

PCA9306

Dual Bidirectional I²C-bus and SMBus Voltage-Level Translator

The PCA9306 is a dual bidirectional I²C-bus and SMBus voltage-level translator with an enable (EN) input.

Features

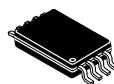
- 2-bit Bidirectional Translator for SDA and SCL Lines in Mixed-Mode I²C-Bus Applications
- Standard-Mode, Fast-Mode, and Fast-Mode Plus I²C-Bus and SMBus Compatible
- Less Than 1.5 ns Maximum Propagation Delay to Accommodate Standard-Mode and Fast-Mode I²C-Bus Devices and Multiple Masters
- Allows Voltage Level Translation Between:
 - ♦ 1.0 V $V_{ref(1)}$ and 1.8 V, 2.5 V, 3.3 V or 5 V $V_{bias(ref)(2)}$
 - ♦ 1.2 V $V_{ref(1)}$ and 1.8 V, 2.5 V, 3.3 V or 5 V $V_{bias(ref)(2)}$
 - ♦ 1.8 V $V_{ref(1)}$ and 3.3 V or 5 V $V_{bias(ref)(2)}$
 - ♦ 2.5 V $V_{ref(1)}$ and 5 V $V_{bias(ref)(2)}$
 - ♦ 3.3 V $V_{ref(1)}$ and 5 V $V_{bias(ref)(2)}$
- Provides Bidirectional Voltage Translation With No Direction Pin
- Low 3.5 Ω ON-State Connection Between Input and Output Ports Provides Less Signal Distortion
- Open-Drain I²C-Bus I/O Ports (SCL1, SDA1, SCL2 and SDA2)
- 5 V Tolerant I²C-Bus I/O Ports to Support Mixed-Mode Signal Operation
- High-Impedance SCL1, SDA1, SCL2 and SDA2 Pins for EN = LOW
- Lock-Up Free Operation
- Flow Through Pinout for Ease of Printed-Circuit Board Trace Routing
- Packages Offered:
 - ♦ TSSOP-8, US8, UQFN8, UDFN8
- ESD Performance: 4000 V Human Body Model, 400 V Machine Model
- NLV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable
- These are Pb-Free Devices



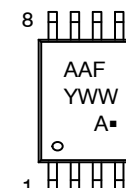
ON Semiconductor®

<http://onsemi.com>

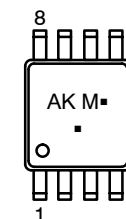
MARKING DIAGRAMS



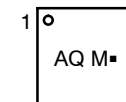
TSSOP-8
DT SUFFIX
CASE 948AL



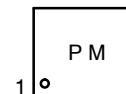
US8
US SUFFIX
CASE 493



UQFN8
MU SUFFIX
CASE 523AN



UDFN8
1.45 x 1.0
CASE 517BZ



AAF, AK, AQ, P = Specific Device Code
A = Assembly Location
Y = Year
WW = Work Week
M = Date Code
▪ = Pb-Free Package

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 6 of this data sheet.

Function Description

The PCA9306 is a dual bidirectional I²C-bus and SMBus voltage-level translator with an enable (EN) input, and is operational from 1.0 V to 3.6 V ($V_{ref(1)}$) and 1.8 V to 5.5 V ($V_{bias(ref)(2)}$).

The PCA9306 allows bidirectional voltage translations between 1.0 V and 5 V without the use of a direction pin. The low ON-state resistance (R_{on}) of the switch allows connections to be made with minimal propagation delay. When EN is HIGH, the translator switch is on, and the SCL1 and SDA1 I/O are connected to the SCL2 and SDA2 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 PCA9306 is not a bus buffer that provides both level translation and physical capacitance isolation to either side of the bus when both sides are connected. The PCA9306 only isolates both sides when the device is disabled and provides voltage level translation when active.

The PCA9306 can be used to run two buses, one at 400 kHz operating frequency and the other at 100 kHz operating frequency. If the two buses are operating at different frequencies, the 100 kHz bus must be isolated when the 400 kHz operation of the other bus is required. If the master is running at 400 kHz, the maximum system operating frequency may be less than 400 kHz because of the delays added by the translator.

