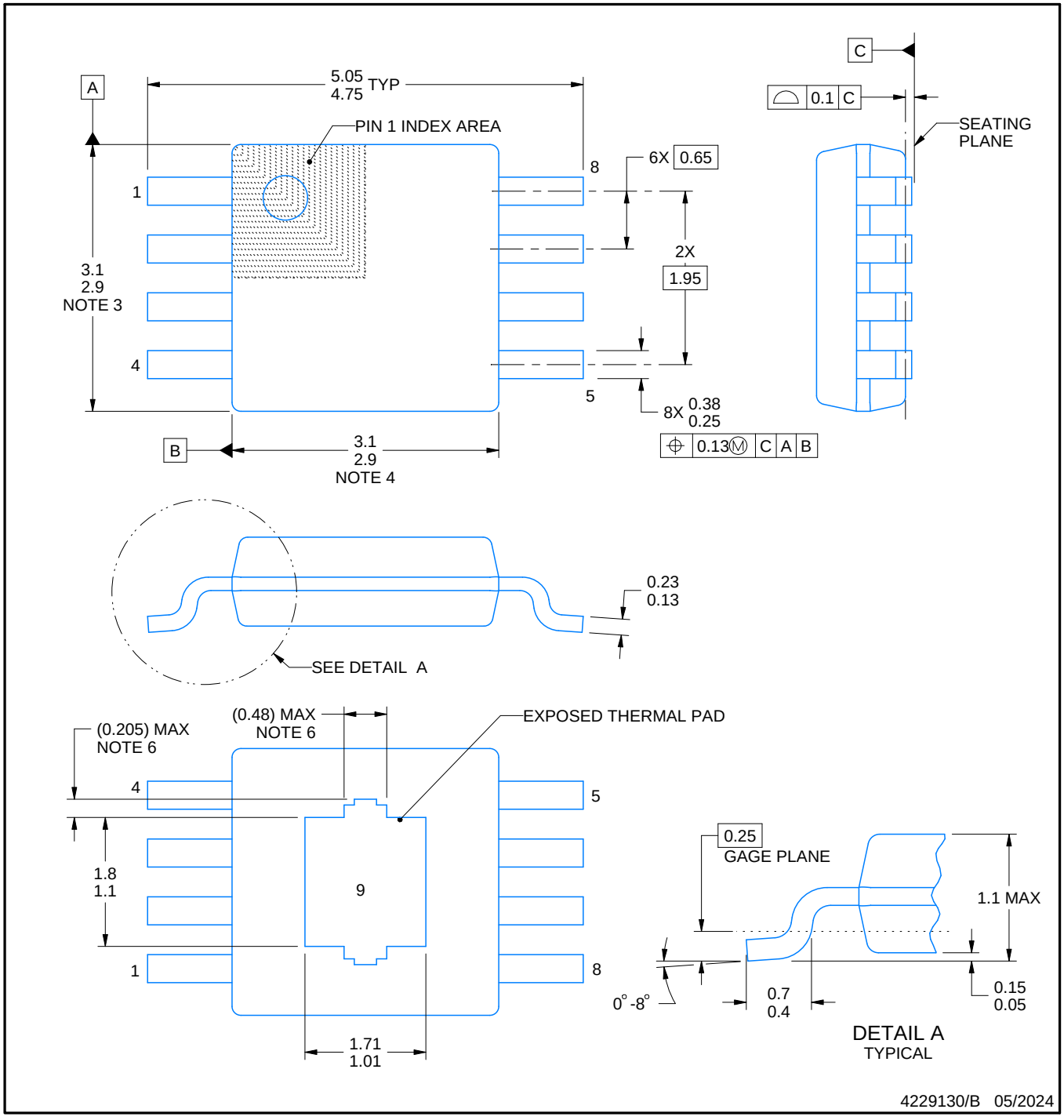
10. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
11. Board assembly site may have different recommendations for stencil design.

