

# TCA9416 立ち上がり時間アクセラレータ搭載、超低電圧 I<sup>2</sup>C トランスレータ

## 1 特長

- I<sup>2</sup>C アプリケーションの SDA および SCL ライン用の 2 ビット双方向トランスレータ
- 方向ピンを必要としない双方向電圧レベル変換
- OE = 0V または V<sub>CC</sub> = 0V 時に出力 SCL\_A、SDA\_A、SCL\_B、SDA\_B ピンはハイ・インピーダンス
- すべての SDA および SCL ピンの内部 10kΩ プルアップ抵抗は、それぞれの V<sub>CC</sub> 電圧に基づいて有効化
- A ポートと B ポートの両方で 1.08V~3.6V
- V<sub>CC</sub> 絶縁機能: どちらかの V<sub>CC</sub> 入力に GND レベルになると、両方のポートが高インピーダンス状態になる (プルアップを除く)
- 電源投入のシーケンス不要: V<sub>CCA</sub> と V<sub>CCB</sub> のどちらからでも立ち上げ可能
- 低 I<sub>off</sub>: V<sub>CCA</sub> または V<sub>CCB</sub> = 0V 時に 2.5μA
- OE 入力は V<sub>CCA</sub> に直結、または GPIO により制御可能
- JESD 78、Class II 準拠で 100mA 超のラッチアップ性能
- JESD 22 を超える ESD 保護
  - 2500V、人体モデル (A114-B)
  - 1500V、デバイス帯電モデル (C101)

## 2 アプリケーション

- ウェアラブル
- パーソナル・エレクトロニクス
- サーバー

## 3 概要

TCA9416 は、出力イネーブル (OE) 入力と立ち上がりおよび立ち下がりエッジ・アクセラレータとを備えた 2 ビット、双方向 I<sup>2</sup>C および SMBus 電圧レベル・トランスレータです。このデバイスは、A 側と B 側の両方で 1.08V~3.6V で動作します。これによって、標準的な 1.2V、1.8V、2.5V、3.3V の電源レールのいずれについても、異なる信号レベル間でのインターフェイスが可能です。

OE 入力ピンは V<sub>CCA</sub> を基準とし、V<sub>CCA</sub> に直結できますが、3.6V も許容します。また、OE ピンを制御してロジック LOW に設定すると、すべての SCL および SDA ピンをハイ・インピーダンス状態にすることができ、静止時消費電流が大幅に減少します。

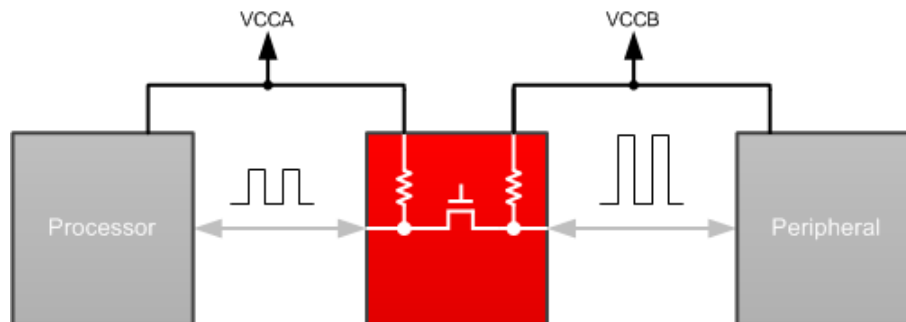
通常の I<sup>2</sup>C および SMBus 構成では、TCA9416 は標準的な速度 (SCL の周波数が 100kHz (標準モード)、400kHz (高速モード)、1MHz (高速モード・プラス)) と互換性があります。

TCA9416 は、SCL\_A、SDA\_A、SCL\_B、SDA\_B に 10kΩ のプルアップ抵抗が内蔵されています。合計プルアップ抵抗を減らし、立ち上がりエッジを高速化するため、バスに外部プルアップ抵抗を追加することもできます。

### 製品情報

部品番号	パッケージ <sup>(1)</sup>	本体サイズ (公称)
TCA9416	X2SON (8)	1.35mm × 0.80mm
	SOT-23-T (8)	2.9mm × 1.6mm

(1) 利用可能なすべてのパッケージについては、この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。



TCA9416 の代表的なアプリケーション・ブロック図



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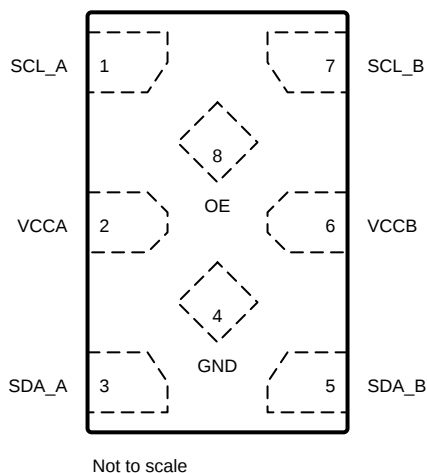
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## 4 Revision History

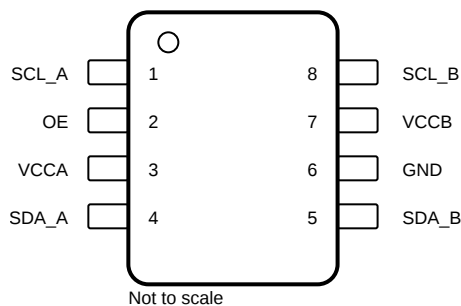
資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

Changes from Revision * (February 2021) to Revision A (August 2021)	Page
• ドキュメントのステータスを事前情報から量産データに変更.....	<b>1</b>

## 5 Pin Configuration and Functions



**图 5-1. 8-PIN DTM, (Top View)**



**图 5-2. 8-PIN DDF, (Top View)**

**表 5-1. Pin Functions**

PIN			TYPE	DESCRIPTION
NAME	DTM	DDF		
SCL_A	1	1	I/O	Input/output A. Referenced to V <sub>CCA</sub> .
VCCA	2	3	Power	A-port supply voltage. $1.08\text{ V} \leq V_{CCA} \leq 3.6\text{ V}$
SDA_A	3	4	I/O	Input/output A. Referenced to V <sub>CCA</sub> .
GND	4	6	GND	Ground
SDA_B	5	5	I/O	Input/output B. Referenced to V <sub>CCB</sub> .
VCCB	6	7	Power	B-port supply voltage. $1.08\text{ V} \leq V_{CCB} \leq 3.6\text{ V}$
SCL_B	7	8	I/O	Input/output B. Referenced to V <sub>CCB</sub> .
OE	8	2	Input	Output enable (active High). Pull OE low to place all outputs in 3-state mode. Referenced to V <sub>CCA</sub> .

## 6 Specifications

### 6.1 Absolute Maximum Ratings

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

			MIN	MAX	UNIT
$V_{CCA}$	Supply voltage range		–0.5	4	V
$V_{CCB}$	Supply voltage range		–0.5	4	V
$V_I$	Input voltage range <sup>(1)</sup>	A port	–0.5	4	V
		B port	–0.5	4	
$V_O$	Voltage range applied to any output in the high-impedance or power-off state <sup>(1)</sup>	A port	–0.5	4	V
		B port	–0.5	4	
$V_O$	Voltage range applied to any output in the high or low state <sup>(1) (2)</sup>	A port	–0.5	4	V
		B port	–0.5	4	
$I_{IK}$	Input clamp current	$V_I < 0$		–50	mA
$I_{OK}$	Output clamp current	$V_O < 0$		–50	mA
$I_O$	Continuous output current			±50	mA
	Continuous current through $V_{CCA}$ , $V_{CCB}$ , or GND			±100	mA
$T_{stg}$	Storage temperature		–65	150	°C

(1) The input and output negative-voltage ratings may be exceeded if the input and output current ratings are observed.

(2) The value of  $V_{CCA}$  and  $V_{CCB}$  are provided in the recommended operating conditions table.

