TUSB211 USB 2.0 High Speed Signal Conditioner

1 Features

- Compatible with USB 2.0, OTG 2.0 and BC 1.2
- Support for LS, FS, HS signaling
- Active Power Consumption of 55 mW (Typical) with 3.3-V Single Supply
- Selectable Signal Gain Via External Pulldown Resistor
- Does Not Break DP, DM Trace
- Scalable Solution – Daisy Chain Device for High Loss Applications
- Compact 1.6 mm x 1.6 mm QFN Package

2 Applications

- Notebooks
- Desktops
- Docking Stations
- Cell Phones
- Active Cable, Cable Extenders
- Backplane
- Televisions
- Tablets

3 Description

The TUSB211 is a USB High-Speed (HS) signal conditioner, designed to compensate for ISI signal loss in a transmission channel.

The device has a patent-pending design which is agnostic to USB Low Speed (LS) and Full Speed (FS) signals. LS and FS signal characteristics are unaffected by the TUSB211. HS signals are compensated.

Programmable signal gain permits fine tuning device performance to optimize High Speed signals at the connector. This helps to pass USB High Speed electrical compliance tests.

The footprint of TUSB211 does not break the continuity of the DP/DM signal path. This permits risk free system design of a complete USB channel.

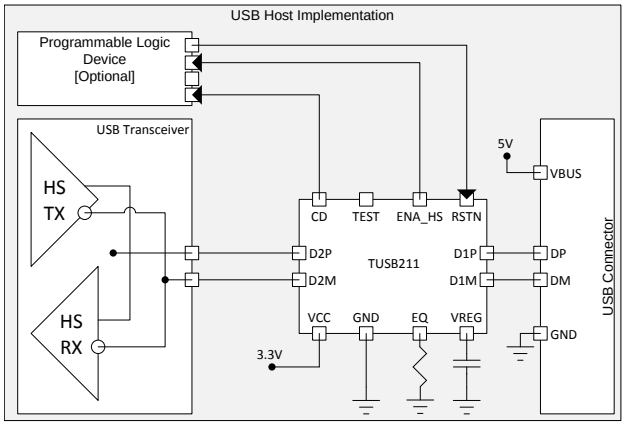
In addition, TUSB211 is compatible with the USB On-The-Go (OTG) and Battery Charging (BC) protocols

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
TUSB211	X2QFN (12)	1.60 mm x 1.60 mm
TUSB211I		

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

Simplified Schematic





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An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Revision History

Changes from Revision C (June 2016) to Revision D — **Page**

- Deleted device TUSB211-Q1 From the data sheet ... 1
- Deleted *Features*: Qualified for Automotive Applications ... 1
- Deleted *Applications*: Automotive Infotainment ... 1

Changes from Revision A (June 2015) to Revision B — **Page**

- Changed From: 1-page datasheet To: Full datasheet ... 1
- Added *Features*: Qualified for Automotive Applications ... 1
- Deleted *Features*: –40°C to 85°C Industrial Temperature Range ... 1
- Added *Applications*: Automotive Infotainment ... 1
- Changed the *Simplified Schematic* ... 1

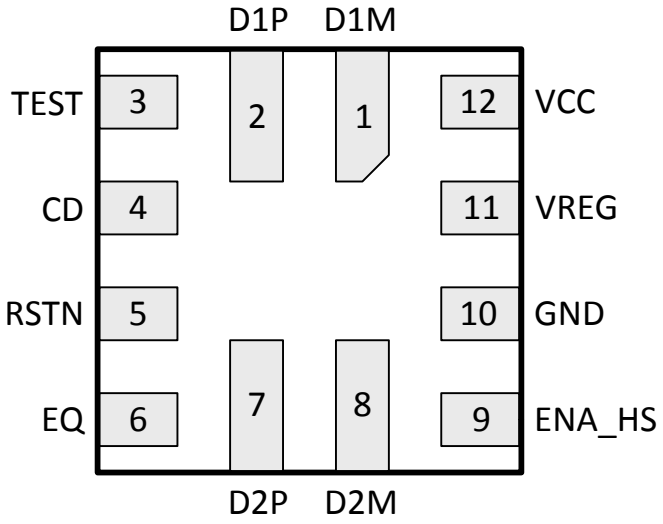
Changes from Original (May 2015) to Revision A — **Page**

- Changed the data sheet From: Product Preview To: Production ... 1

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5 Pin Configuration and Functions

RWB Package
12 Pin (X2QFN)
Top View



Pin Functions

PIN		I/O	INTERNAL PULLUP/PULLDOWN	DESCRIPTION
NAME	NO.			
VCC	12	P	N/A	3.3-V power
VREG	11	O	RSTN asserted: 30 kΩ PD FS, LS mode: 30 kΩ PD HS mode: N/A	1.8-V LDO output. Only enabled when operating in High Speed mode. Requires 0.1-µF external capacitor to GND to stabilize the core.
GND	10	P	N/A	Ground
RSTN	5	I	500 kΩ PU	Device disable/enable. Recommend 0.1-µF external capacitor to GND to ensure clean power on reset if not driven.
EQ	6	I	N/A	USB High Speed boost select via external pull down resistor. Sampled upon power up. Auto selects min EQ when left floating. Does not recognize real time adjustments.
D1P	2	I/O	N/A	USB High Speed positive port. Orientation independent – Can face either upstream or downstream.
D1M	1	I/O	N/A	USB High Speed negative port. Orientation independent – Can face either upstream or downstream.
D2P	7	I/O	N/A	USB High Speed positive port. Orientation independent – Can face either upstream or downstream.
D2M	8	I/O	N/A	USB High Speed negative port. Orientation independent – Can face either upstream or downstream.
TEST	3	I	RSTN asserted: 500 kΩ PD	No function. Leave floating.
ENA_HS	9	O	RSTN asserted: 500kΩ PD	Flag indicating that channel is in High Speed mode. Asserted upon: 1. Detection of USB-IF High Speed test fixture from an unconnected state followed by transmission of USB TEST_PACKET pattern. 2. Squelch detection following USB reset with a successful HS handshake [HS handshake is declared to be successful after single chirp J chirp K pair where each chirp is within 18 µs – 128 µs] De-asserted upon detection of disconnect or suspend. Can be left floating if not needed.
CD	4	O	RSTN asserted: 500 kΩ PD	Flag indicating that a USB device is attached. Asserted from an unconnected state upon detection of DP or DM pull-up resistor. De-asserted upon detection of disconnect. Can be left floating if not needed.

