# PCA9537

## 4-bit I²C-bus and SMBus low power I/O port with interrupt and reset

Rev. 7 — 8 September 2021

Product data sheet
COMPANY PUBLIC

## 1 General description

The PCA9537 is a 10-pin CMOS device that provides 4 bits of General Purpose parallel Input/Output (GPIO) expansion with interrupt and reset for I²C-bus/SMBus applications. It was developed to enhance the NXP Semiconductors family of I²C-bus I/O expanders. I/O expanders provide a simple solution when additional I/O is needed for ACPI power switches, sensors, push-buttons, LEDs, fans, etc.

The PCA9537 consists of a 4-bit Configuration register (input or output selection), 4-bit Input Port register, 4-bit Output Port register and a 4-bit Polarity Inversion register (active HIGH or active LOW operation). The system controller can enable the I/Os as either inputs or outputs by writing to the I/O configuration bits. The data for each input or output is kept in the corresponding Input Port or Output Port register. The polarity of the Input Port register can be inverted with the Polarity Inversion register. All registers can be read by the system controller.

The PCA9537 open-drain interrupt output ($\overline{INT}$) is activated when any input state differs from its corresponding Input Port register state and is used to indicate to the system controller that an input state has changed. The power-on reset sets the registers to their default values and initializes the device state machine. The $\overline{RESET}$ pin causes the same reset/initialization to occur without de-powering the device.

The I²C-bus address is fixed and allows only one device on the same I²C-bus/SMBus.

## 2 Features and benefits

- 4-bit I²C-bus GPIO with interrupt and reset
- Operating power supply voltage range of 2.3 V to 5.5 V
- 5 V tolerant I/Os
- Polarity Inversion register
- Active LOW interrupt output
- Active LOW reset input
- Low standby current
- Noise filter on SCL/SDA inputs
- No glitch on power-up
- Internal power-on reset
- 4 I/O pins that default to 4 inputs
- 0 Hz 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
- Offered in TSSOP10 package

# 3 Ordering information

**Table 1. Ordering information**

*$T_{amb}$ = -40 °C to +85 °C*

| Type number | Topside mark | Package | | |
|---|---|---|---|---|
| | | Name | Description | Version |
| PCA9537DP | 9537 | TSSOP10 | plastic thin shrink small outline package; 10 leads; body width 3 mm | SOT552-1 |

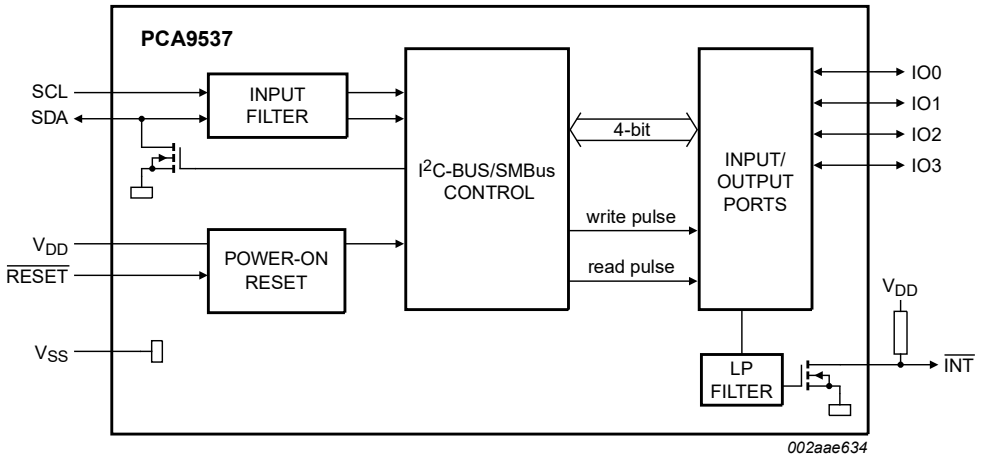
## 3.1 Ordering options

**Table 2. Ordering options**

| Type number | Orderable part number | Package | Packing method | Minimum order quantity | Temperature |
|---|---|---|---|---|---|
| PCA9537DP | PCA9537DP,118 [1] | TSSOP10 | REEL 13" Q1/T1 *STANDARD MARK SMD | 2500 | $T_{amb}$ = -40 °C to +85 °C |
| | PCA9537DPZ | TSSOP10 | REEL 13" Q1/T1 *STANDARD MARK SSB[2] | 2500 | $T_{amb}$ = -40 °C to +85 °C |

[1] Discontinued in 202104010DN - drop in replacement is PCA9537DPZ - this is documented in PCN 2020104008A.
[2] This packing method uses a Static Shielding Bag (SSB) solution. Material should be kept in the sealed bag between uses.

# 4 Block diagram




**Remark:** All I/Os are set to inputs at reset.

**Figure 1. Block diagram of PCA9537**

# 5 Pinning information

## 5.1 Pinning

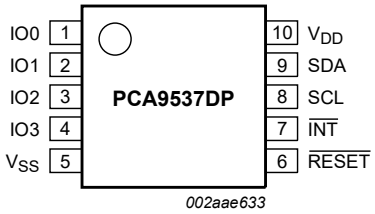



**Figure 2. Pin configuration for TSSOP10**

## 5.2 Pin description

**Table 3. Pin description**

| Symbol | Pin | Description |
|---|---|---|
| IO0 | 1 | input/output 0 |
| IO1 | 2 | input/output 1 |
| IO2 | 3 | input/output 2 |
| IO3 | 4 | input/output 3 |
| $V_{SS}$ | 5 | supply ground |
| $\overline{RESET}$ | 6 | active LOW reset input |
| $\overline{INT}$ | 7 | interrupt output (open-drain) |
| SCL | 8 | serial clock line |
| SDA | 9 | serial data line |
| $V_{DD}$ | 10 | supply voltage |

# 6 Functional description

Refer to Figure 1.

## 6.1 Device address

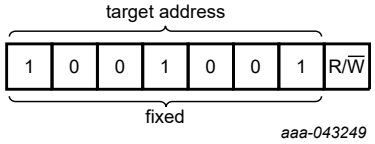



**Figure 3. PCA9537 address**

## 6.2 Registers

### 6.2.1 Command byte

The command byte is the first byte to follow the address byte during a write transmission. It is used as a pointer to determine which of the registers will be written or read.

**Table 4. Command byte**

| Command | Protocol | Function |
|---|---|---|
| 0 | read byte | Input Port register |
| 1 | read/write byte | Output Port register |
| 2 | read/write byte | Polarity Inversion register |
| 3 | read/write byte | Configuration register |

### 6.2.2 Register 0 - Input Port register

This register is a read-only port. It reflects the incoming logic levels of the pins, regardless of whether the pin is defined as an input or an output by Register 3. Writes to this register have no effect.

The default value 'X' is determined by the externally applied logic level.

**Table 5. Register 0 - Input Port register bit description**

*Legend: * default value.*

| Bit | Symbol | Access | Value | Description |
|---|---|---|---|---|
| 7 | I7 | read only | 1* | not used |
| 6 | I6 | read only | 1* | |
| 5 | I5 | read only | 1* | |
| 4 | I4 | read only | 1* | |
| 3 | I3 | read only | X* | value 'X' is determined by externally applied logic level |
| 2 | I2 | read only | X* | |
| 1 | I1 | read only | X* | |
| 0 | I0 | read only | X* | |

### 6.2.3 Register 1 - Output Port register

This register reflects the outgoing logic levels of the pins defined as outputs by Register 3. Bit values in this register have no effect on pins defined as inputs. Reads from this register return the value that is in the flip-flop controlling the output selection, **not** the actual pin value.

