



# PCA9671

Remote 16-bit I/O expander for Fm+ I<sup>2</sup>C-bus with reset

Rev. 3 — 29 September 2011

Product data sheet

## 1. General description

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The PCA9671 provides general purpose remote I/O expansion for most microcontroller families via the two-line bidirectional bus (I<sup>2</sup>C-bus) and is a part of the Fast-mode Plus (Fm+) family.

The PCA9671 is a drop in upgrade for the PCF8575 providing higher I<sup>2</sup>C-bus speeds (1 MHz versus 400 kHz) so that the output can support PWM dimming of LEDs, higher I<sup>2</sup>C-bus drive (30 mA versus 3 mA) so that many more devices can be on the bus without the need for bus buffers, higher total package sink capacity (400 mA versus 100 mA) that supports having all 25 mA LEDs on at the same time and more device addresses (64 versus 8) to allow many more devices on the bus without address conflicts.

The difference between the PCA9671 and the PCF8575 is that the interrupt output on the PCF8575 is replaced by a RESET input on the PCA9671.

The device consists of a 16-bit quasi-bidirectional port and an I<sup>2</sup>C-bus interface. The PCA9671 has a low current consumption and includes latched outputs with 25 mA high current drive capability for directly driving LEDs. The internal Power-On Reset (POR), hardware reset pin ( $\overline{\text{RESET}}$ ) or software reset sequence initializes the I/Os as inputs.

## 2. Features and benefits

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- 1 MHz I<sup>2</sup>C-bus interface
- Compliant with the I<sup>2</sup>C-bus Fast-mode and Standard-mode
- SDA with 30 mA sink capability for 4000 pF buses
- 2.3 V to 5.5 V operation with 5.5 V tolerant I/Os
- 16-bit remote I/O pins that default to inputs at power-up
- Latched outputs with 25 mA sink capability for directly driving LEDs
- Total package sink capability of 400 mA
- Active LOW reset input
- 64 programmable slave addresses using 3 address pins
- Readable device ID (manufacturer, device type, and revision)
- Low standby current
- -40 °C to +85 °C operation
- 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
- Packages offered: SO24, TSSOP24, HVQFN24, DHVQFN24



### 3. Applications

- LED signs and displays
- Servers
- Industrial control
- Medical equipment
- PLCs
- Cellular telephones
- Gaming machines
- Instrumentation and test measurement

### 4. Ordering information

Table 1. Ordering information

| Type number | Topside mark | Package  |  |          |
|-------------|--------------|----------|--|----------|
|             |              | Name     | Description  | Version  |
| PCA9671D    | PCA9671D     | SO24     | plastic small outline package; 24 leads; body width 7.5 mm   | SOT137-1 |
| PCA9671PW   | PCA9671PW    | TSSOP24  | plastic thin shrink small outline package; 24 leads; body width 4.4 mm   | SOT355-1 |
| PCA9671BQ   | 9671         | DHVQFN24 | plastic dual in-line compatible thermal enhanced very thin quad flat package; no leads; 24 terminals; body 3.5 × 5.5 × 0.85 mm | SOT815-1 |
| PCA9671BS   | 9671         | HVQFN24  | plastic thermal enhanced very thin quad flat package; no leads; 24 terminals; body 4 × 4 × 0.85 mm                             | SOT616-1 |

