



# PCA6416A

Low-voltage translating 16-bit I<sup>2</sup>C-bus/SMBus I/O expander with interrupt output, reset, and configuration registers

Rev. 2. — 10 January 2013

Product data sheet

## 1. General description

The PCA6416A is a 16-bit general purpose I/O expander that provides remote I/O expansion for most microcontroller families via the I<sup>2</sup>C-bus interface.

NXP I/O expanders provide a simple solution when additional I/Os are needed while keeping interconnections to a minimum, for example, in battery-powered mobile applications for interfacing to sensors, push buttons, keypad, etc. In addition to providing a flexible set of GPIOs, it simplifies interconnection of a processor running at one voltage level to I/O devices operating at a different (usually higher) voltage level. The PCA6416A has built-in level shifting feature that makes these devices extremely flexible in mixed signal environments where communication between incompatible I/O voltages is required. Its wide  $V_{DD}$  range of 1.65 V to 5.5 V on the dual power rail allows seamless communications with next-generation low voltage microprocessors and microcontrollers on the interface side (SDA/SCL) and peripherals at a higher voltage on the port side.

There are two supply voltages for PCA6416A:  $V_{DD(I2C-bus)}$  and  $V_{DD(P)}$ .  $V_{DD(I2C-bus)}$  provides the supply voltage for the interface at the master side (for example, a microcontroller) and the  $V_{DD(P)}$  provides the supply for core circuits and Port P. The bidirectional voltage level translation in the PCA6416A is provided through  $V_{DD(I2C-bus)}$ .  $V_{DD(I2C-bus)}$  should be connected to the  $V_{DD}$  of the external SCL/SDA lines. This indicates the  $V_{DD}$  level of the I<sup>2</sup>C-bus to the PCA6416A. The voltage level on Port P of the PCA6416A is determined by the  $V_{DD(P)}$ .

The PCA6416A register set consists of four pairs of 8-bit Configuration, Input, Output, and Polarity Inversion registers.

At power-on, the I/Os are configured as inputs. However, the system master 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 or output register. The polarity of the Input Port register can be inverted with the Polarity Inversion register, saving external logic gates.

The system master can reset the PCA6416A in the event of a time-out or other improper operation by asserting a LOW in the  $\overline{RESET}$  input. The power-on reset puts the registers in their default state and initializes the I<sup>2</sup>C-bus/SMBus state machine. The  $\overline{RESET}$  pin causes the same reset/initialization to occur without depowering the part.

The PCA6416A open-drain interrupt ( $\overline{INT}$ ) output is activated when any input state differs from its corresponding Input Port register state and is used to indicate to the system master that an input state has changed.



$\overline{\text{INT}}$  can be connected to the interrupt input of a microcontroller. By sending an interrupt signal on this line, the remote I/O can inform the microcontroller if there is incoming data on its ports without having to communicate via the I<sup>2</sup>C-bus. Thus, the PCA6416A can remain a simple slave device.

The device Port P outputs have 25 mA sink capabilities for directly driving LEDs while consuming low device current.

One hardware pin (ADDR) can be used to program and vary the fixed I<sup>2</sup>C-bus address and allow up to two devices to share the same I<sup>2</sup>C-bus or SMBus.

## 2. Features and benefits

- I<sup>2</sup>C-bus to parallel port expander
- Operating power supply voltage range of 1.65 V to 5.5 V
- Allows bidirectional voltage-level translation and GPIO expansion between:
  - ◆ 1.8 V SCL/SDA and 1.8 V, 2.5 V, 3.3 V or 5 V Port P
  - ◆ 2.5 V SCL/SDA and 1.8 V, 2.5 V, 3.3 V or 5 V Port P
  - ◆ 3.3 V SCL/SDA and 1.8 V, 2.5 V, 3.3 V or 5 V Port P
  - ◆ 5 V SCL/SDA and 1.8 V, 2.5 V, 3.3 V or 5 V Port P
- Low standby current consumption:
  - ◆ 1.5  $\mu\text{A}$  typical at 5 V  $V_{\text{DD}}$
  - ◆ 1.0  $\mu\text{A}$  typical at 3.3 V  $V_{\text{DD}}$
- Schmitt-trigger action allows slow input transition and better switching noise immunity at the SCL and SDA inputs
  - ◆  $V_{\text{hys}} = 0.18 \text{ V}$  (typical) at 1.8 V
  - ◆  $V_{\text{hys}} = 0.25 \text{ V}$  (typical) at 2.5 V
  - ◆  $V_{\text{hys}} = 0.33 \text{ V}$  (typical) at 3.3 V
  - ◆  $V_{\text{hys}} = 0.5 \text{ V}$  (typical) at 5 V
- 5 V tolerant I/O ports
- Active LOW reset input ( $\overline{\text{RESET}}$ )
- Open-drain active LOW interrupt output ( $\overline{\text{INT}}$ )
- 400 kHz Fast-mode I<sup>2</sup>C-bus
- Input/Output Configuration register
- Polarity Inversion register
- Internal power-on reset
- Power-up with all channels configured as inputs
- No glitch on power-up
- Noise filter on SCL/SDA inputs
- Latched outputs with 25 mA drive maximum capability for directly driving LEDs
- Latch-up performance exceeds 100 mA per JESD 78, Class II
- ESD protection exceeds JESD 22
  - ◆ 2000 V Human-Body Model (A114-A)
  - ◆ 1000 V Charged-Device Model (C101)
- Packages offered: TSSOP24, HWQFN24, VFBGA24

### 3. Ordering information

Table 1. Ordering information

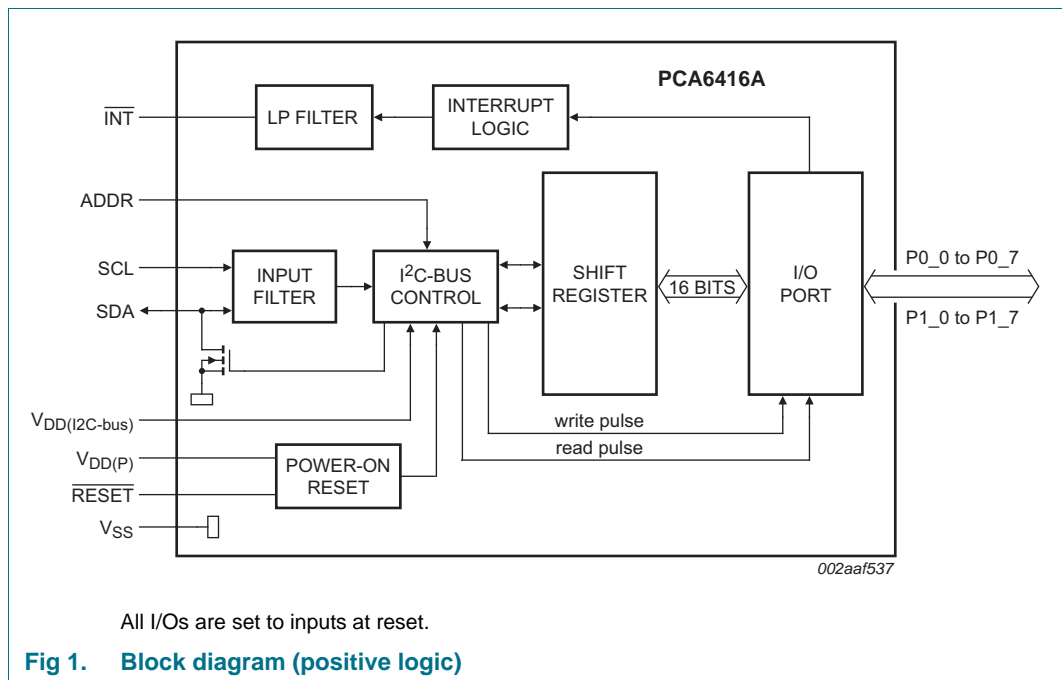
| Type number | Topside marking | Package |   | Version   |
|-------------|-----------------|---------|---|-----------|
|             |                 | Name    | Description   |           |
| PCA6416AEV  | 416A            | VFBGA24 | plastic very thin fine-pitch ball grid array package; 24 balls; body 3 × 3 × 0.85 mm                    | SOT1199-1 |
| PCA6416AHF  | 416A            | HWQFN24 | plastic thermal enhanced very very thin quad flat package; no leads; 24 terminals; body 4 × 4 × 0.75 mm | SOT994-1  |
| PCA6416APW  | PCA6416A        | TSSOP24 | plastic thin shrink small outline package; 24 leads; body width 4.4 mm                                  | SOT355-1  |

#### 3.1 Ordering options

Table 2. Ordering options

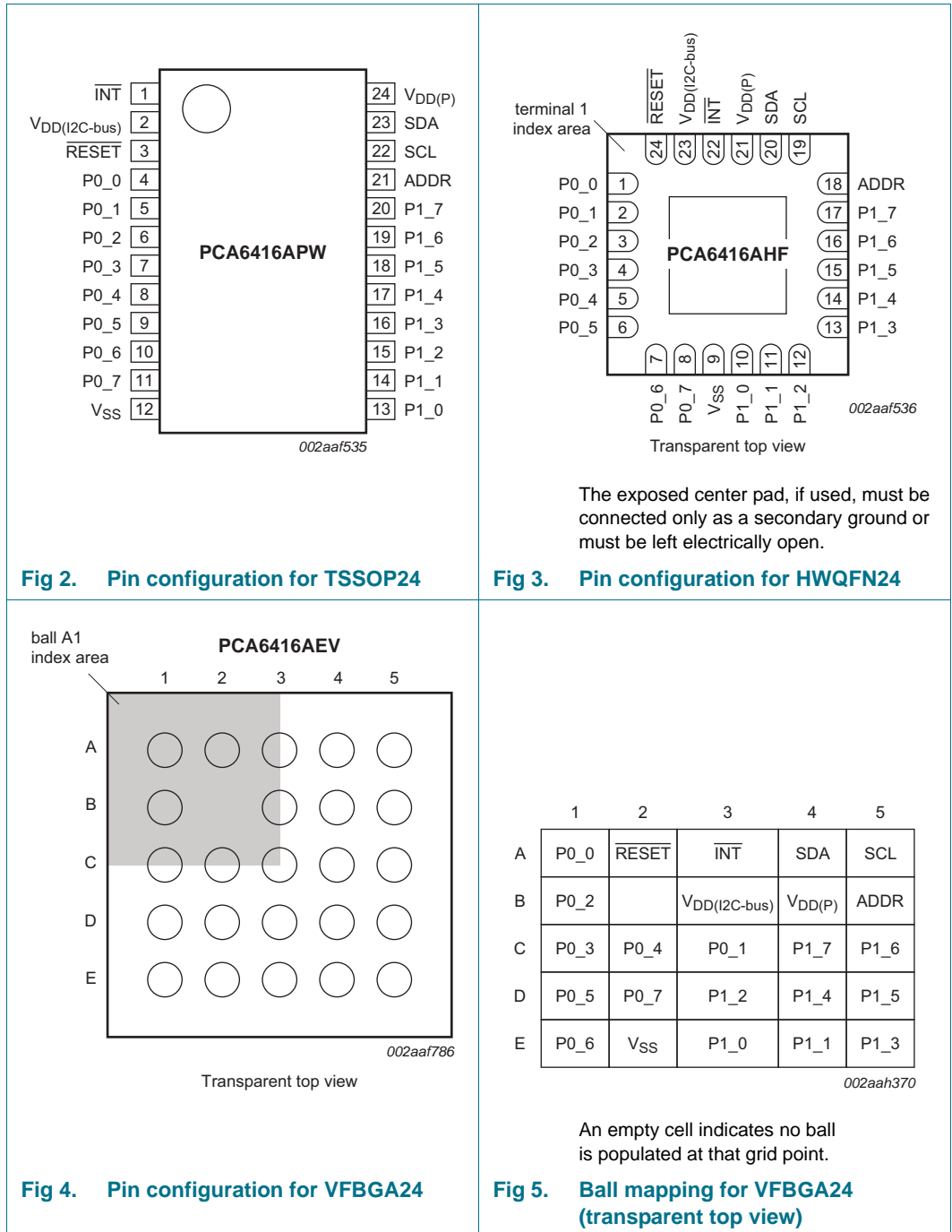
| Type number | Orderable part number | Package | Packing method                  | Minimum order quantity | Temperature                         |
|-------------|-----------------------|---------|---------------------------------|------------------------|-------------------------------------|
| PCA6416AEV  | PCA6416AEVJ           | VFBGA24 | Reel pack, SMD, 13-inch         | 6000                   | T <sub>amb</sub> = -40 °C to +85 °C |
| PCA6416AHF  | PCA6416AHF,128        | HWQFN24 | Reel pack, SMD, 13-inch, turned | 6000                   | T <sub>amb</sub> = -40 °C to +85 °C |
| PCA6416APW  | PCA6416APW,118        | TSSOP24 | Reel pack, SMD, 13-inch         | 2500                   | T <sub>amb</sub> = -40 °C to +85 °C |

### 4. Block diagram



## 5. Pinning information

### 5.1 Pinning



## 5.2 Pin description

Table 3. Pin description

| Symbol                           | Pin     |         |         | Description  |
|----------------------------------|---------|---------|---------|--|
|                                  | TSSOP24 | HWQFN24 | VFBGA24 |  |
| $\overline{\text{INT}}$          | 1       | 22      | A3      | Interrupt output. Connect to $V_{\text{DD(I}^2\text{C-bus)}}$ or $V_{\text{DD(P)}}$ through a pull-up resistor.  |
| $V_{\text{DD(I}^2\text{C-bus)}}$ | 2       | 23      | B3      | Supply voltage of I <sup>2</sup> C-bus. Connect directly to the $V_{\text{DD}}$ of the external I <sup>2</sup> C master. Provides voltage-level translation. |
| $\overline{\text{RESET}}$        | 3       | 24      | A2      | Active LOW reset input. Connect to $V_{\text{DD(I}^2\text{C-bus)}}$ through a pull-up resistor if no active connection is used.                              |
| P0_0 <sup>[1]</sup>              | 4       | 1       | A1      | Port 0 input/output 0.   |
| P0_1 <sup>[1]</sup>              | 5       | 2       | C3      | Port 0 input/output 1.   |
| P0_2 <sup>[1]</sup>              | 6       | 3       | B1      | Port 0 input/output 2.   |
| P0_3 <sup>[1]</sup>              | 7       | 4       | C1      | Port 0 input/output 3.   |
| P0_4 <sup>[1]</sup>              | 8       | 5       | C2      | Port 0 input/output 4.   |
| P0_5 <sup>[1]</sup>              | 9       | 6       | D1      | Port 0 input/output 5.   |
| P0_6 <sup>[1]</sup>              | 10      | 7       | E1      | Port 0 input/output 6.   |
| P0_7 <sup>[1]</sup>              | 11      | 8       | D2      | Port 0 input/output 7.   |
| $V_{\text{SS}}$                  | 12      | 9       | E2      | Ground.  |
| P1_0 <sup>[2]</sup>              | 13      | 10      | E3      | Port 1 input/output 0.   |
| P1_1 <sup>[2]</sup>              | 14      | 11      | E4      | Port 1 input/output 1.   |
| P1_2 <sup>[2]</sup>              | 15      | 12      | D3      | Port 1 input/output 2.   |
| P1_3 <sup>[2]</sup>              | 16      | 13      | E5      | Port 1 input/output 3.   |
| P1_4 <sup>[2]</sup>              | 17      | 14      | D4      | Port 1 input/output 4.   |
| P1_5 <sup>[2]</sup>              | 18      | 15      | D5      | Port 1 input/output 5.   |
| P1_6 <sup>[2]</sup>              | 19      | 16      | C5      | Port 1 input/output 6.   |
| P1_7 <sup>[2]</sup>              | 20      | 17      | C4      | Port 1 input/output 7.   |
| ADDR                             | 21      | 18      | B5      | Address input. Connect directly to $V_{\text{DD(P)}}$ or ground.   |
| SCL                              | 22      | 19      | A5      | Serial clock bus. Connect to $V_{\text{DD(I}^2\text{C-bus)}}$ through a pull-up resistor.  |
| SDA                              | 23      | 20      | A4      | Serial data bus. Connect to $V_{\text{DD(I}^2\text{C-bus)}}$ through a pull-up resistor.   |
| $V_{\text{DD(P)}}$               | 24      | 21      | B4      | Supply voltage of PCA6416A for Port P.   |

[1] Pins P0\_0 to P0\_7 correspond to bits P0.0 to P0.7. At power-on, all I/O are configured as input.