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6 Specifications

6.1 Absolute Maximum Ratings

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

		MIN	MAX	UNIT
Supply voltage range	VCC	–0.3	3.8	V
Voltage range	D1P, D1M, D2P, D2M, RSTN, EQ	–0.3	3.8	V
Storage temperature, T_{stg}		–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.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 (1)	±3000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 (2)	±1000	

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

6.3 Recommended Operating Conditions

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

		MIN	NOM	MAX	UNIT
V_{CC}	Supply voltage	3	3.3	3.6	V
T_A	Operating free-air temperature [TUSB211]	0		70	°C
	Operating free-air temperature [TUSB211I]	–40		85	

6.4 Thermal Information

THERMAL METRIC (1)		RWB	UNIT
		12 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	161.6	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	63.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	75.1	°C/W
ψ_{JT}	Junction-to-top characterization parameter	1.9	°C/W
ψ_{JB}	Junction-to-board characterization parameter	75.1	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

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

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6.5 Electrical Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP (1)	MAX	UNIT
$I_{(ACTIVE_HS)}$	High Speed Active Current	USB channel = HS mode. 480 Mbps traffic. V_{CC} supply stable		16	20	mA
$I_{(IDLE_HS)}$	High Speed Idle Current	USB channel = HS mode. No traffic. V_{CC} supply stable		12	15	mA
$I_{(SUSPEND_HS)}$	Suspend Current	USB channel = Suspend mode.		4.5	5.5	mA
$I_{(FS)}$	Full-Speed Current	USB channel = FS mode		4.5	5.5	mA
$I_{(LS)}$	Low-Speed Current	USB channel = LS mode		4.5	5.5	mA
$I_{(DISCONN)}$	Disconnect Power	Host side application. No device attachment.		4.5	5.5	mA
$I_{(RSTN)}$	Disable Power	RSTN driven low; V_{CC} supply stable; V_{CC} = 3.3 V		4.5	5.5	mA
RSTN						
V_{IH}	High level input voltage		2		V_{CC}	V
V_{IL}	Low-level input voltage		0		0.8	V
I_{IH}	High level input current	V_{IH} = 3.6 V, V_{CC} = 3 V, RPU enabled			±2	µA
I_{IL}	Low level input current	V_{IL} = 0V, V_{CC} = 3.6 V, RPU enabled			±11	µA
EQ						
$R_{(EQ)}$	External pulldown resistor	Level 0 EQ			0.32	kΩ
		Level 1 EQ	1.4		2.2	kΩ
		Level 2 EQ [MAX]	3.7		4.1	kΩ
		Level 3 EQ [MIN]	6			kΩ
CD, ENA_HS						
V_{OH}	High level output voltage	I_O = –50 µA	2.4			V
V_{OL}	Low level output voltage	I_O = 50 µA			0.4	V
DxP, DxM						
$T_{(SHRT_GND)}$	DP, DM low voltage short circuit	DxP or DxM short circuited to GND continuously for 24 hours at T_A = 25°C only	0			V
$C_{IO(DXX)}$	Capacitance to GND	Measured with LCR meter and device powered down. 1 MHz sinusoid, 30 mVpp ripple		5		pF

(1) (1) All typical values are at V_{CC} = 3.3 V, and T_A = 25°C.

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6.6 Switching Characteristics

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

PARAMETER		TEST CONDITIONS	MIN	TYP (1)	MAX	UNIT
DxP, DxM						
$F_{(BR_DXX)}$	Bit Rate	USB channel = HS mode. 480 Mbps traffic. V_{CC} supply stable			480	Mbps
$t_{(R/F_DXX)}$	Rise/Fall time		100			ps
CD, ENA_HS						
$t_{(EN)}$	Enable time			20		µs
$t_{(DIS)}$	Disable time			20		µs
VCC						
$t_{(STABLE)}$	V_{CC} stable before RSTN de-assertion		100			µs
$t_{(RAMP)}$	V_{CC} ramp time		0.2		100	ms

(1) (1) All typical values are at V_{CC} = 3.3 V, and T_A = 25°C.

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7 Detailed Description

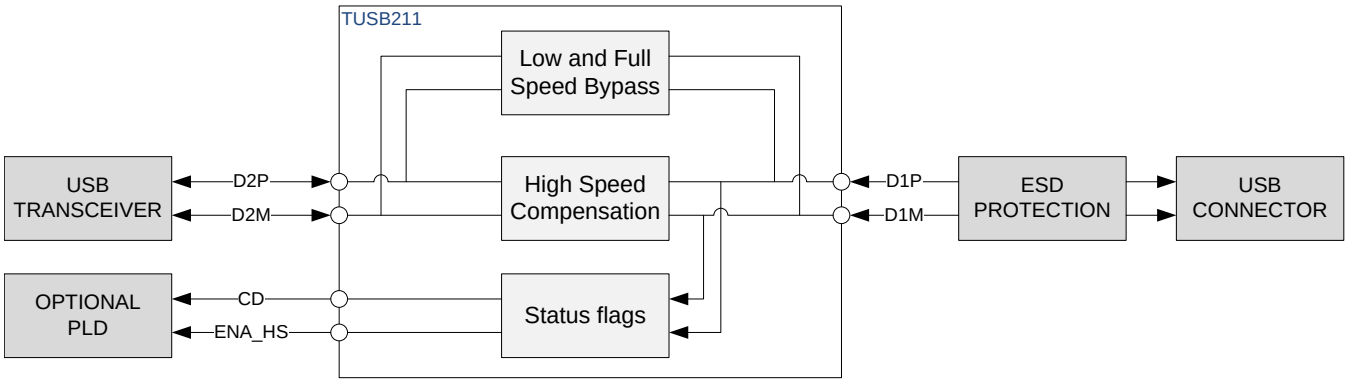
7.1 Overview

The TUSB211 is a USB High-Speed (HS) signal conditioner, designed to compensate for ISI signal loss in a transmission channel. TUSB211 has a patent-pending design which is agnostic to USB Low Speed (LS) and Full Speed (FS) signals and does not alter their signal characteristics, while HS signals are compensated. In addition, the design is compatible with USB On-The-Go (OTG) and Battery Charging (BC) specifications.