### 6.2 ESD Ratings

				VALUE	UNIT
V <sub>(ESD)</sub>	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)</sup>	A-Ports, B-Ports	±2500	V
			V <sub>CCA</sub> , V <sub>CCB</sub> , OE	±2000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101 <sup>(2)</sup>		±1000	V

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

			$V_{CCA}$	$V_{CCB}$	MIN	MAX	UNIT
$V_{CCA}$	Supply voltage				1.08	3.6	V
$V_{CCB}$	Supply voltage				1.08	3.6	V
$V_I$	Input voltage	A-port I/Os, B-port I/Os, OE	0 V to 3.6 V	0 V to 3.6 V	0	3.6	V
$V_{IH}$	High-level input voltage	OE input	1.08 V to 3.6 V	1.08 V to 3.6 V	$V_{CCA} \times 0.65$	3.6	V
$V_{IL}$	Low-level input voltage	OE input	1.08 V to 3.6 V	1.08 V to 3.6 V	0	$V_{CCA} \times 0.35$	V
$T_A$	Operating free-air temperature				–40	125	°C

## 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TCA9416	TCA9416	UNIT
		DDF	DTM	
		8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	177.6	212.5	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	98.7	105.3	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	97.8	124.1	°C/W
$\psi_{JT}$	Junction-to-top characterization parameter	12.2	4.5	°C/W
$\psi_{JB}$	Junction-to-board characterization parameter	97.2	23.8	°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

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

PARAMETER		TEST CONDITIONS	V <sub>CCA</sub>	V <sub>CCB</sub>	MIN	TYP	MAX	UNIT
V <sub>UVLO_RISE</sub>	UVLO Rising Threshold	V <sub>UVLO</sub> for V <sub>CCA</sub> and V <sub>CCB</sub> are independent	0 V to 3.6 V	0 V to 3.6 V	0.65	0.9	1	V
V <sub>UVLO_FALL</sub>	UVLO Falling Threshold	V <sub>UVLO</sub> for V <sub>CCA</sub> and V <sub>CCB</sub> are independent	0 V to 3.6 V	0 V to 3.6 V	0.6	0.85	0.95	V
V <sub>RTA</sub> <sup>(1)</sup>	RTA <sup>(2)</sup> Activation Threshold		1.08 V to 3.6 V	1.08 V to 3.6 V	V <sub>CCI</sub> × 0.30	V <sub>CCI</sub> × 0.45		V
V <sub>FTA</sub> <sup>(1)</sup>	FTA <sup>(2)</sup> Activation Threshold		1.08 V to 3.6 V	1.08 V to 3.6 V		V <sub>CCI</sub> × 0.60	V <sub>CCI</sub> × 0.70	V
R <sub>PU</sub>		V <sub>I</sub> = 0.15 V	1.08V to 3.6V	1.08V to 3.6V	7.5	10	12.5	kΩ
I <sub>I</sub>	OE	V <sub>I</sub> = V <sub>CCA</sub> or GND	1.08 V to 3.6 V	1.08 V to 3.6 V		±0.1	±1	μA
I <sub>OZ</sub>	A or B port	OE less than V <sub>IL</sub>	1.08 V to 3.6 V	1.08 V to 3.6 V		0	±2.5	μA
I <sub>off</sub>	A port	V <sub>I</sub> = 3.6 V, V <sub>O</sub> = 0 V (T <sub>A</sub> ≤ 85 C)	0 V	0 V to 3.6 V		±0.1	±0.5	μA
	B port	V <sub>I</sub> = 3.6 V, V <sub>O</sub> = 0 V (T <sub>A</sub> ≤ 85 C)	0 to 3.6 V	0 V		±0.1	±0.5	
	A port	V <sub>I</sub> = 3.6 V, V <sub>O</sub> = 0 V (T <sub>A</sub> ≤ 125 C)	0 V	0 V to 3.6 V		±0.1	±2.5	
	B port	V <sub>I</sub> = 3.6 V, V <sub>O</sub> = 0 V (T <sub>A</sub> ≤ 125 C)	0 to 3.6 V	0 V		±0.1	±2.5	
I <sub>CC_OFF</sub>	V <sub>CCA</sub>	V <sub>I</sub> = V <sub>O</sub> = open, I <sub>O</sub> = 0, OE = 0 V	1.08 V to 3.6 V	1.08 V to 3.6 V		4	13	μA
	V <sub>CCB</sub>	V <sub>I</sub> = V <sub>O</sub> = open, I <sub>O</sub> = 0, OE = 0 V				3	13	
I <sub>CCA</sub>		V <sub>I</sub> = V <sub>O</sub> = open, I <sub>O</sub> = 0, OE = V <sub>CCA</sub>	1.32 V	1.32 V to 3.6 V		3	6	μA
			1.98 V	1.32 V to 3.6 V		4	10	
			3.6 V	1.32 V to 3.6 V		6	14	
			0 V	1.32 V to 3.6 V	-0.5	0		
			1.32 V to 3.6 V	0 V		3	12	
I <sub>CCB</sub>		V <sub>I</sub> = V <sub>O</sub> = open, I <sub>O</sub> = 0, OE = V <sub>CCA</sub>	1.32 V to 3.6 V	1.32 V		1.5	6	μA
			1.32 V to 3.6 V	1.98 V		2	8	
			1.32 V to 3.6 V	3.6 V		5	12	
			1.32 V to 3.6 V	0 V	-0.5	0		
			0 V	1.32 V to 3.6 V		1	7	
I <sub>CCA</sub> + I <sub>CCB</sub>		V <sub>I</sub> = V <sub>O</sub> = open, I <sub>O</sub> = 0, OE = V <sub>CCA</sub>	1.32 V	1.32 V		4	12	μA
			1.98 V	1.98 V		6	15	
			3.6 V	3.6 V		11	23	
R <sub>on</sub>		V <sub>I</sub> = 0.2 V, I <sub>O</sub> = 2 mA	1.08 V	1.08 V		28	50	Ω
			1.08 V, 1.8 V	1.8 V, 1.08 V		28	50	
			1.65 V	1.65 V		15	25	
			1.08 V, 3.0 V	3.0 V, 1.08 V		30	55	
			1.65 V, 3.0 V	3.0 V, 1.65 V		15	25	
			3.0 V	3.0 V		10	15	
C <sub>I</sub>	OE		3.3 V	3.3 V		2.5	4	pF
C <sub>io</sub>	A or B port		0 V, 1.08 V, 3.6 V	0 V, 1.08 V, 3.6 V		7	10	pF

(1) V<sub>CCI</sub> is the V<sub>CC</sub> associated with the input port.

(2) RTA is "rise time accelerator" and FTA is "fall time accelerator"

## 6.6 Timing Requirements

over operating free-air temperature range (unless otherwise noted). Typical specifications are at  $T_A = 25\text{ }^{\circ}\text{C}$ ,  $V_{CC} = 3.3\text{ V}$ , unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
$t_{RTA}$	Time from $V_{RTA}$ to RTA disabling	SDA,SCL = Hi-Z EN = $V_{CC}$		80	210	ns

