LSF0204x 4-Bits Bidirectional Multi-Voltage Level Translator for Open-Drain and Push-Pull Application

1 Features

- Provides Bidirectional Voltage Translation With No Direction Terminal
- Supports up to 100-MHz up Translation and Greater Than 100-MHz Down Translation at ≤ 30-pF Capacitor Load and up to 40-MHz Up/Down Translation at 50-pF Capacitor Load
- Supports I_{off}, Partial Power Down Mode (Refer to *Feature Description*)
- Allows Bidirectional Voltage Level Translation Between
  - 0.8 V ↔ 1.8, 2.5, 3.3, 5 V
  - 1.2 V ↔ 1.8, 2.5, 3.3, 5 V
  - 1.8 V ↔ 2.5, 3.3, 5 V
  - 2.5 V ↔ 3.3, 5 V
  - 3.3 V ↔ 5 V
- Low Standby Current
- 5 V Tolerance I/O Port to Support TTL
- Low R_{on} Provides Less Signal Distortion
- High-Impedance I/O Terminals For EN = Low
- Flow-Through Pinout for Ease PCB Trace Routing
- Latch-Up Performance Exceeds 100 mA Per JESD17
- –40°C to 125°C Operating Temperature Range
- ESD Performance Tested Per JESD 22
  - 2000-V Human-Body Model (A114-B, Class II)
  - 200-V Machine Model (A115-A)
  - 1000-V Charged-Device Model (C101)

2 Applications

- GPIO, MDIO, PMBus, SMBus, SDIO, UART, I^2C, and Other Interfaces in Telecom Infrastructure
- Industrial
- Automotive
- Personal Computing

3 Description

The LSF family consists of bidirectional voltage level translators that operate from 0.8 V to 4.5 V (Vref_A) and 1.8 V to 5.5 V (Vref_B). This range allows for bidirectional voltage translations between 0.8 V and 5.0 V without the need for a direction terminal in open-drain or push-pull applications. The LSF family supports level translation applications with transmission speeds greater than 100 MHz for open-drain systems that utilize a 15-pF capacitance and 165-Ω pull-up resistor.

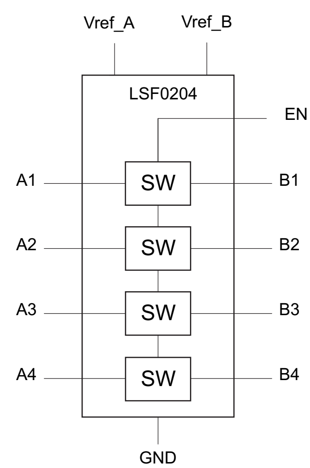
When the An or Bn port is LOW, the switch is in the ON-state and a low resistance connection exists between the An and Bn ports. The low R_{on} of the switch allows connections to be made with minimal propagation delay and signal distortion. The voltage on the A or B side will be limited to Vref_A and can be pulled up to any level between Vref_A and 5 V. This functionality allows a seamless translation between higher and lower voltages selected by the user without the need for directional control.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LSF0204x	TSSOP (14)	5.00 mm × 4.40 mm
	UQFN (12)	2.00 mm × 1.70 mm
	VQFN (14)	3.50 mm × 3.50 mm
	DSBGA (12)	1.90 mm × 1.40 mm

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

Simplified Schematic



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4 Revision History

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

Changes from Revision C (August 2015) to Revision D — **Page**

- Added Type Column to *Pin Functions* table ... 4
- Added Junction Temperatures to *Thermal Information* table ... 5

Changes from Revision B (April 2015) to Revision C — **Page**

- Removed "Less than 1.5 ns max propagation delay" from Features. ... 1
- Updated "Supports High Speed Translation, Greater Than 100 MHz" bullet in Features. ... 1

Changes from Revision A (December 2014) to Revision B — **Page**

- Added YZP package to device. ... 1

Changes from Original (November 2014) to Revision A — **Page**

- Changed From a first page Product Preview To a full datasheet ... 1
- Changed text in the *Description* From: "transmission speeds greater than 100 Mbps" To: "transmission speeds greater than 100 MHz" ... 1

5 Description (continued)

The supply voltage ($V_{pu\#}$) for each channel may be individually set up with a pull up resistor. For example, CH1 may be used in up-translation mode (1.2 V ↔ 3.3 V) and CH2 in down-translation mode (2.5 V ↔ 1.8 V).

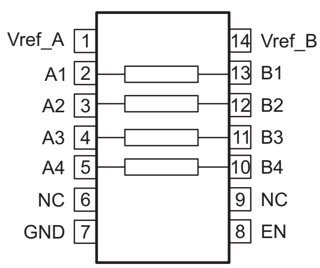
When EN is HIGH, the translator switch is on, and the An I/O is connected to the Bn I/O, respectively, allowing bidirectional data flow between ports. When EN is LOW, the translator switch is off, and a high-impedance state exists between ports. The EN input circuit is designed to be supplied by Vref_A. EN must be LOW to ensure the high-impedance state during power-up or power-down.

6 Device Comparison Table

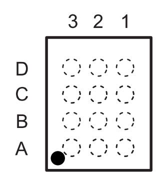
PART NUMBER	EN	An	Bn	DESCRIPTION
LSF0204D	H	Place all data pins in 3 state mode (Hi-Z)	Place all data pins in 3 state mode (Hi-Z)	3-state output mode enable (active Low; referenced to Vref_A)
LSF0204D	L	Input or output	Input or output	
LSF0204	H	Input or output	Input or output	3-state output mode enable (active High, referenced to Vref_A)
LSF0204	L	Place all data pins in 3 state mode (Hi-Z)	Place all data pins in 3 state mode (Hi-Z)	

7 Pin Configuration and Functions

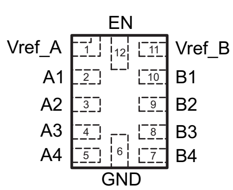
PW Package
14-Pin TSSOP
Top View



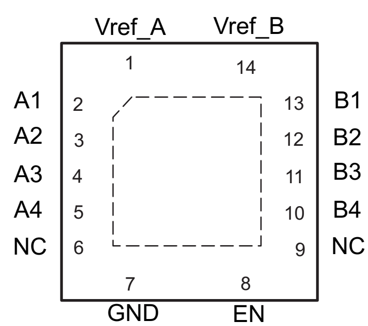
YZP Package
12-Pin DSBGA
Top View



RUT Package
12-Pin UQFN
Top View



RGY Package
14-Pin VQFN
Top View



Pin Functions

PIN				TYPE	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

8 Specifications

8.1 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	VI < 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.

8.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 [(1)]	±2000	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. 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.

8.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
$V_{I/O}$	Input/output voltage	0	5	V
$V_{ref\_A/B/EN}$	Reference voltage	0	5	V
I_{PASS}	Pass transistor current		64	mA
T_A	Operating free-air temperature	–40	125	°C

8.4 Thermal Information

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

8.5 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 mA, V_{EN} = 0				–1.2	V
I_{IH}		V_I = 5 V, V_{EN} = 0				5.0	µA
I_{CCBA}	Leakage from Vref_B to Vref_A	V_{ref_B} = 3.3 V, V_{ref_A} = 1.8 V, V_{EN} = V_{ref_A} I_O = 0, V_I = 3.3 V or GND				3.5	µA
I_{CCA} + I_{CCB}[(2)]	Total Current through GND	V_{ref_B} = 3.3 V, V_{ref_A} = 1.8 V, V_{EN} = V_{ref_A} I_O = 0, V_I = 3.3 V or GND			0.2		µA
I_{IN}	Control pin current	V_{ref_B} = 5.5 V, V_{ref_A} = 4.5 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 V, V_{EN} = GND I_O = 0, V_I = 5 V or GND				±1	µA
$C_{I(ref\_A/B/EN)}$		V_I = 3 V or 0			7		pF
$C_{io(off)}$		V_O = 3 V or 0, VEN = 0			5.0	6.0	pF
$C_{io(on)}$		V_O = 3 V or 0, VEN = Vref_A			10.5	13	pF
[(3)]$V_{IH\ (EN\ pin)}$	High-level input voltage	V_{ref_A} = 1.5 V to 4.5 V		0.7×Vref_A			V
$V_{IL\ (EN\ pin)}$	Low-level input voltage	V_{ref_A} = 1.5 V to 4.5 V				0.3×Vref_A	V
$V_{IH\ (EN\ pin)}$	High-level input voltage	V_{ref_A}= 1.0 V to 1.5 V		0.8×Vref_A			V
$V_{IL\ (EN\ pin)}$	Low-level input voltage	V_{ref_A} = 1.0 V to 1.5 V				0.3×Vref_A	V
Δt/Δv (EN pin)	Input transition rise or fall rate for EN pin				10		ns/V
r_{on} [(4)]		V_I = 0, I_O = 64 mA	V_{ref_A} = V_{EN} = 3.3 V; V_{ref_B} = 5 V		3		Ω
			V_{ref_A} = V_{EN} = 1.8 V; V_{ref_B} = 5 V		4		
		V_I = 0, I_O = 32 mA	V_{ref_A} = V_{EN} = 1.0 V; V_{ref_B} = 5 V		9		Ω
			V_{ref_A} = V_{EN} = 1.8 V; V_{ref_B} = 5 V		4		
		V_I = 0, I_O = 32 mA , V_{ref_A} = V_{EN} = 2.5 V; V_{ref_B} = 5 V			10		Ω
		V_I = 1.8 V, I_O = 15 mA, V_{ref_A} = V_{EN} = 3.3 V; V_{ref_B} = 5 V			5		Ω
		V_I = 1.0 V, I_O = 10 mA, V_{ref_A} = V_{EN} = 1.8 V; V_{ref_B} = 3.3 V			8		Ω
		V_I = 0 V, I_O = 10 mA, V_{ref_A} = V_{EN} = 1.0 V; V_{ref_B} = 3.3 V			6		Ω
		V_I = 0 V, I_O = 10 mA, V_{ref_A} = V_{EN} = 1.0 V; V_{ref_B} = 1.8 V			6		Ω

(1) All typical values are at T_A = 25°C.
(2) The actual supply current for LSF0204 is I_{CCA} + I_{CCB}; the leakage from Vref_B to Vref_A can be measured on Vref_A and Vref_B pin
(3) Enable pin test conditions are for the LSF0204. The enable pin test conditions for LSF0204D are oppositely set.
(4) 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.