[2] Pins P1\_0 to P1\_7 correspond to bits P1.0 to P1.7. At power-on, all I/O are configured as input.

## 6. Voltage translation

Table 4 shows how to set up V<sub>DD</sub> levels for the necessary voltage translation between the I<sup>2</sup>C-bus and the PCA6416A.

**Table 4. Voltage translation**

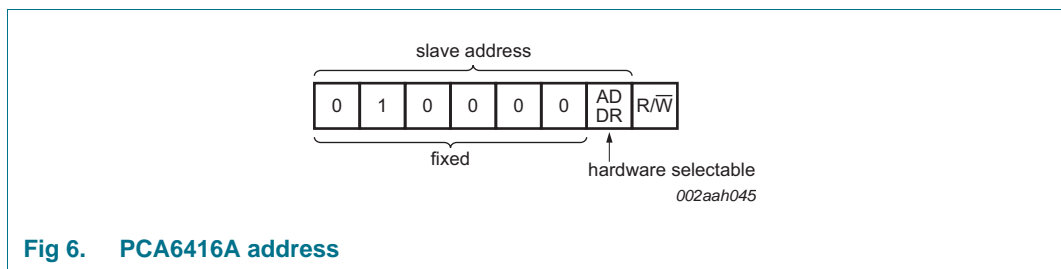
| V <sub>DD(I2C-bus)</sub> (SDA and SCL of I <sup>2</sup> C master) | V <sub>DD(P)</sub> (Port P) |
|---|-----------------------------|
| 1.8 V   | 1.8 V                       |
| 1.8 V   | 2.5 V                       |
| 1.8 V   | 3.3 V                       |
| 1.8 V   | 5 V                         |
| 2.5 V   | 1.8 V                       |
| 2.5 V   | 2.5 V                       |
| 2.5 V   | 3.3 V                       |
| 2.5 V   | 5 V                         |
| 3.3 V   | 1.8 V                       |
| 3.3 V   | 2.5 V                       |
| 3.3 V   | 3.3 V                       |
| 3.3 V   | 5 V                         |
| 5 V   | 1.8 V                       |
| 5 V   | 2.5 V                       |
| 5 V   | 3.3 V                       |
| 5 V   | 5 V                         |

## 7. Functional description

Refer to [Figure 1 “Block diagram \(positive logic\)”](#).

### 7.1 Device address

The address of the PCA6416A is shown in [Figure 6](#).



ADDR is the hardware address package pin and is held to either HIGH (logic 1) or LOW (logic 0) to assign one of the two possible slave addresses. The last bit of the slave address (R/W) defines the operation (read or write) to be performed. A HIGH (logic 1) selects a read operation, while a LOW (logic 0) selects a write operation.

### 7.2 Interface definition

Table 5. Interface definition

| Byte                               | Bit     |      |      |      |      |      |      |              |
|------------------------------------|---------|------|------|------|------|------|------|--------------|
|                                    | 7 (MSB) | 6    | 5    | 4    | 3    | 2    | 1    | 0 (LSB)      |
| I <sup>2</sup> C-bus slave address | L       | H    | L    | L    | L    | L    | ADDR | R/ $\bar{W}$ |
| I/O data bus                       | P0.7    | P0.6 | P0.5 | P0.4 | P0.3 | P0.2 | P0.1 | P0.0         |
|                                    | P1.7    | P1.6 | P1.5 | P1.4 | P1.3 | P1.2 | P1.1 | P1.0         |

### 7.3 Pointer register and command byte

Following the successful acknowledgement of the address byte, the bus master sends a command byte, which is stored in the Pointer register in the PCA6416A. The lower three bits of this data byte state the operation (read or write) and the internal registers (Input, Output, Polarity Inversion, or Configuration) that will be affected. This register is write only.

Once a new command has been sent, the register that was last addressed continues to be accessed by reads until a new command byte is sent.

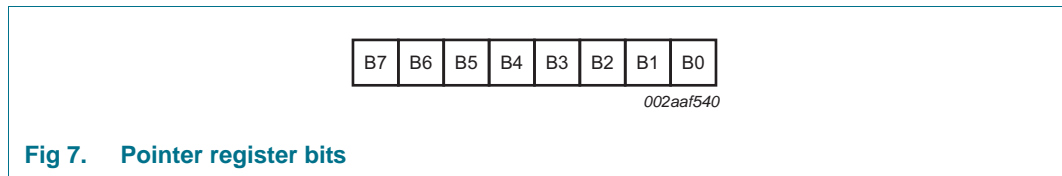


Fig 7. Pointer register bits

Table 6. Command byte

| Pointer register bits |    |    |    |    |    |    |    | Command byte | Register                  | Protocol        | Power-up default         |
|-----------------------|----|----|----|----|----|----|----|--------------|---------------------------|-----------------|--------------------------|
| B7                    | B6 | B5 | B4 | B3 | B2 | B1 | B0 |              |                           |                 |                          |
| 0                     | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 00h          | Input port 0              | read byte       | xxxx xxxx <sup>[1]</sup> |
| 0                     | 0  | 0  | 0  | 0  | 0  | 0  | 1  | 01h          | Input port 1              | read byte       | xxxx xxxx                |
| 0                     | 0  | 0  | 0  | 0  | 0  | 1  | 0  | 02h          | Output port 0             | read/write byte | 1111 1111                |
| 0                     | 0  | 0  | 0  | 0  | 0  | 1  | 1  | 03h          | Output port 1             | read/write byte | 1111 1111                |
| 0                     | 0  | 0  | 0  | 0  | 1  | 0  | 0  | 04h          | Polarity Inversion port 0 | read/write byte | 0000 0000                |
| 0                     | 0  | 0  | 0  | 0  | 1  | 0  | 1  | 05h          | Polarity Inversion port 1 | read/write byte | 0000 0000                |
| 0                     | 0  | 0  | 0  | 0  | 1  | 1  | 0  | 06h          | Configuration port 0      | read/write byte | 1111 1111                |
| 0                     | 0  | 0  | 0  | 0  | 1  | 1  | 1  | 07h          | Configuration port 1      | read/write byte | 1111 1111                |

[1] Undefined.

## 7.4 Register descriptions

### 7.4.1 Input port registers (00h, 01h)

The Input port registers (registers 0 and 1) reflect the incoming logic levels of the pins, regardless of whether the pin is defined as an input or an output by the Configuration register. The Input port registers are read only; writes to these registers have no effect. The default value 'X' is determined by the externally applied logic level. An Input port register read operation is performed as described in [Section 8.2](#).

**Table 7. Input port 0 register (address 00h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | I0.7 | I0.6 | I0.5 | I0.4 | I0.3 | I0.2 | I0.1 | I0.0 |
| Default | X    | X    | X    | X    | X    | X    | X    | X    |

**Table 8. Input port 1 register (address 01h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | I1.7 | I1.6 | I1.5 | I1.4 | I1.3 | I1.2 | I1.1 | I1.0 |
| Default | X    | X    | X    | X    | X    | X    | X    | X    |

### 7.4.2 Output port registers (02h, 03h)

The Output port registers (registers 2 and 3) shows the outgoing logic levels of the pins defined as outputs by the Configuration register. Bit values in these registers have no effect on pins defined as inputs. In turn, reads from these registers reflect the value that was written to these registers, **not** the actual pin value. A register pair write is described in [Section 8.1](#) and a register pair read is described in [Section 8.2](#).

**Table 9. Output port 0 register (address 02h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | O0.7 | O0.6 | O0.5 | O0.4 | O0.3 | O0.2 | O0.1 | O0.0 |
| Default | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |

**Table 10. Output port 1 register (address 03h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | O1.7 | O1.6 | O1.5 | O1.4 | O1.3 | O1.2 | O1.1 | O1.0 |
| Default | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |



### 7.4.3 Polarity inversion registers (04h, 05h)

The Polarity inversion registers (registers 4 and 5) allow polarity inversion of pins defined as inputs by the Configuration register. If a bit in these registers is set (written with '1'), the corresponding port pin's polarity is inverted in the input register. If a bit in this register is cleared (written with a '0'), the corresponding port pin's polarity is retained. A register pair write is described in [Section 8.1](#) and a register pair read is described in [Section 8.2](#).

**Table 11. Polarity inversion port 0 register (address 04h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | N0.7 | N0.6 | N0.5 | N0.4 | N0.3 | N0.2 | N0.1 | N0.0 |
| Default | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

**Table 12. Polarity inversion port 1 register (address 05h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | N1.7 | N1.6 | N1.5 | N1.4 | N1.3 | N1.2 | N1.1 | N1.0 |
| Default | 0    | 0    | 0    | 0    | 0    | 0    | 0    | 0    |

### 7.4.4 Configuration registers (06h, 07h)

The Configuration registers (registers 6 and 7) configure the direction of the I/O pins. If a bit in these registers is set to 1, the corresponding port pin is enabled as a high-impedance input. If a bit in these registers is cleared to 0, the corresponding port pin is enabled as an output. A register pair write is described in [Section 8.1](#) and a register pair read is described in [Section 8.2](#).

**Table 13. Configuration port 0 register (address 06h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | C0.7 | C0.6 | C0.5 | C0.4 | C0.3 | C0.2 | C0.1 | C0.0 |
| Default | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |

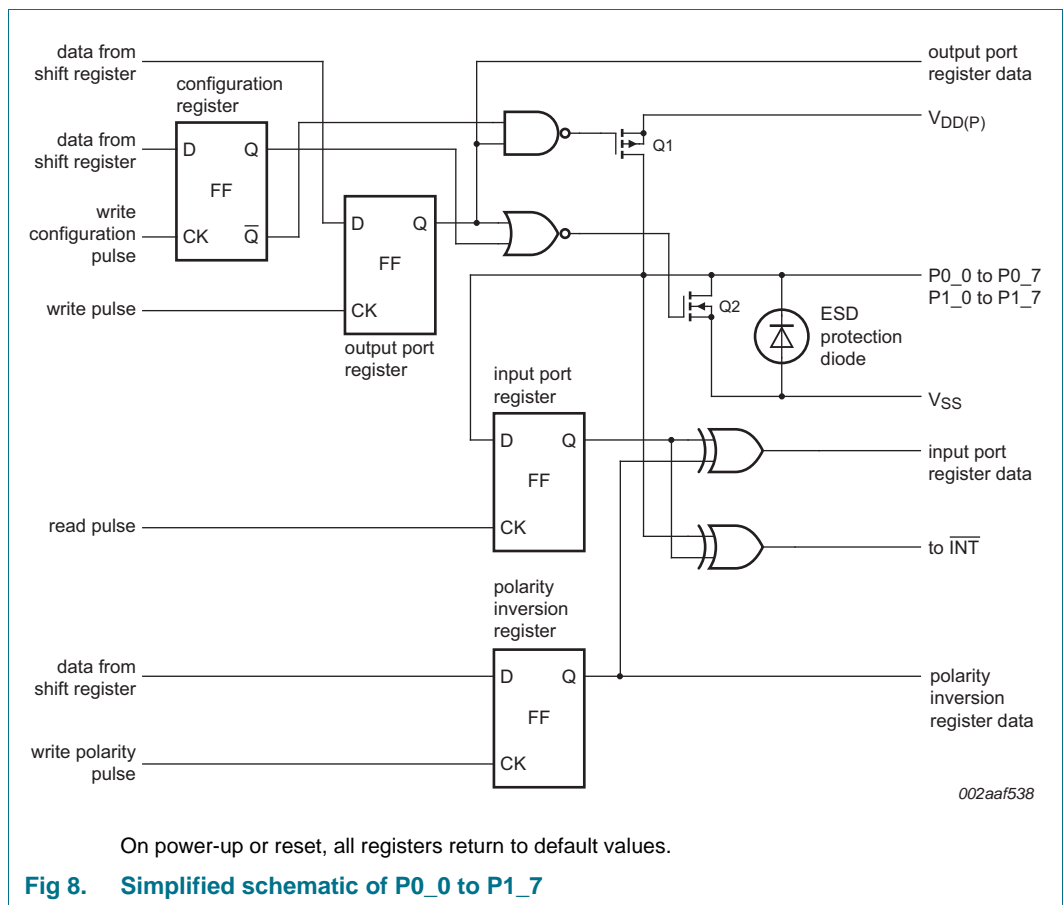
**Table 14. Configuration port 1 register (address 07h)**

| Bit     | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|---------|------|------|------|------|------|------|------|------|
| Symbol  | C1.7 | C1.6 | C1.5 | C1.4 | C1.3 | C1.2 | C1.1 | C1.0 |
| Default | 1    | 1    | 1    | 1    | 1    | 1    | 1    | 1    |

7.5 I/O port

When an I/O is configured as an input, FETs Q1 and Q2 are off, which creates a high-impedance input. The input voltage may be raised above V<sub>DD(P)</sub> to a maximum of 5.5 V.

If the I/O is configured as an output, Q1 or Q2 is enabled, depending on the state of the Output port register. In this case, there are low-impedance paths between the I/O pin and either V<sub>DD(P)</sub> or V<sub>SS</sub>. The external voltage applied to this I/O pin should not exceed the recommended levels for proper operation.



7.6 Power-on reset

When power (from 0 V) is applied to V<sub>DD(P)</sub>, an internal power-on reset holds the PCA6416A in a reset condition until V<sub>DD(P)</sub> has reached V<sub>POR</sub>. At that time, the reset condition is released and the PCA6416A registers and I<sup>2</sup>C-bus/SMBus state machine initializes to their default states. After that, V<sub>DD(P)</sub> must be lowered to below V<sub>POR</sub> and back up to the operating voltage for a power-reset cycle. See [Section 9.2 “Power-on reset requirements”](#).

## 7.7 Reset input ( $\overline{\text{RESET}}$ )

The  $\overline{\text{RESET}}$  input can be asserted to initialize the system while keeping the  $V_{\text{DD(P)}}$  at its operating level. A reset can be accomplished by holding the  $\overline{\text{RESET}}$  pin LOW for a minimum of  $t_{\text{w(rst)}}$ . The PCA6416A registers and I<sup>2</sup>C-bus/SMBus state machine are changed to their default state once  $\overline{\text{RESET}}$  is LOW (0). When  $\overline{\text{RESET}}$  is HIGH (1), the I/O levels at the P port can be changed externally or through the master. This input requires a pull-up resistor to  $V_{\text{DD(I2C-bus)}}$  if no active connection is used.

## 7.8 Interrupt output ( $\overline{\text{INT}}$ )

An interrupt is generated by any rising or falling edge of the port inputs in the Input mode. After time  $t_{\text{v(INT)}}$ , the signal  $\overline{\text{INT}}$  is valid. The interrupt is reset when data on the port changes back to the original value or when data is read from the port that generated the interrupt (see [Figure 12](#)). Resetting occurs in the Read mode at the acknowledge (ACK) or not acknowledge (NACK) bit after the rising edge of the SCL signal. Interrupts that occur during the ACK or NACK clock pulse can be lost (or be very short) due to the resetting of the interrupt during this pulse. Any change of the I/Os after resetting is detected and is transmitted as  $\overline{\text{INT}}$ .

A pin configured as an output cannot cause an interrupt. 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.

The  $\overline{\text{INT}}$  output has an open-drain structure and requires pull-up resistor to  $V_{\text{DD(P)}}$  or  $V_{\text{DD(I2C-bus)}}$  depending on the application.  $\overline{\text{INT}}$  should be connected to the voltage source of the device that requires the interrupt information.

