

LSF0204x 适用于漏极开路和三态应用的 4 位双向多电压电平转换器

1 特性

- 无需方向端子即可提供双向电压转换
- 在电容负载不超过 30pF 的情况下，支持最高 100MHz 的上行转换和大于 100MHz 的下行转换，在 50pF 电容负载下支持最高 40MHz 的上行/下行转换
- 支持 I_{off} 、局部断电模式（参阅 [特性说明](#)）
- 可实现以下电压之间的双向电压电平转换
 - 0.8V ↔ 1.8/2.5/3.3/5V
 - 1.2V ↔ 1.8/2.5/3.3/5V
 - 1.8V ↔ 2.5/3.3/5V
 - 2.5V ↔ 3.3/5V
 - 3.3V ↔ 5V
- 低待机电流
- 支持 TTL 的 5V 耐受 I/O 端口
- 低 R_{on} 可实现较少的信号失真
- 实现 $EN =$ 低电平的高阻抗 I/O 端子
- 采用直通引脚排列来简化 PCB 布线
- 闩锁性能超过 100mA，符合 JESD17 规范
 - 40°C 至 125°C 工作温度范围
- ESD 性能测试符合 JESD 22 标准
 - 2000V 人体放电模型 (A114-B, II 类)
 - 200V 机器放电模型 (A115-A)
 - 1000V 充电器件模型 (C101)

2 应用

- GPIO、MDIO、PMBus、SMBus、SDIO、UART、I²C 和电信基础设施中的其他接口
- 工业类
- 汽车类
- 个人计算

3 说明

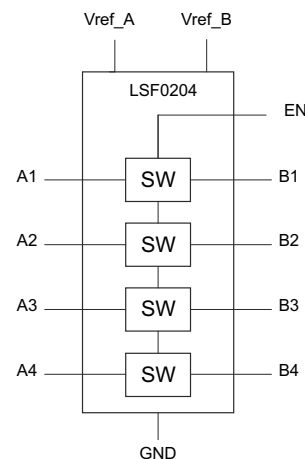
LSF 系列包含双向电压电平转换器，该转换器可在 0.8V 至 4.5V (V_{ref_A}) 和 1.8V 至 5.5V (V_{ref_B}) 电压范围内运行。该范围支持在 0.8V 和 5.0V 之间进行双向电压转换，无需在漏极开路或三态应用中使用方向端子。对于采用 15pF 电容器和 165Ω 上拉电阻器的漏极开路系统，LSF 系列支持传输速度大于 100MHz 的电平转换应用。

当 A_n 或 B_n 端口为低电平时，此开关处于接通状态，而且 A_n 和 B_n 端口之间存在低电阻连接。开关的低 R_{on} 可实现具有超小传播延迟和信号失真的连接。A 端或 B 端的电压将限制为 V_{ref_A} ，且可上拉至 V_{ref_A} 到 5V 之间的任何电压水平。利用此功能，可在无需方向控制的情况下，在用户选择的较高和较低电压之间实现无缝转换。

器件信息⁽¹⁾

器件型号	封装	封装尺寸 (标称值)
LSF0204x	TSSOP (14)	5.00mm × 4.40mm
	UQFN (12)	2.00mm × 1.70mm
	VQFN (14)	3.50mm × 3.50mm
	DSBGA (12)	1.90mm × 1.40mm

(1) 如需了解所有可用封装，请参阅数据表末尾的可订购产品附录。



简化原理图



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4 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 G (November 2019) to Revision H (April 2021)	Page
• 更新了整个文档的表、图和交叉参考的编号格式.....	1
• Updated the <i>Bidirectional Translation</i> section to include inclusive terminology.....	14
Changes from Revision F (January 2019) to Revision G (November 2019)	Page
• Changed $V_{ref_A/B/EN}$ max voltage to 5.5 V in the Recommended Operating Conditions table.....	6
Changes from Revision E (December 2018) to Revision F (January 2019)	Page
• Changed location of YZP-package indicator dot to A3 position.	4
• Added YZP package to <i>Thermal Information</i> table.....	6
Changes from Revision D (December 2015) to Revision E (December 2018)	Page
• Changed location of YZP-package A1-pin indicator dot. View is looking through the device, as in an X-ray.	4
Changes from Revision C (August 2015) to Revision D (December 2015)	Page
• Added Type Column to <i>Pin Functions</i> table.....	4
• Added Junction Temperatures to <i>Thermal Information</i> table.....	6
Changes from Revision B (April 2015) to Revision C (August 2015)	Page
• 删除了“特性”中的“低于最大传播延迟 1.5ns”项目符号.....	1
• 更新了“特性”中的“支持 100MHz 以上的高速转换”项目符号.....	1

Changes from Revision A (December 2014) to Revision B (April 2015)	Page
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- | | |
|----------------------|-------------------|
| • 向器件添加了 YZP 封装..... | 1 |
|----------------------|-------------------|
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Changes from Revision * (November 2014) to Revision A (December 2014)	Page
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- | | |
|---|-------------------|
| • 从首页“产品预发布”更改为完整数据表..... | 1 |
| • 将 节 3 中的文本从“传输速度大于 100Mbps”更改为“传输速度大于 100MHz” | 1 |
-

5 说明 (续)

每个通道的电源电压 ($V_{pu\#}$) 可以用上拉电阻器单独进行设置。例如, CH1 可用于上行转换模式 ($1.2V \leftrightarrow 3.3V$), CH2 可用于下行转换模式 ($2.5V \leftrightarrow 1.8V$)。

当 EN 为高电平时, 转换器开关打开, 并且 An I/O 分别连接至 Bn I/O, 从而实现端口间的双向数据流。当 EN 为低电平时, 转换器开关关闭, 端口之间呈高阻抗状态。EN 输入电路被设计成由 Vref_A 供电。EN 必须为低电平, 从而确保上电或断电期间的高阻抗状态。

器件比较表

器件型号	EN	An	Bn	说明
LSF0204D	H	将所有数据引脚置于三态模式 (高阻态)	将所有数据引脚置于三态模式 (高阻态)	三态输出模式启用 (低电平有效; 以 Vref_A 为基准)
LSF0204D	L	输入或输出	输入或输出	
LSF0204	H	输入或输出	输入或输出	三态输出模式启用 (高电平有效, 以 Vref_A 为基准)
LSF0204	L	将所有数据引脚置于三态模式 (高阻态)	将所有数据引脚置于三态模式 (高阻态)	

6 Pin Configuration and Functions

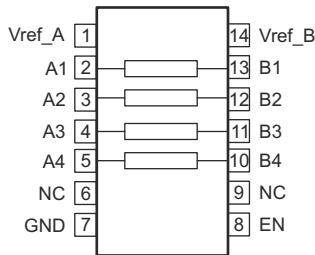


图 6-1. PW Package,
14-Pin TSSOP
(Top View)

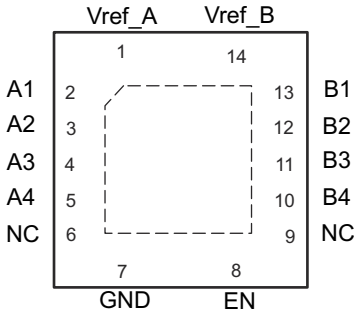


图 6-2. RGY Package,
14-Pin VQFN
(Transparent Top View)

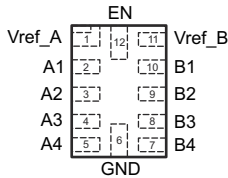


图 6-3. RUT Package,
12-Pin UQFN
(Transparent Top View)

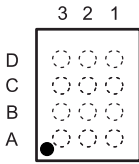


图 6-4. YZP Package,
12-Pin DSBGA
(Transparent Top View)

表 6-1. Pin Functions

PIN				TYPE ⁽¹⁾	DESCRIPTION
NAME	NO.				
	PW, RGY	RUT	YZP		
V _{ref_A}	1	1	B2	—	Reference supply voltage; see Application and Implementation section
A1	2	2	A3	I/O	Input/output 1.
A2	3	3	B3	I/O	Input/output 2.
A3	4	4	C3	I/O	Input/output 3.
A4	5	5	D3	I/O	Input/output 4.
NC	6	–	—	—	No connection. Not internally connected.
GND	7	6	D2	—	Ground
EN	8	12	C2	I	Switch enable input; LSF0204: EN is high-active; LSF0204D: EN is low-active
NC	9	–	—	—	No connection. Not internally connected.
B4	10	7	D1	I/O	Input/output 4.
B3	11	8	C1	I/O	Input/output 3.
B2	12	9	B1	I/O	Input/output 2.
B1	13	10	A1	I/O	Input/output 1.
V _{ref_B}	14	11	A2	—	Reference supply voltage; see Application and Implementation section

(1) I = input, O = output

7 Specifications

7.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
V _I	Input voltage ⁽²⁾		– 0.5	7	V
V _{I/O}	Input/output voltage ⁽²⁾		– 0.5	7	V
Continuous channel current				128	mA
I _{IK}	Input clamp current	V _I < 0		– 50	mA
T _J	Junction temperature			150	°C
T _{stg}	Storage temperature		– 65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The input and input/output negative-voltage ratings may be exceeded if the input and input/output clamp-current ratings are observed.

7.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 ⁽¹⁾	±2000
		Charged-device model (CDM), per JEDEC specification JESD22-C101 ⁽²⁾	±1000

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 500-V HBM is possible with the necessary precautions.
- (2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process. Manufacturing with less than 250-V CDM is possible with the necessary precautions.

7.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
$V_{I/O}$	Input/output voltage	0	5.5	V
$V_{ref_A/B/EN}$	Reference voltage	0	5.5	V
I_{PASS}	Pass transistor current		64	mA
T_A	Operating free-air temperature	– 40	125	°C

7.4 Thermal Information

THERMAL METRIC ⁽¹⁾		LSF0204				UNIT
		RGY (VQFN)	RUT (UQFN)	PW (TSSOP)	YZP (DSBGA)	
		14 PINS	12 PINS	14 PINS	12 BALLS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	83.2	195.8	157.9	83.7	°C
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	98.2	98.7	82.3	0.6	°C
$R_{\theta JB}$	Junction-to-board thermal resistance	59.2	122.6	100.0	23.7	°C
ψ_{JT}	Junction-to-top characterization parameter	17.4	6.2	22.9	0.4	°C
ψ_{JB}	Junction-to-board characterization parameter	59.4	122.6	99.0	23.7	°C
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	38.7	N/A	N/A	N/A	°C

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

7.5 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP ⁽¹⁾	MAX	UNIT
V_{IK}		$I_I = -18 \text{ mA}$, $V_{EN} = 0$			-1.2	V
I_{IH}		$V_I = 5 \text{ V}$, $V_{EN} = 0$			5.0	μA
I_{CCBA}	Leakage from V_{ref_B} to V_{ref_A}	$V_{ref_B} = 3.3 \text{ V}$, $V_{ref_A} = 1.8 \text{ V}$, $V_{EN} = V_{ref_A}$, $I_O = 0$, $V_I = 3.3 \text{ V}$ or GND			3.5	μA
$I_{CCA} + I_{CCB}$ ⁽⁴⁾		Total Current through GND $V_{ref_B} = 3.3 \text{ V}$, $V_{ref_A} = 1.8 \text{ V}$, $V_{EN} = V_{ref_A}$, $I_O = 0$, $V_I = 3.3 \text{ V}$ or GND		0.2		μA
I_{IN}		Control pin current $V_{ref_B} = 5.5 \text{ V}$, $V_{ref_A} = 4.5 \text{ V}$, $V_{EN} = 0$ to V_{ref_A} , $I_O = 0$			± 1	μA
I_{off}		Power Off Leakage Current $V_{ref_B} = V_{ref_A} = 0 \text{ V}$, $V_{EN} = \text{GND}$, $I_O = 0$, $V_I = 5 \text{ V}$ or GND			± 1	μA
$C_{I(ref_A/B/EN)}$		$V_I = 3 \text{ V}$ or 0		7		pF
$C_{Io(off)}$		$V_O = 3 \text{ V}$ or 0, $V_{EN} = 0$		5.0	6.0	pF
$C_{Io(on)}$		$V_O = 3 \text{ V}$ or 0, $V_{EN} = V_{ref_A}$		10.5	13	pF
⁽³⁾ V_{IH} (EN pin)	High-level input voltage	$V_{ref_A} = 1.5 \text{ V}$ to 4.5 V	$0.7 \times V_{ref_A}$			V
V_{IL} (EN pin)	Low-level input voltage	$V_{ref_A} = 1.5 \text{ V}$ to 4.5 V		$0.3 \times V_{ref_A}$		V
V_{IH} (EN pin)	High-level input voltage	$V_{ref_A} = 1.0 \text{ V}$ to 1.5 V	$0.8 \times V_{ref_A}$			V
V_{IL} (EN pin)	Low-level input voltage	$V_{ref_A} = 1.0 \text{ V}$ to 1.5 V		$0.3 \times V_{ref_A}$		V
$\Delta t/\Delta v$ (EN pin)		Input transition rise or fall rate for EN pin		10		ns/V
r_{on} ⁽²⁾	$V_I = 0$, $I_O = 64 \text{ mA}$	$V_{ref_A} = V_{EN} = 3.3 \text{ V}$; $V_{ref_B} = 5 \text{ V}$		3		Ω
		$V_{ref_A} = V_{EN} = 1.8 \text{ V}$; $V_{ref_B} = 5 \text{ V}$		4		
	$V_I = 0$, $I_O = 32 \text{ mA}$	$V_{ref_A} = V_{EN} = 1.0 \text{ V}$; $V_{ref_B} = 5 \text{ V}$		9		Ω
		$V_{ref_A} = V_{EN} = 1.8 \text{ V}$; $V_{ref_B} = 5 \text{ V}$		4		
	$V_I = 0$, $I_O = 32 \text{ mA}$, $V_{ref_A} = V_{EN} = 2.5 \text{ V}$; $V_{ref_B} = 5 \text{ V}$			10		Ω
	$V_I = 1.8 \text{ V}$, $I_O = 15 \text{ mA}$, $V_{ref_A} = V_{EN} = 3.3 \text{ V}$; $V_{ref_B} = 5 \text{ V}$			5		Ω
	$V_I = 1.0 \text{ V}$, $I_O = 10 \text{ mA}$, $V_{ref_A} = V_{EN} = 1.8 \text{ V}$; $V_{ref_B} = 3.3 \text{ V}$			8		Ω
	$V_I = 0 \text{ V}$, $I_O = 10 \text{ mA}$, $V_{ref_A} = V_{EN} = 1.0 \text{ V}$; $V_{ref_B} = 3.3 \text{ V}$			6		Ω
		$V_I = 0 \text{ V}$, $I_O = 10 \text{ mA}$, $V_{ref_A} = V_{EN} = 1.0 \text{ V}$; $V_{ref_B} = 1.8 \text{ V}$		6		Ω

