

# DATA SHEET



## **PCA9516A** 5-channel I<sup>2</sup>C hub

Product data sheet  
Supersedes data of 2004 May 28

2004 Sep 29

## 5-channel I<sup>2</sup>C hub

## PCA9516A

### DESCRIPTION

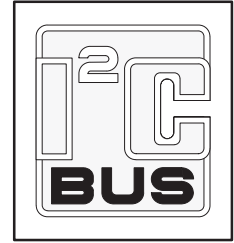
The PCA9516A is a CMOS integrated circuit intended for application in I<sup>2</sup>C and SMBus systems.

While retaining all the operating modes and features of the I<sup>2</sup>C system, it permits extension of the I<sup>2</sup>C-bus by buffering both the data (SDA) and the clock (SCL) lines, thus enabling five buses of 400 pF.

The I<sup>2</sup>C-bus capacitance limit of 400 pF restricts the number of devices and bus length. Using the PCA9516A enables the system designer to divide the bus into five segments off of a hub where any segment to segment transition sees only one repeater delay.

It can also be used to run different buses at 5 V and 3.3 V or 400 kHz and 100 kHz buses where the 100 kHz bus is isolated when 400 kHz operation of the other bus is required.

**Two or more PCA9516As cannot be put in series.** The PCA9516A design does not allow this configuration. Since there is no direction pin, slightly different “legal” low voltage levels are used to avoid lock-up conditions between the input and the output of each repeater in the hub. A “regular LOW” applied at the input of a PCA9516A will be propagated as a “buffered LOW” with a slightly higher value on all the enabled outputs. When this “buffered LOW” is applied to another PCA9515A, PCA9516A, or PCA9518 in series, the second PCA9515A, PCA9516A, or PCA9518 will not recognize it as a “regular LOW” and will not propagate it as a “buffered LOW” again. The PCA9510/9511/9513/9514 and PCA9512 cannot be used in series with the PCA9515A, PCA9516A, or PCA9518 but can be used in series with themselves since they use shifting instead of static offsets to avoid lock-up conditions.



### FEATURES

- 5 channel, bi-directional buffer
- I<sup>2</sup>C-bus and SMBus compatible
- Active HIGH individual repeater enable input
- Open-drain input/outputs
- Lock-up free operation
- Supports arbitration and clock stretching across the repeater
- Accommodates standard mode and fast mode I<sup>2</sup>C devices and multiple masters
- Powered-off high impedance I<sup>2</sup>C pins
- Operating supply voltage range of 2.3 V to 3.6 V
- 5.5 V tolerant I<sup>2</sup>C and enable pins
- 0 kHz to 400 kHz clock frequency<sup>1</sup>
- ESD protection exceeds 2000 V HBM per JESD22-A114, 200 V MM per JESD22-A115, and 1000 V CDM per JESD22-C101.
- Latch-up testing is done to JEDEC Standard JESD78 which exceeds 100 mA.
- Package offerings: SO16 and TSSOP16

### ORDERING INFORMATION

DESCRIPTION	TEMPERATURE RANGE	ORDER CODE	TOPSIDE MARK	DRAWING NUMBER
16-pin plastic SO	-40 °C to +85 °C	PCA9516AD	PCA9516AD	SOT109-1
16-pin plastic TSSOP	-40 °C to +85 °C	PCA9516APW	PA9516A	SOT403-1

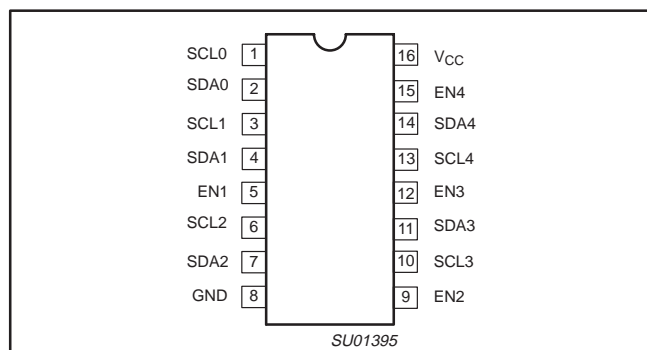
Standard packing quantities and other packaging data is available at [www.standardproducts.philips.com/packaging](http://www.standardproducts.philips.com/packaging).

1. The maximum system operating frequency may be less than 400 kHz because of the delays added by the repeater.

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## PIN CONFIGURATION



**Figure 1. Pin configuration**

## PIN DESCRIPTION

PIN	SYMBOL	FUNCTION
1	SCL0	Serial clock bus 0
2	SDA0	Serial data bus 0
3	SCL1	Serial clock bus 1
4	SDA1	Serial data bus 1
5	EN1	Active-HIGH Bus 1 enable Input
6	SCL2	Serial clock bus 2
7	SDA2	Serial data bus 2
8	GND	Supply ground
9	EN2	Active-HIGH Bus 2 enable Input
10	SCL3	Serial clock bus 3
11	SDA3	Serial data bus 3
12	EN3	Active-HIGH Bus 3 enable Input
13	SCL4	Serial clock bus 4
14	SDA4	Serial data bus 4
15	EN4	Active-HIGH Bus 4 enable Input
16	VCC	Supply power

