

TMUX131 4V、低静電容量、3 : 12 チャネル・マルチプレクサ

1 特長

- 高速 I³C 信号と互換
- V_{DD} 範囲: 2.5V ~ 4.3V
- 高性能スイッチ特性:
 - 帯域幅 (–3dB): 6.5GHz
 - R_{ON} (標準値): 5.5Ω
 - C_{ON} (標準値): 1.3pF
- 消費電流: 28μA (標準値)
- ロジック・ピンにプルダウン抵抗を内蔵
- 特別な機能:
 - I_{OFF} 保護により、パワー・ダウン状態 (V_{DD} = 0V) での電流リークを防止
 - 1.8V 互換の制御入力 (SEL)
 - 外部部品なしで、すべての I/O ピンにおいて最大 5.5V の過電圧耐性 (OVT)
- ESD 性能:
 - 2kV、人体モデル (A114-B, Class II)
 - 1kV、デバイス帯電モデル (C101)
- パッケージ:
 - 12 ピンの VQFN パッケージ (1.8mm × 1.8mm、0.5mm 刻み)

2 アプリケーション

- I³C (SenseWire)
- I³C および I²C ペリフェラル・スイッチング
- サーバー
- 携帯電話: スマートフォン
- ノート PC
- タブレット: マルチメディア
- レジ用電子機器
- 現場用計測機器
- ポータブル・モニタ

3 概要

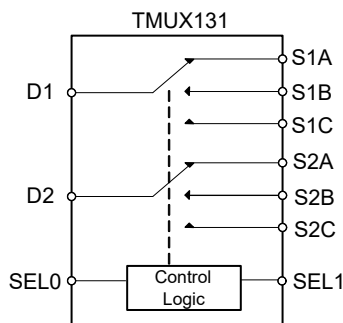
TMUX131 デバイスは、高性能双方向 2 チャネルの 3:1 マルチプレクサで、差動およびシングル・エンドの両方の信号をサポートします。TMUX131 は、電源オフ保護機能を備えたアナログ・パッシブ・マルチプレクサで、V_{DD} ピンに電力が供給されていないときは、すべての I/O ピンが強制的に高インピーダンス・モードになります。TMUX131 の選択ピンは、1.8V および 3.3V 制御ロジックと互換性があるため、低電圧プロセッサからの汎用 I/O (GPIO) と直接インターフェイスが可能です。この TMUX131 はオン抵抗が低くオン静電容量が小さいため、I³C などの高速規格を含め、幅広いアナログ信号およびデジタル通信プロトコル規格のスイッチングをサポートするのに最適なデバイスです。

TMUX131 は、小型の 12 ピン VQFN パッケージで供給されており、そのサイズはわずか 1.8mm × 1.8 mm であることから、PCB 面積が限られている場合に便利です。

パッケージ情報

部品番号	パッケージ (1)	パッケージ・サイズ (2)
TMUX131	RMG (VQFN, 12)	1.8mm × 1.8 mm

- (1) 利用可能なすべてのパッケージについては、データシートの末尾にある注文情報を参照してください。
- (2) パッケージ・サイズ (長さ×幅) は公称値であり、該当する場合はピンも含まれます。



スイッチ図



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4 Revision History

DATE	REVISION	NOTES
August 2023	*	Initial Release

5 Pin Configuration and Functions

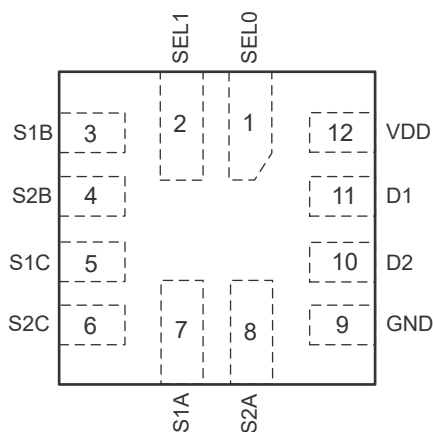


図 5-1. RMG Package, 12-Pin VQFN (Top View)

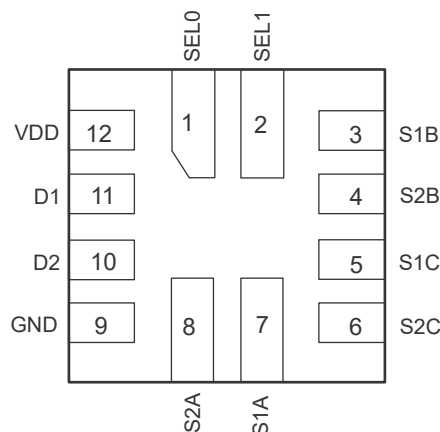


図 5-2. RMG Package, 12-Pin VQFN (Bottom View)

表 5-1. Pin Functions

PIN		TYPE ⁽¹⁾	DESCRIPTION
NAME	NO.		
SEL0	1	I	Switch logic control. Controls the switch connects as provided in 表 7-1
SEL1	2	I	Switch logic control. Controls the switch connects as provided in 表 7-1
S1B	3	I/O	Source pin 1B. Can be an input or output.
S2B	4	I/O	Source pin 2B. Can be an input or output.
S1C	5	I/O	Source pin 1C. Can be an input or output.
S2C	6	I/O	Source pin 2C. Can be an input or output.
S1A	7	I/O	Source pin 1A. Can be an input or output.
S2A	8	I/O	Source pin 2A. Can be an input or output.
GND	9	G	Ground
D2	10	I/O	Drain pin 2. Can be an input or output.
D1	11	I/O	Drain pin 1. Can be an input or output.
VDD	12	P	Power Supply

(1) G = Ground, I = Input, O = Output, P = Power

6 Specifications

6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)^{(1) (2)}

		MIN	MAX	UNIT
V _{DD}	Supply voltage ⁽³⁾	−0.3	5.5	V
V _{S/D}	Input/Output DC voltage ⁽³⁾	−0.3	5.5	V
I _K	Input/Output port diode current (V _{S/D} < 0)	−50		mA
V _I	Digital input voltage (SEL0, SEL1)	−0.3	5.5	
I _{IK}	Digital logic input clamp current (V _I < 0) ⁽³⁾	−50		mA
I _{I/O}	Continuous switch DC output current		60	mA
T _{stg}	Storage temperature	−65	150	°C

- (1) Operation outside the *Absolute Maximum Rating* may cause permanent device damage. *Absolute Maximum Rating* do not imply functional operation of the device at these or any other conditions beyond those listed under *Recommended Operating Condition*. If used outside the *Recommended Operating Condition* but within the *Absolute Maximum Rating*, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) The algebraic convention, whereby the most negative value is a minimum and the most positive value is a maximum.
- (3) All voltages are with respect to ground, unless otherwise specified.