(1) All typical values are at $T_A = 25^\circ\text{C}$.

(2) Measured by the voltage drop between the A and B terminals at the indicated current through the switch. On-state resistance is determined by the lowest voltage of the two (A or B) terminals.

(3) Enable pin test conditions are for the LSF0204. The enable pin test conditions for LSF0204D are oppositely set.

(4) The actual supply current for LSF0204 is $I_{CCA} + I_{CCB}$; the leakage from V_{ref_B} to V_{ref_A} can be measured on V_{ref_A} and V_{ref_B} pin

7.6 Switching Characteristics: AC Performance (Translating Down, 3.3 V to 1.8 V)

over recommended operating free-air temperature range, $V_{rev-A} = 1.8 \text{ V}$, $V_{rev-B} = 3.3 \text{ V}$, $V_{EN} = 1.8 \text{ V}$, $V_{pu_1} = 3.3 \text{ V}$, $V_{pu_2} = 1.8 \text{ V}$, $R_L = \text{NA}$, $V_{IH} = 3.3 \text{ V}$, $V_{IL} = 0 \text{ V}$, $V_M = 1.15 \text{ V}$ (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$C_L = 50 \text{ pF}$		$C_L = 30 \text{ pF}$		$C_L = 15 \text{ pF}$		UNIT
			TYP	MAX	TYP	MAX	TYP	MAX	
t_{PLH}	A or B	B or A	0.7	5.49	0.5	5.29	0.3	5.19	ns
t_{PHL}			0.9	4.9	0.7	4.7	0.5	4.5	ns
t_{PLZ}			13	18	12	16.5	11	15	ns
t_{PZL}			33	45	30	40	23	37	ns
f_{MAX}			50		100		100		MHz

7.7 Switching Characteristics: AC Performance (Translating Down, 3.3 V to 1.2 V)

over recommended operating free-air temperature range $V_{\text{rev-A}} = 1.2 \text{ V}$, $V_{\text{rev-B}} = 3.3 \text{ V}$, $V_{\text{EN}} = 1.2 \text{ V}$, $V_{\text{pu}_1} = 3.3 \text{ V}$, $V_{\text{pu}_2} = 1.2 \text{ V}$, $R_L = \text{NA}$, $V_{\text{IH}} = 3.3 \text{ V}$, $V_{\text{IL}} = 0 \text{ V}$, $V_M = 0.85 \text{ V}$ (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$C_L = 50 \text{ pF}$		$C_L = 30 \text{ pF}$		$C_L = 15 \text{ pF}$		UNIT
			TYP	MAX	TYP	MAX	TYP	MAX	
t_{PLH}	A or B	B or A	0.8	4.1	0.5	3.9	0.3	3.8	ns
t_{PHL}			0.9	4.7	0.7	4.5	0.6	4.3	ns
f_{MAX}			50		100		100		MHz

7.8 Switching Characteristics: AC Performance (Translating Up, 1.8 V to 3.3 V)

over recommended operating free-air temperature range $V_{\text{rev-A}} = 1.8 \text{ V}$, $V_{\text{rev-B}} = 3.3 \text{ V}$, $V_{\text{EN}} = 1.8 \text{ V}$, $V_{\text{pu}_1} = 3.3 \text{ V}$, $V_{\text{pu}_2} = 1.8 \text{ V}$, $R_L = 500 \text{ } \Omega$, $V_{\text{IH}} = 1.8 \text{ V}$, $V_{\text{IL}} = 0 \text{ V}$, $V_M = 0.9 \text{ V}$ (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$C_L = 50 \text{ pF}$		$C_L = 30 \text{ pF}$		$C_L = 15 \text{ pF}$		UNIT
			TYP	MAX	TYP	MAX	TYP	MAX	
t_{PLH}	A or B	B or A	0.6	5.7	0.4	5.3	0.2	5.13	ns
t_{PHL}			1.3	6.7	1	6.4	0.7	5.3	ns
t_{PLZ}			13	18	12	16.5	11	15	ns
t_{PZL}			33	45	30	40	23	37	ns
f_{MAX}			50		100		100		MHz

7.9 Switching Characteristics: AC Performance (Translating Up, 1.2 V to 1.8 V)

over recommended operating free-air temperature range, $V_{\text{rev-A}} = 1.2 \text{ V}$, $V_{\text{rev-B}} = 1.8 \text{ V}$, $V_{\text{EN}} = 1.2 \text{ V}$, $V_{\text{pu}_1} = 1.8 \text{ V}$, $V_{\text{pu}_2} = 1.2 \text{ V}$, $R_L = 500 \text{ } \Omega$, $V_{\text{IH}} = 1.2 \text{ V}$, $V_{\text{IL}} = 0 \text{ V}$, $V_M = 0.6 \text{ V}$ (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	$C_L = 50 \text{ pF}$		$C_L = 30 \text{ pF}$		$C_L = 15 \text{ pF}$		UNIT
			TYP	MAX	TYP	MAX	TYP	MAX	
t_{PLH}	A or B	B or A	0.65	7.25	0.4	7.05	0.2	6.85	ns
t_{PHL}			1.6	7.03	1.3	6.5	1	5.4	ns
f_{MAX}			50		100		100		MHz

7.10 Typical Characteristics

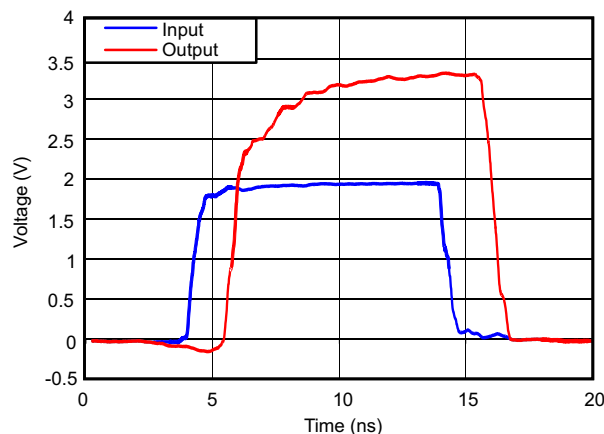
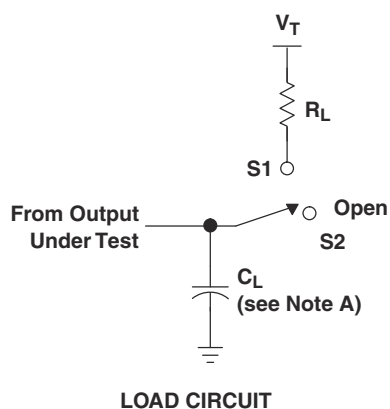
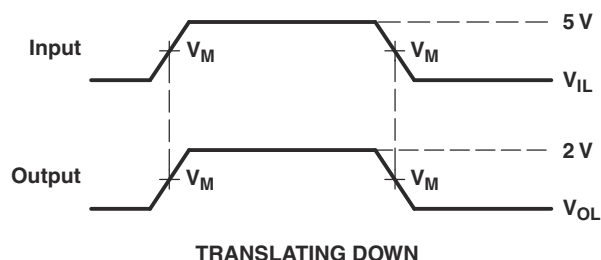
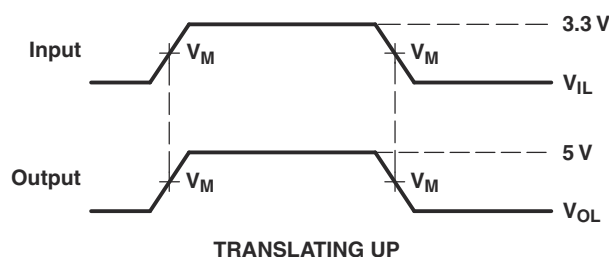


图 7-1. Signal Integrity (1.8 V to 3.3 V Translation Up at 50 MHz)

8 Parameter Measurement Information



USAGE	SWITCH
Translating up	S1
Translating down	S2



- NOTES: A. C_L includes probe and jig capacitance.
B. All input pulses are supplied by generators having the following characteristics: PRR $\leq$ 10 MHz, $Z_O = 50 \Omega$, $t_r \leq 2$ ns, $t_f \leq 2$ ns.
C. The outputs are measured one at a time, with one transition per measurement.