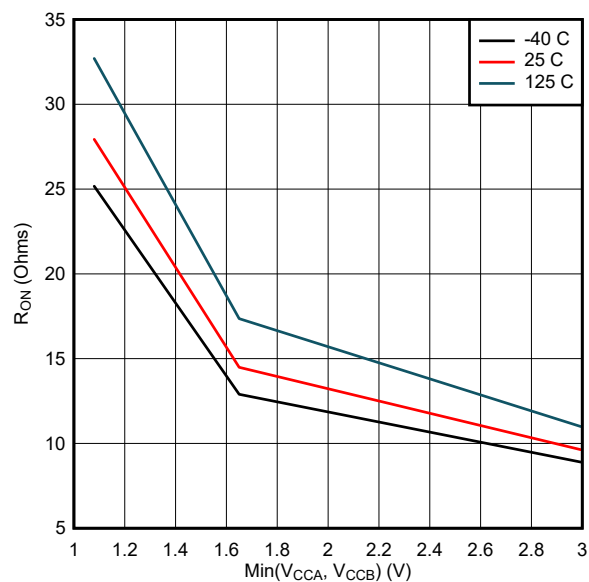
## 6.7 Switching Characteristics

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

PARAMETER	FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t <sub>PHL</sub>	A	B	V <sub>CCA</sub> = 1.08 V		17	30	ns
			V <sub>CCA</sub> = 1.8 V		10	20	
			V <sub>CCA</sub> = 2.5 V		7	25	
			V <sub>CCA</sub> = 3.6 V		6	23	
t <sub>PLH</sub>	A	B	V <sub>CCA</sub> = 1.08 V		9	25	ns
			V <sub>CCA</sub> = 1.8 V		5	20	
			V <sub>CCA</sub> = 2.5 V		4	20	
			V <sub>CCA</sub> = 3.6 V		2	20	
t <sub>PHL</sub>	B	A	V <sub>CCB</sub> = 1.08 V		17	30	ns
			V <sub>CCB</sub> = 1.8 V		10	20	
			V <sub>CCB</sub> = 2.5 V		7	25	
			V <sub>CCB</sub> = 3.6 V		6	23	
t <sub>PLH</sub>	B	A	V <sub>CCB</sub> = 1.08 V		9	25	ns
			V <sub>CCB</sub> = 1.8 V		5	20	
			V <sub>CCB</sub> = 2.5 V		4	20	
			V <sub>CCB</sub> = 3.6 V		2	20	
t <sub>SK(O)-RISE</sub>	Rising Channel-to-channel skew (Propagation)					8	ns
t <sub>SK(O)-FALL</sub>	Falling Channel-to-channel skew (Propagation)					8	ns
t <sub>en</sub>	OE	A or B			70	350	ns
t <sub>dis</sub>	OE	A or B			60	160	ns
t <sub>rA</sub>	B-port	A-port	V <sub>CCA</sub> = 1.08 V		18	35	ns
			V <sub>CCA</sub> = 1.8 V		12	30	
			V <sub>CCA</sub> = 2.5 V		11	25	
			V <sub>CCA</sub> = 3.6 V		10	25	
t <sub>rB</sub>	A-port	B-port	V <sub>CCB</sub> = 1.08 V		18	35	ns
			V <sub>CCB</sub> = 1.8 V		12	30	
			V <sub>CCB</sub> = 2.5 V		11	25	
			V <sub>CCB</sub> = 3.6 V		10	25	
t <sub>fA</sub>	B-port	A-port	V <sub>CCA</sub> = 1.08 V		13	30	ns
			V <sub>CCA</sub> = 1.8 V		12	30	
			V <sub>CCA</sub> = 2.5 V		12	35	
			V <sub>CCA</sub> = 3.6 V		11	40	
t <sub>fB</sub>	A-port	B-port	V <sub>CCB</sub> = 1.08 V		13	30	ns
			V <sub>CCB</sub> = 1.8 V		12	30	
			V <sub>CCB</sub> = 2.5 V		12	35	
			V <sub>CCB</sub> = 3.6 V		11	40	



## 6.8 Typical Characteristics



The Min(V<sub>CCA</sub>, V<sub>CCB</sub>) signifies that the lower voltage of V<sub>CCA</sub> or V<sub>CCB</sub> is used. As an example, if V<sub>CCA</sub> = 1.8 V and V<sub>CCB</sub> = 3.3 V, then the Min(V<sub>CCA</sub>, V<sub>CCB</sub>) is 1.8 V.

Figure 6-1. R<sub>ON</sub> (Ω) vs Min(V<sub>CCA</sub>, V<sub>CCB</sub>) (V)

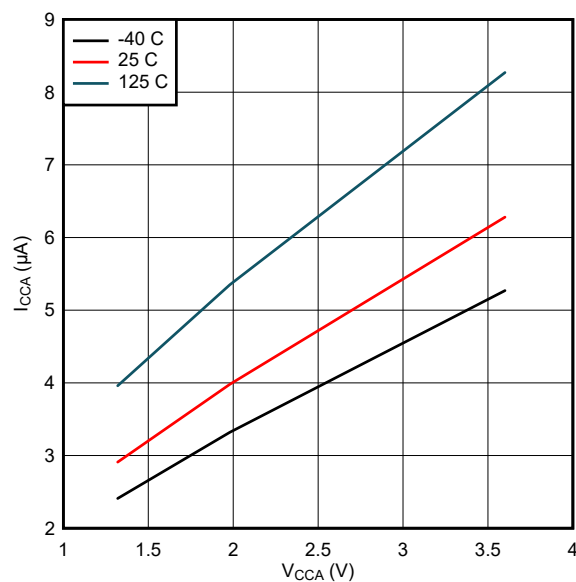


Figure 6-2. I<sub>CCA</sub> (μA) vs V<sub>CCA</sub> (V)

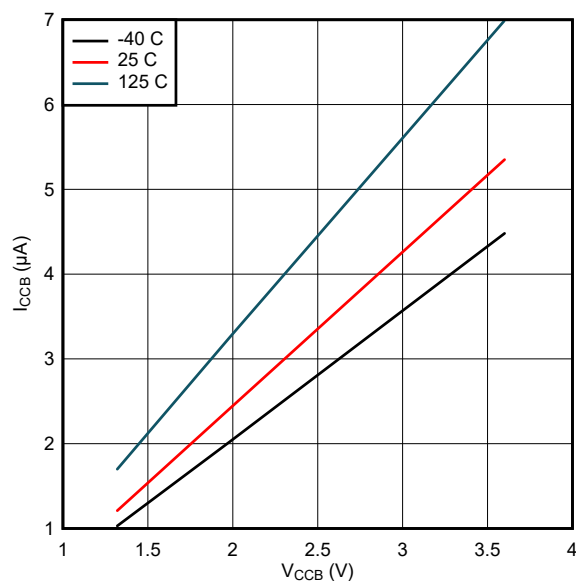
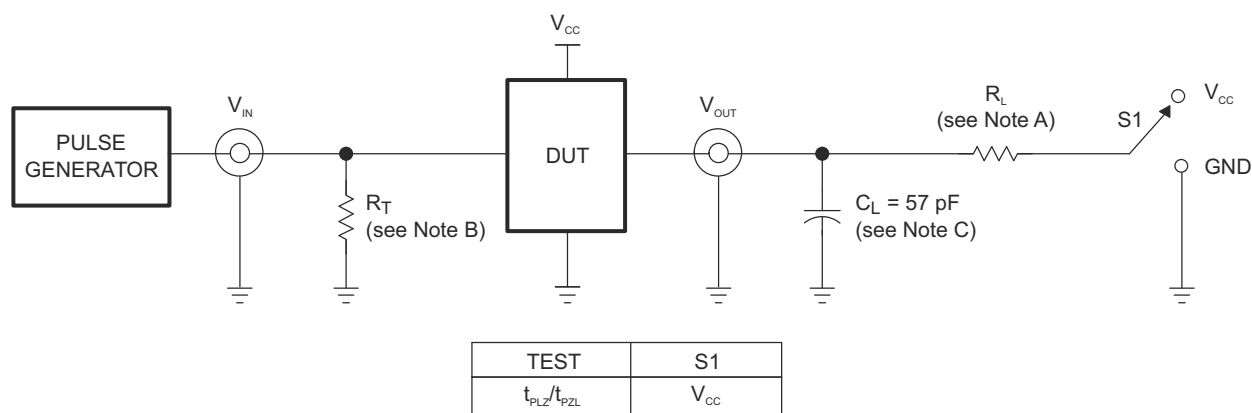


Figure 6-3. I<sub>CCB</sub> (μA) vs V<sub>CCB</sub> (V)