6.2 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 ANSI/ESDA/JEDEC JS-002 ⁽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. Pins listed as ±2000 V may actually have higher performance.
- (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. Pins listed as ±1000 V may actually have higher performance.

6.3 Recommended Operating Conditions

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

		MIN	MAX	UNIT
V _{DD}	Supply voltage	2.5	4.3	V
V _{S/D}	Analog voltage	0	3.6	V
V _{SEL}	Digital input voltage (SEL0, SEL1)	0	V _{DD}	V
T _{RAMP (VDD)}	Power supply ramp time requirement (VDD)	100	1000	μs/V
I _{S/D, PEAK}	Peak switch DC output current (1-ms duration pulse at <10% duty cycle)		150	mA
T _A	Operating free-air temperature	−40	85	°C

6.4 Thermal Information

THERMAL METRIC ⁽¹⁾		TMUX131	UNIT
		RMG (VQFN)	
		12 PINS	
R _{θJA}	Junction-to-ambient thermal resistance	160.8	°C/W
R _{θJC(top)}	Junction-to-case (top) thermal resistance	95.5	°C/W
R _{θJB}	Junction-to-board thermal resistance	91.2	°C/W
ψ _{JT}	Junction-to-top characterization parameter	7.4	°C/W
ψ _{JB}	Junction-to-board characterization parameter	91.2	°C/W

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

6.5 Electrical Characteristics

$T_A = -40^\circ\text{C}$ to 85°C , typical values are at $V_{DD} = 3.3\text{ V}$ and $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
R_{ON}	ON-state resistance	$V_{DD} = 2.5\text{ V}$, $V_S = 1.5\text{ V}$, $I_{ON} = -8\text{ mA}$ (see 7-1)		5.5	7	Ω
ΔR_{ON}	ON-state resistance match between channels	$V_{DD} = 2.5\text{ V}$, $V_S = 1.5\text{ V}$, $I_{ON} = -8\text{ mA}$		0.1		Ω
$R_{ON (FLAT)}$	ON-state resistance flatness	$V_{DD} = 2.5\text{ V}$, $V_S = 1.5\text{ V}$ to 3.3 V , $I_{ON} = -8\text{ mA}$		1		Ω
I_{OZ}	OFF leakage current	$V_{DD} = 4.3\text{ V}$, Switch OFF, $V_S = 1.5\text{ V}$ to 3.3 V , $V_D = 0\text{ V}$ (see 7-2)	-2		2	μA
I_{OFF}	Power-off leakage current	$V_{DD} = 0\text{ V}$, Power off, $V_S = 1.5\text{ V}$ to 3.3 V , $V_D = \text{NC}$	-10		10	μA
I_{ON}	ON leakage current	$V_{DD} = 4.3\text{ V}$, Switch ON, $V_S = 1.5\text{ V}$ to 3.3 V , $V_D = \text{NC}$	-2		2	μA
DIGITAL CONTROL INPUTS (SEL)						
V_{IH}	Input logic high	$V_{DD} = 2.5\text{ V}$ to 4.3 V	1.3			V
V_{IL}	Input logic low	$V_{DD} = 2.5\text{ V}$ to 4.3 V			0.6	V
I_{IN}	Input leakage current	$V_{DD} = 4.3\text{ V}$, $V_{S/D} = 0\text{ V}$ to 3.6 V , $V_{SEL} = 0\text{ V}$ to 4.3 V	-10		10	μA

6.6 Dynamic Characteristics

$T_A = -40^\circ\text{C}$ to 85°C , Typical values are at $V_{DD} = 3.3\text{ V}$, $T_A = 25^\circ\text{C}$ (unless otherwise noted)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{pd}	Propagation delay	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $V_{DD} = 2.5\text{ V}$ to 4.3 V , $V_S = 0.4\text{ V}$ or 3.3 V		50		ps
t_{TRAN}	Switching time from control input	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $V_{DD} = 2.5\text{ V}$ to 4.3 V , $V_S = 0.4\text{ V}$ or 3.3 V			400	ns
t_{ON}	Switch turnon time (from disabled to active mode)	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $V_{DD} = 2.5\text{ V}$ to 4.3 V , $V_S = 0.4\text{ V}$ or 3.3 V			100	μs
t_{OFF}	Switch turnoff time (from active to disabled mode)	$R_L = 50\ \Omega$, $C_L = 5\text{ pF}$, $V_{DD} = 2.5\text{ V}$ to 4.3 V , $V_S = 0.4\text{ V}$ or 3.3 V			100	μs
$C_{S(ON)}$ $C_{D(ON)}$	ON capacitance	$V_{DD} = 3.3\text{ V}$, $V_S = 0\text{ V}$ or 3.3 V , $f = 240\text{ MHz}$, Switch ON		1.3		pF
$C_{S(OFF)}$	OFF capacitance	$V_{DD} = 3.3\text{ V}$, $V_S = 0\text{ V}$ or 3.3 V , $f = 240\text{ MHz}$, Switch OFF		1		pF
C_I	Digital input capacitance	$V_{DD} = 3.3\text{ V}$, $V_I = 0\text{ V}$ or 2 V		2.2		pF
O_{ISO}	Differential OFF isolation	$V_S = -10\text{ dBm}$, $V_{DC_BIAS} = 2.4\text{ V}$, $R_T = 50\ \Omega$, $f = 240\text{ MHz}$ (see 7-3), Switch OFF		-38		dB
X_{TALK}	Channel-to-Channel Crosstalk	$V_S = -10\text{ dBm}$, $V_{DC_BIAS} = 0.2\text{ V}$, $R_T = 50\ \Omega$, $f = 240\text{ MHz}$ (see 7-4), Switch ON		-38		dB
BW	-3-dB bandwidth	$V_{DD} = 2.5\text{ V}$ to 4.3 V , $R_L = 50\ \Omega$ (see 7-5), Switch ON		6.5		GHz
SUPPLY						
V_{DD}	Power supply voltage		2.5		4.3	V
I_{DD}	Positive supply current	$V_{DD} = 4.3\text{ V}$, $V_{IN} = V_{DD}$ or GND, $V_S = 0\text{ V}$, Switch ON or OFF		28	40	μA

