



# PCA9538

## 8-bit I<sup>2</sup>C-bus and SMBus low power I/O port with interrupt and reset

Rev. 8 — 8 November 2017

Product data sheet

### 1. General description

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The PCA9538 is a 16-pin CMOS device that provides 8 bits of General Purpose parallel Input/Output (GPIO) expansion with interrupt and reset for I<sup>2</sup>C-bus/SMBus applications and was developed to enhance the NXP Semiconductors family of I<sup>2</sup>C-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 PCA9538 consists of an 8-bit Configuration register (input or output selection), 8-bit Input Port register, 8-bit Output Port register and an 8-bit Polarity Inversion register (active HIGH or active LOW operation). 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 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 master.

The PCA9538 is identical to the PCA9554 except for the removal of the internal I/O pull-up resistor which greatly reduces power consumption when the I/Os are held LOW, replacement of A2 with  $\overline{\text{RESET}}$  and different address range.

The PCA9538 open-drain interrupt output ( $\overline{\text{INT}}$ ) 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. The power-on reset sets the registers to their default values and initializes the device state machine. The  $\overline{\text{RESET}}$  pin causes the same reset/initialization to occur without de-powering the device.

Two hardware pins (A0 and A1) vary the fixed I<sup>2</sup>C-bus address and allow up to four devices to share the same I<sup>2</sup>C-bus/SMBus.

### 2. Features and benefits

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- 8-bit I<sup>2</sup>C-bus GPIO with interrupt and reset
- Operating power supply voltage range of 2.3 V to 5.5 V (3.0 V to 5.5 V for PCA9538PW/Q900)
- 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
- 8 I/O pins which default to 8 inputs
- 0 Hz to 400 kHz clock frequency
- ESD protection exceeds 2000 V HBM per JESD22-A114 and 1000 V CDM per JESD22-C101
- Latch-up testing is done to JEDEC Standard JESD78 which exceeds 100 mA
- Offered in three different packages: SO16, TSSOP16 and HVQFN16

### 3. Ordering information

Table 1. Ordering information

| Type number                   | Topside marking | Package |                                                                                                    |          |
|-------------------------------|-----------------|---------|----------------------------------------------------------------------------------------------------|----------|
|                               |                 | Name    | Description                                                                                        | Version  |
| PCA9538BS                     | 9538            | HVQFN16 | plastic thermal enhanced very thin quad flat package; no leads; 16 terminals; body 4 × 4 × 0.85 mm | SOT629-1 |
| PCA9538D                      | PCA9538D        | SO16    | plastic small outline package; 16 leads; body width 7.5 mm                                         | SOT162-1 |
| PCA9538PW                     | PCA9538         | TSSOP16 | plastic thin shrink small outline package; 16 leads; body width 4.4 mm                             | SOT403-1 |
| PCA9538PW/Q900 <sup>[1]</sup> | PCA9538         | TSSOP16 | plastic thin shrink small outline package; 16 leads; body width 4.4 mm                             | SOT403-1 |

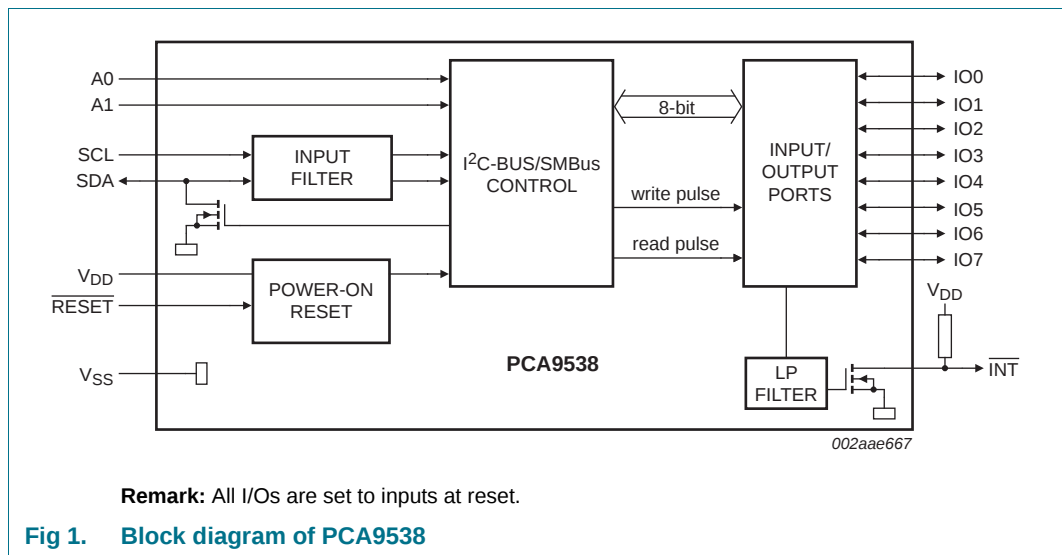
[1] PCA9538PW/Q900 is AEC-Q100 compliant. Contact [i2c.support@nxp.com](mailto:i2c.support@nxp.com) for PPAP.

#### 3.1 Ordering options

Table 2. Ordering options

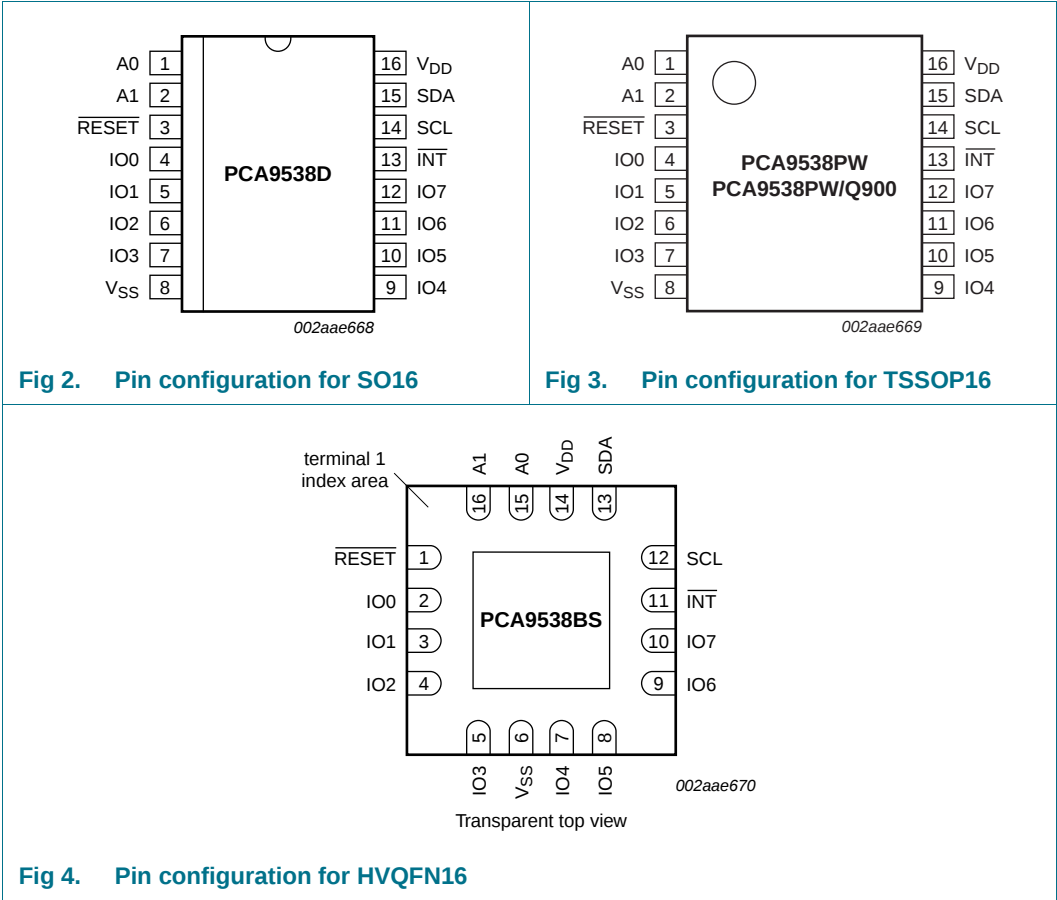
| Type number    | Orderable part number | Package | Packing method          | Minimum order quantity | Temperature                          |
|----------------|-----------------------|---------|-------------------------|------------------------|--------------------------------------|
| PCA9538BS      | PCA9538BS,118         | HVQFN16 | Reel pack, SMD, 13-inch | 6000                   | T <sub>amb</sub> = -40 °C to +85 °C  |
| PCA9538D       | PCA9538D,112          | SO16    | Tube, bulk pack         | 1920                   | T <sub>amb</sub> = -40 °C to +85 °C  |
|                | PCA9538D,118          | SO16    | Reel pack, SMD, 13-inch | 1000                   | T <sub>amb</sub> = -40 °C to +85 °C  |
| PCA9538PW      | PCA9538PW,112         | TSSOP16 | Tube, bulk pack         | 2400                   | T <sub>amb</sub> = -40 °C to +85 °C  |
|                | PCA9538PW,118         | TSSOP16 | Reel pack, SMD, 13-inch | 2500                   | T <sub>amb</sub> = -40 °C to +85 °C  |
| PCA9538PW/Q900 | PCA9538PW/Q900,118    | TSSOP16 | Reel pack, SMD, 13-inch | 2500                   | T <sub>amb</sub> = -40 °C to +125 °C |

## 4. Block diagram



5. Pinning information

5.1 Pinning



## 5.2 Pin description

Table 3. Pin description

| Symbol                    | Pin           |                  | Description                   |
|---------------------------|---------------|------------------|-------------------------------|
|                           | SO16, TSSOP16 | HVQFN16          |                               |
| A0                        | 1             | 15               | address input 0               |
| A1                        | 2             | 16               | address input 1               |
| $\overline{\text{RESET}}$ | 3             | 1                | active LOW reset input        |
| IO0                       | 4             | 2                | input/output 0                |
| IO1                       | 5             | 3                | input/output 1                |
| IO2                       | 6             | 4                | input/output 2                |
| IO3                       | 7             | 5                | input/output 3                |
| V <sub>SS</sub>           | 8             | 6 <sup>[1]</sup> | supply ground                 |
| IO4                       | 9             | 7                | input/output 4                |
| IO5                       | 10            | 8                | input/output 5                |
| IO6                       | 11            | 9                | input/output 6                |
| IO7                       | 12            | 10               | input/output 7                |
| $\overline{\text{INT}}$   | 13            | 11               | interrupt output (open-drain) |
| SCL                       | 14            | 12               | serial clock line             |
| SDA                       | 15            | 13               | serial data line              |
| V <sub>DD</sub>           | 16            | 14               | supply voltage                |

- [1] HVQFN16 package die supply ground is connected to both the V<sub>SS</sub> pin and the exposed center pad. The V<sub>SS</sub> pin must be connected to supply ground for proper device operation. For enhanced thermal, electrical, and board-level performance, the exposed pad needs to be soldered to the board using a corresponding thermal pad on the board, and for proper heat conduction through the board thermal vias need to be incorporated in the printed-circuit board in the thermal pad region.