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

over recommended operating free-air temperature range, $V_{rev\text{-}A}$ = 1.8 V, $V_{rev\text{-}B}$ = 3.3 V, V_{EN} = 1.8 V, Vpu_1 = 3.3 V, Vpu_2 = 1.8 V, R_L = NA, V_{IH} = 3.3 V, V_{IL} = 0 V_M = 1.15 V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	C_L = 50 pF		C_L = 30 pF		C_L = 15 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

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

over recommended operating free-air temperature range $V_{rev\text{-}A}$ = 1.2 V, $V_{rev\text{-}B}$ = 3.3 V, V_{EN} = 1.2 V, Vpu_1 = 3.3 V, Vpu_2 = 1.2 V, R_L = NA, V_{IH} = 3.3V, V_{IL} = 0 V_M = 0.85 V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	C_L = 50 pF		C_L = 30 pF		C_L = 15 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

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

over recommended operating free-air temperature range $V_{rev\text{-}A}$ = 1.8 V, $V_{rev\text{-}B}$ = 3.3 V, V_{EN} = 1.8 V, Vpu_1 = 3.3 V, Vpu_2 = 1.8V, R_L = 500 Ω, V_{IH} = 1.8V, $_{VIL}$ = 0 V_M = 0.9V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	C_L = 50 pF		C_L = 30 pF		C_L = 15 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

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

over recommended operating free-air temperature range, $V_{rev\text{-}A}$ = 1.2 V, $V_{rev\text{-}B}$ = 1.8 V, V_{EN} = 1.2 V, Vpu_1 = 1.8 V, Vpu_2 = 1.2 V, R_L = 500 Ω, V_{IH} = 1.2V, V_{IL} = 0 V_M = 0.6 V (unless otherwise noted)

PARAMETER	FROM (INPUT)	TO (OUTPUT)	C_L = 50 pF		C_L = 30 pF		C_L = 15 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

8.10 Typical Characteristics

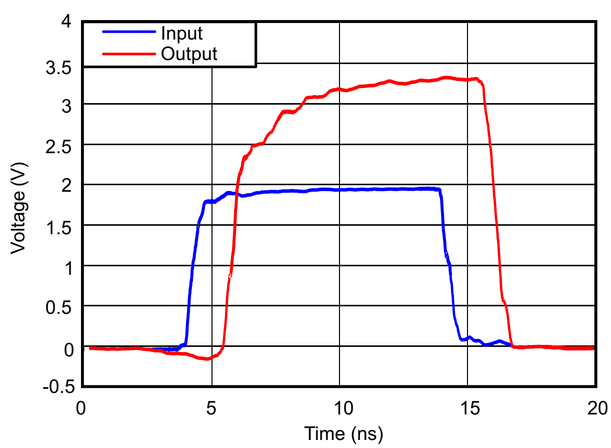
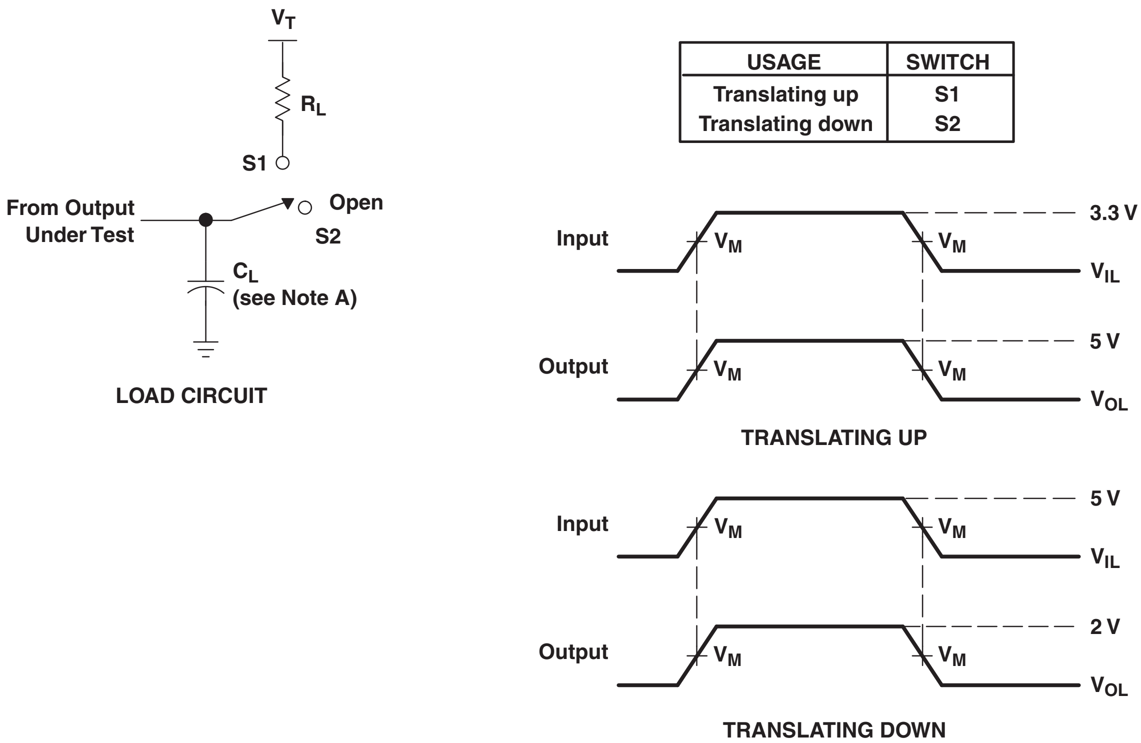


Figure 4. Signal Integrity (1.8 V to 3.3 V Translation Up at 50 MHz)

9 Parameter Measurement Information



NOTES: A. C_L includes probe and jig capacitance.

B. All input pulses are supplied by generators having the following characteristics: PRR ≤ 10 MHz, Z_O = 50 Ω, t_r ≤ 2 ns, t_f ≤ 2 ns.

