

# DATA SHEET



## **PCA9510; PCA9511**

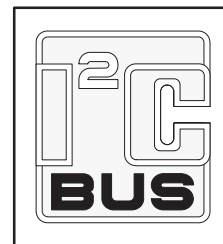
Hot swappable I<sup>2</sup>C and SMBus bus buffer

Product data sheet  
Supersedes data of 2003 Dec 18

2004 Oct 05

Hot swappable I<sup>2</sup>C and SMBus bus buffer

## PCA9510; PCA9511



## DESCRIPTION

The PCA9510 and PCA9511 are hot swappable I<sup>2</sup>C and SMBus buffers that allows I/O card insertion into a live backplane without corrupting the data and clock buses. Control circuitry prevents the backplane from being connected to the card until a stop command or bus idle occurs on the backplane without bus contention on the card. When the connection is made, the PCA9510 and PCA9511 provides bi-directional buffering, keeping the backplane and card capacitances isolated.

The PCA9511 rise time accelerator circuitry allows the use of weaker DC pull-up currents while still meeting rise time requirements, while the PCA9510 has no rise time accelerator circuitry to prevent interference when there are multiple devices in the same system. The PCA9510 and PCA9511 incorporate a digital ENABLE input pin, which enables the device when asserted HIGH and forces the device into a low current mode when asserted LOW, and an open-drain READY output pin, which indicates that the backplane and card sides are connected together (HIGH) or not (LOW).

During insertion, the PCA9510 (IN only) and PCA9511 SDA and SCL lines are precharged to 1 V to minimize the current required to charge the parasitic capacitance of the chip.

The dynamic offset design of the PCA9510/11/12/13/14 I/O drivers allow them to be connected to another PCA9510/11/12/13/14 device in series or in parallel and to the A side of the PCA9517. The PCA9510/11/12/13/14 can **not** connect to the static offset I/Os used on the PCA9515/15A/16/16A/17 B side and PCA9518.

## APPLICATION

- cPCI, VME, AdvancedTCA cards and other multi-point backplane cards that are required to be inserted or removed from an operating system.

## FEATURES

- Bi-directional buffer for SDA and SCL lines increases fanout and prevents SDA and SCL corruption during live board insertion and removal from multi-point backplane systems
- Compatible with I<sup>2</sup>C standard mode, I<sup>2</sup>C fast mode, and SMBus standards
- $\Delta V/\Delta t$  rise time accelerators on all SDA and SCL lines (PCA9511 only)
- Rise time accelerator threshold of 0.6 V
- Active high ENABLE input
- Active high READY open-drain output
- High impedance SDA and SCL pins for  $V_{CC} = 0$  V
- 1 V precharge on all SDA and SCL lines (PCA9510 IN only)
- Supports clock stretching and multiple master arbitration/synchronization
- Operating power supply voltage range: 2.7 V to 5.5 V
- 5.5 V tolerant I/Os
- 0 to 400 kHz clock frequency
- 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 offer: SO8, TSSOP8 (MSOP8)

## ORDERING INFORMATION

| PACKAGES                   | TEMPERATURE RANGE | ORDER CODE | TOPSIDE MARK | DRAWING NUMBER |
|----------------------------|-------------------|------------|--------------|----------------|
| 8-pin plastic SO           | -40 °C to +85 °C  | PCA9510D   | PCA9510      | SOT96-1        |
| 8-pin plastic SO           | -40 °C to +85 °C  | PCA9511D   | PCA9511      | SOT96-1        |
| 8-pin plastic TSSOP (MSOP) | -40 °C to +85 °C  | PCA9510DP  | 9510         | SOT505-1       |
| 8-pin plastic TSSOP (MSOP) | -40 °C to +85 °C  | PCA9511DP  | 9511         | SOT505-1       |

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

# Hot swappable I<sup>2</sup>C and SMBus bus buffer

# PCA9510; PCA9511

## PIN CONFIGURATION

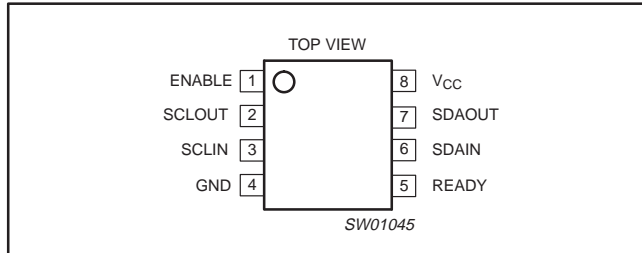


Figure 1. Pin configuration.

## PIN DESCRIPTION

| PIN | SYMBOL          | DESCRIPTION  |
|-----|-----------------|--|
| 1   | ENABLE          | Chip enable pin. Grounding this pin puts the part in a low current (<1 μA) mode. It also disables the rise time accelerators, isolates SDAIN from SDAOUT and isolates SCLIN from SCLOUT. |
| 2   | SCLOUT          | Serial clock output to and from the SCL bus on the card.   |
| 3   | SCLIN           | Serial clock input to and from the SCL bus on the backplane.   |
| 4   | GND             | Ground. Connect this pin to a ground plane for best results.   |
| 5   | READY           | This is an open-drain output which pulls LOW when SDAIN and SCLIN are disconnected from SDAOUT and SCLOUT, and turns off when the two sides are connected.                               |
| 6   | SDAIN           | Serial data input to and from the SDA bus on the backplane.  |
| 7   | SDAOUT          | Serial data output to and from the SDA bus on the card.  |
| 8   | V <sub>CC</sub> | Power supply.  |

## FEATURE SELECTION CHART

| FEATURES   | PCA9510 | PCA9511 | PCA9512 | PCA9513 | PCA9514 |
|--|---------|---------|---------|---------|---------|
| Idle detect  | Yes     | Yes     | Yes     | Yes     | Yes     |
| High impedance SDA, SCL pins for V <sub>CC</sub> = 0 V   | Yes     | Yes     | Yes     | Yes     | Yes     |
| Rise time accelerator circuitry on all SDA and SCL lines                                       | —       | Yes     | Yes     | Yes     | Yes     |
| Rise time accelerator circuitry hardware disable pin for lightly loaded systems                | —       | —       | Yes     | —       | —       |
| Rise time accelerator threshold 0.8 V vs 0.6 V improves noise margin                           | —       | —       | —       | Yes     | Yes     |
| Ready open drain output  | Yes     | Yes     | —       | Yes     | Yes     |
| Two V <sub>CC</sub> pins to support 5 V to 3.3 V level translation with improved noise margins | —       | —       | Yes     | —       | —       |
| 1 V precharge on all SDA and SCL lines   | IN only | Yes     | Yes     | —       | —       |
| 92 μA current source on SCLIN and SDAIN for PICMG applications                                 | —       | —       | —       | Yes     | —       |