Programmable signal gain through an external resistor permits fine tuning device performance to optimize signals helping to pass USB HS electrical compliance tests at the connector.

The footprint of TUSB211 allows a board layout using this device such that it does not break the continuity of the DP/DM signal traces. This permits risk free system design of a complete USB channel with flexible use of one or multiple TUSB211 devices as needed for optimal signal integrity. This allows system designers to plan for this device and use it only if signal integrity analysis and/or lab measurements show a need. If such a need is not warranted, the device can be left unpopulated without any board rework.

7.2 Functional Block Diagram



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7.3 Device Functional Modes

7.3.1 Low Speed (LS) Mode

TUSB211 automatically detects a LS connection and does not enable signal compensation. CD pin is asserted high.

7.3.2 Full Speed (FS) Mode

TUSB211 automatically detects a FS connection and does not enable signal compensation. CD pin is asserted high.

7.3.3 High Speed (HS) Mode

TUSB211 automatically detects a HS connection and enables signal compensation as determined by the configuration of the external pulldown resistance on its EQ pin. ENA_HS pin asserted high in addition to the CD pin.

7.3.4 Disable Mode

TUSB211 can be disabled when its RSTN pin is asserted low. The USB channel is still fully operational, but there is neither signal compensation, nor any indication from the CD pin or ENA_HS pin as to the status of the channel.

8 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.

8.1 Application Information

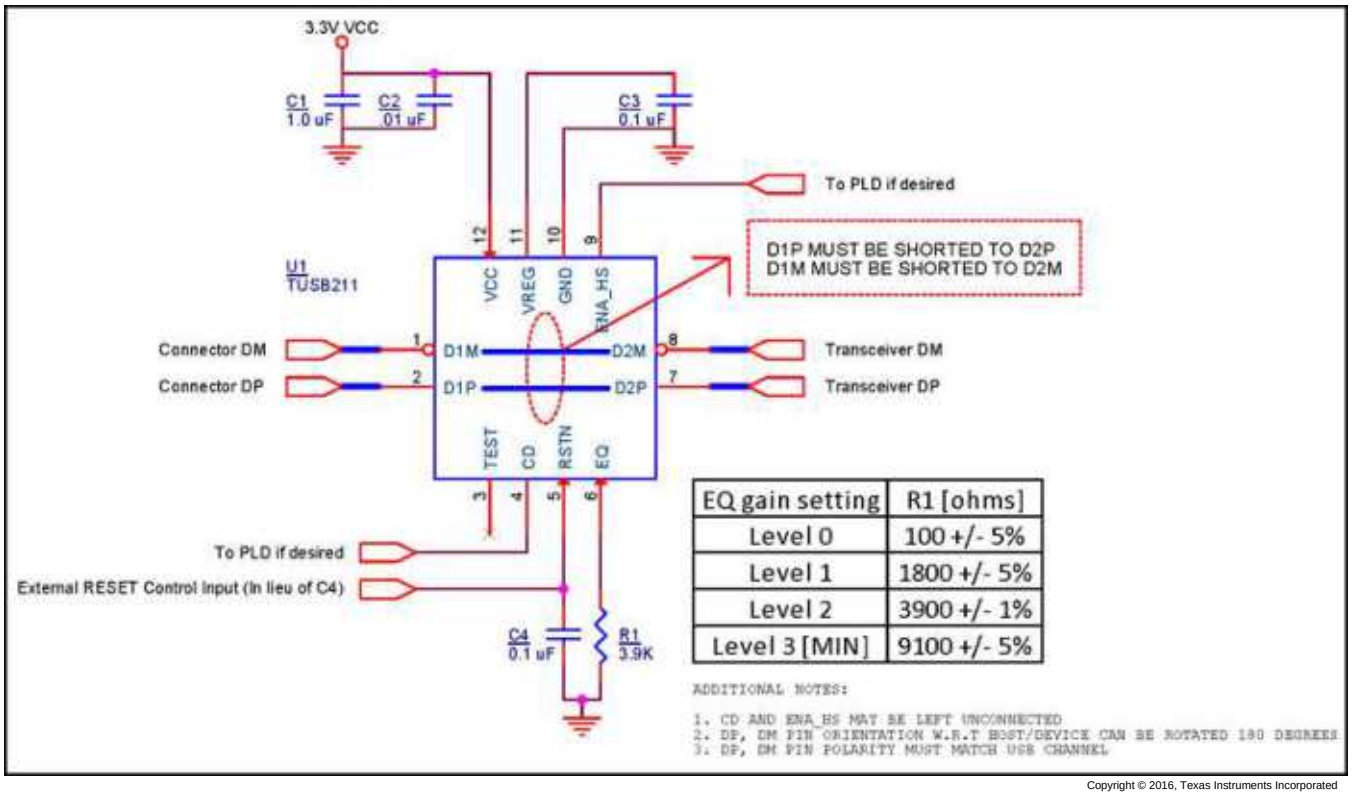
The primary purpose of the TUSB211 is to re-store the signal integrity of a USB High Speed channel up to the USB connector. The loss in signal quality stems from reduced channel bandwidth due to high loss PCB trace and other components that contribute a capacitive load. This can cause the channel to fail the USB near end eye mask. Proper use of the TUSB211 can help to pass this eye mask.

A secondary purpose is to use the CD pin and ENA_HS pin of the TUSB211 to control other blocks on the customer platform if so desired.