**Table 6. Register 1 - Output Port register bit description**

*Legend: * default value.*

| Bit | Symbol | Access | Value | Description |
|---|---|---|---|---|
| 7 | O7 | R | 1* | not used |
| 6 | O6 | R | 1* | |
| 5 | O5 | R | 1* | |
| 4 | O4 | R | 1* | |

**Table 6. Register 1 - Output Port register bit description**...*continued*

*Legend: * default value.*

| Bit | Symbol | Access | Value | Description |
|---|---|---|---|---|
| 3 | O3 | R | 1* | reflects outgoing logic levels of pins defined as outputs by Register 3 |
| 2 | O2 | R | 1* | |
| 1 | O1 | R | 1* | |
| 0 | O0 | R | 1* | |

### 6.2.4 Register 2 - Polarity Inversion register

This register allows the user to invert the polarity of the Input Port register data. If a bit in this register is set (written with 1), the corresponding Input Port data is inverted. If a bit in this register is cleared (written with a 0), the Input Port data polarity is retained.

**Table 7. Register 2 - Polarity Inversion register bit description**

*Legend: * default value.*

| Bit | Symbol | Access | Value | Description |
|---|---|---|---|---|
| 7 | N7 | R/W | 0* | not used |
| 6 | N6 | R/W | 0* | |
| 5 | N5 | R/W | 0* | |
| 4 | N4 | R/W | 0* | |
| 3 | N3 | R/W | 0* | inverts polarity of Input Port register data<br>0 = Input Port register data retained (default value)<br>1 = Input Port register data inverted |
| 2 | N2 | R/W | 0* | |
| 1 | N1 | R/W | 0* | |
| 0 | N0 | R/W | 0* | |

### 6.2.5 Register 3 - Configuration register

This register configures the directions of the I/O pins. If a bit in this register is set, the corresponding port pin is enabled as an input with high-impedance output driver. If a bit in this register is cleared, the corresponding port pin is enabled as an output. At reset, the I/Os are configured as inputs.

**Table 8. Register 3 - Configuration register bit description**

*Legend: * default value.*

| Bit | Symbol | Access | Value | Description |
|---|---|---|---|---|
| 7 | C7 | R/W | 1* | not used |
| 6 | C6 | R/W | 1* | |
| 5 | C5 | R/W | 1* | |
| 4 | C4 | R/W | 1* | |
| 3 | C3 | R/W | 1* | configures the directions of the I/O pins<br>0 = corresponding port pin enabled as an output<br>1 = corresponding port pin configured as an input (default value) |
| 2 | C2 | R/W | 1* | |
| 1 | C1 | R/W | 1* | |
| 0 | C0 | R/W | 1* | |

## 6.3 Power-on reset

When power is applied to $V_{DD}$, an internal Power-On Reset (POR) holds the PCA9537 in a reset condition until $V_{DD}$ has reached $V_{POR}$. At that point, the reset condition is released and the PCA9537 registers and state machine will initialize to their default states. Thereafter, $V_{DD}$ must be lowered below 0.2 V to reset the device.

For a power reset cycle, $V_{DD}$ must be lowered below 0.2 V and then restored to the operating voltage.

## 6.4 RESET input

A reset can be accomplished by holding the $\overline{\text{RESET}}$ pin LOW for a minimum of $t_{w(rst)}$. The PCA9537 registers and SMBus/I²C-bus state machine will be held in their default state until the $\overline{\text{RESET}}$ input is once again HIGH. This input requires a pull-up resistor to $V_{DD}$ if no active connection is used.

## 6.5 Interrupt output

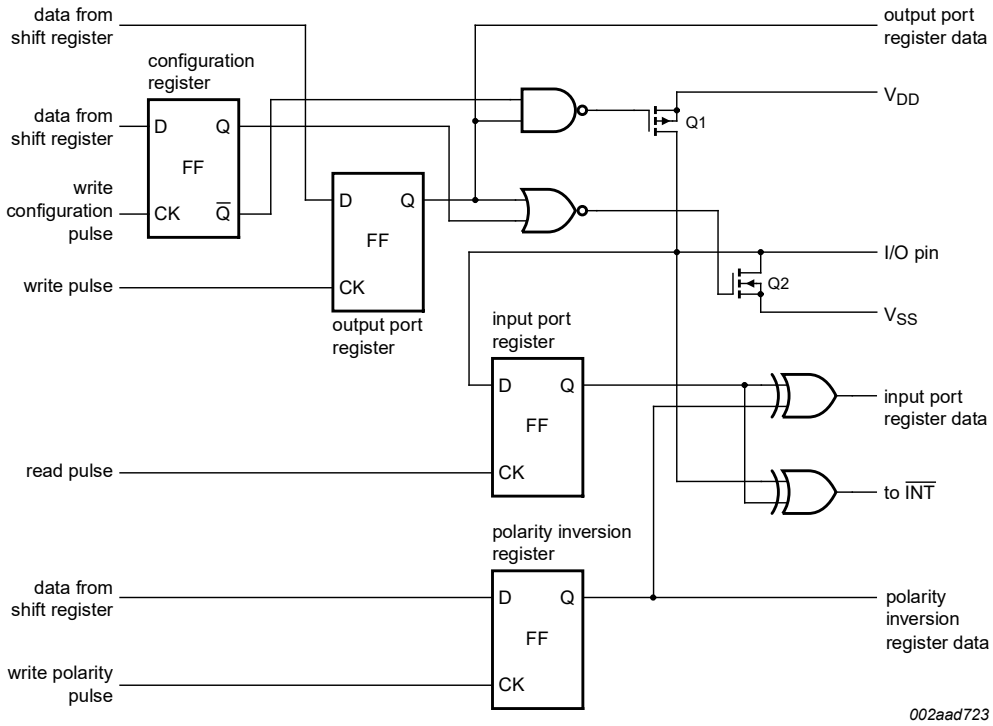
The open-drain interrupt output ($\overline{\text{INT}}$) is activated when one of the port pins changes state and the pin is configured as an input. The interrupt is de-activated when the input returns to its previous state or the Input Port register is read.

Note that changing an I/O from an output to an input may cause a false interrupt to occur if the state of the pin does not match the contents of the Input Port register.

## 6.6 I/O port

When an I/O is configured as an input, FETs Q1 and Q2 are off, creating a high-impedance input. The input voltage may be raised above $V_{DD}$ to a maximum of 5.5 V.

If the I/O is configured as an output, then either Q1 or Q2 is enabled, depending on the state of the Output Port register. Care should be exercised if an external voltage is applied to an I/O configured as an output because of the low-impedance paths that exist between the pin and either $V_{DD}$ or $V_{SS}$.

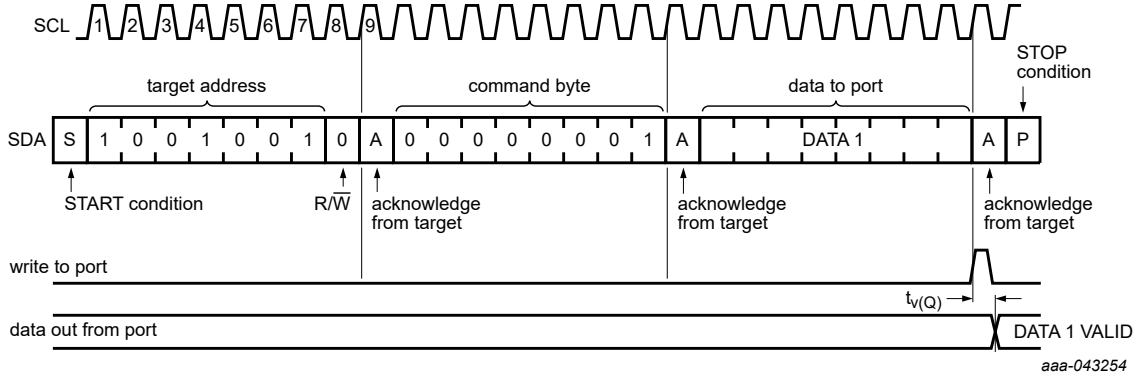



**Remark:** At power-on reset, all registers return to default values.

**Figure 4. Simplified schematic of IO0 to IO3**

## 6.7 Bus transactions

Data is transmitted to the PCA9537 registers using the write mode as shown in Figure 5 and Figure 6. Data is read from the PCA9537 registers using the read mode as shown in Figure 7 and Figure 8. These devices do not implement an auto-increment function so once a command byte has been sent, the register which was addressed will continue to be accessed by reads until a new command byte has been sent.