# Hot swappable I<sup>2</sup>C and SMBus bus buffer

# PCA9510; PCA9511

## TYPICAL APPLICATION — PCA9510

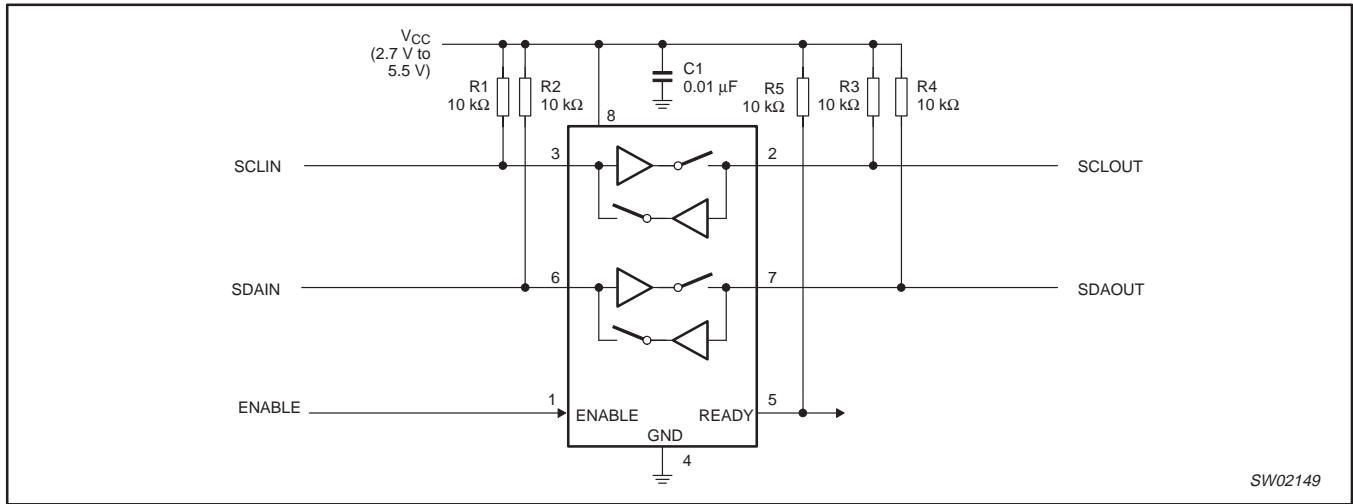


Figure 2. Typical application — PCA9510

## BLOCK DIAGRAM — PCA9510

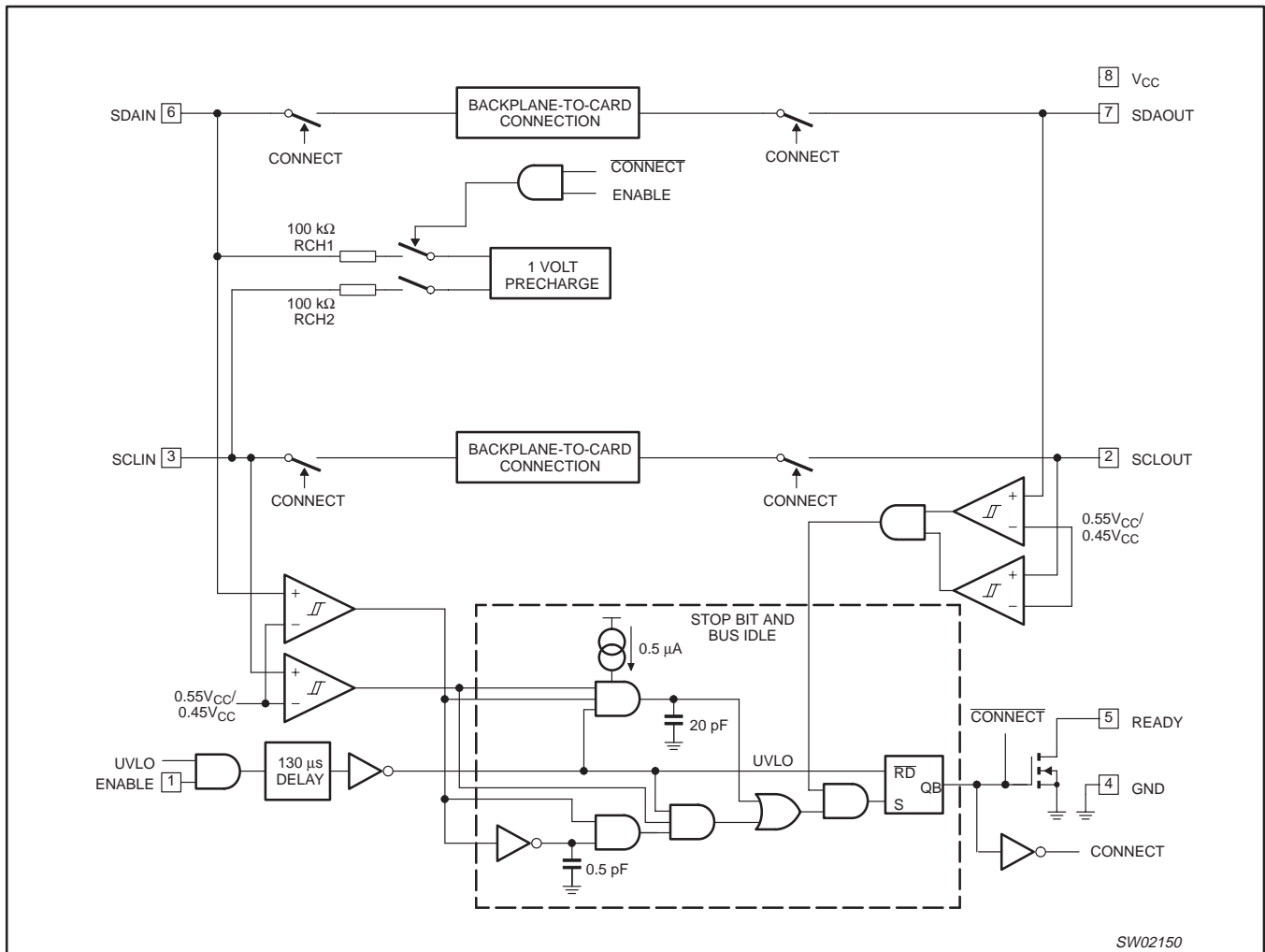


Figure 3. Block diagram — PCA9510

# Hot swappable I<sup>2</sup>C and SMBus bus buffer

# PCA9510; PCA9511

## TYPICAL APPLICATION — PCA9511

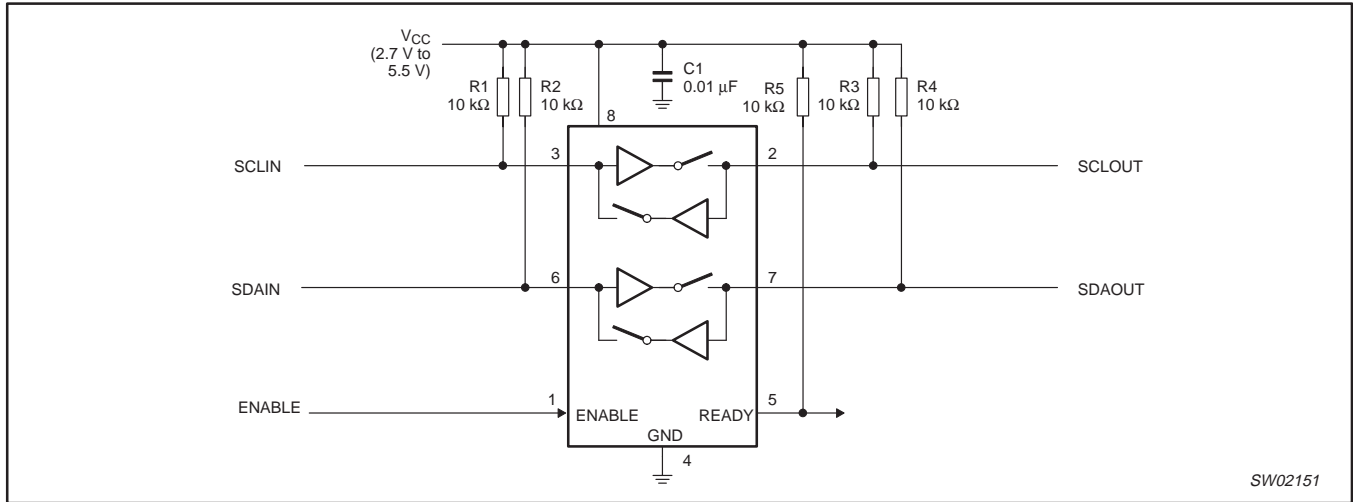


Figure 4. Typical application — PCA9511

## BLOCK DIAGRAM — PCA9511

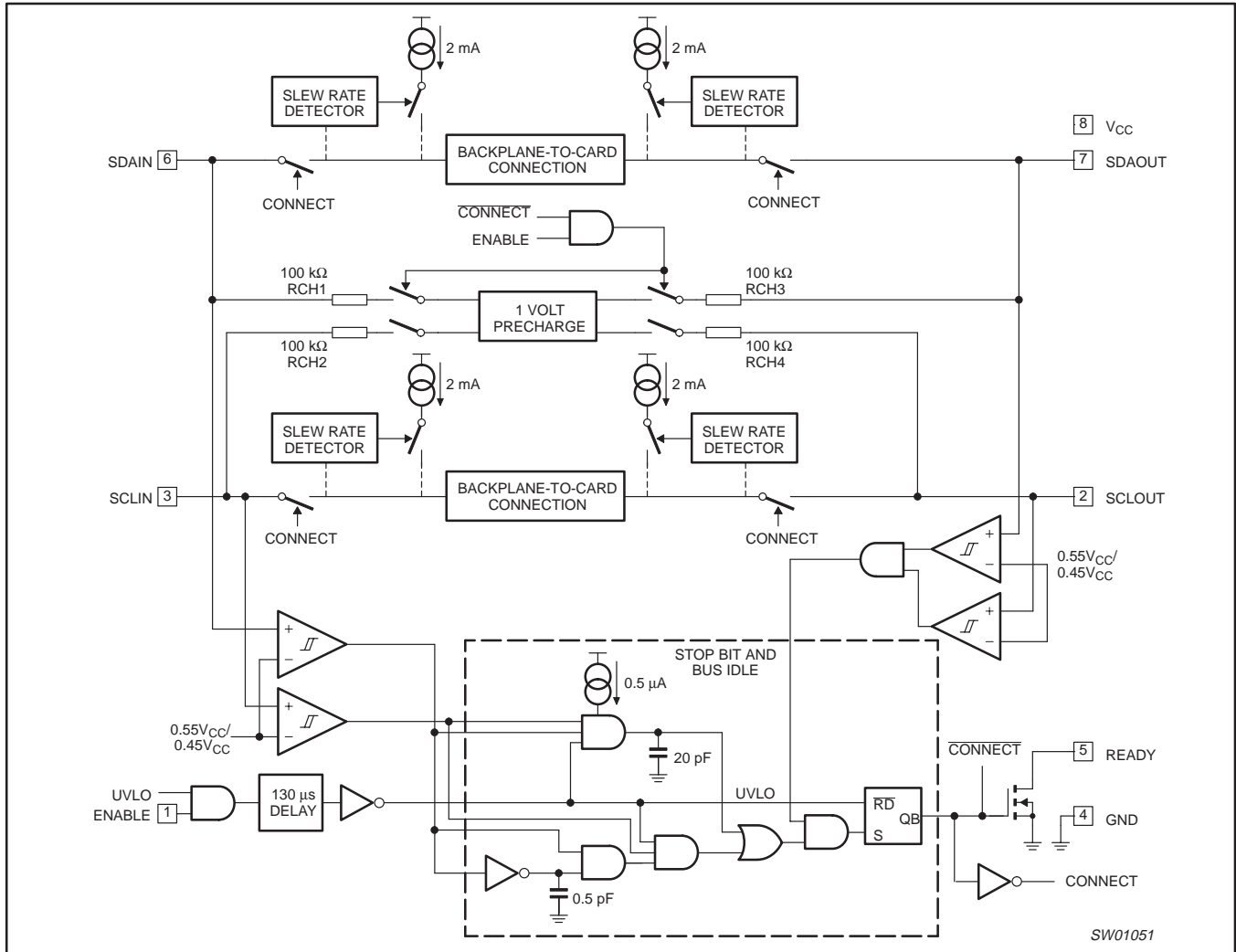


Figure 5. Block diagram — PCA9511

Hot swappable I<sup>2</sup>C and SMBus bus buffer

## PCA9510; PCA9511

## OPERATION

## Start-up

An under voltage/initialization circuit holds the parts in a disconnected state which presents high impedance to all SDA and SCL pins during power-up. A low on the enable pin also forces the parts into the low current disconnected state when the I<sub>CC</sub> is essentially zero. As the power supply is brought up and the enable is high or the part is powered and the enable is taken from low to high it enters an initialization state where the internal references are stabilized and the precharge circuit for PCA9510 (IN only) and PCA9511 are enabled. At the end of the initialization state the “Stop Bit And Bus Idle” detect circuit is enabled. With the enable pin high long enough to complete the initialization state and remaining high when all the SDA and SCL pins have been high for the bus idle time or when all pins are high and a stop condition is seen on the SDAIN and SCLIN pins, SDAIN is connected to SDAOUT and SCLIN is connected to SCLOUT. The 1 V precharge circuitry is activated during the initialization and is deactivated when the connection is made. The precharge circuitry pulls up the SDA and SCL pins to 1 V through individual 100 k nominal resistors. This precharges the pins to 1 V to minimize the worst case disturbances that result from inserting a card into the backplane where the backplane and the card are at opposite logic levels.