# 8. Bus transactions

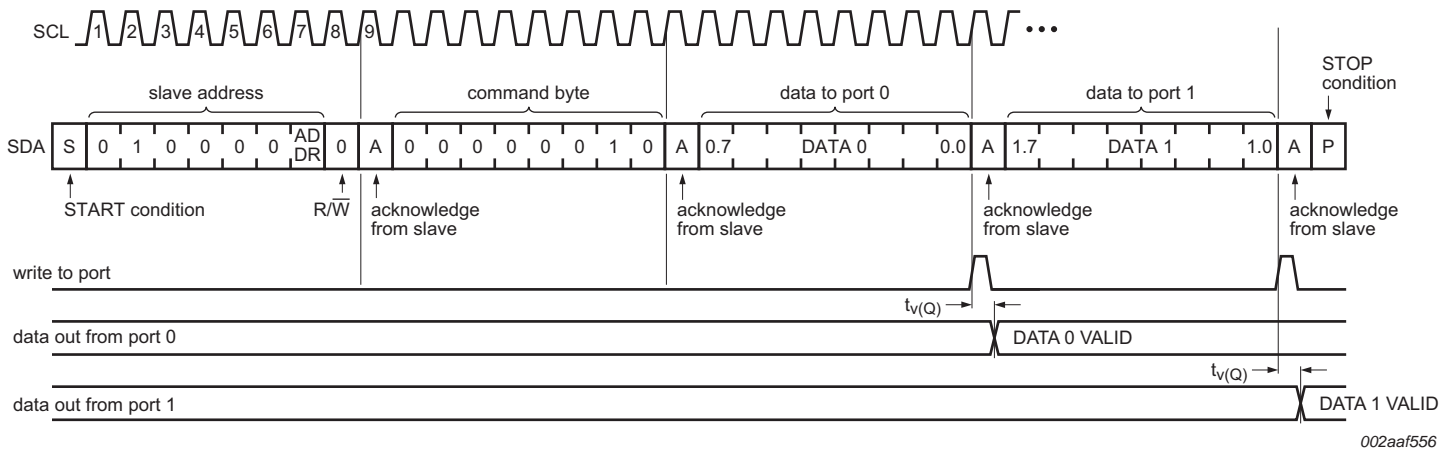
The PCA6416A is an I<sup>2</sup>C-bus slave device. Data is exchanged between the master and PCA6416A through write and read commands using I<sup>2</sup>C-bus. The two communication lines are a serial data line (SDA) and a serial clock line (SCL). Both lines must be connected to a positive supply via a pull-up resistor when connected to the output stages of a device. Data transfer may be initiated only when the bus is not busy.

## 8.1 Write commands

Data is transmitted to the PCA6416A by sending the device address and setting the Least Significant Bit (LSB) to a logic 0 (see [Figure 6](#) for device address). The command byte is sent after the address and determines which register receives the data that follows the command byte.

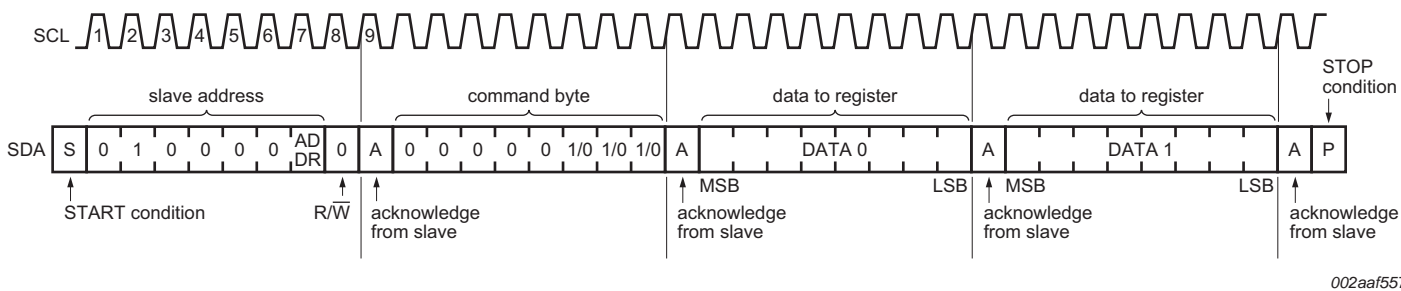
The eight registers within the PCA6416A are configured to operate as four register pairs. The four pairs are input ports, output ports, polarity inversion and configuration registers. After sending data to one register, the next data byte is sent to the other register in the pair (see [Figure 9](#) and [Figure 10](#)). For example, if the first byte is sent to Output Port 1 (register 3), the next byte is stored in Output Port 0 (register 2).

There is no limit on the number of data bytes sent in one write transmission. In this way, the host can continuously update a register pair independently of the other registers or the host can simply update a single register.



002aaf556

Fig 9. Write to Output port register



002aaf557

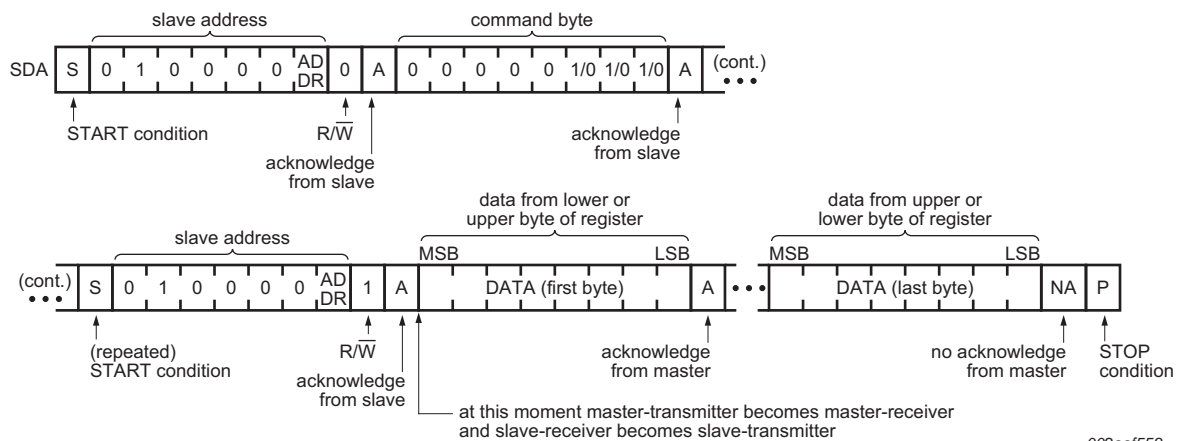
Fig 10. Write to device registers

### 8.2 Read commands

To read data from the PCA6416A, the bus master must first send the PCA6416A address with the least significant bit set to a logic 0 (see [Figure 6](#) for device address). The command byte is sent after the address and determines which register is to be accessed.

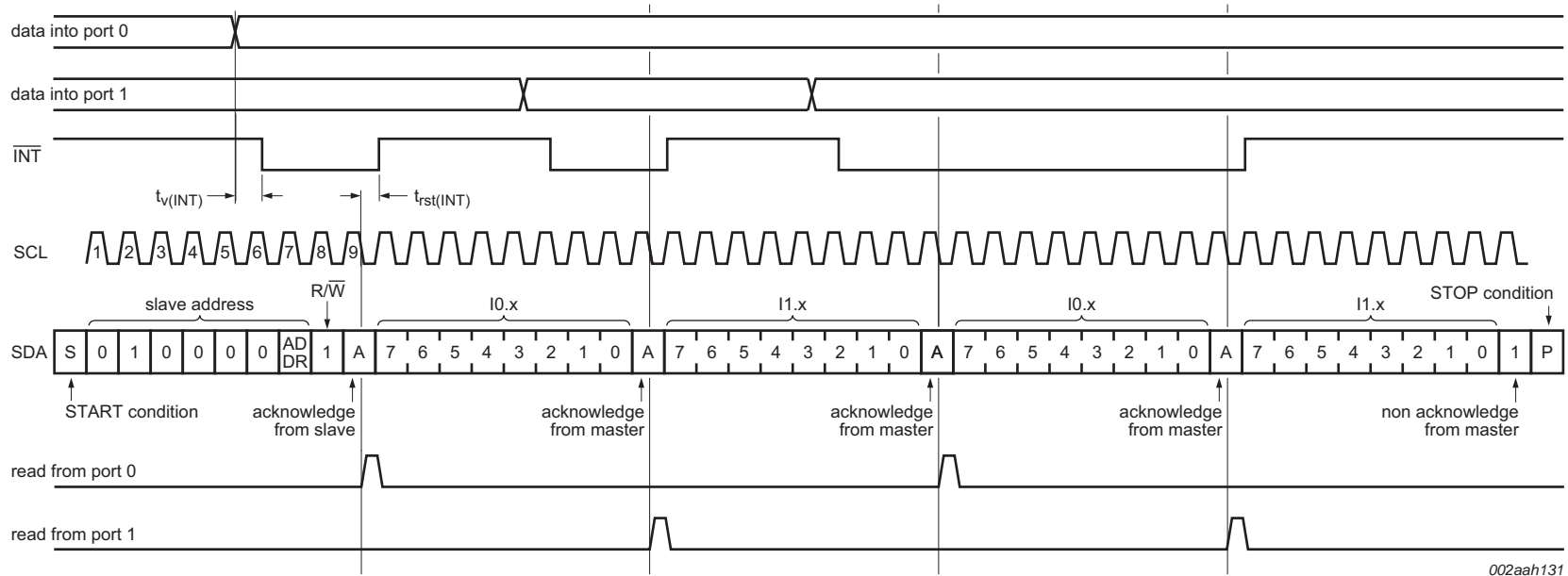
After a restart, the device address is sent again, but this time the least significant bit is set to a logic 1. Data from the register defined by the command byte is sent by the PCA6416A (see [Figure 11](#) and [Figure 12](#)). Data is clocked into the register on the rising edge of the ACK clock pulse. After the first byte is read, additional bytes may be read, but the data now reflects the information in the other register in the pair. For example, if Input Port 1 is read, the next byte read is Input Port 0. There is no limit on the number of data bytes received in one read transmission, but on the final byte received the bus master must not acknowledge the data.

After a subsequent restart, the command byte contains the value of the next register to be read in the pair. For example, if Input Port 1 was read last before the restart, the register that is read after the restart is the Input Port 0.



002aaf558

Fig 11. Read from device registers

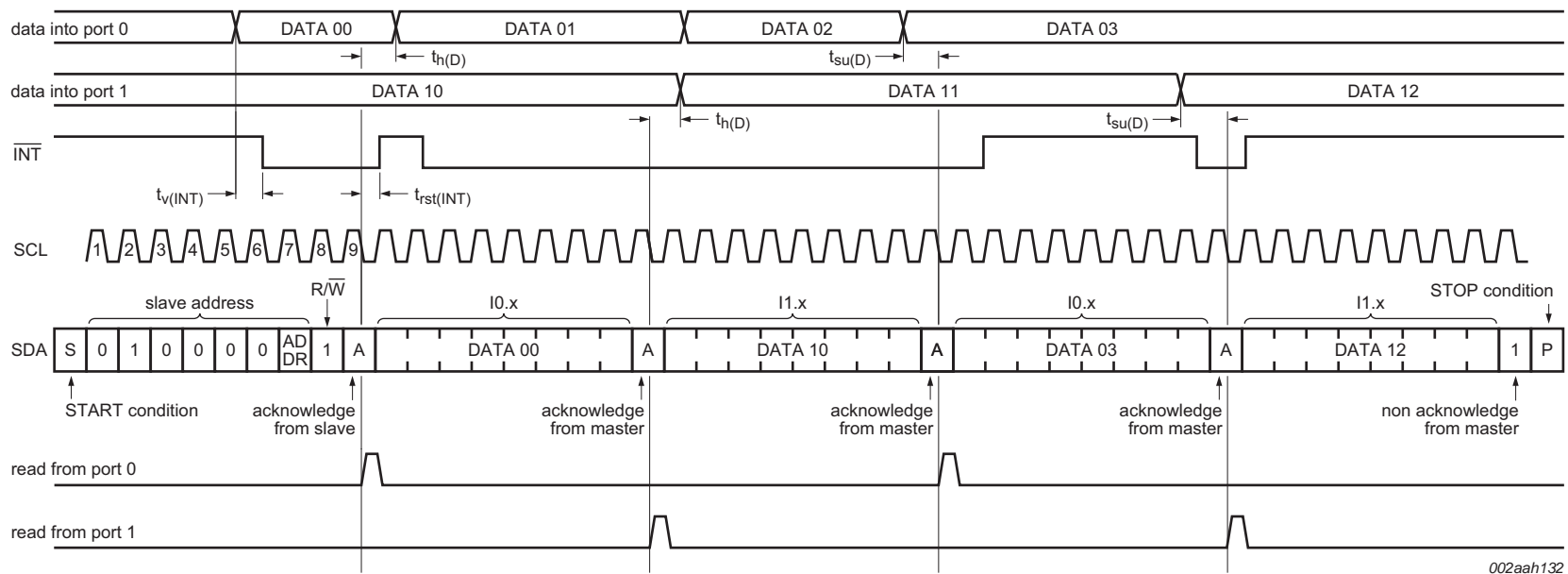


002aah131

**Remark:** Transfer of data can be stopped at any moment by a STOP condition. When this occurs, data present at the latest acknowledge phase is valid (output mode). It is assumed that the command byte has previously been set to '00' (read input port register).

This figure eliminates the command byte transfer and a restart between the initial slave address call and actual data transfer from P port (see [Figure 11](#)).

**Fig 12. Read input port register, scenario 1**



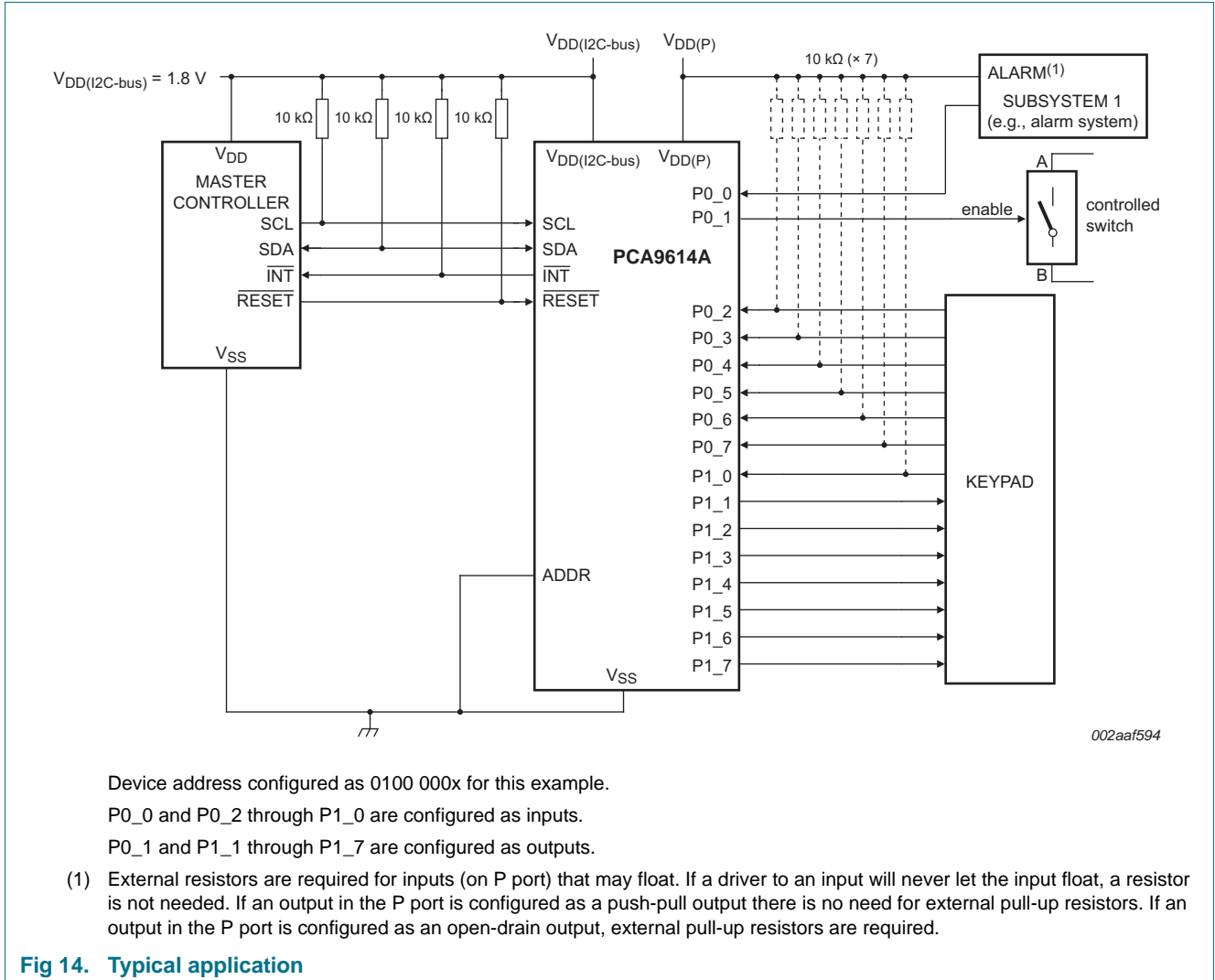
002aah132

**Remark:** Transfer of data can be stopped at any moment by a STOP condition. When this occurs, data present at the latest acknowledge phase is valid (output mode). It is assumed that the command byte has previously been set to '00' (read input port register).

This figure eliminates the command byte transfer and a restart between the initial slave address call and actual data transfer from P port (see [Figure 11](#)).