6.7 Typical Characteristics

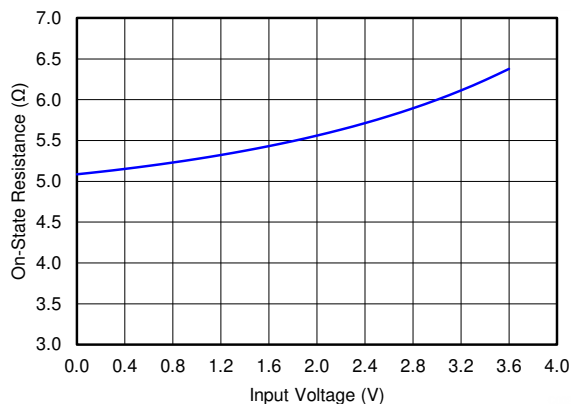


图 6-1. ON-Resistance vs V_S

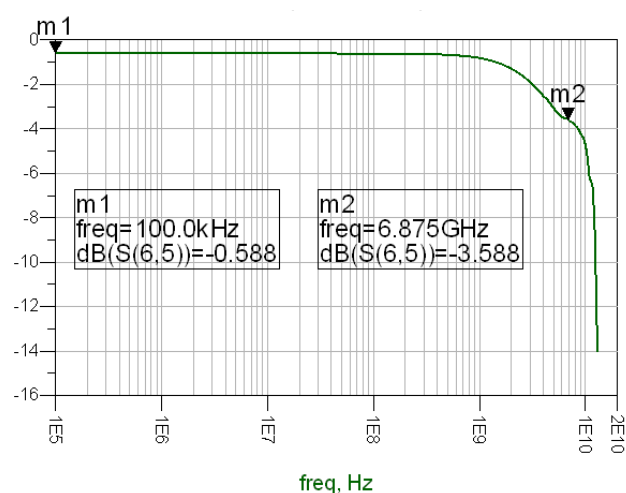


图 6-2. Typical Differential Bandwidth vs Frequency

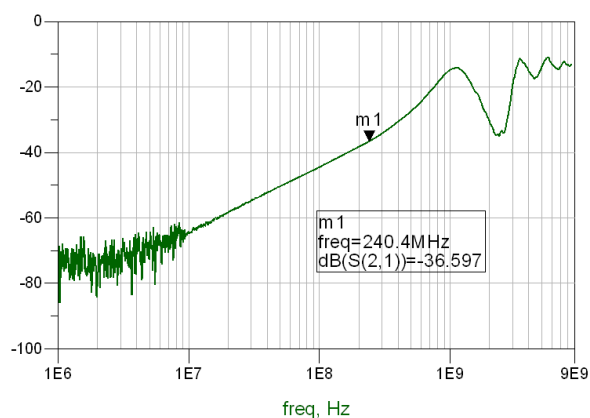


图 6-3. OFF Isolation vs Frequency

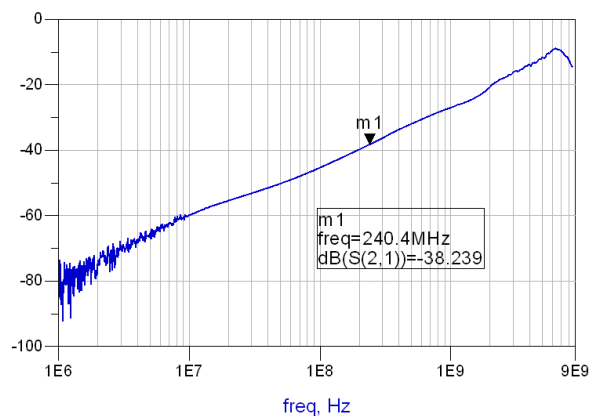
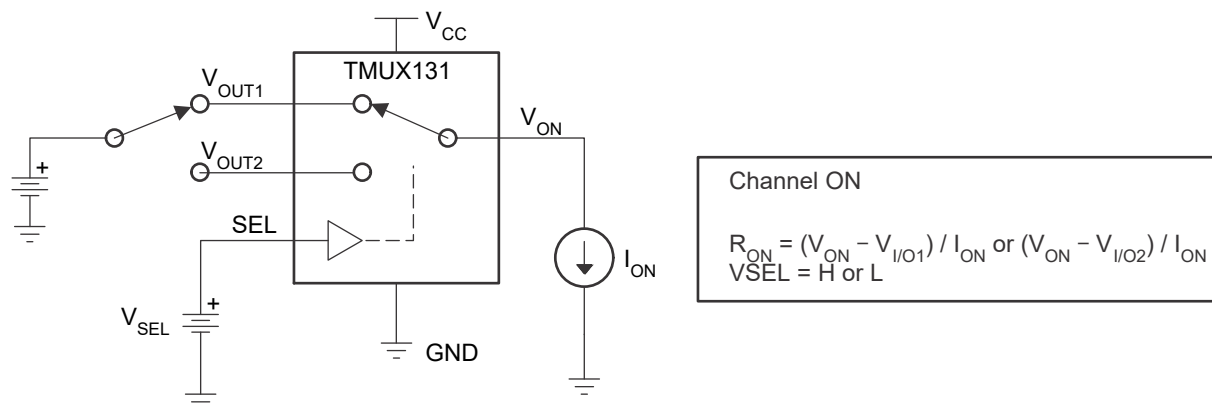
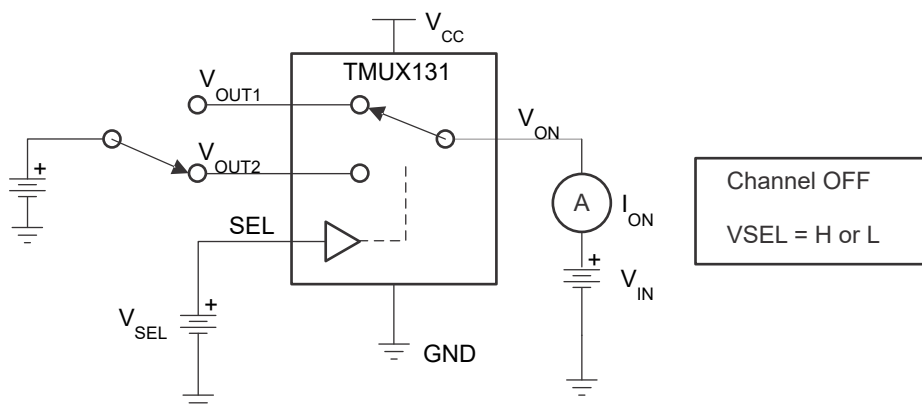