8.2 Typical Application

A typical application is shown below. In this setup, D1P and D1M face the USB connector while D2P and D2M face the USB transceiver. If desired, the orientation may be reversed [that is, D1 faces transceiver and D2 faces connector].

Note that CD and ENA_HS are connected to PLDs. This is for platforms where other circuit blocks must be modified based on the status of the USB channel. They could also be connected to LEDs to give a physical indication of current channel status for debug purposes. If neither use is desired, they can be left floating.



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Figure 1. Reference Schematic

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Typical Application (continued)

8.2.1 Design Requirements

TUSB211 requires a valid reset signal as described in the power supply recommendations section. The capacitor C4 is not required if a microcontroller drives the RSTN pin according to recommendations.

Pin 11 VREG is an internal LDO output that requires a 0.1 μF external capacitor to GND to stabilize the core.

Pin 6 EQ requires an external pulldown resistor if EQ levels 0-2 are needed. If EQ level 3 is needed, then the EQ pin can be left floating.

8.2.2 Detailed Design Procedure

The ideal EQ setting is dependent upon the signal chain loss characteristics of the target platform. The general recommendation is to start with EQ level 0, and then increment to EQ level 1, and so on. if permissible.

In order for the TUSB211 to recognize any change to the EQ setting, the RSTN pin must be toggled. This is because the EQ pin is latched on power up and the pin is ignored thereafter.

In addition, TUSB211 does not compensate for any DC attenuation in the signal path. Therefore, minimizing DC loss (that is, resistance) in the system design, is suggested. As a consequence, this might lead to increased line capacitance. This is acceptable because the TUSB211 can compensate for the additional capacitive load.

Placement of the device is also dependent on the application goal. Table 1 summarizes the recommendations.

Table 1. TUSB211 Platform Placement Guideline

PLATFORM GOAL	SUGGESTED TUSB211 PLACEMENT
Pass USB Near End Mask	Close to measurement point
Pass USB Far End Eye Mask	Close to USB PHY
Cascade multiple 211s to improve device enumeration	Midway between each USB interconnect

NOTE

USB-IF certification tests for High Speed eye masks require the *mandated use* of the USB-IF developed test fixtures. These test fixtures do not require the use of oscilloscope probes. Instead they use SMA cables. More information can be found at the USB-IF Compliance Updates Page. It is located under the 'Electricals' section, ID 86 dated March 2013.

The following procedure must be followed before using any oscilloscope compliance software to construct a USB High Speed Eye Mask:

8.2.2.1 For a Host Side Application

1. Configure the TUSB211 to the desired EQ setting
2. Power on (or toggle the RSTN pin if already powered on) the TUSB211
3. Using SMA cables, connect the oscilloscope and the USB-IF host-side test fixture to the TUSB211
4. Enable the host to transmit USB TEST_PACKET
5. Execute the oscilloscope's USB compliance software.
6. Repeat the above steps in order to re-test TUSB211 with a different EQ setting

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8.2.2.2 For a Device Side Application

1. Configure the TUSB211 to the desired EQ setting
2. Power on (or toggle the RSTN pin if already powered on) the TUSB211
3. Connect a USB host, the USB-IF device-side test fixture, and USB device to the TUSB211. Ensure that the USB-IF device test fixture is configured to the 'INIT' position
4. Allow the host to enumerate the device
5. Enable the device to transmit USB TEST_PACKET
6. Using SMA cables, connect the oscilloscope to the USB-IF device-side test fixture and ensure that the device-side test fixture is configured to the 'TEST' position.
7. Execute the oscilloscope's USB compliance software.
8. Repeat the above steps in order to re-test TUSB211 with a different EQ setting