**Fig 13. Read input port register, scenario 2**

## 9. Application design-in information

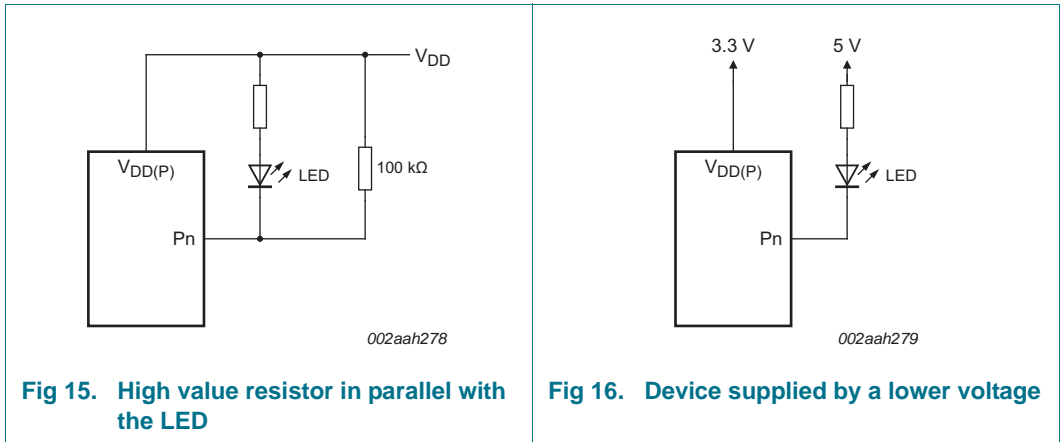


### 9.1 Minimizing I<sub>DD</sub> when the I/Os are used to control LEDs

When the I/Os are used to control LEDs, they are normally connected to V<sub>DD(P)</sub> through a resistor as shown in Figure 14. Since the LED acts as a diode, when the LED is off the I/O V<sub>I</sub> is about 1.2 V less than V<sub>DD(P)</sub>. The supply current, I<sub>DD(P)</sub>, increases as V<sub>I</sub> becomes lower than V<sub>DD(P)</sub>.

Designs needing to minimize current consumption, such as battery power applications, should consider maintaining the I/O pins greater than or equal to V<sub>DD(P)</sub> when the LED is off. Figure 15 shows a high value resistor in parallel with the LED. Figure 16 shows V<sub>DD(P)</sub> less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O V<sub>I</sub> at or above V<sub>DD(P)</sub> and prevents additional supply current consumption when the LED is off.

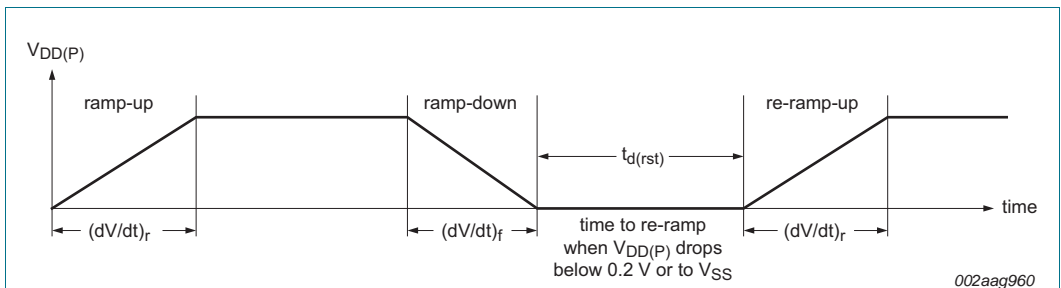




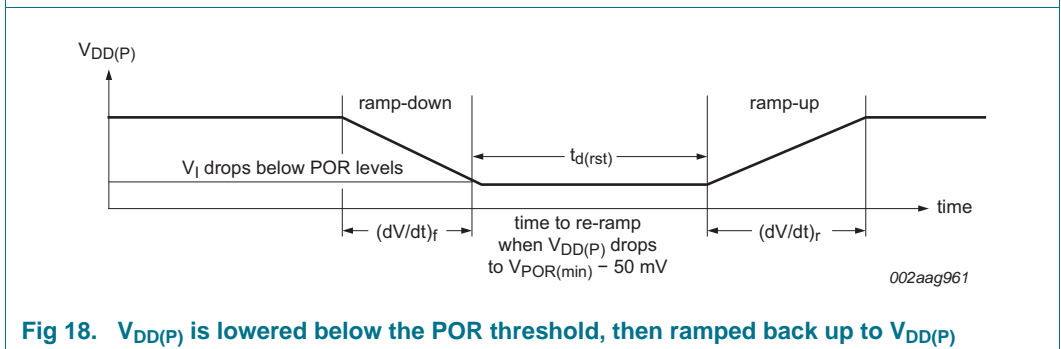
### 9.2 Power-on reset requirements

In the event of a glitch or data corruption, PCA6416A can be reset to its default conditions by using the power-on reset feature. Power-on reset requires that the device go through a power cycle to be completely reset. This reset also happens when the device is powered on for the first time in an application.

The two types of power-on reset are shown in [Figure 17](#) and [Figure 18](#).



**Fig 17. V<sub>DD(P)</sub> is lowered below 0.2 V or to 0 V and then ramped up to V<sub>DD(P)</sub>**



**Fig 18. V<sub>DD(P)</sub> is lowered below the POR threshold, then ramped back up to V<sub>DD(P)</sub>**

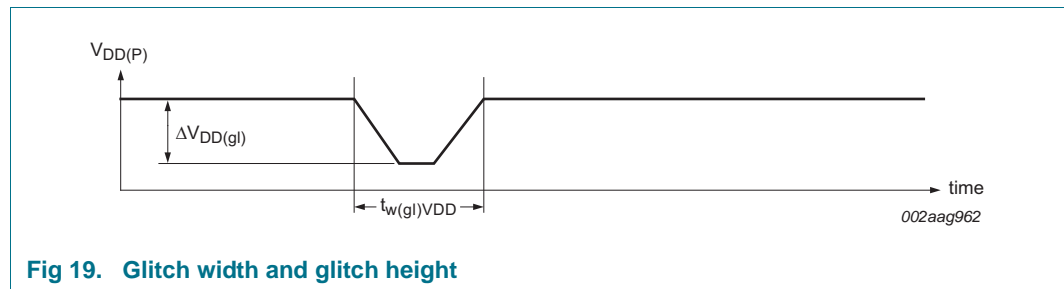
[Table 15](#) specifies the performance of the power-on reset feature for PCA6416A for both types of power-on reset.

**Table 15. Recommended supply sequencing and ramp rates**  
*T<sub>amb</sub> = 25 °C (unless otherwise noted). Not tested; specified by design.*

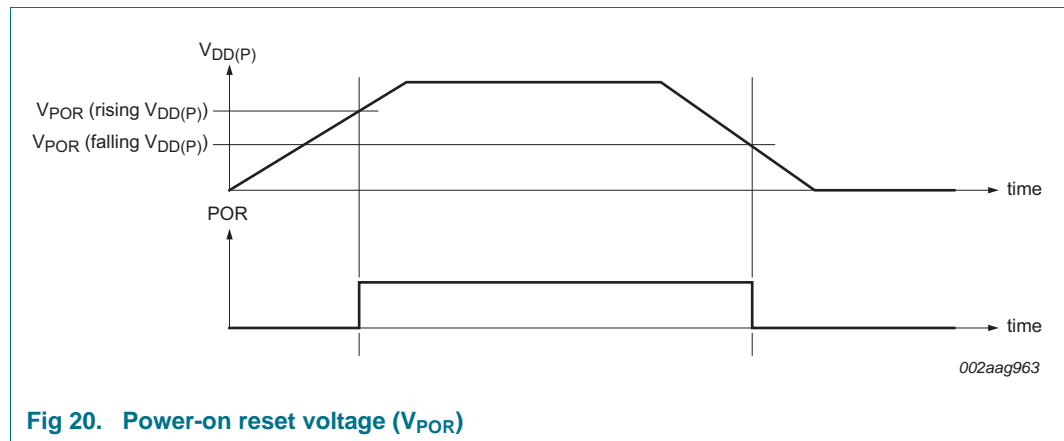
| Symbol                 | Parameter                         | Condition   | Min | Typ | Max  | Unit |
|------------------------|-----------------------------------|---|-----|-----|------|------|
| (dV/dt) <sub>f</sub>   | fall rate of change of voltage    | Figure 17   | 0.1 | -   | 2000 | ms   |
| (dV/dt) <sub>r</sub>   | rise rate of change of voltage    | Figure 17   | 0.1 | -   | 2000 | ms   |
| t <sub>d(rst)</sub>    | reset delay time                  | Figure 17; re-ramp time when V <sub>DD(P)</sub> drops below 0.2 V or to V <sub>SS</sub> | 1   | -   | -    | μs   |
|                        |                                   | Figure 18; re-ramp time when V <sub>DD(P)</sub> drops to V <sub>POR(min)</sub> - 50 mV  | 1   | -   | -    | μs   |
| ΔV <sub>DD(gl)</sub>   | glitch supply voltage difference  | Figure 19   | [1] | -   | 1.0  | V    |
| t <sub>w(gl)VDD</sub>  | supply voltage glitch pulse width | Figure 19   | [2] | -   | 10   | μs   |
| V <sub>POR(trip)</sub> | power-on reset trip voltage       | falling V <sub>DD(P)</sub>  | 0.7 | -   | -    | V    |
|                        |                                   | rising V <sub>DD(P)</sub>   | -   | -   | 1.4  | V    |

- [1] Level that V<sub>DD(P)</sub> can glitch down to with a ramp rate at 0.4 μs/V, but not cause a functional disruption when t<sub>w(gl)VDD</sub> < 1 μs.
- [2] Glitch width that will not cause a functional disruption when ΔV<sub>DD(gl)</sub> = 0.5 × V<sub>DD(P)</sub>.

Glitches in the power supply can also affect the power-on reset performance of this device. The glitch width (t<sub>w(gl)VDD</sub>) and glitch height (ΔV<sub>DD(gl)</sub>) are dependent on each other. The bypass capacitance, source impedance, and device impedance are factors that affect power-on reset performance. Figure 19 and Table 15 provide more information on how to measure these specifications.



V<sub>POR</sub> is critical to the power-on reset. V<sub>POR</sub> is the voltage level at which the reset condition is released and all the registers and the I<sup>2</sup>C-bus/SMBus state machine are initialized to their default states. The value of V<sub>POR</sub> differs based on the V<sub>DD</sub> being lowered to or from 0 V. Figure 20 and Table 15 provide more details on this specification.



## 10. Limiting values

**Table 16. Limiting values**
*In accordance with the Absolute Maximum Rating System (IEC 60134).*

| Symbol                   | Parameter                           | Conditions  | Min      | Max  | Unit |
|--------------------------|-------------------------------------|---|----------|------|------|
| V <sub>DD(I2C-bus)</sub> | I <sup>2</sup> C-bus supply voltage |   | -0.5     | +6.5 | V    |
| V <sub>DD(P)</sub>       | supply voltage port P               |   | -0.5     | +6.5 | V    |
| V <sub>I</sub>           | input voltage                       |   | [1] -0.5 | +6.5 | V    |
| V <sub>O</sub>           | output voltage                      |   | [1] -0.5 | +6.5 | V    |
| I <sub>IK</sub>          | input clamping current              | ADDR, $\overline{\text{RESET}}$ , SCL; V <sub>I</sub> < 0 V                                 | -        | ±20  | mA   |
| I <sub>OK</sub>          | output clamping current             | $\overline{\text{INT}}$ ; V <sub>O</sub> < 0 V  | -        | ±20  | mA   |
| I <sub>IOK</sub>         | input/output clamping current       | P port; V <sub>O</sub> < 0 V or V <sub>O</sub> > V <sub>DD(P)</sub>                         | -        | ±20  | mA   |
|                          |                                     | SDA; V <sub>O</sub> < 0 V or V <sub>O</sub> > V <sub>DD(I2C-bus)</sub>                      | -        | ±20  | mA   |
| I <sub>OL</sub>          | LOW-level output current            | continuous; P port; V <sub>O</sub> = 0 V to V <sub>DD(P)</sub>                              | -        | 50   | mA   |
|                          |                                     | continuous; SDA, $\overline{\text{INT}}$ ; V <sub>O</sub> = 0 V to V <sub>DD(I2C-bus)</sub> | -        | 25   | mA   |
| I <sub>OH</sub>          | HIGH-level output current           | continuous; P port; V <sub>O</sub> = 0 V to V <sub>DD(P)</sub>                              | -        | 25   | mA   |
| I <sub>DD</sub>          | supply current                      | continuous through V <sub>SS</sub>  | -        | 200  | mA   |
| I <sub>DD(P)</sub>       | supply current port P               | continuous through V <sub>DD(P)</sub>   | -        | 160  | mA   |
| I <sub>DD(I2C-bus)</sub> | I <sup>2</sup> C-bus supply current | continuous through V <sub>DD(I2C-bus)</sub>   | -        | 10   | mA   |
| T <sub>stg</sub>         | storage temperature                 |   | -65      | +150 | °C   |
| T <sub>j(max)</sub>      | maximum junction temperature        |   | -        | 125  | °C   |

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

## 11. Recommended operating conditions

**Table 17. Operating conditions**

| Symbol                   | Parameter                           | Conditions                          | Min                          | Max                          | Unit |
|--------------------------|-------------------------------------|-------------------------------------|------------------------------|------------------------------|------|
| V <sub>DD(I2C-bus)</sub> | I <sup>2</sup> C-bus supply voltage |                                     | 1.65                         | 5.5                          | V    |
| V <sub>DD(P)</sub>       | supply voltage port P               |                                     | 1.65                         | 5.5                          | V    |
| V <sub>IH</sub>          | HIGH-level input voltage            | SCL, SDA, $\overline{\text{RESET}}$ | $0.7 \times V_{DD(I2C-bus)}$ | 5.5                          | V    |
|                          |                                     | ADDR, P1_7 to P0_0                  | $0.7 \times V_{DD(P)}$       | 5.5                          | V    |
| V <sub>IL</sub>          | LOW-level input voltage             | SCL, SDA, $\overline{\text{RESET}}$ | -0.5                         | $0.3 \times V_{DD(I2C-bus)}$ | V    |
|                          |                                     | ADDR, P1_7 to P0_0                  | -0.5                         | $0.3 \times V_{DD(P)}$       | V    |
| I <sub>OH</sub>          | HIGH-level output current           | P1_7 to P0_0                        | -                            | 10                           | mA   |
| I <sub>OL</sub>          | LOW-level output current            | P1_7 to P0_0                        | -                            | 25                           | mA   |
| T <sub>amb</sub>         | ambient temperature                 | operating in free air               | -40                          | +85                          | °C   |

## 12. Thermal characteristics

Table 18. Thermal characteristics

| Symbol               | Parameter  | Conditions      | Max     | Unit |
|----------------------|--|-----------------|---------|------|
| Z <sub>th(j-a)</sub> | transient thermal impedance from junction to ambient | TSSOP24 package | [1] 88  | K/W  |
|                      |  | HWQFN24 package | [1] 66  | K/W  |
|                      |  | VFBGA24 package | [1] 171 | K/W  |

[1] The package thermal impedance is calculated in accordance with JESD 51-7.