## Connect Circuitry

Once the connection circuitry is activated, the behavior of SDAIN and SDAOUT as well as SCLIN and SCLOUT become identical with each acting as a bidirectional buffer that isolates the input capacitance from the output bus capacitance while communicating the logic levels. A low forced on either SDAIN or SDAOUT will cause the other pin to be driven to a low by the part. The same is also true for the SCL pins. Noise between  $0.7V_{CC}$  and  $V_{CC}$  is generally ignored because a falling edge is only recognized when it falls below  $0.7V_{CC}$  with a slew rate of at least  $1.25 V/\mu s$ . When a falling edge is seen on one pin the other pin in the pair turns on a pull down driver that is referenced to a small voltage above the falling pin. The driver will pull the pin down at a slew rate determined by the driver and the load initially, because it does not start until the first falling pin is below  $0.7V_{CC}$ . The first falling pin may have a fast or slow slew rate, if it is faster than the pull down slew rate then the initial pull down rate will continue. If the first falling pin has a slow slew rate then the second pin will be pulled down at its initial slew rate only until it is just above the first pin voltage the they will both continue down at the slew rate of the first.

Once both sides are low they will remain low until all the external drivers have stopped driving lows. If both sides are being driven low to the same value for instance, 10 mV by external drivers, which is the case for clock stretching and is typically the case for acknowledge, and one side external driver stops driving that pin will rise and rise above the nominal offset voltage until the internal driver catches up and pulls it back down to the offset voltage. This bounce is worst for low capacitances and low resistances, and may become excessive. When the last external driver stops driving a low, that pin will bounce up and settle out just above the other pin as both rise together with a slew rate determined by the internal slew rate control and the RC time constant. As long as the slew rate is at least  $1.25 V/\mu s$ , when the pin voltage exceeds 0.6 V for the PCA9511, the rise time accelerators circuits are turned on and the pull down driver is turned off.

## Maximum number of devices in series

Each buffer adds about 0.065 V dynamic level offset at 25 °C with the offset larger at higher temperatures. Maximum offset ( $V_{OS}$ ) is 0.150 V. The LOW level at the signal origination end (master) is dependent upon the load and the only specification point is the I<sup>2</sup>C-bus specification of 3 mA will produce  $V_{OL} < 0.4 V$ , although if lightly loaded the  $V_{OL}$  may be  $\sim 0.1 V$ . Assuming  $V_{OL} = 0.1 V$  and  $V_{OS} = 0.1 V$ , the level after four buffers would be 0.5 V, which is only about 0.1 V below the threshold of the rising edge accelerator (about 0.6 V). With great care a system with four buffers may work, but as the  $V_{OL}$  moves up from 0.1 V, noise or bounces on the line will result in firing the rising edge accelerator thus introducing false clock edges. Generally it is recommended to limit the number of buffers in series to two.

The PCA9510 (rise time accelerator is permanently disabled) and the PCA9512 (rise time accelerator can be turned off) are a little different with the rise time accelerator turned off because the rise time accelerator will not pull the node up, but the same logic that turns on the accelerator turns the pull-down off. If the  $V_{IL}$  is above  $\sim 0.6 V$  and a rising edge is detected, the pull-down will turn off and will not turn back on until a falling edge is detected; so if the noise is small enough it may be possible to use more than two PCA9510 or PCA9512 parts in series but is not recommended.

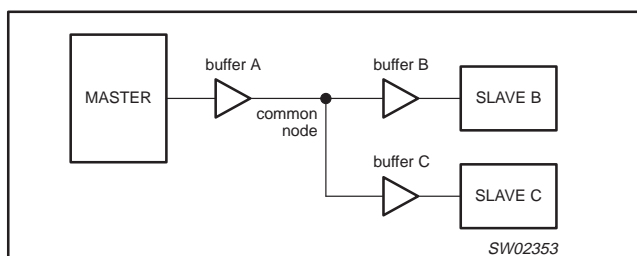


Figure 6.

Consider a system with three buffers connected to a common node and communication between the Master and Slave B that are connected at either end of Buffer A and Buffer B in series as shown in Figure 6. Consider if the  $V_{OL}$  at the input of Buffer A is 0.3 V and the  $V_{OL}$  of Slave B (when acknowledging) is 0.4 V with the direction changing from Master to Slave B and then from Slave B to Master. Before the direction change you would observe  $V_{IL}$  at the input of Buffer A of 0.3 V and its output, the common node, is  $\sim 0.4 V$ . The output of Buffer B and Buffer C would be  $\sim 0.5 V$ , but Slave B is driving 0.4 V, so the voltage at Slave B is 0.4 V. The output of Buffer C is  $\sim 0.5 V$ . When the Master pull-down turns off, the input of Buffer A rises and so does its output, the common node, because it is the only part driving the node. The common node will rise to 0.5 V before Buffer B's output turns on, if the pull-up is strong the node will bounce. If the bounce goes above the threshold for the rising edge accelerator  $\sim 0.6 V$  the accelerators on both Buffer A and Buffer C will fire contending with the output of Buffer B. The node on the input of Buffer A will go HIGH as will the input node of Buffer C. After the common node voltage is stable for a while the rising edge accelerators will turn off and the common node will return to  $\sim 0.5 V$  because the Buffer B is still on. The voltage at both the Master and Slave C nodes would then fall to  $\sim 0.6 V$  until Slave B turned off. This would not cause a failure on the data line as long as the return to 0.5 V on the common node ( $\sim 0.6 V$  at the Master and Slave C) occurred before the data setup time. If this were the SCL line, the parts on Buffer A and Buffer C would see a false clock rather than a stretched clock, which would cause a system error.

# Hot swappable I<sup>2</sup>C and SMBus bus buffer

# PCA9510; PCA9511

## Propagation Delays

The delay for a rising edge is determined by the combined pull-up current from the bus resistors and the rise time accelerator current source and the effective capacitance on the lines. If the pull-up currents are the same, any difference in rise time is directly proportional to the difference in capacitance between the two sides. The  $t_{pLH}$  may be negative if the output capacitance is less than the input capacitance and would be positive if the output capacitance is larger than the input capacitance, when the currents are the same.

The  $t_{pHL}$  can never be negative because the output does not start to fall until the input is below  $0.7V_{CC}$ , and the output turn on has a non zero delay, and the output has a limited maximum slew rate, and even if the input slew rate is slow enough that the output catches up it will still lag the falling voltage of the input by the offset voltage. The maximum  $t_{pHL}$  occurs when the input is driven low with zero delay and the output is still limited by its turn on delay and the falling edge slew rate. The output falling edge slew rate is a function of the internal maximum slew rate which is a function of temperature,  $V_{CC}$  and process, as well as the load current and the load capacitance.

## Rise Time Accelerators

During positive bus transitions a 2 mA current source is switched on to quickly slew the SDA and SCL lines high once the input level of 0.6 V for the PCA9511 is exceeded. The rising edge rate should be at least  $1.25 V/\mu s$  to guarantee turn on of the accelerators. The PCA9510 doesn't have any rise time accelerator circuitry.

## READY Digital Output

This pin provides a digital flag which is low when either ENABLE is low or the start-up sequence described earlier in this section has not been completed. READY goes high when ENABLE is high and start-up is complete. The pin is driven by an open drain pull-down capable of sinking 3 mA while holding 0.4 V on the pin. Connect a resistor of 10 k to  $V_{CC}$  to provide the pull-up.

## ENABLE Low Current Disable

Grounding the ENABLE pin disconnects the backplane side from the card side, disables the rise-time accelerators, drives READY low, disables the bus precharge circuitry, and puts the part in a low current state. When the pin voltage is driven all the way to  $V_{CC}$ , the part waits for data transactions on both the backplane and card sides to be complete before reconnecting the two sides.

## Resistor Pull-up Value Selection

The system pull-up resistors must be strong enough to provide a positive slew rate of  $1.25 V/\mu s$  on the SDA and SCL pins, in order to activate the boost pull-up currents during rising edges. Choose maximum resistor value using the formula:

$$R \leq 800 \cdot 10^3 \times \frac{V_{CC(MIN)} - 0.6}{C}$$

where R is the pull-up resistor value in  $\Omega$ ,  $V_{CC(MIN)}$  is the minimum  $V_{CC}$  voltage in volts and C is the equivalent bus capacitance in picofarads (pF).