C. The outputs are measured one at a time, with one transition per measurement.

Figure 5. Load Circuit for Outputs

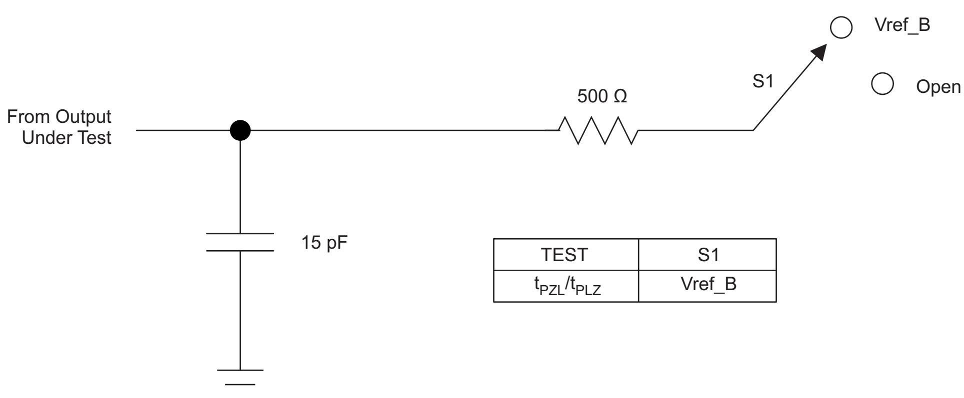


Figure 6. Load Circuit for Enable/Disable Time Measurement

9.1 Load Circuit AC Waveform for Outputs

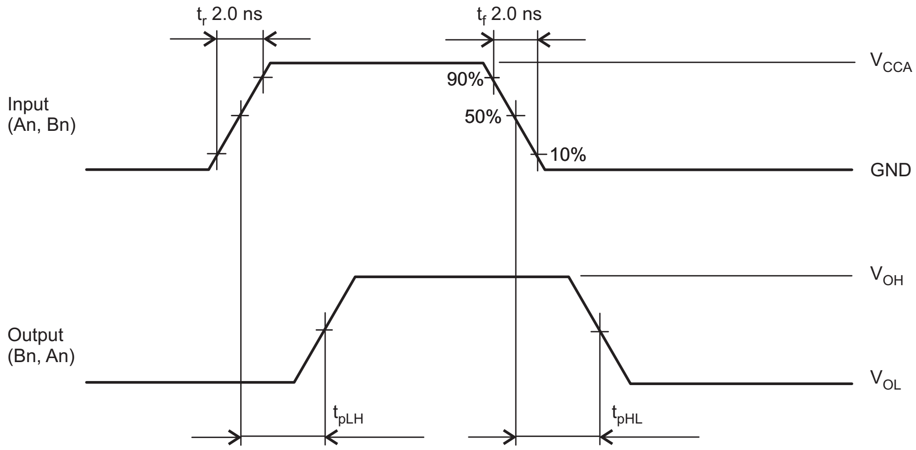


Figure 7. t_{PLH}, t_{PHL}

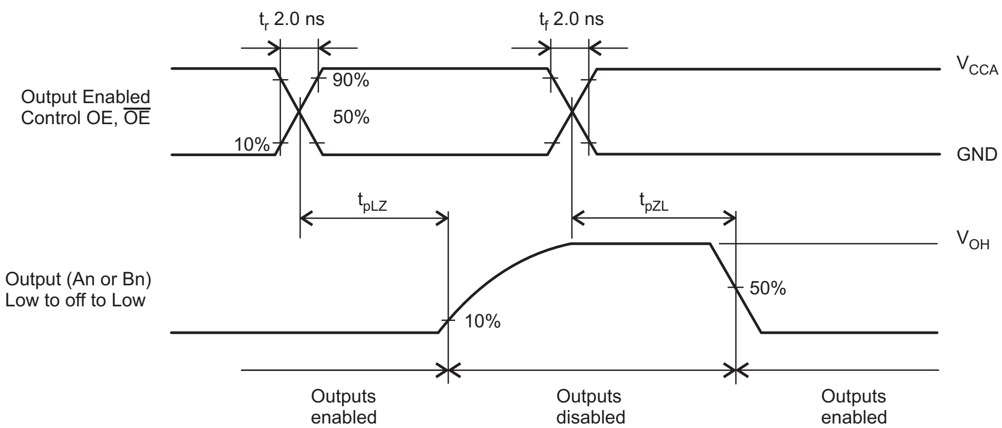


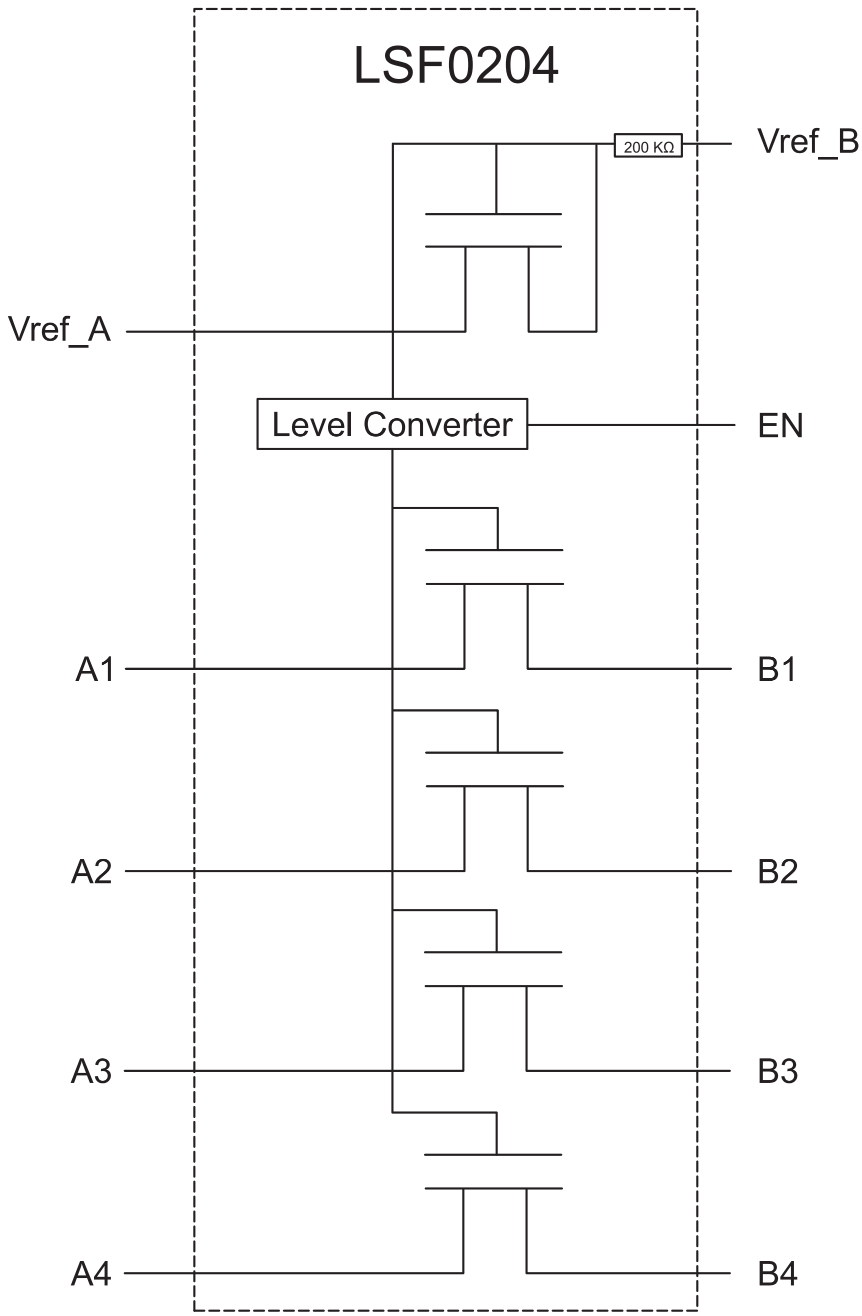
Figure 8. t_{PLZ}, t_{PZL}

10 Detailed Description

10.1 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.

10.2 Functional Block Diagram



10.3 Feature Description

10.3.1 Support High Speed Translation, Greater than 100 MHz

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

10.3.2 Bidirectional Voltage Translation Without DIR Terminal

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

10.3.3 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.

10.3.4 Channel Specific Translation

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

10.3.5 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.

10.4 Device Functional Modes

Table 1 lists the device functional modes of the LSF0204x family of devices.

Table 1. Function Table

INPUT EN(1) TERMINAL	FUNCTION
H	An = Bn
L	Hi-Z

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

11 Application and Implementation

NOTE

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

11.1 Application Information

LSF performs voltage translation for open-drain or push-pull interface. Table 2 provides some consumer/telecom interfaces as reference in regards to the different channel numbers that are supported by the LSF family.

Table 2. 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

11.2 Typical Applications

11.2.1 I²C PMBus, SMBus, GPIO, Application

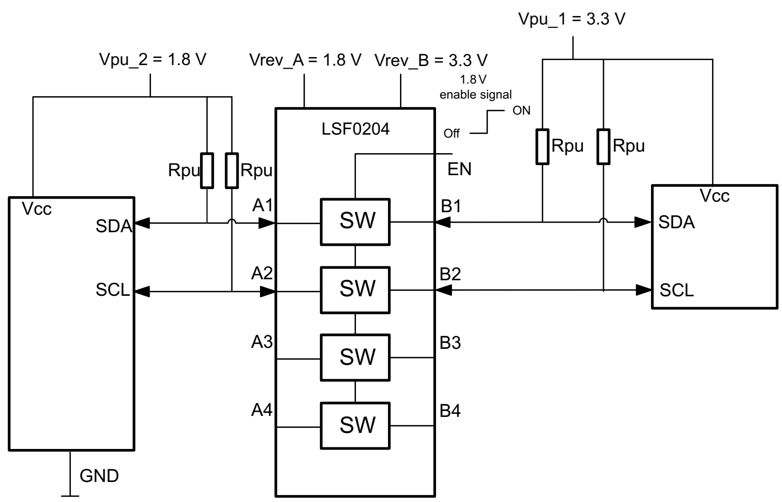


Figure 9. Bidirectional Translation to Multiple Voltage Levels

11.2.1.1 Design Requirements

11.2.1.1.1 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).

Typical Applications (continued)

Table 3. 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.

NOTE

Vref_A must be set as lowest voltage level.

11.2.1.2 Detailed Design Procedure

11.2.1.2.1 Bidirectional Translation

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

NOTE

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 Figure 9, 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.

11.2.1.2.1.1 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 Equation 1.

$$Rpu = (Vpu - 0.35\ V) / 0.015\ A \quad (1)$$

Table 4 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.

Table 4. Pullup Resistor Values(1)(2)

V_{DPU}	PULLUP RESISTOR VALUE (Ω)					
	15 mA	10 mA	3 mA			
	NOMINAL	+10%(3)	NOMINAL	+10%(3)	NOMINAL	+10%(3)
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) Calculated for V_{OL} = 0.35 V
(2) Assumes output driver V_{OL} = 0.175 V at stated current
(3) +10% to compensate for V_{DD} range and resistor tolerance

11.2.1.2.2 LS Family Bandwidth

The maximum frequency of the LSF family is dependent on the application. The device may operate at speeds of >100MHz gave 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.

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

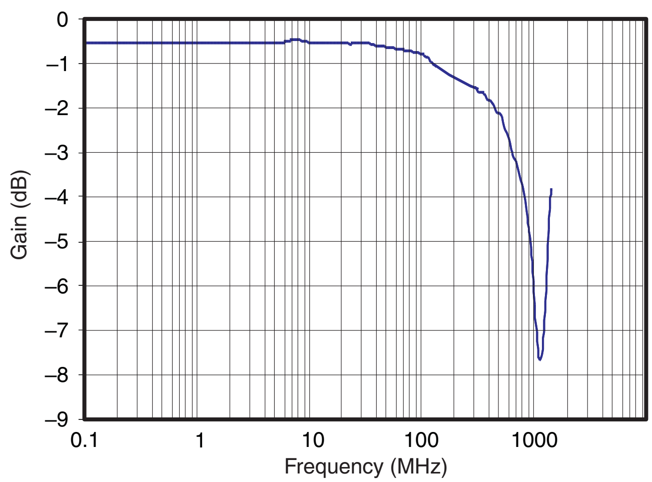


Figure 10. 3-dB Bandwidth

The 3-dB point of the LSF family is ≈600MHz; 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:

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

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

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 I^2C 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.