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## BLOCK DIAGRAM

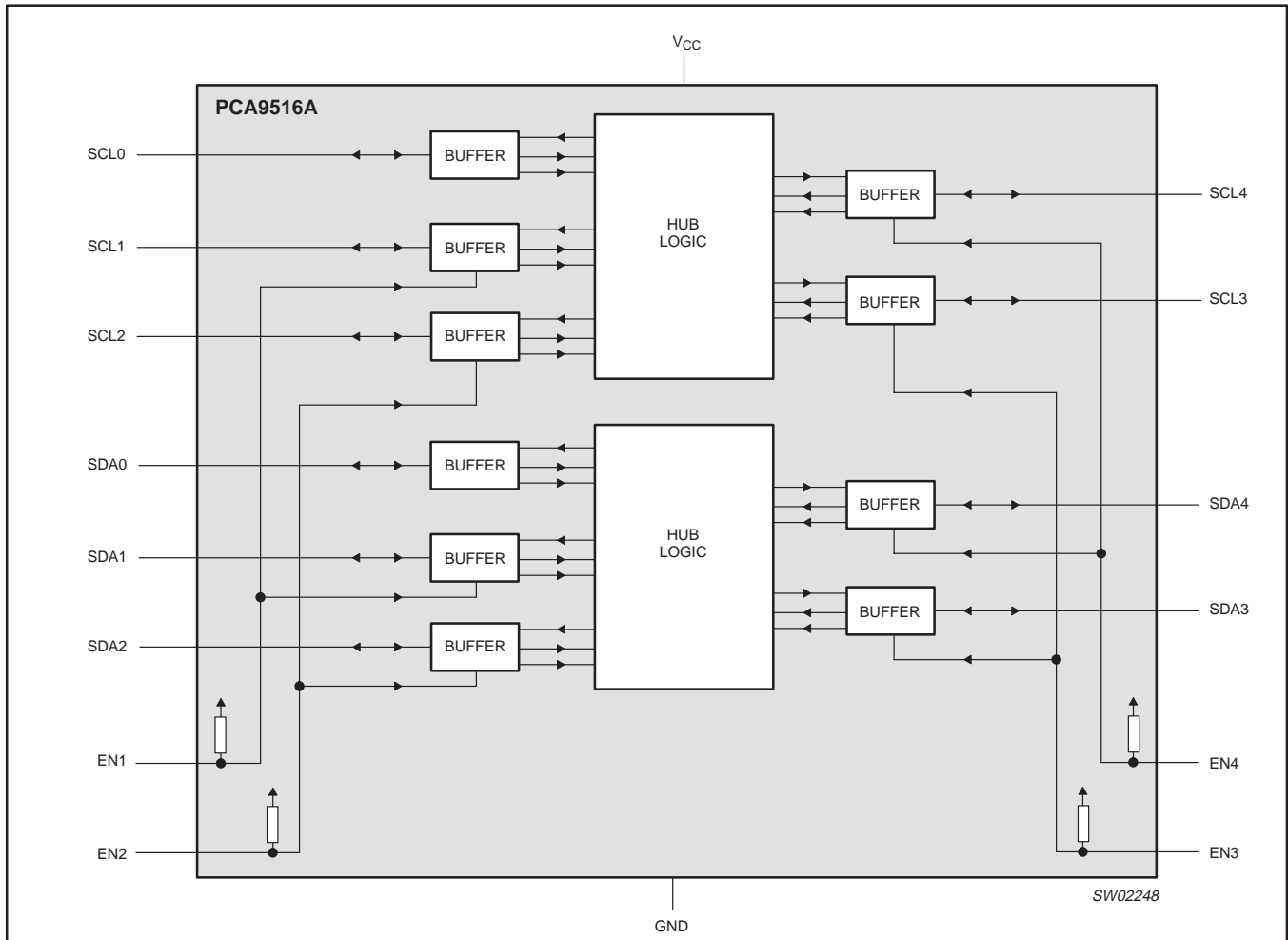


Figure 2. Block Diagram: PCA9516A

A more detailed view of Figure 2 buffer is shown in Figure 3.

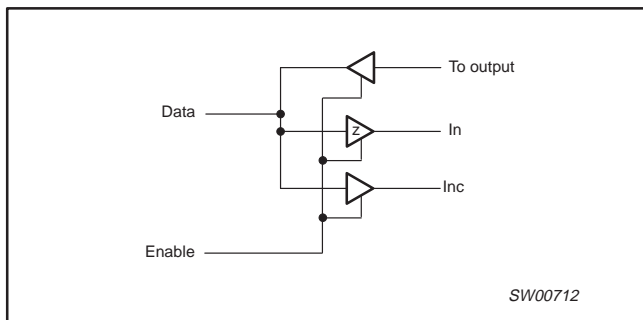


Figure 3.

The output pull-down of each internal buffer is set for approximately 0.5 V, while the input threshold of each internal buffer is set about 0.07 V lower, when the output is internally driven LOW. This prevents a lock-up condition from occurring.

# 5-channel I<sup>2</sup>C hub

# PCA9516A

## FUNCTIONAL DESCRIPTION

The PCA9516A is a five way hub repeater, which enables I<sup>2</sup>C and similar bus systems to be expanded with only one repeater delay and no functional degradation of system performance.