As with the standard I²C-bus system, pull-up resistors are required to provide the logic HIGH levels on the translator's

bus. The PCA9306 has a standard open-collector configuration of the I²C-bus. The size of these pull-up resistors depends on the system, but each side of the translator must have a pull-up resistor. The device is designed to work with Standard-mode, Fast-mode and Fast mode Plus I²C-bus devices in addition to SMBus devices. The maximum frequency is dependent on the RC time constant, but generally supports > 2 MHz.

When the SDA1 or SDA2 port is LOW, the clamp is in the ON-state and a low resistance connection exists between the SDA1 and SDA2 ports. Assuming the higher voltage is on the SDA2 port, when the SDA2 port is HIGH, the voltage on the SDA1 port is limited to the voltage set by VREF1. When the SDA1 port is HIGH, the SDA2 port is pulled to the drain pull-up supply voltage ($V_{pu(D)}$) by the pull-up resistors. This functionality allows a seamless translation between higher and lower voltages selected by the user without the need for directional control. The SCL1/SCL2 channel also functions as the SDA1/SDA2 channel.

All channels have the same electrical characteristics and there is minimal deviation from one output to another in voltage or propagation delay. This is a benefit over discrete transistor voltage translation solutions, since the fabrication of the switch is symmetrical. The translator provides excellent ESD protection to lower voltage devices, and at the same time protects less ESD-resistant devices.

FUNCTIONAL DIAGRAM

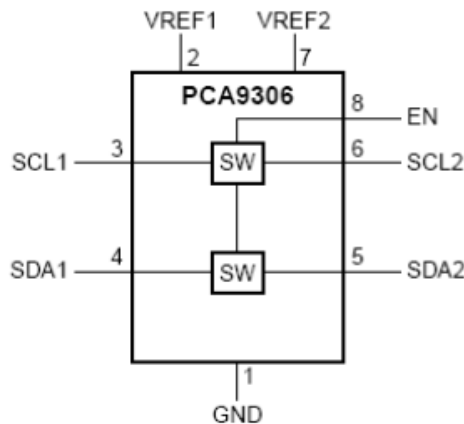


Figure 1. Logic Diagram

PCA9306

PIN ASSIGNMENTS

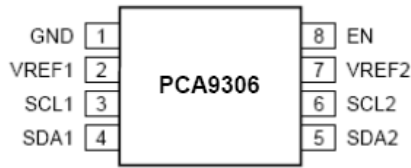


Figure 2. TSSOP-8 / US8 Pinouts

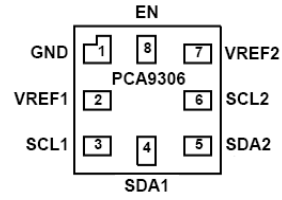


Figure 3. UQFN8 Pinout (Top Thru View)

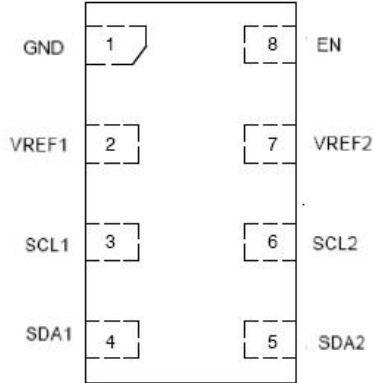


Figure 4. UDFN8 Pinout (Top Thru View)

Table 1. PIN DESCRIPTION

Pin	Description
GND	Ground
VREF1	Low-voltage side reference supply voltage for SCL1 and SDA1
SCL1	Serial clock, low-voltage side; connect to VREF1 through a pull-up resistor
SDA1	Serial data, low-voltage side; connect to VREF1 through a pull-up resistor
SDA2	Serial data, high-voltage side; connect to VREF2 through a pull-up resistor
SCL2	Serial clock, high-voltage side; connect to VREF2 through a pull-up resistor
VREF2	High-voltage side reference supply voltage for SCL2 and SDA2
EN	Switch enable input; connect to VREF2 and pull-up through a high resistor

Table 2. FUNCTION TABLE

Input EN (Note 1)	Function
Low	Disconnect
High	SCL1 = SCL2; SDA1 = SDA2

1. EN is controlled by the $V_{bias(ref)(2)}$ logic levels and should be at least 1 V higher than $V_{ref(1)}$ for best translator operation.