In addition, regardless of the bus capacitance, always choose  $R \leq 16 k\Omega$  for  $V_{CC} = 5.5 V$  maximum,  $R \leq 24 k\Omega$  for  $V_{CC} = 3.6 V$  maximum. The start-up circuitry requires logic high voltages on SDAOUT and SCLOUT to connect the backplane to the card, and these pull-up values are needed to overcome the precharge voltage. See the curves in Figures 7 and 8 for guidance in resistor pull-up selection.

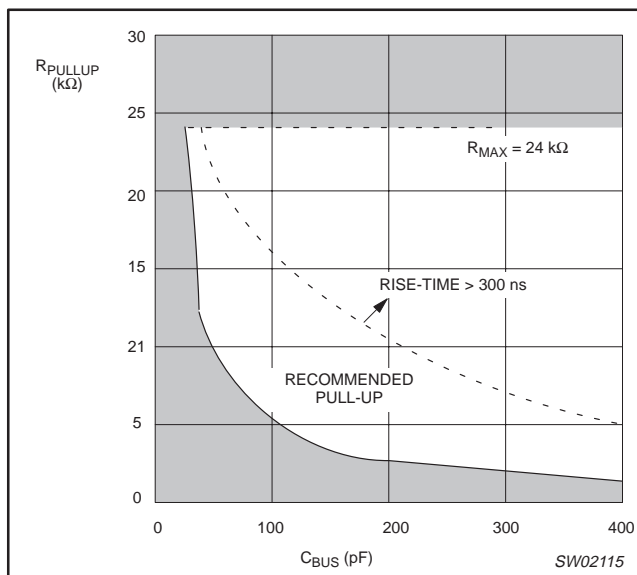


Figure 7. Bus requirements for 3.3 V systems

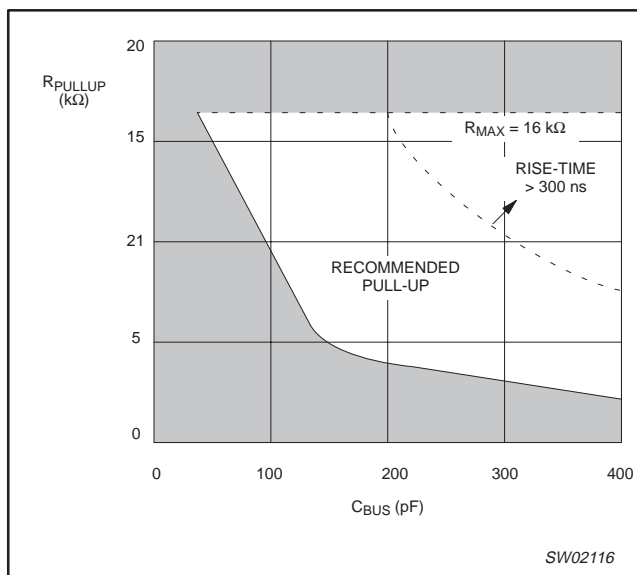


Figure 8. Bus requirements for 5 V systems

## Minimum SDA and SCL Capacitance Requirements

The device connection circuitry requires a minimum capacitance loading on the SDA and SCL pins in order to function properly. The value of this capacitance is a function of  $V_{CC}$  and the bus pull-up resistance. Estimate the bus capacitance on both the backplane and the card data and clock buses, and refer to Figures 7 and 8 to choose appropriate pull-up resistor values. Note from the figures that 5 V systems should have at least 47 pF capacitance on their buses and 3.3 V systems should have at least 22 pF capacitance for proper operation. Although the device has been designed to be marginally stable with smaller capacitance loads, for applications with less capacitance, provisions need to be made to add a capacitor to ground to ensure these minimum capacitance conditions if oscillations are noticed during initial signal integrity verification.

# Hot swappable I<sup>2</sup>C and SMBus bus buffer

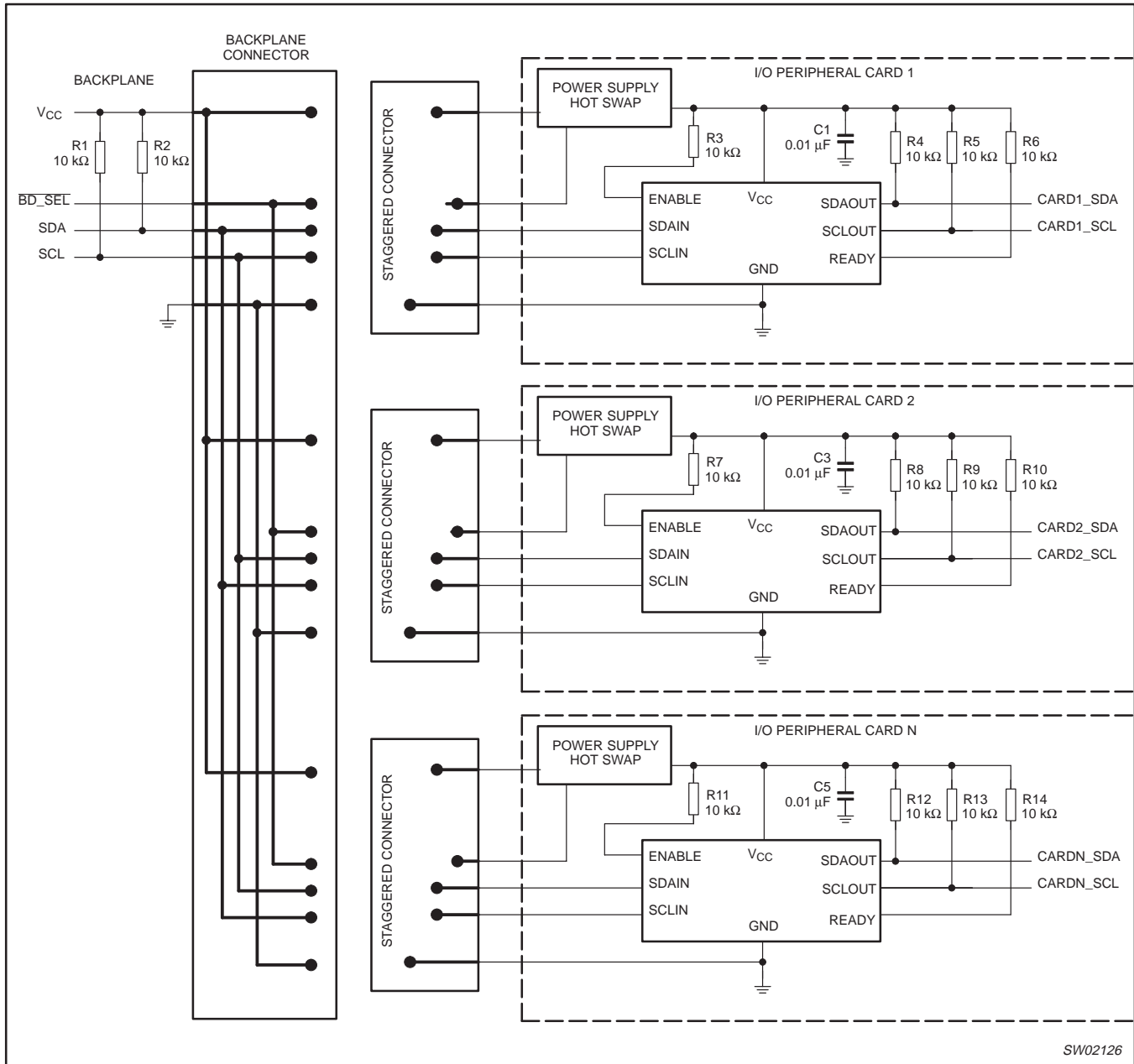
# PCA9510; PCA9511

## Hot Swapping and Capacitance Buffering Application

Figures 9 through 11 illustrate the usage of the PCA9510 and PCA9511 in applications that take advantage of both its hot swapping and capacitance buffering features. In all of these applications, note that if the I/O cards were plugged directly into the backplane, all of the backplane and card capacitances would add directly together, making rise- and fall-time requirements difficult to

meet. Placing a bus buffer on the edge of each card, however, isolates the card capacitance from the backplane. For a given I/O card, the PCA9510 and PCA9511 drive the capacitance of everything on the card and the backplane must drive only the capacitance of the bus buffer, which is less than 10 pF, the connector, trace, and all additional cards on the backplane.

See Application Note *AN10160, Hot Swap Bus Buffer* for more information on applications and technical assistance.



**NOTE:** The PCA9510 and PCA9511 can be used in any combination depending on the number of rise time accelerators that are needed by the system. Normally only one PCA9511 would be required per bus.