## 7 Parameter Measurement Information



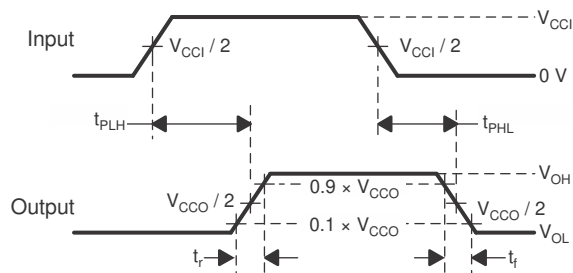
TEST CIRCUIT FOR OPEN-DRAIN OUTPUT

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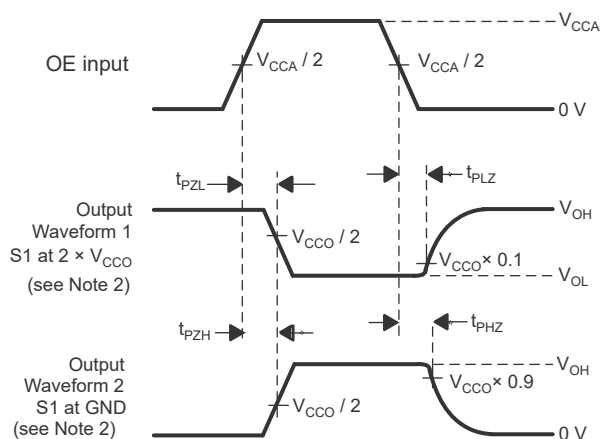
### 7-1. Load Circuit for Pulse Duration, Propagation Delay, Output Rise-Time and Fall-Time Measurement

1.  $R_L = 1.35 \text{ k}\Omega$
2.  $R_T$  termination resistance should be equal to  $Z_{OUT}$  of pulse generators.
3.  $C_L$  includes probe and jig capacitance.  $C_L = 50 \text{ pF}$  when on the B-side.
4. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ , slew rate  $\geq 1 \text{ V/ns}$ .
5.  $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .
6.  $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .
7.  $V_{CCI}$  is the  $V_{CC}$  associated with the input port.
8.  $V_{CCO}$  is the  $V_{CC}$  associated with the output port.

## 7.1 Voltage Waveforms



**Figure 7-2. Propagation Delay Times**



1.  $C_L$  includes probe and jig capacitance.
2. Waveform 1 in Figure 7-3 is for an output with internal such that the output is high, except when OE is high (see Figure 7-1). Waveform 2 in Figure 7-3 is for an output with conditions such that the output is low, except when OE is high.
3. All input pulses are supplied by generators having the following characteristics:  $PRR \leq 10 \text{ MHz}$ ,  $Z_O = 50 \Omega$ ,  $dv/dt \geq 1 \text{ V/ns}$ .
4. The outputs are measured one at a time, with one transition per measurement.
5.  $t_{PLZ}$  and  $t_{PHZ}$  are the same as  $t_{dis}$ .
6.  $t_{PZL}$  and  $t_{PZH}$  are the same as  $t_{en}$ .
7.  $t_{PLH}$  and  $t_{PHL}$  are the same as  $t_{pd}$ .
8.  $V_{CCI}$  is the  $V_{CC}$  associated with the input port.
9.  $V_{CCO}$  is the  $V_{CC}$  associated with the output port.

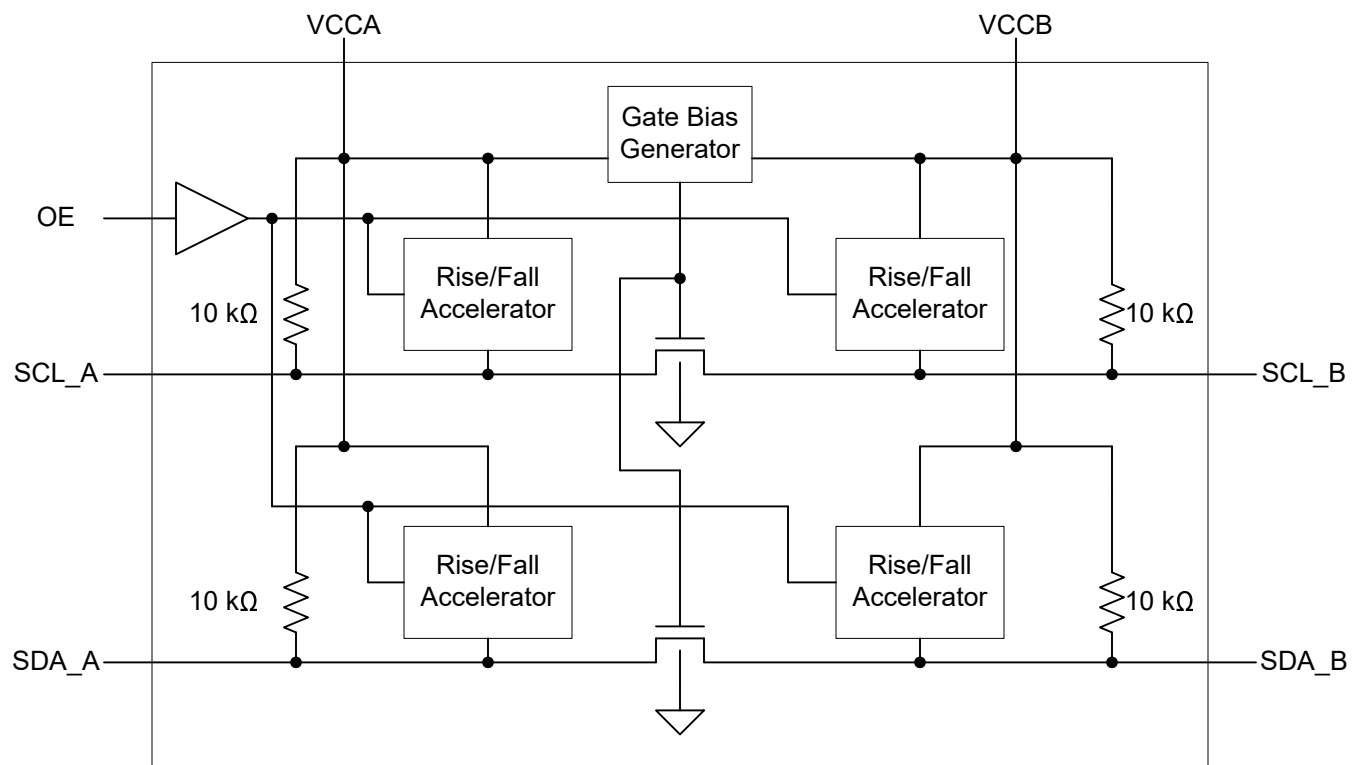
**Figure 7-3. Enable and Disable Times**

## 8 Detailed Description

### 8.1 Overview

The TCA9416 device is a directionless voltage-level translator specifically designed for translating logic voltage levels. The A and B ports are able to accept I/O voltages ranging from 1.08 V to 3.6 V. The device is a pass-gate architecture with edge-rate accelerators (one-shots) to improve the overall data rate. 10-k $\Omega$  pull up resistors, commonly used in open-drain applications, have been conveniently integrated so that an external resistor is not needed. When TCA9416 is disabled the one shots are also disabled, but the internal pull ups are still enabled. Pull up resistors are gated on the supply voltage. When supply is above UVLO, the pull up resistor for that specific side (A vs B) is enabled.