Table 3. MAXIMUM RATINGS

Symbol	Parameter	Value	Unit
$V_{ref(1)}$	Reference Voltage (Note 2)	-0.5 to +7.0	V
$V_{bias(ref)(2)}$	Reference Bias Voltage (Note 3)	-0.5 to +7.0	V
V_{IN}	Input Voltage	-0.5 to +7.0	V
$V_{I/O}$	Input / Output Pin Voltage	-0.5 to +7.0	V
I_{CH}	DC Channel Current	128	mA
I_{IK}	DC Input Diode Current $V_{IN} < GND$	-50	mA
T_{STG}	Storage Temperature Range	-65 to +150	°C
T_L	Lead Temperature, 1 mm from Case for 10 Seconds	$T_L = 260$	°C
T_J	Junction Temperature Under Bias	$T_J = 150$	°C
θ_{JA}	Thermal Resistance (Note 2)	$\theta_{JA} = 150$	°C/W
P_D	Power Dissipation in Still Air at 85°C	$P_D = 833$	mW
MSL	Moisture Sensitivity	Level 1	
F_R	Flammability Rating Oxygen Index: 28 to 34	UL 94 V-0 @ 0.125 in	
V_{ESD}	ESD Withstand Voltage Human Body Mode (Note 3) Machine Model (Note 4) Charged Device Model (Note 5)	> 4000 > 400 N/A	V
$I_{LATCHUP}$	Latchup Performance Above V_{CC} and Below GND at 125 °C (Note 6)	± 100	mA

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

2. Measured with minimum pad spacing on an FR4 board, using 10 mm-by-1 inch, 2 ounce copper trace no air flow.

3. Tested to EIA / JESD22-A114-A.

4. Tested to EIA / JESD22-A115-A.

5. Tested to JESD22-C101-A.

6. Tested to EIA / JESD78.

Table 4. RECOMMENDED OPERATING CONDITIONS

Symbol	Parameter	Min	Max	Unit
$V_{ref(1)}$	Reference Voltage (1) (Note 7) V_{REF1}	0	5.5	V
$V_{bias(ref)(2)}$	Reference Bias Voltage (2) (Note 7) V_{REF2}	0	5.5	V
$V_{I/O}$	Input / Output Pin Voltage SCL1, SDA1, SCL2, SDA2	0	5.5	V
$V_{I(EN)}$	Control Pin Input Voltage EN	0	5.5	V
$I_{sw(pass)}$	Pass Switch Current	0	64	mA
T_A	Operating Free-Air Temperature	-55	+125	°C

7. $V_{(ref)(1)} \leq V_{bias(ref)(2)} - 1$ V for best results in level shifting applications.

Table 5. DC ELECTRICAL CHARACTERISTICS

Symbol	Parameter	Conditions	T _A = -55°C to +125°C			Unit
			Min	Typ (Note 8)	Max	
V _{IK}	Input Clamping Voltage	I _I = -18 mA; V _{I(EN)} = 0 V			-1.2	V
I _{IH}	High-Level Input Current	V _I = 5 V; V _{I(EN)} = 0 V			5	μA
C _{I(EN)}	EN Pin Input Capacitance	V _I = 3 V or 0 V		7.1		pF
C _{I/O(off)}	OFF-State I/O Pin Capacitance SCLn, SDAn	V _O = 3 V or 0 V; V _{I(EN)} = 0 V		4	6	pF
C _{I/O(on)}	ON-State I/O Pin Capacitance SCLn, SDAn	V _O = 3 V or 0 V; V _{I(EN)} = 3 V		9.3	12.5	pF
R _{ON}	ON-State Resistance ⁽²⁾⁽³⁾ SCLn, SDAn	V _I = 0 V; I _O = 64 mA V _{I(EN)} = 4.5 V V _{I(EN)} = 3 V V _{I(EN)} = 2.3 V V _{I(EN)} = 1.5 V		2.4 3.0 3.8 9.0	5.0 6.0 8.0 20	Ω
		V _I = 2.4 V; I _O = 15 mA V _{I(EN)} = 4.5 V V _{I(EN)} = 3 V		4.8 46	7.5 80	
		V _I = 1.7 V; I _O = 15 mA V _{I(EN)} = 2.3 V		40	80	