Expanded diagram is shown in Figure 16.

**Figure 5. Write to output port register**

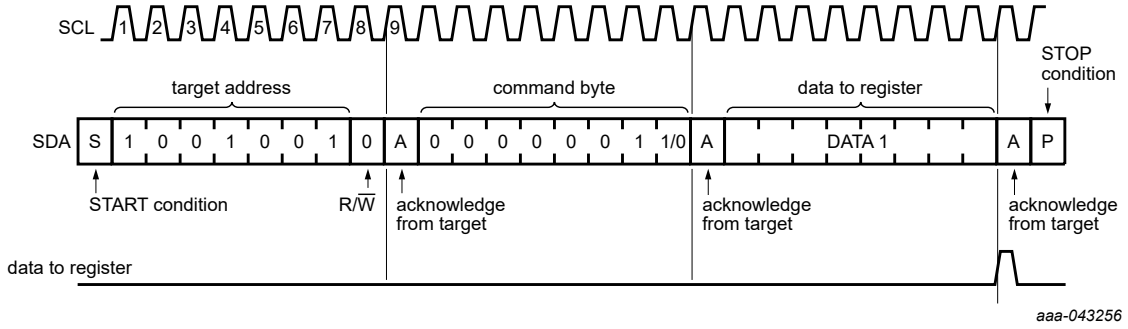



**Figure 6. Write to configuration or polarity inversion registers**

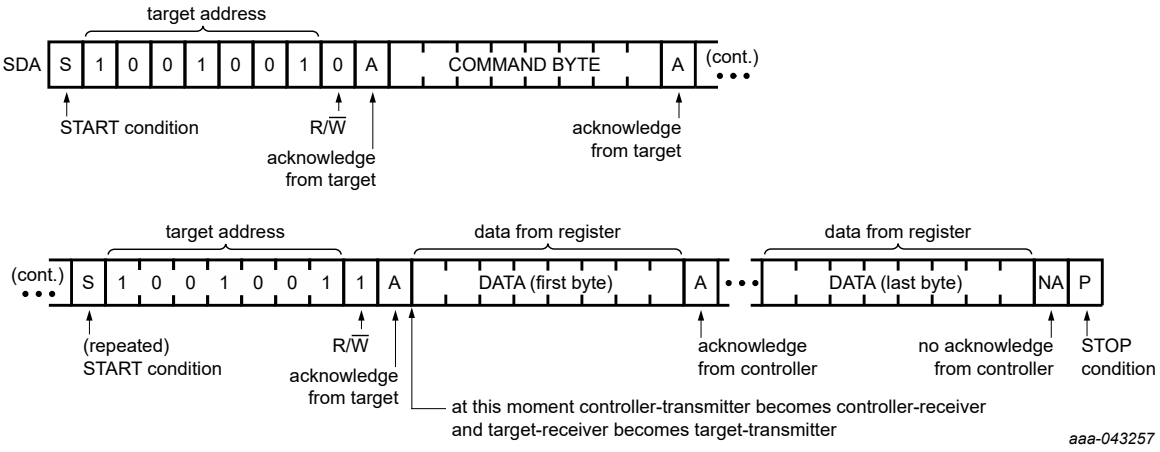
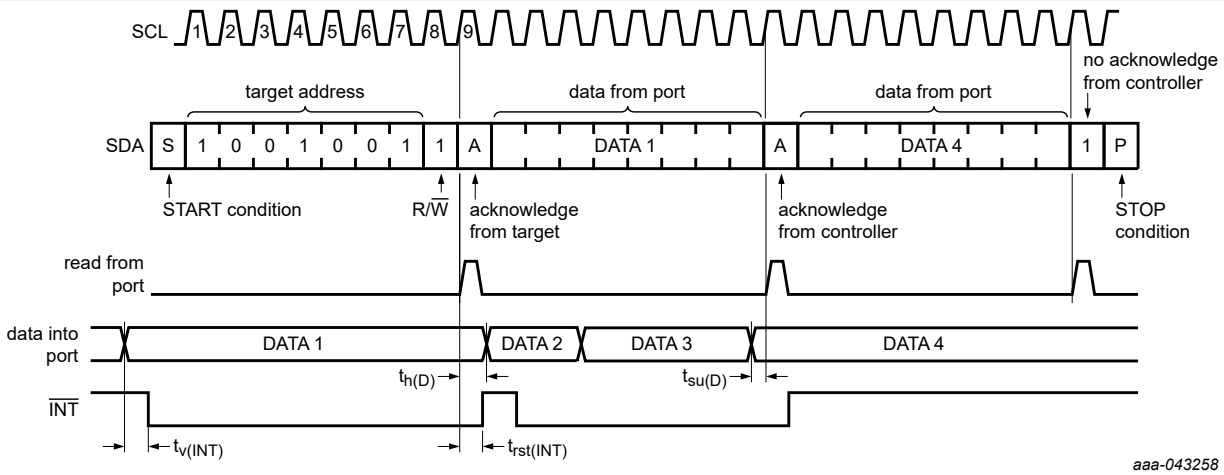



**Figure 7. Read from register**



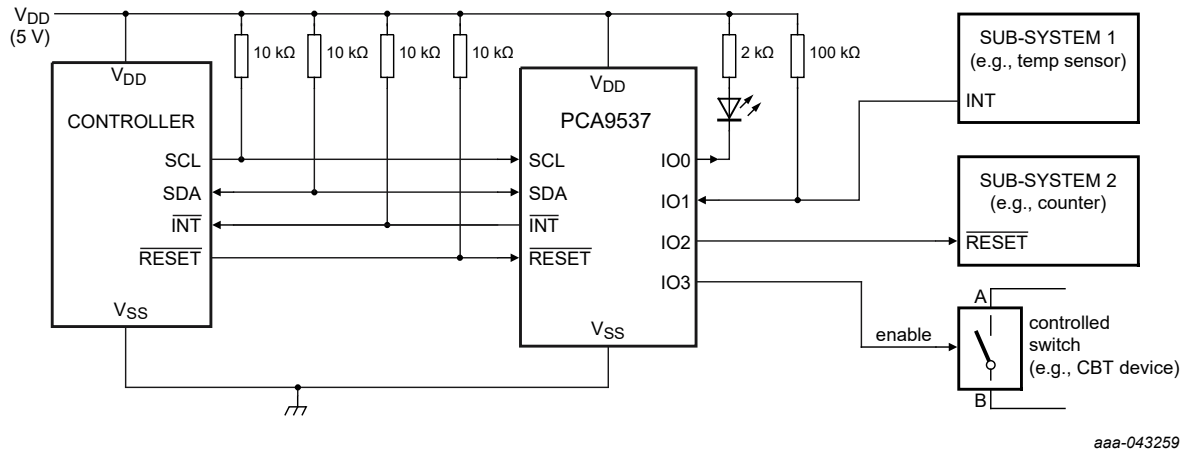

This figure assumes the command byte has previously been programmed with 00h.

Transfer of data can be stopped at any moment by a STOP condition.

Expanded diagram is shown in Figure 15.

**Figure 8. Read input port register**

# 7 Application design-in information




Device address is 1001 001x for this example.

IO0, IO2, IO3 configured as outputs.

IO1 configured as input.

**Figure 9. Typical application**

## 7.1 Minimizing $I_{DD}$ when the I/Os are used to control LEDs

When the I/Os are used to control LEDs, they are normally connected to $V_{DD}$ through a resistor as shown in Figure 9. Since the LED acts as a diode, when the LED is off the I/O $V_I$ is about 1.2 V less than $V_{DD}$. The supply current, $I_{DD}$, increases as $V_I$ becomes lower than $V_{DD}$.