The PCA9516A contains five bi-directional, open drain buffers specifically designed to support the standard low-level-contention arbitration of the I<sup>2</sup>C-bus. Except during arbitration or clock stretching, the PCA9516A acts like five pairs of non-inverting, open drain buffers, one for SDA and one for SCL.

### Enable

The enable pins EN1 through EN4 are active HIGH and have internal pull-up resistors. Each enable pin ENn controls its associated SDA<sub>n</sub> and SCL<sub>n</sub> ports. When LOW, the ENn pin blocks the inputs from SDA<sub>n</sub> and SCL<sub>n</sub> as well as disabling the output drivers on the SDA<sub>n</sub> and SCL<sub>n</sub> pins. The enable pins should only change state when both the global bus and the local port are in an idle state to prevent system failures.

The active HIGH enable pins allow the use of open drain drivers which can be wire-ORed to create a distributed enable where either centralized control signal (master) or spoke signal (submaster) can enable the channel when it is idle.

### I<sup>2</sup>C Systems

As with the standard I<sup>2</sup>C system, pull-up resistors are required to provide the logic HIGH levels on the Buffered bus. (Standard open-collector configuration of the I<sup>2</sup>C-bus). The size of these pull-up resistors depends on the system, but each side of the repeater must have a pull-up resistor. This part is designed to work with standard mode and fast mode I<sup>2</sup>C devices in addition to SMBus devices. Standard mode I<sup>2</sup>C devices only specify 3 mA output drive, this limits the termination current to 3 mA in a generic I<sup>2</sup>C system where standard mode devices and multiple masters are possible. Please see Application Note AN255 "I<sup>2</sup>C & SMBus Repeaters, Hubs and Expanders" for additional information on sizing resistors and precautions when using more than one PCA9515A/PCA9516A in a system or using the PCA9515A/16A in conjunction with the P82B96.

## APPLICATION INFORMATION

A typical application is shown in Figure 4. In this example, the system master is running on a 3.3 V I<sup>2</sup>C-bus while the slave is connected to a 5 V bus. All buses run at 100 kHz unless slave 3 is isolated and then the master bus and slave 1 and 2 can run at 400 kHz.

Any segment of the hub can talk to any other segment of the hub. Bus masters and slaves can be located on all five segments with 400 pF load allowed on each segment.

Unused ports should be isolated by holding the enable pin to GND and/or pulling SDA/SCL pins to V<sub>CC</sub> through appropriately sized resistors. The primary bus master is normally connected to

SDA0/SCL0. If the SDA0/SCL0 port is not used, the pins need to be pulled to V<sub>CC</sub> through appropriately sized resistors.

The PCA9516A is 5.5 V tolerant so it does not require any additional circuitry to translate between the different bus voltages.

When one side of the PCA9516A is pulled LOW by a device on the I<sup>2</sup>C-bus, a CMOS hysteresis type input detects the falling edge and causes an internal driver on the other side to turn on, thus causing the other side to also go LOW. The side driven LOW by the PCA9516A will typically be at V<sub>OL</sub> = 0.5 V.

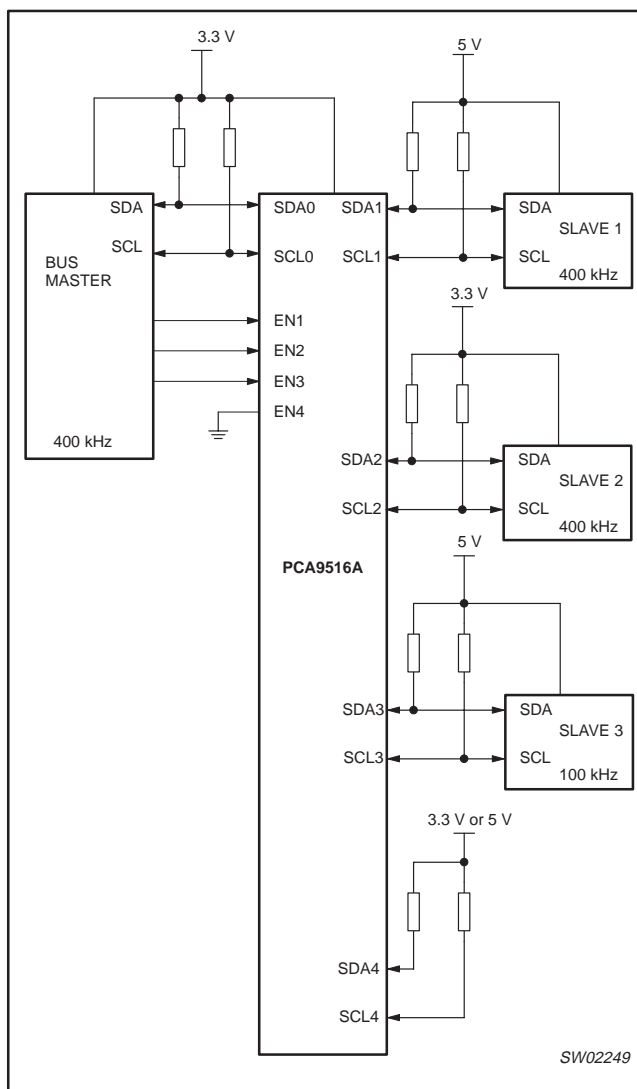


Figure 4. Typical application

# 5-channel I<sup>2</sup>C hub

# PCA9516A

In order to illustrate what would be seen in a typical application, refer to Figures 5 and 6. If the bus master in Figure 4 were to write to the slave through the PCA9516A, we would see the waveform shown in Figure 5 on Bus 0. This looks like a normal I<sup>2</sup>C transmission until the falling edge of the 8th clock pulse. At that point, the master releases the data line (SDA) while the slave pulls it LOW through the PCA9516A. Because the  $V_{OL}$  of the PCA9516A is typically around 0.5 V, a step in the SDA will be seen. After the master has transmitted the 9th clock pulse, the slave releases the data line.