5. Block diagram

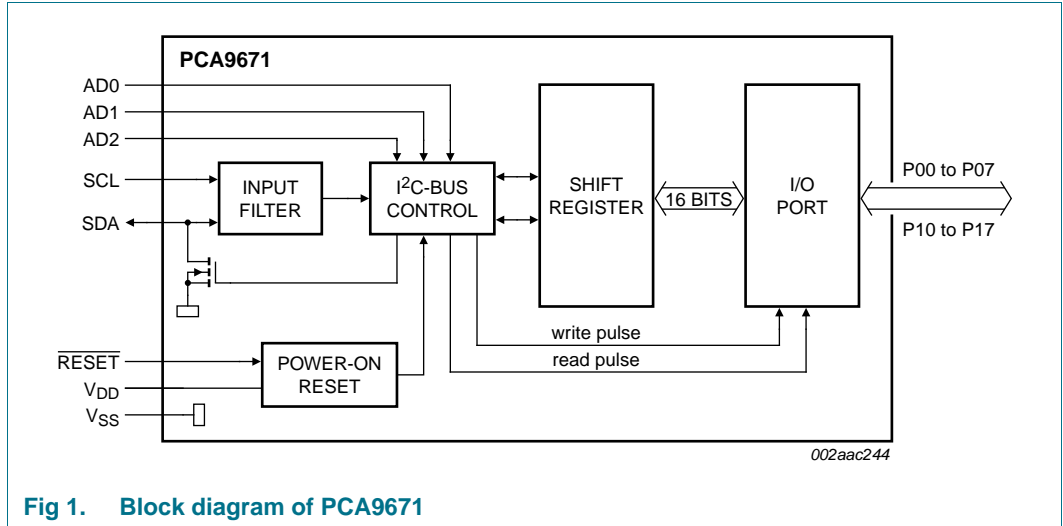


Fig 1. Block diagram of PCA9671

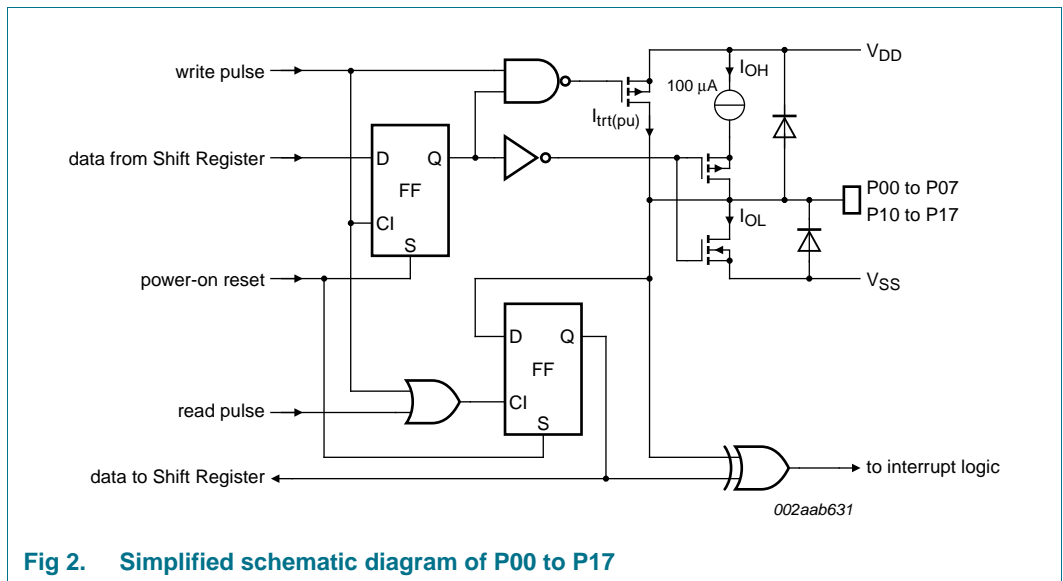
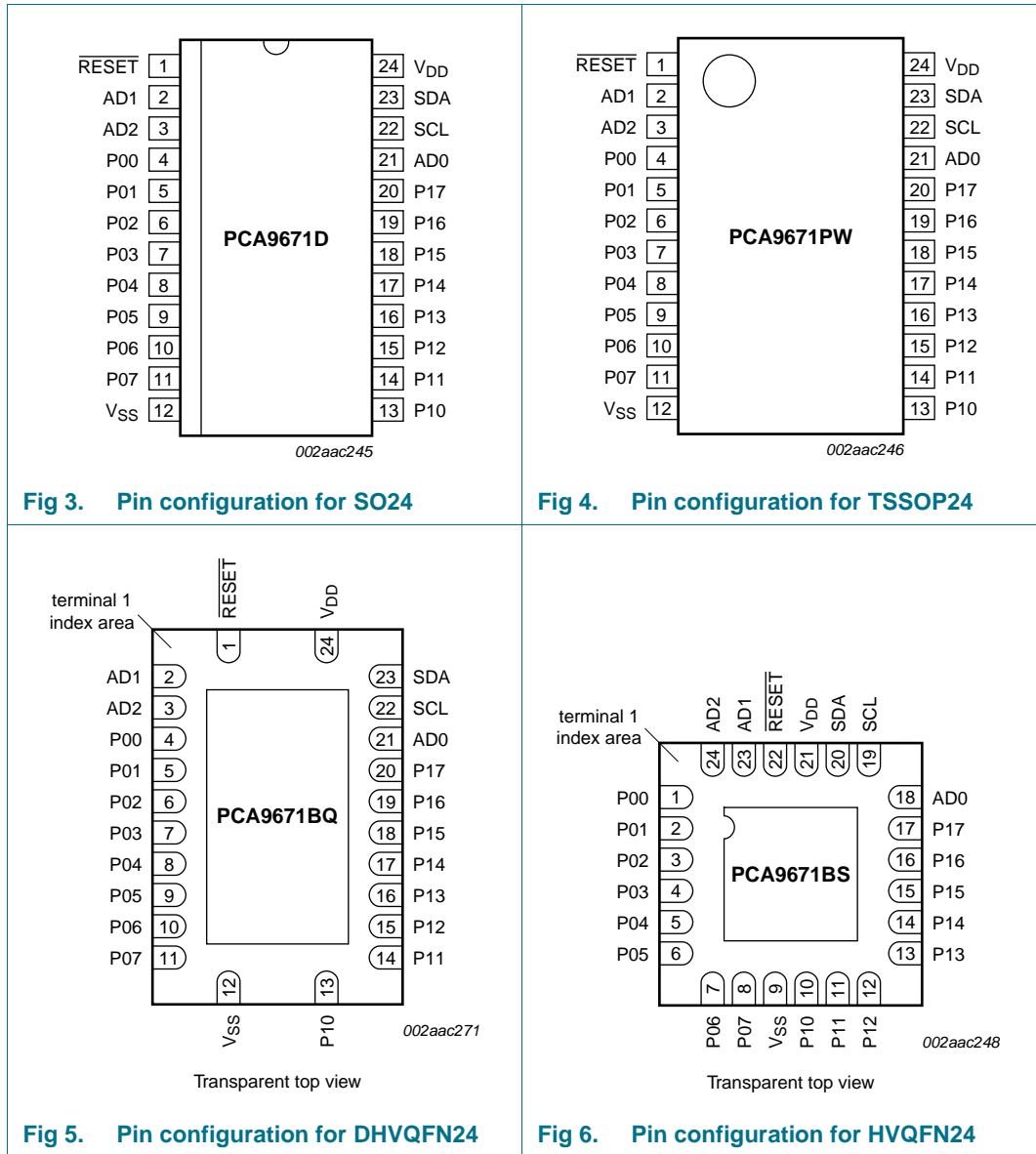