Designs needing to minimize current consumption, such as battery power applications, should consider maintaining the I/O pins greater than or equal to $V_{DD}$ when the LED is off. Figure 10 shows a high value resistor in parallel with the LED. Figure 11 shows $V_{DD}$ less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O $V_I$ at or above $V_{DD}$ and prevents additional supply current consumption when the LED is off.

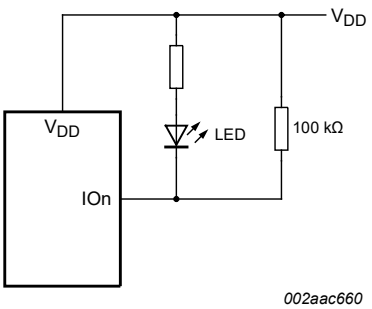



**Figure 10. High value resistor in parallel with the LED**

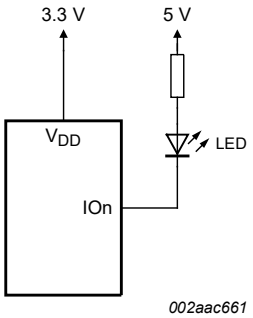



**Figure 11. Device supplied by a lower voltage**

# 8 Limiting values

**Table 9. Limiting values**

*In accordance with the Absolute Maximum Rating System (IEC 60134).*

| Symbol | Parameter | Conditions | | Min | Max | Unit |
|---|---|---|---|---|---|---|
| $V_{DD}$ | supply voltage | | | -0.5 | +6.0 | V |
| $I_I$ | input current | | | - | ±20 | mA |
| $V_{I/O}$ | voltage on an input/output pin | | | $V_{SS}$ - 0.5 | 5.5 | V |
| $I_{O(IOn)}$ | output current on pin IOn | | | - | ±50 | mA |
| $I_{DD}$ | supply current | | | - | 85 | mA |
| $I_{SS}$ | ground supply current | | | - | 100 | mA |
| $P_{tot}$ | total power dissipation | | | - | 200 | mW |
| $T_{stg}$ | storage temperature | | | -65 | +150 | °C |
| $T_{amb}$ | ambient temperature | operating | | -40 | +85 | °C |
| $T_{j(max)}$ | maximum junction temperature | | | - | +125 | °C |

# 9 Static characteristics

**Table 10. Static characteristics**

*$V_{DD}$ = 2.3 V to 5.5 V; $V_{SS}$ = 0 V; $T_{amb}$ = -40 °C to +85 °C; unless otherwise specified.*

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| **Supplies** | | | | | | | |
| $V_{DD}$ | supply voltage | | | 2.3 | - | 5.5 | V |
| $I_{DD}$ | supply current | operating mode; $V_{DD}$ = 5.5 V; no load; $f_{SCL}$ = 100 kHz | | - | 104 | 175 | µA |
| $I_{stbL}$ | LOW-level standby current | Standby mode; $V_{DD}$ = 5.5 V; no load; $V_I$ = $V_{SS}$; $f_{SCL}$ = 0 kHz; I/O = inputs | | - | 0.25 | 1 | µA |
| $I_{stbH}$ | HIGH-level standby current | Standby mode; $V_{DD}$ = 5.5 V; no load; $V_I$ = $V_{DD}$; $f_{SCL}$ = 0 kHz; I/O = inputs | | - | 0.25 | 1 | µA |
| $V_{POR}$ | power-on reset voltage | no load; $V_I$ = $V_{DD}$ or $V_{SS}$ | [1] | - | 1.7 | 2.2 | V |
| **Input SCL; input/output SDA** | | | | | | | |
| $V_{IL}$ | LOW-level input voltage | | | -0.5 | - | +0.3$V_{DD}$ | V |
| $V_{IH}$ | HIGH-level input voltage | | | 0.7$V_{DD}$ | - | 5.5 | V |
| $I_{OL}$ | LOW-level output current | $V_{OL}$ = 0.4 V | | 3 | 7 | - | mA |
| $I_L$ | leakage current | $V_I$ = $V_{DD}$ = $V_{SS}$ | | -1 | - | +1 | µA |
| $C_i$ | input capacitance | $V_I$ = $V_{SS}$ | | - | 5 | 10 | pF |
| **I/Os** | | | | | | | |
| $V_{IL}$ | LOW-level input voltage | | | -0.5 | - | +0.8 | V |
| $V_{IH}$ | HIGH-level input voltage | | | 2.0 | - | 5.5 | V |

**Table 10. Static characteristics**...*continued*

*$V_{DD}$ = 2.3 V to 5.5 V; $V_{SS}$ = 0 V; $T_{amb}$ = -40 °C to +85 °C; unless otherwise specified.*

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|---|
| $I_{OL}$ | LOW-level output current | $V_{OL}$ = 0.5 V | | | | | |
| | | $V_{DD}$ = 2.3 V | [2] | 8 | 10 | - | mA |
| | | $V_{DD}$ = 3.0 V | [2] | 8 | 14 | - | mA |
| | | $V_{DD}$ = 4.5 V | [2] | 8 | 17 | - | mA |
| | | $V_{OL}$ = 0.7 V | | | | | |
| | | $V_{DD}$ = 2.3 V | [2] | 10 | 13 | - | mA |
| | | $V_{DD}$ = 3.0 V | [2] | 10 | 19 | - | mA |
| | | $V_{DD}$ = 4.5 V | [2] | 10 | 24 | - | mA |
| $V_{OH}$ | HIGH-level output voltage | $I_{OH}$ = -8 mA | | | | | |
| | | $V_{DD}$ = 2.3 V | [3] | 1.8 | - | - | V |
| | | $V_{DD}$ = 3.0 V | [3] | 2.6 | - | - | V |
| | | $V_{DD}$ = 4.5 V | [3] | 4.1 | - | - | V |
| | | $I_{OH}$ = -10 mA | | | | | |
| | | $V_{DD}$ = 2.3 V | [3] | 1.7 | - | - | V |
| | | $V_{DD}$ = 3.0 V | [3] | 2.5 | - | - | V |
| | | $V_{DD}$ = 4.5 V | [3] | 4.0 | - | - | V |
| $I_L$ | leakage current | $V_I = V_{DD} = V_{SS}$ | | -1 | - | +1 | µA |
| $C_i$ | input capacitance | | | - | 5 | 10 | pF |
| **Interrupt $\overline{INT}$** | | | | | | | |
| $I_{OL}$ | LOW-level output current | $V_{OL}$ = 0.4 V | | 3 | 13 | - | mA |
| $I_{OH}$ | HIGH-level output current | $V_{OL}$ = 0.4 V | | -1 | - | +1 | µA |
| **Select input $\overline{RESET}$** | | | | | | | |
| $V_{IL}$ | LOW-level input voltage | | | -0.5 | - | +0.8 | V |
| $V_{IH}$ | HIGH-level input voltage | | | 2.0 | - | 5.5 | V |
| $I_L$ | leakage current | $V_I = V_{DD} = V_{SS}$ | | -1 | - | +1 | µA |

[1] $V_{DD}$ must be lowered to 0.2 V in order to reset part.
[2] Each I/O must be externally limited to a maximum of 25 mA and the device must be limited to a maximum current of 100 mA.
[3] The total current sourced by all I/Os must be limited to 85 mA.