图 6-4. Cross Talk vs Frequency

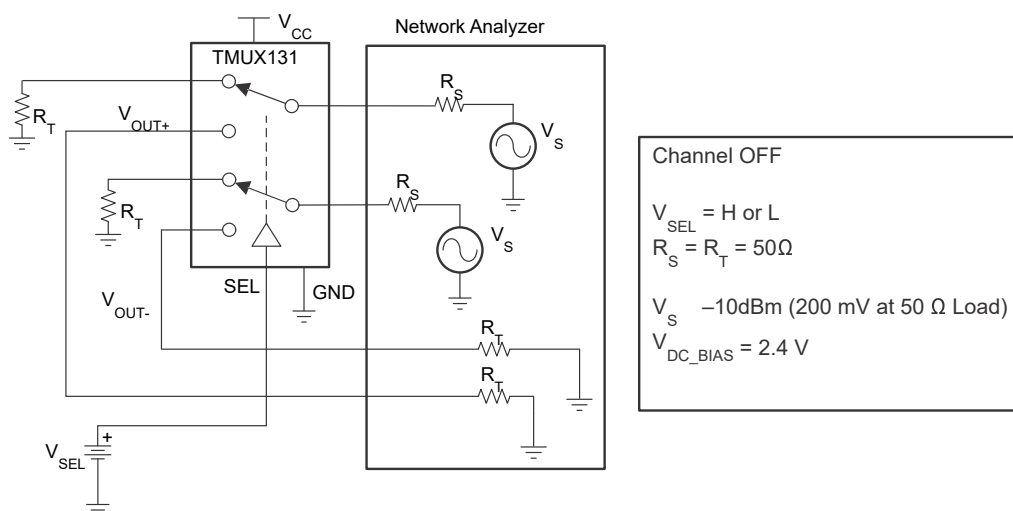
Parameter Measurement Information



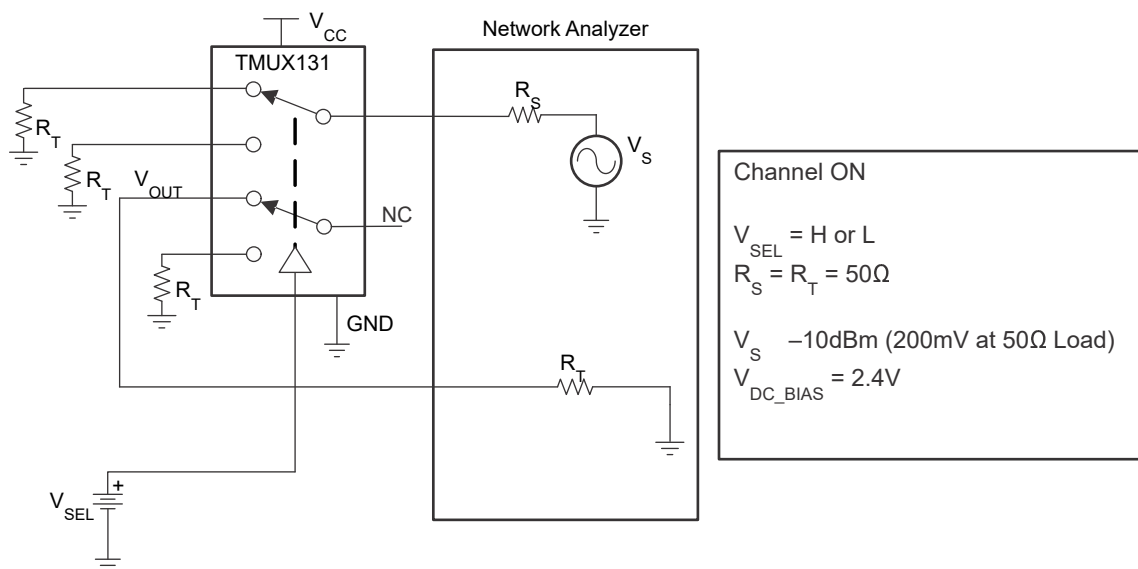
7-1. ON-State Resistance (R_{ON})