On the Bus 1 side of the PCA9516A, the clock and data lines would have a positive offset from ground equal to the  $V_{OL}$  of the PCA9516A. After the 8th clock pulse, the data line will be pulled to the  $V_{OL}$  of the slave device that is very close to ground in our example.

It is important to note that any arbitration or clock stretching events on Bus 1 require that the  $V_{OL}$  of the devices on Bus 1 be 70 mV below the  $V_{OL}$  of the PCA9516A (see  $V_{OL} - V_{ilc}$  in the DC Characteristics section) to be recognized by the PCA9516A and then transmitted to Bus 0.

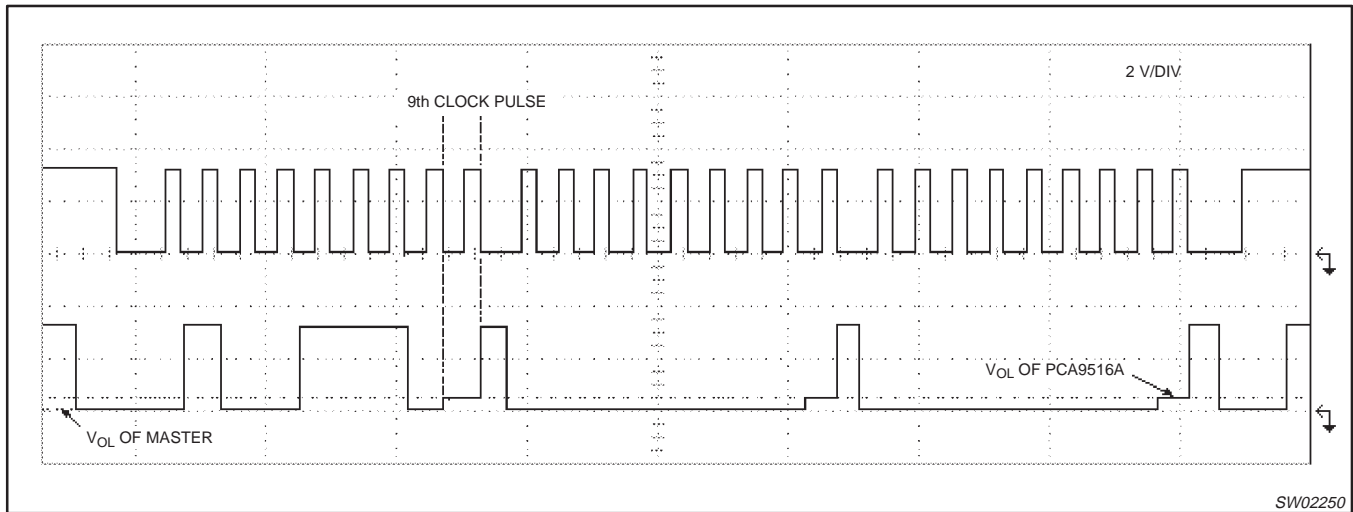


Figure 5. Bus 0 waveform

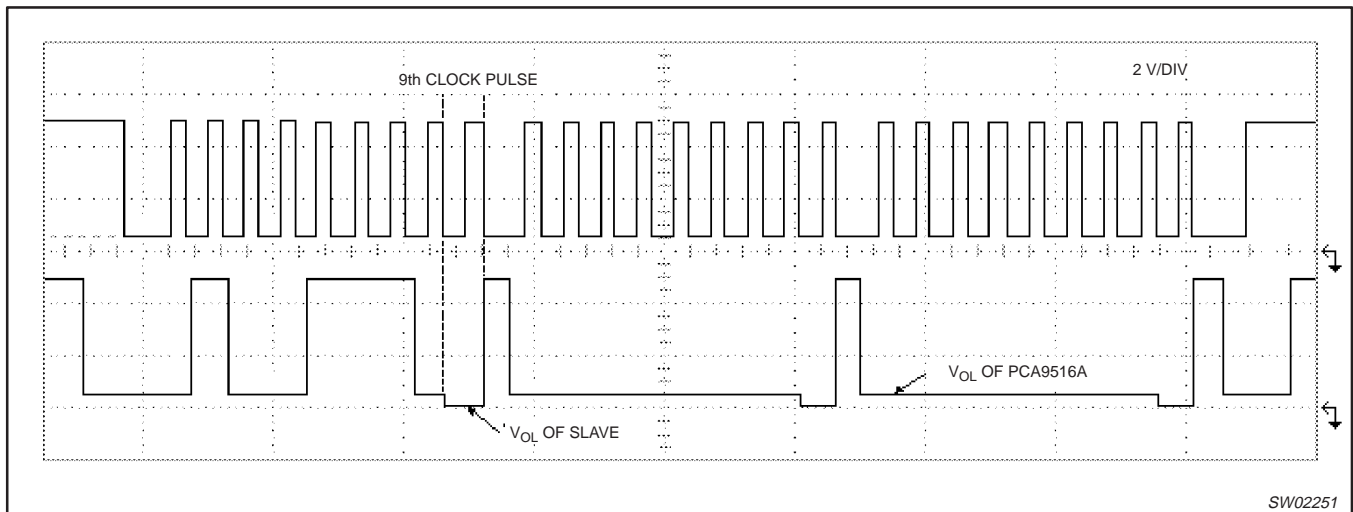


Figure 6. Bus 1 waveform

5-channel I<sup>2</sup>C hub

PCA9516A

**ABSOLUTE MAXIMUM RATINGS**

Limiting values in accordance with the Absolute Maximum System (IEC 134).  
 Voltages with respect to pin GND.

SYMBOL	PARAMETER	LIMITS		UNIT
		MIN.	MAX.	
V <sub>CC</sub> to GND	Supply voltage range V <sub>CC</sub>	-0.5	+7	V
V <sub>bus</sub>	Voltage range I <sup>2</sup> C-bus, SCL or SDA	-0.5	+7	V
I	DC current (any pin)	—	50	mA
P <sub>tot</sub>	Power dissipation	—	300	mW
T <sub>stg</sub>	Storage temperature range	-55	+125	°C
T <sub>amb</sub>	Operating ambient temperature range	-40	+85	°C

**DC ELECTRICAL CHARACTERISTICS**

V<sub>CC</sub> = 3.0 V to 3.6 V; GND = 0 V; T<sub>amb</sub> = -40 °C to +85 °C; unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN.	TYP. <sup>2</sup>	MAX.	
<b>Supplies</b>						
V <sub>CC</sub>	DC supply voltage		3.0	—	3.6	V
I <sub>CCH</sub>	Quiescent supply current, both channels HIGH	V <sub>CC</sub> = 3.6 V; SDAn = SCLn = V <sub>CC</sub>	—	2.1	5	mA