11.2.1.3 Application Curve

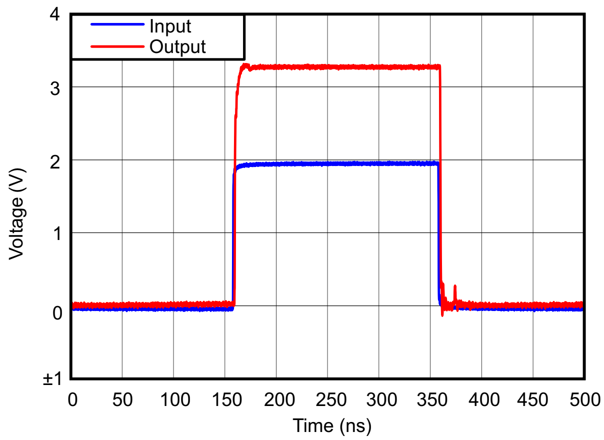


Figure 11. Captured Waveform From Above I^2C Set-Up (1.8 V to 3.3 V at 2.5 MHz)

11.2.2 MDIO Application

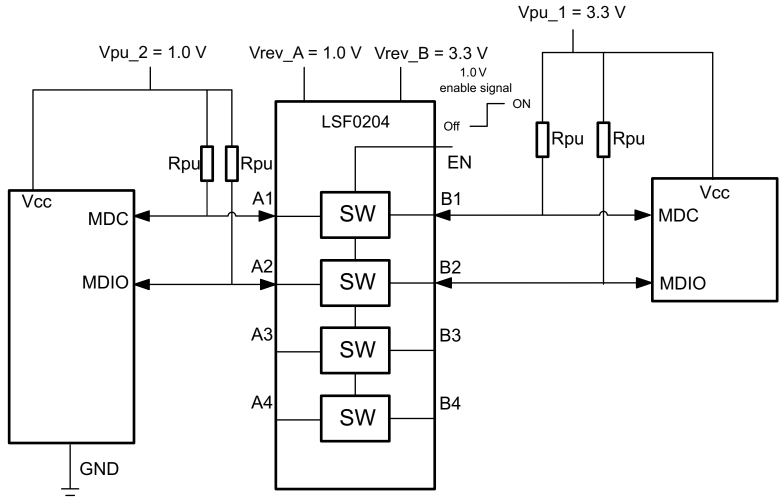


Figure 12. Typical Application Circuit (MDIO/Bidirectional Interface)

11.2.2.1 Design Requirements

Refer to *Design Requirements*.

11.2.2.2 Detailed Design Procedure

Refer to *Detailed Design Procedure*

11.2.2.3 Application Curve

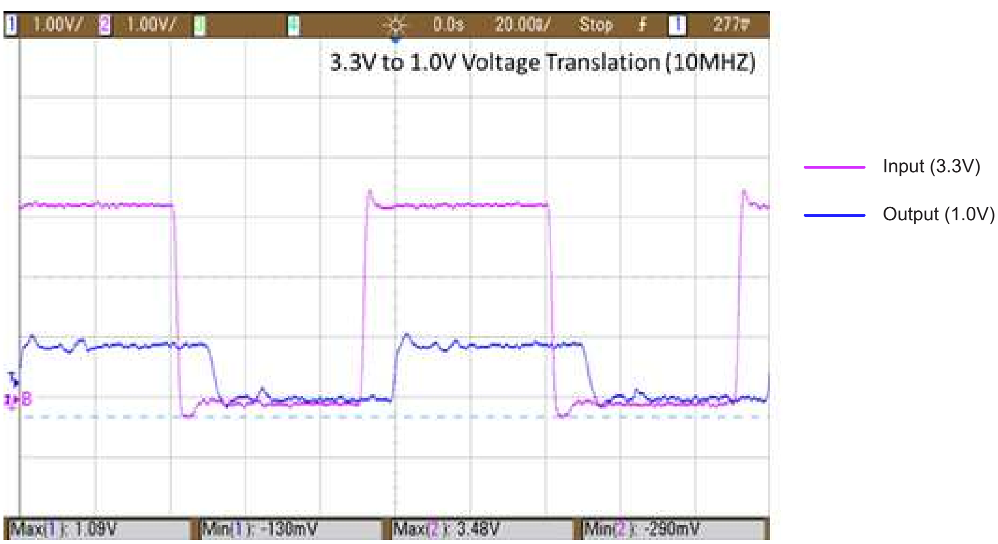
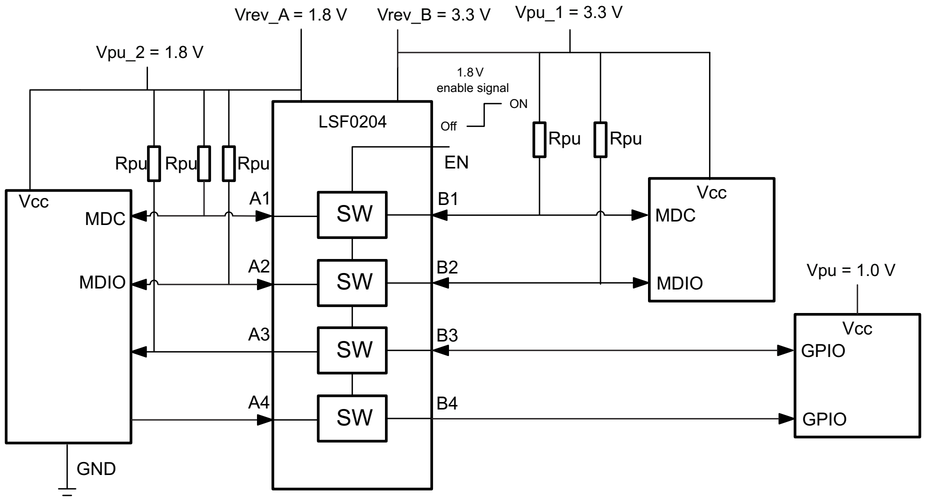


Figure 13. Captured Waveform From Above MDIO Setup

11.2.3 Multiple Voltage Translation in Single Device, Application



11.2.3.1 Design Requirements

Refer to *Design Requirements*.

11.2.3.2 Detailed Design Procedure

Refer to *Detailed Design Procedure*

11.2.3.3 Application Curve

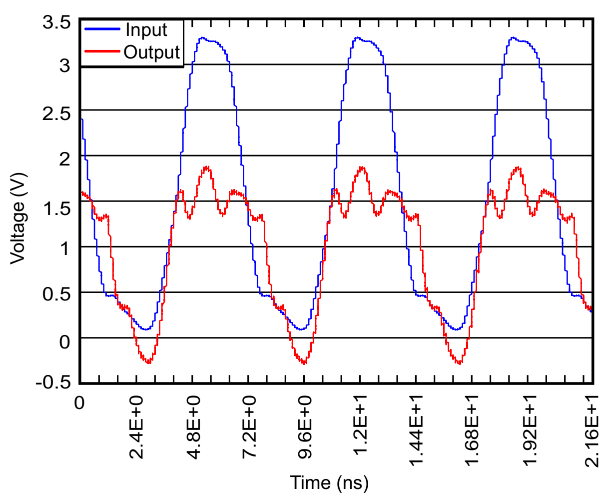


Figure 14. Translation Down (3.3 V to 1.8 V) at 150 MHz

12 Power Supply Recommendations

There are no power sequence requirements for the LSF Family. Refer to the *Enable, Disable, and Reference Voltage Guidelines* for enabling and reference voltage guidelines.

13 Layout

13.1 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.

13.2 Layout Example

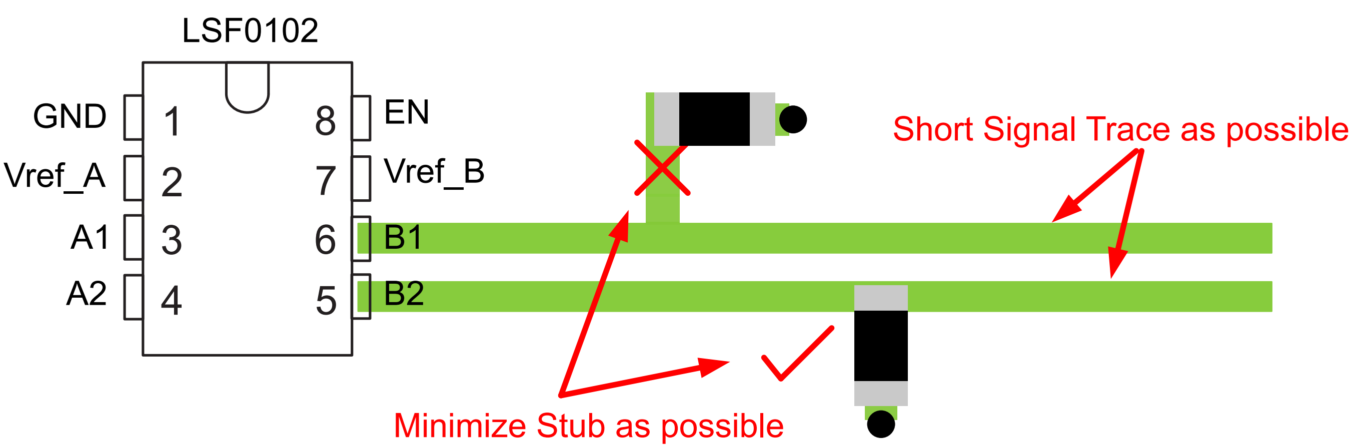


Figure 15. Short Trace Layout

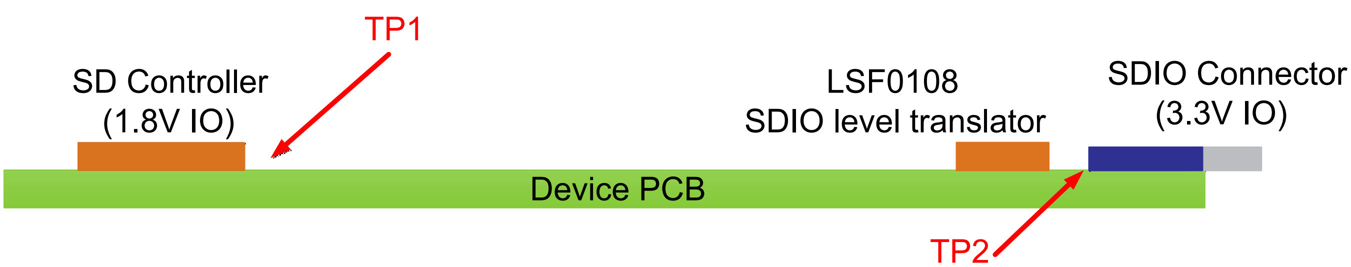


Figure 16. Device Placement

Layout Example (continued)