图 8-1. Load Circuit for Outputs

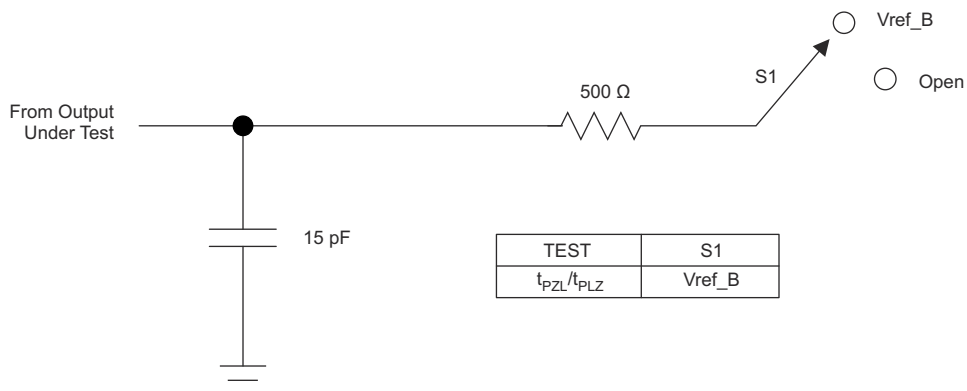


图 8-2. Load Circuit for Enable/Disable Time Measurement

8.1 Load Circuit AC Waveform for Outputs

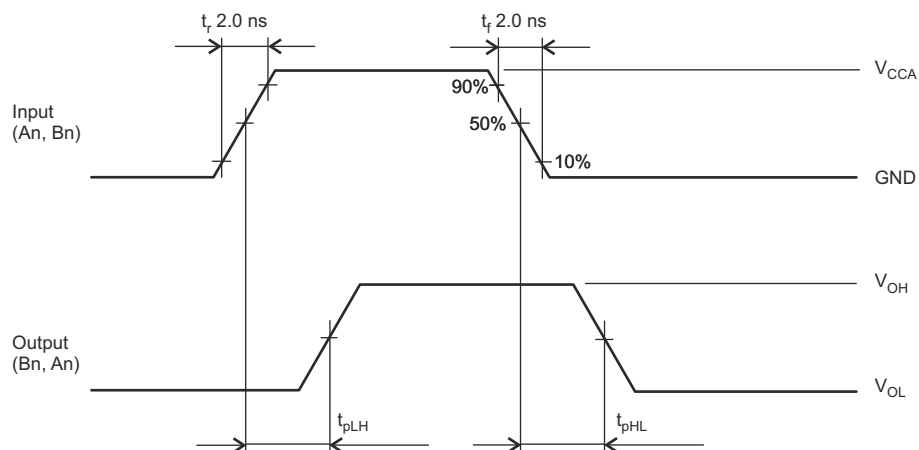


图 8-3. t_{PLH} , t_{PHL}

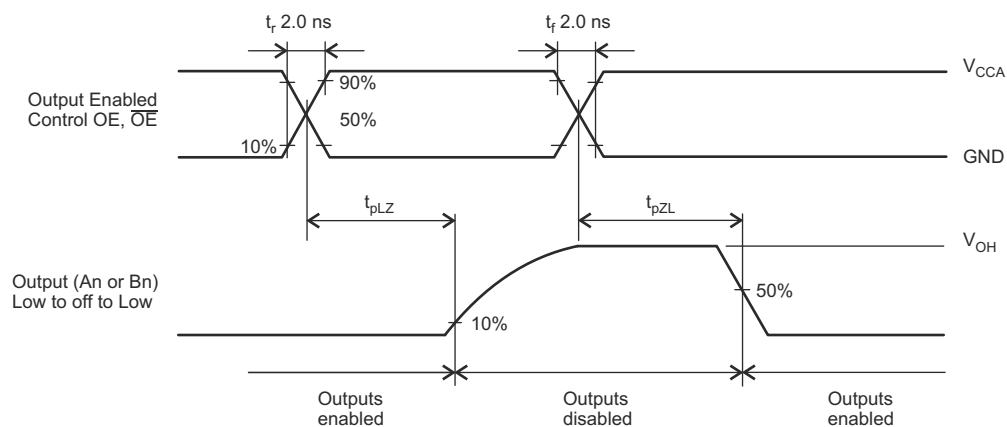


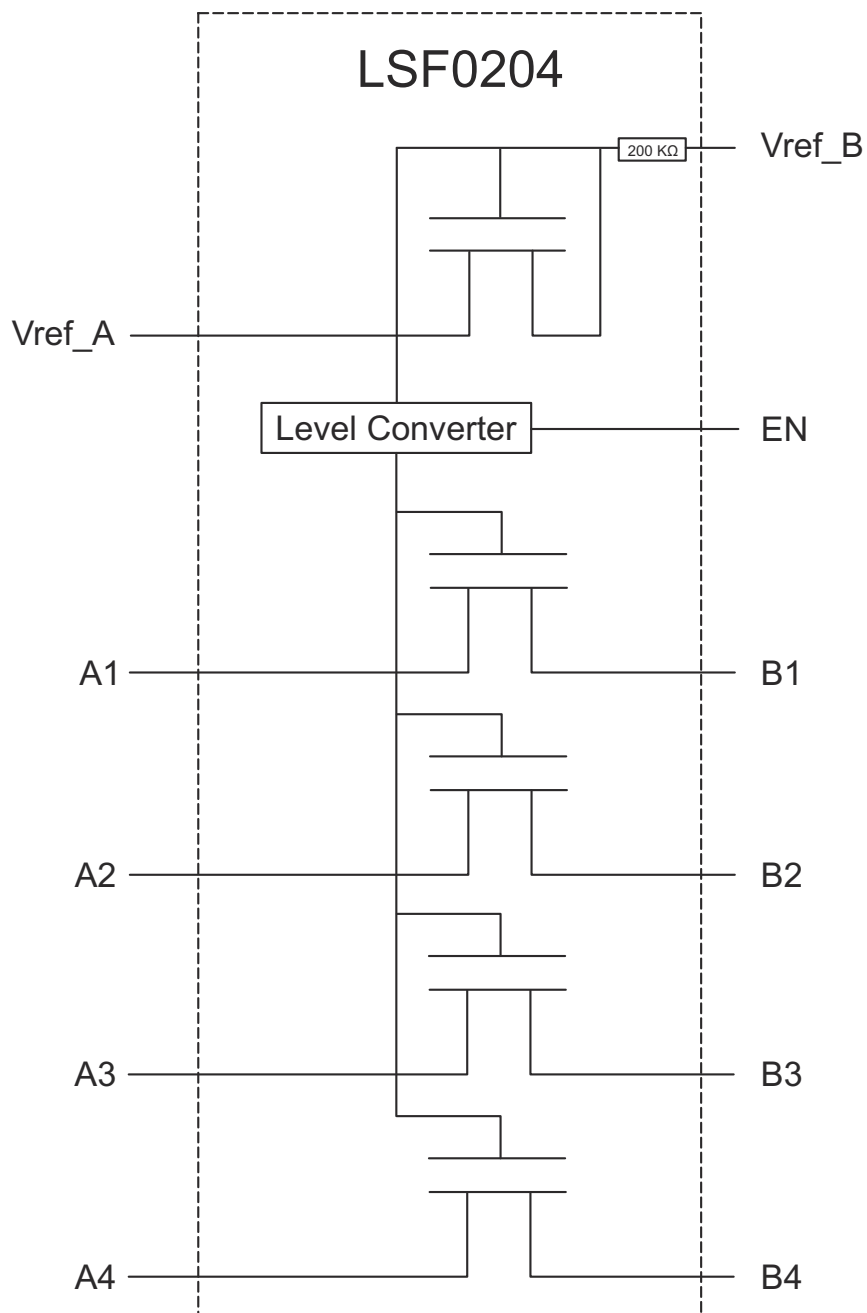
图 8-4. t_{PLZ} , t_{PZL}

9 Detailed Description

9.1 Overview

The LSF Family may be used in level translation applications for interfacing devices or systems operating at different interface voltages with one another. The LSF Family is ideal for use in applications where an open-drain driver is connected to the data I/Os. LSF can achieve 100 MHz with the appropriate pull-up resistors and layout. The LSF Family may also be used in applications where a push-pull driver is connected to the data I/Os.

9.2 Functional Block Diagram



9.3 Feature Description

9.3.1 Support High Speed Translation, Greater than 100 MHz

Allows the LSF family to support more consumer or telecom interfaces (MDIO or SDIO).

9.3.2 Bidirectional Voltage Translation Without DIR Terminal

Minimizes system effort to develop voltage translation for bidirectional interface (PMBus, I2C, or SMBus).

9.3.3 5-V Tolerance on IO Port and 125°C Support

The LSF family, with 5-V tolerance and 125°C support, is flexible and compliant with TTL levels in industrial and telecom applications.

9.3.4 Channel Specific Translation

The LSF family is able to set up different voltage translation levels on each channel.

9.3.5 Ioff, Partial Power Down Mode

When V_{ref_A} , $V_{ref_B} = 0$, all of data pins and EN pin are Hi-Z.

EN logic circuit is supplied by V_{ref_A} , once V_{ref_A} power up first and all of data pins are unknown state until V_{ref_B} and EN ready. No power sequence is required to enable LSF0204 and operate function normally.

9.4 Device Functional Modes

表 9-1 lists the device functional modes of the LSF0204x family of devices.

表 9-1. Function Table

INPUT EN ⁽¹⁾ TERMINAL	FUNCTION
H	$A_n = B_n$
L	Hi-Z

(1) EN is controlled by V_{ref_A} logic levels.

10 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。

10.1 Application Information

LSF performs voltage translation for open-drain or push-pull interface. 表 10-1 provides some consumer/telecom interfaces as reference in regards to the different channel numbers that are supported by the LSF family.

表 10-1. Voltage Translator for Consumer/Telecom Interface

PART NAME	CH#	INTERFACE
LSF0101	1	GPIO
LSF0102	2	GPIO, MDIO, SMBus, PMBus, I2C
LSF0204	4	GPIO, SPI, MDIO, SMBus, PMBus, I2C, UART, SVID
LSF0108	8	GPIO, MDIO, SDIO, SVID, UART, SMBus, PMBus, I2C, SPI

10.2 Typical Applications

10.2.1 I²C PMBus, SMBus, GPIO, Application

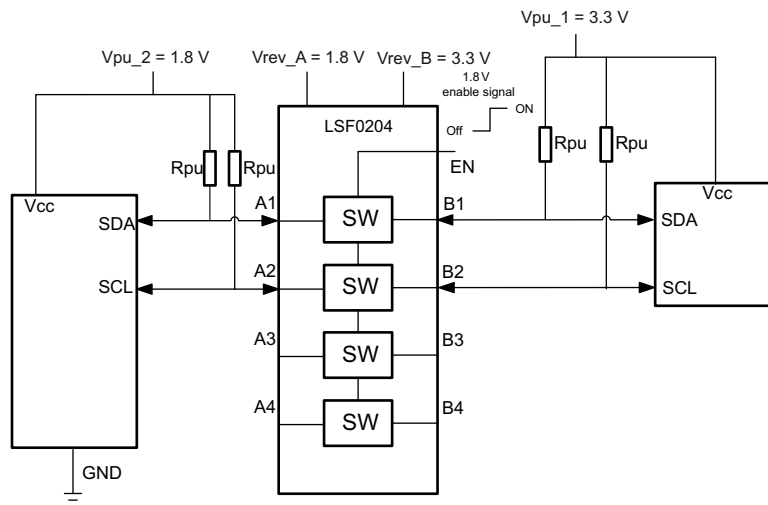


图 10-1. Bidirectional Translation to Multiple Voltage Levels

10.2.1.1 Design Requirements

10.2.1.1.1 Enable, Disable, and Reference Voltage Guidelines

The LSF family has an EN input that is used to disable the device by setting EN LOW, which places all I/Os in the high-impedance state. Since LSF family is switch-type voltage translator, the power consumption is very low. It is recommended to always enable LSF family for bidirectional application (I2C, SMBus, PMBus, or MDIO).

表 10-2. Application Operating Condition

SYMBOL	PARAMETER	MIN	TYP	MAX	UNIT
Vref_A	Reference voltage (A)	0.8		4.5	V
Vref_B	Reference voltage (B)	Vref_A + 0.8		5.5	V
V _{I(EN)} ⁽¹⁾	Input voltage on EN terminal	0		Vref_A	V
Vpu	Pull-up supply voltage	0		Vref_B	V

(1) Refer V_{IH} and V_{IL} for V_{I(EN)}

Also Vref_B is recommended to be at 1.0 V higher than Vref_A for best signal integrity.

The LSF Family is able to set different voltage translation level on each channel.

备注

Vref_A must be set as lowest voltage level.

10.2.1.2 Detailed Design Procedure

10.2.1.2.1 Bidirectional Translation

The controller output driver may be push-pull or open-drain (pull-up resistors may be required) and the peripheral device output can be push-pull or open-drain (pull-up resistors are required to pull the Bn outputs to Vpu).

备注

However, if either output is push-pull, data must be unidirectional or the outputs must be 3-state and be controlled by some direction-control mechanism to prevent HIGH-to-LOW contentions in either direction. If both outputs are open-drain, no direction control is needed.

In 图 10-1, the reference supply voltage (Vref_A) is connected to the processor core power supply voltage. When Vref_B is connected through to a 3.3 V Vpu power supply, and Vref_A is set 1.0V. The output of A3 and B4 has a maximum output voltage equal to Vref_A, and the bidirectional interface (Ch1/2, MDIO) has a maximum output voltage equal to Vpu.

10.2.1.2.1.1 Pull-Up Resistor Sizing

The pull-up resistor value needs to limit the current through the pass transistor when it is in the ON state to about 15 mA. This ensures a pass voltage of 260 mV to 350 mV. If the current through the pass transistor is higher than 15 mA, the pass voltage also is higher in the ON state. To set the current through each pass transistor at 15 mA, to calculate the pull-up resistor value use 方程式 1.

$$R_{pu} = (V_{pu} - 0.35 \text{ V}) / 0.015 \text{ A} \quad (1)$$

表 10-3 summarizes resistor values, reference voltages, and currents at 15 mA, 10 mA, and 3 mA. The resistor value shown in the +10% column (or a larger value) should be used to ensure that the pass voltage of the transistor is 350 mV or less. The external driver must be able to sink the total current from the resistors on both sides of the LSF family device at 0.175 V, although the 15 mA applies only to current flowing through the LSF family device.

表 10-3. Pullup Resistor Values

PULLUP RESISTOR VALUE (Ω)						
V_{DDU}	15 mA	10 mA	3 mA			
	NOMINAL	+10% ⁽¹⁾	NOMINAL	+10% ⁽¹⁾	NOMINAL	+10% ⁽¹⁾
5 V	310	341	465	512	1550	1705
3.3 V	197	217	295	325	983	1082
2.5 V	143	158	215	237	717	788
1.8 V	97	106	145	160	483	532
1.5 V	77	85	115	127	383	422
1.2 V	57	63	85	94	283	312

(1) +10% to compensate for V_{DD} range and resistor tolerance

10.2.1.2.2 LS Family Bandwidth

The maximum frequency of the LSF family is dependent on the application. The device may operate at speeds of >100 MHz given the correct conditions. The maximum frequency is dependent upon the loading of the application. The LSF family behaves like a standard switch where the bandwidth of the device is dictated by the on resistance and on capacitance of the device.