I <sub>CCL</sub>	Quiescent supply current, both channels LOW	V <sub>CC</sub> = 3.6 V; one SDA and one SCL = GND, other SDA and SCL open	—	4.7	10	mA
I <sub>CCLc</sub>	Quiescent supply current in contention	V <sub>CC</sub> = 3.6 V; SDAn = SCLn = GND	—	4.0	10	mA
<b>Input SCL; input/output SDA</b>						
V <sub>IH</sub>	HIGH-level input voltage		0.7 V <sub>CC</sub>	—	5.5	V
V <sub>IL</sub>	LOW-level input voltage (Note 1)		-0.5	—	0.3 V <sub>CC</sub>	V
V <sub>ILc</sub>	LOW-level input voltage contention (Note 1)		-0.5	—	0.4	V
V <sub>IK</sub>	Input clamp voltage	I <sub>I</sub> = -18 mA	—	—	-1.2	V
I <sub>LI</sub>	Input leakage current	V <sub>I</sub> = 3.6 V	-1	—	1	μA
I <sub>IL</sub>	Input current LOW, SDA, SCL	V <sub>I</sub> = 0.2 V, SDA, SCL	—	—	5	μA
V <sub>OL</sub>	LOW-level output voltage	I <sub>OL</sub> = 0 or 6 mA	0.47	0.52	0.6	V
V <sub>OL</sub> -V <sub>ILc</sub>	LOW-level input voltage below output LOW-level voltage	Guaranteed by design	—	—	70	mV
C <sub>I</sub>	Input capacitance	V <sub>I</sub> = 3 V or 0 V	—	6	10	pF
<b>Enable 1-4</b>						
V <sub>IL</sub>	LOW-level input voltage		-0.5	—	0.8	V
V <sub>IH</sub>	HIGH-level input voltage		2.0	—	5.5	V
I <sub>IL</sub>	Input current LOW, EN1-EN4	V <sub>I</sub> = 0.2 V, EN1-EN4	—	-12	-30	μA
I <sub>LI</sub>	Input leakage current		-1	—	1	μA
C <sub>I</sub>	Input capacitance	V <sub>I</sub> = 3.0 V or 0 V	—	6	7	pF

**NOTES:**

- V<sub>IL</sub> specification is for the first LOW level seen by the SDAx/SCLx lines. V<sub>ILc</sub> is for the second and subsequent LOW levels seen by the SDAx/SCLx lines.
- Typical value taken at 3.3 V and 25 °C.
- For operation between published voltage ranges, refer to worst case parameter in both ranges.