8. All typical values are at T_A = 25°C.

9. Measured by the voltage drop between the SCL1 and SCL2, or SDA1 and SDA2 terminals at the indicated current through the switch.
ON-state resistance is determined by the lowest voltage of the two terminals.

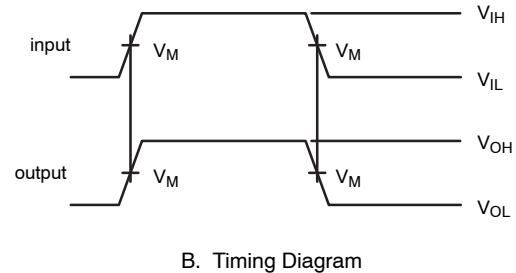
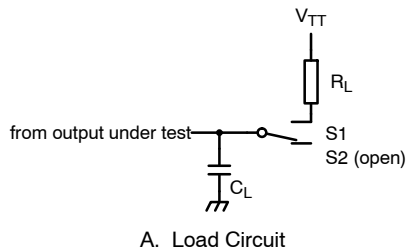
10. Guaranteed by design.

Table 6. AC ELECTRICAL CHARACTERISTICS (Translating Down) – Values Guaranteed by Design

Symbol	Parameter	Test Condition	Load Condition	T _A = -55°C to +125°C		Unit
				Min	Max	
SEE FIGURE 4 LOAD SWITCH AT S2 POSITION						
t _{PLH}	Low-to-High Propagation Delay, from (input) SCL2 or SDA2 to (output) SCL1 or SDA1	V _{I(EN)} = 3.3 V; V _{IH} = 3.3 V; V _{IL} = 0 V; V _M = 1.15 V	C _L = 15 pF	0	0.6	ns
			C _L = 30 pF	0	1.2	
			C _L = 50 pF	0	2.0	
t _{PHL}	High-to-Low Propagation Delay, from (input) SCL2 or SDA2 to (output) SCL1 or SDA1		C _L = 15 pF	0	0.75	
			C _L = 30 pF	0	1.5	
			C _L = 50 pF	0	2.0	
t _{PLH}	Low-to-High Propagation Delay, from (input) SCL2 or SDA2 to (output) SCL1 or SDA1	V _{I(EN)} = 2.5 V; V _{IH} = 2.5 V; V _{IL} = 0 V; V _M = 0.75 V	C _L = 15 pF	0	0.6	ns
			C _L = 30 pF	0	1.2	
			C _L = 50 pF	0	2.0	
t _{PHL}	High-to-Low Propagation Delay, from (input) SCL2 or SDA2 to (output) SCL1 or SDA1		C _L = 15 pF	0	0.75	
			C _L = 30 pF	0	1.5	
			C _L = 50 pF	0	2.5	

Table 7. AC ELECTRICAL CHARACTERISTICS (Translating Up) – Values Guaranteed by Design