8.2.3 Application Curves

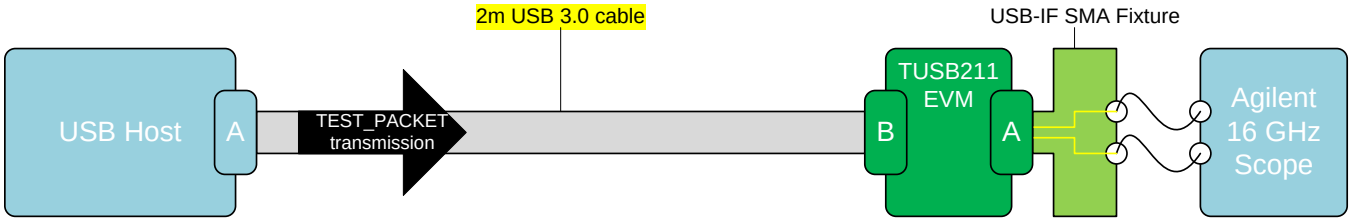


Figure 2. Eye Diagram Bench Setup

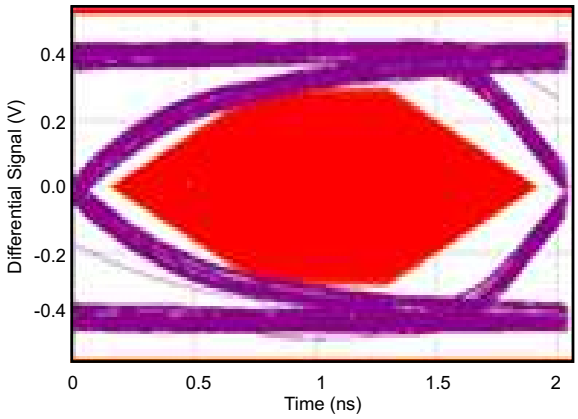


Figure 3. TUSB211 Disabled

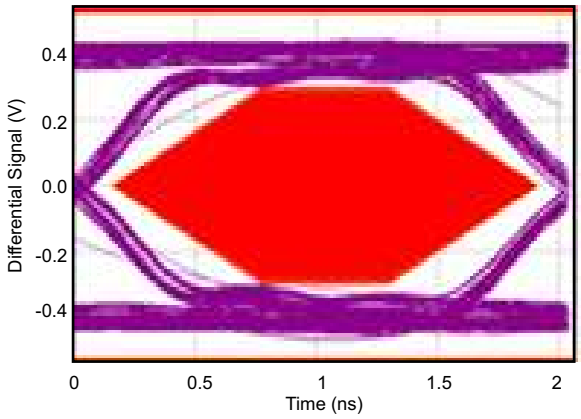


Figure 4. EQ Level 0

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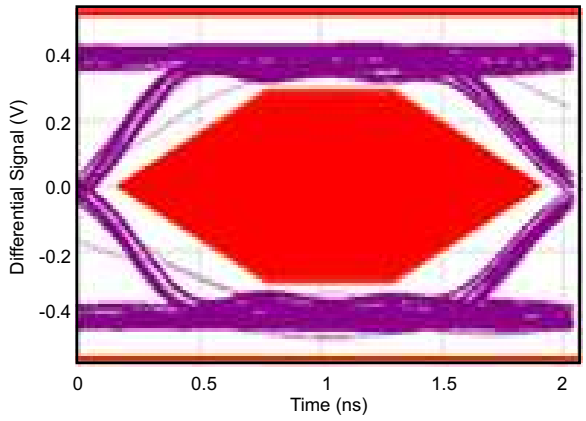


Figure 5. EQ Level 1

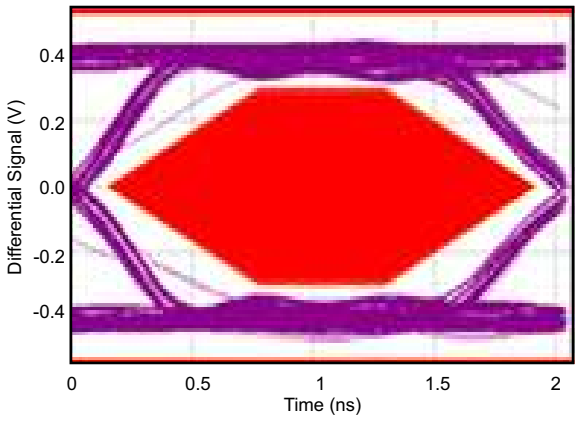


Figure 6. EQ Level 2

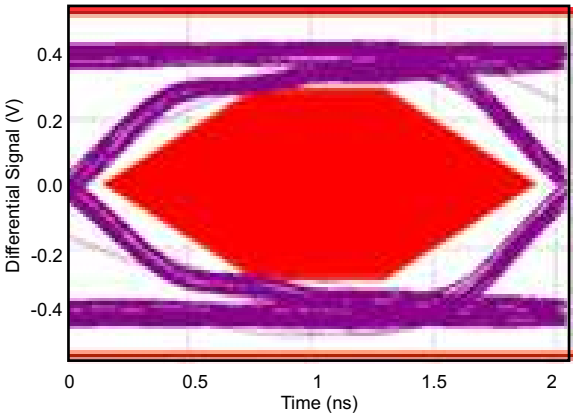


Figure 7. EQ Level 3

9 Power Supply Recommendations

On power up, the interaction of the RSTN pin and power on ramp could result in digital circuits not being set correctly. The device should not be enabled until the power on ramp has settled to 3 V or higher to guarantee a correct power on reset of the digital circuitry. If RSTN cannot be held low by microcontroller or other circuitry until the power on ramp has settled, then an external capacitor from the RSTN pin to GND is required to hold the device in the low power reset state.

The RC time constant should be larger than five times of the power on ramp time (0 to V_{CC}). With a typical internal pullup resistance of 500 kΩ, the recommended minimum external capacitance is calculated as:

[Ramp Time x 5] ÷ [500 kΩ] (1)

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10 Layout

10.1 Layout Guidelines

There is no need to break the USB signal trace. Thus, even with the TUSB211 powered down, or not populated, the USB link is still fully operational. To avoid the need for signal vias, routing the High Speed traces directly underneath the TUSB211 package, as illustrated in the PCB land pattern shown in Figure 8, is recommended.

Although the land pattern shown below has matched trace width to pad width, optimal impedance control is based on the user's own PCB stack-up. It is recommended to maintain 90 Ω differential routing underneath the device.

All dimensions are in millimetres (mm).