# 10 Dynamic characteristics

**Table 11. Dynamic characteristics**

| Symbol | Parameter | Conditions | | Standard-mode I²C-bus | | Fast-mode I²C-bus | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | Min | Max | |
| $f_{SCL}$ | SCL clock frequency | | | 0 | 100 | 0 | 400 | kHz |
| $t_{BUF}$ | bus free time between a STOP and START condition | | | 4.7 | - | 1.3 | - | µs |

**Table 11. Dynamic characteristics**...*continued*

| Symbol | Parameter | Conditions | | Standard-mode I²C-bus | | Fast-mode I²C-bus | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | | Min | Max | Min | Max | |
| $t_{HD;STA}$ | hold time (repeated) START condition | | | 4.0 | - | 0.6 | - | µs |
| $t_{SU;STA}$ | set-up time for a repeated START condition | | | 4.7 | - | 0.6 | - | µs |
| $t_{SU;STO}$ | set-up time for STOP condition | | | 4.0 | - | 0.6 | - | µs |
| $t_{HD;DAT}$ | data hold time | | | 0 | - | 0 | - | ns |
| $t_{VD;ACK}$ | data valid acknowledge time | | [1] | 0.3 | 3.45 | 0.1 | 0.9 | µs |
| $t_{VD;DAT}$ | data valid time | | [2] | 300 | - | 50 | - | ns |
| $t_{SU;DAT}$ | data set-up time | | | 250 | - | 100 | - | ns |
| $t_{LOW}$ | LOW period of the SCL clock | | | 4.7 | - | 1.3 | - | µs |
| $t_{HIGH}$ | HIGH period of the SCL clock | | | 4.0 | - | 0.6 | - | µs |
| $t_r$ | rise time of both SDA and SCL signals | | | - | 1000 | $20 + 0.1C_b$ [3] | 300 | ns |
| $t_f$ | fall time of both SDA and SCL signals | | | - | 300 | $20 + 0.1C_b$ [3] | 300 | ns |
| $t_{SP}$ | pulse width of spikes that must be suppressed by the input filter | | | - | 50 | - | 50 | ns |
| **Port timing** | | | | | | | | |
| $t_{v(Q)}$ | data output valid time | | | - | 200 | - | 200 | ns |
| $t_{su(D)}$ | data input set-up time | | | 100 | - | 100 | - | ns |
| $t_{h(D)}$ | data input hold time | | | 1 | - | 1 | - | µs |
| **Interrupt timing** | | | | | | | | |
| $t_{v(INT)}$ | valid time on pin $\overline{INT}$ | | | - | 4 | - | 4 | µs |
| $t_{rst(INT)}$ | reset time on pin $\overline{INT}$ | | | - | 4 | - | 4 | µs |
| **$\overline{RESET}$** | | | | | | | | |
| $t_{w(rst)}$ | reset pulse width | | | 4 | - | 4 | - | ns |
| $t_{rec(rst)}$ | reset recovery time | | | 0 | - | 0 | - | ns |
| $t_{rst}$ | reset time | | | 400 | - | 400 | - | ns |

[1] $t_{VD;ACK}$ = time for Acknowledgement signal from SCL LOW to SDA (out) LOW.
[2] $t_{VD;DAT}$ = minimum time for the SDA data out to be valid following SCL LOW.
[3] $C_b$ = total capacitance of one bus line in pF.

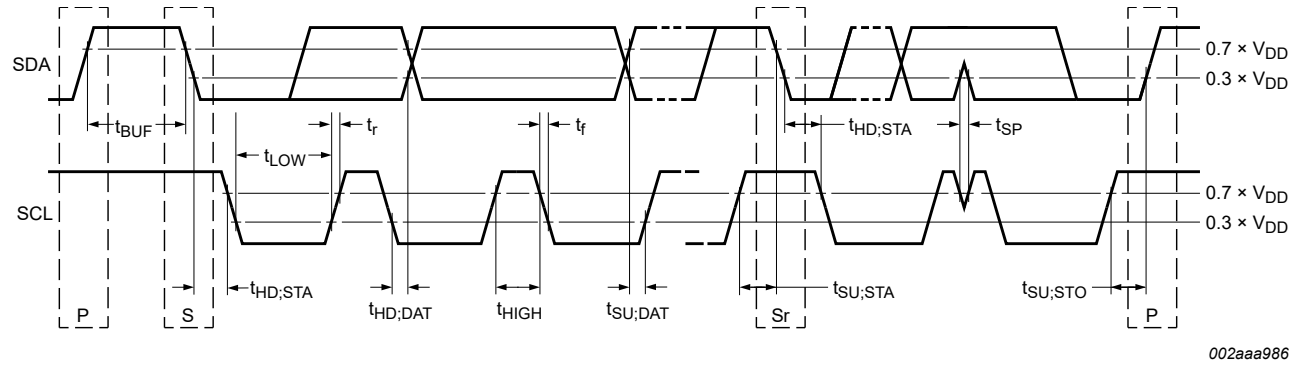
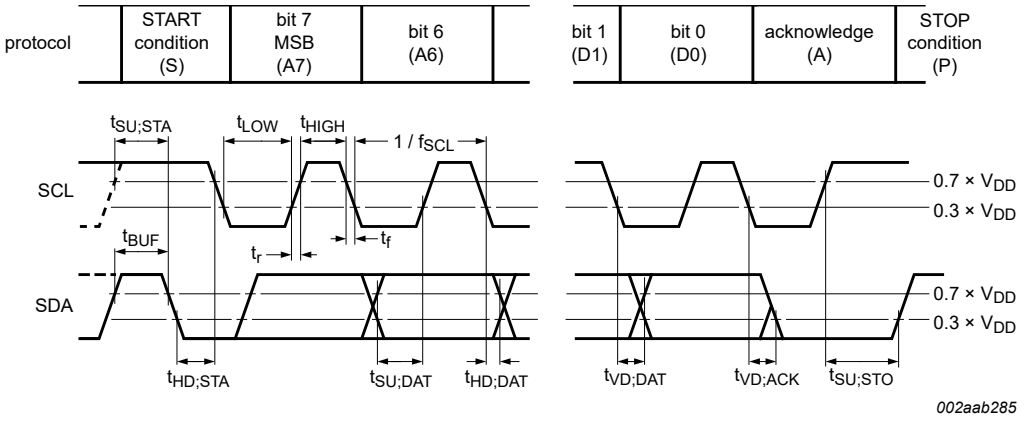



**Figure 12. Definition of timing**




Rise and fall times refer to $V_{IL}$ and $V_{IH}$.