Symbol	Parameter	Test Condition	Load Condition	T _A = -55°C to +125°C		Unit
				Min	Max	
SEE FIGURE 4 LOAD SWITCH AT S1 POSITION						
t _{PLH}	Low-to-High Propagation Delay, from (input) SCL1 or SDA1 to (output) SCL2 or SDA2	V _{I(EN)} = 3.3 V; V _{IH} = 2.3 V; V _{IL} = 0 V; V _{TT} = 3.3 V; V _M = 1.15 V	R _L = 300 Ω, C _L = 15 pF	0	0.5	ns
			R _L = 300 Ω, C _L = 30 pF	0	1.0	
			R _L = 300 Ω, C _L = 50 pF	0	1.75	
t _{PHL}	High-to-Low Propagation Delay, from (input) SCL1 or SDA1 to (output) SCL2 or SDA2		R _L = 300 Ω, C _L = 15 pF	0	0.8	
			R _L = 300 Ω, C _L = 30 pF	0	1.65	
			R _L = 300 Ω, C _L = 50 pF	0	2.75	
t _{PLH}	Low-to-High Propagation Delay, from (input) SCL1 or SDA1 to (output) SCL2 or SDA2	V _{I(EN)} = 2.5 V; V _{IH} = 1.5 V; V _{IL} = 0 V; V _{TT} = 2.5 V; V _M = 0.75 V	R _L = 300 Ω, C _L = 15 pF	0	0.5	ns
			R _L = 300 Ω, C _L = 30 pF	0	1.0	
			R _L = 300 Ω, C _L = 50 pF	0	1.75	
t _{PHL}	High-to-Low Propagation Delay, from (input) SCL1 or SDA1 to (output) SCL2 or SDA2		R _L = 300 Ω, C _L = 15 pF	0	1.0	
			R _L = 300 Ω, C _L = 30 pF	0	2.0	
			R _L = 300 Ω, C _L = 50 pF	0	3.3	



S1 = translating up; S2 = translating down.

C_L includes probe and jig capacitance.

All input pulses are supplied by generators having the following characteristics: $PRR \leq 10\text{ MHz}$; $Z_0 = 50\ \Omega$; $t_r \leq 2\text{ ns}$; $t_f \leq 2\text{ ns}$.

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

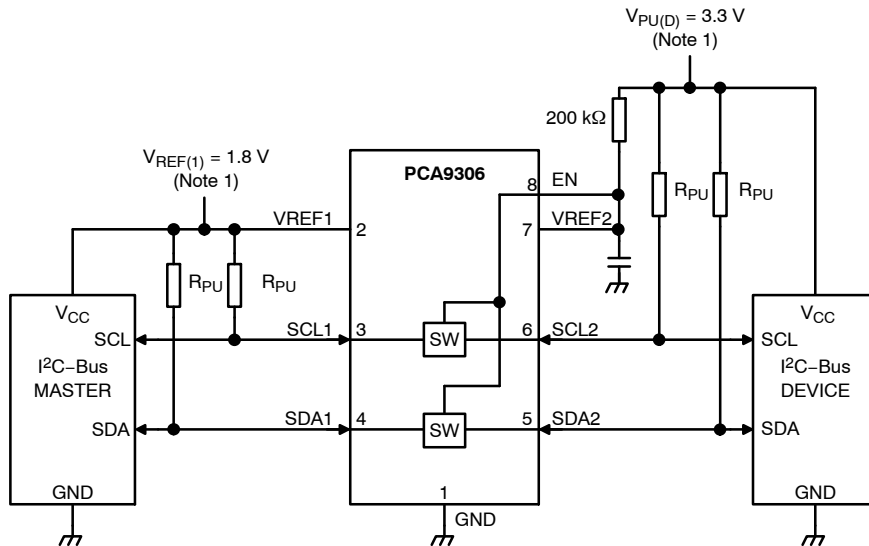
Figure 5. Load Circuit for Outputs**ORDERING INFORMATION**

Device	Package	Shipping [†]
PCA9306DTR2G	TSSOP-8 (Pb-Free)	4000 / Tape & Reel
PCA9306AMUTCG	UQFN-8 (Pb-Free)	3000 / Tape & Reel
PCA9306FMUTCG	UDFN8 (Pb-Free)	3000 / Tape & Reel
PCA9306USG	US8 (Pb-Free)	3000 / Tape & Reel
NLV9306USG*		