Fig 2. Simplified schematic diagram of P00 to P17

## 6. Pinning information

### 6.1 Pinning



## 6.2 Pin description

Table 2. Pin description

| Symbol                    | Pin                        |                  | Description                   |
|---------------------------|----------------------------|------------------|-------------------------------|
|                           | SO24, TSSOP24,<br>DHVQFN24 | HVQFN24          |                               |
| $\overline{\text{RESET}}$ | 1                          | 22               | reset input (active LOW)      |
| AD1                       | 2                          | 23               | address input 1               |
| AD2                       | 3                          | 24               | address input 2               |
| P00                       | 4                          | 1                | quasi-bidirectional I/O 00    |
| P01                       | 5                          | 2                | quasi-bidirectional I/O 01    |
| P02                       | 6                          | 3                | quasi-bidirectional I/O 02    |
| P03                       | 7                          | 4                | quasi-bidirectional I/O 03    |
| P04                       | 8                          | 5                | quasi-bidirectional I/O 04    |
| P05                       | 9                          | 6                | quasi-bidirectional I/O 05    |
| P06                       | 10                         | 7                | quasi-bidirectional I/O 06    |
| P07                       | 11                         | 8                | quasi-bidirectional I/O 07    |
| V <sub>SS</sub>           | 12 <sup>[1]</sup>          | 9 <sup>[1]</sup> | supply ground                 |
| P10                       | 13                         | 10               | quasi-bidirectional I/O 10    |
| P11                       | 14                         | 11               | quasi-bidirectional I/O 11    |
| P12                       | 15                         | 12               | quasi-bidirectional I/O 12    |
| P13                       | 16                         | 13               | quasi-bidirectional I/O 13    |
| P14                       | 17                         | 14               | quasi-bidirectional I/O 14    |
| P15                       | 18                         | 15               | quasi-bidirectional I/O 15    |
| P16                       | 19                         | 16               | quasi-bidirectional I/O 16    |
| P17                       | 20                         | 17               | quasi-bidirectional I/O 17    |
| AD0                       | 21                         | 18               | address input 0               |
| SCL                       | 22                         | 19               | serial clock line input       |
| SDA                       | 23                         | 20               | serial data line input/output |
| V <sub>DD</sub>           | 24                         | 21               | supply voltage                |