图 10-2 shows a bandwidth measurement of the LSF family using a two-port network analyzer.

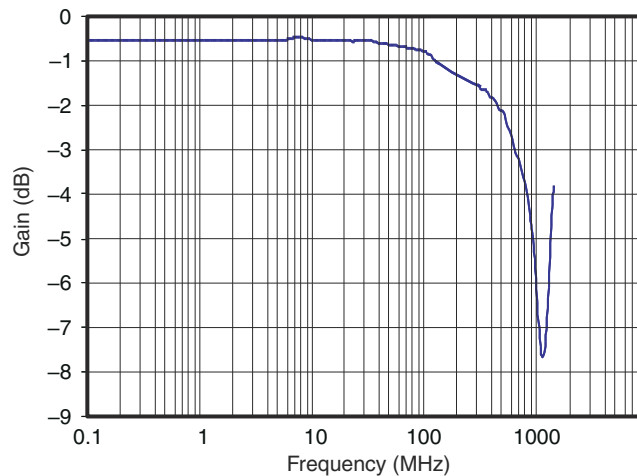


图 10-2. 3-dB Bandwidth

The 3-dB point of the LSF family is ≈ 600 MHz; however, this measurement is an analog type of measurement. For digital applications, the signal should not degrade up to the fifth harmonic of the digital signal. The frequency bandwidth should be at least five times the maximum digital clock rate. This component of the signal is important in determining the overall shape of the digital signal. In the case of the LSF family, a digital clock frequency of greater than 100 MHz may be achieved.

The LSF family does not provide any drive capability. Therefore higher frequency applications will require higher drive strength from the host side. No pullup resistor is needed on the host side (3.3 V) if the LSF family is being driven by standard CMOS totem pole output driver. Best practice is to minimize the trace length from the LSF family on the sink side (1.8 V) to minimize signal degradation.

All fast edges have an infinite spectrum of frequency components; however, there is an inflection (or *knee*) in the frequency spectrum of fast edges where frequency components higher than f_{knee} are insignificant in determining the shape of the signal.

To calculate the maximum *practical* frequency component, or the *knee* frequency (f_{knee}), use the following equations:

$$f_{knee} = 0.5/RT \text{ (10 - 80\%)} \quad (2)$$

$$f_{knee} = 0.4/RT \text{ (20 - 80\%)} \quad (3)$$

For signals with rise time characteristics based on 10- to 90-percent thresholds, f_{knee} is equal to 0.5 divided by the rise time of the signal. For signals with rise time characteristics based on 20% to 80% thresholds, which is very common in many of today's device specifications, f_{knee} is equal to 0.4 divided by the rise time of the signal.

Some guidelines to follow that will help maximize the performance of the device:

- Keep trace length to a minimum by placing the LSF family close to the I²C output of the processor.
- The trace length should be less than half the time of flight to reduce ringing and line reflections or non-monotonic behavior in the switching region.
- To reduce overshoots, a pullup resistor can be added on the 1.8 V side; be aware that a slower fall time is to be expected.

10.2.1.3 Application Curve

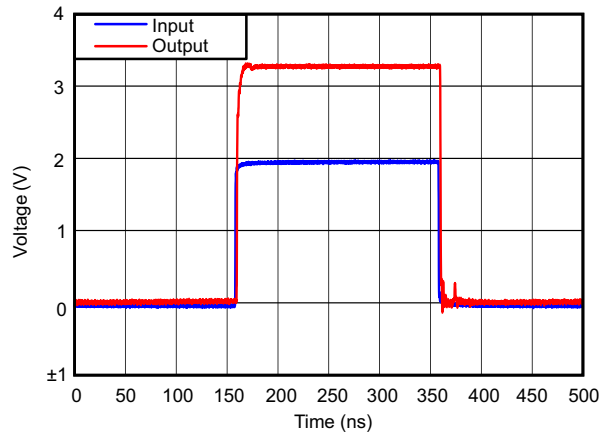


图 10-3. Captured Waveform From Above I²C Set-Up (1.8 V to 3.3 V at 2.5 MHz)

10.2.2 MDIO Application

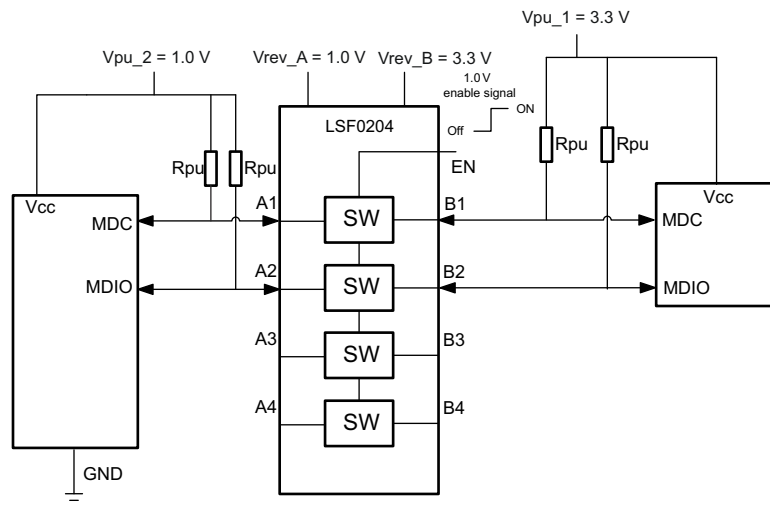


图 10-4. Typical Application Circuit (MDIO/Bidirectional Interface)

10.2.2.1 Design Requirements

Refer to [Design Requirements](#).

10.2.2.2 Detailed Design Procedure

Refer to [Detailed Design Procedure](#)

10.2.2.3 Application Curve

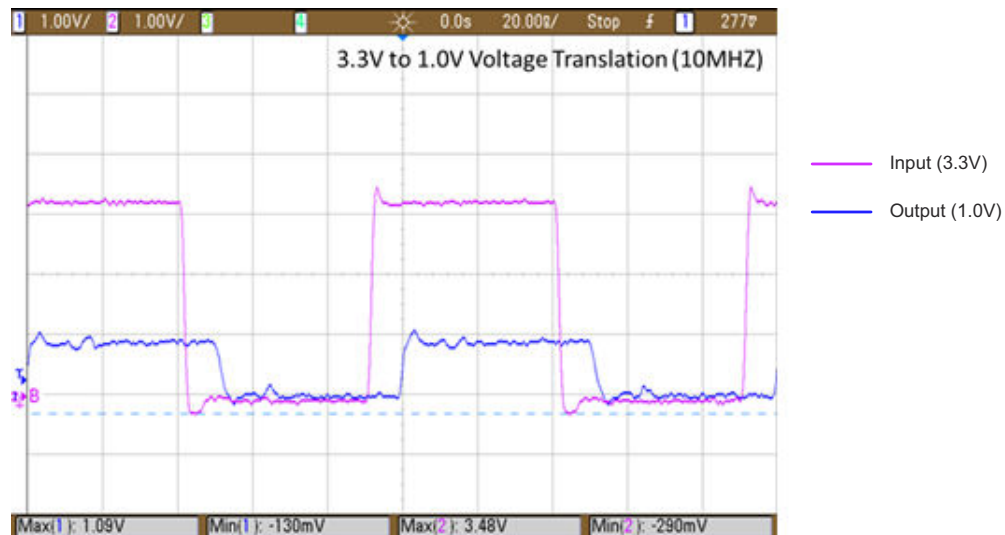
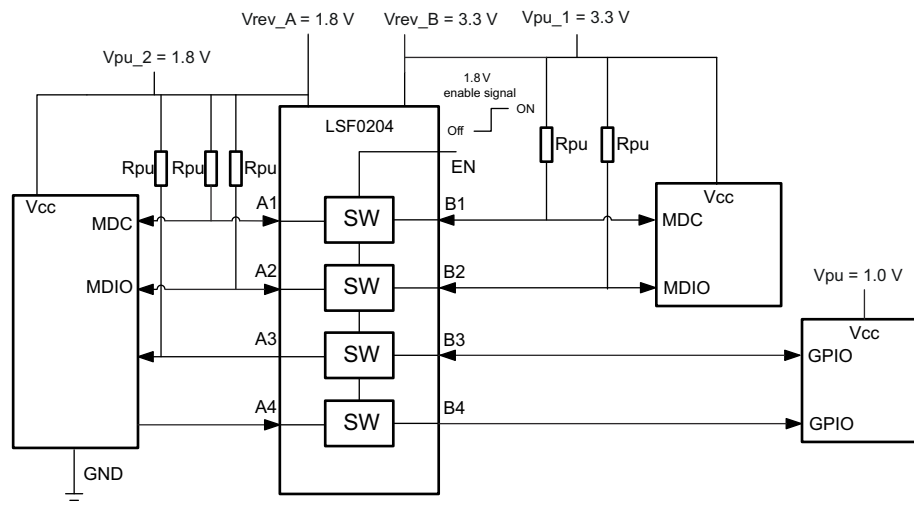


图 10-5. Captured Waveform From Above MDIO Setup

10.2.3 Multiple Voltage Translation in Single Device, Application



10.2.3.1 Design Requirements

Refer to [Design Requirements](#).

10.2.3.2 Detailed Design Procedure

Refer to [Detailed Design Procedure](#)

10.2.3.3 Application Curve

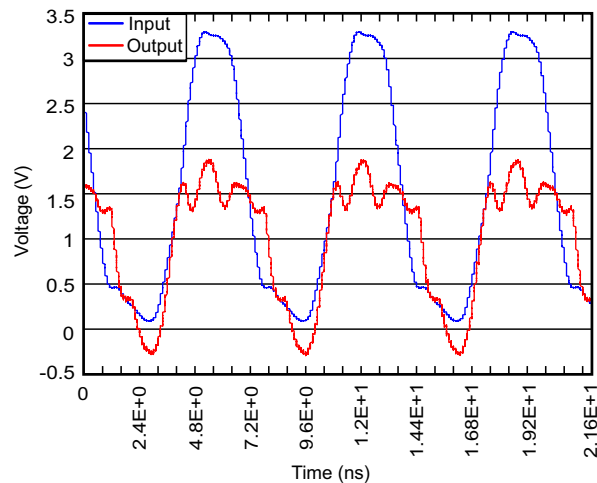


图 10-6. Translation Down (3.3 V to 1.8 V) at 150 MHz

11 Power Supply Recommendations

There are no power sequence requirements for the LSF Family. Refer to [§ 10.2.1.1.1](#) for enabling and reference voltage guidelines.

12 Layout

12.1 Layout Guidelines

The signal integrity is highly related with pull-up resistor and PCB capacitance condition because LSF Family is switch-type level translator

- Short signal trace as possible to reduce capacitance and minimize stub from pull-up resistor.
- Place LSF close to high voltage side.
- Select the appropriate pull-up resistor that applies to translation levels and driving capability of transmitter.