## 6. Functional description

Refer to [Figure 1 “Block diagram of PCA9538”](#).

### 6.1 Device address

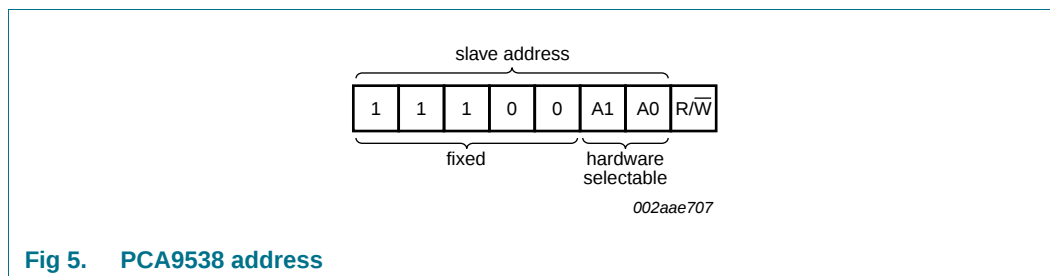


Fig 5. PCA9538 address

### 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 | X*    | value 'X' is determined by externally applied logic level |
| 6   | I6     | read only | X*    |                                                           |
| 5   | I5     | read only | X*    |                                                           |
| 4   | I4     | read only | X*    |                                                           |
| 3   | I3     | read only | X*    |                                                           |
| 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*    | reflects outgoing logic levels of pins defined as outputs by Register 3 |
| 6   | O6     | R      | 1*    |                                                                         |
| 5   | O5     | R      | 1*    |                                                                         |
| 4   | O4     | R      | 1*    |                                                                         |
| 3   | O3     | R      | 1*    |                                                                         |
| 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*    | inverts polarity of Input Port register data<br>0 = Input Port register data retained (default value)<br>1 = Input Port register data inverted |
| 6   | N6     | R/W    | 0*    |                                                                                                                                                |
| 5   | N5     | R/W    | 0*    |                                                                                                                                                |
| 4   | N4     | R/W    | 0*    |                                                                                                                                                |
| 3   | N3     | R/W    | 0*    |                                                                                                                                                |
| 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*    | configures the directions of the I/O pins<br><br>0 = corresponding port pin enabled as an output<br>1 = corresponding port pin configured as an input (default value) |
| 6   | C6     | R/W    | 1*    |                                                                                                                                                                       |
| 5   | C5     | R/W    | 1*    |                                                                                                                                                                       |
| 4   | C4     | R/W    | 1*    |                                                                                                                                                                       |
| 3   | C3     | R/W    | 1*    |                                                                                                                                                                       |
| 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 PCA9538 in a reset condition until  $V_{DD}$  has reached  $V_{POR}$ . At that point, the reset condition is released and the PCA9538 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  $t_{w(\text{rst})}$ . The PCA9538 registers and SMBus/I<sup>2</sup>C-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

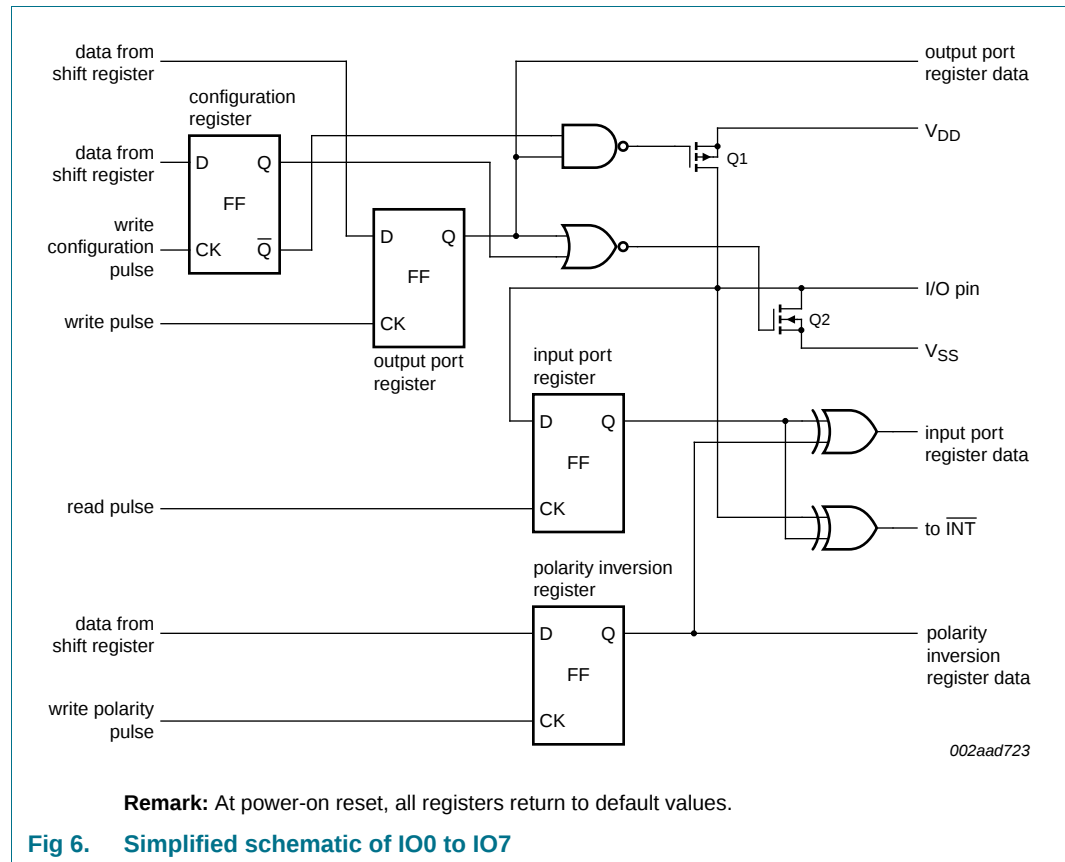
The open-drain interrupt output ( $\overline{\text{INT}}$ ) is activated when one of the port pins changes state and the pin is configured as an input. The interrupt is de-activated when the input returns to its previous state or the Input Port register is read.

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

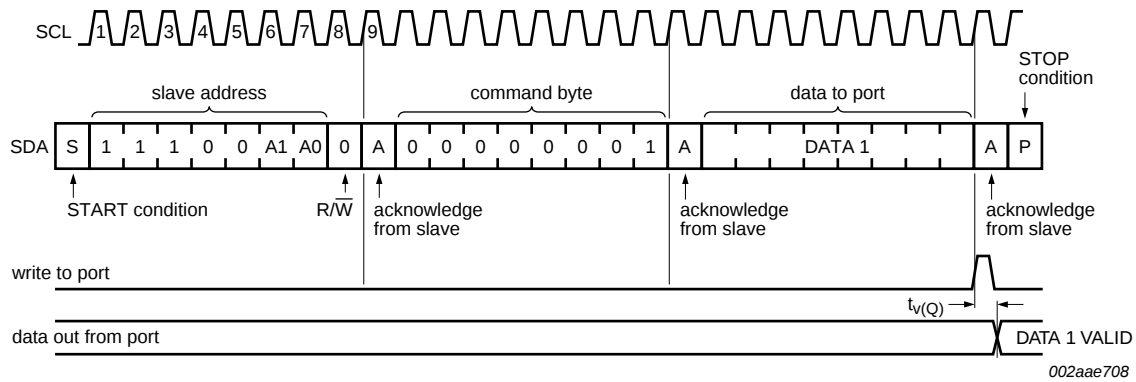
When an I/O is configured as an input, FETs Q1 and Q2 are off, creating a high-impedance input. The input voltage may be raised above  $V_{DD}$  to a maximum of 5.5 V.

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  $V_{SS}$ .

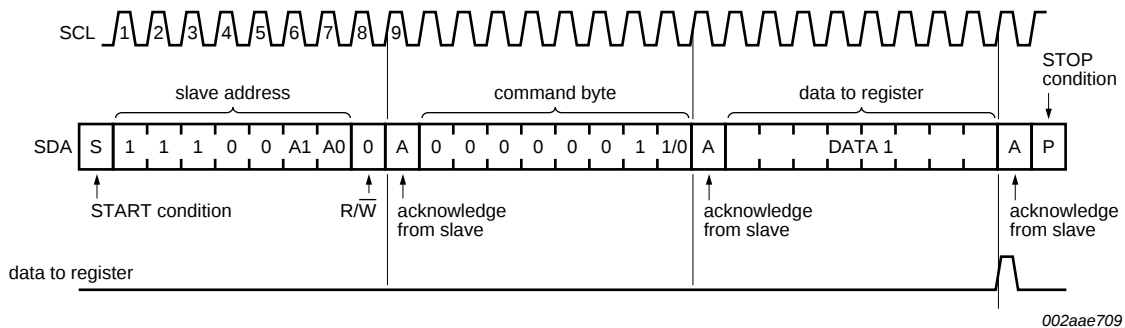


## 6.7 Bus transactions

Data is transmitted to the PCA9538 registers using the write mode as shown in [Figure 7](#) and [Figure 8](#). Data is read from the PCA9538 registers using the read mode as shown in [Figure 9](#) and [Figure 10](#). 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.