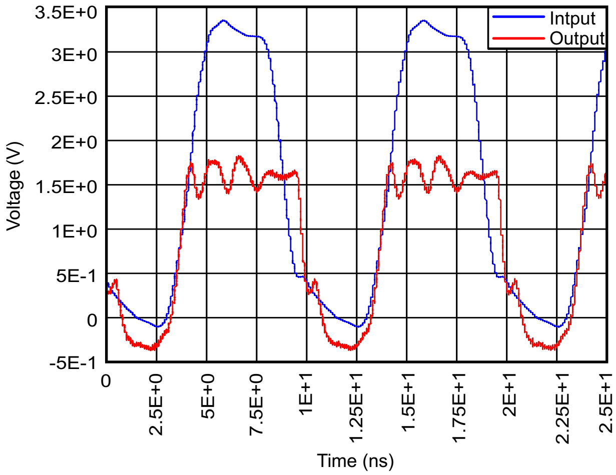


Figure 17. Waveform From TP1 (Pullup Resistor: 160-Ω and 50-pF Capacitance 3.3 to 1.8 V at 100 MHz)

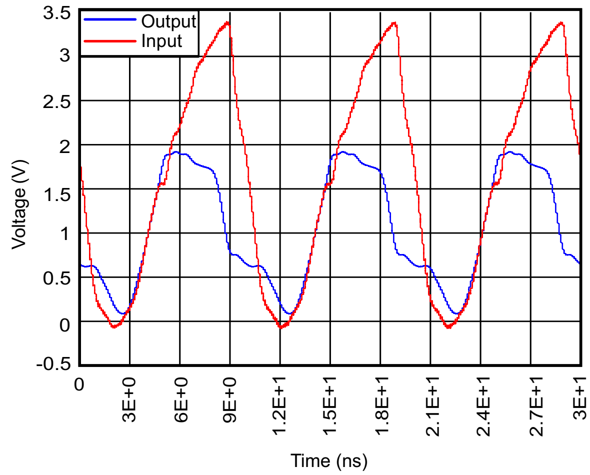


Figure 18. Waveform From TP2 (Pullup Resistor: 160-Ω and 50-pF Capacitance 1.8 to 3.3 V at 100 MHz)

14 Device and Documentation Support

14.1 Related Links

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

Table 5. Related Links

PARTS	PRODUCT FOLDER	SAMPLE & BUY	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
LSF0204	Click here	Click here	Click here	Click here	Click here
LSF0204D	Click here	Click here	Click here	Click here	Click here

14.2 Community Resources

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

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

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

14.3 Trademarks

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

14.4 Electrostatic Discharge Caution

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

14.5 Glossary

SLYZ022 — *TI Glossary*.

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

15 Mechanical, Packaging, and Orderable Information

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

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LSF0204DPWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LSF204D	Samples
LSF0204DRGYR	ACTIVE	VQFN	RGY	14	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LSF24D	Samples
LSF0204DRUTR	ACTIVE	UQFN	RUT	12	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIO	Samples
LSF0204DYZPR	ACTIVE	DSBGA	YZP	12	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 125	G6	Samples
LSF0204PWR	ACTIVE	TSSOP	PW	14	2000	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	-40 to 125	LSF204	Samples
LSF0204RGYR	ACTIVE	VQFN	RGY	14	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-2-260C-1 YEAR	-40 to 125	LSF24	Samples
LSF0204RUTR	ACTIVE	UQFN	RUT	12	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	SIN	Samples
LSF0204YZPR	ACTIVE	DSBGA	YZP	12	3000	Green (RoHS & no Sb/Br)	SNAGCU	Level-1-260C-UNLIM	-40 to 125	G5	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

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

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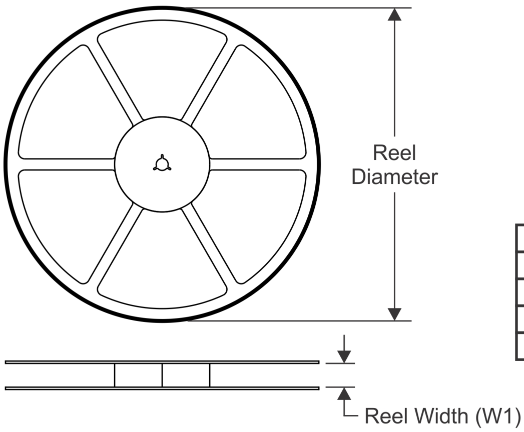
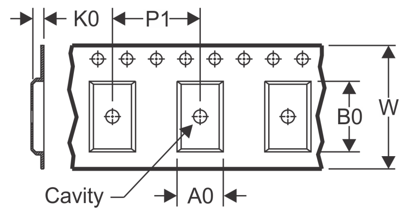
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

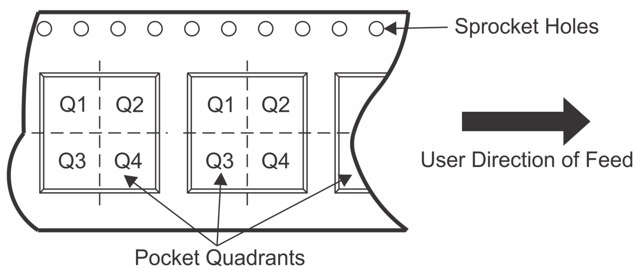


TAPE DIMENSIONS



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

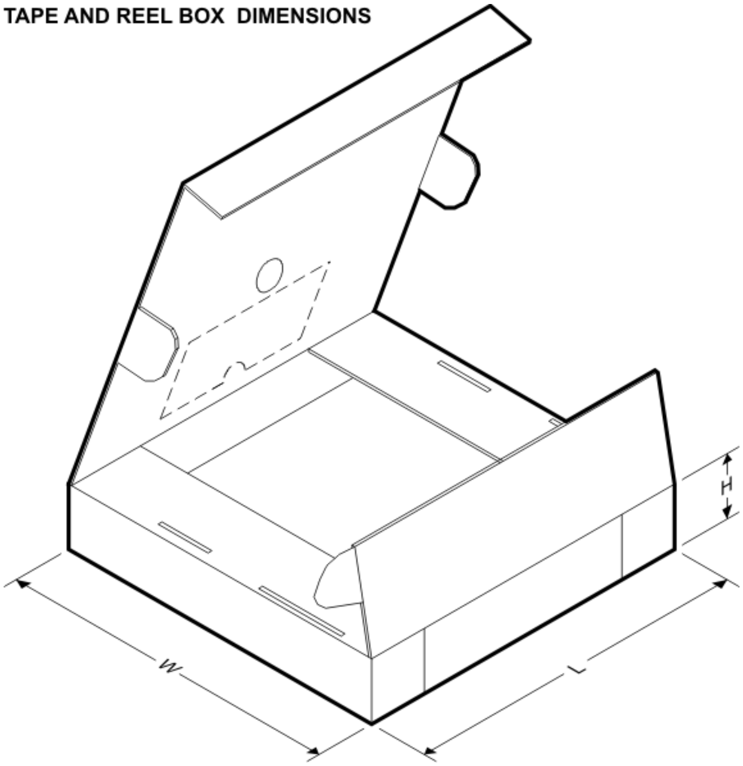
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
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	Q1
LSF0204DRUTR	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	Q1
LSF0204RUTR	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