12.2 Layout Example

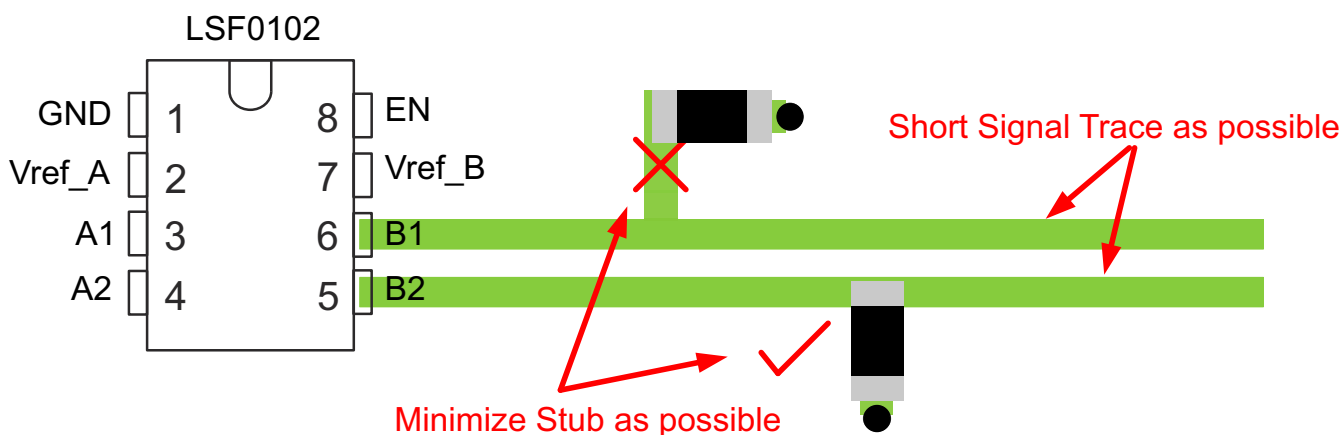


图 12-1. Short Trace Layout

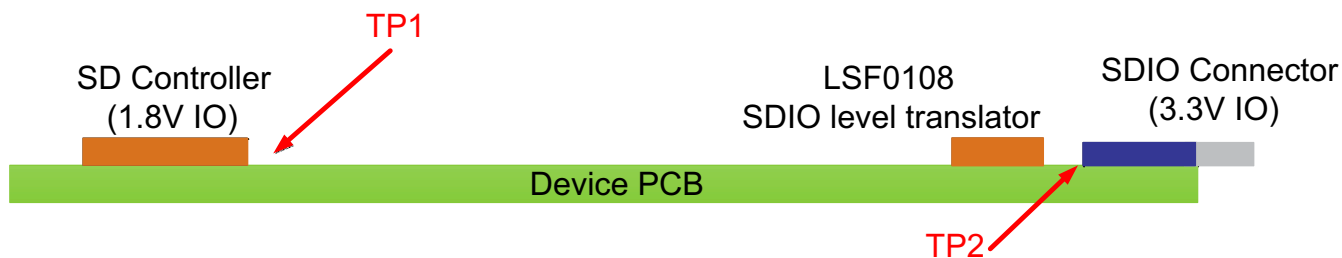


图 12-2. Device Placement

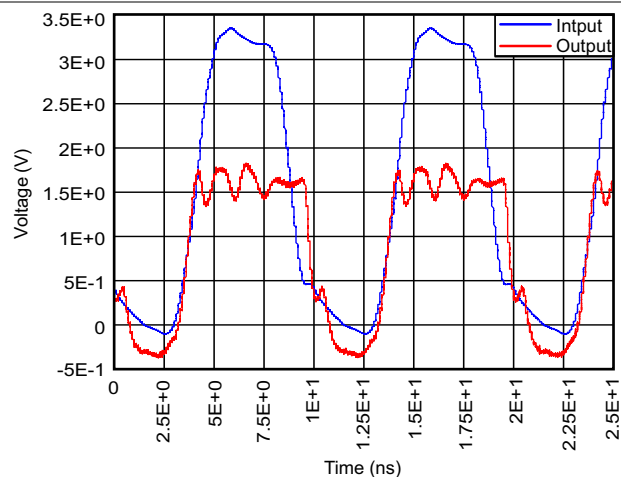


图 12-3. Waveform From TP1 (Pullup Resistor: 160- Ω and 50-pF Capacitance 3.3 to 1.8 V at 100 MHz)

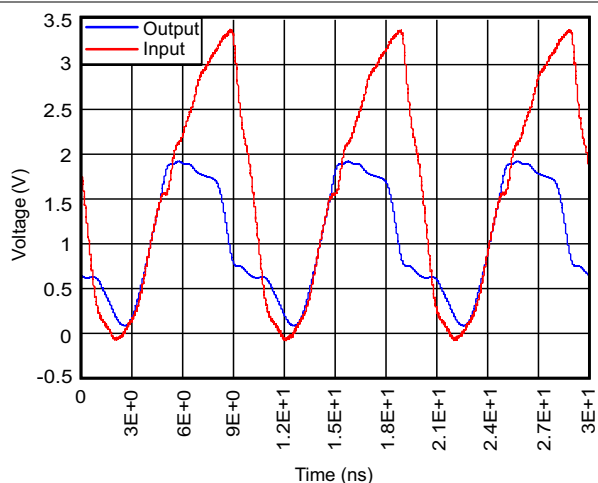


图 12-4. Waveform From TP2 (Pullup Resistor: 160- Ω and 50-pF Capacitance 1.8 to 3.3 V at 100 MHz)

13 Device and Documentation Support

13.1 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 [订阅更新](#) 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。

13.2 支持资源

TI E2E™ 支持论坛 是工程师的重要参考资料，可直接从专家获得快速、经过验证的解答和设计帮助。搜索现有解答或提出自己的问题可获得所需的快速设计帮助。

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](#)》。

13.3 Trademarks

TI E2E™ is a trademark of Texas Instruments.
所有商标均为其各自所有者的财产。

13.4 Electrostatic Discharge Caution



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

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

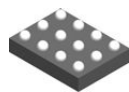
13.5 术语表

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。

14 Mechanical, Packaging, and Orderable Information

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

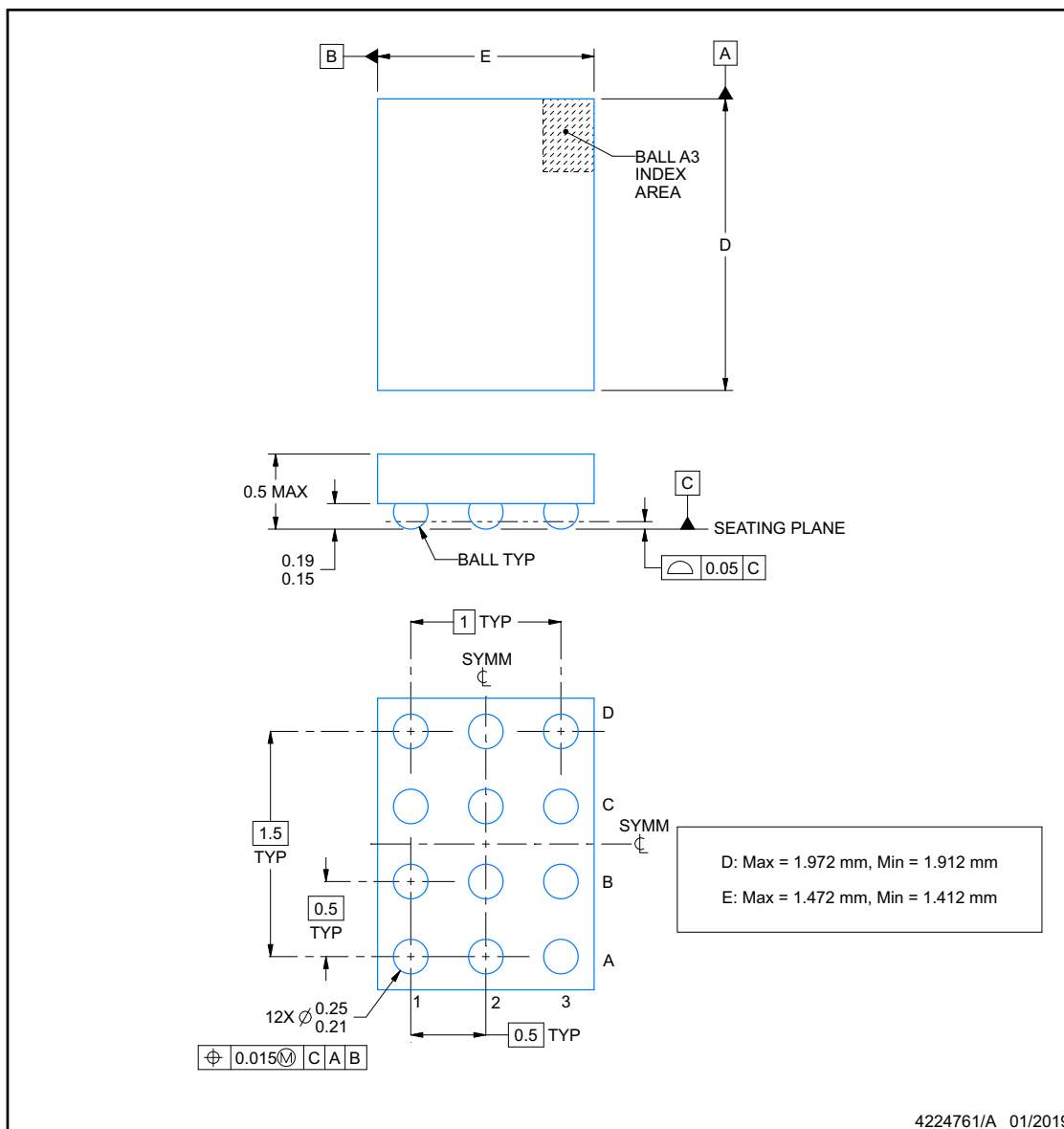
LSF0204/LSF0204D
YZP0012-C01



PACKAGE OUTLINE

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY



NOTES:

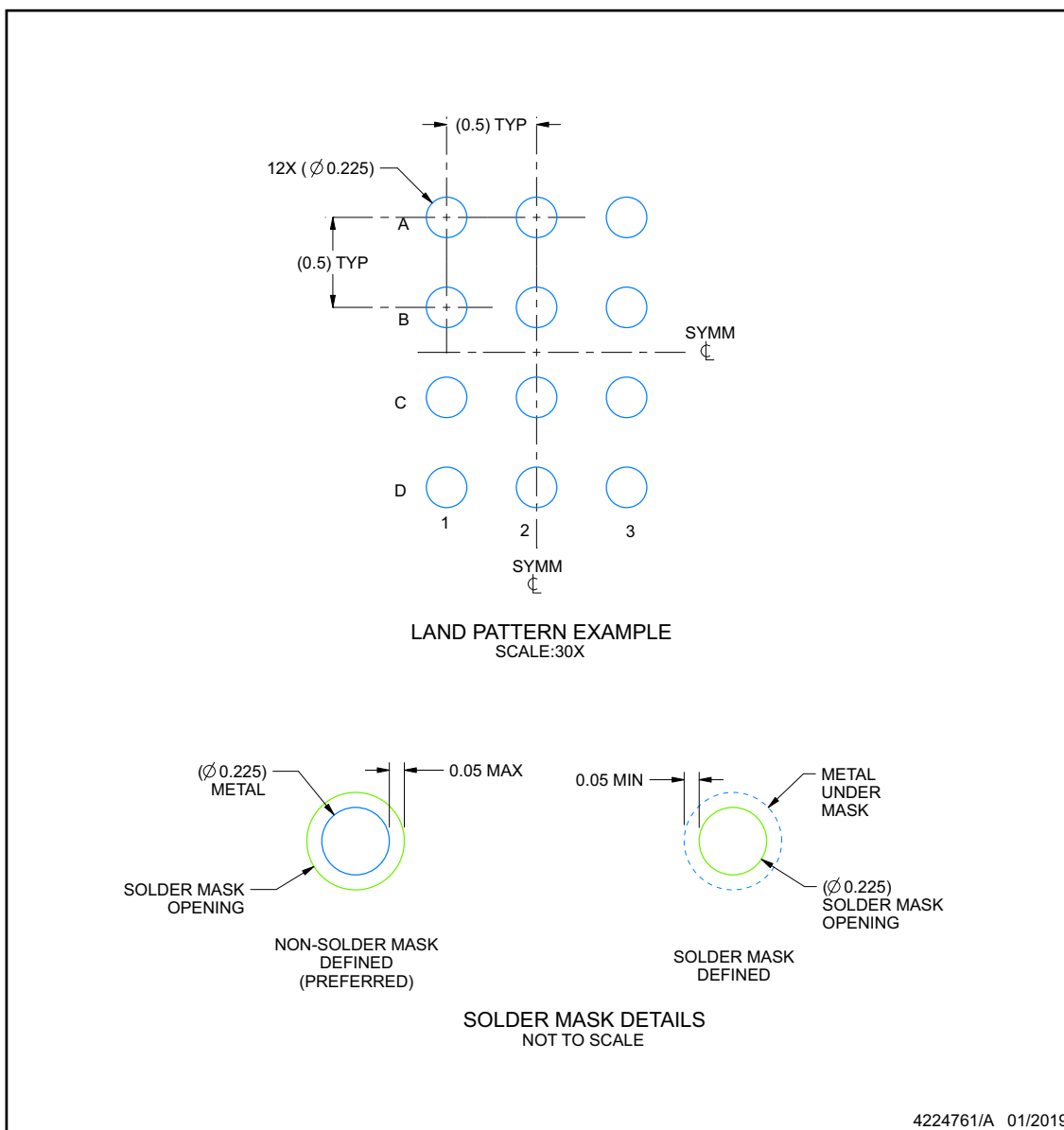
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.