**Fig 7. Write to output port register**



**Fig 8. Write to configuration or polarity inversion registers**

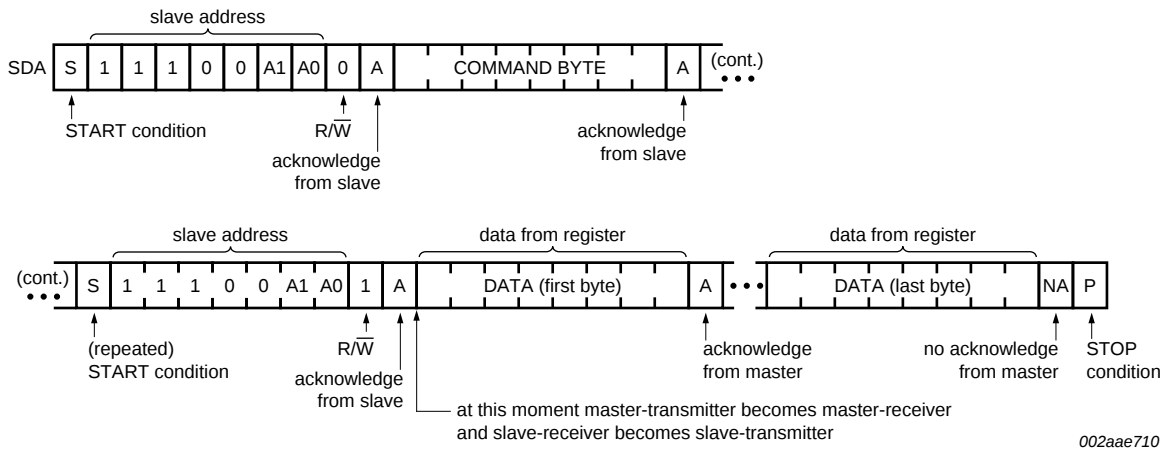
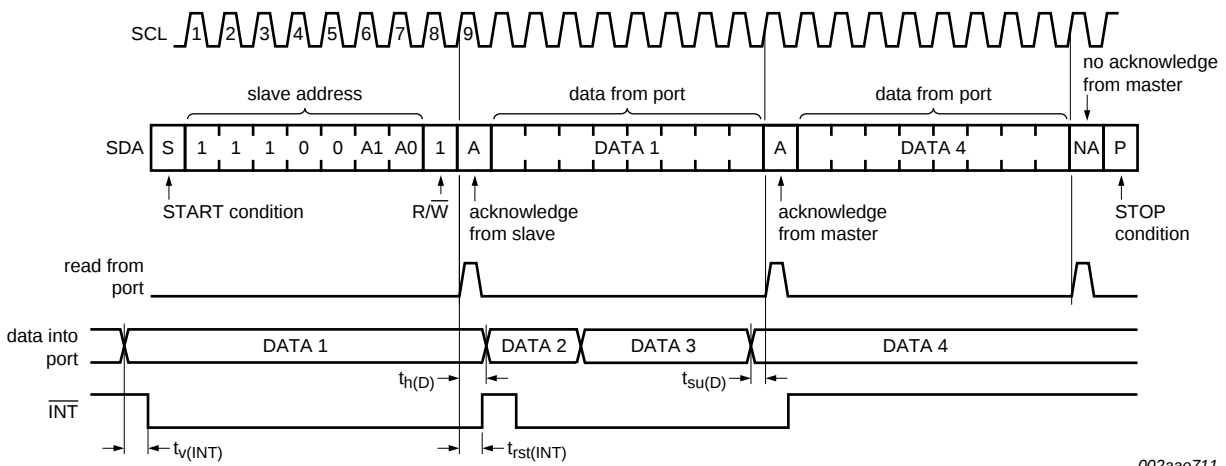


Fig 9. Read from register



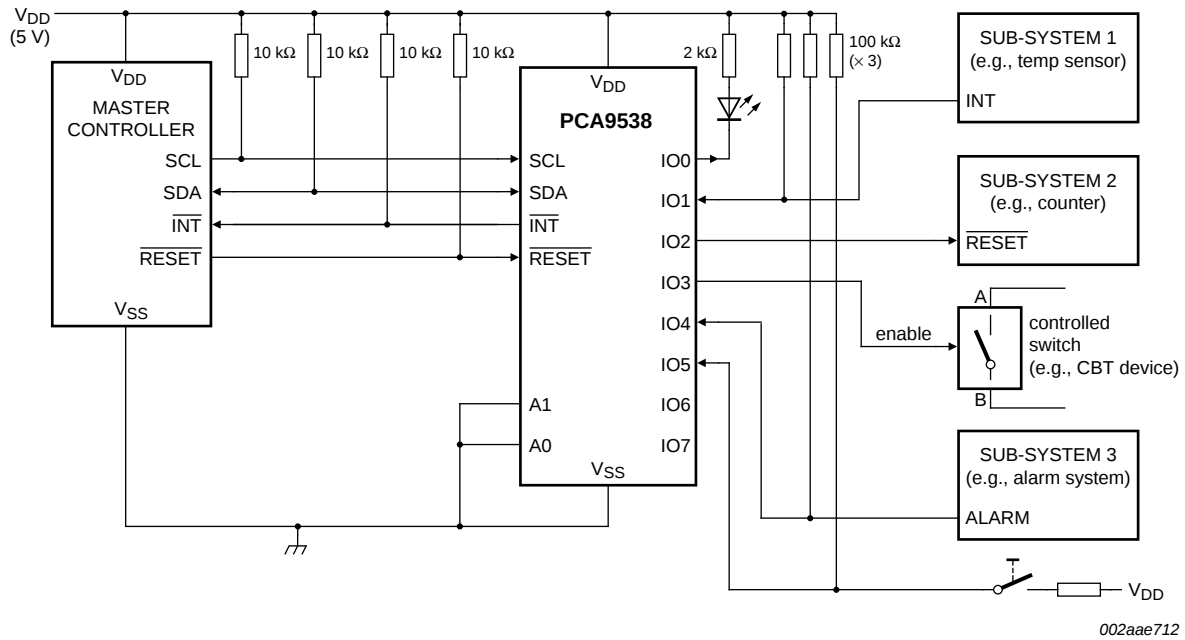
This figure assumes the command byte has previously been programmed with 00h.

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

Expanded diagram is shown in [Figure 17](#).

Fig 10. Read input port register

## 7. Application design-in information



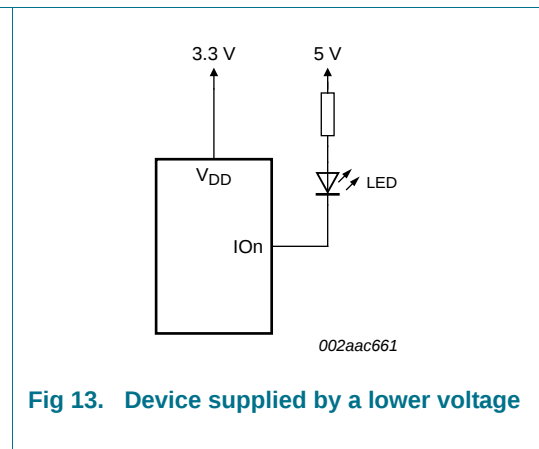
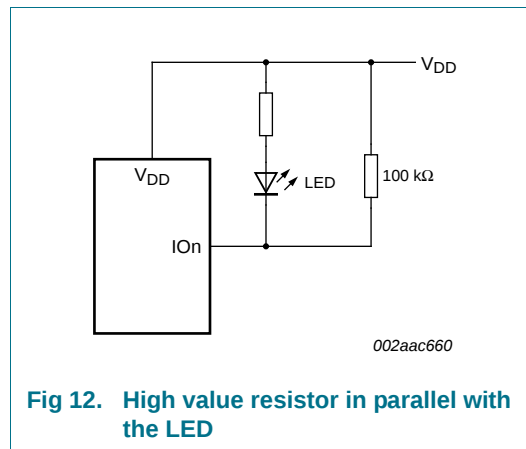
Device address is 1110 000x for this example.  
 IO0, IO2, IO3 configured as outputs.  
 IO1, IO4, IO5 configured as inputs.  
 IO6, IO7 are not used and need 100 kΩ pull-up resistors to protect them from floating.

**Fig 11. Typical application**

## 7.1 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</sub> through a resistor as shown in [Figure 11](#). 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</sub>. The supply current, I<sub>DD</sub>, increases as V<sub>I</sub> becomes lower than V<sub>DD</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</sub> when the LED is off. [Figure 12](#) shows a high value resistor in parallel with the LED. [Figure 13](#) shows V<sub>DD</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</sub> and prevents additional supply current consumption when the LED is off.



## 8. Limiting values

**Table 9. Limiting values**

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

| Symbol              | Parameter                      | Conditions                        | Min                   | Max  | Unit |
|---------------------|--------------------------------|-----------------------------------|-----------------------|------|------|
| V <sub>DD</sub>     | supply voltage                 |                                   | −0.5                  | +6.0 | V    |
| I <sub>I</sub>      | input current                  |                                   | -                     | ±20  | mA   |
| V <sub>I/O</sub>    | voltage on an input/output pin |                                   | V <sub>SS</sub> − 0.5 | 5.5  | V    |
| I <sub>O(ION)</sub> | output current on pin ION      |                                   | -                     | ±50  | mA   |
| I <sub>DD</sub>     | supply current                 |                                   | -                     | 85   | mA   |
| I <sub>SS</sub>     | ground supply current          |                                   | -                     | 100  | mA   |
| P <sub>tot</sub>    | total power dissipation        |                                   | -                     | 200  | mW   |
| T <sub>stg</sub>    | storage temperature            |                                   | −65                   | +150 | °C   |
| T <sub>amb</sub>    | ambient temperature            | operating                         |                       |      |      |
|                     |                                | all devices except PCA9538PW/Q900 | −40                   | +85  | °C   |
|                     |                                | PCA9538PW/Q900                    | −40                   | +125 | °C   |
| T <sub>j(max)</sub> | maximum junction temperature   |                                   | -                     | +125 | °C   |