**Figure 9. Hot swapping multiple I/O cards into a backplane using the PCA9510 and PCA9511 in a CompactPCI, VME, and AdvancedTCA system**



# Hot swappable I<sup>2</sup>C and SMBus bus buffer

# PCA9510; PCA9511

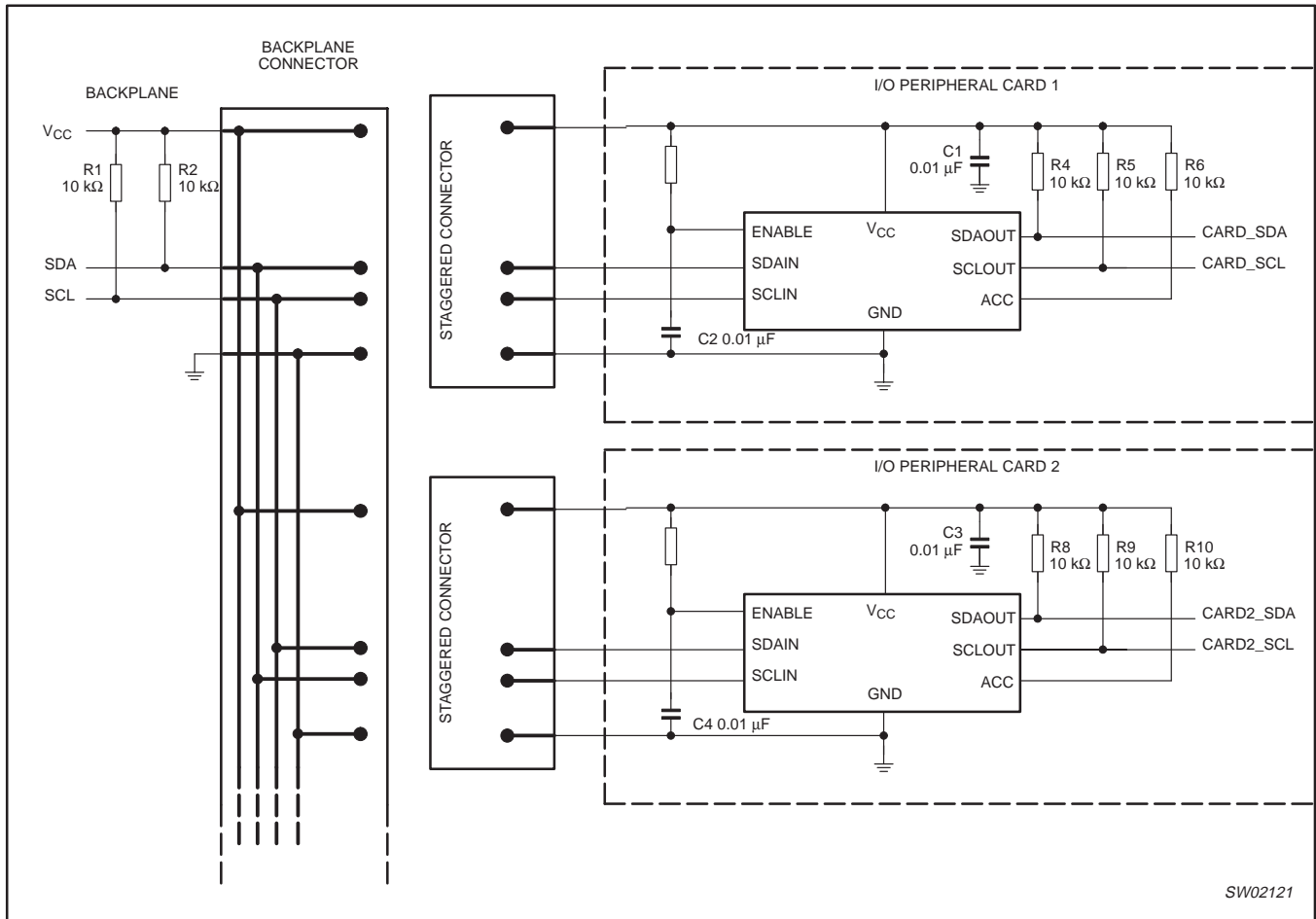


Figure 10. Hot swapping multiple I/O cards into a backplane using the PCA9510 and PCA9511 in a PCI system

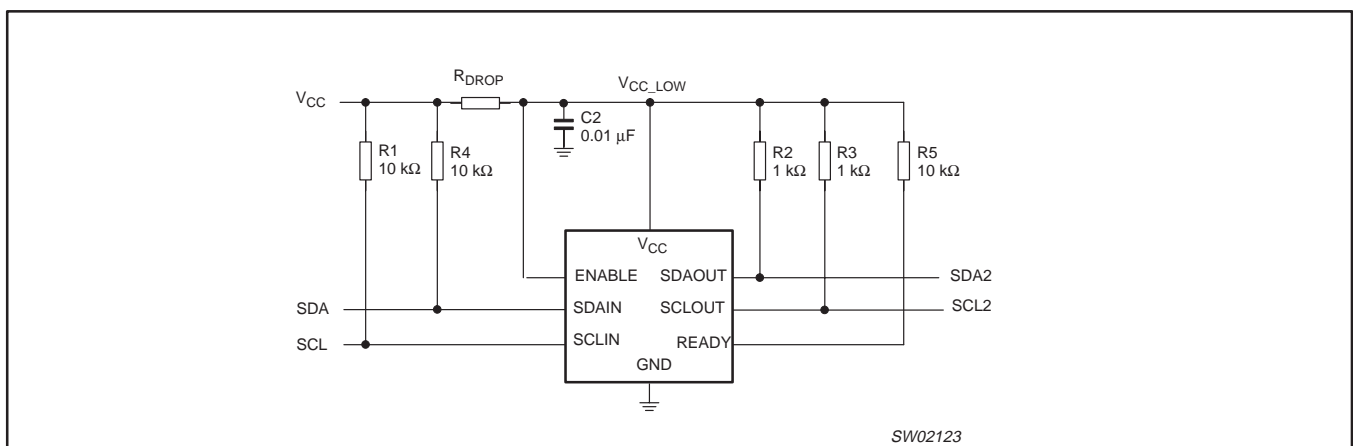


Figure 11. System with disparate  $V_{CC}$  voltages

Hot swappable I<sup>2</sup>C and SMBus bus buffer

## PCA9510; PCA9511

**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>     | Supply voltage range V <sub>CC</sub>        | -0.5   | +7   | V    |
| V <sub>n</sub>      | SDAIN, SCLIN, SDAOUT, SCLOUT, READY, ENABLE | -0.5   | +7   | V    |
| I <sub>I</sub>      | Maximum current for inputs                  | -      | ±20  | mA   |
| I <sub>IO</sub>     | Maximum current for I/O pins                | -      | ±50  | mA   |
| T <sub>opr</sub>    | Operating temperature range                 | -40    | +85  | °C   |
| T <sub>stg</sub>    | Storage temperature range                   | -65    | +125 | °C   |
| T <sub>sld</sub>    | Lead soldering temperature (10 sec max)     | -      | +300 | °C   |
| T <sub>j(max)</sub> | Maximum junction temperature                | -      | +125 | °C   |

**NOTE:**

- Stresses beyond those listed may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Hot swappable I<sup>2</sup>C and SMBus bus buffer

## PCA9510; PCA9511

**ELECTRICAL CHARACTERISTICS**

$V_{CC} = 2.7 \text{ V to } 5.5 \text{ V}$ ;  $T_{amb} = -40 \text{ to } +85 \text{ }^\circ\text{C}$  unless otherwise noted.

| SYMBOL                         | PARAMETER                                       | TEST CONDITIONS  | LIMITS              |                     |                     | UNIT          |
|--------------------------------|---|--|---------------------|---------------------|---------------------|---------------|
|                                |   |  | MIN.                | TYP.                | MAX.                |               |
| <b>Power supply</b>            |   |  |                     |                     |                     |               |
| $V_{CC}$                       | Supply voltage                                  | Note 1.  | 2.7                 | —                   | 5.5                 | V             |
| $I_{CC}$                       | Supply current                                  | $V_{CC} = 5.5 \text{ V}$ ;<br>$V_{SDAIN} = V_{SCLIN} = 0 \text{ V}$ ; Note 1.                                      | —                   | 2.8                 | 6                   | mA            |
| $I_{CC(sd)}$                   | Supply current in shut-down mode                | $V_{ENABLE} = 0 \text{ V}$ , all other pins at $V_{CC}$<br>or GND  | —                   | 200                 | —                   | $\mu\text{A}$ |
| <b>Start-up circuitry</b>      |   |  |                     |                     |                     |               |
| $V_{PRE}$                      | Precharge voltage                               | SDA, SCL floating; Note 1.   | 0.8                 | 1.0                 | 1.2                 | V             |
| $V_{EN}$                       | Enable threshold voltage                        |  | —                   | $0.5 \times V_{CC}$ | $0.7 \times V_{CC}$ | V             |
| $V_{DIS}$                      | Disable threshold voltage                       |  | $0.3 \times V_{CC}$ | $0.5 \times V_{CC}$ | —                   | V             |
| $I_{EN}$                       | Enable input current                            | Enable from 0 V to $V_{CC}$  | —                   | $\pm 0.1$           | $\pm 1$             | $\mu\text{A}$ |
| $t_{EN}$                       | Enable delay or initialization time             |  | —                   | 130                 | —                   | $\mu\text{s}$ |
| $t_{IDLE}$                     | Bus idle time                                   | Note 1.  | 50                  | 120                 | 250                 | $\mu\text{s}$ |
| $t_{DIS}$                      | Disable time, ENABLE to Ready                   |  | —                   | 15                  | —                   | ns            |
| $t_{STOP}$                     | SDA <sub>IN</sub> to READY deLay after STOP     | Note 7   | —                   | 1.3                 | —                   | $\mu\text{s}$ |
| $t_{READY}$                    | SCL <sub>OUT</sub> /SDA <sub>OUT</sub> to READY | Note 7   | —                   | 1.2                 | —                   | $\mu\text{s}$ |
| $I_{OFF}$                      | Ready off state leakage current                 | $V_{EN} = V_{CC}$  | —                   | $\pm 0.3$           | —                   | $\mu\text{A}$ |
| $C_i$                          | ENABLE capacitance                              | $V_i = V_{CC}$ or GND, Note 4  | —                   | 2                   | —                   | pF            |
| $C_o$                          | Ready capacitance                               | $V_i = V_{CC}$ or GND, Note 4  | —                   | 2                   | —                   | pF            |
| $V_{OL(READY)}$                | LOW-level output voltage on READY pin           | $I_{pull-up} = 3 \text{ mA}$ ; $V_{EN} = V_{CC}$ ; Note 1.   | —                   | —                   | 0.4                 | V             |
| <b>Rise time accelerators</b>  |   |  |                     |                     |                     |               |
| $I_{PULLUPAC}$                 | Transient boosted pull-up current               | Positive transition on SDA, SCL,<br>$V_{CC} = 2.7 \text{ V}$ ;<br>Slew rate = $1.25 \text{ V}/\mu\text{s}$ Note 2. | 1                   | 2                   | —                   | mA            |
| <b>Input–output connection</b> |   |  |                     |                     |                     |               |
| $V_{OS}$                       | Input–output offset voltage                     | $10 \text{ k}\Omega$ to $V_{CC}$ on SDA, SCL;<br>$V_{CC} = 3.3 \text{ V}$ ; Note 1; Note 3.                        | 0                   | 65                  | 150                 | mV            |
| $f_{SCL\_SDA}$                 | operating frequency                             |  | 0                   | —                   | 400                 | kHz           |
| $t_{PLH}$                      | SCL to SCL and SDA to SDA                       | $10 \text{ k}\Omega$ to $V_{CC}$ , $C_L = 100 \text{ pF}$ each side  | —                   | 25                  | —                   | ns            |
| $t_{PHL}$                      | SCL to SCL and SDA to SDA                       | $10 \text{ k}\Omega$ to $V_{CC}$ , $C_L = 100 \text{ pF}$ each side  | —                   | 380                 | —                   | ns            |
| $C_{IN}$                       | Digital input capacitance                       | Note 4   | —                   | —                   | 10                  | pF            |
| $V_{OL}$                       | LOW-level output voltage                        | Input = 0 V,<br>SDA, SCL pins, $I_{SINK} = 3 \text{ mA}$ ;<br>$V_{CC} = 2.7 \text{ V}$ ; Note 1                    | 0                   | —                   | 0.4                 | V             |
| $I_{LI}$                       | Input leakage current                           | SDA, SCL pins = $V_{CC} = 5.5 \text{ V}$   | —                   | —                   | $\pm 5$             | $\mu\text{A}$ |