LSF0204/LSF0204D
YZP0012-C01

EXAMPLE BOARD LAYOUT

DSBGA - 0.5 mm max height

DIE SIZE BALL GRID ARRAY

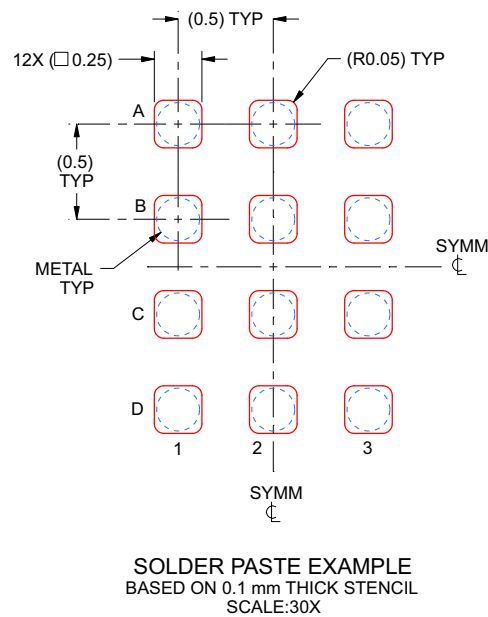


NOTES: (continued)

- Final dimensions may vary due to manufacturing tolerance considerations and also routing constraints. For more information, see Texas Instruments literature number SBVA017 (www.ti.com/lit/sbva017).

LSF0204/LSF0204D
YZP0012-C01
EXAMPLE STENCIL DESIGN**DSBGA - 0.5 mm max height**

DIE SIZE BALL GRID ARRAY



4224761/A 01/2019

NOTES: (continued)

4. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release.

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)
LSF0204DPWR	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LSF204D
LSF0204DPWR.B	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LSF204D
LSF0204DRGYR	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LSF24D
LSF0204DRGYR.B	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LSF24D
LSF0204DRGYRG4	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LSF24D
LSF0204DRGYRG4.B	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LSF24D
LSF0204DRUTR	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIO
LSF0204DRUTR.B	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIO
LSF0204DRUTRG4	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIO
LSF0204DRUTRG4.B	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIO
LSF0204DYZPR	Active	Production	DSBGA (YZP) 12	3000 LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 125	G6
LSF0204DYZPR.B	Active	Production	DSBGA (YZP) 12	3000 LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 125	G6
LSF0204PWR	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LSF204
LSF0204PWR.B	Active	Production	TSSOP (PW) 14	2000 LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	LSF204
LSF0204RGYR	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LSF24
LSF0204RGYR.B	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LSF24
LSF0204RGYRG4	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LSF24
LSF0204RGYRG4.B	Active	Production	VQFN (RGY) 14	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LSF24
LSF0204RUTR	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIN
LSF0204RUTR.B	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIN
LSF0204RUTRG4	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIN
LSF0204RUTRG4.B	Active	Production	UQFN (RUT) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIN
LSF0204YZPR	Active	Production	DSBGA (YZP) 12	3000 LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 125	G5
LSF0204YZPR.B	Active	Production	DSBGA (YZP) 12	3000 LARGE T&R	Yes	SNAGCU	Level-1-260C-UNLIM	-40 to 125	G5

⁽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.

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

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

OTHER QUALIFIED VERSIONS OF LSF0204 :

- Automotive : [LSF0204-Q1](#)

NOTE: Qualified Version Definitions:

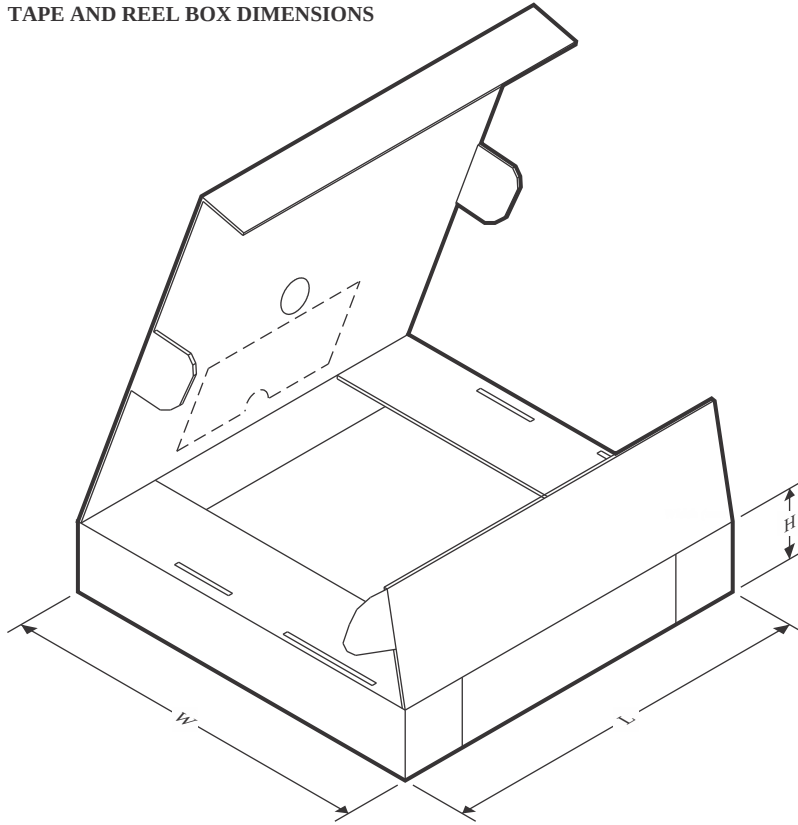
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION


*All dimensions are nominal

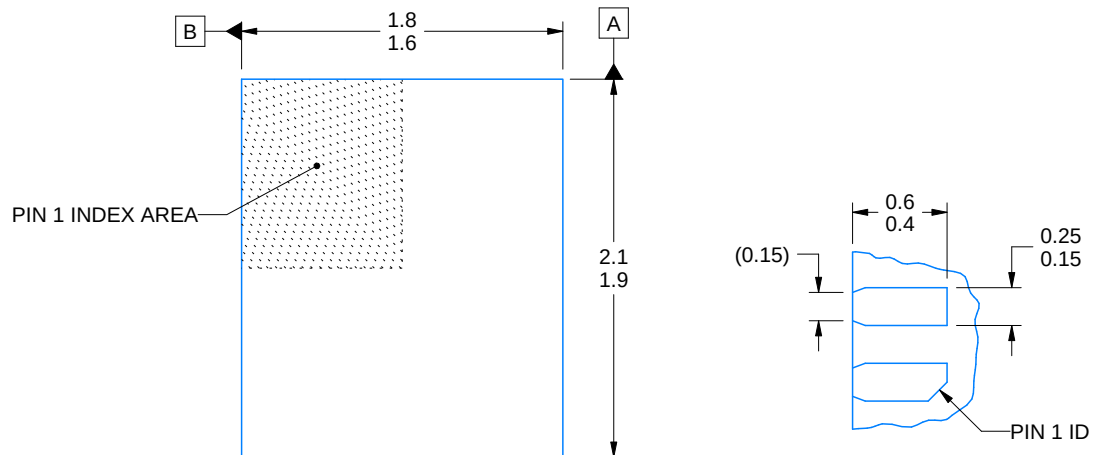
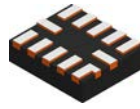
Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LSF0204DPWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
LSF0204DRGYR	VQFN	RGY	14	3000	330.0	12.4	3.75	3.75	1.15	8.0	12.0	Q2
LSF0204DRGYRG4	VQFN	RGY	14	3000	330.0	12.4	3.75	3.75	1.15	8.0	12.0	Q2
LSF0204DRUTR	UQFN	RUT	12	3000	180.0	9.5	1.9	2.3	0.75	4.0	8.0	Q1
LSF0204DRUTRG4	UQFN	RUT	12	3000	180.0	9.5	1.9	2.3	0.75	4.0	8.0	Q1
LSF0204DYZPR	DSBGA	YZP	12	3000	180.0	8.4	1.63	2.08	0.69	4.0	8.0	Q2
LSF0204PWR	TSSOP	PW	14	2000	330.0	12.4	6.9	5.6	1.6	8.0	12.0	Q1
LSF0204RGYR	VQFN	RGY	14	3000	330.0	12.4	3.75	3.75	1.15	8.0	12.0	Q2
LSF0204RGYRG4	VQFN	RGY	14	3000	330.0	12.4	3.75	3.75	1.15	8.0	12.0	Q2
LSF0204RUTR	UQFN	RUT	12	3000	180.0	9.5	1.9	2.3	0.75	4.0	8.0	Q1
LSF0204RUTRG4	UQFN	RUT	12	3000	180.0	9.5	1.9	2.3	0.75	4.0	8.0	Q1
LSF0204YZPR	DSBGA	YZP	12	3000	180.0	8.4	1.63	2.08	0.69	4.0	8.0	Q2

TAPE AND REEL BOX DIMENSIONS

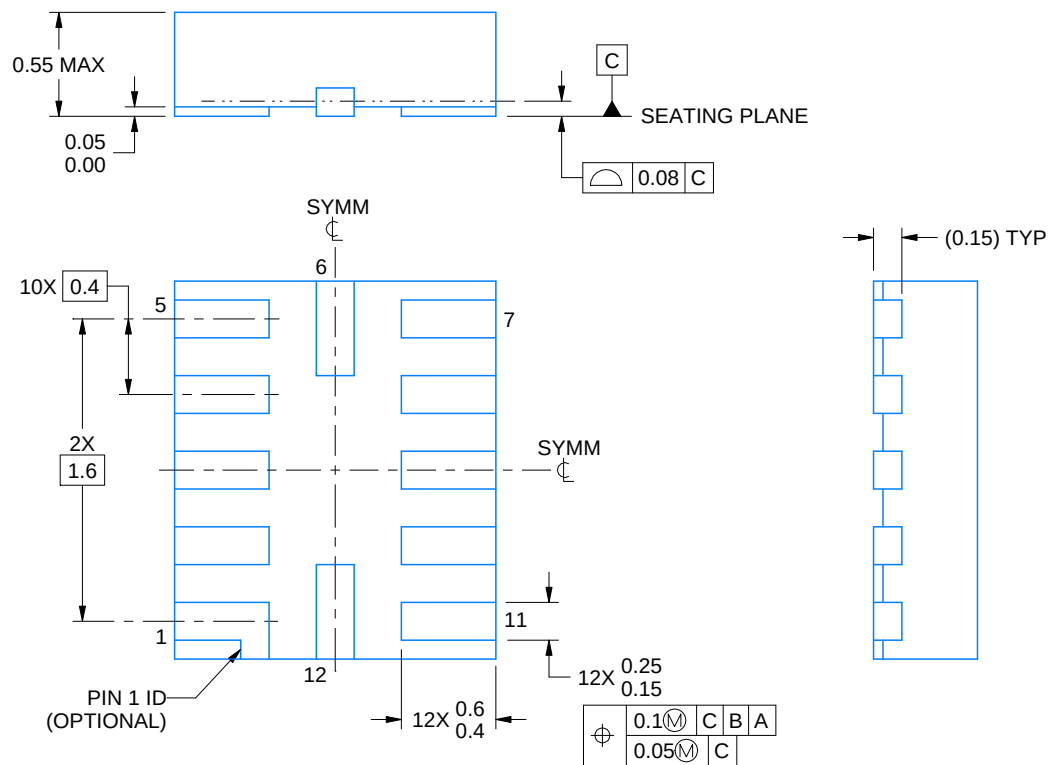


*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LSF0204DPWR	TSSOP	PW	14	2000	364.0	364.0	27.0
LSF0204DRGYR	VQFN	RGY	14	3000	346.0	346.0	33.0
LSF0204DRGYRG4	VQFN	RGY	14	3000	346.0	346.0	33.0
LSF0204DRUTR	UQFN	RUT	12	3000	184.0	184.0	19.0
LSF0204DRUTRG4	UQFN	RUT	12	3000	184.0	184.0	19.0
LSF0204DYZPR	DSBGA	YZP	12	3000	182.0	182.0	20.0
LSF0204PWR	TSSOP	PW	14	2000	364.0	364.0	27.0
LSF0204RGYR	VQFN	RGY	14	3000	346.0	346.0	33.0
LSF0204RGYRG4	VQFN	RGY	14	3000	346.0	346.0	33.0
LSF0204RUTR	UQFN	RUT	12	3000	184.0	184.0	19.0
LSF0204RUTRG4	UQFN	RUT	12	3000	184.0	184.0	19.0
LSF0204YZPR	DSBGA	YZP	12	3000	182.0	182.0	20.0



OPTIONAL TERMINAL & PIN 1 ID



4220310/A 11/2016

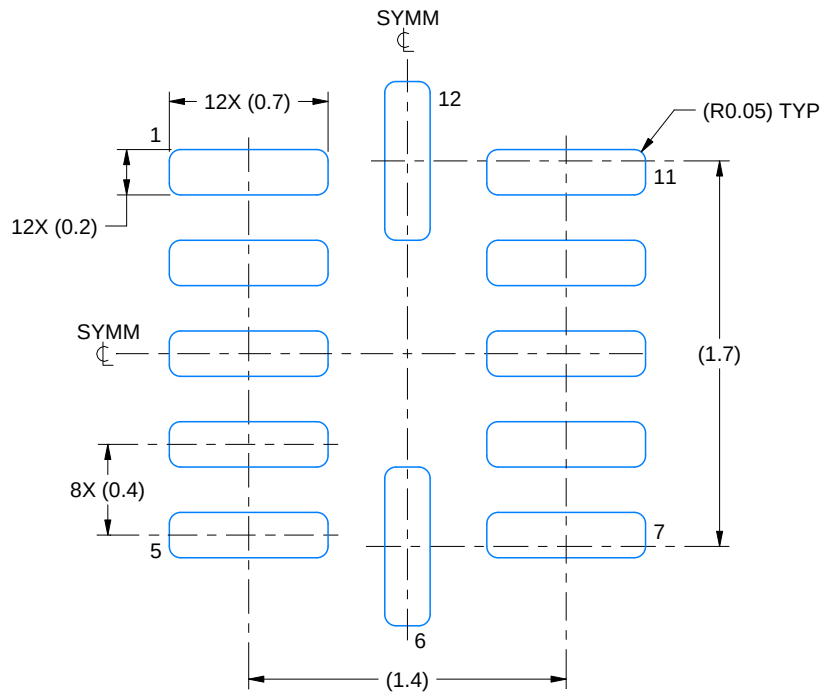
NOTES:

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.