## 13. Static characteristics

Table 19. Static characteristics

T<sub>amb</sub> = -40 °C to +85 °C; V<sub>DD(I<sup>2</sup>C-bus)</sub> = 1.65 V to 5.5 V; unless otherwise specified.

| Symbol           | Parameter  | Conditions   | Min     | Typ[1] | Max  | Unit |
|------------------|--|--|---------|--------|------|------|
| V <sub>IK</sub>  | input clamping voltage                               | I <sub>I</sub> = -18 mA  | -1.2    | -      | -    | V    |
| V <sub>POR</sub> | power-on reset voltage                               | V <sub>I</sub> = V <sub>DD(P)</sub> or V <sub>SS</sub> ; I <sub>O</sub> = 0 mA | -       | 1.1    | 1.4  | V    |
| V <sub>OH</sub>  | HIGH-level output voltage                            | P port   |         |        |      |      |
|                  |  | I <sub>OH</sub> = -8 mA; V <sub>DD(P)</sub> = 1.65 V                           | [2] 1.2 | -      | -    | V    |
|                  |  | I <sub>OH</sub> = -10 mA; V <sub>DD(P)</sub> = 1.65 V                          | [2] 1.1 | -      | -    | V    |
|                  |  | I <sub>OH</sub> = -8 mA; V <sub>DD(P)</sub> = 2.3 V                            | [2] 1.8 | -      | -    | V    |
|                  |  | I <sub>OH</sub> = -10 mA; V <sub>DD(P)</sub> = 2.3 V                           | [2] 1.7 | -      | -    | V    |
|                  |  | I <sub>OH</sub> = -8 mA; V <sub>DD(P)</sub> = 3.0 V                            | [2] 2.6 | -      | -    | V    |
|                  |  | I <sub>OH</sub> = -10 mA; V <sub>DD(P)</sub> = 3.0 V                           | [2] 2.5 | -      | -    | V    |
|                  |  | I <sub>OH</sub> = -8 mA; V <sub>DD(P)</sub> = 4.5 V                            | [2] 4.1 | -      | -    | V    |
|                  | I <sub>OH</sub> = -10 mA; V <sub>DD(P)</sub> = 4.5 V | [2] 4.0  | -       | -      | V    |      |
| V <sub>OL</sub>  | LOW-level output voltage                             | P port; I <sub>OL</sub> = 8 mA   |         |        |      |      |
|                  |  | V <sub>DD(P)</sub> = 1.65 V  | [2] -   | -      | 0.45 | V    |
|                  |  | V <sub>DD(P)</sub> = 2.3 V   | [2] -   | -      | 0.25 | V    |
|                  |  | V <sub>DD(P)</sub> = 3 V   | [2] -   | -      | 0.25 | V    |
|                  | V <sub>DD(P)</sub> = 4.5 V                           | [2] -  | -       | 0.2    | V    |      |
| I <sub>OL</sub>  | LOW-level output current                             | V <sub>OL</sub> = 0.4 V; V <sub>DD(P)</sub> = 1.65 V to 5.5 V                  |         |        |      |      |
|                  |  | SDA  | [3] 3   | -      | -    | mA   |
|                  |  | $\overline{\text{INT}}$  | [3] 3   | 15[4]  | -    | mA   |
|                  |  | P port   |         |        |      |      |
|                  |  | V <sub>OL</sub> = 0.5 V; V <sub>DD(P)</sub> = 1.65 V                           | [3] 8   | 10     | -    | mA   |
|                  |  | V <sub>OL</sub> = 0.7 V; V <sub>DD(P)</sub> = 1.65 V                           | [3] 10  | 13     | -    | mA   |
|                  |  | V <sub>OL</sub> = 0.5 V; V <sub>DD(P)</sub> = 2.3 V                            | [3] 8   | 10     | -    | mA   |
|                  |  | V <sub>OL</sub> = 0.7 V; V <sub>DD(P)</sub> = 2.3 V                            | [3] 10  | 13     | -    | mA   |
|                  |  | V <sub>OL</sub> = 0.5 V; V <sub>DD(P)</sub> = 3.0 V                            | [3] 8   | 14     | -    | mA   |
|                  |  | V <sub>OL</sub> = 0.7 V; V <sub>DD(P)</sub> = 3.0 V                            | [3] 10  | 19     | -    | mA   |
|                  | V <sub>OL</sub> = 0.5 V; V <sub>DD(P)</sub> = 4.5 V  | [3] 8  | 17      | -      | mA   |      |
|                  | V <sub>OL</sub> = 0.7 V; V <sub>DD(P)</sub> = 4.5 V  | [3] 10   | 24      | -      | mA   |      |

**Table 19. Static characteristics ...continued**

$T_{amb} = -40\text{ °C to }+85\text{ °C}$ ;  $V_{DD(I2C-bus)} = 1.65\text{ V to }5.5\text{ V}$ ; unless otherwise specified.

| Symbol  | Parameter                | Conditions  | Min                                 | Typ <sup>[1]</sup>   | Max     | Unit          |
|---|--------------------------|---|-------------------------------------|--|---------|---------------|
| $I_I$   | input current            | $V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$<br>SCL, SDA, $\overline{\text{RESET}}$ ; $V_I = V_{DD(I2C-bus)}$ or $V_{SS}$  | -                                   | -  | $\pm 1$ | $\mu\text{A}$ |
|   |                          | ADDR; $V_I = V_{DD(P)}$ or $V_{SS}$   | -                                   | -  | $\pm 1$ | $\mu\text{A}$ |
| $I_{IH}$  | HIGH-level input current | P port; $V_I = V_{DD(P)}$ ; $V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$   | -                                   | -  | 1       | $\mu\text{A}$ |
| $I_{IL}$  | LOW-level input current  | P port; $V_I = V_{SS}$ ; $V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$  | -                                   | -  | 1       | $\mu\text{A}$ |
| $I_{DD}$  | supply current           | $I_{DD(I2C-bus)} + I_{DD(P)}$ ;<br>SDA, P port, ADDR, $\overline{\text{RESET}}$ ;<br>$V_I$ on SDA and $\overline{\text{RESET}} = V_{DD(I2C-bus)}$ or $V_{SS}$ ;<br>$V_I$ on P port and ADDR = $V_{DD(P)}$ ;<br>$I_O = 0\text{ mA}$ ; I/O = inputs; $f_{SCL} = 400\text{ kHz}$<br>$V_{DD(P)} = 3.6\text{ V to }5.5\text{ V}$                   | -                                   | 10   | 25      | $\mu\text{A}$ |
|   |                          | $V_{DD(P)} = 2.3\text{ V to }3.6\text{ V}$  | -                                   | 6.5  | 15      | $\mu\text{A}$ |
|   |                          | $V_{DD(P)} = 1.65\text{ V to }2.3\text{ V}$   | -                                   | 4  | 9       | $\mu\text{A}$ |
|   |                          | $I_{DD(I2C-bus)} + I_{DD(P)}$ ;<br>SCL, SDA, P port, ADDR, $\overline{\text{RESET}}$ ;<br>$V_I$ on SCL, SDA and $\overline{\text{RESET}} = V_{DD(I2C-bus)}$ or $V_{SS}$ ;<br>$V_I$ on P port and ADDR = $V_{DD(P)}$ ;<br>$I_O = 0\text{ mA}$ ; I/O = inputs; $f_{SCL} = 0\text{ kHz}$<br>$V_{DD(P)} = 3.6\text{ V to }5.5\text{ V}$           | -                                   | 1.5  | 7       | $\mu\text{A}$ |
|   |                          | $V_{DD(P)} = 2.3\text{ V to }3.6\text{ V}$  | -                                   | 1  | 3.2     | $\mu\text{A}$ |
|   |                          | $V_{DD(P)} = 1.65\text{ V to }2.3\text{ V}$   | -                                   | 0.5  | 1.7     | $\mu\text{A}$ |
|   |                          | Active mode; $I_{DD(I2C-bus)} + I_{DD(P)}$ ;<br>P port, ADDR, $\overline{\text{RESET}}$ ;<br>$V_I$ on $\overline{\text{RESET}} = V_{DD(I2C-bus)}$ ;<br>$V_I$ on P port and ADDR = $V_{DD(P)}$ ;<br>$I_O = 0\text{ mA}$ ; I/O = inputs;<br>$f_{SCL} = 400\text{ kHz}$ , continuous register read<br>$V_{DD(P)} = 3.6\text{ V to }5.5\text{ V}$ | -                                   | 60   | 125     | $\mu\text{A}$ |
|   |                          | $V_{DD(P)} = 2.3\text{ V to }3.6\text{ V}$  | -                                   | 40   | 75      | $\mu\text{A}$ |
|   |                          | $V_{DD(P)} = 1.65\text{ V to }2.3\text{ V}$   | -                                   | 20   | 45      | $\mu\text{A}$ |
|   |                          | $\Delta I_{DD}$   | additional quiescent supply current | SCL, SDA, $\overline{\text{RESET}}$ ;<br>one input at $V_{DD(I2C-bus)} - 0.6\text{ V}$ ,<br>other inputs at $V_{DD(I2C-bus)}$ or $V_{SS}$ ;<br>$V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$ | -       | -             |
| P port, ADDR; one input at $V_{DD(P)} - 0.6\text{ V}$ ,<br>other inputs at $V_{DD(P)}$ or $V_{SS}$ ;<br>$V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$ | -                        |   |                                     | -  | 80      | $\mu\text{A}$ |
| $C_i$   | input capacitance        | $V_I = V_{DD(I2C-bus)}$ or $V_{SS}$ ; $V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$   | -                                   | 6  | 7       | pF            |
| $C_{iO}$  | input/output capacitance | $V_{I/O} = V_{DD(I2C-bus)}$ or $V_{SS}$ ; $V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$   | -                                   | 7  | 8       | pF            |
|   |                          | $V_{I/O} = V_{DD(P)}$ or $V_{SS}$ ; $V_{DD(P)} = 1.65\text{ V to }5.5\text{ V}$   | -                                   | 7.5  | 8.5     | pF            |

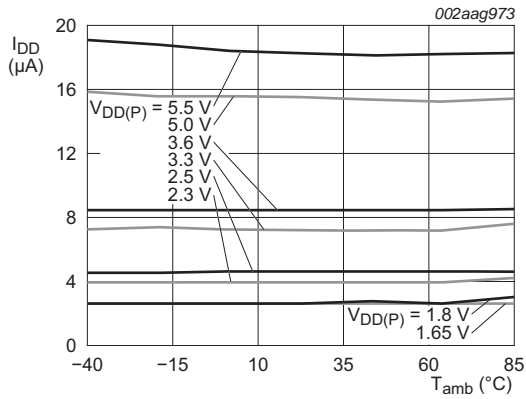
[1] For  $I_{DD}$ , all typical values are at nominal supply voltage (1.8 V, 2.5 V, 3.3 V, 3.6 V or 5 V  $V_{DD}$ ) and  $T_{amb} = 25\text{ °C}$ . Except for  $I_{DD}$ , the typical values are at  $V_{DD(P)} = V_{DD(I2C-bus)} = 3.3\text{ V}$  and  $T_{amb} = 25\text{ °C}$ .

[2] The total current sourced by all I/Os must be limited to 160 mA.

[3] Each I/O must be externally limited to a maximum of 25 mA, for a device total of 200 mA.

[4] Typical value for  $T_{amb} = 25\text{ °C}$ .  $V_{OL} = 0.4\text{ V}$  and  $V_{DD} = 3.3\text{ V}$ . Typical value for  $V_{DD} < 2.5\text{ V}$ ,  $V_{OL} = 0.6\text{ V}$ .

13.1 Typical characteristics



$$I_{DD} = I_{DD(I2C-bus)} + I_{DD(P)}$$

Fig 21. Supply current versus ambient temperature

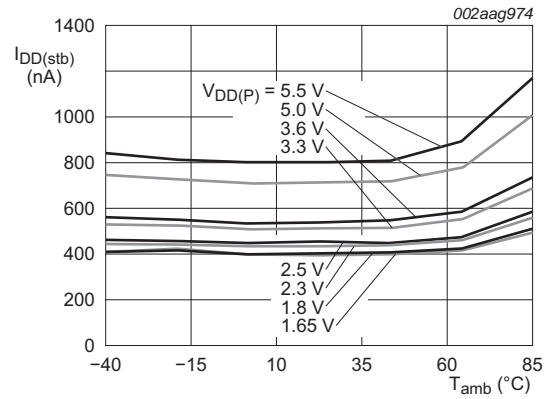
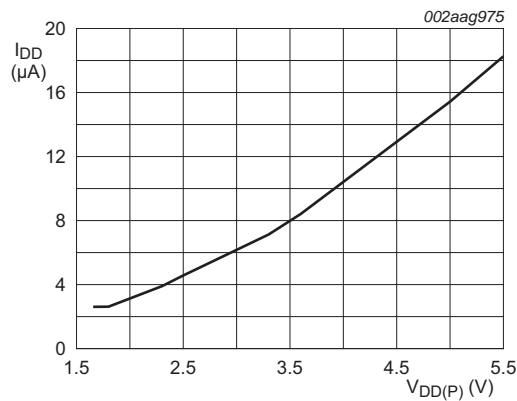


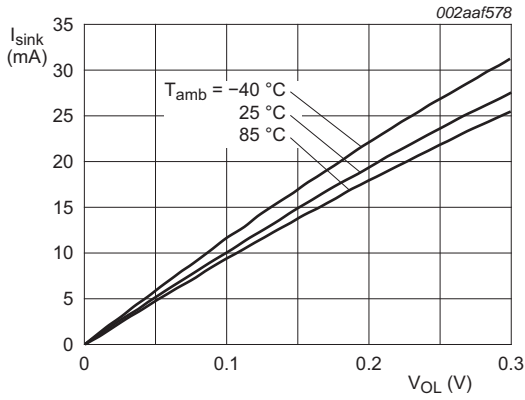
Fig 22. Standby supply current versus ambient temperature



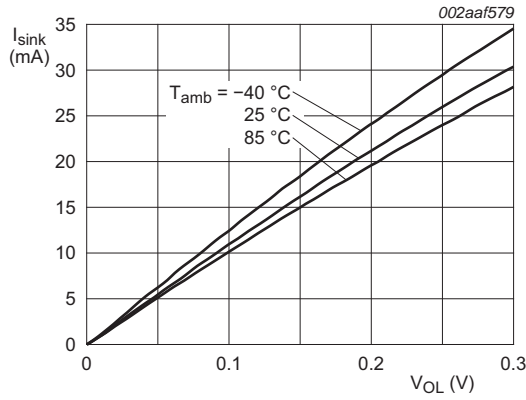
T<sub>amb</sub> = 25 °C

$$I_{DD} = I_{DD(I2C-bus)} + I_{DD(P)}$$

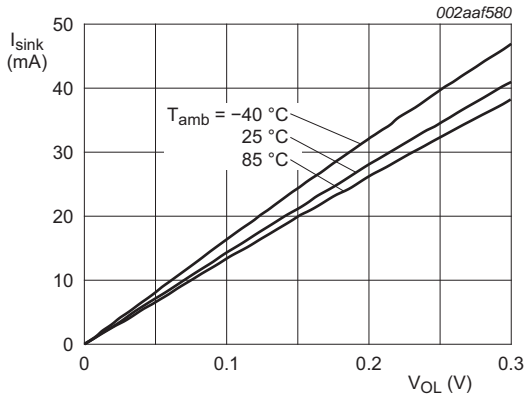
Fig 23. Supply current versus supply voltage



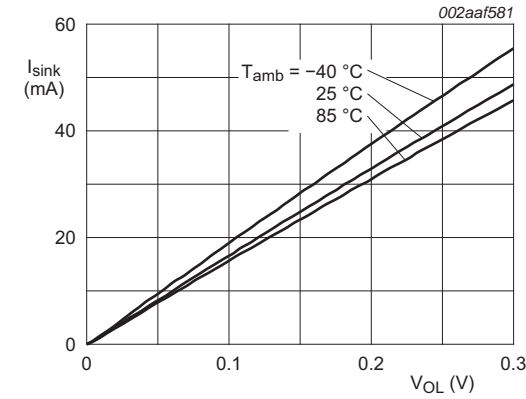
a.  $V_{DD(P)} = 1.65 \text{ V}$



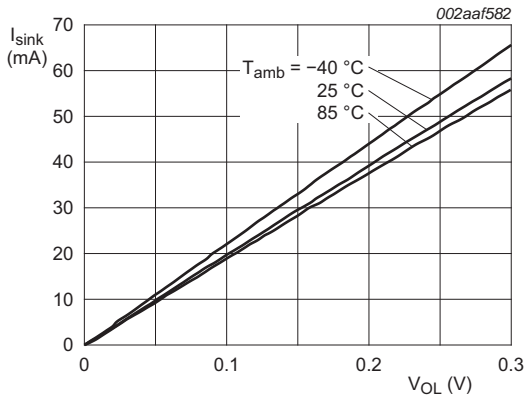
b.  $V_{DD(P)} = 1.8 \text{ V}$



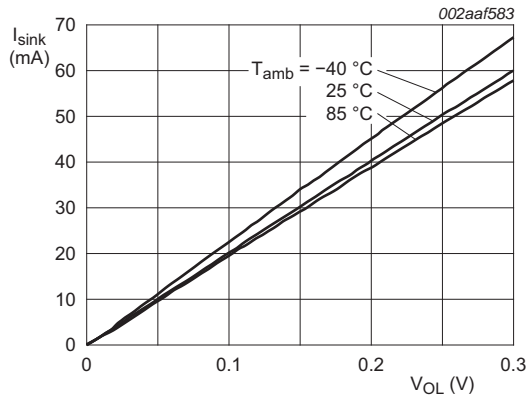
c.  $V_{DD(P)} = 2.5 \text{ V}$



d.  $V_{DD(P)} = 3.3 \text{ V}$

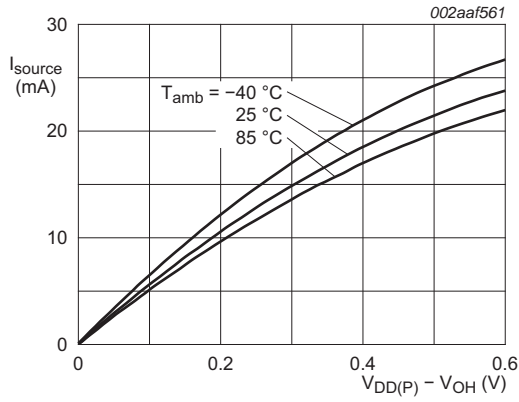


e.  $V_{DD(P)} = 5.0 \text{ V}$

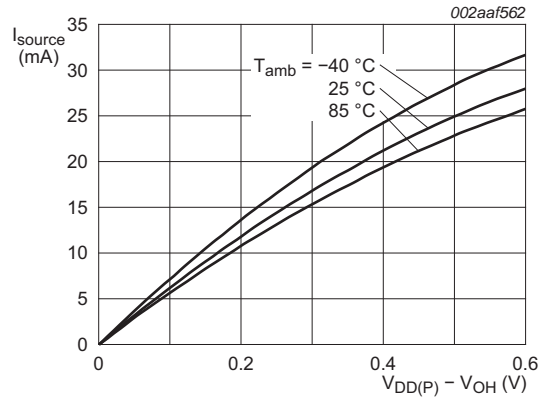


f.  $V_{DD(P)} = 5.5 \text{ V}$

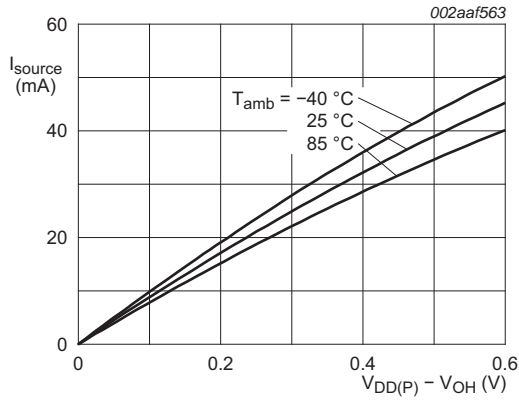
Fig 24. I/O sink current versus LOW-level output voltage