Hot swappable I<sup>2</sup>C and SMBus bus buffer

## PCA9510; PCA9511

| SYMBOL                        | PARAMETER                                      | TEST CONDITIONS | LIMITS                       |      |      | UNIT |
|-------------------------------|--|-----------------|------------------------------|------|------|------|
|                               |  |                 | MIN.                         | TYP. | MAX. |      |
| <b>System characteristics</b> |  |                 |                              |      |      |      |
| f <sub>I2C</sub>              | I <sup>2</sup> C operating frequency           |                 | 0                            | —    | 400  | kHz  |
| t <sub>BUF</sub>              | Bus free time between stop and start condition | Note 4          | 1.3                          | —    | —    | μs   |
| t <sub>hD,STA</sub>           | Hold time after (repeated) start condition     | Note 4          | 0.6                          | —    | —    | μs   |
| t <sub>su,STA</sub>           | Repeated start condition setup time            | Note 4          | 0.6                          | —    | —    | μs   |
| t <sub>su,STO</sub>           | Stop condition setup time                      | Note 4          | 0.6                          | —    | —    | μs   |
| t <sub>hD,DAT</sub>           | Data hold time                                 | Note 4          | 300                          | —    | —    | ns   |
| t <sub>su,DAT</sub>           | Data setup time                                | Note 4          | 100                          | —    | —    | ns   |
| t <sub>LOW</sub>              | Clock low period                               | Note 4          | 1.3                          | —    | —    | μs   |
| t <sub>HIGH</sub>             | Clock high period                              | Note 4          | 0.6                          | —    | —    | μs   |
| t <sub>f</sub>                | Clock, data fall time                          | Notes 4 and 5   | 20 + 0.1 x<br>C <sub>B</sub> | —    | 300  | ns   |
| t <sub>r</sub>                | Clock, data rise time                          | Notes 4 and 5   | 20 + 0.1 x<br>C <sub>B</sub> | —    | 300  | ns   |

**NOTES:**

1. This specification applies over the full operating temperature range.
2. I<sub>PULLUPAC</sub> varies with temperature and V<sub>CC</sub> voltage, as shown in the Typical Performance Characteristics section.
3. The connection circuitry always regulates its output to a higher voltage than its input. The magnitude of this offset voltage as a function of the pull-up resistor and V<sub>CC</sub> voltage is shown in the Typical Performance Characteristics section.
4. Guaranteed by design, not production tested.
5. C<sub>B</sub> = total capacitance of one bus line in pF.
6. SDA\_IN/SCL\_IN = 0.1 V, SDA\_OUT/SCL\_OUT through resistor to V<sub>CC</sub>.
7. Delays that can occur after ENABLE and/or idle times have passed.

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TYPICAL PERFORMANCE CHARACTERISTICS

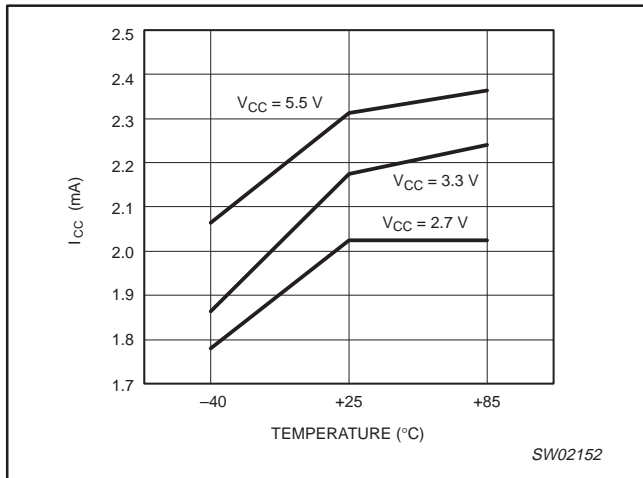


Figure 12. I<sub>CC</sub> versus Temperature.

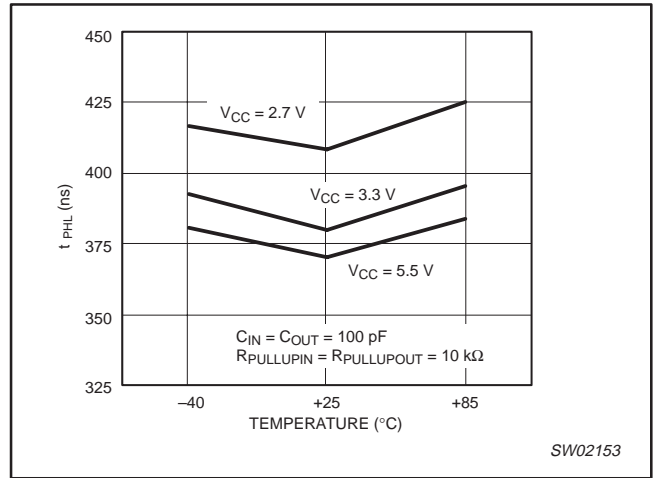


Figure 14. Input-output t<sub>PHL</sub> versus Temperature.

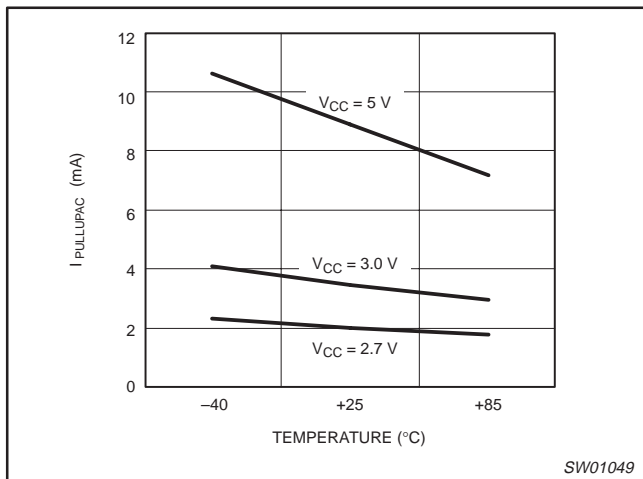


Figure 13. I<sub>PULLUPAC</sub> versus Temperature.

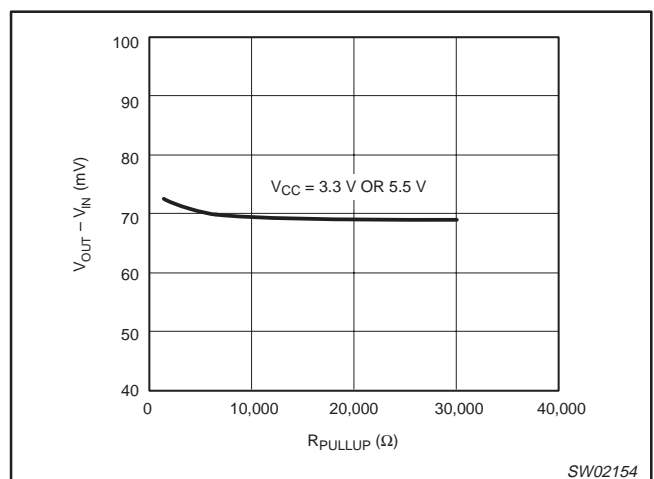


Figure 15. Connection circuitry V<sub>OUT</sub> - V<sub>IN</sub>.