10.2 Layout Example

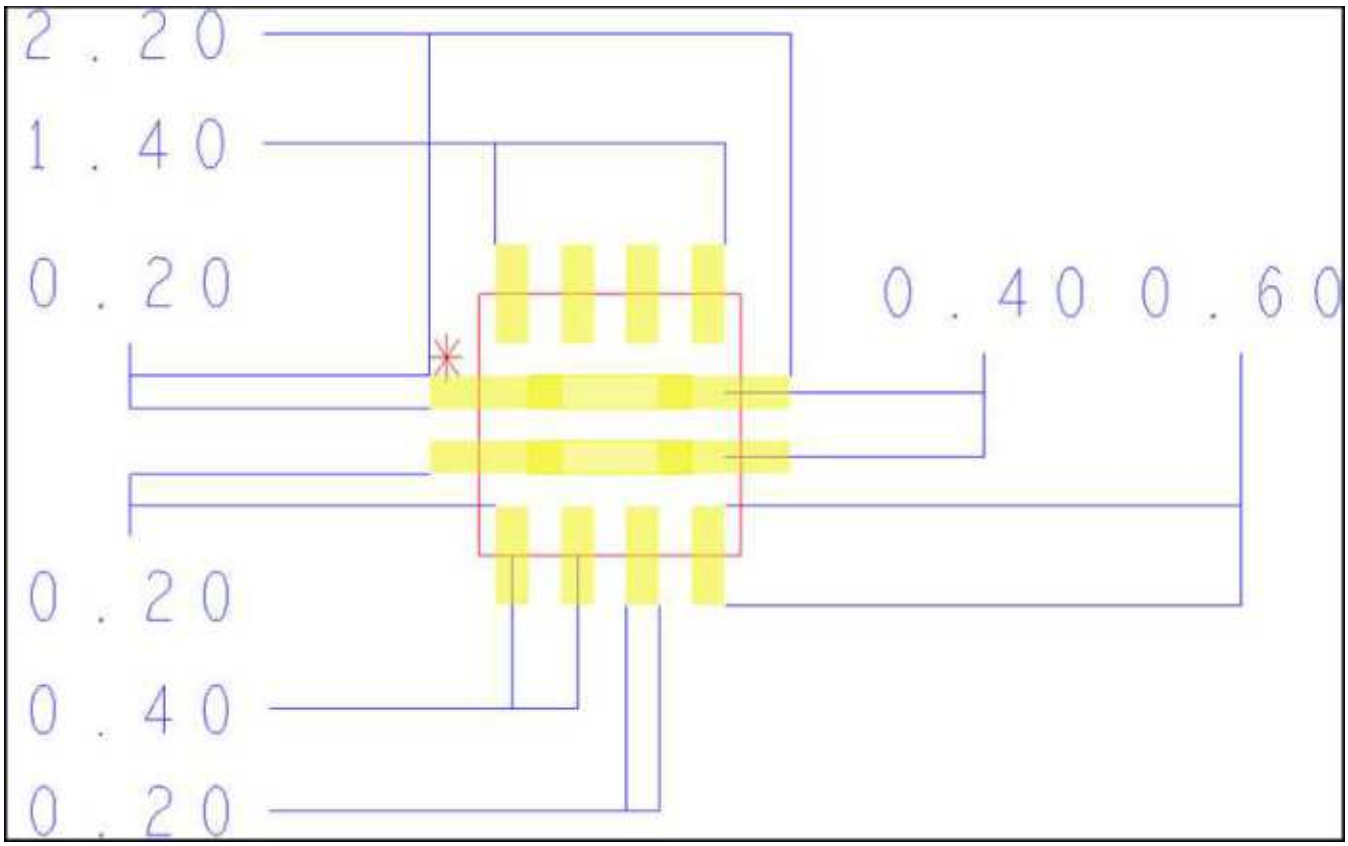


Figure 8. DP and DM Routing Underneath Device Package

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11 Device and Documentation Support

11.1 Related Links

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

Table 2. Related Links

PARTS	PRODUCT FOLDER	ORDER NOW	TECHNICAL DOCUMENTS	TOOLS & SOFTWARE	SUPPORT & COMMUNITY
TUSB211	Click here	Click here	Click here	Click here	Click here
TUSB211I	Click here	Click here	Click here	Click here	Click here

11.2 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.

11.3 Trademarks

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

11.4 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.

11.5 Glossary

SLYZ022 — *TI Glossary*.

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

12 Mechanical, Packaging, and Orderable Information

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

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
TUSB211IRWBR	NRND	Production	X2QFN (RWB) | 12	3000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	I1
TUSB211IRWBR.A	NRND	Production	X2QFN (RWB) | 12	3000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	-40 to 85	I1
TUSB211RWBR	NRND	Production	X2QFN (RWB) | 12	3000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	0 to 70	C1
TUSB211RWBR.A	NRND	Production	X2QFN (RWB) | 12	3000 | LARGE T&R	Yes	NIPDAU	Level-2-260C-1 YEAR	0 to 70	C1

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

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

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

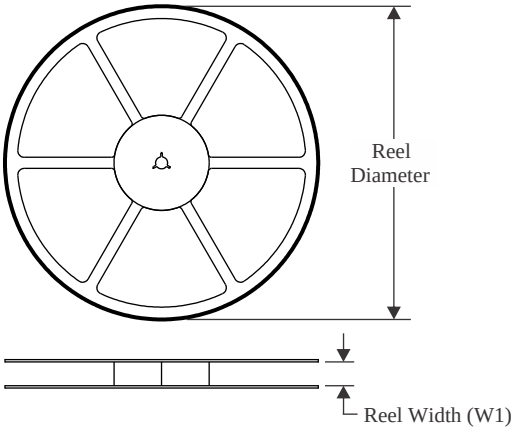
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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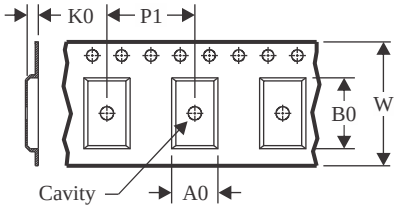
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TAPE AND REEL INFORMATION

REEL DIMENSIONS

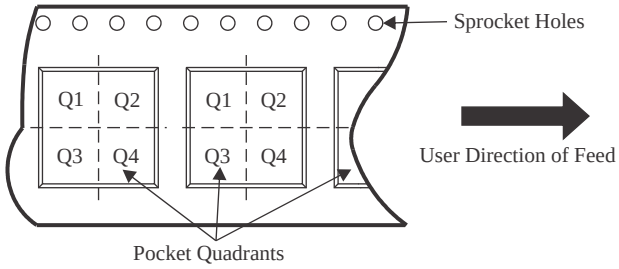


TAPE DIMENSIONS



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

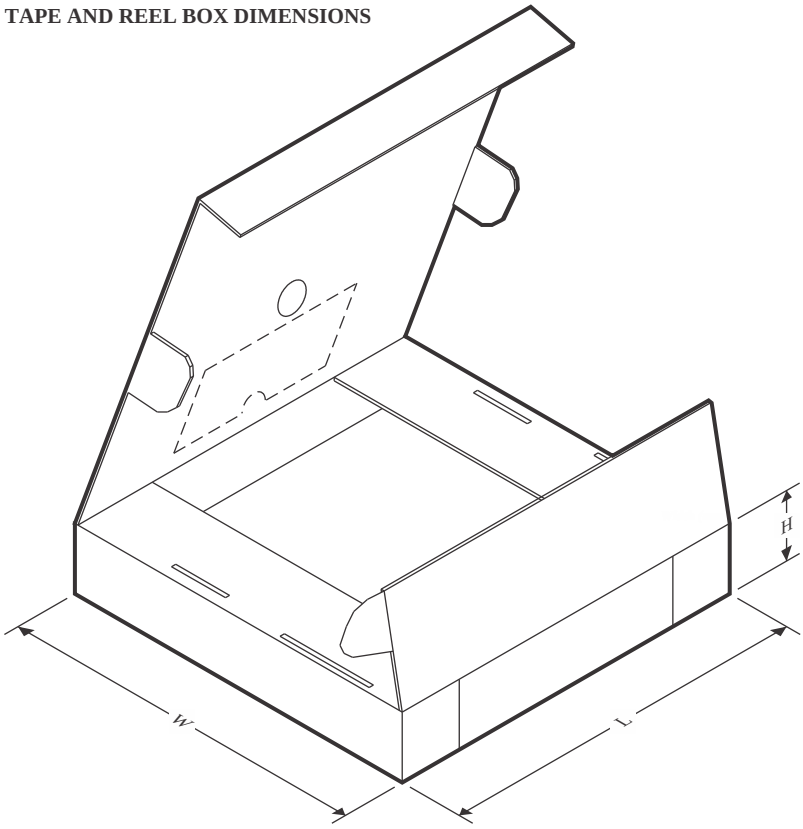
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
TUSB211IRWBR	X2QFN	RWB	12	3000	180.0	8.4	1.8	1.8	0.48	4.0	8.0	Q2
TUSB211RWBR	X2QFN	RWB	12	3000	180.0	8.4	1.8	1.8	0.48	4.0	8.0	Q2
TUSB211RWBR	X2QFN	RWB	12	3000	180.0	8.4	1.8	1.8	0.61	4.0	8.0	Q2