5-channel I<sup>2</sup>C hub

## PCA9516A

**DC ELECTRICAL CHARACTERISTICS**

$V_{CC} = 2.3 \text{ V to } 2.7 \text{ V}$ ;  $GND = 0 \text{ V}$ ;  $T_{amb} = -40 \text{ }^\circ\text{C to } +85 \text{ }^\circ\text{C}$ ; unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN.	TYP. <sup>2</sup>	MAX.	
<b>Supplies</b>						
$V_{CC}$	DC supply voltage		2.3	—	2.7	V
$I_{CCH}$	Quiescent supply current, both channels HIGH	$V_{CC} = 2.7 \text{ V}$ ; $SDA_n = SCL_n = V_{CC}$	—	2.1	5	mA
$I_{CCL}$	Quiescent supply current, both channels LOW	$V_{CC} = 2.7 \text{ V}$ ; one SDA and one SCL = GND, other SDA and SCL open	—	4.6	10	mA
$I_{CCLc}$	Quiescent supply current in contention	$V_{CC} = 2.7 \text{ V}$ ; $SDA_n = SCL_n = GND$	—	3.9	10	mA
<b>Input SCL; input/output SDA</b>						
$V_{IH}$	HIGH-level input voltage		$0.7 V_{CC}$	—	5.5	V
$V_{IL}$	LOW-level input voltage (Note 1)		-0.5	—	$0.3 V_{CC}$	V
$V_{ILc}$	LOW-level input voltage contention (Note 1)		-0.5	—	0.4	V
$V_{IK}$	Input clamp voltage	$I_I = -18 \text{ mA}$	—	—	-1.2	V
$I_{LI}$	Input leakage current	$V_I = 2.7 \text{ V}$	-1	—	1	$\mu\text{A}$
$I_{LL}$	Input current LOW, SDA, SCL	$V_I = 0.2 \text{ V}$ , SDA, SCL	—	—	5	$\mu\text{A}$
$V_{OL}$	LOW-level output voltage	$I_{OL} = 0 \text{ or } 6 \text{ mA}$	0.47	0.52	0.6	V
$V_{OL} - V_{ILc}$	LOW-level input voltage below output LOW-level voltage	Guaranteed by design	—	—	70	mV
$C_I$	Input capacitance	$V_I = 3 \text{ V or } 0 \text{ V}$	—	6	10	pF
<b>Enable 1-4</b>						
$V_{IL}$	LOW-level input voltage		-0.5	—	0.8	V
$V_{IH}$	HIGH-level input voltage		1.5	—	5.5	V
$I_{LL}$	Input current LOW, EN1-EN4	$V_I = 0.2 \text{ V}$ , EN1-EN4	—	-10	-30	$\mu\text{A}$
$I_{LI}$	Input leakage current		-1	—	1	$\mu\text{A}$
$C_I$	Input capacitance	$V_I = 3.0 \text{ V or } 0 \text{ V}$	—	6	7	pF

**NOTES:**

- $V_{IL}$  specification is for the first LOW level seen by the SDAx/SCLx lines.  $V_{ILc}$  is for the second and subsequent LOW levels seen by the SDAx/SCLx lines.
- Typical value taken at 2.5 V and 25 °C.



# 5-channel I<sup>2</sup>C hub

# PCA9516A

## AC ELECTRICAL CHARACTERISTICS

V<sub>CC</sub> = 2.3 V to 2.7 V

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN.	TYP. <sup>2</sup>	MAX.	
t <sub>PHL</sub>	Propagation delay	Waveform 1	45	93	150	ns
t <sub>PLH</sub>	Propagation delay	Waveform 1; Note 1	33	90	135	ns
t <sub>THL</sub>	Transition time	Waveform 1	—	60	—	ns
t <sub>TLH</sub>	Transition time	Waveform 1; Note 1	—	131	—	ns
t <sub>SET</sub>	Enable to Start condition		100	—	—	ns
t <sub>HOLD</sub>	Enable after Stop condition		130	—	—	ns

**NOTES:**

1. Different load resistance and capacitance will alter the RC time constant, thereby changing the propagation delay and transition times.
2. Typical value taken at 2.5 V and 25 °C.

## AC ELECTRICAL CHARACTERISTICS

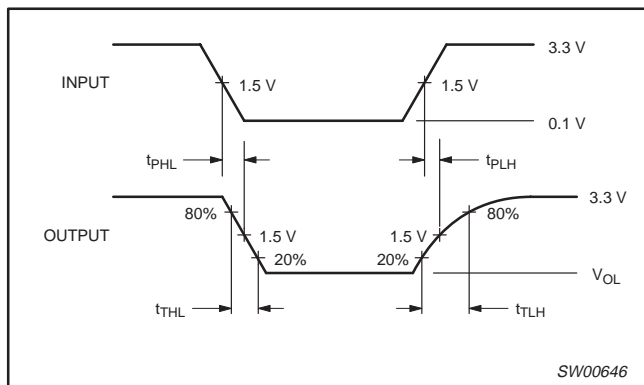
V<sub>CC</sub> = 3.0 V to 3.6 V

SYMBOL	PARAMETER	TEST CONDITIONS	LIMITS			UNIT
			MIN.	TYP. <sup>2</sup>	MAX.	
t <sub>PHL</sub>	Propagation delay	Waveform 1	45	75	120	ns
t <sub>PLH</sub>	Propagation delay	Waveform 1; Note 1	33	60	83	ns
t <sub>THL</sub>	Transition time	Waveform 1	—	47	—	ns
t <sub>TLH</sub>	Transition time	Waveform 1; Note 1	—	130	—	ns
t <sub>SET</sub>	Enable to Start condition		100	—	—	ns
t <sub>HOLD</sub>	Enable after Stop condition		100	—	—	ns

**NOTES:**

1. Different load resistance and capacitance will alter the RC time constant, thereby changing the propagation delay and transition times.
2. Typical value taken at 3.3 V and 25 °C.