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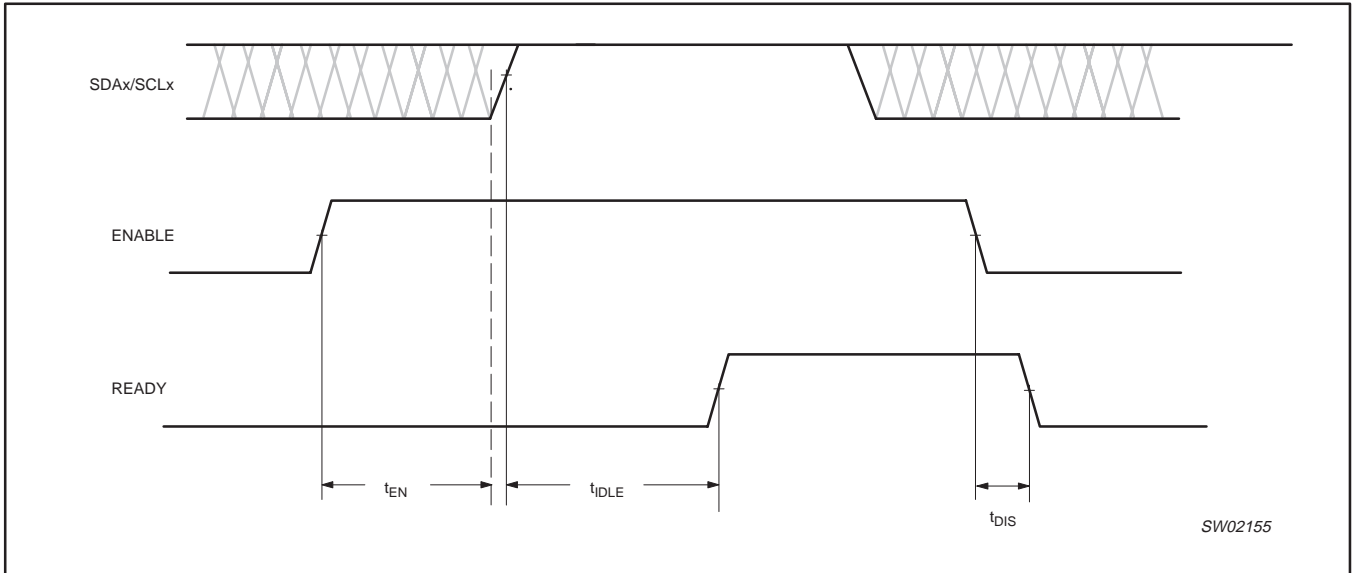


Figure 16. Timing for  $t_{ENABLE}$ ,  $t_{IDLE}$ , and  $t_{DISABLE}$

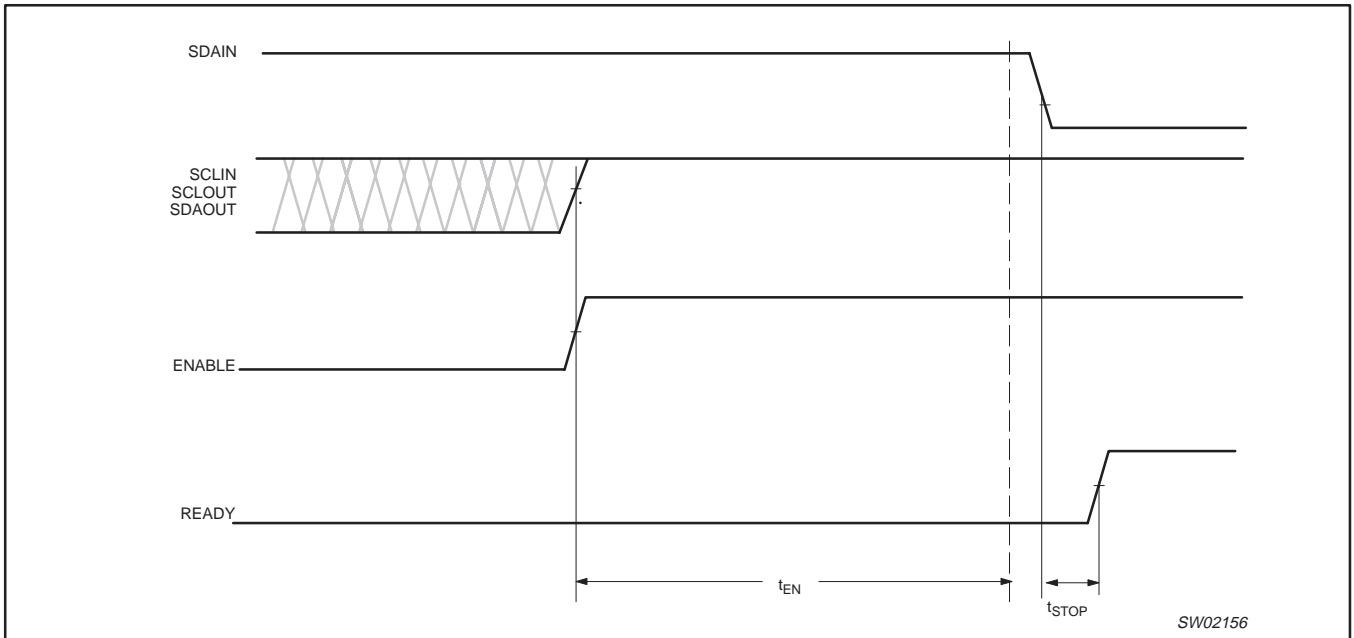


Figure 17.  $t_{STOP}$  that can occur after  $t_{ENABLE}$

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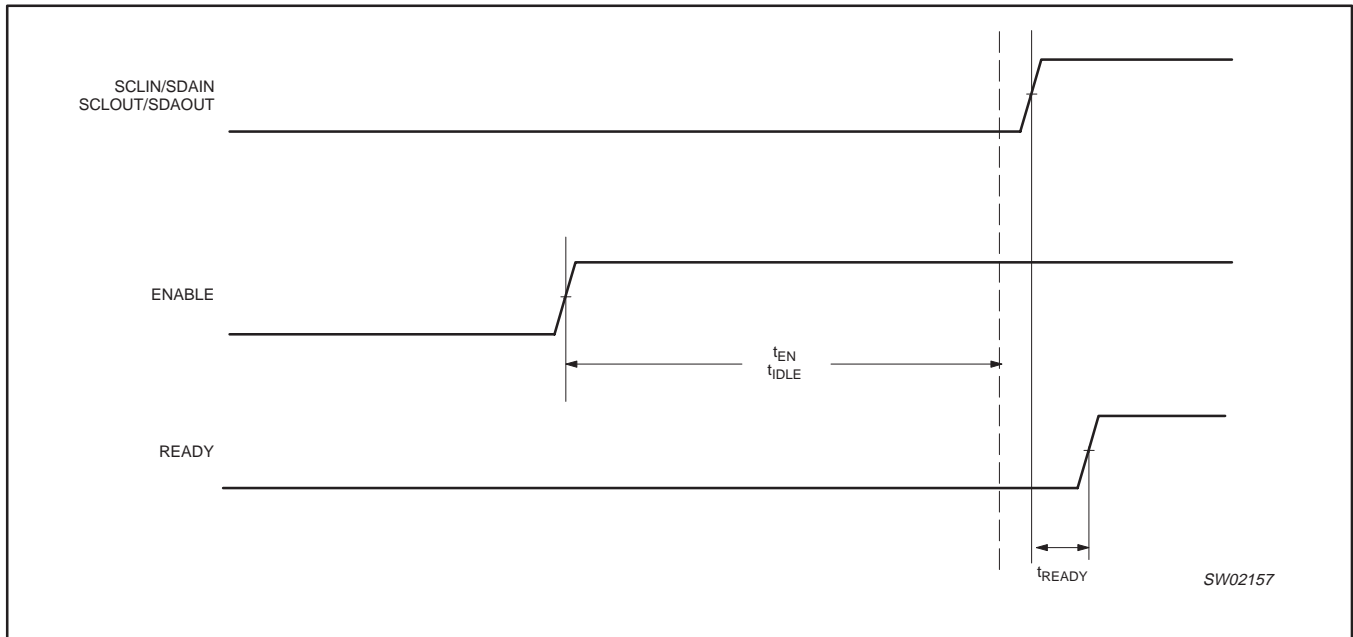