**Figure 13. I²C-bus timing diagram**

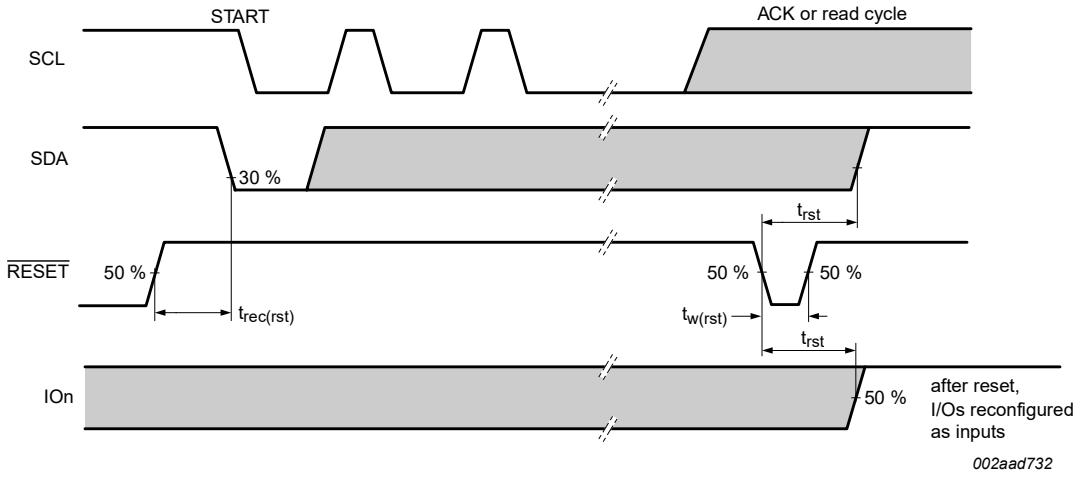



**Figure 14. Definition of RESET timing**

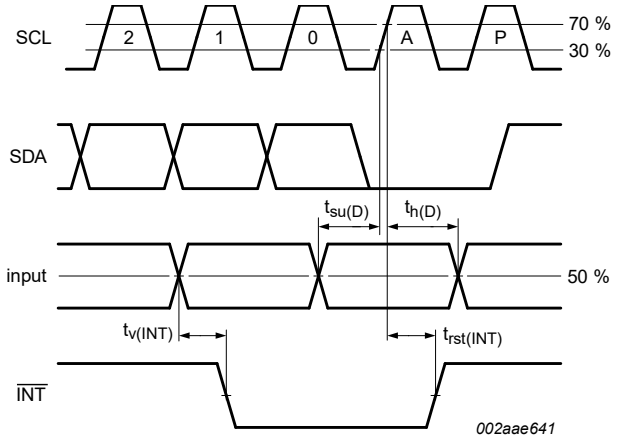



**Figure 15. Expanded view of read input port register**

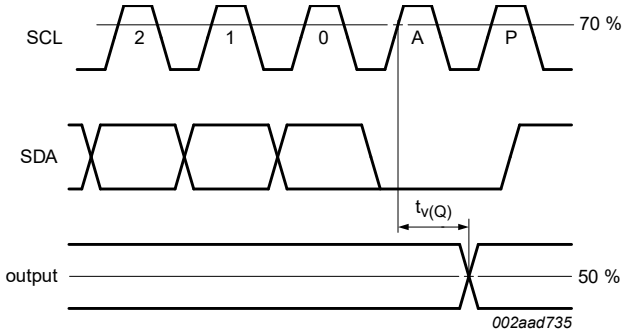
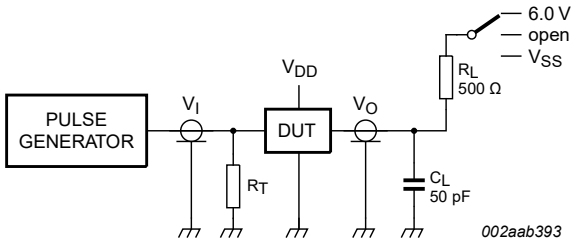



**Figure 16. Expanded view of write to output port register**

# 11 Test information




$R_L$ = load resistor.

$C_L$ = load capacitance includes jig and probe capacitance.

$R_T$ = termination resistance should be equal to the output impedance $Z_o$ of the pulse generators.

**Figure 17. Test circuitry for switching times**

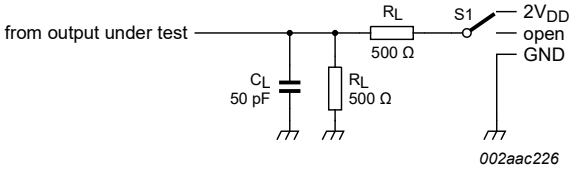


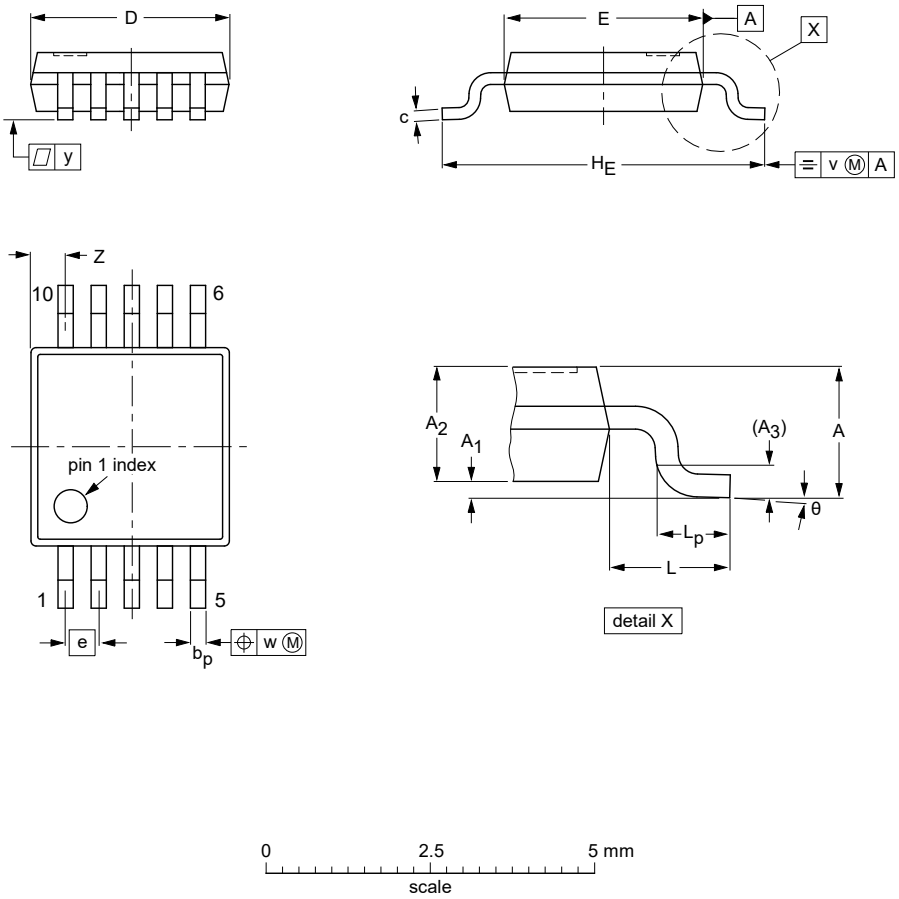

**Figure 18. Test circuit**

**Table 12. Test data**

| Test | Load | | Switch |
|---|---|---|---|
| | $R_L$ | $C_L$ | |
| $t_{v(Q)}$ | 500 Ω | 50 pF | 2 × $V_{DD}$ |

## 12 Package outline

**TSSOP10: plastic thin shrink small outline package; 10 leads; body width 3 mm** **SOT552-1**




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

| UNIT | A max. | $A_1$ | $A_2$ | $A_3$ | $b_p$ | c | $D^{(1)}$ | $E^{(2)}$ | e | $H_E$ | L | $L_p$ | v | w | y | $Z^{(1)}$ | θ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | 1.1 | 0.15<br>0.05 | 0.95<br>0.80 | 0.25 | 0.30<br>0.15 | 0.23<br>0.15 | 3.1<br>2.9 | 3.1<br>2.9 | 0.5 | 5.0<br>4.8 | 0.95 | 0.7<br>0.4 | 0.1 | 0.1 | 0.1 | 0.67<br>0.34 | 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 | | | |
| SOT552-1 | | | | | | ~~99-07-29~~<br>03-02-18 |

**Figure 19. Package outline SOT552-1 (TSSOP10)**

# 13 Handling information

All input and output pins are protected against ElectroStatic Discharge (ESD) under normal handling. When handling ensure that the appropriate precautions are taken as described in *JESD625-A* or equivalent standards.

# 14 Soldering of SMD packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering ICs can be found in Application Note *AN10365 "Surface mount reflow soldering description"*.

## 14.1 Introduction to soldering

Soldering is one of the most common methods through which packages are attached to Printed Circuit Boards (PCBs), to form electrical circuits. The soldered joint provides both the mechanical and the electrical connection. There is no single soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and Surface Mount Devices (SMDs) are mixed on one printed wiring board; however, it is not suitable for fine pitch SMDs. Reflow soldering is ideal for the small pitches and high densities that come with increased miniaturization.

## 14.2 Wave and reflow soldering

Wave soldering is a joining technology in which the joints are made by solder coming from a standing wave of liquid solder. The wave soldering process is suitable for the following:

- Through-hole components
- Leaded or leadless SMDs, which are glued to the surface of the printed circuit board

Not all SMDs can be wave soldered. Packages with solder balls, and some leadless packages which have solder lands underneath the body, cannot be wave soldered. Also, leaded SMDs with leads having a pitch smaller than ~0.6 mm cannot be wave soldered, due to an increased probability of bridging.