## AC WAVEFORMS



Waveform 1.

## TEST CIRCUIT

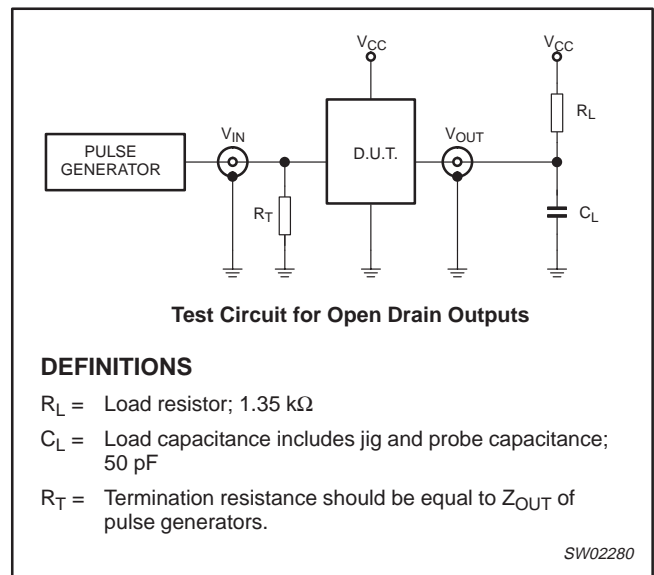


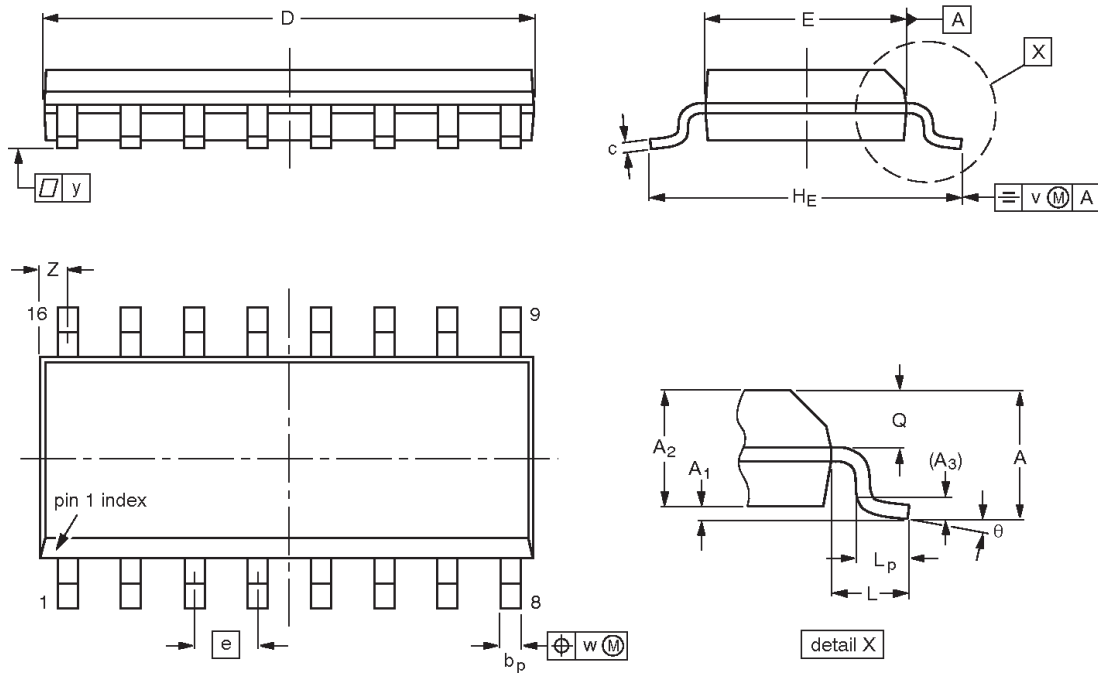
Figure 7. Test circuit

# 5-channel I<sup>2</sup>C hub

# PCA9516A

**SO16:** plastic small outline package; 16 leads; body width 3.9 mm

**SOT109-1**



**DIMENSIONS (inch dimensions are derived from the original mm dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(1)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	z <sup>(1)</sup>	θ
mm	1.75	0.25 0.10	1.45 1.25	0.25	0.49 0.36	0.25 0.19	10.0 9.8	4.0 3.8	1.27	6.2 5.8	1.05	1.0 0.4	0.7 0.6	0.25	0.25	0.1	0.7 0.3	8° 0°
inches	0.069	0.010 0.004	0.057 0.049	0.01	0.019 0.014	0.0100 0.0075	0.39 0.38	0.16 0.15	0.05	0.244 0.228	0.041	0.039 0.016	0.028 0.020	0.01	0.01	0.004	0.028 0.012	

**Note**

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.