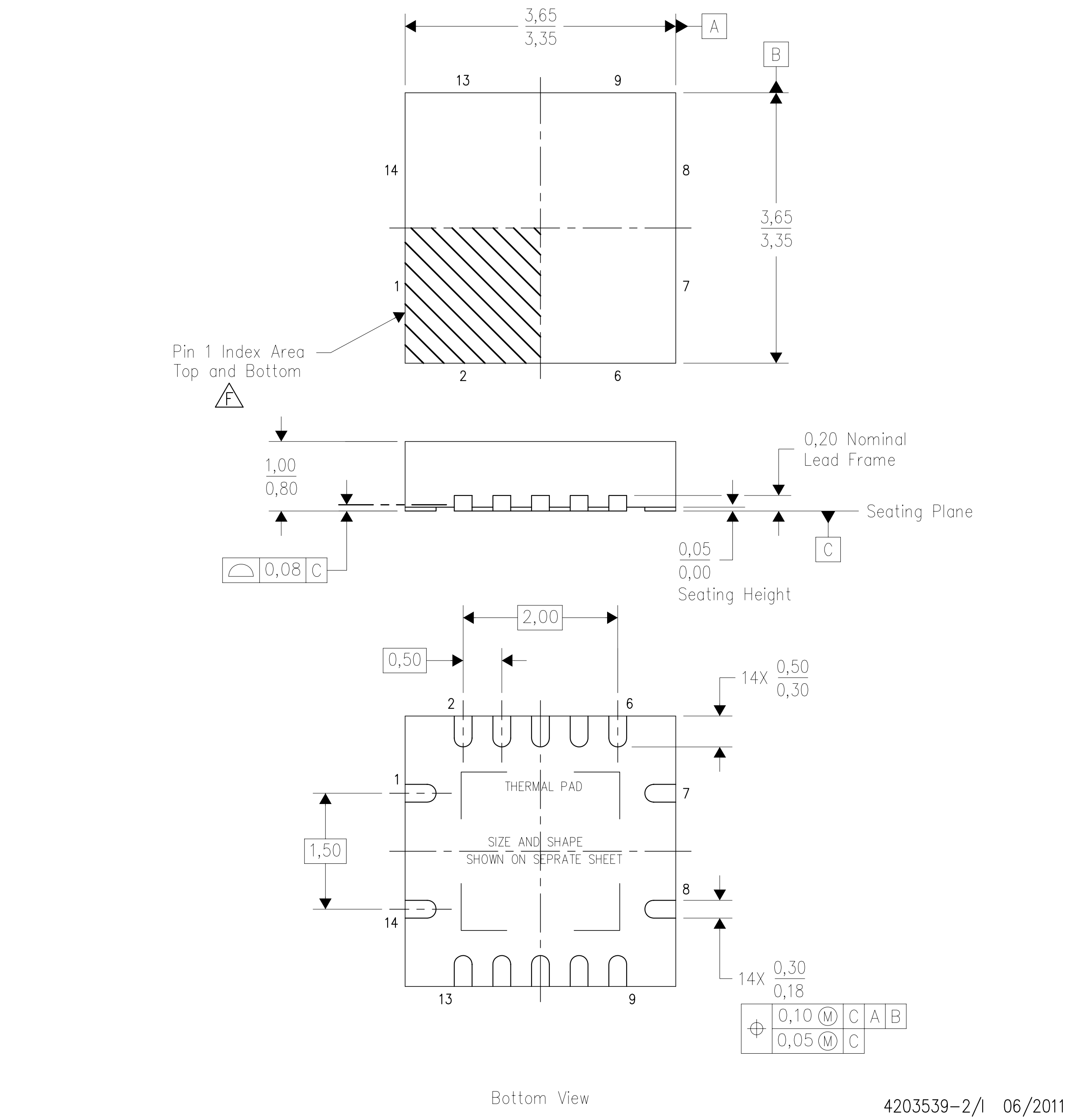
TAPE AND REEL BOX DIMENSIONS



*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	367.0	367.0	35.0
LSF0204DRUTR	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	367.0	367.0	35.0
LSF0204RUTR	UQFN	RUT	12	3000	184.0	184.0	19.0
LSF0204YZPR	DSBGA	YZP	12	3000	182.0	182.0	20.0

RGY (S-PVQFN-N14) PLASTIC QUAD FLATPACK NO-LEAD



4203539-2/I 06/2011

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. QFN (Quad Flatpack No-Lead) package configuration.
- D. The package thermal pad must be soldered to the board for thermal and mechanical performance.
- E. See the additional figure in the Product Data Sheet for details regarding the exposed thermal pad features and dimensions.
- F. Pin 1 identifiers are located on both top and bottom of the package and within the zone indicated. The Pin 1 identifiers are either a molded, marked, or metal feature.
- G. Package complies to JEDEC MO-241 variation BA.

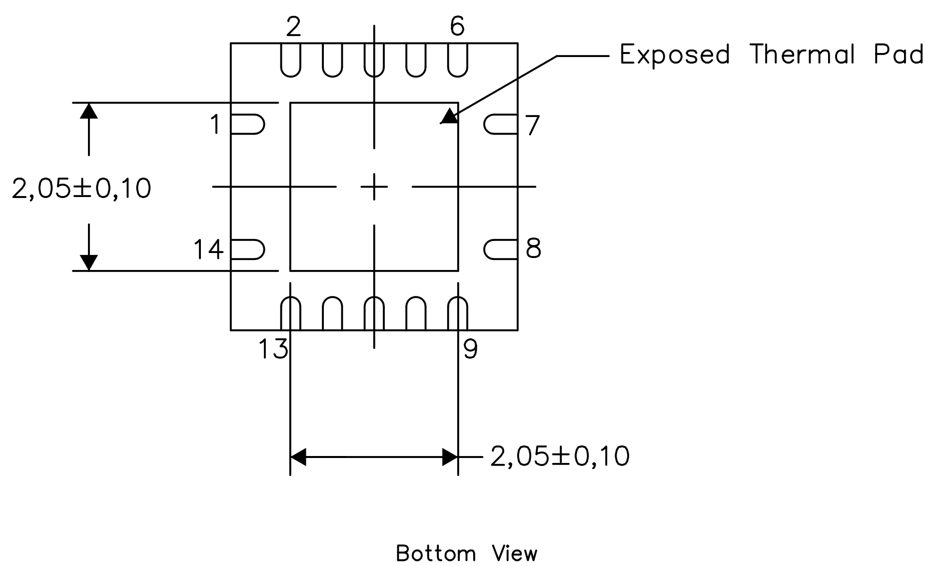
RGY (S-PVQFN-N14) PLASTIC QUAD FLATPACK NO-LEAD

THERMAL INFORMATION

This package incorporates an exposed thermal pad that is designed to be attached directly to an external heatsink. The thermal pad must be soldered directly to the printed circuit board (PCB). After soldering, the PCB can be used as a heatsink. In addition, through the use of thermal vias, the thermal pad can be attached directly to the appropriate copper plane shown in the electrical schematic for the device, or alternatively, can be attached to a special heatsink structure designed into the PCB. This design optimizes the heat transfer from the integrated circuit (IC).

For information on the Quad Flatpack No-Lead (QFN) package and its advantages, refer to Application Report, QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271. This document is available at www.ti.com.

The exposed thermal pad dimensions for this package are shown in the following illustration.