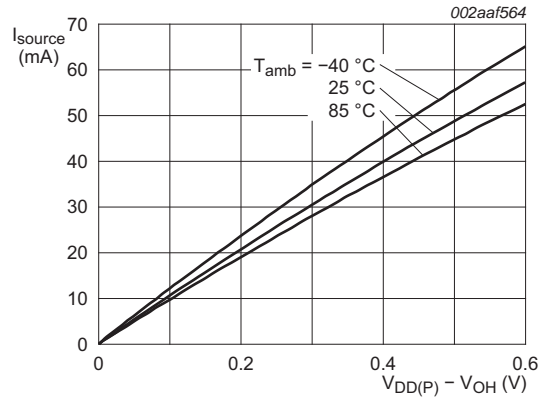
a.  $V_{DD(P)} = 1.65 \text{ V}$



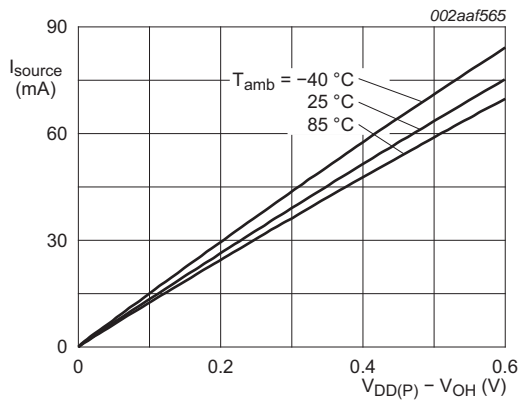
b.  $V_{DD(P)} = 1.8 \text{ V}$



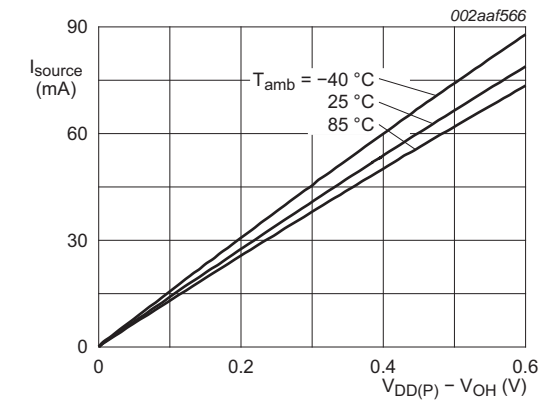
c.  $V_{DD(P)} = 2.5 \text{ V}$



d.  $V_{DD(P)} = 3.3 \text{ V}$



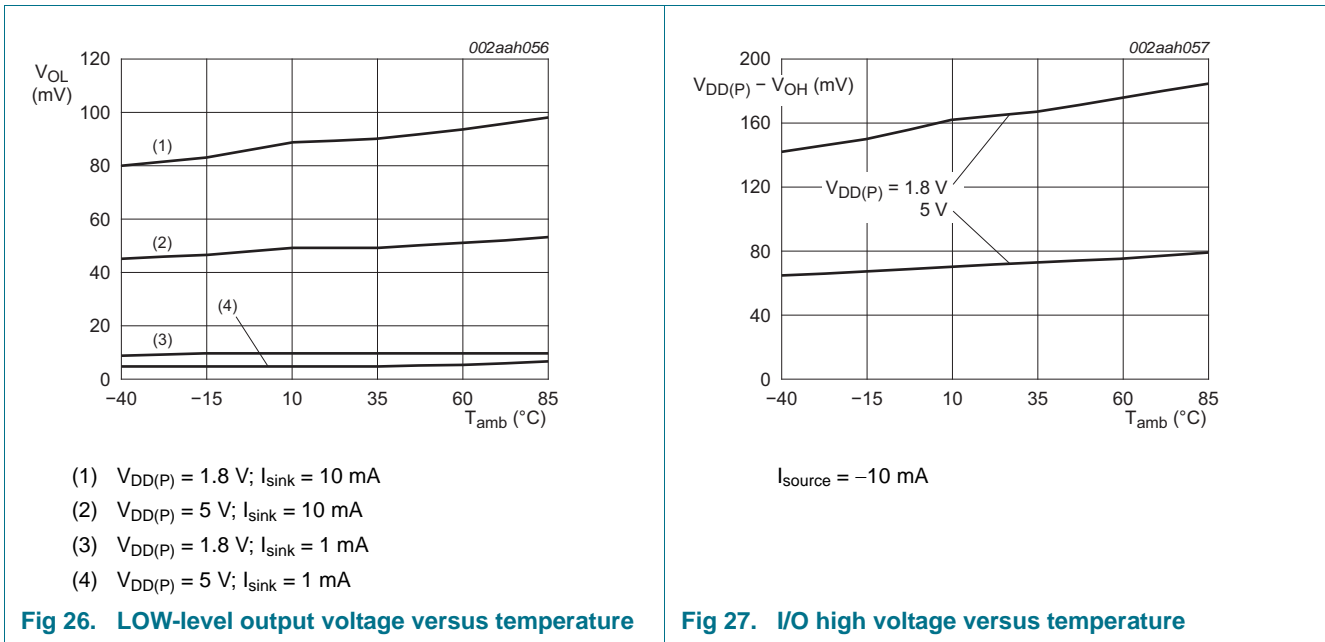
e.  $V_{DD(P)} = 5.0 \text{ V}$



f.  $V_{DD(P)} = 5.5 \text{ V}$

Fig 25. I/O source current versus HIGH-level output voltage





## 14. Dynamic characteristics

**Table 20. I<sup>2</sup>C-bus interface timing requirements**

Over recommended operating free air temperature range, unless otherwise specified. See [Figure 29](#).

| Symbol              | Parameter   | Conditions                               | Standard-mode I <sup>2</sup> C-bus |      | Fast-mode I <sup>2</sup> C-bus    |     | Unit |
|---------------------|---|--|------------------------------------|------|-----------------------------------|-----|------|
|                     |   |  | Min                                | Max  | Min                               | Max |      |
| f <sub>SCL</sub>    | SCL clock frequency   |  | 0                                  | 100  | 0                                 | 400 | kHz  |
| t <sub>HIGH</sub>   | HIGH period of the SCL clock                                      |  | 4                                  | -    | 0.6                               | -   | μs   |
| t <sub>LOW</sub>    | LOW period of the SCL clock                                       |  | 4.7                                | -    | 1.3                               | -   | μs   |
| t <sub>SP</sub>     | pulse width of spikes that must be suppressed by the input filter |  | 0                                  | 50   | 0                                 | 50  | ns   |
| t <sub>SU;DAT</sub> | data set-up time  |  | 250                                | -    | 100                               | -   | ns   |
| t <sub>HD;DAT</sub> | data hold time  |  | 0                                  | -    | 0                                 | -   | ns   |
| t <sub>r</sub>      | rise time of both SDA and SCL signals                             |  | -                                  | 1000 | 20                                | 300 | ns   |
| t <sub>f</sub>      | fall time of both SDA and SCL signals                             |  | -                                  | 300  | 20 ×<br>(V <sub>DD</sub> / 5.5 V) | 300 | ns   |
| t <sub>BUF</sub>    | bus free time between a STOP and START condition                  |  | 4.7                                | -    | 1.3                               | -   | μs   |
| t <sub>SU;STA</sub> | set-up time for a repeated START condition                        |  | 4.7                                | -    | 0.6                               | -   | μs   |
| t <sub>HD;STA</sub> | hold time (repeated) START condition                              |  | 4                                  | -    | 0.6                               | -   | μs   |
| t <sub>SU;STO</sub> | set-up time for STOP condition                                    |  | 4                                  | -    | 0.6                               | -   | μs   |
| t <sub>VD;DAT</sub> | data valid time   | SCL LOW to SDA output valid              | -                                  | 3.45 | -                                 | 0.9 | μs   |
| t <sub>VD;ACK</sub> | data valid acknowledge time                                       | ACK signal from SCL LOW to SDA (out) LOW | -                                  | 3.45 | -                                 | 0.9 | μs   |

**Table 21. Reset timing requirements**

Over recommended operating free air temperature range, unless otherwise specified. See [Figure 31](#).

| Symbol                | Parameter           | Conditions | Standard-mode I <sup>2</sup> C-bus |     | Fast-mode I <sup>2</sup> C-bus |     | Unit |
|-----------------------|---------------------|------------|------------------------------------|-----|--------------------------------|-----|------|
|                       |                     |            | Min                                | Max | Min                            | Max |      |
| t <sub>w(rst)</sub>   | reset pulse width   |            | 30                                 | -   | 30                             | -   | ns   |
| t <sub>rec(rst)</sub> | reset recovery time |            | 200                                | -   | 200                            | -   | ns   |
| t <sub>rst</sub>      | reset time          | [1]        | 600                                | -   | 600                            | -   | ns   |

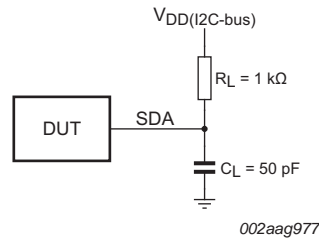
[1] Minimum time for SDA to become HIGH or minimum time to wait before doing a START.

**Table 22. Switching characteristics**

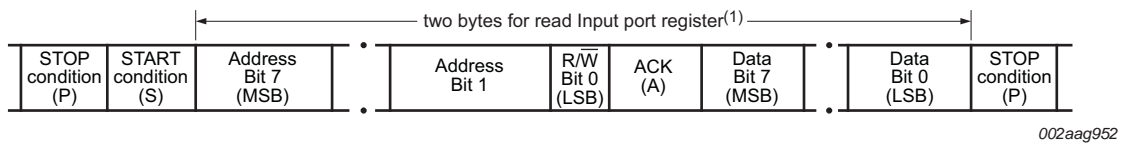
Over recommended operating free air temperature range;  $C_L \leq 100$  pF; unless otherwise specified. See [Figure 30](#).

| Symbol         | Parameter                          | Conditions                      | Standard-mode I <sup>2</sup> C-bus |     | Fast-mode I <sup>2</sup> C-bus |     | Unit    |
|----------------|------------------------------------|---------------------------------|------------------------------------|-----|--------------------------------|-----|---------|
|                |                                    |                                 | Min                                | Max | Min                            | Max |         |
| $t_{V(INT)}$   | valid time on pin $\overline{INT}$ | from P port to $\overline{INT}$ | -                                  | 1   | -                              | 1   | $\mu$ s |
| $t_{rst(INT)}$ | reset time on pin $\overline{INT}$ | from SCL to $\overline{INT}$    | -                                  | 1   | -                              | 1   | $\mu$ s |
| $t_{V(Q)}$     | data output valid time             | from SCL to P port              | -                                  | 400 | -                              | 400 | ns      |
| $t_{su(D)}$    | data input set-up time             | from P port to SCL              | 0                                  | -   | 0                              | -   | ns      |
| $t_h(D)$       | data input hold time               | from P port to SCL              | 300                                | -   | 300                            | -   | ns      |

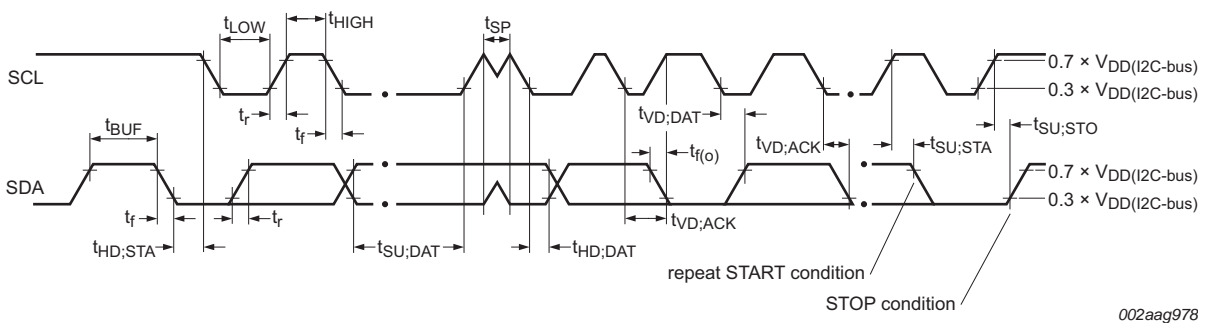
## 15. Parameter measurement information



### a. SDA load configuration



### b. Transaction format



### c. Voltage waveforms

$C_L$  includes probe and jig capacitance.

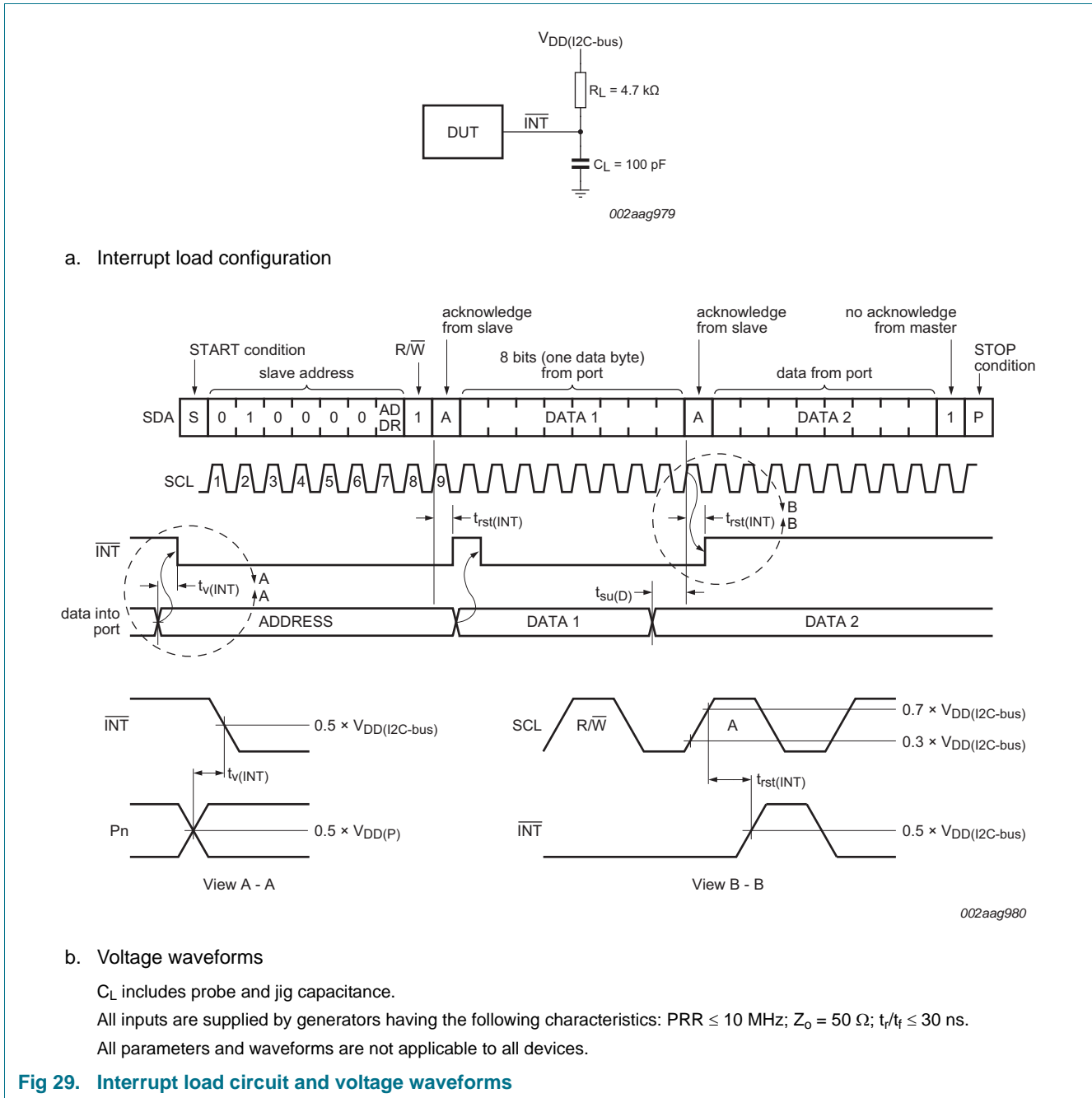
All inputs are supplied by generators having the following characteristics: PRR  $\leq$  10 MHz;  $Z_o = 50 \Omega$ ;  $t_r/t_f \leq 30$  ns.