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

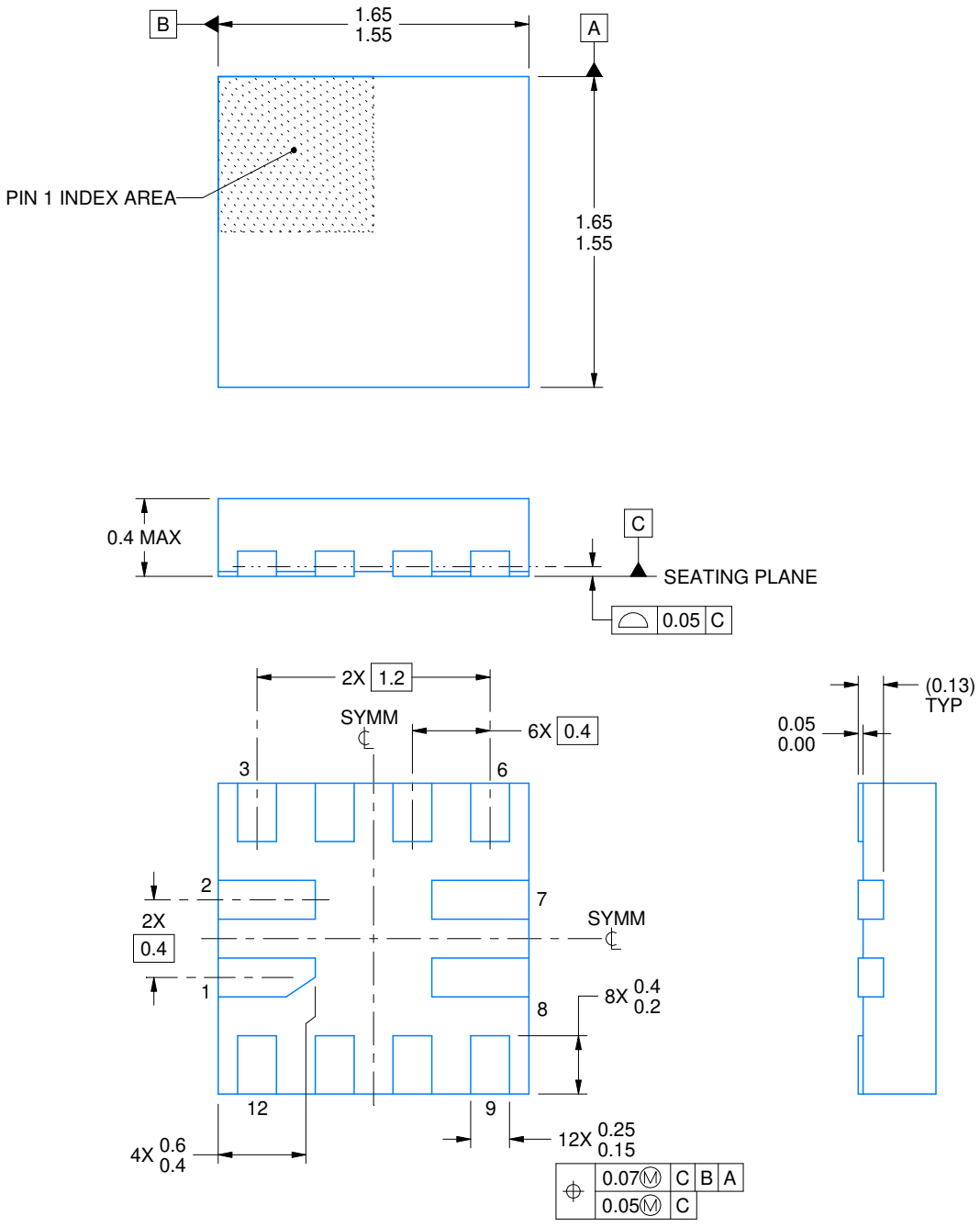
Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TUSB211IRWBR	X2QFN	RWB	12	3000	210.0	185.0	35.0
TUSB211RWBR	X2QFN	RWB	12	3000	210.0	185.0	35.0
TUSB211RWBR	X2QFN	RWB	12	3000	213.0	191.0	35.0