## 9. Static characteristics

**Table 10. Static characteristics for all devices except PCA9538PW/Q900**

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

| Symbol                             | Parameter                  | Conditions                                                                                                        | Min          | Typ  | Max           | Unit          |
|------------------------------------|----------------------------|-------------------------------------------------------------------------------------------------------------------|--------------|------|---------------|---------------|
| <b>Supplies</b>                    |                            |                                                                                                                   |              |      |               |               |
| $V_{DD}$                           | supply voltage             |                                                                                                                   | 2.3          | -    | 5.5           | V             |
| $I_{DD}$                           | supply current             | operating mode; $V_{DD} = 5.5 \text{ V}$ ;<br>no load; $f_{SCL} = 100 \text{ kHz}$                                | -            | 104  | 175           | $\mu\text{A}$ |
| $I_{stbL}$                         | LOW-level standby current  | Standby mode; $V_{DD} = 5.5 \text{ V}$ ;<br>no load; $V_I = V_{SS}$ ;<br>$f_{SCL} = 0 \text{ kHz}$ ; I/O = inputs | -            | 0.25 | 1             | $\mu\text{A}$ |
| $I_{stbH}$                         | HIGH-level standby current | Standby mode; $V_{DD} = 5.5 \text{ V}$ ;<br>no load; $V_I = V_{DD}$ ;<br>$f_{SCL} = 0 \text{ kHz}$ ; I/O = inputs | -            | 0.25 | 1             | $\mu\text{A}$ |
| $V_{POR}$                          | power-on reset voltage     | no load; $V_I = V_{DD} \text{ or } V_{SS}$ <a href="#">[1]</a>                                                    | -            | 1.7  | 2.2           | V             |
| <b>Input SCL; input/output SDA</b> |                            |                                                                                                                   |              |      |               |               |
| $V_{IL}$                           | 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   | $V_{OL} = 0.4 \text{ V}$                                                                                          | 3            | 7    | -             | mA            |
| $I_L$                              | leakage current            | $V_I = V_{DD} = V_{SS}$                                                                                           | -1           | -    | +1            | $\mu\text{A}$ |
| $C_i$                              | input capacitance          | $V_I = V_{SS}$                                                                                                    | -            | 5    | 10            | pF            |
| <b>I/Os</b>                        |                            |                                                                                                                   |              |      |               |               |
| $V_{IL}$                           | LOW-level input voltage    |                                                                                                                   | -0.5         | -    | +0.8          | V             |
| $V_{IH}$                           | HIGH-level input voltage   |                                                                                                                   | 2.0          | -    | 5.5           | V             |
| $I_{OL}$                           | LOW-level output current   | $V_{OL} = 0.5 \text{ V}$                                                                                          |              |      |               |               |
|                                    |                            | $V_{DD} = 2.3 \text{ V}$ <a href="#">[2]</a>                                                                      | 8            | 10   | -             | mA            |
|                                    |                            | $V_{DD} = 3.0 \text{ V}$ <a href="#">[2]</a>                                                                      | 8            | 14   | -             | mA            |
|                                    |                            | $V_{DD} = 4.5 \text{ V}$ <a href="#">[2]</a>                                                                      | 8            | 17   | -             | mA            |
|                                    |                            | $V_{OL} = 0.7 \text{ V}$                                                                                          |              |      |               |               |
|                                    |                            | $V_{DD} = 2.3 \text{ V}$ <a href="#">[2]</a>                                                                      | 10           | 13   | -             | mA            |
|                                    |                            | $V_{DD} = 3.0 \text{ V}$ <a href="#">[2]</a>                                                                      | 10           | 19   | -             | mA            |
|                                    |                            | $V_{DD} = 4.5 \text{ V}$ <a href="#">[2]</a>                                                                      | 10           | 24   | -             | mA            |
| $V_{OH}$                           | HIGH-level output voltage  | $I_{OH} = -8 \text{ mA}$                                                                                          |              |      |               |               |
|                                    |                            | $V_{DD} = 2.3 \text{ V}$ <a href="#">[3]</a>                                                                      | 1.8          | -    | -             | V             |
|                                    |                            | $V_{DD} = 3.0 \text{ V}$ <a href="#">[3]</a>                                                                      | 2.6          | -    | -             | V             |
|                                    |                            | $V_{DD} = 4.5 \text{ V}$ <a href="#">[3]</a>                                                                      | 4.1          | -    | -             | V             |
|                                    |                            | $I_{OH} = -10 \text{ mA}$                                                                                         |              |      |               |               |
|                                    |                            | $V_{DD} = 2.3 \text{ V}$ <a href="#">[3]</a>                                                                      | 1.7          | -    | -             | V             |
|                                    |                            | $V_{DD} = 3.0 \text{ V}$ <a href="#">[3]</a>                                                                      | 2.5          | -    | -             | V             |
|                                    |                            | $V_{DD} = 4.5 \text{ V}$ <a href="#">[3]</a>                                                                      | 4.0          | -    | -             | V             |
| $I_{LI}$                           | input leakage current      | $V_I = V_{DD} = V_{SS}$                                                                                           | -1           | -    | +1            | $\mu\text{A}$ |
| $C_i$                              | input capacitance          |                                                                                                                   | -            | 5    | 10            | pF            |

8-bit I<sup>2</sup>C-bus and SMBus low power I/O port with interrupt and reset**Table 10. Static characteristics for all devices except PCA9538PW/Q900 ...continued** $V_{DD} = 2.3 \text{ V to } 5.5 \text{ V}$ ;  $V_{SS} = 0 \text{ V}$ ;  $T_{amb} = -40 \text{ }^{\circ}\text{C to } +85 \text{ }^{\circ}\text{C}$ ; unless otherwise specified.

| Symbol                             | Parameter                | Conditions               | Min  | Typ | Max  | Unit          |
|------------------------------------|--------------------------|--------------------------|------|-----|------|---------------|
| <b>Interrupt INT</b>               |                          |                          |      |     |      |               |
| $I_{OL}$                           | LOW-level output current | $V_{OL} = 0.4 \text{ V}$ | 3    | 13  | -    | mA            |
| <b>Select inputs A0, A1, RESET</b> |                          |                          |      |     |      |               |
| $V_{IL}$                           | LOW-level input voltage  |                          | -0.5 | -   | +0.8 | V             |
| $V_{IH}$                           | HIGH-level input voltage |                          | 2.0  | -   | 5.5  | V             |
| $I_{LI}$                           | input leakage current    |                          | -1   | -   | +1   | $\mu\text{A}$ |

[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.

**Table 11. Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device** $V_{DD} = 3.0 \text{ V to } 5.5 \text{ V}$ ;  $V_{SS} = 0 \text{ V}$ ;  $T_{amb} = -40 \text{ }^{\circ}\text{C to } +125 \text{ }^{\circ}\text{C}$ ; unless otherwise specified.

| Symbol                             | Parameter                     | Conditions                                                                                                        | Min          | Typ  | Max           | Unit          |
|------------------------------------|-------------------------------|-------------------------------------------------------------------------------------------------------------------|--------------|------|---------------|---------------|
| <b>Supplies</b>                    |                               |                                                                                                                   |              |      |               |               |
| $V_{DD}$                           | supply voltage                |                                                                                                                   | 3.0          | -    | 5.5           | V             |
| $I_{DD}$                           | supply current                | operating mode; $V_{DD} = 5.5 \text{ V}$ ;<br>no load; $f_{SCL} = 100 \text{ kHz}$                                | -            | 104  | 175           | $\mu\text{A}$ |
| $I_{stbL}$                         | LOW-level standby current     | Standby mode; $V_{DD} = 5.5 \text{ V}$ ;<br>no load; $V_I = V_{SS}$ ;<br>$f_{SCL} = 0 \text{ kHz}$ ; I/O = inputs | -            | 0.25 | 1             | $\mu\text{A}$ |
| $I_{stbH}$                         | HIGH-level standby current    | Standby mode; $V_{DD} = 5.5 \text{ V}$ ;<br>no load; $V_I = V_{DD}$ ;<br>$f_{SCL} = 0 \text{ kHz}$ ; I/O = inputs | -            | 0.25 | 1             | $\mu\text{A}$ |
| $V_{POR}$                          | power-on reset voltage        | no load; $V_I = V_{DD}$ or $V_{SS}$ <a href="#">[1]</a>                                                           | -            | 1.7  | 2.2           | V             |
| <b>Input SCL; input/output SDA</b> |                               |                                                                                                                   |              |      |               |               |
| $V_{IL}$                           | 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, SDA | $V_{OL} = 0.4 \text{ V}$                                                                                          |              |      |               |               |
|                                    |                               | $V_{DD} = 5.5 \text{ V}$                                                                                          | 3            | 7    | -             | mA            |
|                                    |                               | $V_{DD} = 3.0 \text{ V}$                                                                                          | 2.5          | -    | -             | mA            |
| $I_L$                              | leakage current               | $V_I = V_{DD} = V_{SS}$                                                                                           | -1           | -    | +1            | $\mu\text{A}$ |
| $C_i$                              | input capacitance             | $V_I = V_{SS}$                                                                                                    | -            | 5    | 10            | pF            |
| <b>I/Os</b>                        |                               |                                                                                                                   |              |      |               |               |
| $V_{IL}$                           | LOW-level input voltage       |                                                                                                                   | -0.5         | -    | +0.8          | V             |
| $V_{IH}$                           | HIGH-level input voltage      |                                                                                                                   | 2.0          | -    | 5.5           | V             |
| $I_{OL}$                           | LOW-level output current      | $V_{OL} = 0.5 \text{ V}$                                                                                          |              |      |               |               |
|                                    |                               | $V_{DD} = 4.5 \text{ V}$ <a href="#">[2]</a>                                                                      | 8            | 17   | -             | mA            |
|                                    |                               | $V_{DD} = 3.0 \text{ V}$ <a href="#">[2]</a>                                                                      | 7.5          | -    | -             | mA            |
|                                    |                               | $V_{OL} = 0.7 \text{ V}$                                                                                          |              |      |               |               |
|                                    |                               | $V_{DD} = 4.5 \text{ V}$ <a href="#">[2]</a>                                                                      | 10           | 24   | -             | mA            |
|                                    |                               | $V_{DD} = 3.0 \text{ V}$ <a href="#">[2]</a>                                                                      | 9.5          | -    | -             | mA            |

**Table 11.** Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device ...continued $V_{DD} = 3.0\text{ V}$  to  $5.5\text{ V}$ ;  $V_{SS} = 0\text{ V}$ ;  $T_{amb} = -40\text{ }^{\circ}\text{C}$  to  $+125\text{ }^{\circ}\text{C}$ ; unless otherwise specified.

| Symbol                             | Parameter                 | Conditions                  | Min  | Typ | Max  | Unit          |
|------------------------------------|---------------------------|-----------------------------|------|-----|------|---------------|
| $V_{OH}$                           | HIGH-level output voltage | $I_{OH} = -8\text{ mA}$     |      |     |      |               |
|                                    |                           | $V_{DD} = 4.5\text{ V}$ [3] | 4.1  | -   | -    | V             |
|                                    |                           | $V_{DD} = 3.0\text{ V}$ [3] | 2.5  | -   | -    | V             |
|                                    |                           | $I_{OH} = -10\text{ mA}$    |      |     |      |               |
|                                    |                           | $V_{DD} = 4.5\text{ V}$ [3] | 4.0  | -   | -    | V             |
|                                    |                           | $V_{DD} = 3.0\text{ V}$ [3] | 2.4  | -   | -    | V             |
| $I_{LI}$                           | input leakage current     | $V_I = V_{DD} = V_{SS}$     | -1   | -   | +1   | $\mu\text{A}$ |
| $C_i$                              | input capacitance         |                             | -    | 5   | 10   | pF            |
| <b>Interrupt INT</b>               |                           |                             |      |     |      |               |
| $I_{OL}$                           | LOW-level output current  | $V_{OL} = 0.4\text{ V}$     | 3    | 13  | -    | mA            |
| <b>Select inputs A0, A1, RESET</b> |                           |                             |      |     |      |               |
| $V_{IL}$                           | LOW-level input voltage   |                             | -0.5 | -   | +0.8 | V             |
| $V_{IH}$                           | HIGH-level input voltage  |                             | 2.0  | -   | 5.5  | V             |
| $I_{LI}$                           | input leakage current     |                             | -1   | -   | +1   | $\mu\text{A}$ |