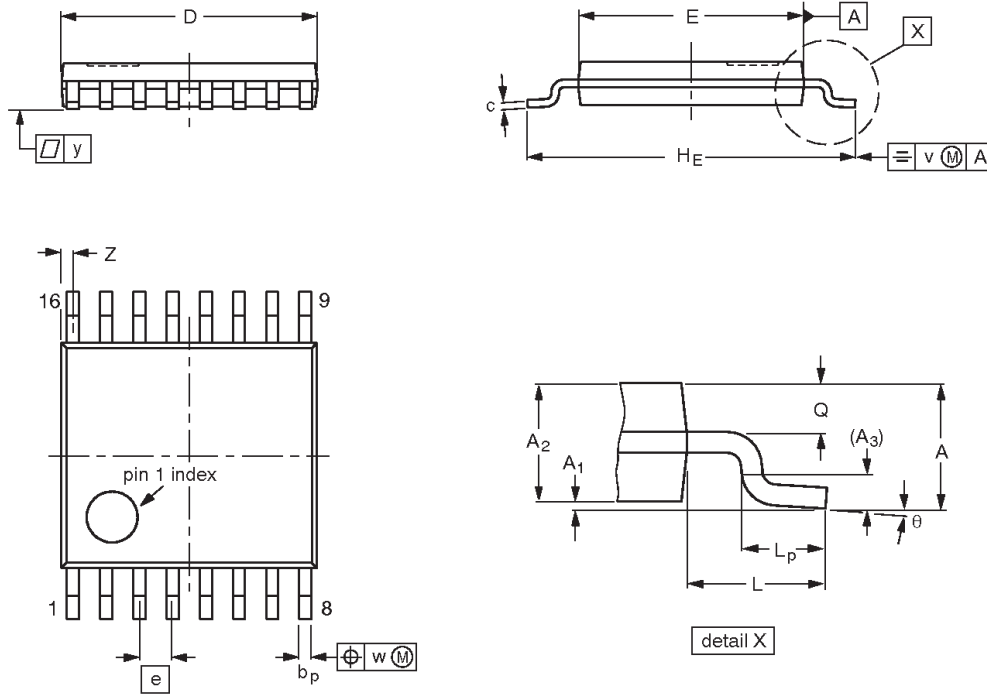
OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT109-1	076E07	MS-012				99-12-27 03-02-19

# 5-channel I<sup>2</sup>C hub

# PCA9516A

**TSSOP16:** plastic thin shrink small outline package; 16 leads; body width 4.4 mm

**SOT403-1**



**DIMENSIONS (mm are the original dimensions)**

UNIT	A max.	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	b <sub>p</sub>	c	D <sup>(1)</sup>	E <sup>(2)</sup>	e	H <sub>E</sub>	L	L <sub>p</sub>	Q	v	w	y	Z <sup>(1)</sup>	θ
mm	1.1	0.15 0.05	0.95 0.80	0.25	0.30 0.19	0.2 0.1	5.1 4.9	4.5 4.3	0.65	6.6 6.2	1	0.75 0.50	0.4 0.3	0.2	0.13	0.1	0.40 0.06	8° 0°

**Notes**

1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic interlead protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT403-1		MO-153				-99-12-27 03-02-18

5-channel I<sup>2</sup>C hub

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**REVISION HISTORY**

Rev	Date	Description
_2	20040929	<b>Product data sheet (9397 750 14108). Supersedes data of 2004 May 28 (9397 750 13238).</b> Modifications: <ul style="list-style-type: none"><li>● “Application information” section on page 5:<ul style="list-style-type: none"><li>– First paragraph, third sentence: change from “... unless slave 3 and 4 are isolated ...” to “... unless slave 3 is isolated ...”</li><li>– Add (new) third paragraph.</li><li>– Figure 4 modified.</li></ul></li></ul>
_1	20040528	<b>Product data sheet (9397 750 13238).</b>

5-channel I<sup>2</sup>C hub

PCA9516A



Purchase of Philips I<sup>2</sup>C components conveys a license under the Philips' I<sup>2</sup>C patent to use the components in the I<sup>2</sup>C system provided the system conforms to the I<sup>2</sup>C specifications defined by Philips. This specification can be ordered using the code 9398 393 40011.

## Data sheet status

Level	Data sheet status <sup>[1]</sup>	Product status <sup>[2]</sup> [3]	Definitions
I	Objective data	Development	This data sheet contains data from the objective specification for product development. Philips Semiconductors reserves the right to change the specification in any manner without notice.
II	Preliminary data	Qualification	This data sheet contains data from the preliminary specification. Supplementary data will be published at a later date. Philips Semiconductors reserves the right to change the specification without notice, in order to improve the design and supply the best possible product.
III	Product data	Production	This data sheet contains data from the product specification. Philips Semiconductors reserves the right to make changes at any time in order to improve the design, manufacturing and supply. Relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN).

[1] Please consult the most recently issued data sheet before initiating or completing a design.

[2] The product status of the device(s) described in this data sheet may have changed since this data sheet was published. The latest information is available on the Internet at URL <http://www.semiconductors.philips.com>.

[3] For data sheets describing multiple type numbers, the highest-level product status determines the data sheet status.

## Definitions

**Short-form specification** — The data in a short-form specification is extracted from a full data sheet with the same type number and title. For detailed information see the relevant data sheet or data handbook.

**Limiting values definition** — Limiting values given are in accordance with the Absolute Maximum Rating System (IEC 60134). Stress above one or more of the limiting values may cause permanent damage to the device. These are stress ratings only and operation of the device at these or at any other conditions above those given in the Characteristics sections of the specification is not implied. Exposure to limiting values for extended periods may affect device reliability.

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