PACKAGE OUTLINE

DGN0008H

PowerPAD™ VSSOP - 1.1 mm max height

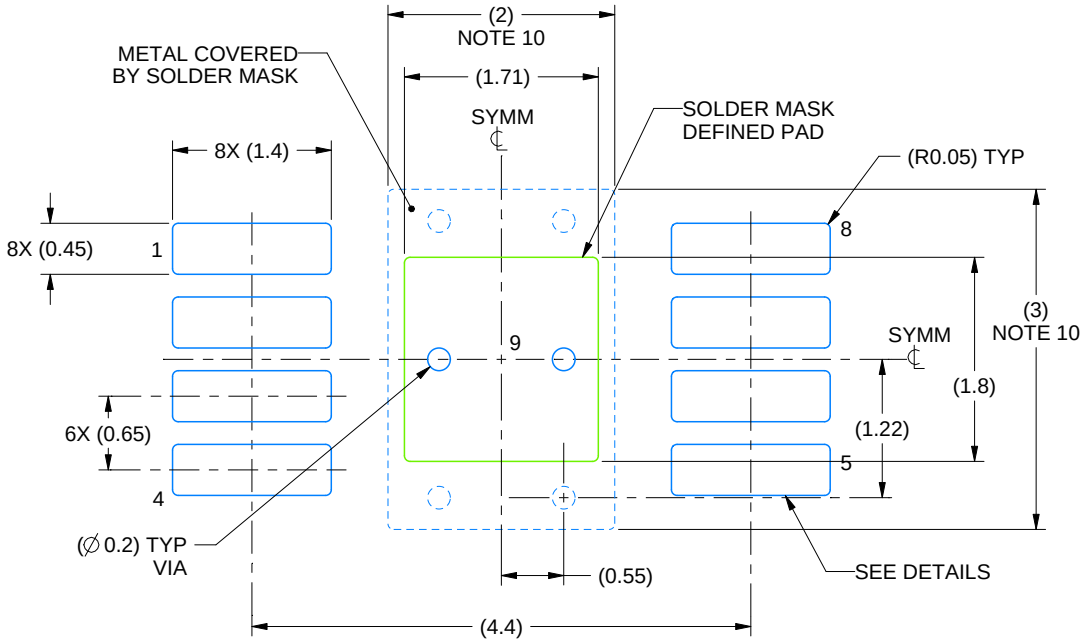
SMALL OUTLINE PACKAGE



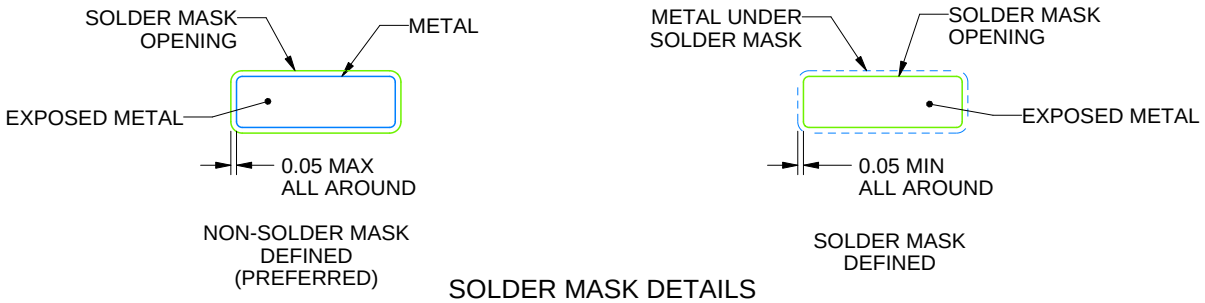
PowerPAD is a trademark of Texas Instruments.