- [1] HVQFN24 and DHVQFN24 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 PCB in the thermal pad region.

## 7. Functional description

Refer to [Figure 1 “Block diagram of PCA9671”](#).

### 7.1 Device address

Following a START condition, the bus master must send the address of the slave it is accessing and the operation it wants to perform (read or write). The address of the PCA9671 is shown in [Figure 7](#). Slave address pins AD2, AD1, and AD0 choose 1 of 64 slave addresses. To conserve power, no internal pull-up resistors are incorporated on AD2, AD1, and AD0. Address values depending on AD2, AD1, and AD0 can be found in [Table 3 “PCA9671 address map”](#).

**Remark:** The General Call address (0000 0000) and the Device ID address (1111 100X) are reserved and cannot be used as device address. Failure to follow this requirement will cause the PCA9671 not to acknowledge.

**Remark:** Reserved I<sup>2</sup>C-bus addresses must be used with caution since they can interfere with:

- “reserved for future use” I<sup>2</sup>C-bus addresses (0000 011, 1111 101, 1111 110, 1111 111)
- slave devices that use the 10-bit addressing scheme (1111 0xx)
- High speed mode (Hs-mode) master code (0000 1xx)

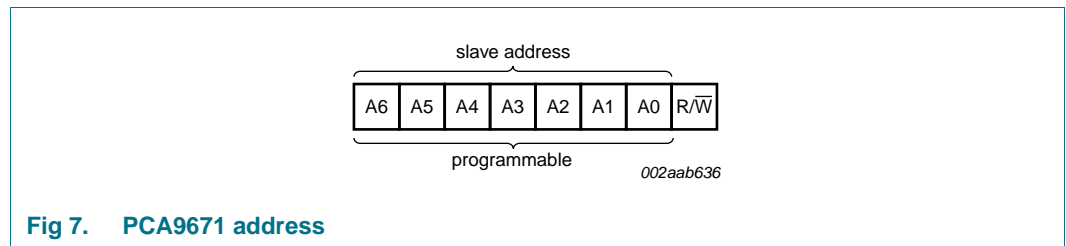


Fig 7. PCA9671 address

The last bit of the first byte defines the operation to be performed. When set to logic 1 a read is selected, while a logic 0 selects a write operation.

When AD2, AD1 and AD0 are held to V<sub>DD</sub> or V<sub>SS</sub>, the same address as the PCF8575 is applied.

#### 7.1.1 Address maps

Table 3. PCA9671 address map

| AD2             | AD1 | AD0             | A6 | A5 | A4 | A3 | A2 | A1 | A0 | Address (hex) |
|-----------------|-----|-----------------|----|----|----|----|----|----|----|---------------|
| V <sub>SS</sub> | SCL | V <sub>SS</sub> | 0  | 0  | 1  | 0  | 0  | 0  | 0  | 20h           |
| V <sub>SS</sub> | SCL | V <sub>DD</sub> | 0  | 0  | 1  | 0  | 0  | 0  | 1  | 22h           |
| V <sub>SS</sub> | SDA | V <sub>SS</sub> | 0  | 0  | 1  | 0  | 0  | 1  | 0  | 24h           |
| V <sub>SS</sub> | SDA | V <sub>DD</sub> | 0  | 0  | 1  | 0  | 0  | 1  | 1  | 26h           |
| V <sub>DD</sub> | SCL | V <sub>SS</sub> | 0  | 0  | 1  | 0  | 1  | 0  | 0  | 28h           |
| V <sub>DD</sub> | SCL | V <sub>DD</sub> | 0  | 0  | 1  | 0  | 1  | 0  | 1  | 2Ah           |
| V <sub>DD</sub> | SDA | V <sub>SS</sub> | 0  | 0  | 1  | 0  | 1  | 1  | 0  | 2Ch           |
| V <sub>DD</sub> | SDA | V <sub>DD</sub> | 0  | 0  | 1  | 0  | 1  | 1  | 1  | 2Eh           |