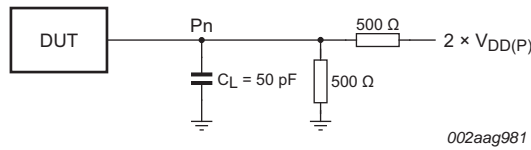
All parameters and waveforms are not applicable to all devices.

Byte 1 = I<sup>2</sup>C-bus address; Byte 2, byte 3 = P port data.

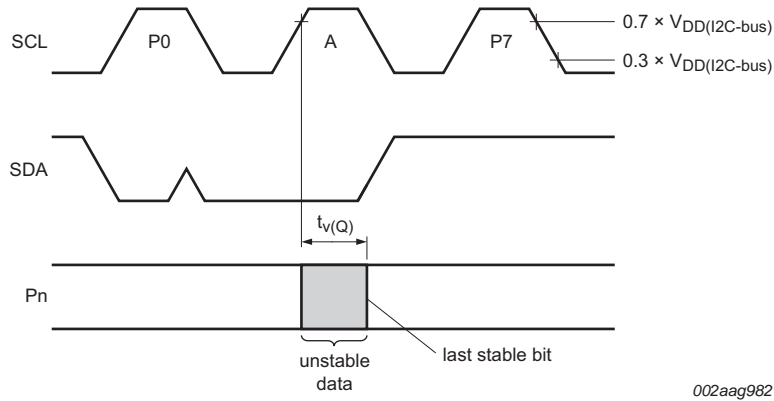
(1) See [Figure 12](#).

**Fig 28. I<sup>2</sup>C-bus interface load circuit and voltage waveforms**

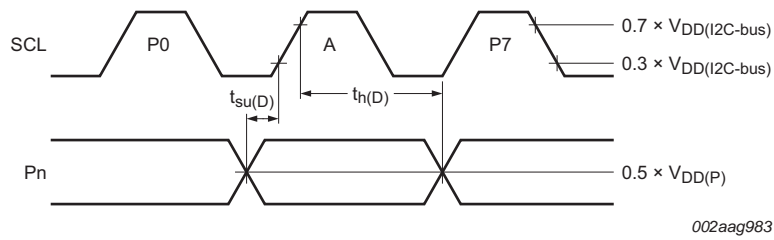




a. P port load configuration



b. Write mode ( $\overline{R/\overline{W}} = 0$ )



c. Read mode ( $\overline{R/\overline{W}} = 1$ )

$C_L$  includes probe and jig capacitance.

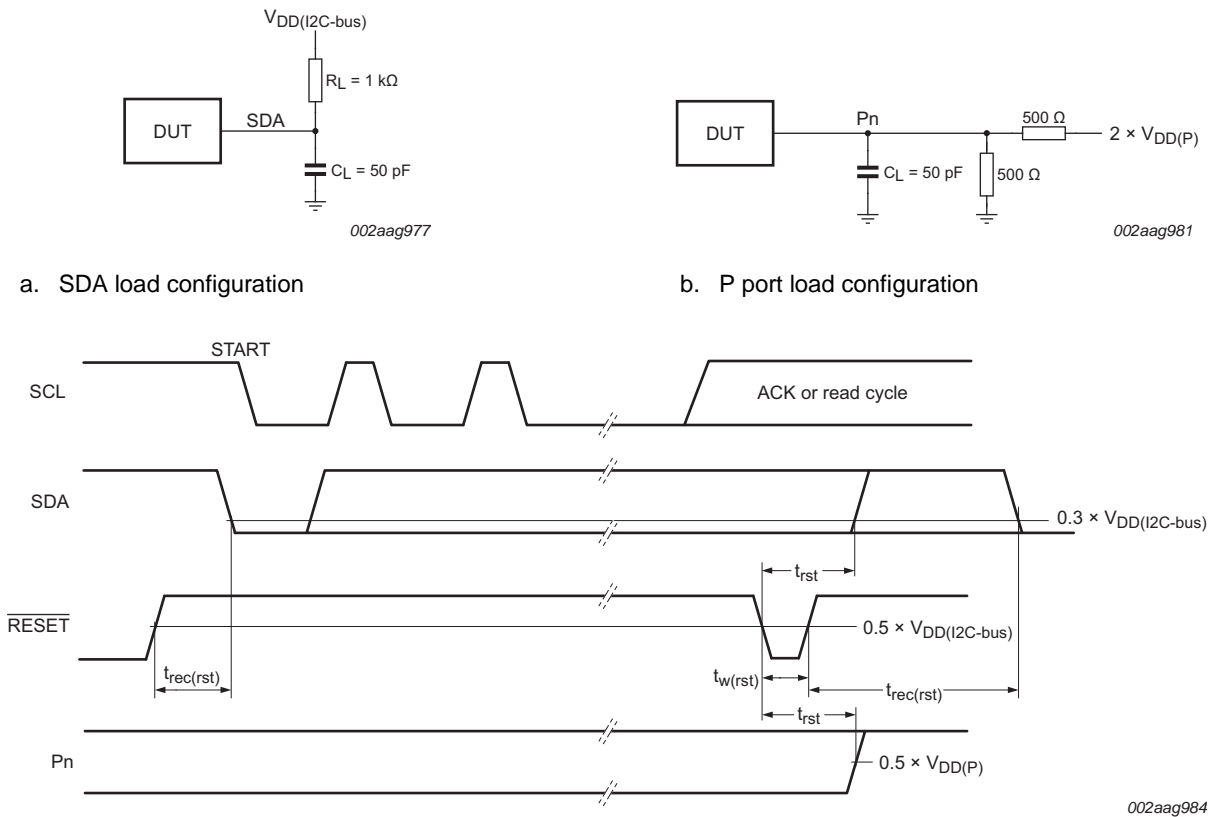
$t_{V(Q)}$  is measured from  $0.7 \times V_{DD(I2C-bus)}$  on SCL to 50 % I/O (Pn) output.

All inputs are supplied by generators having the following characteristics: PRR  $\leq$  10 MHz;  $Z_o = 50 \Omega$ ;  $t_r/t_f \leq 30$  ns.

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

All parameters and waveforms are not applicable to all devices.

**Fig 30. P port load circuit and voltage waveforms**



c. RESET timing

$C_L$  includes probe and jig capacitance.

All inputs are supplied by generators having the following characteristics:  $PRR \leq 10$  MHz;  $Z_o = 50 \Omega$ ;  $t_r/t_f \leq 30$  ns.

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

I/Os are configured as inputs.

All parameters and waveforms are not applicable to all devices.

Fig 31. Reset load circuits and voltage waveforms

16. Package outline

HWQFN24: plastic thermal enhanced very very thin quad flat package; no leads; 24 terminals; body 4 x 4 x 0.75 mm

SOT994-1

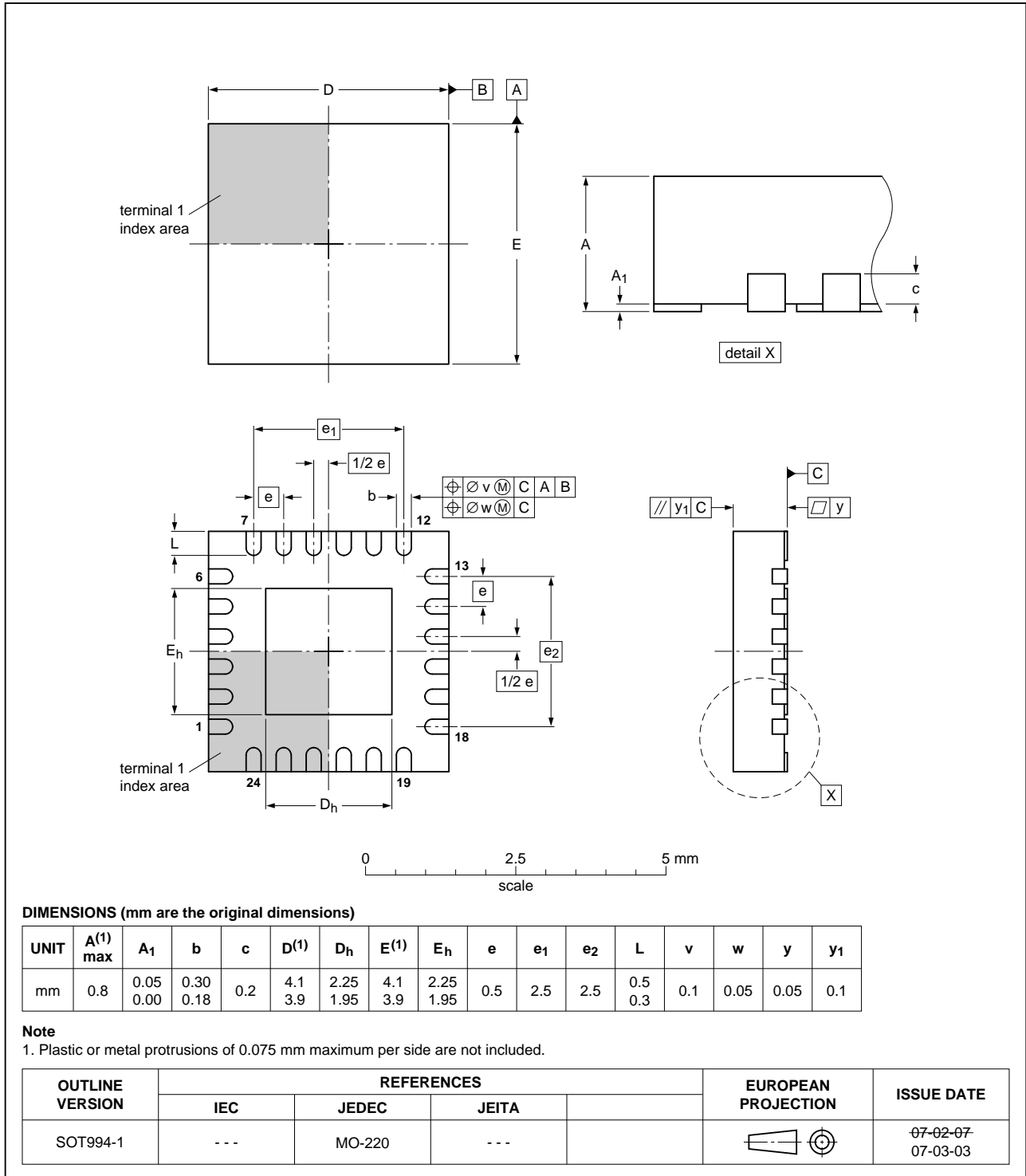


Fig 32. Package outline SOT994-1 (HWQFN24)

TSSOP24: plastic thin shrink small outline package; 24 leads; body width 4.4 mm

SOT355-1

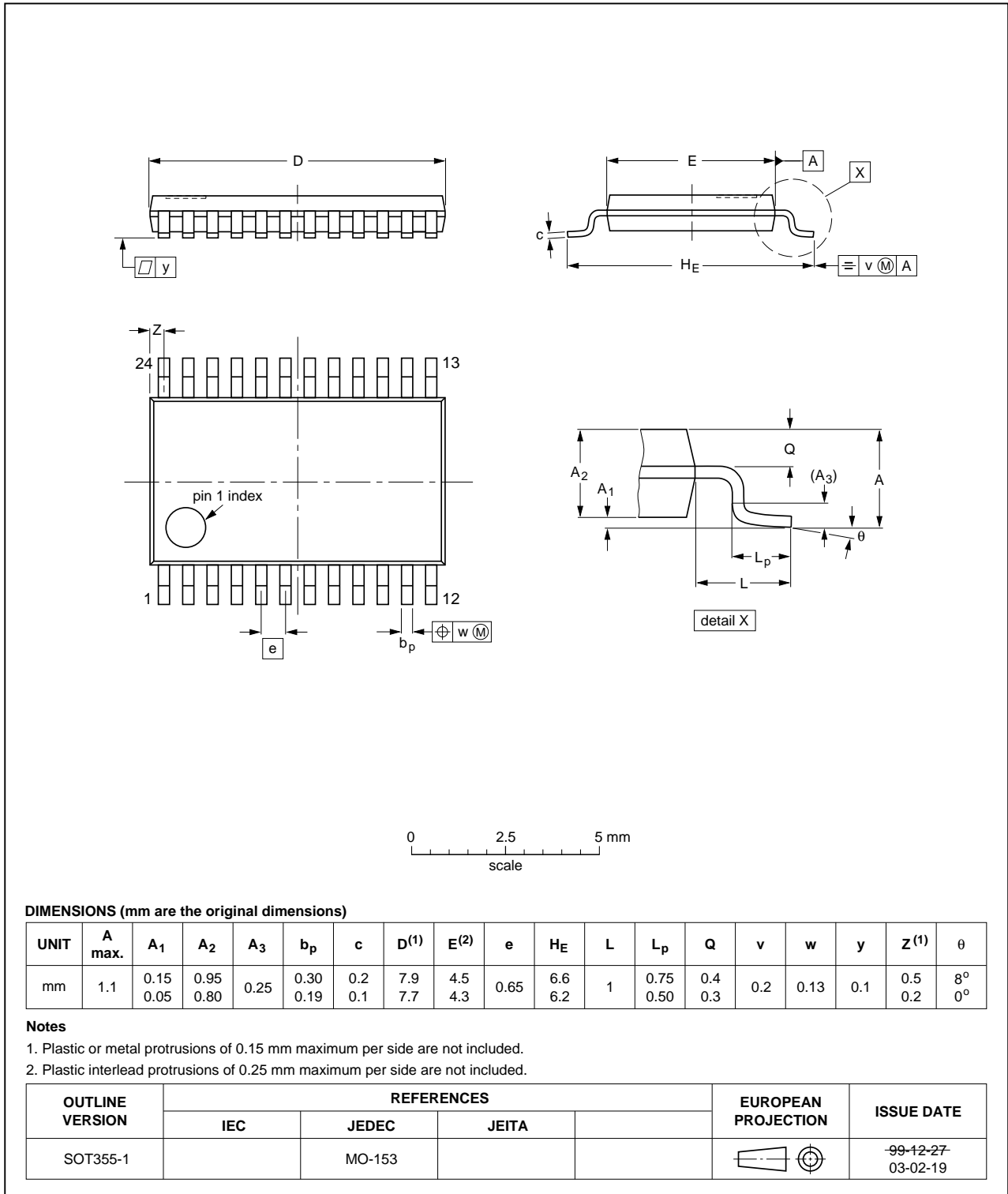


Fig 33. Package outline SOT355-1 (TSSOP24)



VFBGA24: plastic very thin fine-pitch ball grid array package;  
24 balls; body 3 x 3 x 0.85 mm