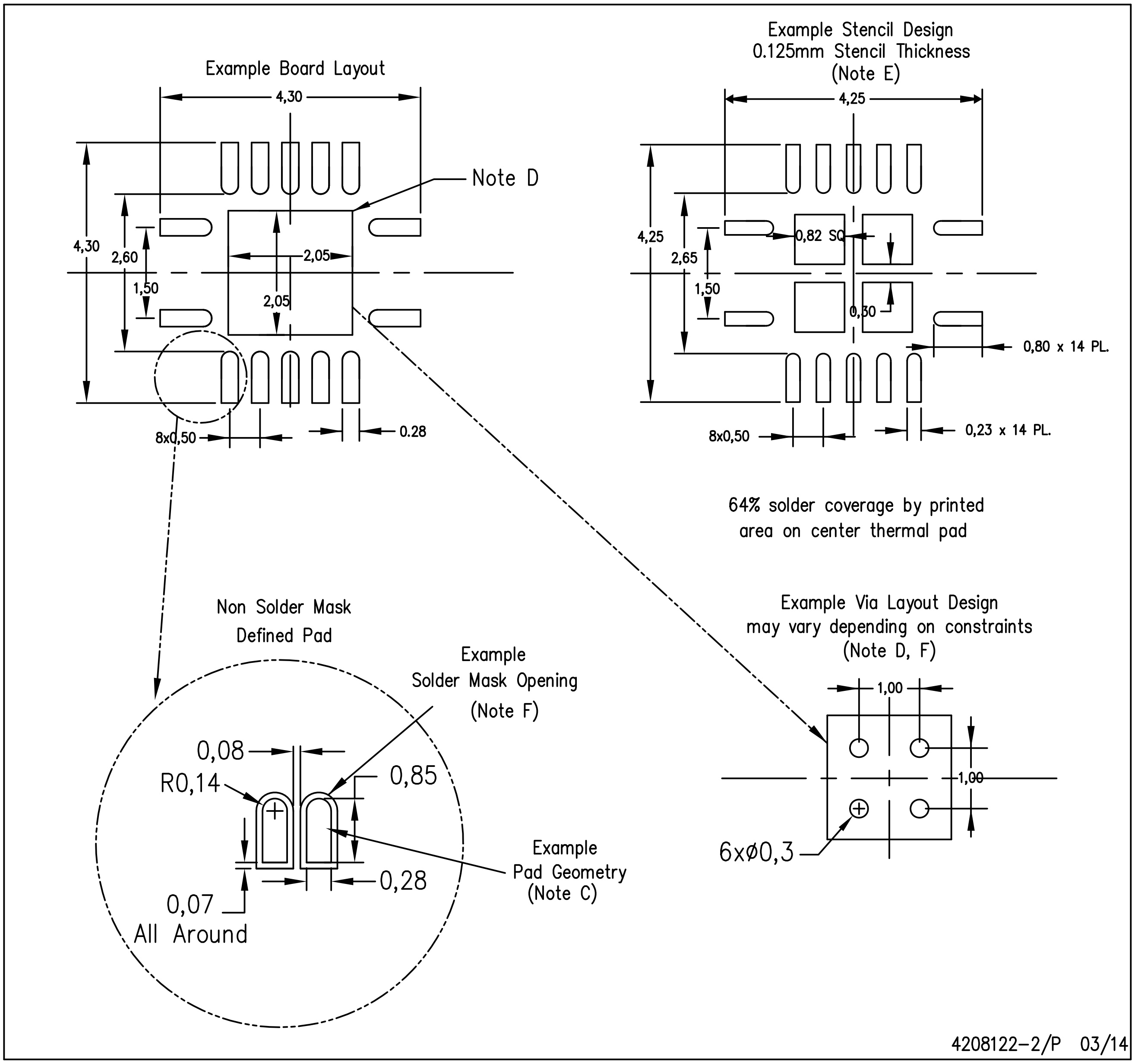


Exposed Thermal Pad Dimensions

4206353-2/P 03/14

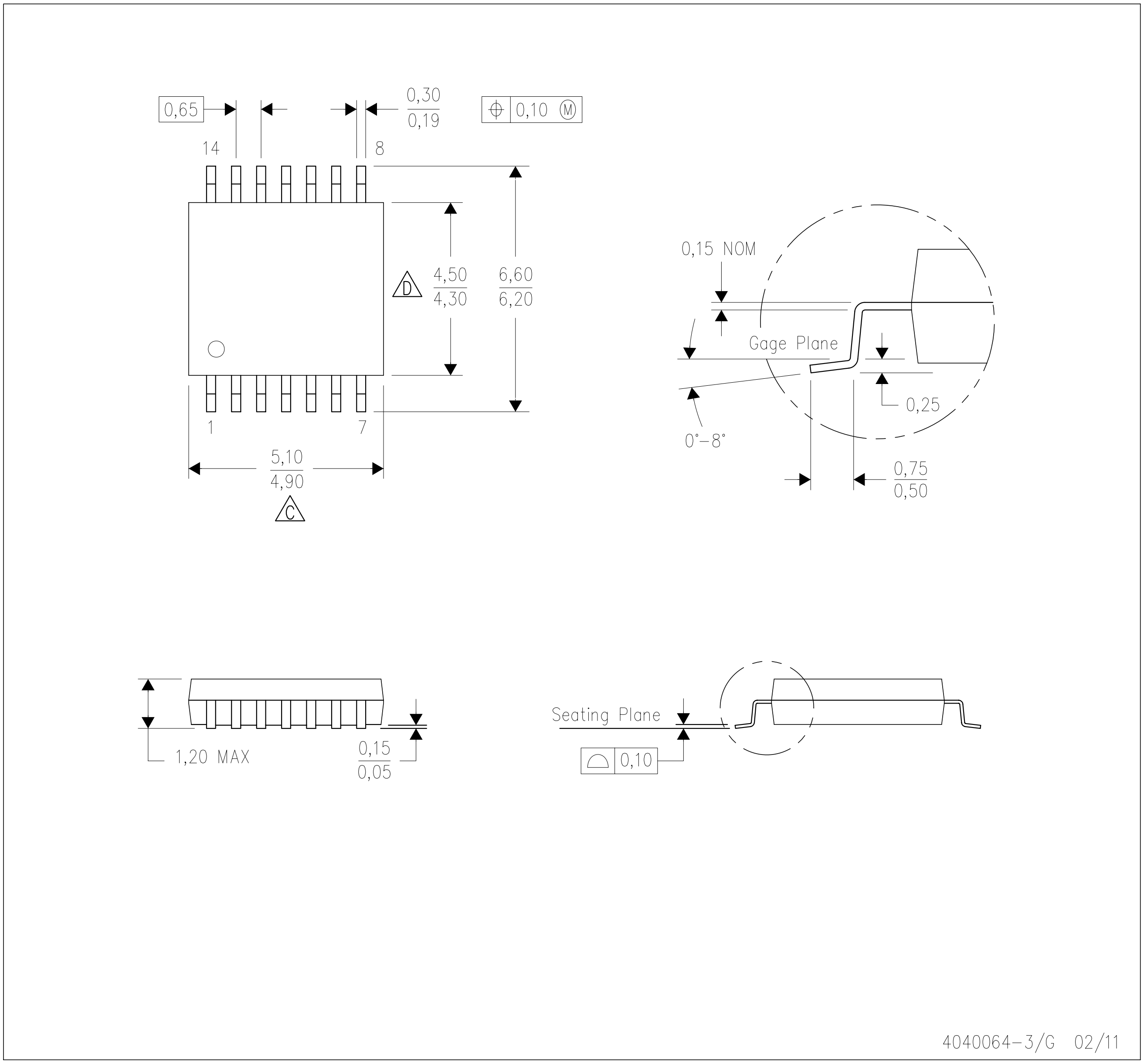
NOTE: All linear dimensions are in millimeters

RGY (S-PVQFN-N14) PLASTIC QUAD FLATPACK NO-LEAD



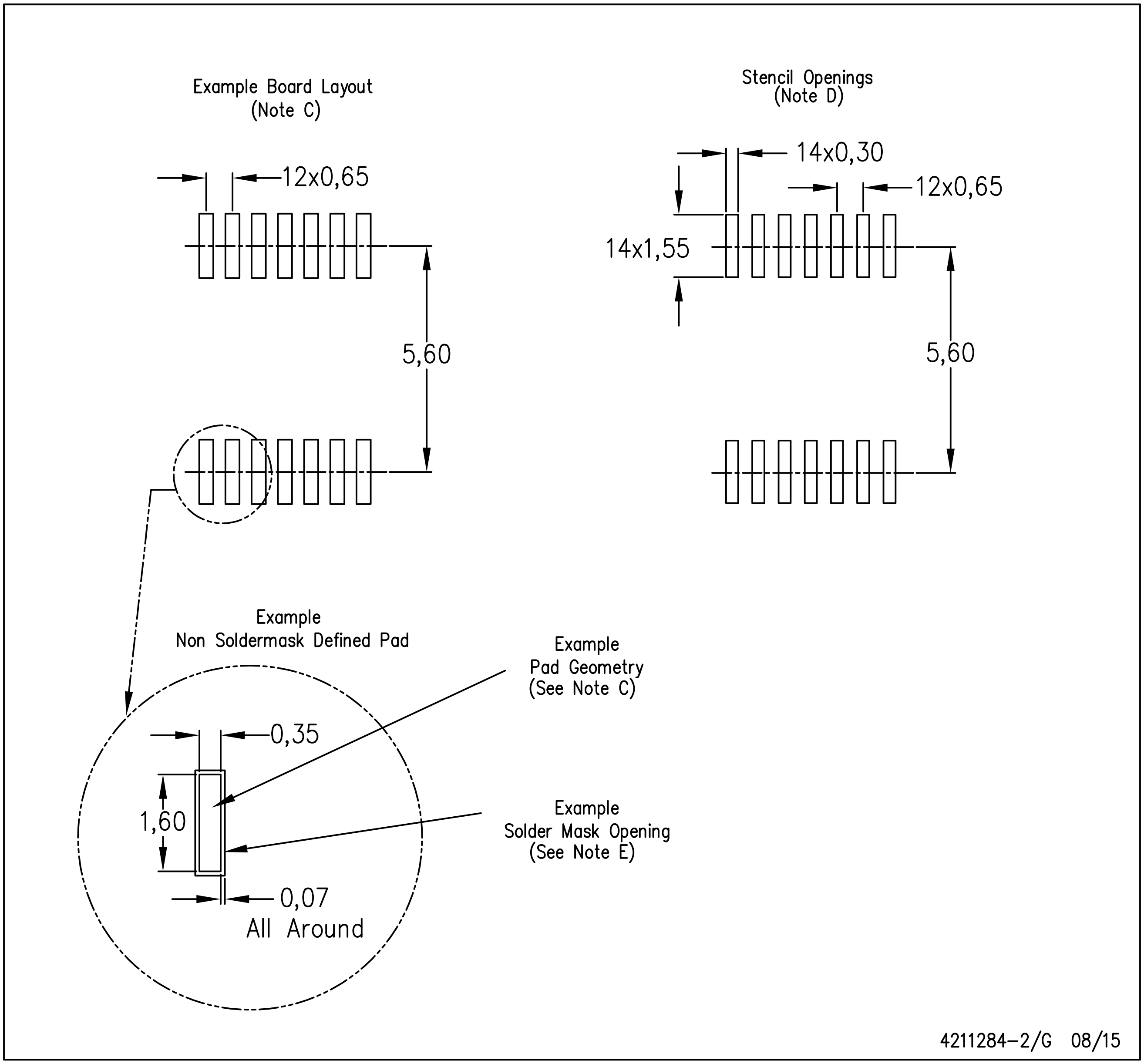
NOTES:
- A. All linear dimensions are in millimeters.
- B. This drawing is subject to change without notice.
- C. Publication IPC-7351 is recommended for alternate designs.
- D. This package is designed to be soldered to a thermal pad on the board. Refer to Application Note, Quad Flat-Pack QFN/SON PCB Attachment, Texas Instruments Literature No. SLUA271, and also the Product Data Sheets for specific thermal information, via requirements, and recommended board layout. These documents are available at www.ti.com <http://www.ti.com>.
- E. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
- F. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.

PW (R-PDSO-G14) PLASTIC SMALL OUTLINE



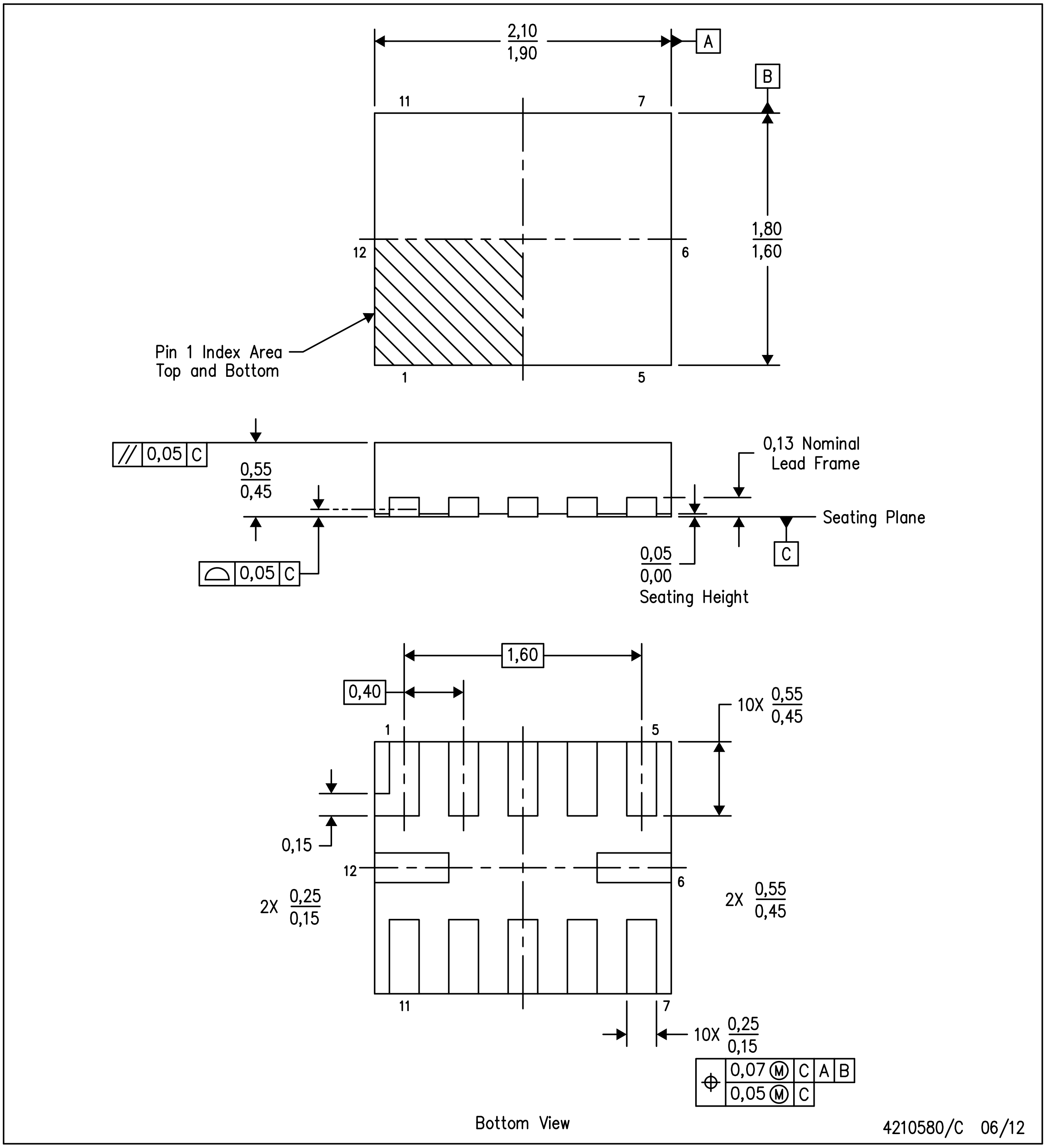
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0,15 each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0,25 each side.
E. Falls within JEDEC MO–153