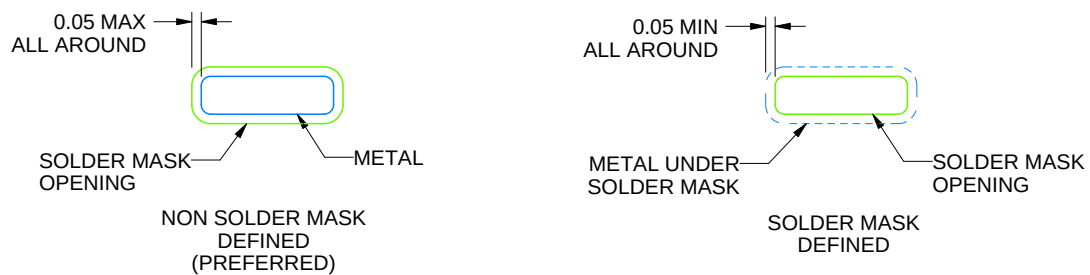
RUT0012A

UQFN - 0.55 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
SCALE:30X



SOLDER MASK DETAILS

4220310/A 11/2016

NOTES: (continued)

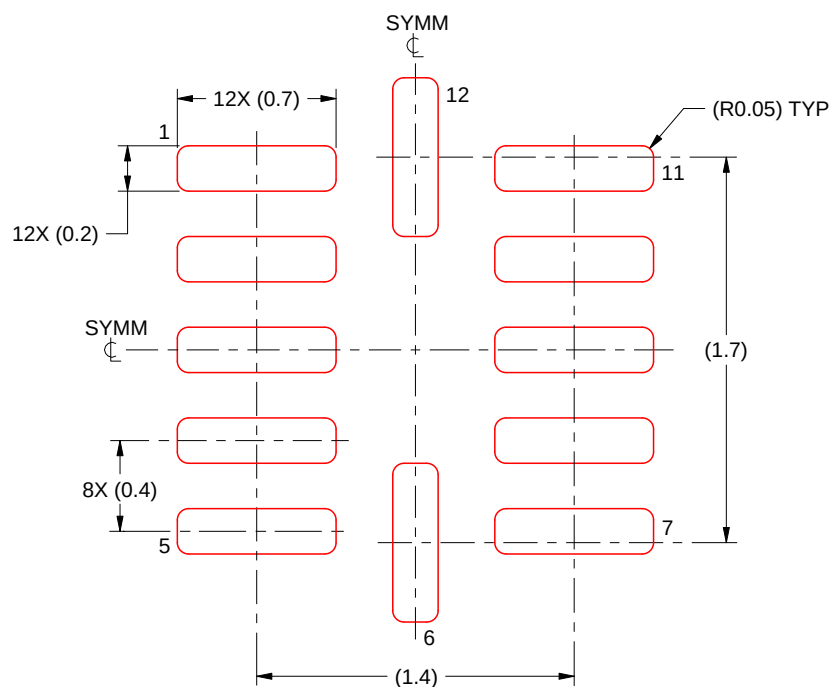
3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/sl原因271).

EXAMPLE STENCIL DESIGN

RUT0012A

UQFN - 0.55 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

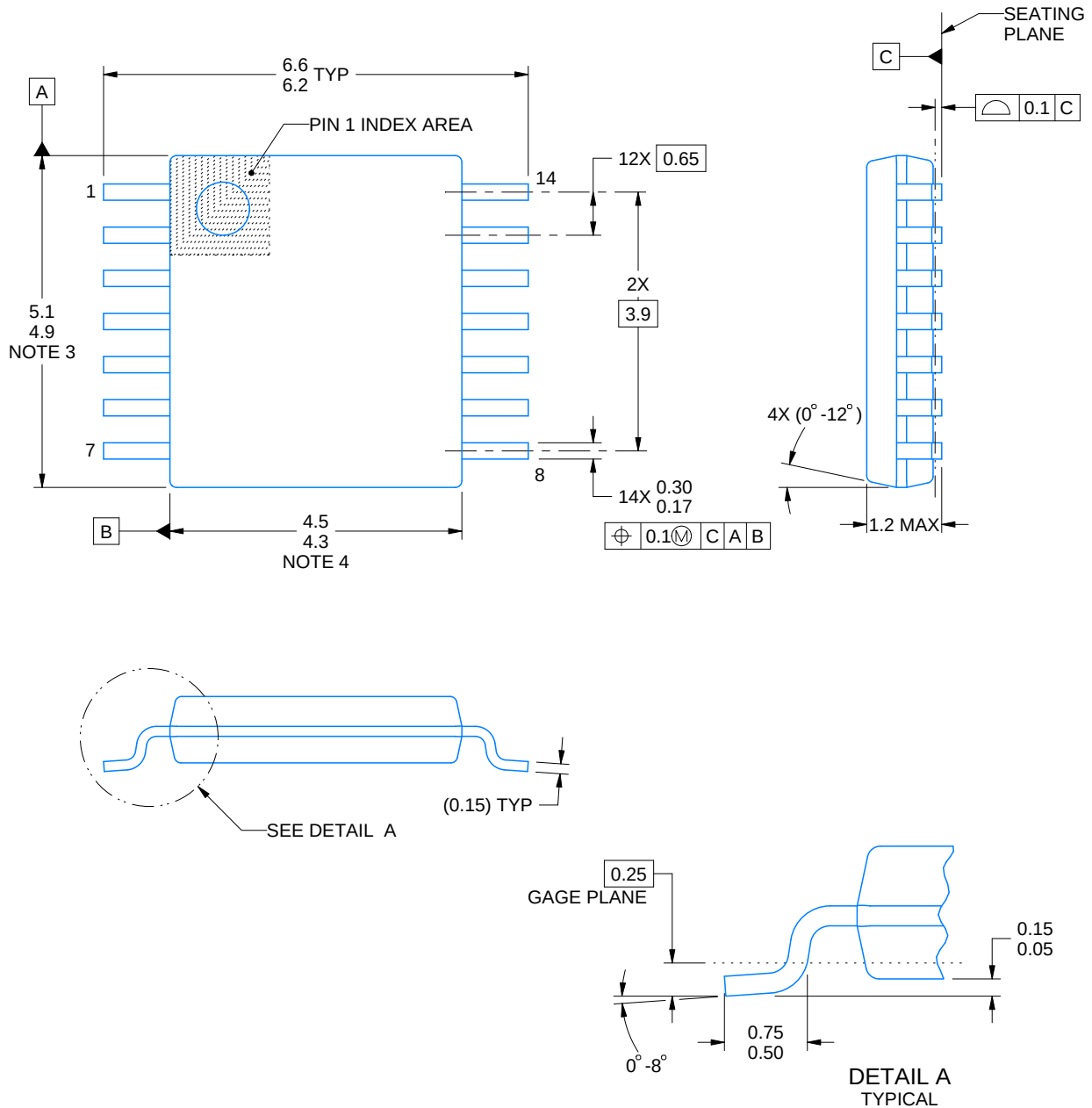
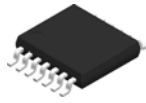


SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL
SCALE: 30X

4220310/A 11/2016

NOTES: (continued)

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



4220202/B 12/2023

NOTES:

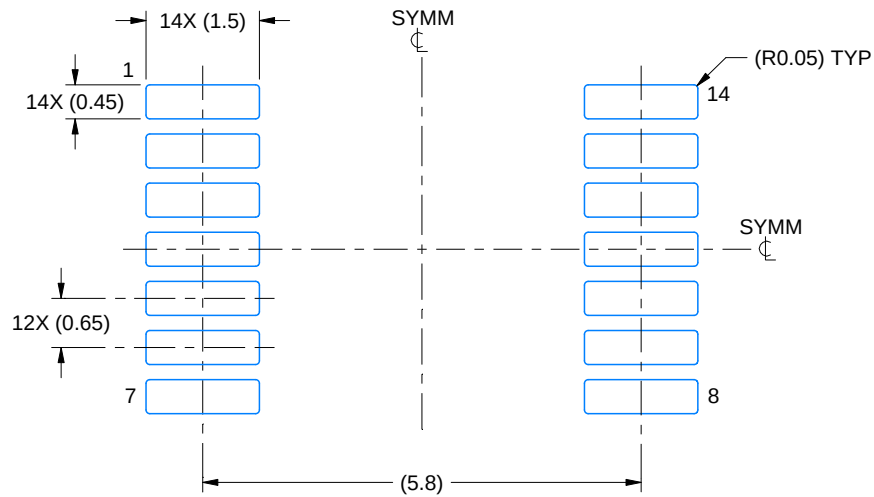
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or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

EXAMPLE BOARD LAYOUT

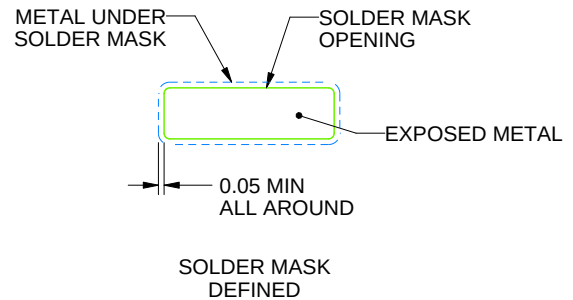
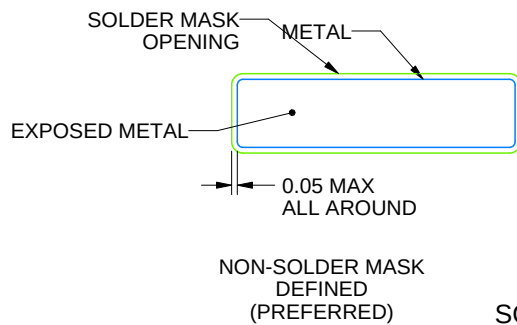
PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 10X



SOLDER MASK DETAILS

4220202/B 12/2023

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.