The reflow soldering process involves applying solder paste to a board, followed by component placement and exposure to a temperature profile. Leaded packages, packages with solder balls, and leadless packages are all reflow solderable.

Key characteristics in both wave and reflow soldering are:

- Board specifications, including the board finish, solder masks and vias
- Package footprints, including solder thieves and orientation
- The moisture sensitivity level of the packages
- Package placement
- Inspection and repair
- Lead-free soldering versus SnPb soldering

## 14.3 Wave soldering

Key characteristics in wave soldering are:

- Process issues, such as application of adhesive and flux, clinching of leads, board transport, the solder wave parameters, and the time during which components are exposed to the wave
- Solder bath specifications, including temperature and impurities

## 14.4 Reflow soldering

Key characteristics in reflow soldering are:

- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see Figure 20) than a SnPb process, thus reducing the process window
- Solder paste printing issues including smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature) and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic). In addition, the peak temperature must be low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with Table 13 and Table 14

**Table 13. SnPb eutectic process (from J-STD-020D)**

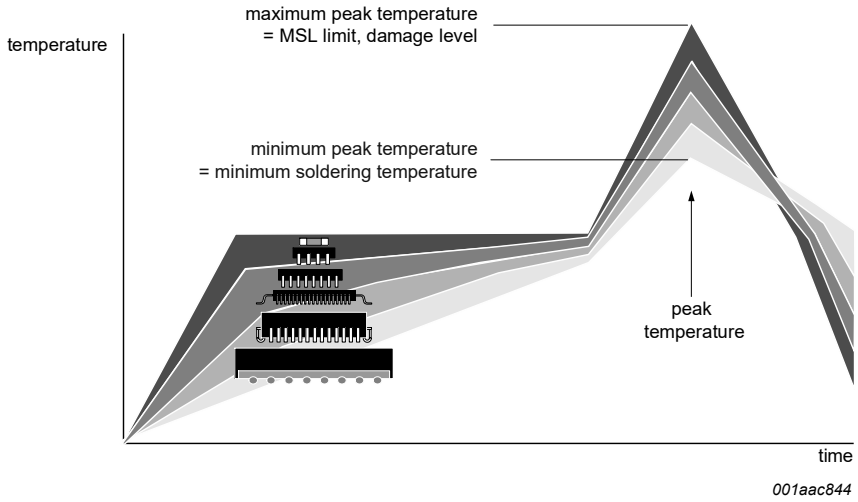
| Package thickness (mm) | Package reflow temperature (°C) | |
|---|---|---|
| | Volume (mm³) | |
| | < 350 | ≥ 350 |
| < 2.5 | 235 | 220 |
| ≥ 2.5 | 220 | 220 |

**Table 14. Lead-free process (from J-STD-020D)**

| Package thickness (mm) | Package reflow temperature (°C) | | |
|---|---|---|---|
| | Volume (mm³) | | |
| | < 350 | 350 to 2000 | > 2000 |
| < 1.6 | 260 | 260 | 260 |
| 1.6 to 2.5 | 260 | 250 | 245 |
| > 2.5 | 250 | 245 | 245 |

Moisture sensitivity precautions, as indicated on the packing, must be respected at all times.

Studies have shown that small packages reach higher temperatures during reflow soldering, see Figure 20.




MSL: Moisture Sensitivity Level

**Figure 20. Temperature profiles for large and small components**

For further information on temperature profiles, refer to Application Note *AN10365 "Surface mount reflow soldering description"*.

## 15 Abbreviations

**Table 15. Abbreviations**

| Acronym | Description |
|---|---|
| ACPI | Advanced Configuration and Power Interface |
| CBT | Cross-Bar Technology |
| CDM | Charged-Device Model |
| CMOS | Complementary Metal-Oxide Semiconductor |
| DUT | Device Under Test |
| ESD | ElectroStatic Discharge |
| FET | Field-Effect Transistor |
| FF | Flip-Flop |
| GPIO | General Purpose Input/Output |
| HBM | Human Body Model |
| $I^2C$-bus | Inter-Integrated Circuit bus |
| I/O | Input/Output |
| LED | Light Emitting Diode |
| LP | Low-Pass |
| MM | Machine Model |
| POR | Power-On Reset |
| SMBus | System Management Bus |

# 16 Revision history

**Table 16. Revision history**

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|---|---|---|---|---|
| PCA9537 v.7 | 20210908 | Product data sheet | 202104008A | PCA9537 v.6 |
| Modifications | • Updated ordering information to reflect discontinuation of ATP-1 device and move to ASEN. See change notice column.<br>• The terms "master" and "slave" changed to "controller" and "target" to comply with NXP inclusive language policy. | | | |
| PCA9537 v.6 | 20171107 | Product data sheet | 201710002I | PCA9537_5 |
| Modifications: | • Table 10: Corrected $V_{POR}$ typ and max limit<br>• Added Section 3.1 | | | |
| PCA9537_5 | 20090507 | Product data sheet | - | PCA9537_4 |
| Modifications: | • The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors.<br>• Legal texts have been adapted to the new company name where appropriate.<br>• Pin names changed from "I/O0, I/O1, I/O2, I/O3" to "IO0, IO1, IO2, IO3", respectively<br>• Section 6.4, 1st sentence: changed symbol from "$t_W$" to "$t_{w(rst)}$"<br>• Figure 5: changed symbol from "$t_{pv}$" to "$t_{v(Q)}$"<br>• Figure 8:<br>– changed symbol from "$t_{ph}$" to "$t_{h(D)}$"<br>– changed symbol from "$t_{ps}$" to "$t_{su(D)}$"<br>– changed symbol from "$t_{iv}$" to "$t_{v(INT)}$"<br>– changed symbol from "$t_{ir}$" to "$t_{rst(INT)}$"<br>• Table 9:<br>– parameter description for symbol $V_{I/O}$ changed from "DC voltage on an I/O" to "voltage on an input/output pin"<br>– parameter description for symbol $I_{SS}$ changed from "supply current" to "ground supply current"<br>– symbol/parameter changed from "$I_{I/O}$, DC output current on an I/O" to "$I_{O(IOn)}$, output current on pin IOn"<br>• Table 10, sub-section "Supplies":<br>– symbol/parameter changed from "$I_{stbl}$, Standby current" to "$I_{stbL}$, LOW-level standby current"<br>– symbol/parameter changed from "$I_{stbh}$, Standby current" to "$I_{stbH}$, HIGH-level standby current"<br>• Table 11, sub-section "Port timing":<br>– symbol/parameter changed from "$t_{PV}$, Output data valid" to "$t_{v(Q)}$, data output valid time"<br>– symbol/parameter changed from "$t_{PS}$, Input data setup time" to "$t_{su(D)}$, data input set-up time"<br>– symbol/parameter changed from "$t_{PH}$, Input data hold time" to "$t_{h(D)}$, data input hold time"<br>• Table 11, sub-section "Interrupt timing":<br>– symbol/parameter changed from "$t_{IV}$, Interrupt valid" to "$t_{v(INT)}$, valid time on pin $\overline{INT}$"<br>– symbol/parameter changed from "$t_{IR}$, Interrupt reset" to "$t_{rst(INT)}$, reset time on pin $\overline{INT}$" | | | |