Table 3. PCA9671 address map ...continued

| AD2             | AD1             | AD0             | A6 | A5 | A4 | A3 | A2 | A1 | A0 | Address (hex) |
|-----------------|-----------------|-----------------|----|----|----|----|----|----|----|---------------|
| V <sub>SS</sub> | SCL             | SCL             | 0  | 0  | 1  | 1  | 0  | 0  | 0  | 30h           |
| V <sub>SS</sub> | SCL             | SDA             | 0  | 0  | 1  | 1  | 0  | 0  | 1  | 32h           |
| V <sub>SS</sub> | SDA             | SCL             | 0  | 0  | 1  | 1  | 0  | 1  | 0  | 34h           |
| V <sub>SS</sub> | SDA             | SDA             | 0  | 0  | 1  | 1  | 0  | 1  | 1  | 36h           |
| V <sub>DD</sub> | SCL             | SCL             | 0  | 0  | 1  | 1  | 1  | 0  | 0  | 38h           |
| V <sub>DD</sub> | SCL             | SDA             | 0  | 0  | 1  | 1  | 1  | 0  | 1  | 3Ah           |
| V <sub>DD</sub> | SDA             | SCL             | 0  | 0  | 1  | 1  | 1  | 1  | 0  | 3Ch           |
| V <sub>DD</sub> | SDA             | SDA             | 0  | 0  | 1  | 1  | 1  | 1  | 1  | 3Eh           |
| V <sub>SS</sub> | V <sub>SS</sub> | V <sub>SS</sub> | 0  | 1  | 0  | 0  | 0  | 0  | 0  | 40h           |
| V <sub>SS</sub> | V <sub>SS</sub> | V <sub>DD</sub> | 0  | 1  | 0  | 0  | 0  | 0  | 1  | 42h           |
| V <sub>SS</sub> | V <sub>DD</sub> | V <sub>SS</sub> | 0  | 1  | 0  | 0  | 0  | 1  | 0  | 44h           |
| V <sub>SS</sub> | V <sub>DD</sub> | V <sub>DD</sub> | 0  | 1  | 0  | 0  | 0  | 1  | 1  | 46h           |
| V <sub>DD</sub> | V <sub>SS</sub> | V <sub>SS</sub> | 0  | 1  | 0  | 0  | 1  | 0  | 0  | 48h           |
| V <sub>DD</sub> | V <sub>SS</sub> | V <sub>DD</sub> | 0  | 1  | 0  | 0  | 1  | 0  | 1  | 4Ah           |
| V <sub>DD</sub> | V <sub>DD</sub> | V <sub>SS</sub> | 0  | 1  | 0  | 0  | 1  | 1  | 0  | 4Ch           |
| V <sub>DD</sub> | V <sub>DD</sub> | V <sub>DD</sub> | 0  | 1  | 0  | 0  | 1  | 1  | 1  | 4Eh           |
| V <sub>SS</sub> | V <sub>SS</sub> | SCL             | 0  | 1  | 0  | 1  | 0  | 0  | 0  | 50h           |
| V <sub>SS</sub> | V <sub>SS</sub> | SDA             | 0  | 1  | 0  | 1  | 0  | 0  | 1  | 52h           |
| V <sub>SS</sub> | V <sub>DD</sub> | SCL             | 0  | 1  | 0  | 1  | 0  | 1  | 0  | 54h           |
| V <sub>SS</sub> | V <sub>DD</sub> | SDA             | 0  | 1  | 0  | 1  | 0  | 1  | 1  | 56h           |
| V <sub>DD</sub> | V <sub>SS</sub> | SCL             | 0  | 1  | 0  | 1  | 1  | 0  | 0  | 58h           |
| V <sub>DD</sub> | V <sub>SS</sub> | SDA             | 0  | 1  | 0  | 1  | 1  | 0  | 1  | 5Ah           |
| V <sub>DD</sub> | V <sub>DD</sub> | SCL             | 0  | 1  | 0  | 1  | 1  | 1  | 0  | 5Ch           |
| V <sub>DD</sub> | V <sub>DD</sub> | SDA             | 0  | 1  | 0  | 1  | 1  | 1  | 1  | 5Eh           |
| SCL             | SCL             | V <sub>SS</sub> | 1  | 0  | 1  | 0  | 0  | 0  | 0  | A0h           |
| SCL             | SCL             | V <sub>DD</sub> | 1  | 0  | 1  | 0  | 0  | 0  | 1  | A2h           |
| SCL             | SDA             | V <sub>SS</sub> | 1  | 0  | 1  | 0  | 0  | 1  | 0  | A4h           |
| SCL             | SDA             | V <sub>DD</sub> | 1  | 0  | 1  | 0  | 0  | 1  | 1  | A6h           |
| SDA             | SCL             | V <sub>SS</sub> | 1  | 0  | 1  | 0  | 1  | 0  | 0  | A8h           |
| SDA             | SCL             | V <sub>DD</sub> | 1  | 0  | 1  | 0  | 1  | 0  | 1  | AAh           |
| SDA             | SDA             | V <sub>SS</sub> | 1  | 0  | 1  | 0  | 1  | 1  | 0  | ACh           |
| SDA             | SDA             | V <sub>DD</sub> | 1  | 0  | 1  | 0  | 1  | 1  | 1  | AEh           |
| SCL             | SCL             | SCL             | 1  | 0  | 1  | 1  | 0  | 0  | 0  | B0h           |
| SCL             | SCL             | SDA             | 1  | 0  | 1  | 1  | 0  | 0  | 1  | B2h           |
| SCL             | SDA             | SCL             | 1  | 0  | 1  | 1  | 0  | 1  | 0  | B4h           |
| SCL             | SDA             | SDA             | 1  | 0  | 1  | 1  | 0  | 1  | 1  | B6h           |
| SDA             | SCL             | SCL             | 1  | 0  | 1  | 1  | 1  | 0  | 0  | B8h           |
| SDA             | SCL             | SDA             | 1  | 0  | 1  | 1  | 1  | 0  | 1  | BAh           |
| SDA             | SDA             | SCL             | 1  | 0  | 1  | 1  | 1  | 1  | 0  | BCh           |
| SDA             | SDA             | SDA             | 1  | 0  | 1  | 1  | 1  | 1  | 1  | BEh           |