PACKAGE OUTLINE

RWB0012A

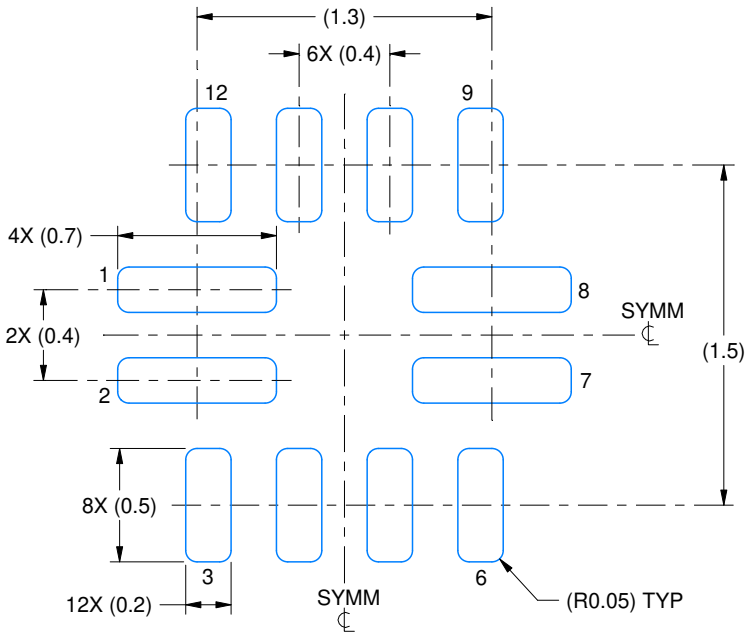
X2QFN - 0.4 mm max height

PLASTIC QUAD FLATPACK - NO LEAD

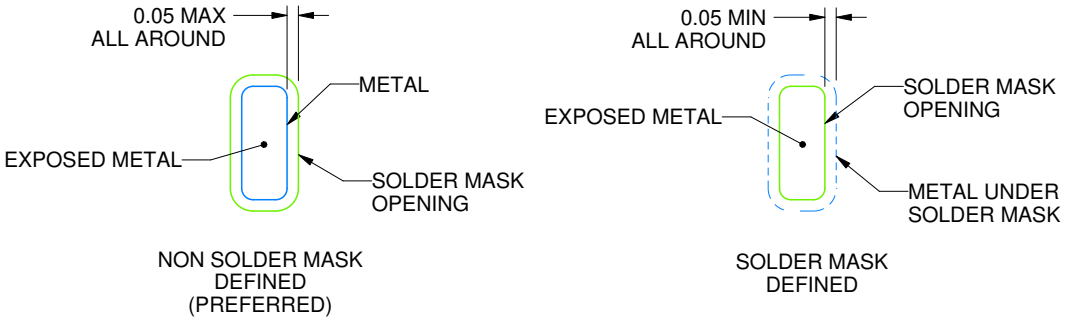


NOTES:

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.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:30X

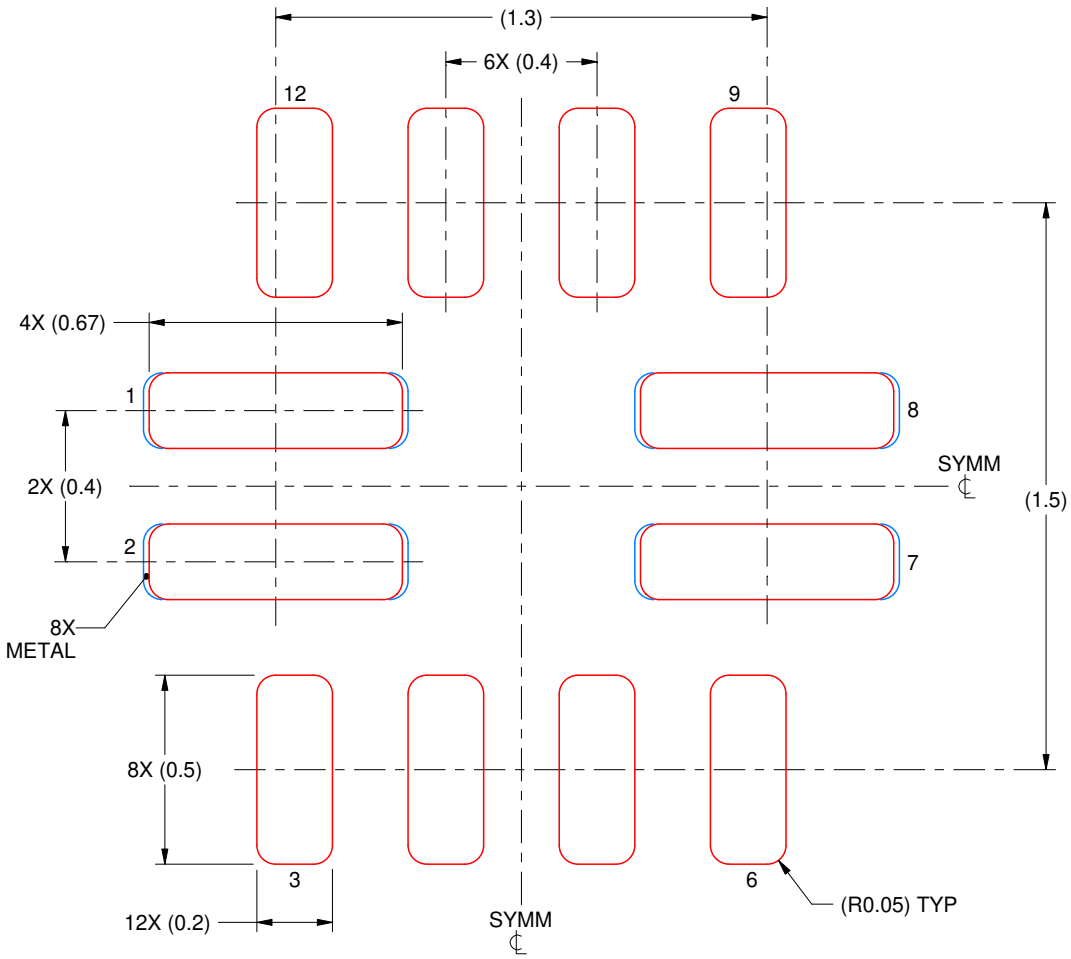


SOLDER MASK DETAILS

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NOTES: (continued)

3. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).



SOLDER PASTE EXAMPLE
BASED ON 0.1 mm THICK STENCIL

PADS 1,2,7 & 8
96% PRINTED SOLDER COVERAGE BY AREA
SCALE:50X

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NOTES: (continued)

4. 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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