**Table 16. Revision history**...*continued*

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|---|---|---|---|---|
| Modifications (continued): | • Table 11, sub-section "$\overline{\text{RESET}}$":<br>– symbol changed from "$t_W$" to "$t_{w(rst)}$"<br>– symbol changed from "$t_{REC}$" to "$t_{rec(rst)}$"<br>– symbol/parameter changed from "$t_{RESET}$, Time to reset" to "$t_{rst}$, reset time"<br>• Figure 14:<br>– symbol changed from "$t_W$" to "$t_{w(rst)}$"<br>– symbol changed from "$t_{REC}$" to "$t_{rec(rst)}$"<br>– symbol changed from "$t_{RESET}$" to "$t_{rst}$"<br>• Figure 15:<br>– changed symbol from "$t_{PH}$" to "$t_{h(D)}$"<br>– changed symbol from "$t_{PS}$" to "$t_{su(D)}$"<br>– changed symbol from "$t_{IV}$" to "$t_{v(INT)}$"<br>– changed symbol from "$t_{IR}$" to "$t_{rst(INT)}$"<br>• Figure 16: changed symbol from "$t_{PV}$" to "$t_{v(Q)}$"<br>• (Old) Figure 18, "Test circuit" split into Figure 18 and Table 12<br>– symbol changed from "$t_{pv}$" to "$t_{v(Q)}$"<br>• Added soldering information<br>• Added Table 15 | | | |
| PCA9537_4 | 20060921 | Product data sheet | - | PCA9537_3 |
| PCA9537_3 (9397 750 14259) | 20041129 | Product data sheet | - | PCA9537_2 |
| PCA9537_2 (9397 750 14052) | 20040930 | Objective data sheet | - | PCA9537_1 |
| PCA9537_1 (9397 750 12894) | 20040820 | Objective data sheet | - | - |

# 17 Legal information

## 17.1 Data sheet status

| Document status[1][2] | Product status[3] | Definition |
|---|---|---|
| Objective [short] data sheet | Development | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification | This document contains data from the preliminary specification. |
| Product [short] data sheet | Production | This document contains the product specification. |

[1] Please consult the most recently issued document before initiating or completing a design.
[2] The term 'short data sheet' is explained in section "Definitions".
[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

## 17.2 Definitions

**Draft** — A draft status on a document indicates that the content is still under internal review and subject to formal approval, which may result in modifications or additions. NXP Semiconductors does not give any representations or warranties as to the accuracy or completeness of information included in a draft version of a document and shall have no liability for the consequences of use of such information.

**Short data sheet** — A short data sheet is an extract from a full data sheet with the same product type number(s) and title. A short data sheet is intended for quick reference only and should not be relied upon to contain detailed and full information. For detailed and full information see the relevant full data sheet, which is available on request via the local NXP Semiconductors sales office. In case of any inconsistency or conflict with the short data sheet, the full data sheet shall prevail.

**Product specification** — The information and data provided in a Product data sheet shall define the specification of the product as agreed between NXP Semiconductors and its customer, unless NXP Semiconductors and customer have explicitly agreed otherwise in writing. In no event however, shall an agreement be valid in which the NXP Semiconductors product is deemed to offer functions and qualities beyond those described in the Product data sheet.

## 17.3 Disclaimers

**Limited warranty and liability** — Information in this document is believed to be accurate and reliable. However, NXP Semiconductors does not give any representations or warranties, expressed or implied, as to the accuracy or completeness of such information and shall have no liability for the consequences of use of such information. NXP Semiconductors takes no responsibility for the content in this document if provided by an information source outside of NXP Semiconductors. In no event shall NXP Semiconductors be liable for any indirect, incidental, punitive, special or consequential damages (including - without limitation - lost profits, lost savings, business interruption, costs related to the removal or replacement of any products or rework charges) whether or not such damages are based on tort (including negligence), warranty, breach of contract or any other legal theory. Notwithstanding any damages that customer might incur for any reason whatsoever, NXP Semiconductors' aggregate and cumulative liability towards customer for the products described herein shall be limited in accordance with the Terms and conditions of commercial sale of NXP Semiconductors.

**Right to make changes** — NXP Semiconductors reserves the right to make changes to information published in this document, including without limitation specifications and product descriptions, at any time and without notice. This document supersedes and replaces all information supplied prior to the publication hereof.

**Suitability for use** — NXP Semiconductors products are not designed, authorized or warranted to be suitable for use in life support, life-critical or safety-critical systems or equipment, nor in applications where failure or malfunction of an NXP Semiconductors product can reasonably be expected to result in personal injury, death or severe property or environmental damage. NXP Semiconductors and its suppliers accept no liability for inclusion and/or use of NXP Semiconductors products in such equipment or applications and therefore such inclusion and/or use is at the customer's own risk.

**Applications** — Applications that are described herein for any of these products are for illustrative purposes only. NXP Semiconductors makes no representation or warranty that such applications will be suitable for the specified use without further testing or modification. Customers are responsible for the design and operation of their applications and products using NXP Semiconductors products, and NXP Semiconductors accepts no liability for any assistance with applications or customer product design. It is customer's sole responsibility to determine whether the NXP Semiconductors product is suitable and fit for the customer's applications and products planned, as well as for the planned application and use of customer's third party customer(s). Customers should provide appropriate design and operating safeguards to minimize the risks associated with their applications and products. NXP Semiconductors does not accept any liability related to any default, damage, costs or problem which is based on any weakness or default in the customer's applications or products, or the application or use by customer's third party customer(s). Customer is responsible for doing all necessary testing for the customer's applications and products using NXP Semiconductors products in order to avoid a default of the applications and the products or of the application or use by customer's third party customer(s). NXP does not accept any liability in this respect.

**Limiting values** — Stress above one or more limiting values (as defined in the Absolute Maximum Ratings System of IEC 60134) will cause permanent damage to the device. Limiting values are stress ratings only and (proper) operation of the device at these or any other conditions above those given in the Recommended operating conditions section (if present) or the Characteristics sections of this document is not warranted. Constant or repeated exposure to limiting values will permanently and irreversibly affect the quality and reliability of the device.

**Terms and conditions of commercial sale** — NXP Semiconductors products are sold subject to the general terms and conditions of commercial sale, as published at http://www.nxp.com/profile/terms, unless otherwise agreed in a valid written individual agreement. In case an individual agreement is concluded only the terms and conditions of the respective agreement shall apply. NXP Semiconductors hereby expressly objects to applying the customer's general terms and conditions with regard to the purchase of NXP Semiconductors products by customer.

**No offer to sell or license** — Nothing in this document may be interpreted or construed as an offer to sell products that is open for acceptance or the grant, conveyance or implication of any license under any copyrights, patents or other industrial or intellectual property rights.

**Quick reference data** — The Quick reference data is an extract of the product data given in the Limiting values and Characteristics sections of this document, and as such is not complete, exhaustive or legally binding.

**Export control** — This document as well as the item(s) described herein may be subject to export control regulations. Export might require a prior authorization from competent authorities.

**Non-automotive qualified products** — Unless this data sheet expressly states that this specific NXP Semiconductors product is automotive qualified, the product is not suitable for automotive use. It is neither qualified nor tested in accordance with automotive testing or application requirements. NXP Semiconductors accepts no liability for inclusion and/or use of non-automotive qualified products in automotive equipment or applications. In the event that customer uses the product for design-in and use in automotive applications to automotive specifications and standards, customer (a) shall use the product without NXP Semiconductors' warranty of the product for such automotive applications, use and specifications, and (b) whenever customer uses the product for automotive applications beyond NXP Semiconductors' specifications such use shall be solely at customer's own risk, and (c) customer fully indemnifies NXP Semiconductors for any liability, damages or failed product claims resulting from customer design and use of the product for automotive applications beyond NXP Semiconductors' standard warranty and NXP Semiconductors' product specifications.

**Translations** — A non-English (translated) version of a document is for reference only. The English version shall prevail in case of any discrepancy between the translated and English versions.

## 17.4 Trademarks

Notice: All referenced brands, product names, service names and trademarks are the property of their respective owners.

**I²C-bus** — logo is a trademark of NXP B.V.

**NXP** — wordmark and logo are trademarks of NXP B.V.

## Tables



## Figures

## Contents





For more information, please visit: http://www.nxp.com
For sales office addresses, please send an email to: salesaddresses@nxp.com

**Date of release: 8 September 2021**
**Document identifier: PCA9537**