[†]For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

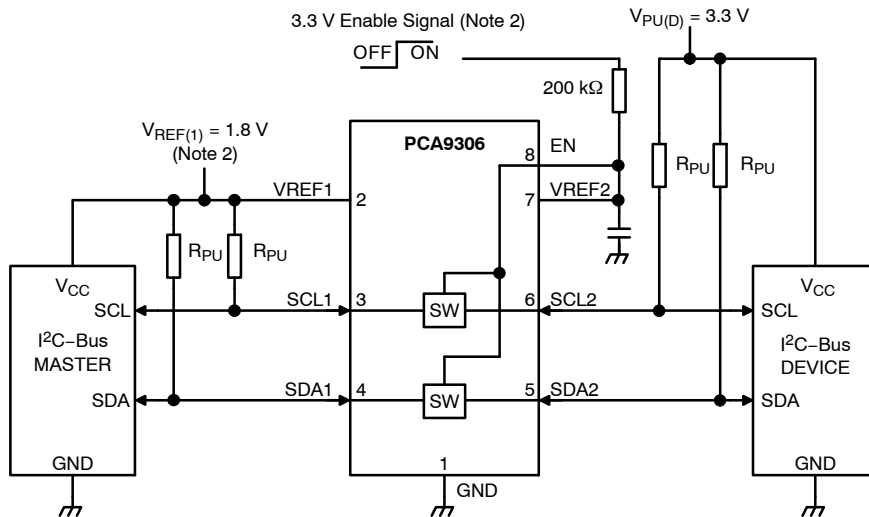
*NLV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable.

APPLICATION INFORMATION



1. The applied voltages at $V_{ref(1)}$ and $V_{pu(D)}$ should be such that $V_{bias(ref)(2)}$ is at least 1 V higher than $V_{ref(1)}$ for best translator operation.

Figure 6. Typical Application (Switch Always Enabled)



2. In the Enabled mode, the applied enable voltage and the applied voltage at $V_{ref(1)}$ should be such that $V_{bias(ref)(2)}$ is at least 1 V higher than $V_{ref(1)}$ for best translator operation.

Figure 7. Typical Application (Switch Enable Control)

Bidirectional Translation

For the bidirectional clamping configuration (higher voltage to lower voltage or lower voltage to higher voltage), the EN input must be connected to VREF2 and both pins pulled to HIGH side $V_{pu(D)}$ through a pull-up resistor (typically 200 kΩ). This allows VREF2 to regulate the EN input. A filter capacitor on VREF2 is recommended. The I²C-bus master output can be totem-pole or open-drain (pull-up resistors may be required) and the I²C-bus device output can be totem-pole or open-drain (pull-up resistors are required to pull the SCL2 and SDA2 outputs to $V_{pu(D)}$). However, if either output is totem-pole, data must be

unidirectional or the outputs must be 3-stateable 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.

The reference supply voltage ($V_{ref(1)}$) is connected to the processor core power supply voltage. When VREF2 is connected through a 200 kΩ resistor to a 3.3 V to 5.5 V $V_{pu(D)}$ power supply, and $V_{ref(1)}$ is set between 1.0 V and ($V_{pu(D)} - 1$ V), the output of each SCL1 and SDA1 has a maximum output voltage equal to VREF1, and the output of each SCL2 and SDA2 has a maximum output voltage equal to $V_{pu(D)}$.

Table 8. APPLICATION OPERATING CONDITIONS Refer to Figure 6.

Symbol	Parameter	Conditions	Min	Typ ⁽¹⁾	Max	Unit
V _{bias(ref)(2)}	Reference Bias Voltage (2)		V _{ref(1)} + 0.6	2.1	5	V
V _{I(EN)}	EN Pin Input Voltage		V _{ref(1)} + 0.6	2.1	5	V
V _{ref(1)}	Reference Voltage (1)		0	1.5	4.4	V
I _{sw(pass)}	Pass Switch Current			14		mA
I _{ref}	Reference Current	Transistor		5		μA
T _{amb}	Ambient Temperature	Operating in free-air	-55		+125	°C