[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 12. Dynamic characteristics

| 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>BUF</sub>        | bus free time between a STOP and START condition                  |            | 4.7                                | -    | 1.3                            | -   | μs   |
| t <sub>HD;STA</sub>     | hold time (repeated) START condition                              |            | 4.0                                | -    | 0.6                            | -   | μs   |
| t <sub>SU;STA</sub>     | set-up time for a repeated START condition                        |            | 4.7                                | -    | 0.6                            | -   | μs   |
| t <sub>SU;STO</sub>     | set-up time for STOP condition                                    |            | 4.0                                | -    | 0.6                            | -   | μs   |
| t <sub>HD;DAT</sub>     | data hold time                                                    |            | 0                                  | -    | 0                              | -   | ns   |
| t <sub>VD;ACK</sub>     | data valid acknowledge time                                       | [1]        | 0.3                                | 3.45 | 0.1                            | 0.9 | μs   |
| t <sub>VD;DAT</sub>     | data valid time                                                   | [2]        | 300                                | -    | 50                             | -   | ns   |
| t <sub>SU;DAT</sub>     | data set-up time                                                  |            | 250                                | -    | 100                            | -   | ns   |
| t <sub>LOW</sub>        | LOW period of the SCL clock                                       |            | 4.7                                | -    | 1.3                            | -   | μs   |
| t <sub>HIGH</sub>       | HIGH period of the SCL clock                                      |            | 4.0                                | -    | 0.6                            | -   | μs   |
| t <sub>r</sub>          | rise time of both SDA and SCL signals                             |            | -                                  | 1000 | 20 + 0.1C <sub>b</sub> [3]     | 300 | ns   |
| t <sub>f</sub>          | fall time of both SDA and SCL signals                             |            | -                                  | 300  | 20 + 0.1C <sub>b</sub> [3]     | 300 | ns   |
| t <sub>SP</sub>         | pulse width of spikes that must be suppressed by the input filter |            | -                                  | 50   | -                              | 50  | ns   |
| <b>Port timing</b>      |                                                                   |            |                                    |      |                                |     |      |
| t <sub>V(Q)</sub>       | data output valid time                                            |            | -                                  | 200  | -                              | 200 | ns   |
| t <sub>SU(D)</sub>      | data input set-up time                                            |            | 100                                | -    | 100                            | -   | ns   |
| t <sub>H(D)</sub>       | data input hold time                                              |            | 1                                  | -    | 1                              | -   | μs   |
| <b>Interrupt timing</b> |                                                                   |            |                                    |      |                                |     |      |
| t <sub>V(INT)</sub>     | valid time on pin $\overline{\text{INT}}$                         |            | -                                  | 4    | -                              | 4   | μs   |
| t <sub>RST(INT)</sub>   | reset time on pin $\overline{\text{INT}}$                         |            | -                                  | 4    | -                              | 4   | μs   |
| <b>RESET</b>            |                                                                   |            |                                    |      |                                |     |      |
| t <sub>W(rst)</sub>     | reset pulse width                                                 |            | 4                                  | -    | 4                              | -   | ns   |
| t <sub>REC(rst)</sub>   | reset recovery time                                               |            | 0                                  | -    | 0                              | -   | ns   |
| t <sub>RST</sub>        | reset time                                                        |            | 400                                | -    | 400                            | -   | ns   |

[1] t<sub>VD;ACK</sub> = time for Acknowledgement signal from SCL LOW to SDA (out) LOW.

[2] t<sub>VD;DAT</sub> = minimum time for the SDA data out to be valid following SCL LOW.

[3] C<sub>b</sub> = total capacitance of one bus line in pF.

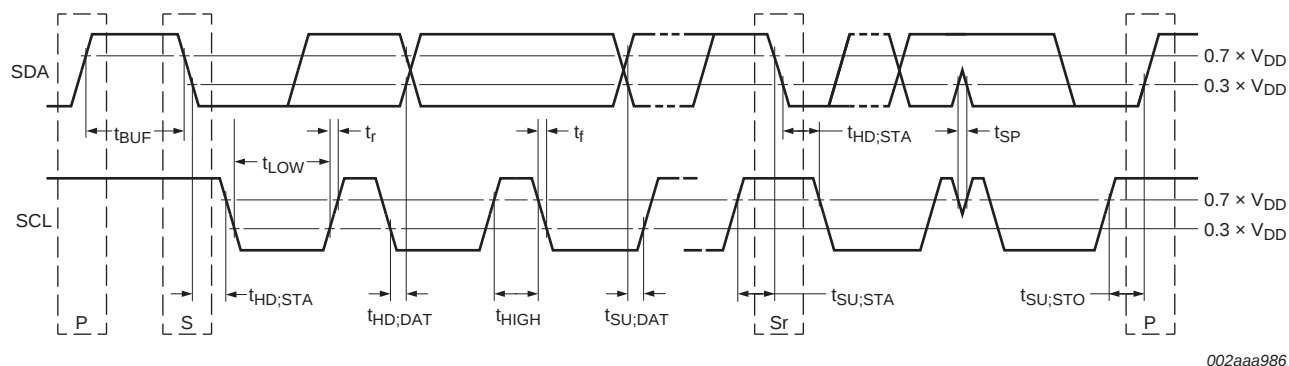
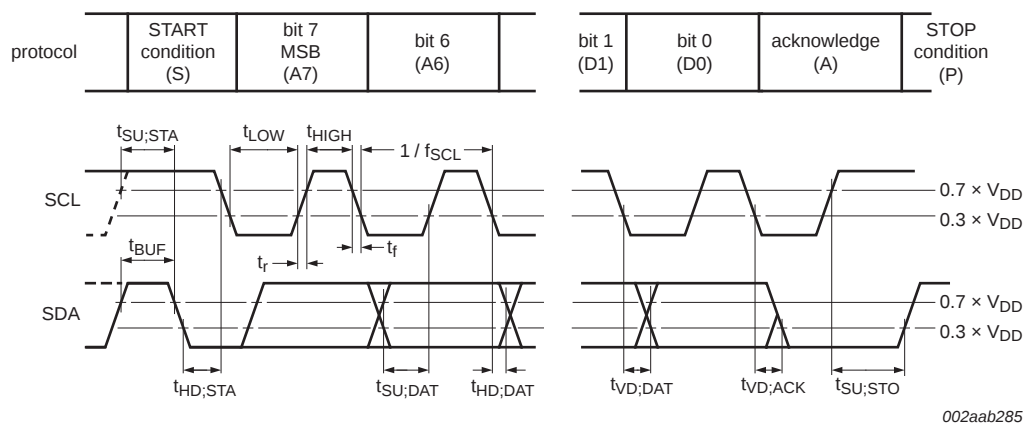