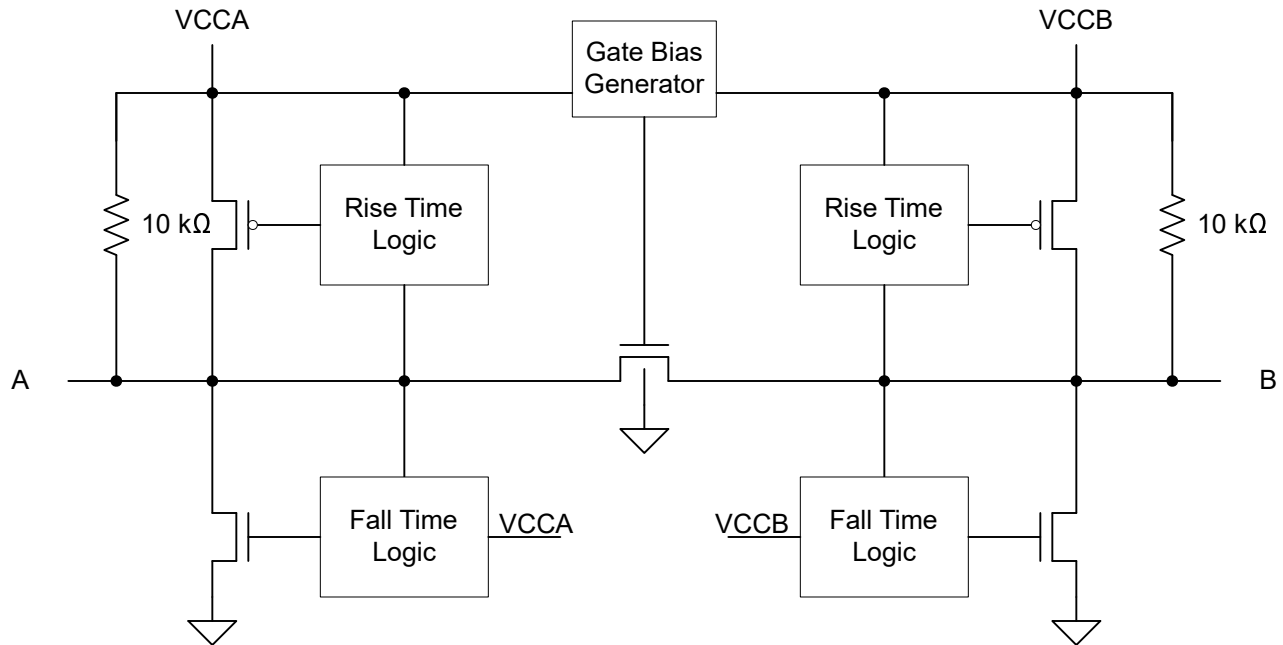
### 8.2 Functional Block Diagram



### 8.3 Feature Description

#### 8.3.1 Architecture

The TCA9416 architecture (see [Figure 8-1](#)) is an auto-direction-sensing based translator that does not require a direction-control signal to control the direction of data flow from A to B or from B to A.



**FIG 8-1. Architecture of a TCA9416 Cell**

These two bidirectional channels support both directions of data flow without a direction-control signal. By properly biasing the gate of the pass-FET, the FET can turn on (low  $R_{DS(on)}$ ), when either side input voltage drops to  $\sim 1$  voltage threshold below the lowest of the two supplies.

The TCA9416 is part of the TI "Switch" type voltage translator family and employs key circuits to enable this voltage translation:

1. An N-channel pass-gate transistor topology that ties the A-port to the B-port.
2. Output rise time accelerator circuitry to detect and accelerate rising edges on the A or B ports
3. Output fall time accelerator circuitry to detect and accelerate falling edges on the A or B ports

For bidirectional voltage translation, pull up resistors are included on the device for dc current sourcing capability. The  $V_{GATE}$  gate bias of the N-channel pass transistor is set to the lower supply voltage and can be represented with  $\text{MIN}(V_{CCA}, V_{CCB})$ .

The rise and fall time accelerator (RTA and FTA, respectively) circuitry speeds up the output slew rate by monitoring the input edge for transitions, helping maintain the data rate through the device. During a low-to-high signal rising edge, the rise time accelerator (RTA) circuit turns on to increase the current drive capability of the driver. This edge-rate acceleration provides high ac drive by bypassing the internal 10-kΩ pull up resistors during the low-to-high transition to speed up the signal. The output resistance of the driver is decreased to approximately 150 Ω during this acceleration phase. During a high-to-low signal falling edge, the fall time accelerator (FTA) turns on to increase the current drive capability of the driver, similar to the rise time accelerator. This helps reduce the fall time for large capacitive loads. For light capacitive loads, the fall time accelerator will not enable.

Both the rise and fall time accelerators have logic to control the rate at which they turn on and off, in order to reduce ringing and over/undershoots.

### 8.3.2 Enable and Disable

The TCA9416 has an OE input that is used to disable the device by setting OE low, which prevents any signals from propagating across the device. This pin is referenced to the  $V_{CCA}$  supply. The rise and fall time accelerators are also disabled. Note that the internal pull up resistors will still be enabled if the supply is above  $V_{UVLO}$ . The disable time ( $t_{dis}$ ) indicates the delay between the time when OE goes low and when the outputs are disabled (Hi-Z). The enable time ( $t_{en}$ ) indicates the amount of time the user must allow for the one-shot circuitry to become operational after OE is taken high.

### 8.3.3 Pull up resistors on I/O Lines

Each A-port I/O has an internal 10-k $\Omega$  pull up resistor to  $V_{CCA}$ , and each B-port I/O has an internal 10-k $\Omega$  pull up resistor to  $V_{CCB}$ . If a smaller value of pull up resistor is required, an external resistor must be added from the I/O to  $V_{CCA}$  or  $V_{CCB}$  (in parallel with the internal 10-k $\Omega$  resistors). However, adding lower value pull up resistors effects  $V_{OL}$  levels. It is recommended not to go below 1.5-k $\Omega$ . The internal pull ups of the TCA9416 are controlled by their respective supplies. The resistors have back-biasing protection, so that if a supply is off, the current cannot flow through the resistors back into the supply. If a supply is above  $V_{UVLO\_RISE}$ , the pull up resistor for its side is enabled.

### 8.4 Device Functional Modes

The TCA9416 device has two functional modes, enabled and disabled. To disable the device set the OE input low, which disables the rise time and fall time accelerators, and prevents signals from propagating across the channels. The internal pull up resistors are not affected by the OE input. Setting the OE input high enables the device.

## 9 Application and Implementation

### Note

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### 9.1 Application Information

The TCA9416 can be used to bridge the digital-switching compatibility gap between two voltage nodes to successfully interface logic threshold levels found in electronic systems. It should be used in a point-to-point topology for interfacing devices or systems operating at different interface voltages with one another. The primary target application use is for interfacing with open-drain drivers on the data I/Os such as I<sup>2</sup>C or SMBus, where the data is bidirectional and no control signal is available.

### 9.2 Typical Application

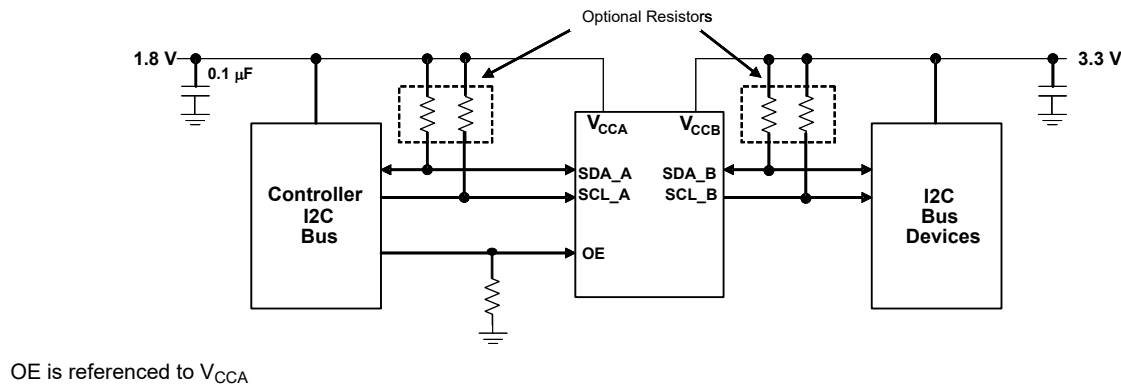


図 9-1. Typical Application Circuit

#### 9.2.1 Design Requirements

For this design example, use the parameters listed in 表 9-1.