11. All typical values are at T_{amb} = 25 °C.

Sizing Pull-up Resistor

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, the pull-up resistor value is calculated as:

$$R_{PU} = \frac{V_{PU(D)} - 0.35 \text{ V}}{0.015 \text{ A}} \quad (\text{eq. 1})$$

The following table summarizes resistor reference voltages and currents at 15 mA, 10 mA, and 3 mA. The resistor values shown in the +10% column or a larger value should be used to ensure that the pass voltage of the transistor would be 350 mV or less. The external driver must be able to sink the total current from the resistors on both sides of the PCA9306 device at 0.175 V, although the 15 mA only applies to current flowing through the PCA9306 device.

Table 9. PULLUP RESISTOR VALUES Calculated for V_{OL} = 0.35 V; assumes output driver V_{OL} = 0.175 V at stated current.

V _{pu(D)}	Pullup Resistor Value (Ω)					
	15 mA		10 mA		3 mA	
	Nominal	+10% (Note 12)	Nominal	+10% ⁽¹⁾	Nominal	+10% (Note 12)
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

12. +10% to compensate for V_{CC} range and resistor tolerance.

Maximum Frequency Calculation

The maximum frequency is totally dependent upon the specifics of the application and the device can operate > 33 MHz. Basically, the PCA9306 behaves like a wire with the additional characteristics of transistor device physics and should be capable of performing at higher frequencies if used correctly.

Here are some guidelines to follow that will help maximize the performance of the device:

- Keep trace length to a minimum by placing the PCA9306 close to the processor.
- The trace length should be less than half the time of flight to reduce ringing and reflections.
- The faster the edge of the signal, the higher the chance for ringing.
- The higher the drive strength (up to 15 mA), the higher the frequency the device can use.

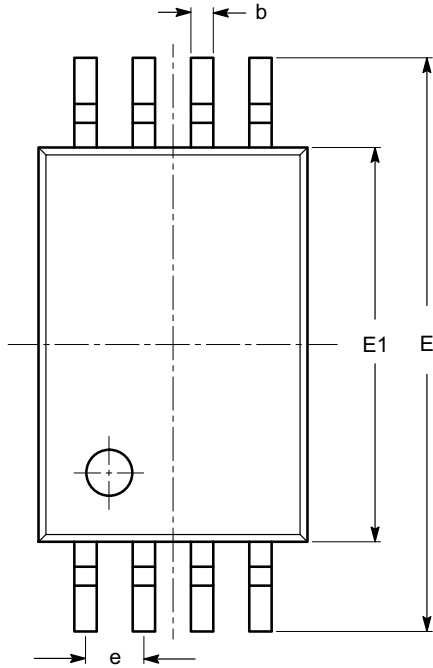
In a 3.3 V to 1.8 V direction level shift, if the 3.3 V side is being driven by a totem pole type driver no pull-up

resistor is needed on the 3.3 V side. The capacitance and line length of concern is on the 1.8 V side since it is driven through the ON resistance of the PCA9306. If the line length on the 1.8 V side is long enough there can be a reflection at the chip/terminating end of the wire when the transition time is shorter than the time of flight of the wire because the PCA9306 looks like a high-impedance compared to the wire. If the wire is not too long and the lumped capacitance is not excessive the signal will only be slightly degraded by the series resistance added by passing through the PCA9306. If the lumped capacitance is large the rise time will deteriorate, the fall time is much less affected and if the rise time is slowed down too much the duty cycle of the clock will be degraded and at some point the clock will no longer be useful. So the principle design consideration is to minimize the wire length and the capacitance on the 1.8 V side for the clock path. A pull-up resistor on the 1.8 V side can also be used to trade a slower fall time for a faster rise time and can also reduce the overshoot in some cases.