Fig 14. Definition of timing



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

Fig 15. I<sup>2</sup>C-bus timing diagram

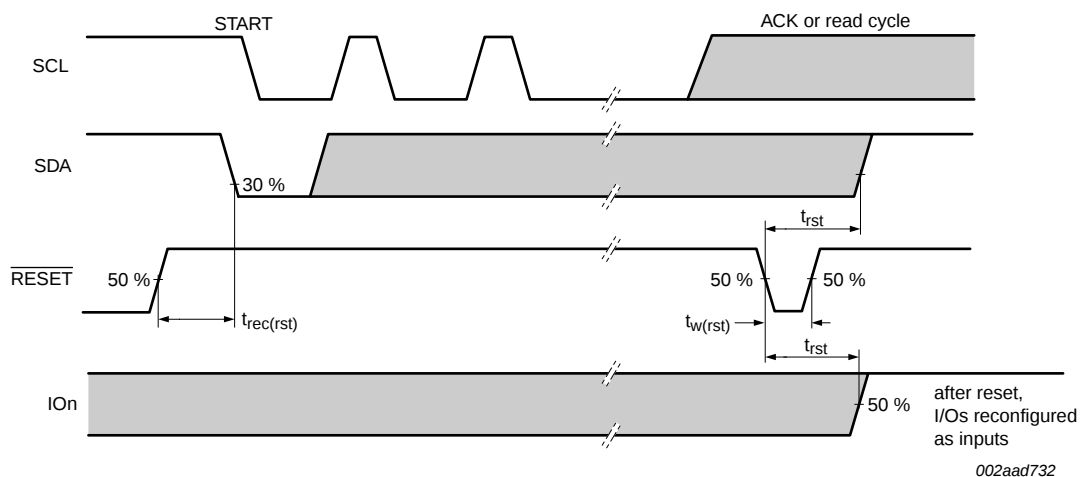


Fig 16. Definition of RESET timing

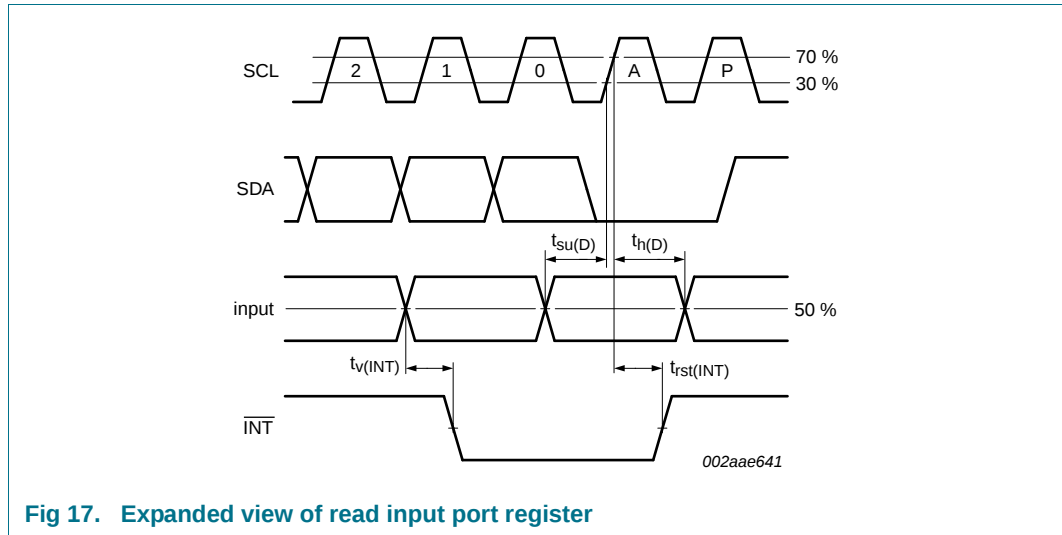


Fig 17. Expanded view of read input port register

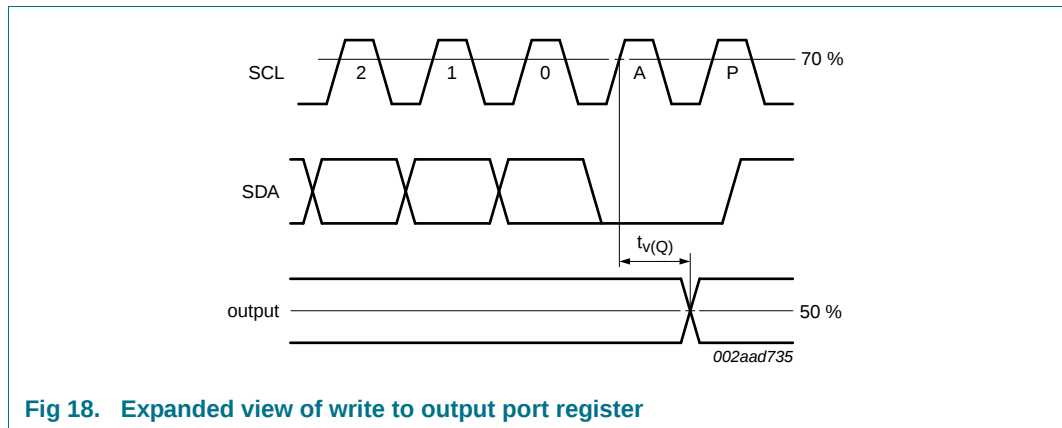


Fig 18. Expanded view of write to output port register

11. Test information

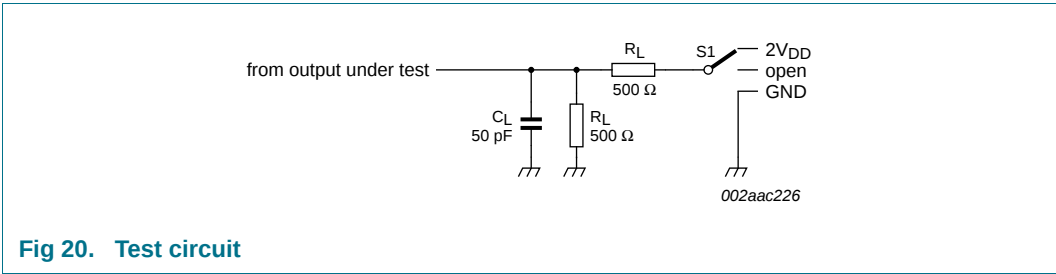
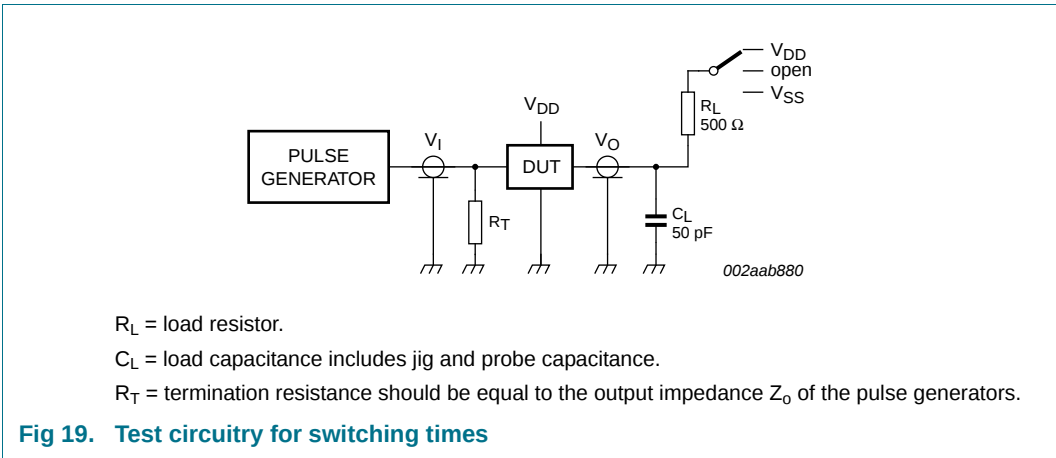


Table 13. Test data

| Test       | Load         |       | Switch            |
|------------|--------------|-------|-------------------|
|            | $R_L$        | $C_L$ |                   |
| $t_{V(Q)}$ | 500 $\Omega$ | 50 pF | $2 \times V_{DD}$ |

## 12. Package outline

SO16: plastic small outline package; 16 leads; body width 7.5 mm

SOT162-1

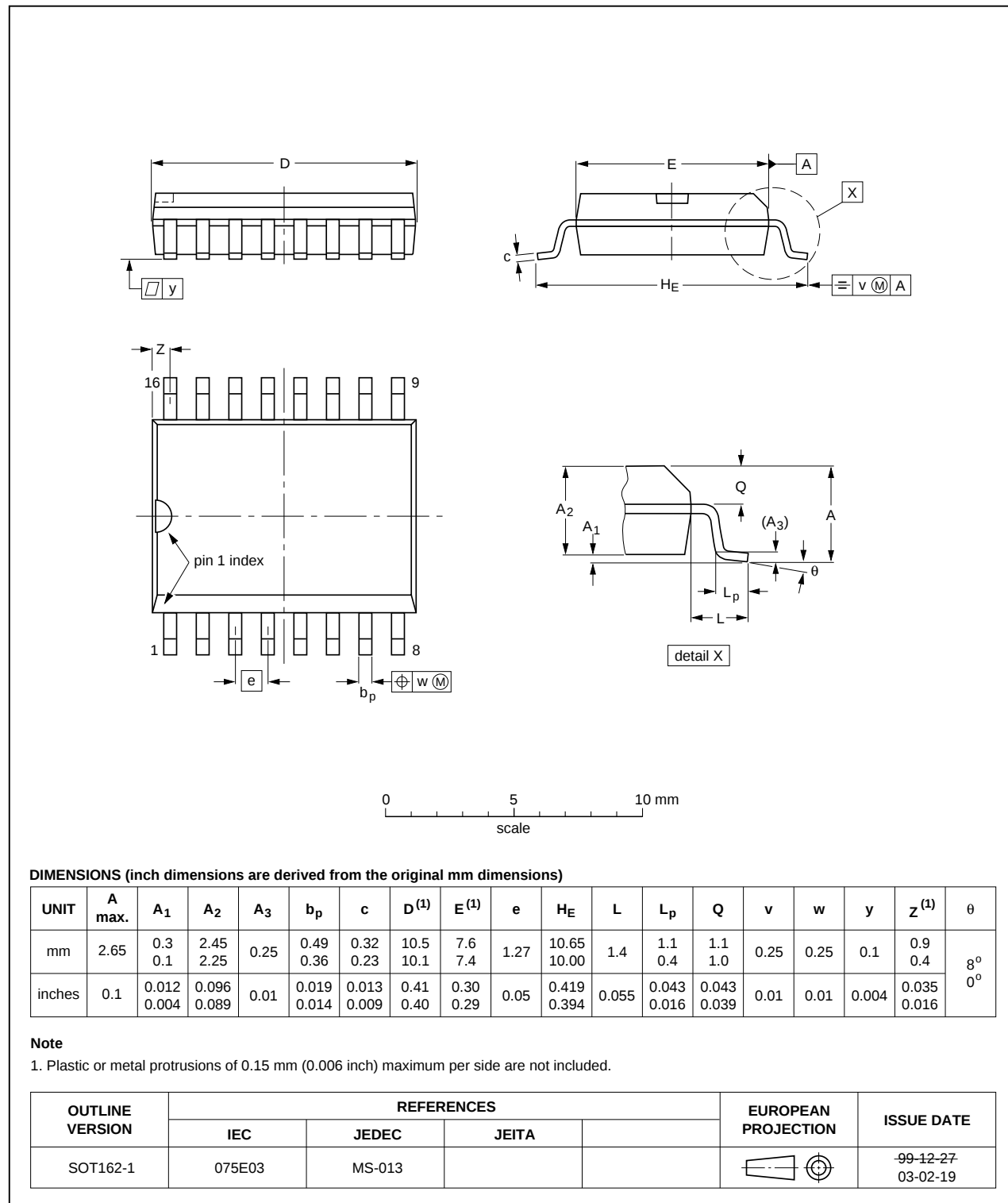


Fig 21. Package outline SOT162-1 (SO16)