表 9-1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input voltage range	1.08 to 3.6 V
Output voltage range	1.08 to 3.6 V

#### 9.2.2 Detailed Design Procedure

To begin the design process, determine the following:

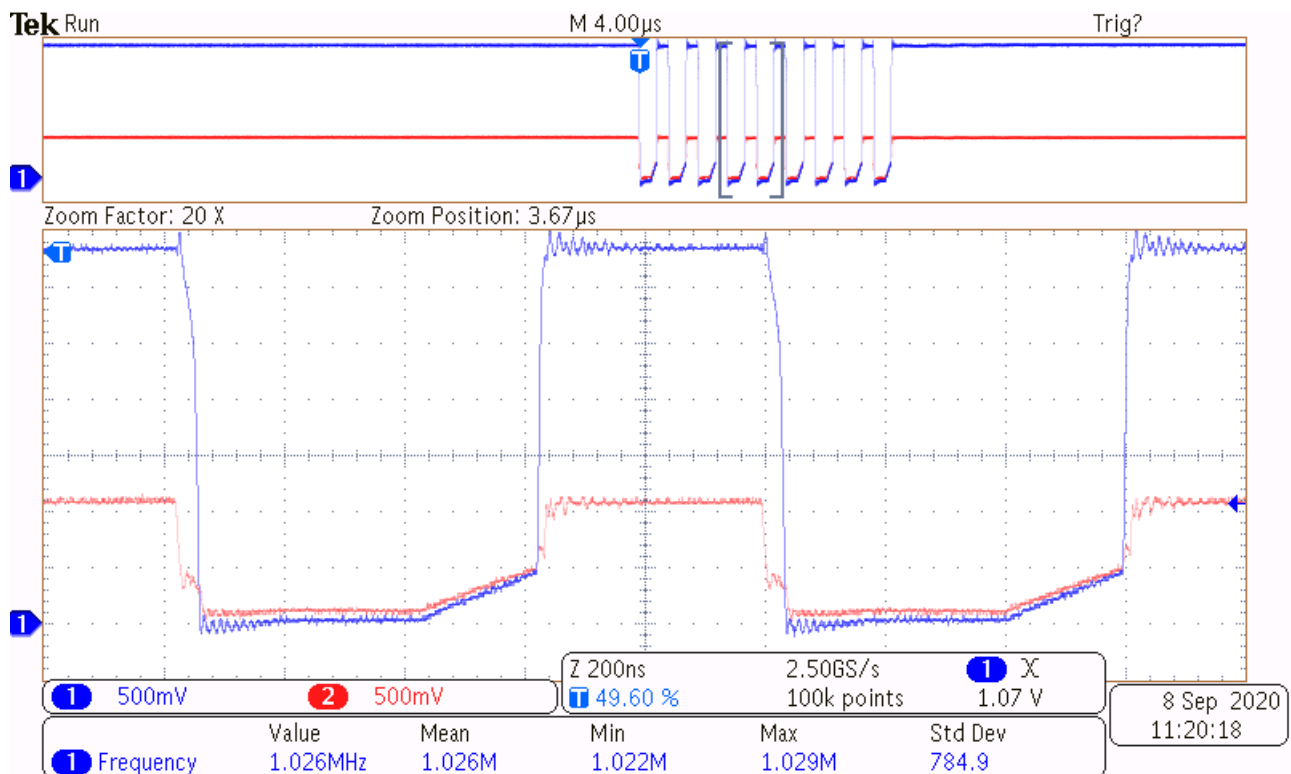
- Input voltage range
  - Use the supply voltage of the device that is driving the TCA9416 device to determine the input voltage range. For a valid logic high, the value must exceed the V<sub>IH</sub> of the input port. For a valid logic low, the value must be less than the V<sub>IL</sub> of the input port.
- Output voltage range
  - Use the supply voltage of the device that the TCA9416 device is driving to determine the output voltage range
  - The TCA9416 device has 10-kΩ internal pull up resistors. External pull up resistors can be added to reduce the total RC of a signal trace if necessary.

### 9.2.2.1 Startup Considerations with Large Capacitive Load Mismatches

Due to the FET based architecture of this translator, there are some considerations a system designer must be aware of during powering up with large differences in capacitance between the sides. If one supply with smaller capacitance is already powered up, and the other is ramping (with OE pin high), the side with the heavier load can ramp slower than the power supply ramp, due to only having an internal 10k $\Omega$  pull up resistor. In this situation, once the rising POR threshold is met, the device enables all circuitry. If the heavy capacitance side has not yet risen above about 70% of supply, the device determines this as low, and briefly turns on the fall time accelerators to propagate a low. Once the fall time accelerator has timed out, the signals rise and sit idle high.

This phenomenon can be eliminated by holding the OE pin low (disabled) until all supplies and busses have ramped up, since this explicitly disables the bus acceleration circuitry until the bus has completed power up. Slower supply ramps also help reduce this since the bus voltage follows the supply closer if the ramp is slow.

### 9.2.3 Application Curve



9-2. Level-Translation of a 1-MHz Signal



## 10 Power Supply Recommendations

The TCA9416 has no supply restrictions outside of the 1.08 V to 3.6 V range.  $V_{CCA}$  can be higher than or lower than  $V_{CCB}$ . The internal circuitry will select the appropriate supply automatically to correctly support translation.  $V_{CCA}$  can also be the same as  $V_{CCB}$ , and the device can be used as a buffer.

The sequencing of each power supply does not damage the device during the power up operation, so either power supply can be ramped up first. The output-enable (OE) input circuit is designed so that when the (OE) input is low, the outputs are disabled. No signals may propagate, and the rise time and fall time accelerators are disabled, but the internal pull up resistors will remain unaffected. To make sure the signals do not pass through during power up or power down, the OE input pin must be tied to GND through a pull down resistor and should not be enabled until  $V_{CCA}$  and  $V_{CCB}$  are fully ramped and stable. If OE is tied to  $V_{CCA}$ , this is OK, but might result in a glitch on the bus during power up depending on the capacitive load and ramp rates. The minimum value of the pull down resistor to ground is determined by the current-sourcing capability of the driver.

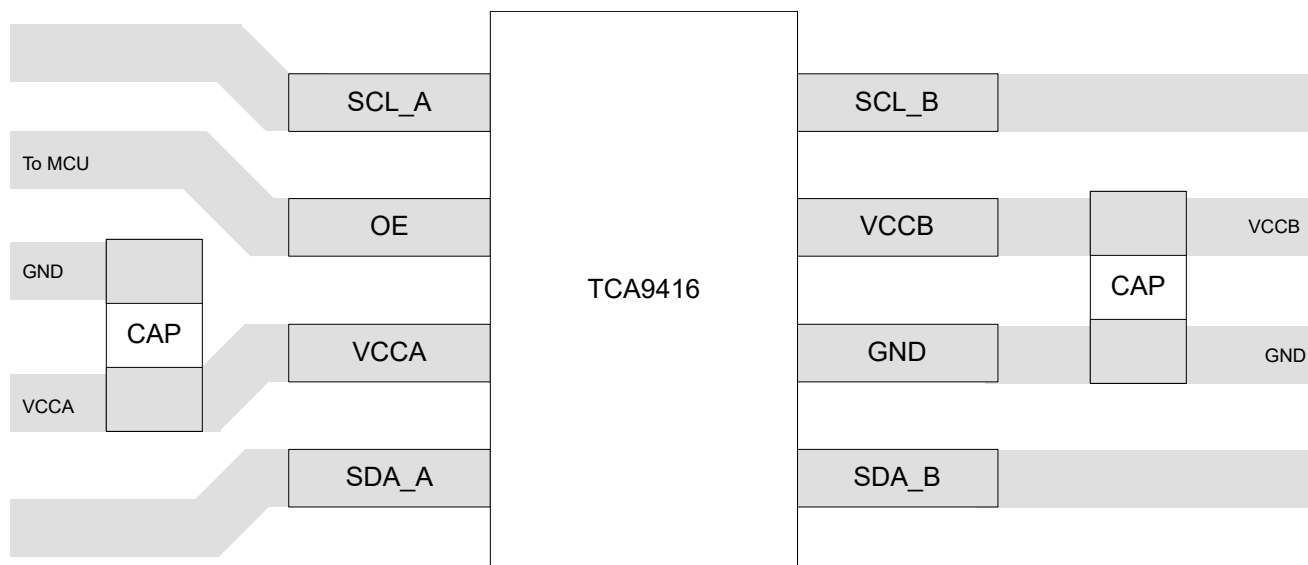
## 11 Layout

### 11.1 Layout Guidelines

For reliability of the device, the following common printed-circuit board layout guidelines are recommended:

1. Bypass capacitors should be used on power supplies and should be placed as close as possible to the  $V_{CCA}$ ,  $V_{CCB}$  pin, and  $G_{ND}$  pin.
2. Short trace lengths should be used to avoid excessive loading.
3. Keep SCL and SDA lengths close to prevent skewing the signals.
4. PCB signal trace-lengths must be kept short enough so that the round-trip delay of any reflection is less than the one-shot duration, approximately 30 ns. Making sure that any reflection encounters low impedance at the source driver.

### 11.2 Layout Example



11-1. TCA9416 Layout Example (DDF)

## 12 Device and Documentation Support

### 12.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](https://www.ti.com). Click on *Subscribe to updates* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 12.2 サポート・リソース

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### 12.3 Trademarks

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### 12.4 Electrostatic Discharge Caution



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

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

### 12.5 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 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)
<a href="#">TCA9416DDFR</a>	Active	Production	SOT-23-THIN (DDF)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2JGF
TCA9416DDFR.A	Active	Production	SOT-23-THIN (DDF)   8	3000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	2JGF
<a href="#">TCA9416DTMR</a>	Active	Production	X2SON (DTM)   8	5000   LARGE T&R	Yes	NIPDAU   NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	LC
TCA9416DTMR.A	Active	Production	X2SON (DTM)   8	5000   LARGE T&R	Yes	NIPDAUAG	Level-1-260C-UNLIM	-40 to 125	LC
TCA9416DTMRG4.A	Active	Production	X2SON (DTM)   8	5000   LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	LC

<sup>(1)</sup> **Status:** For more details on status, see our [product life cycle](#).

<sup>(2)</sup> **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.

<sup>(3)</sup> **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

<sup>(4)</sup> **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.

<sup>(5)</sup> **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.

<sup>(6)</sup> **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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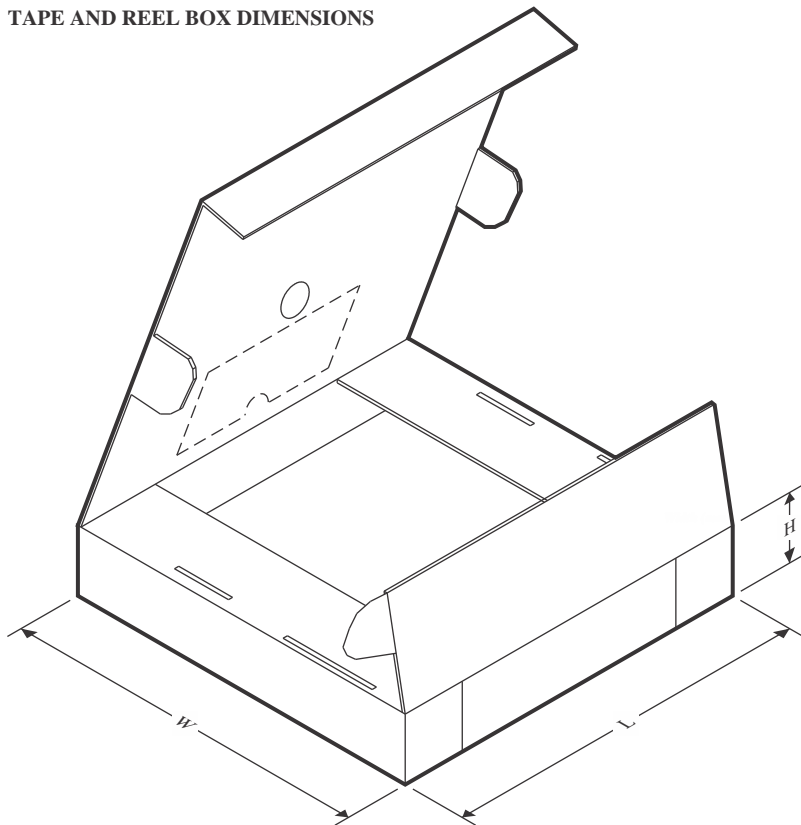
## TAPE AND REEL INFORMATION



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
TCA9416DDFR	SOT-23-THIN	DDF	8	3000	180.0	8.4	3.2	3.2	1.4	4.0	8.0	Q3
TCA9416DTMR	X2SON	DTM	8	5000	178.0	8.4	0.93	1.49	0.43	2.0	8.0	Q1
TCA9416DTMR	X2SON	DTM	8	5000	180.0	9.5	0.93	1.49	0.43	2.0	8.0	Q1

## TAPE AND REEL BOX DIMENSIONS



\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
TCA9416DDFR	SOT-23-THIN	DDF	8	3000	210.0	185.0	35.0
TCA9416DTMR	X2SON	DTM	8	5000	205.0	200.0	33.0
TCA9416DTMR	X2SON	DTM	8	5000	189.0	185.0	36.0



## X2SON - 0.4 mm max height

Figure 1 shows the mechanical drawings of the connector. The top drawing is a side view showing a rectangular component with a hatched "PIN 1 INDEX AREA" on the left. Dimensions include a width of 0.85 (0.75) and a height of 1.4 (1.3). The bottom drawing is a top view showing a square component with a central diamond-shaped hole and four corner holes. It includes various dimensions like 0.4 MAX, 0.04, 0.00, 0.05, 0.27, 0.17, 0.54, 0.25, 0.15, and 0.5. It also features a "SEATING PLANE" and a "PIN 1 ID" label. A table of material properties is provided at the bottom right.

0.1	M	C	B	A
0.05	M	C		

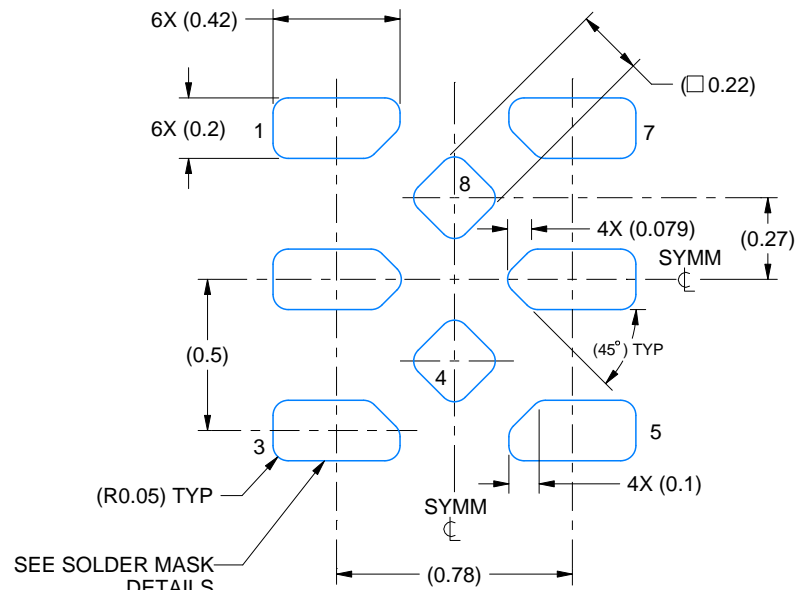
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad(s) must be soldered to the printed circuit board for thermal and mechanical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

# EXAMPLE BOARD LAYOUT

DTM0008A

X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:40X



SOLDER MASK DETAILS

4224755/B 10/2022

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](http://www.ti.com/lit/slue271)).