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

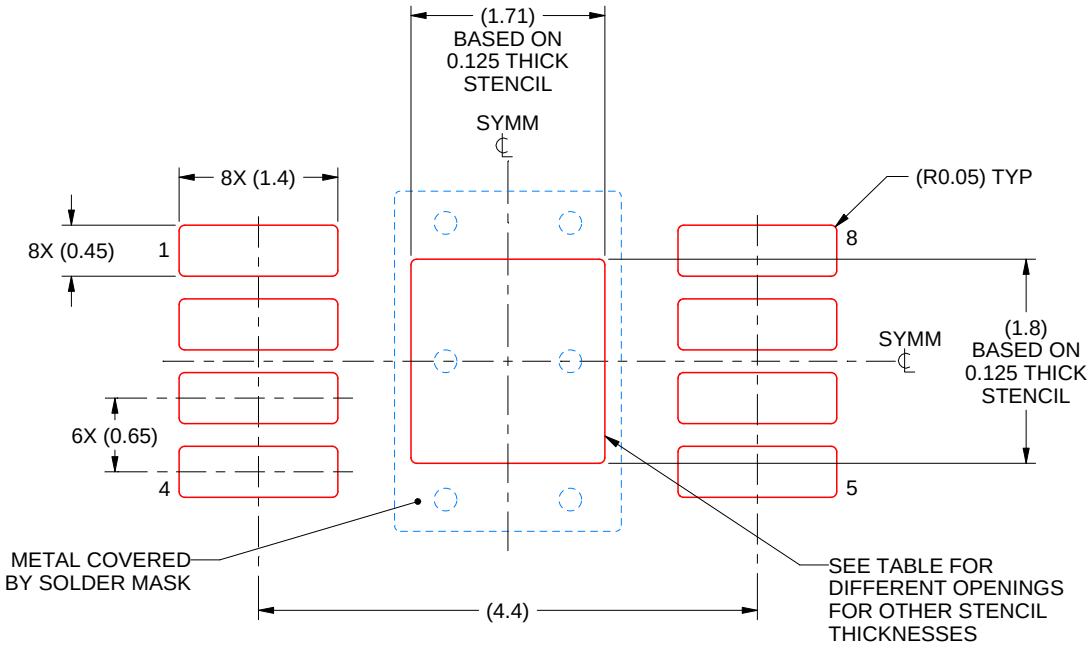


SOLDER MASK DETAILS

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.



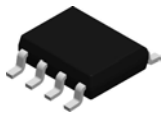
SOLDER PASTE EXAMPLE
EXPOSED PAD 9:
100% PRINTED SOLDER COVERAGE BY AREA
SCALE: 15X

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.