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

SOT403-1

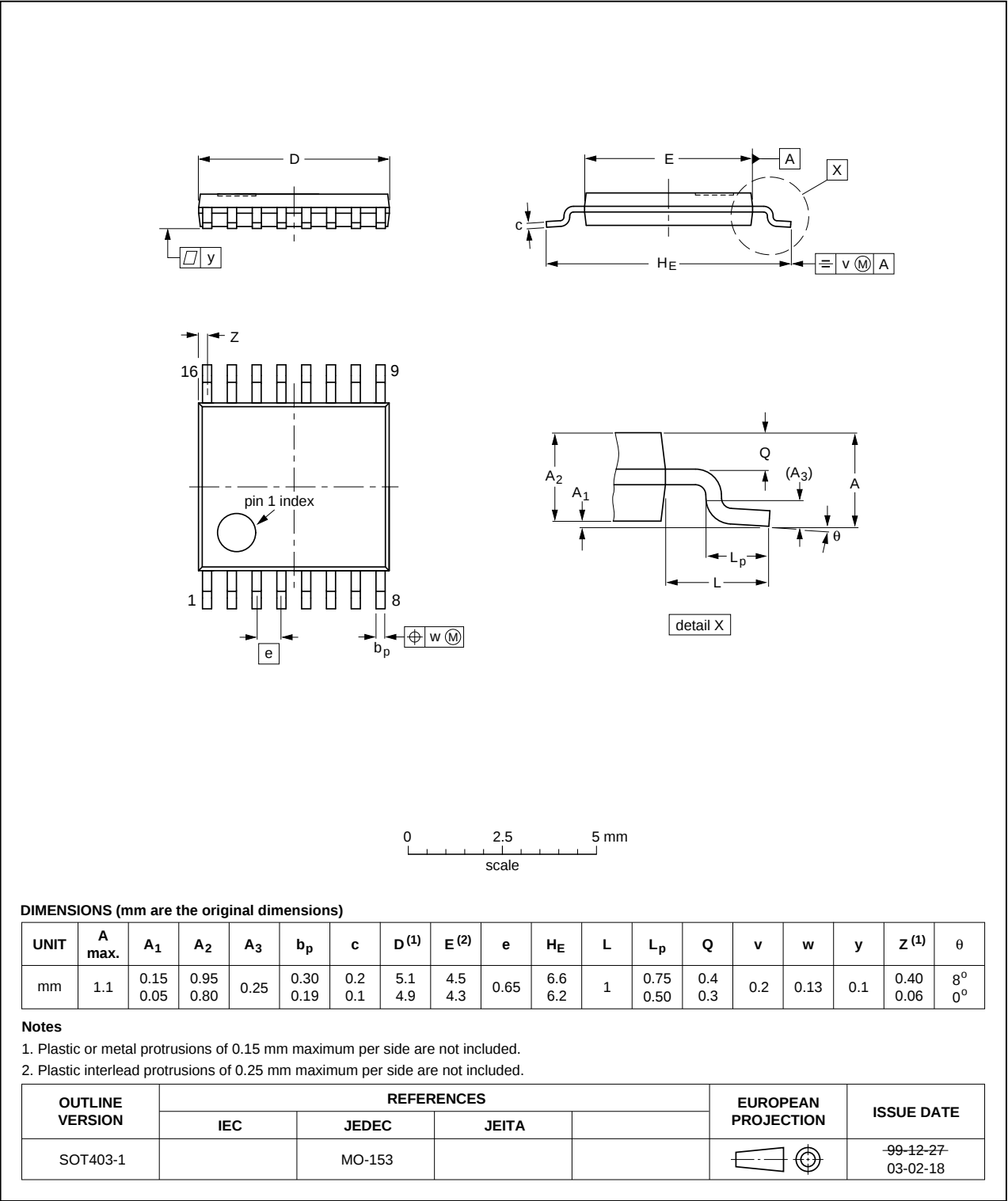
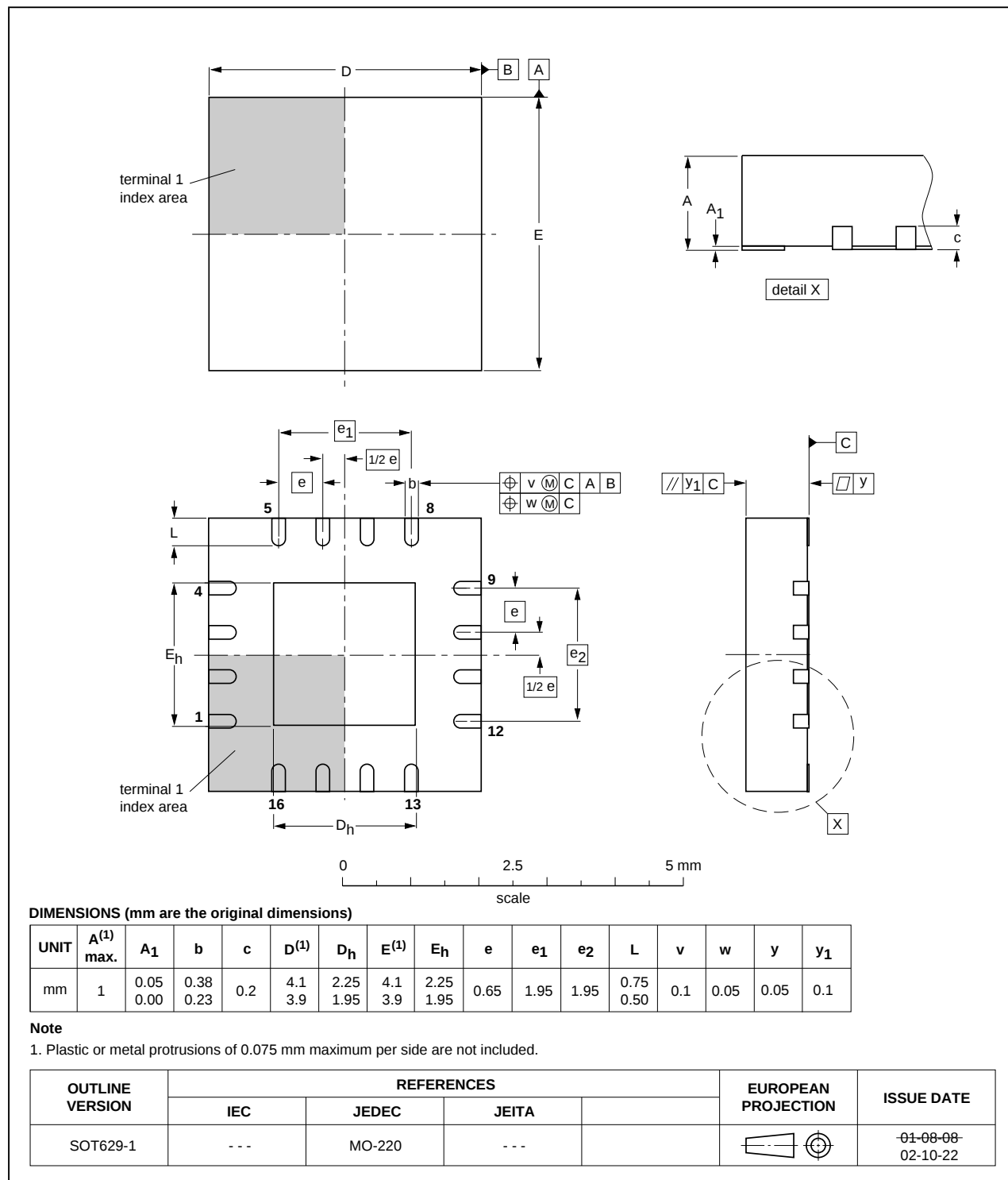


Fig 22. Package outline SOT403-1 (TSSOP16)

**HVQFN16:** plastic thermal enhanced very thin quad flat package; no leads;  
16 terminals; body 4 x 4 x 0.85 mm

**SOT629-1**



**Fig 23. Package outline SOT629-1 (HVQFN16)**

## 13. Handling information

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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 24](#)) 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 14](#) and [15](#)

**Table 14. SnPb eutectic process (from J-STD-020D)**

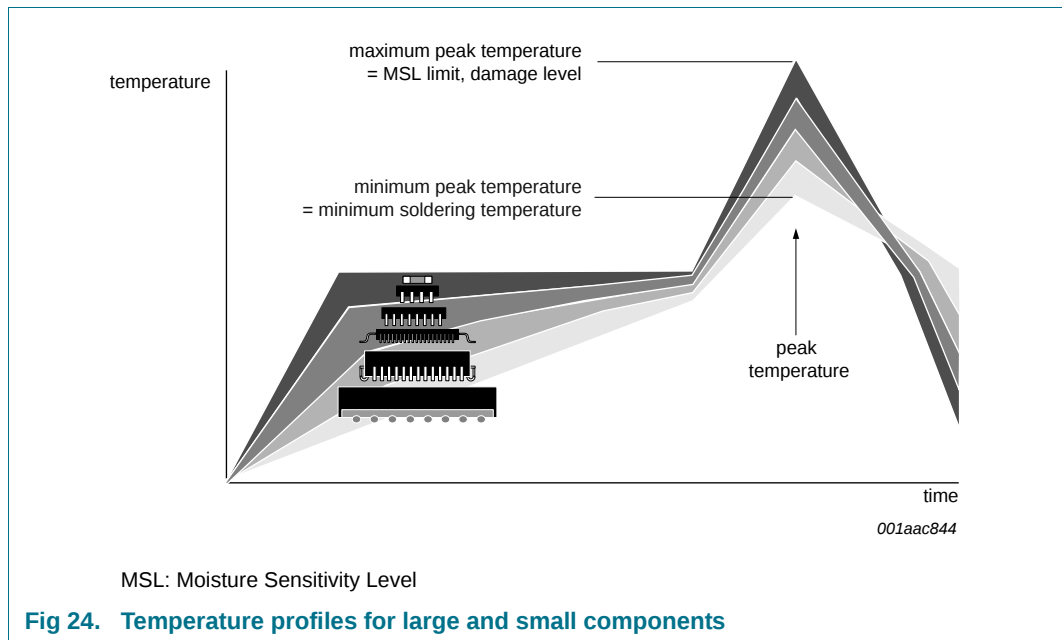
| Package thickness (mm) | Package reflow temperature (°C) |       |
|------------------------|---------------------------------|-------|
|                        | Volume (mm <sup>3</sup> )       |       |
|                        | < 350                           | ≥ 350 |
| < 2.5                 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

**Table 15. Lead-free process (from J-STD-020D)**

| 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 24](#).