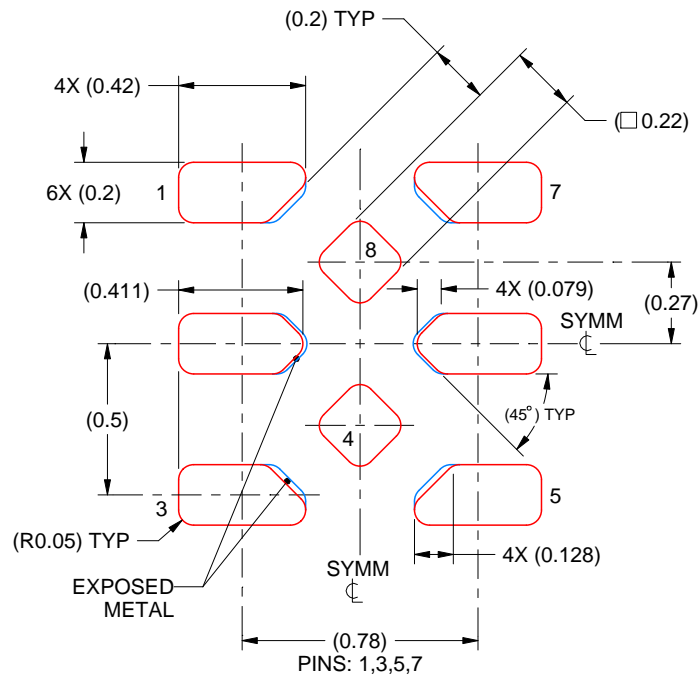


# EXAMPLE STENCIL DESIGN

DTM0008A

X2SON - 0.4 mm max height

PLASTIC SMALL OUTLINE - NO LEAD



**SOLDER PASTE EXAMPLE**  
BASED ON 0.075 mm THICK STENCIL  
SCALE: 40X

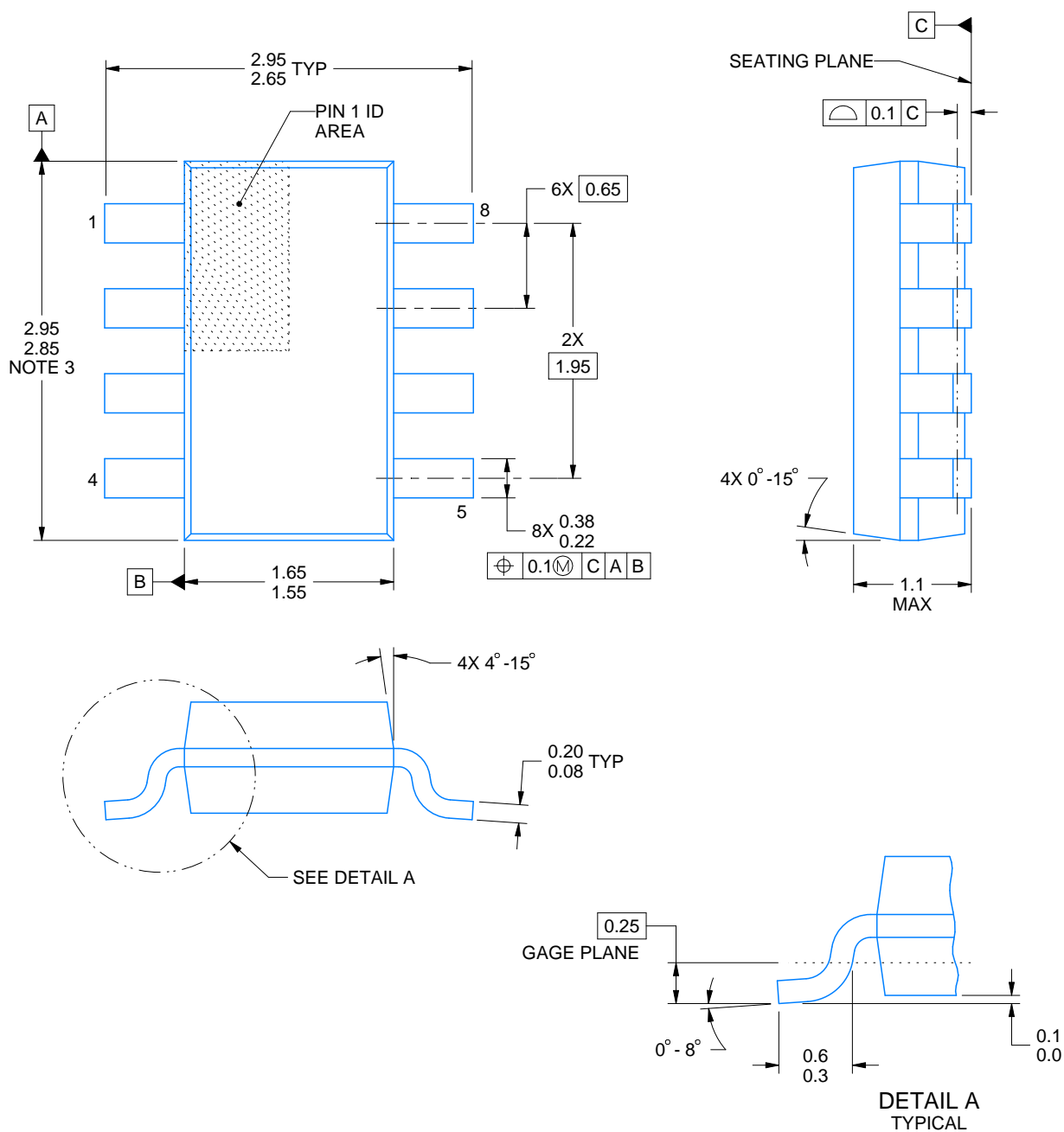
4224755/B 10/2022

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



## SOT-23-THIN - 1.1 mm max height

## PLASTIC SMALL OUTLINE



4222047/E 07/2024

NOTES:

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

# EXAMPLE BOARD LAYOUT

DDF0008A

SOT-23-THIN - 1.1 mm max height

PLASTIC SMALL OUTLINE



LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X



SOLDER MASK DETAILS

4222047/E 07/2024

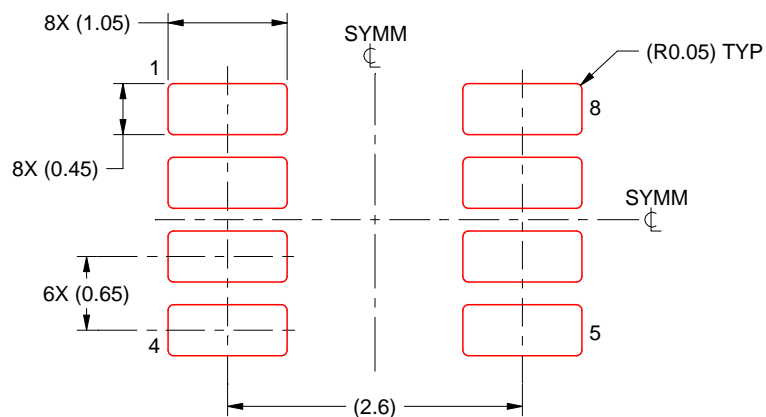
NOTES: (continued)

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

**DDF0008A**

## SOT-23-THIN - 1.1 mm max height

## PLASTIC SMALL OUTLINE



SOLDER PASTE EXAMPLE  
BASED ON 0.125 mm THICK STENCIL  
SCALE:15X

4222047/E 07/2024

NOTES: (continued)

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

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