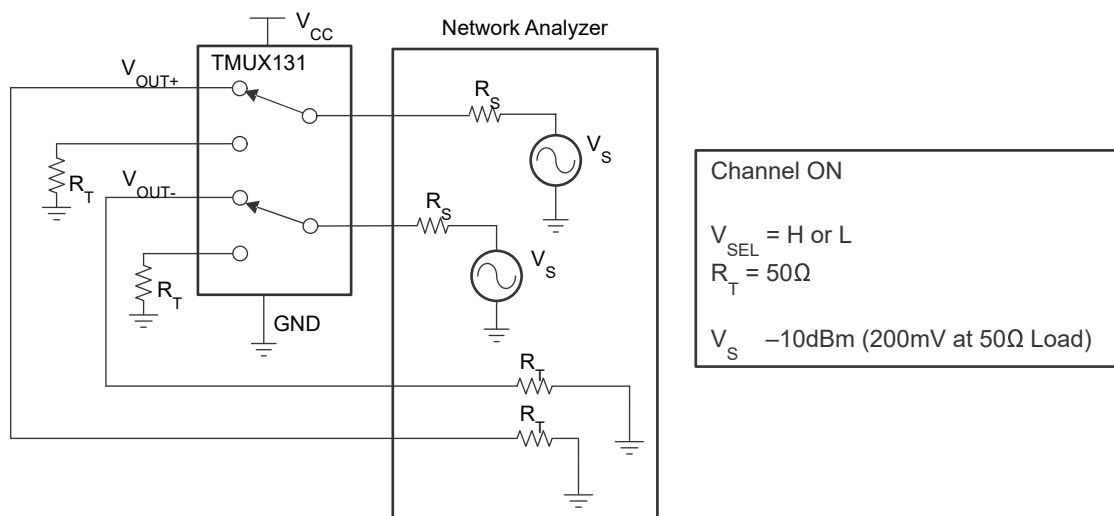
7-2. OFF Leakage Current (I_{OZ})



7-3. Differential Off-Isolation (O_{ISO})



7-4. Crosstalk (Xtalk)



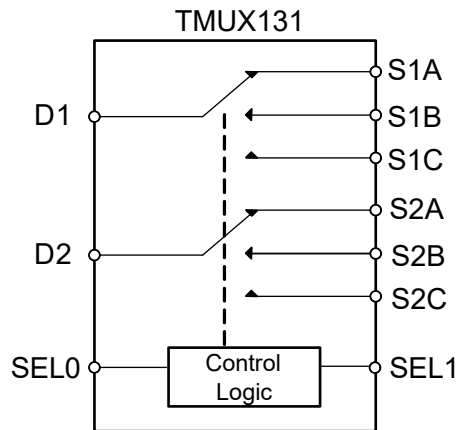
7-5. Differential Bandwidth (BW)

7 Detailed Description

7.1 Overview

The TMUX131 device is an analog passive 2 channel, 3:1 multiplexer that can work for any low-speed, high-speed, differential or single ended signals. Excellent low capacitance characteristics of the device allow signal switching with minimal attenuation and very little added jitter. The signals must be within the allowable voltage range of 0 to 3.6 V.

7.2 Functional Block Diagram



7.3 Feature Description

7.3.1 I_{OFF} Protection

I_{OFF} protection prevents current leakage through the device when V_{DD} = 0 V. This allows signals to be present on the source and drain pins before the device is powered up without damaging the device or system.

7.3.2 1.8-V Compatible Logic

The TMUX131 device supports 1.8-V logic irrespective to the supply voltage applied to the IC.

7.3.3 Overvoltage Tolerant (OVT)

The source and drain pins of the device can support signals up to 5.5 V without damaging the device. This protects the TMUX131 in case of an overvoltage fault event with no extra components needed.

7.3.4 Integrated Pull-Down Resistors

The TMUX131 has internal weak pull-down resistors (6 MΩ) to GND so that the logic pins are not left floating. This feature integrates up to two external components and reduces system size and cost.

7.4 Device Functional Modes

表 7-1 lists the functional modes of the TMUX131.

表 7-1. Function Table

SEL1	SEL0	SWITCH STATUS
Low	Low	D1/D2 connected to S1B/S2B
Low	High	D1/D2 connected to S1C/S2C
High	Low	D1/D2 connected to S1A/S2A
High	High	All switches in High-Z

8 Application and Implementation

注

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

8.1 Application Information

The TMUX131 is a passive, bidirectional, 2-channel 1:3 switch, which makes it versatile for many high speed 1:3 switching applications. This device can be used for general protocol switching applications such as I³C, I²C, UART, LVDS, and other analog signal applications.

8.2 Typical Application

8.2.1 Signal Expansion (I³C and I²C)

There are many applications in which microprocessors or controllers have a limited number of I/Os. The TMUX131 solution can effectively expand the limited I/Os by switching between multiple buses to interface them to a single microprocessor or controller. A common application where the TMUX131 is used as a I³C 1:3 multiplexer. In this application, the TMUX131 is used to route communicating between different peripherals from a single controller or driver within a server, as shown in [Figure 8-1](#). The high bandwidth of the TMUX131 will preserve signal integrity at even the fastest communication protocols that may be used in server applications, such as I³C. Also, because I³C is backwards compatible, any of the peripherals can also be I²C, and the TMUX131 will still support it.