PCA9306

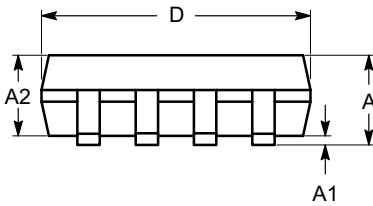
PACKAGE DIMENSIONS

TSSOP8, 4.4x3
CASE 948AL
ISSUE O

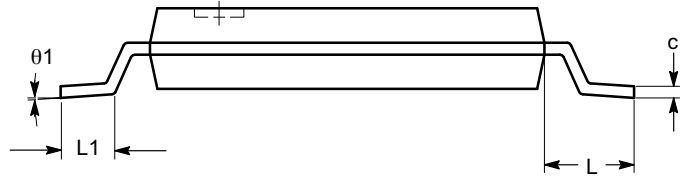


SYMBOL	MIN	NOM	MAX
A			1.20
A1	0.05		0.15
A2	0.80	0.90	1.05
b	0.19		0.30
c	0.09		0.20
D	2.90	3.00	3.10
E	6.30	6.40	6.50
E1	4.30	4.40	4.50
e	0.65 BSC		
L	1.00 REF		
L1	0.50	0.60	0.75
θ	0°		8°

TOP VIEW



SIDE VIEW



END VIEW

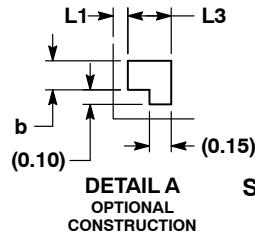
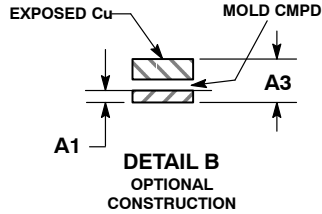
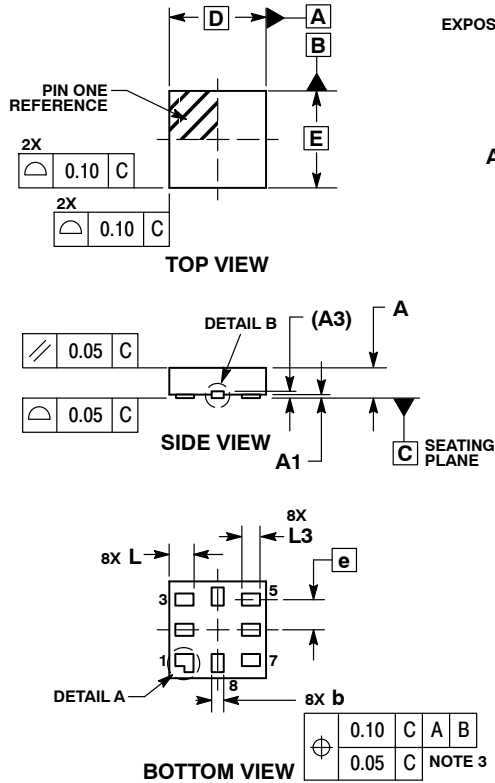
Notes:

- (1) All dimensions are in millimeters. Angles in degrees.
- (2) Complies with JEDEC MO-153.

PCA9306

PACKAGE DIMENSIONS

UQFN8, 1.6x1.6, 0.5P
CASE 523AN
ISSUE O

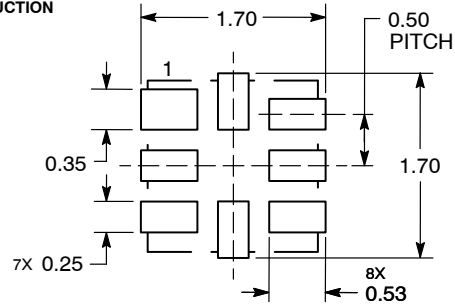


NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30 mm FROM THE TERMINAL TIP.

MILLIMETERS		
DIM	MIN	MAX
A	0.45	0.60
A1	0.00	0.05
A3	0.13	REF
b	0.15	0.25
D	1.60	BSC
E	1.60	BSC
e	0.50	BSC
L	0.35	0.45
L1	---	0.15
L3	0.25	0.35

SOLDERING FOOTPRINT*



DIMENSIONS: MILLIMETERS

*For additional information on our Pb-Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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