Table 3. PCA9671 address map ...continued

| AD2 | AD1             | AD0             | A6 | A5 | A4 | A3 | A2 | A1 | A0 | Address (hex) |
|-----|-----------------|-----------------|----|----|----|----|----|----|----|---------------|
| SCL | V <sub>SS</sub> | V <sub>SS</sub> | 1  | 1  | 0  | 0  | 0  | 0  | 0  | C0h           |
| SCL | V <sub>SS</sub> | V <sub>DD</sub> | 1  | 1  | 0  | 0  | 0  | 0  | 1  | C2h           |
| SCL | V <sub>DD</sub> | V <sub>SS</sub> | 1  | 1  | 0  | 0  | 0  | 1  | 0  | C4h           |
| SCL | V <sub>DD</sub> | V <sub>DD</sub> | 1  | 1  | 0  | 0  | 0  | 1  | 1  | C6h           |
| SDA | V <sub>SS</sub> | V <sub>SS</sub> | 1  | 1  | 0  | 0  | 1  | 0  | 0  | C8h           |
| SDA | V <sub>SS</sub> | V <sub>DD</sub> | 1  | 1  | 0  | 0  | 1  | 0  | 1  | CAh           |
| SDA | V <sub>DD</sub> | V <sub>SS</sub> | 1  | 1  | 0  | 0  | 1  | 1  | 0  | CCh           |
| SDA | V <sub>DD</sub> | V <sub>DD</sub> | 1  | 1  | 0  | 0  | 1  | 1  | 1  | CEh           |
| SCL | V <sub>SS</sub> | SCL             | 1  | 1  | 1  | 0  | 0  | 0  | 0  | E0h           |
| SCL | V <sub>SS</sub> | SDA             | 1  | 1  | 1  | 0  | 0  | 0  | 1  | E2h           |
| SCL | V <sub>DD</sub> | SCL             | 1  | 1  | 1  | 0  | 0  | 1  | 0  | E4h           |
| SCL | V <sub>DD</sub> | SDA             | 1  | 1  | 1  | 0  | 0  | 1  | 1  | E6h           |
| SDA | V <sub>SS</sub> | SCL             | 1  | 1  | 1  | 0  | 1  | 0  | 0  | E8h           |
| SDA | V <sub>SS</sub> | SDA             | 1  | 1  | 1  | 0  | 1  | 0  | 1  | EAh           |
| SDA | V <sub>DD</sub> | SCL             | 1  | 1  | 1  | 0  | 1  | 1  | 0  | ECh           |
| SDA | V <sub>DD</sub> | SDA             | 1  | 1  | 1  | 0  | 1  | 1  | 1  | EEh           |