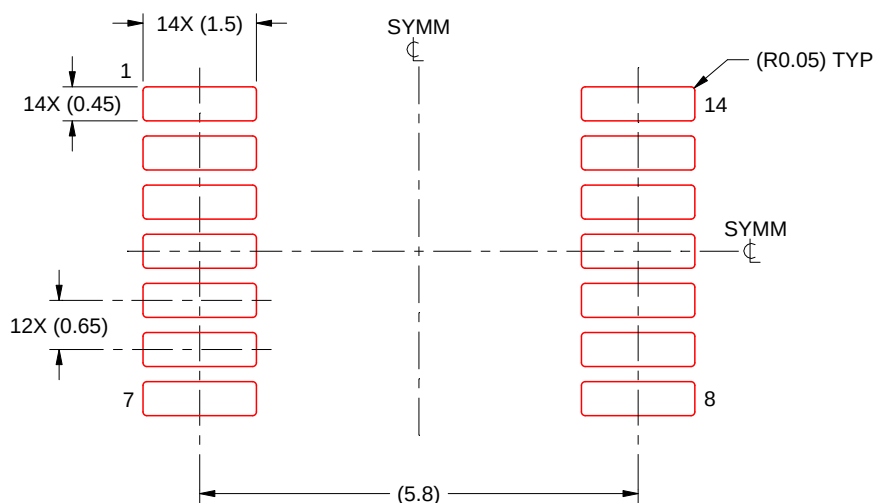
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

EXAMPLE STENCIL DESIGN

PW0014A

TSSOP - 1.2 mm max height

SMALL OUTLINE PACKAGE



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

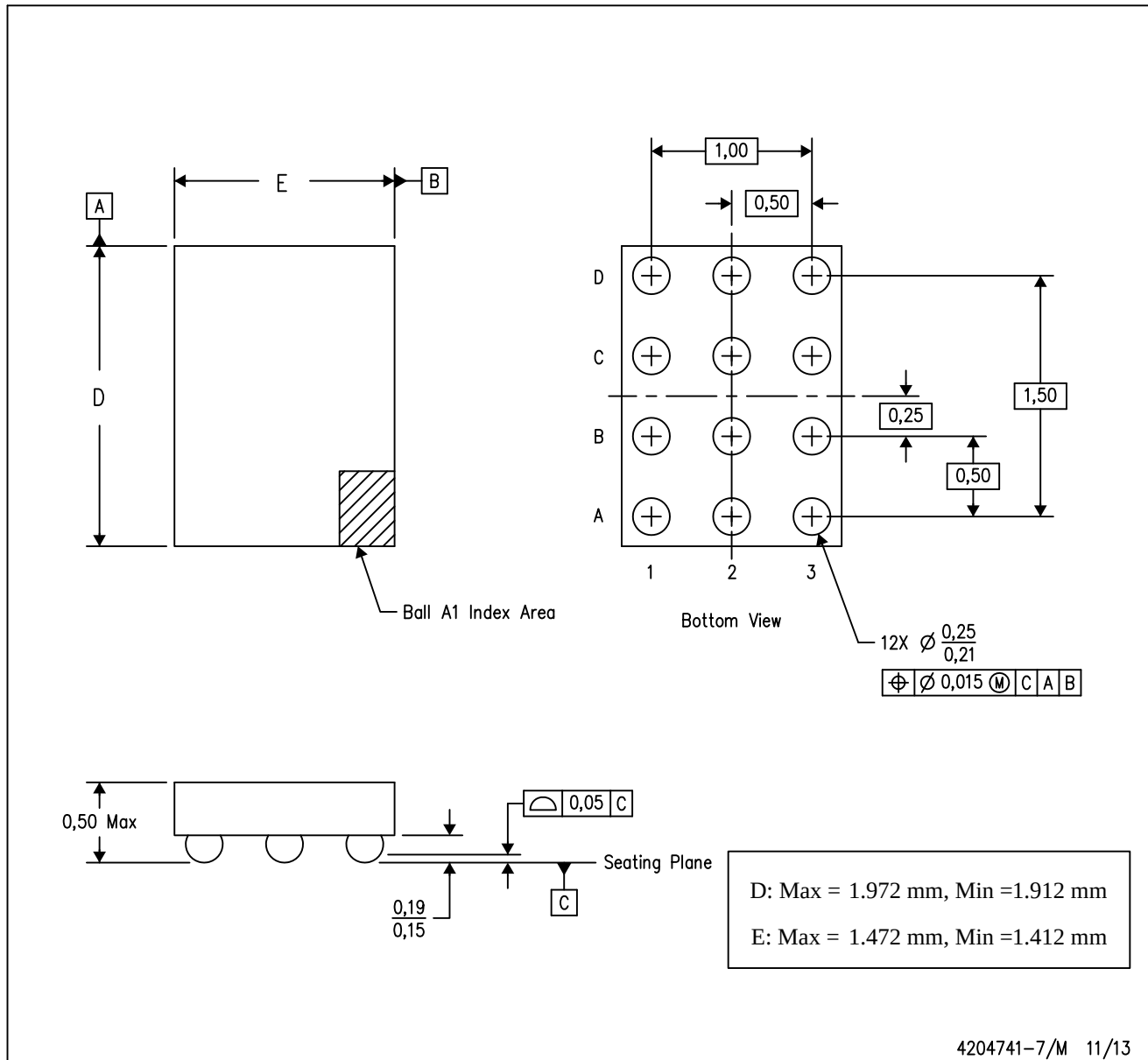
4220202/B 12/2023

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.

YZP (R-XBGA-N12)

DIE-SIZE BALL GRID ARRAY



- NOTES:
- A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
 - B. This drawing is subject to change without notice.
 - C. NanoFree™ package configuration.

GENERIC PACKAGE VIEW

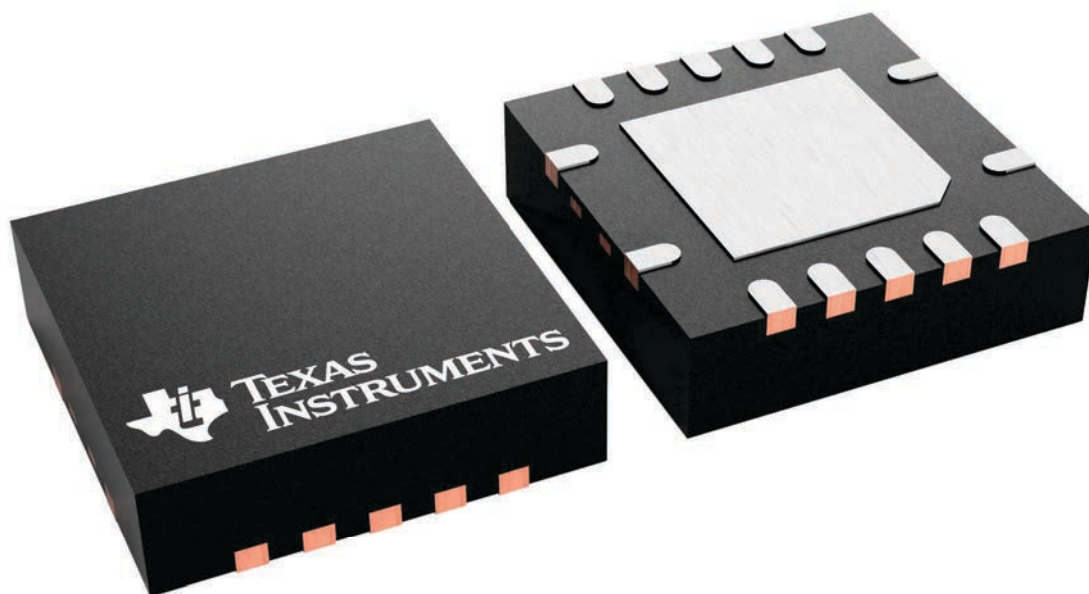
RGY 14

VQFN - 1 mm max height

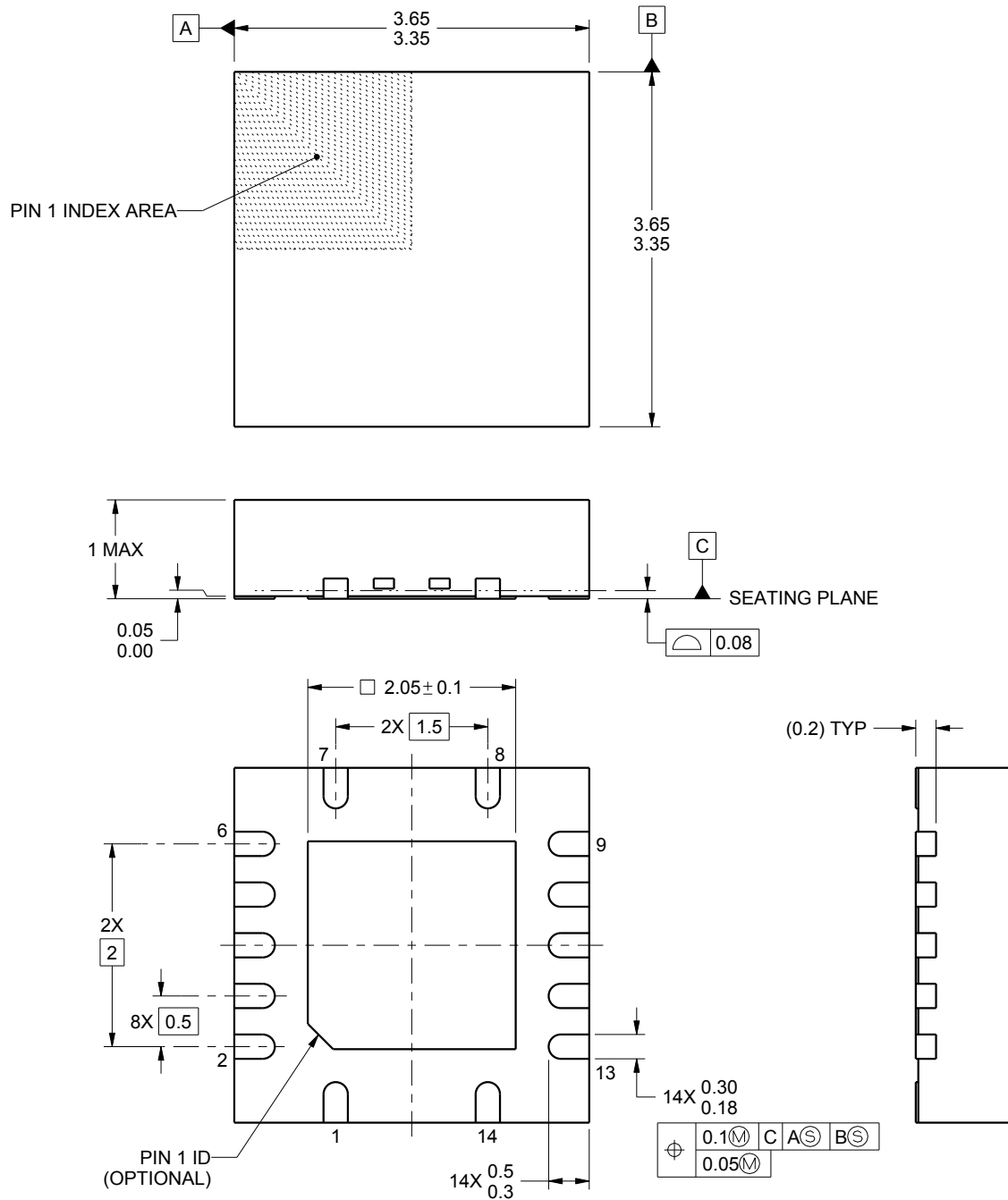
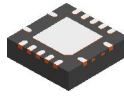
3.5 x 3.5, 0.5 mm pitch

PLASTIC QUAD FLATPACK - NO LEAD

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



4231541/A



4219040/A 09/2015

NOTES:

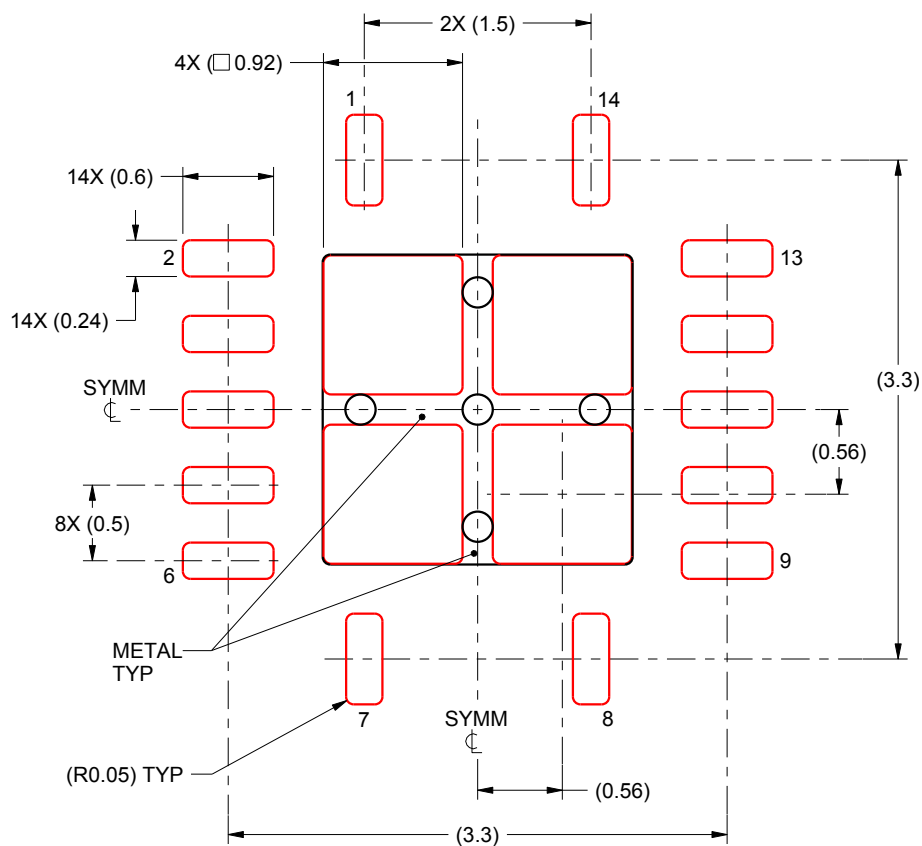
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE STENCIL DESIGN

RGY0014A

VQFN - 1 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
80% PRINTED SOLDER COVERAGE BY AREA
SCALE:20X

4219040/A 09/2015

NOTES: (continued)

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

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