SOT1199-1

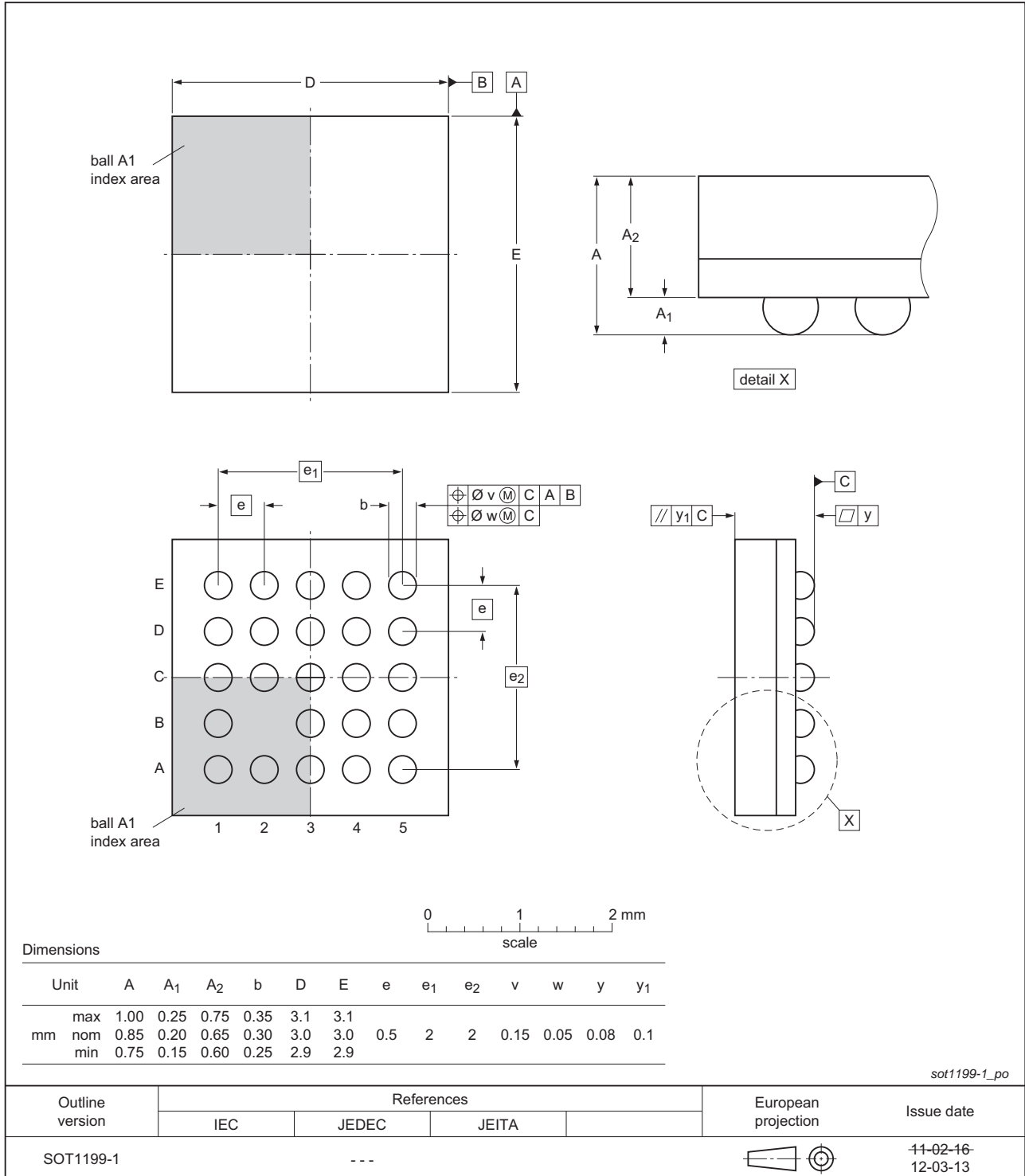


Fig 34. Package outline SOT1199-1 (VFBGA24)

## 17. 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"*.

### 17.1 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.

### 17.2 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

### 17.3 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

### 17.4 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 35](#)) 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 23](#) and [24](#)

**Table 23. SnPb eutectic process (from J-STD-020C)**

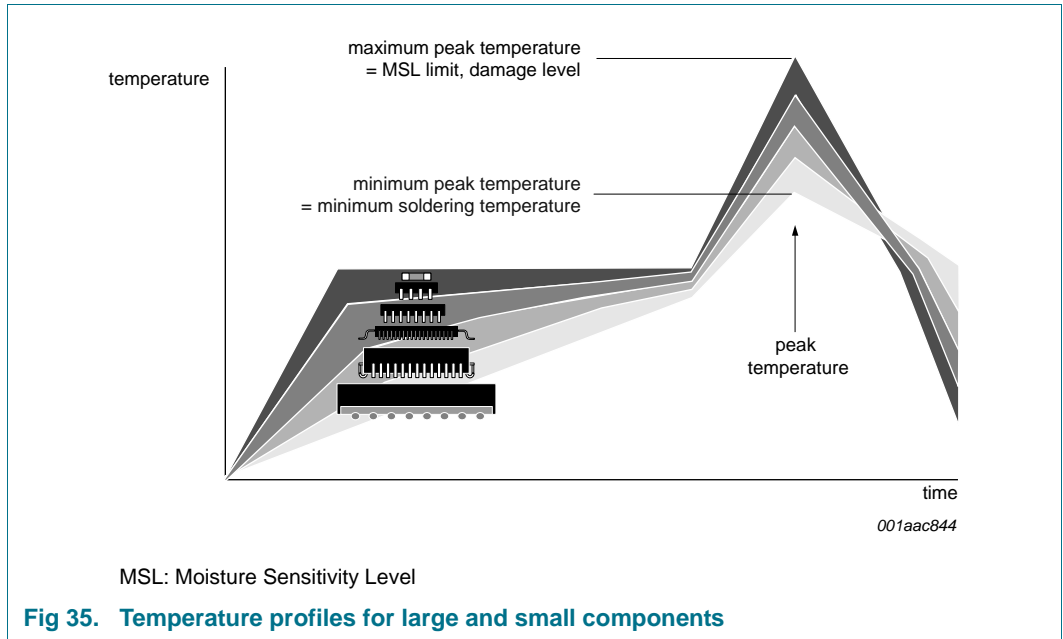
| Package thickness (mm) | Package reflow temperature (°C) |       |
|------------------------|---------------------------------|-------|
|                        | Volume (mm <sup>3</sup> )       |       |
|                        | < 350                           | ≥ 350 |
| < 2.5                  | 235                             | 220   |
| ≥ 2.5                  | 220                             | 220   |

**Table 24. Lead-free process (from J-STD-020C)**

| Package thickness (mm) | Package reflow temperature (°C) |             |        |
|------------------------|---------------------------------|-------------|--------|
|                        | Volume (mm <sup>3</sup> )       |             |        |
|                        | < 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 35](#).



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

### 18. Soldering: PCB footprints

Footprint information for reflow soldering of TSSOP24 package

SOT355-1

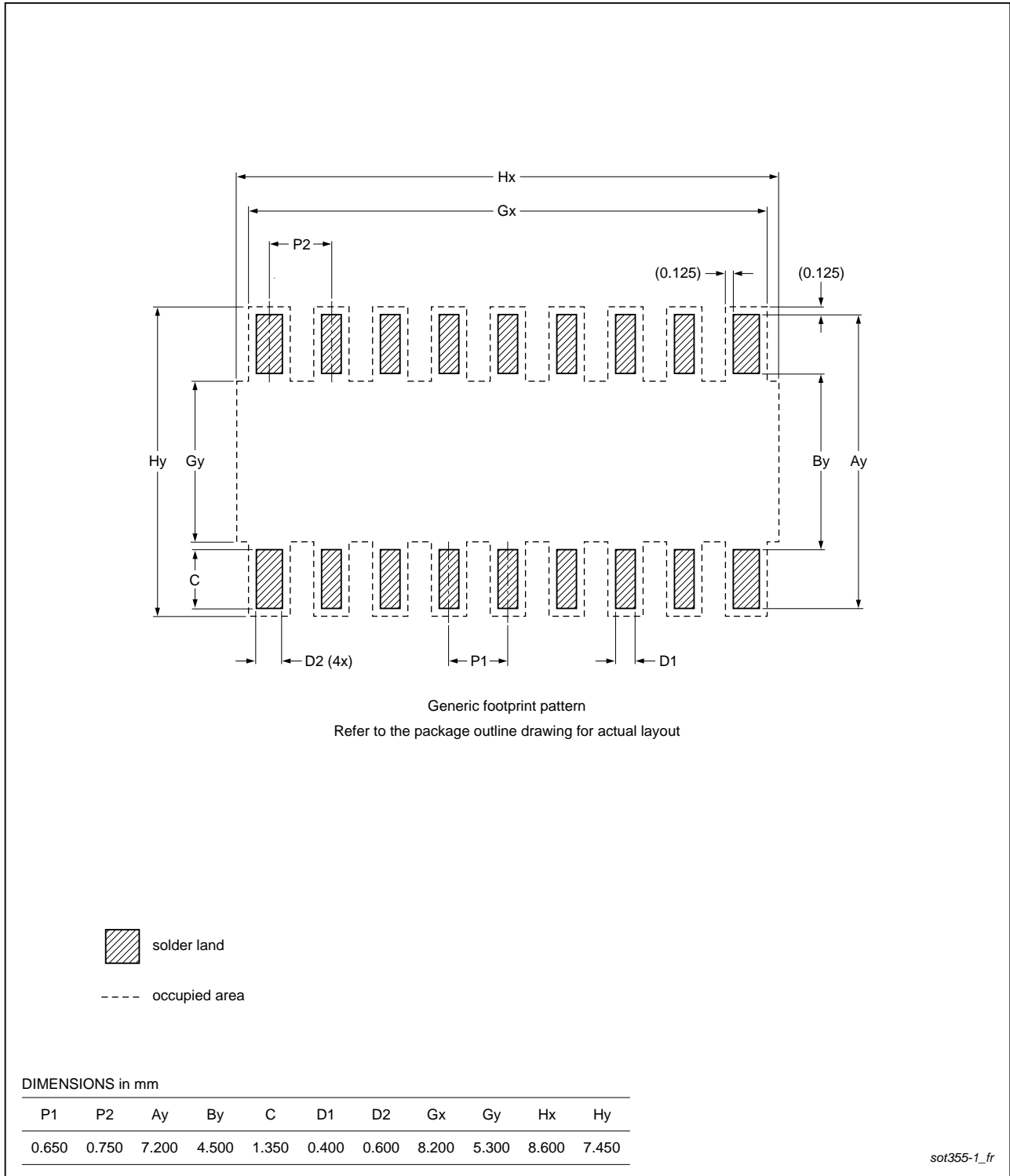


Fig 36. PCB footprint for SOT355-1 (TSSOP24); reflow soldering

Footprint information for reflow soldering of HVQFN24 package

SOT994-1

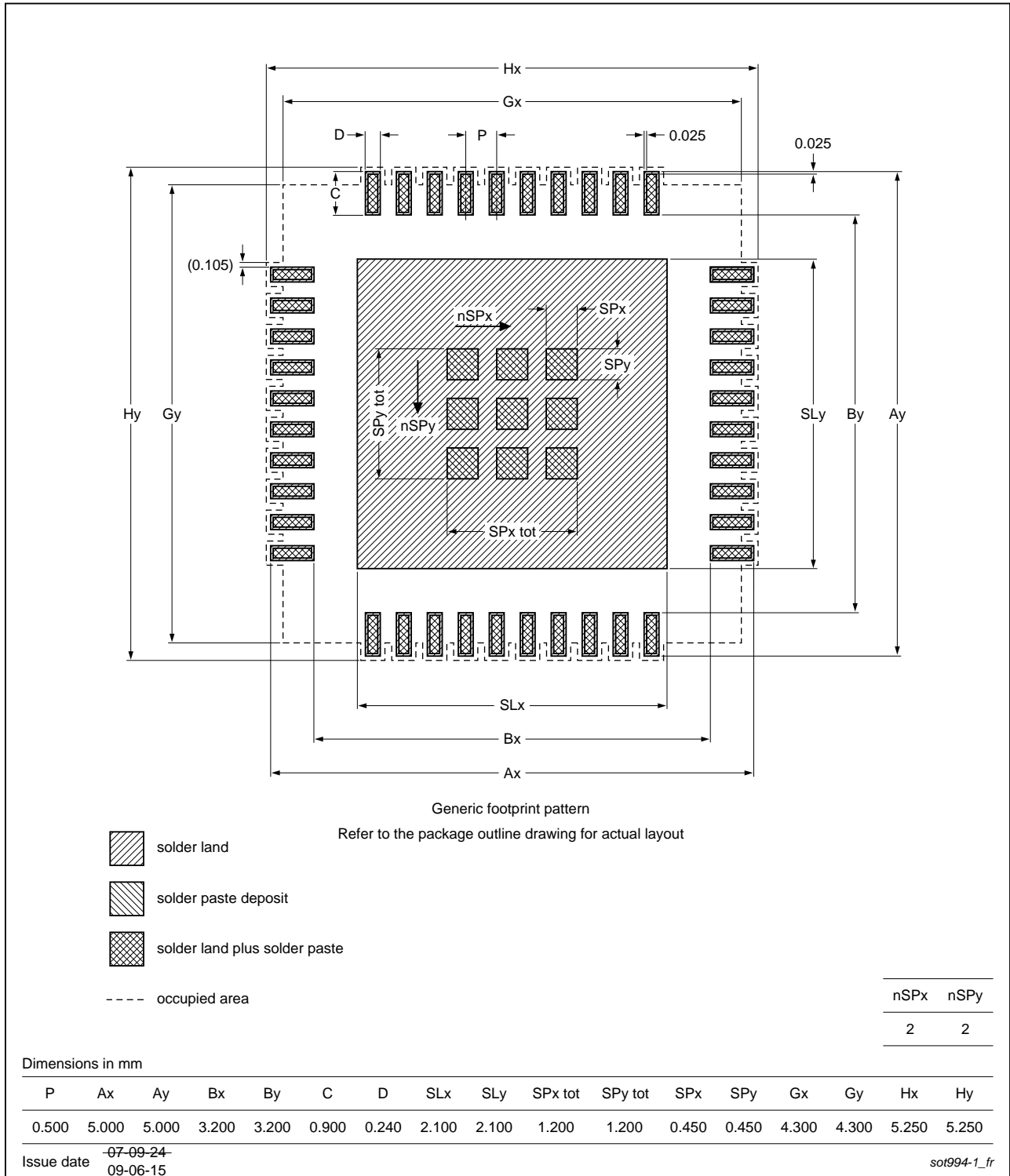


Fig 37. PCB footprint for SOT994-1 (HVQFN24); reflow soldering

## 19. Abbreviations

**Table 25. Abbreviations**

| Acronym              | Description                  |
|----------------------|------------------------------|
| ESD                  | ElectroStatic Discharge      |
| FET                  | Field-Effect Transistor      |
| GPIO                 | General Purpose Input/Output |
| I <sup>2</sup> C-bus | Inter-Integrated Circuit bus |
| I/O                  | Input/Output                 |
| LED                  | Light-Emitting Diode         |
| LSB                  | Least Significant Bit        |
| MSB                  | Most Significant Bit         |
| NACK                 | Not ACKnowledge              |
| PCB                  | Printed-Circuit Board        |
| POR                  | Power-On Reset               |
| PRR                  | Pulse Repetition Rate        |
| SMBus                | System Management Bus        |

## 20. Revision history

**Table 26. Revision history**

| Document ID    | Release date  | Data sheet status  | Change notice | Supersedes   |
|----------------|---|--------------------|---------------|--------------|
| PCA6416A v.2   | 20130110  | Product data sheet | -             | PCA6416A v.1 |
| Modifications: | <ul style="list-style-type: none"> <li>Updated <a href="#">Table 1 “Ordering information”</a>: added “Topside marking” column</li> <li>Updated <a href="#">Table 2 “Ordering options”</a>: added columns “Orderable part number”, “Packing method” and “Minimum order quantity”; topside marking column is moved to <a href="#">Table 1</a></li> <li><a href="#">Figure 3 “Pin configuration for HWQFN24”</a>: corrected type number from “PCA9416AHF” to “PCA6416AHF”</li> </ul> |                    |               |              |
| PCA6416A v.1   | 20120911  | Product data sheet | -             | -            |

## 21. Legal information

### 21.1 Data sheet status

| Document status <sup>[1][2]</sup> | Product status <sup>[3]</sup> | 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>.

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