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

15. Soldering: PCB footprints

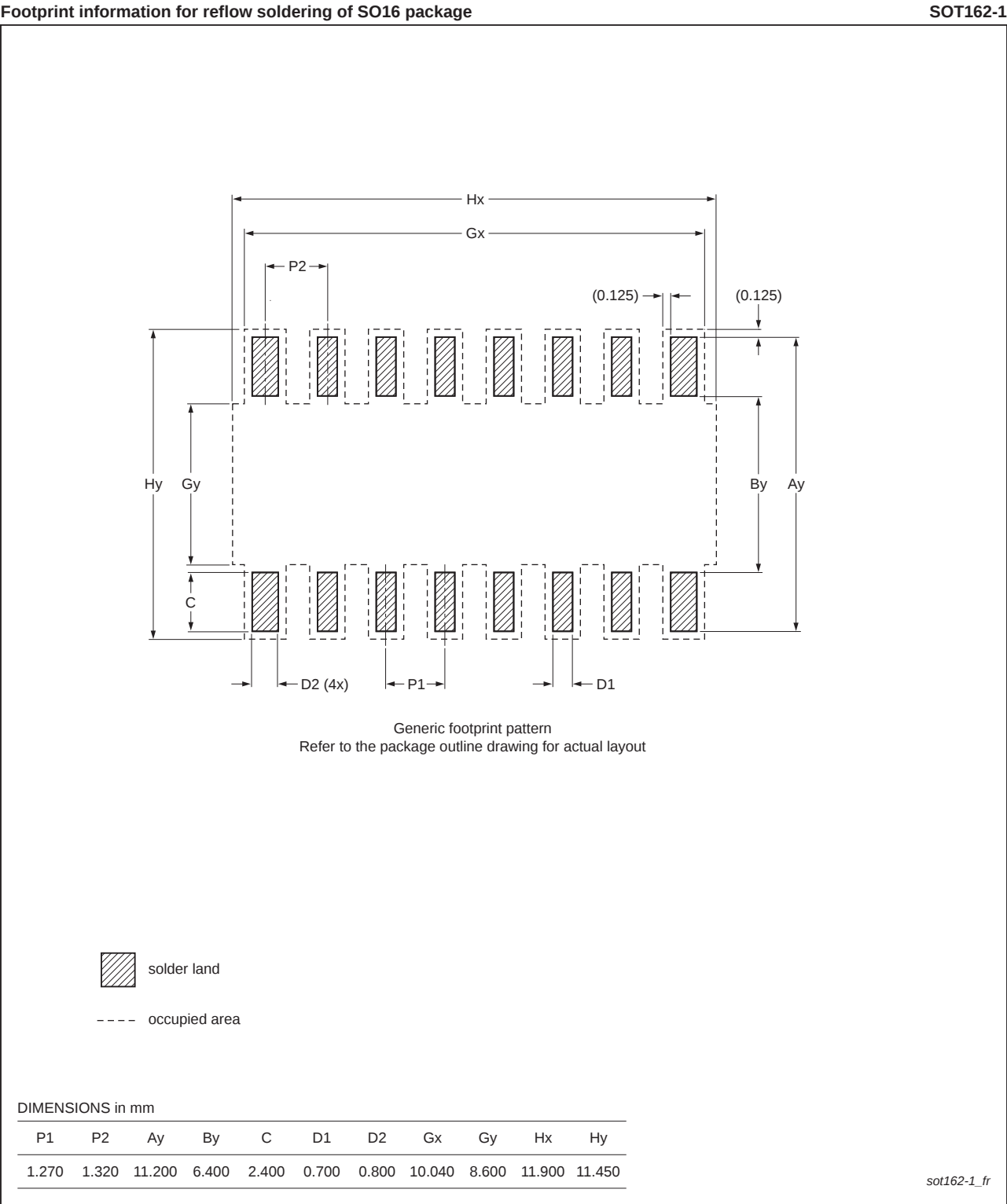


Fig 25. PCB footprint for SOT162-1 (SO16); reflow soldering

Footprint information for reflow soldering of TSSOP16 package

SOT403-1

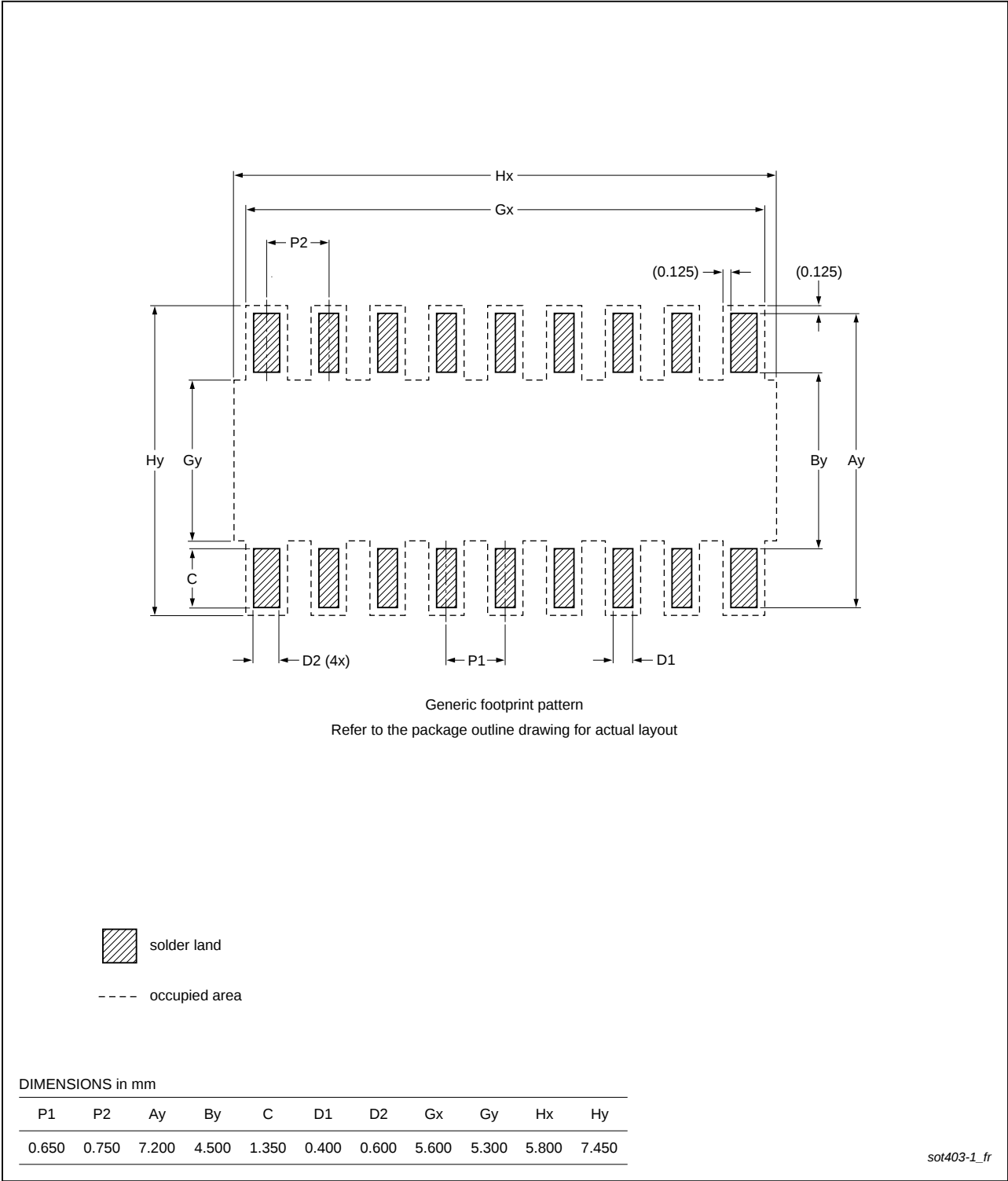


Fig 26. PCB footprint for SOT403-1 (TSSOP16); reflow soldering

Footprint information for reflow soldering of HVQFN16 package

SOT629-1

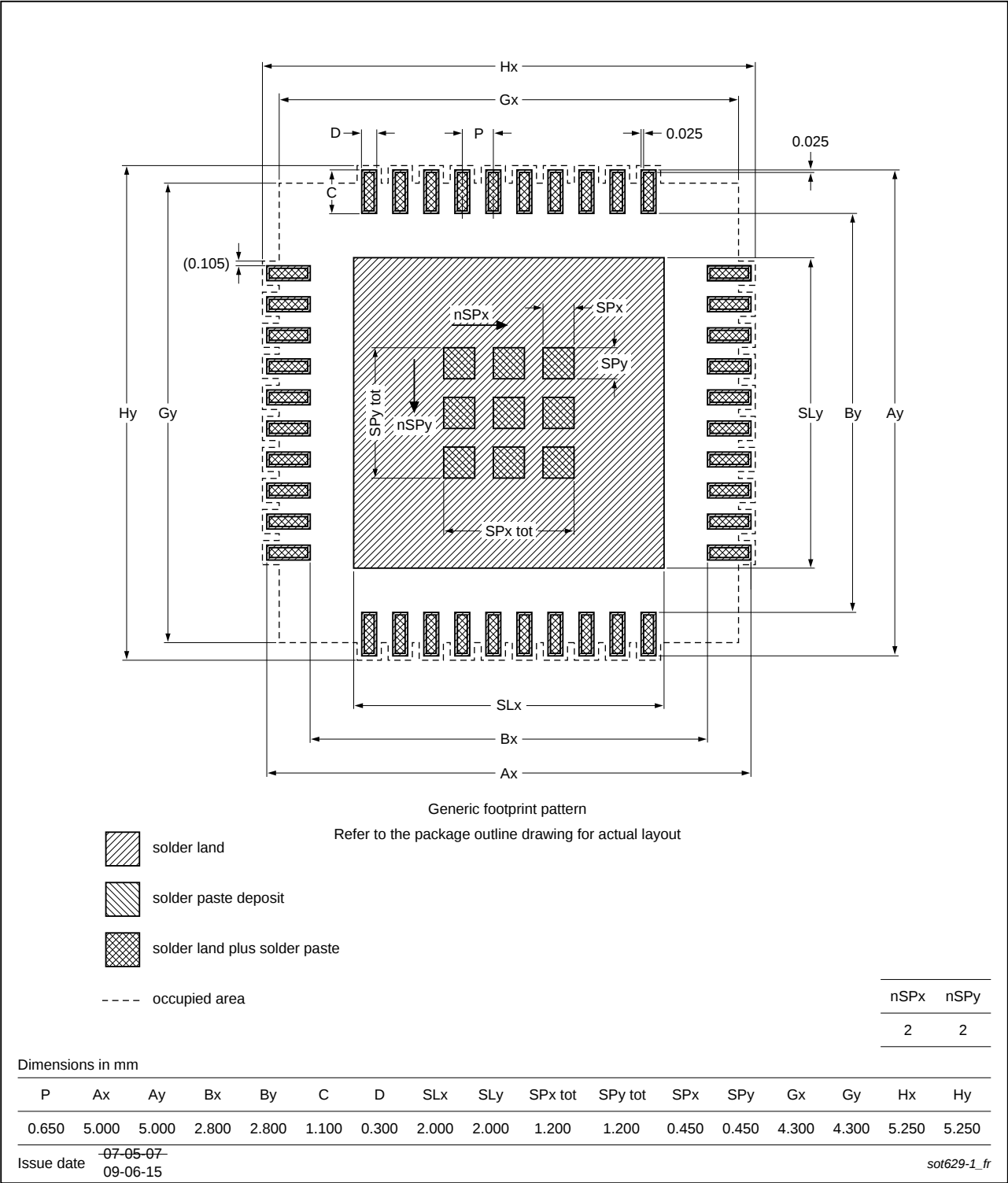


Fig 27. PCB footprint for SOT629-1 (HVQFN16); reflow soldering

## 16. Abbreviations

Table 16. 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 <sup>2</sup> C-bus | Inter-Integrated Circuit bus               |
| I/O                  | Input/Output                               |
| LED                  | Light Emitting Diode                       |
| LP                   | Low-Pass                                   |
| POR                  | Power-On Reset                             |
| SMBus                | System Management Bus                      |

## 17. Revision history

Table 17. Revision history

| Document ID                     | Release date                                                                                                                                                                                                                                                                                         | Data sheet status    | Change notice | Supersedes  |
|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|---------------|-------------|
| PCA9538 v.8                     | 20171108                                                                                                                                                                                                                                                                                             | Product data sheet   | 201710002I    | PCA9538 v.7 |
| Modifications:                  | <ul style="list-style-type: none"> <li><a href="#">Table 10 "Static characteristics for all devices except PCA9538PW/Q900"</a>, <a href="#">Table 11 "Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device"</a>: Corrected V<sub>POR</sub> typ and max limit</li> </ul>               |                      |               |             |
| PCA9538 v.7                     | 20141126                                                                                                                                                                                                                                                                                             | Product data sheet   |               | PCA9538 v.6 |
| Modifications:                  | <ul style="list-style-type: none"> <li><a href="#">Table 11 "Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device"</a>: updated I<sub>OL</sub> and V<sub>OH</sub>; changed operating power supply voltage range from "5.0 V ± 10 %" to "3.0 V to 5.5 V" for PCA9538PW/Q900</li> </ul> |                      |               |             |
| PCA9538 v.6                     | 20130206                                                                                                                                                                                                                                                                                             | Product data sheet   |               | PCA9538 v.5 |
| PCA9538 v.5                     | 20090528                                                                                                                                                                                                                                                                                             | Product data sheet   | -             | PCA9538 v.4 |
| PCA9538 v.4                     | 20060921                                                                                                                                                                                                                                                                                             | Product data sheet   | -             | PCA9538 v.3 |
| PCA9538 v.3<br>(9397 750 14176) | 20041005                                                                                                                                                                                                                                                                                             | Product data sheet   | -             | PCA9538 v.2 |
| PCA9538 v.2<br>(9397 750 14049) | 20040930                                                                                                                                                                                                                                                                                             | Objective data sheet | -             | PCA9538 v.1 |
| PCA9538 v.1<br>(9397 750 12881) | 20040820                                                                                                                                                                                                                                                                                             | Objective data sheet | -             | -           |

## 18. Legal information

### 18.1 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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Date of release: 8 November 2017

Document identifier: PCA9538