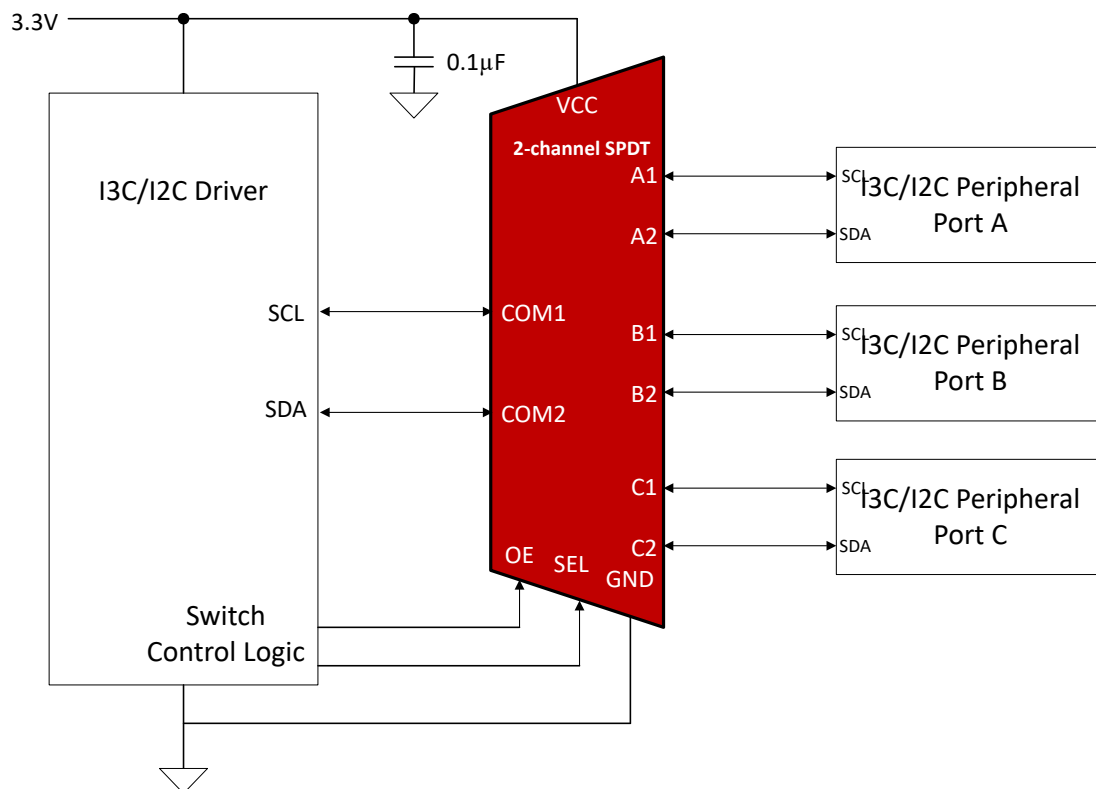


Figure 8-1. Typical TMUX131 Application

8.2.2 Design Requirements

The TMUX131 supports I³C standard by maintaining signal integrity through the switch. 表 8-1 details how the TMUX131 specifications make this device optimal for switching I³C signals.

表 8-1. TMUX131 I³C Compatibility

	I ³ C Requirements	TMUX131
Voltage	1.0 V, 1.2 V, 1.8 V, and 3.3 V	0 – 3.6 V
Frequency	Up to 12.5 MHz	6.5 GHz Bandwidth
Capacitance	50 pF maximum bus capacitance	< 2 pF On or Off Capacitance

8.2.3 Detailed Design Procedure

The TMUX131 can operate properly without any external components. However, TI recommends to connect unused signal I/O pins to ground through a 50-Ω resistor to prevent signal reflections back into the device.

8.2.4 Application Curves

図 8-2 shows TMUX131 bandwidth. This bandwidth can easily support the maximum data rate of the I³C standard. A combination of low on-resistance, low capacitance, and low added jitter from the device allows it to be used for I³C.

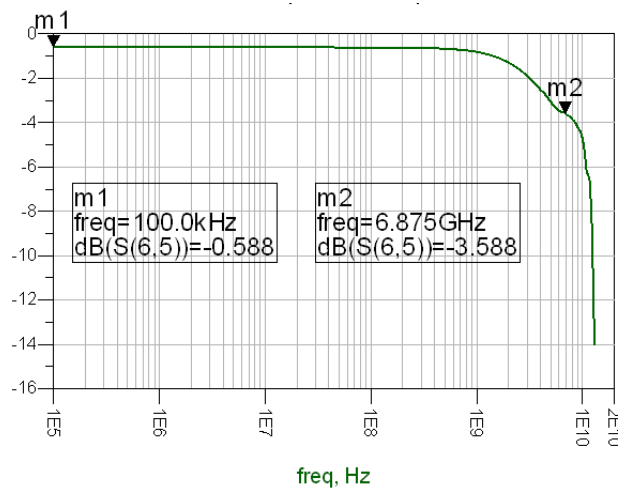


図 8-2. Typical Differential Bandwidth vs Frequency

8.3 Power Supply Recommendations

The TMUX131 does not require a power supply sequence. However, TI recommends to enable the device after VDD is stable and in specification. TI also recommends to place a bypass capacitor as close to the supply pin (VDD) as possible to help smooth out lower frequency noise and provide better load regulation across the frequency spectrum.

8.4 Layout

8.4.1 Layout Guidelines

Place supply bypass capacitors as close to VDD pin as possible and avoid placing the bypass capacitors near the high speed traces.

Route the high-speed signals using a minimum of vias and corners which reduces signal reflections and impedance changes. When a via must be used, increase the clearance size around it to minimize its capacitance. Each via introduces discontinuities in the signal's transmission line and increases the chance of picking up interference from the other layers of the board. Be careful when designing test points on twisted pair lines; through-hole pins are not recommended.

When it becomes necessary to turn 90°, use two 45° turns or an arc instead of making a single 90° turn. Doing this reduces reflections on the signal traces by minimizing impedance discontinuities. Avoid stubs on the high-speed signals because they cause signal reflections. Route all high-speed signal traces over continuous planes (VDD or GND) with no interruptions.

Due to high frequencies, a printed circuit board with at least four layers is recommended; two signal layers separated by a ground and power layer as shown in [Figure 8-3](#).