PW (R-PDSO-G14) PLASTIC SMALL OUTLINE



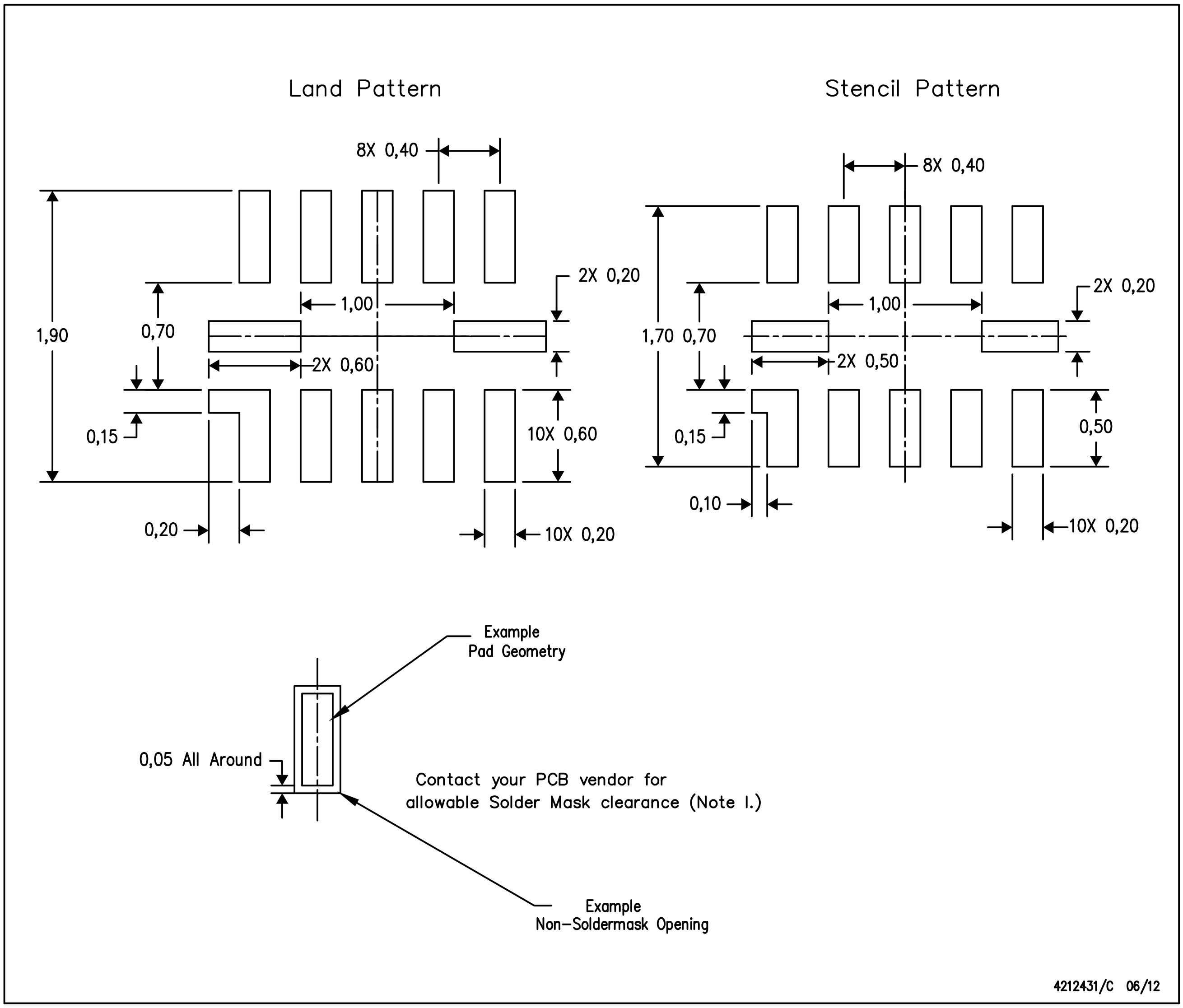
NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC-7351 is recommended for alternate designs.
D. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC-7525 for other stencil recommendations.
E. Customers should contact their board fabrication site for solder mask tolerances between and around signal pads.

RUT (R-PUQFN-N12) PLASTIC QUAD FLATPACK NO-LEAD



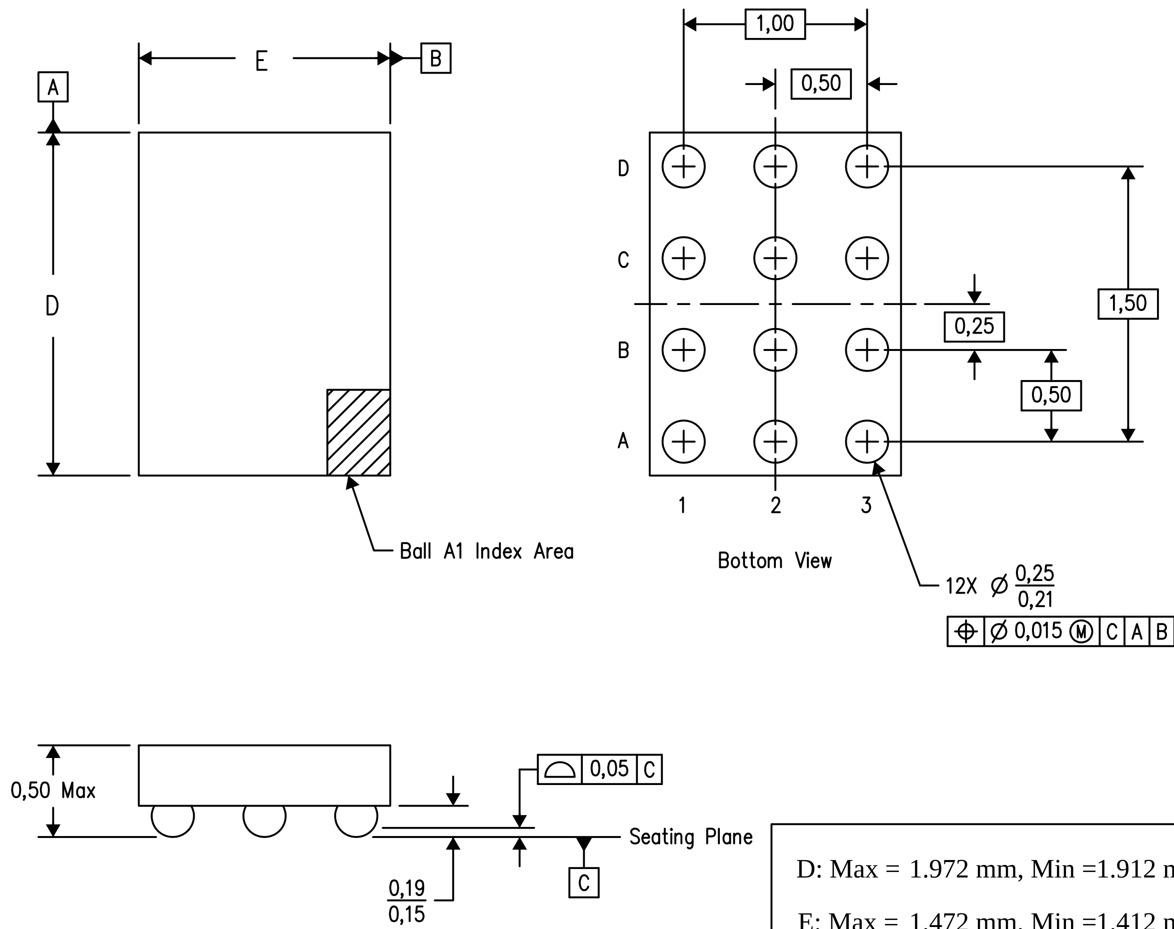
NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M-1994.
B. This drawing is subject to change without notice.
C. QFN (Quad Flatpack No-Lead) package configuration.

RUT (R–PUQFN–N12) PLASTIC QUAD FLATPACK NO–LEAD



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Publication IPC–7351 is recommended for alternate designs.
D. Customers should contact their board fabrication site for minimum solder mask web tolerances between signal pads.
E. Maximum stencil thickness 0,1016 mm (4 mils). All linear dimensions are in millimeters.
F. Laser cutting apertures with trapezoidal walls and also rounding corners will offer better paste release. Customers should contact their board assembly site for stencil design recommendations. Refer to IPC 7525 for stencil design considerations.
G. Over–printing land for larger area ratio is not advised due to land width and bridging potential. Exersize extreme caution.
H. Suggest stencils cut with lasers such as Fiber Laser that produce the greatest positional accuracy.
I. Component placement force should be minimized to prevent excessive paste block deformation.

YZP (R–XBGA–N12) DIE–SIZE BALL GRID ARRAY



D: Max = 1.972 mm, Min =1.912 mm

E: Max = 1.472 mm, Min =1.412 mm

4204741–7/M 11/13

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.

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