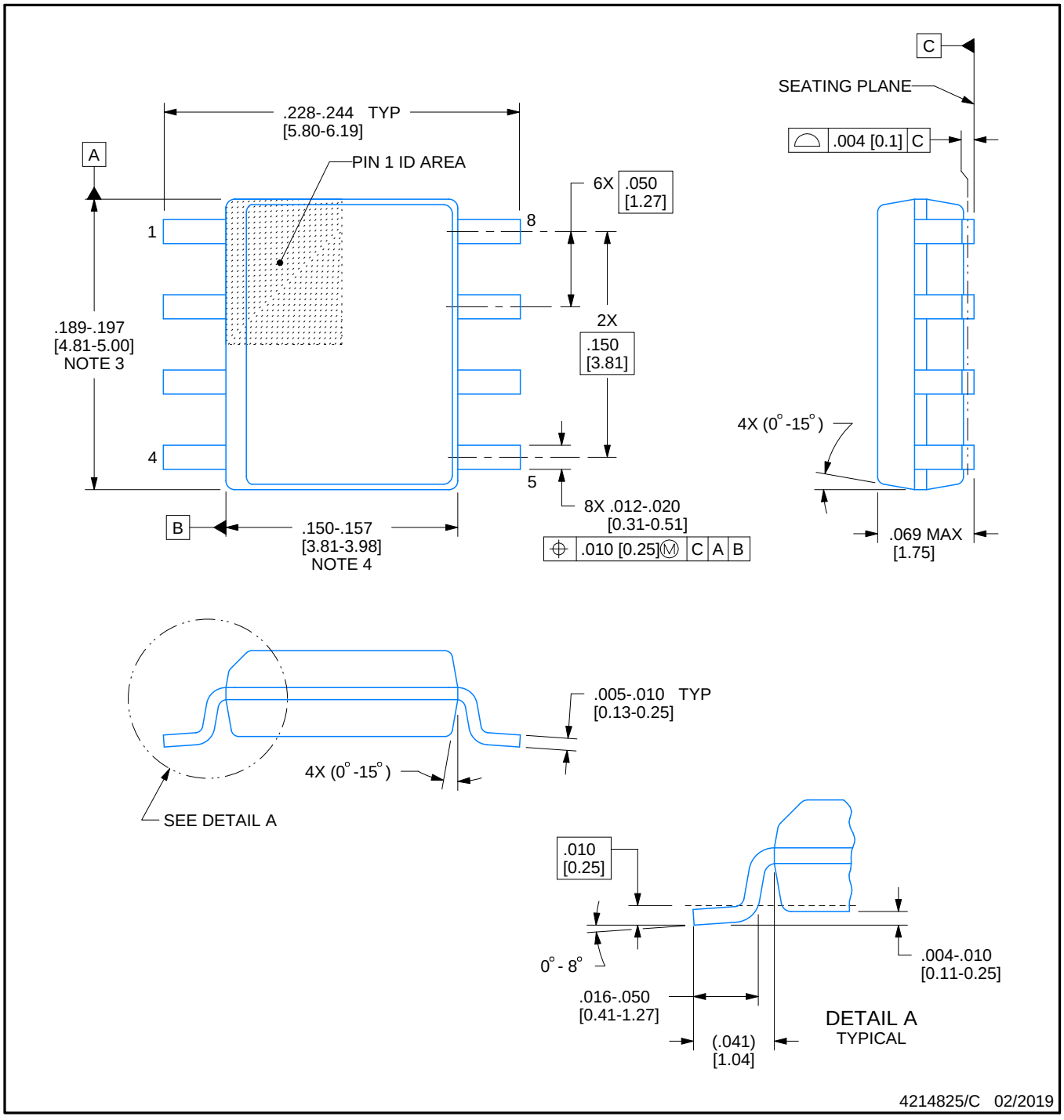


PACKAGE OUTLINE

D0008A

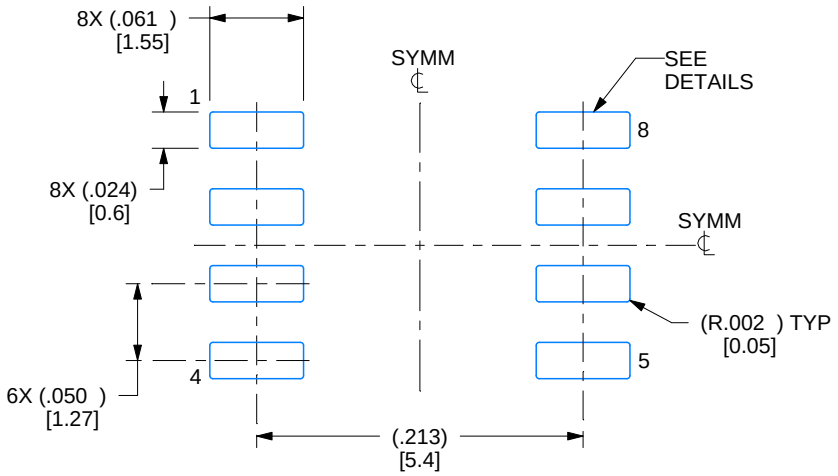
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

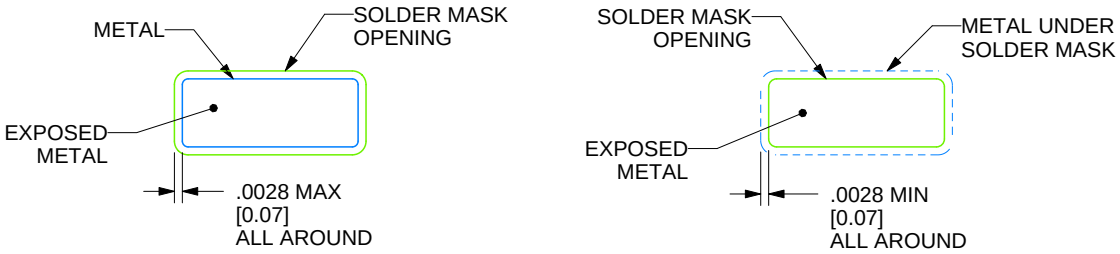


NOTES:

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)

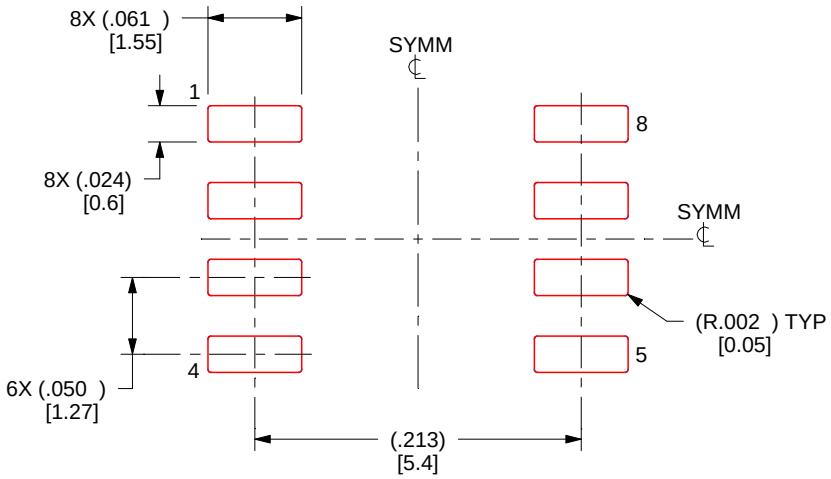
6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

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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