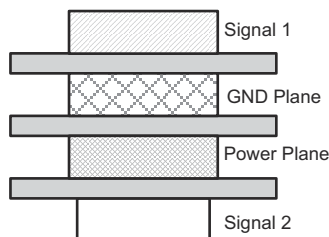
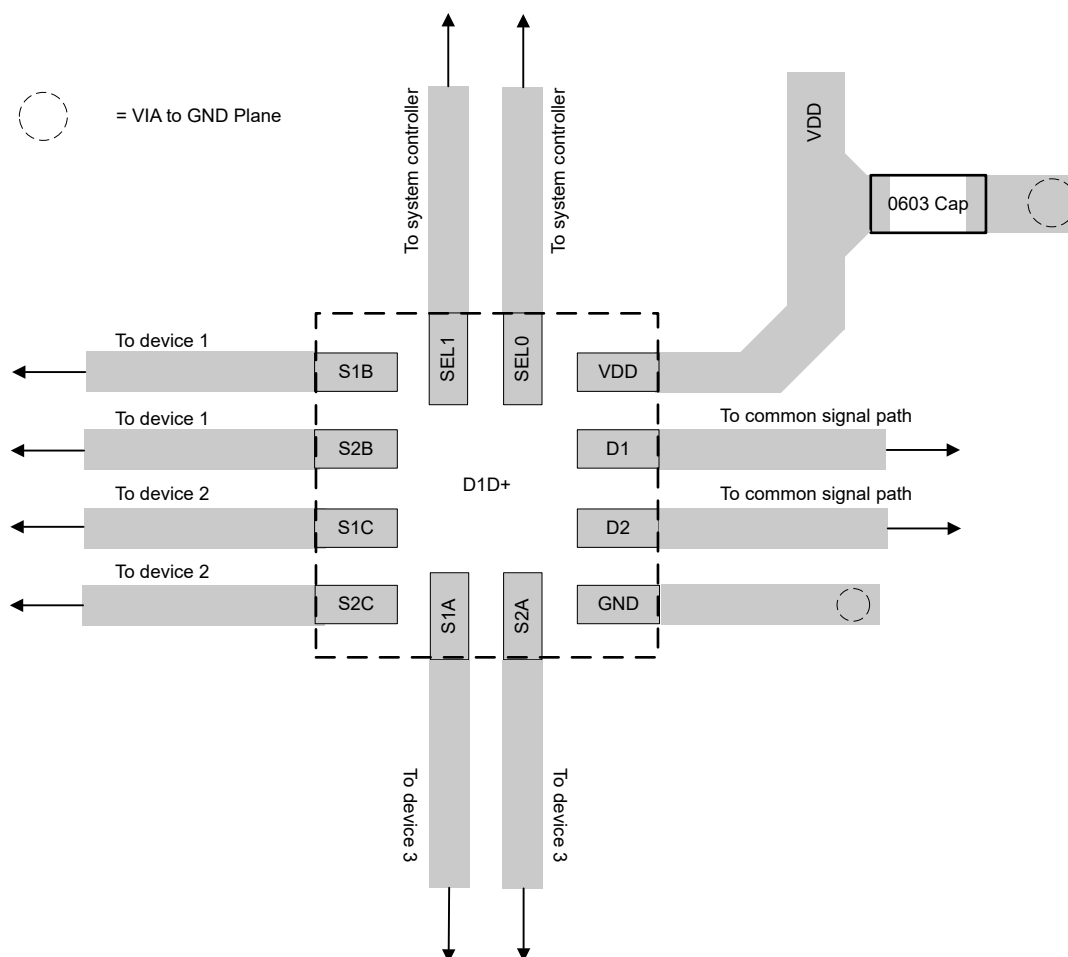


Figure 8-3. Four-Layer Board Stack-Up

The majority of signal traces must run on a single layer, preferably Signal 1. Immediately next to this layer must be the GND plane, which is solid with no cuts. Avoid running signal traces across a split in the ground or power plane. When running across split planes is unavoidable, sufficient decoupling must be used. Minimizing the number of signal vias reduces EMI by reducing inductance at high frequencies.

For high speed layout guidelines, refer to [High-Speed Layout Guidelines application note](#).

8.4.2 Layout Example




8-4. Layout Recommendation

9 Device and Documentation Support

9.1 Documentation Support

9.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, [High Speed Layout Guidelines](#)

9.2 ドキュメントの更新通知を受け取る方法

ドキュメントの更新についての通知を受け取るには、[ti.com](#) のデバイス製品フォルダを開いてください。「更新の通知を受け取る」をクリックして登録すると、変更されたすべての製品情報に関するダイジェストを毎週受け取れます。変更の詳細については、修正されたドキュメントに含まれている改訂履歴をご覧ください。

9.3 サポート・リソース

[TI E2E™ サポート・フォーラム](#)は、エンジニアが検証済みの回答と設計に関するヒントをエキスパートから迅速かつ直接得ることができる場所です。既存の回答を検索したり、独自の質問をしたりすることで、設計に必要な支援を迅速に得ることができます。

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9.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

すべての商標は、それぞれの所有者に帰属します。

9.5 静電気放電に関する注意事項



この IC は、ESD によって破損する可能性があります。テキサス・インスツルメンツは、IC を取り扱う際には常に適切な注意を払うことを推奨します。正しい取り扱いおよび設置手順に従わない場合、デバイスを破損するおそれがあります。

ESD による破損は、わずかな性能低下からデバイスの完全な故障まで多岐にわたります。精密な IC の場合、パラメータがわずかに変化するだけで公表されている仕様から外れる可能性があるため、破損が発生しやすくなっています。

9.6 用語集

[テキサス・インスツルメンツ用語集](#) この用語集には、用語や略語の一覧および定義が記載されています。

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.

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)
TMUX131RMGR	Active	Production	WQFN (RMG) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	OH
TMUX131RMGR.A	Active	Production	WQFN (RMG) 12	3000 LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 85	OH

⁽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.



WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



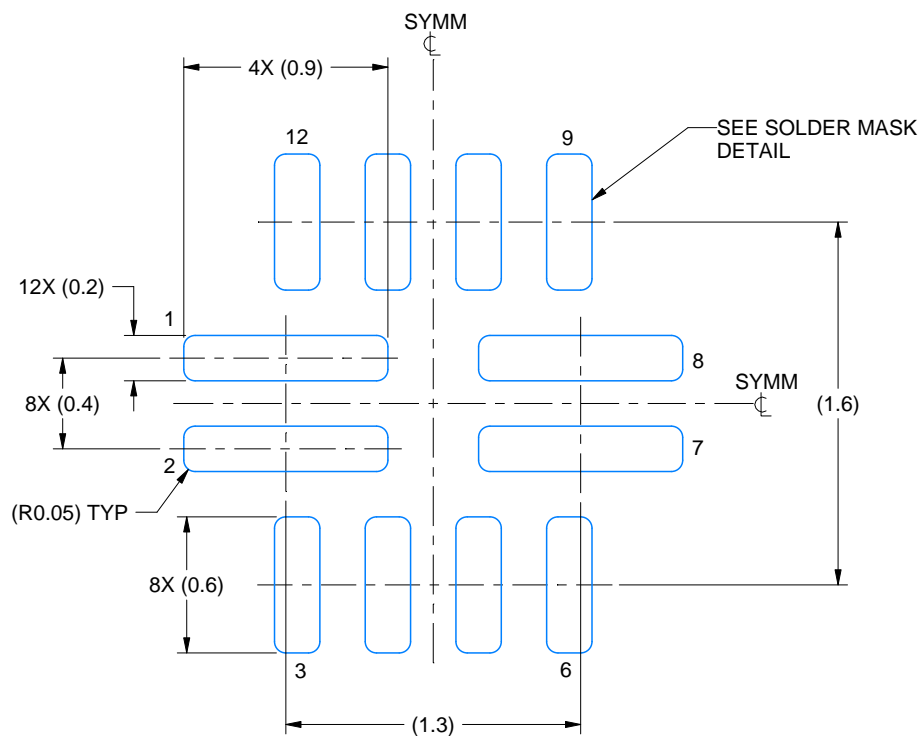
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.

EXAMPLE BOARD LAYOUT

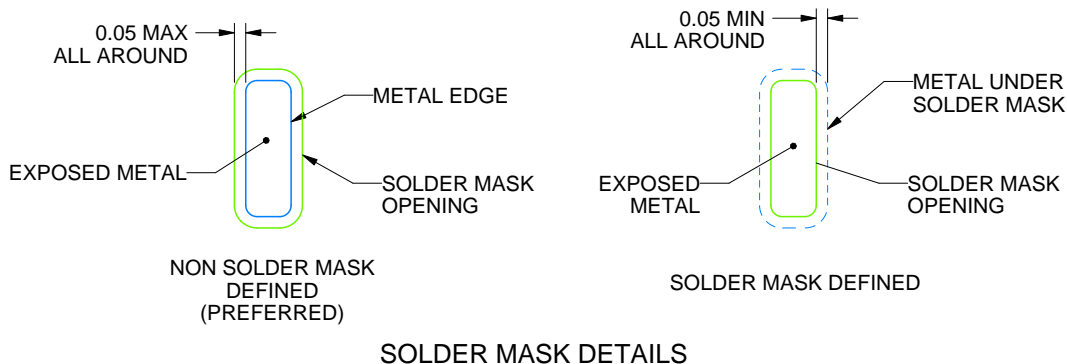
RMG0012A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE: 30X



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NOTES: (continued)

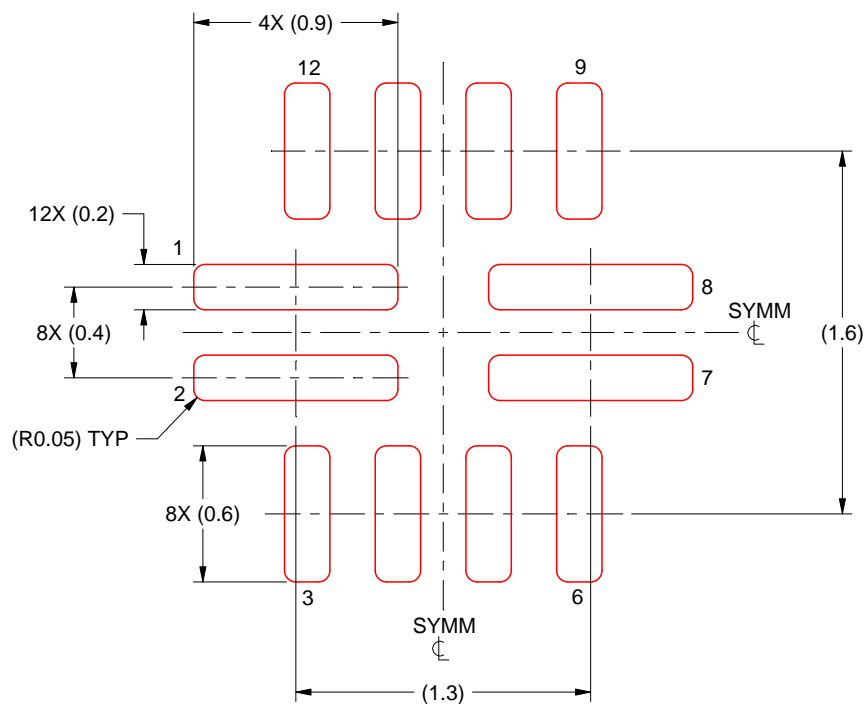
- This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slue271).
- Vias are optional depending on application, refer to device data sheet. If any vias are implemented, refer to their locations shown on this view. It is recommended that vias under paste be filled, plugged or tented.

EXAMPLE STENCIL DESIGN

RMG0012A

WQFN - 0.8 mm max height

PLASTIC QUAD FLATPACK - NO LEAD



SOLDER PASTE EXAMPLE
BASED ON 0.125 MM THICK STENCIL
SCALE: 30X

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NOTES: (continued)

6. 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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