Figure 18.  $t_{READY}$  delay that can occur after  $t_{EN}$  and  $t_{IDLE}$

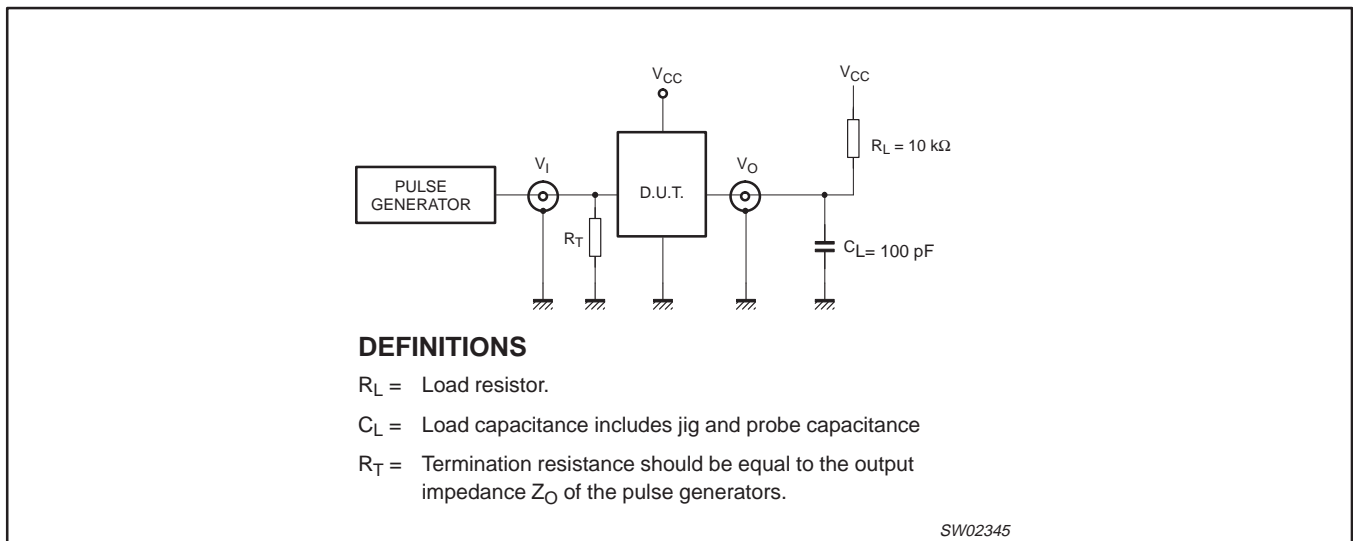


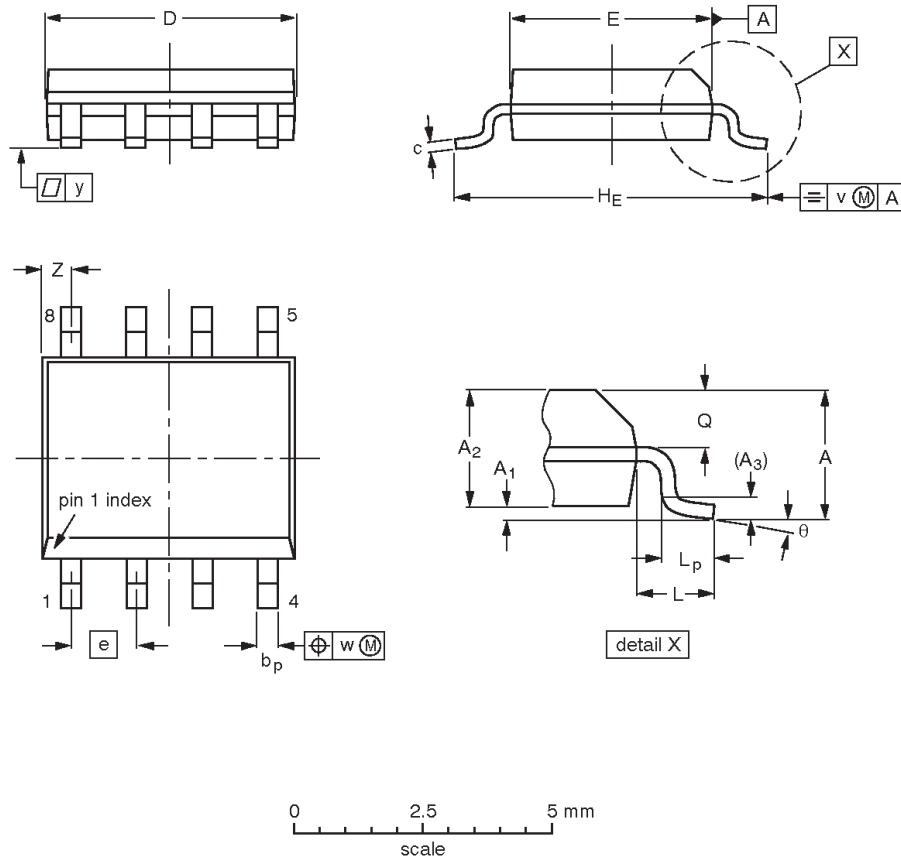
Figure 19. Test circuitry for switching times

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**SO8:** plastic small outline package; 8 leads; body width 3.9 mm

**SOT96-1**



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

| UNIT   | A <sub>max.</sub> | 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     | 1.75              | 0.25<br>0.10   | 1.45<br>1.25   | 0.25           | 0.49<br>0.36   | 0.25<br>0.19     | 5.0<br>4.8       | 4.0<br>3.8       | 1.27 | 6.2<br>5.8     | 1.05  | 1.0<br>0.4     | 0.7<br>0.6     | 0.25 | 0.25 | 0.1   | 0.7<br>0.3       | 8°<br>0° |
| inches | 0.069             | 0.010<br>0.004 | 0.057<br>0.049 | 0.01           | 0.019<br>0.014 | 0.0100<br>0.0075 | 0.20<br>0.19     | 0.16<br>0.15     | 0.05 | 0.244<br>0.228 | 0.041 | 0.039<br>0.016 | 0.028<br>0.024 | 0.01 | 0.01 | 0.004 | 0.028<br>0.012   |          |

**Notes**

1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.
2. Plastic or metal protrusions of 0.25 mm (0.01 inch) maximum per side are not included.

| OUTLINE VERSION | REFERENCES |        |       |  | EUROPEAN PROJECTION | ISSUE DATE           |
|-----------------|------------|--------|-------|--|---------------------|----------------------|
|                 | IEC        | JEDEC  | JEITA |  |                     |                      |
| SOT96-1         | 076E03     | MS-012 |       |  |                     | 99-12-27<br>03-02-18 |

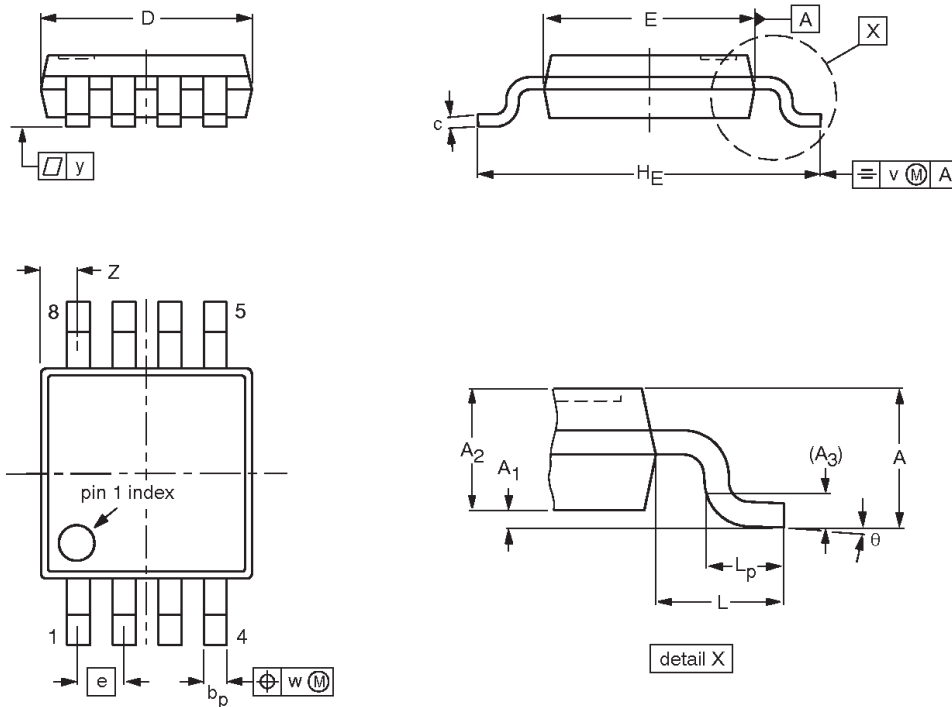


Hot swappable I<sup>2</sup>C and SMBus bus buffer

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TSSOP8: plastic thin shrink small outline package; 8 leads; body width 3 mm

SOT505-1



**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> | v   | w   | y   | Z <sup>(1)</sup> | θ        |
|------|--------|----------------|----------------|----------------|----------------|--------------|------------------|------------------|------|----------------|------|----------------|-----|-----|-----|------------------|----------|
| mm   | 1.1    | 0.15<br>0.05   | 0.95<br>0.80   | 0.25           | 0.45<br>0.25   | 0.28<br>0.15 | 3.1<br>2.9       | 3.1<br>2.9       | 0.65 | 5.1<br>4.7     | 0.94 | 0.7<br>0.4     | 0.1 | 0.1 | 0.1 | 0.70<br>0.35     | 6°<br>0° |

**Notes**

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

| OUTLINE VERSION | REFERENCES |       |       |  | EUROPEAN PROJECTION | ISSUE DATE                      |
|-----------------|------------|-------|-------|--|---------------------|---------------------------------|
|                 | IEC        | JEDEC | JEITA |  |                     |                                 |
| SOT505-1        |            |       |       |  |                     | <del>99-04-09</del><br>03-02-18 |

Hot swappable I<sup>2</sup>C and SMBus bus buffer

## PCA9510; PCA9511

## REVISION HISTORY

| Rev | Date     | Description   |
|-----|----------|---|
| _2  | 20041005 | <p><b>Product data sheet (9397 750 13998). Supersedes data of 2003 Dec 18 (9397 750 12561).</b></p> <p>Modifications:</p> <ul style="list-style-type: none"> <li>● “Description” section on page 2: add fourth paragraph.</li> <li>● “Features” section on page 2, last bullet: add “(MSOP8)”</li> <li>● Add section “Maximum number of devices in series” on page 6.</li> <li>● Section “Minimum SDA and SCL Capacitance Requirements” on page 7 re-written</li> <li>● Delete (old) Figure 10 “Repeater/bus extender application using the PCA9510 and PCA9511”</li> <li>● ‘Absolute Maximum Ratings’ table on page 10: add parameters I<sub>I</sub> and I<sub>IO</sub>.</li> <li>● Electrical characteristics, subsection “System characteristics” on page 12: change Unit for t<sub>hd;DAT</sub> and t<sub>su;DAT</sub> from μs to ns.</li> <li>● Figure 19 modified.</li> </ul> |
| _1  | 20031218 | <b>Product data (9397 750 12561). ECN 853-2442 01-A14987 dated 15 December 2003.</b>  |

Hot swappable I<sup>2</sup>C and SMBus bus buffer

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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.             |
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[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.

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**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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For sales offices addresses send e-mail to:  
[sales.addresses@www.semiconductors.philips.com](mailto:sales.addresses@www.semiconductors.philips.com)

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9397 750 13998

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