### 7.2 Software Reset call, and device ID addresses

Two other different addresses can be sent to the PCA9671.

- General Call address: allows to reset the PCA9671 through the I<sup>2</sup>C-bus upon reception of the right I<sup>2</sup>C-bus sequence. See [Section 7.2.1 “Software Reset”](#) for more information.
- Device ID address: allows to read ID information from the device (manufacturer, part identification, revision). See [Section 7.2.2 “Device ID \(PCA9671 ID field\)”](#) for more information.

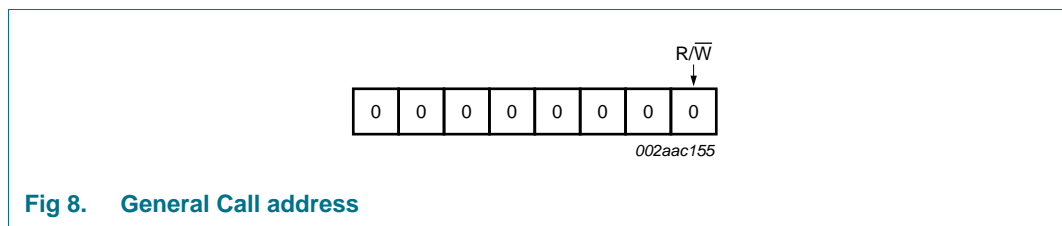


Fig 8. General Call address

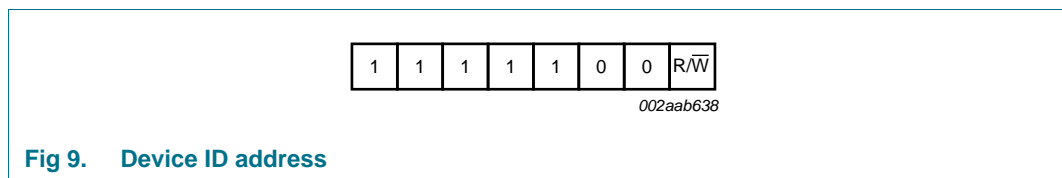


Fig 9. Device ID address



7.2.1 Software Reset

The Software Reset Call allows all the devices in the I<sup>2</sup>C-bus to be reset to the power-up state value through a specific formatted I<sup>2</sup>C-bus command. To be performed correctly, it implies that the I<sup>2</sup>C-bus is functional and that there is no device hanging the bus.

The Software Reset sequence is defined as following:

1. A START command is sent by the I<sup>2</sup>C-bus master.
2. The reserved General Call I<sup>2</sup>C-bus address '0000 000' with the R/W bit set to logic 0 (write) is sent by the I<sup>2</sup>C-bus master.
3. The PCA9671 device(s) acknowledge(s) after seeing the General Call address '0000 0000' (00h) only. If the R/W bit is set to logic 1 (read), no acknowledge is returned to the I<sup>2</sup>C-bus master.
4. Once the General Call address has been sent and acknowledged, the master sends 1 byte. The value of the byte must be equal to 06h.
  - a. The PCA9671 acknowledges this value only. If the byte is not equal to 06h, the PCA9671 does not acknowledge it.

If more than 1 byte of data is sent, the PCA9671 does not acknowledge any more.

5. Once the right byte has been sent and correctly acknowledged, the master sends a STOP command to end the Software Reset sequence: the PCA9671 then resets to the default value (power-up value) and is ready to be addressed again within the specified bus free time. If the master sends a Repeated START instead, no reset is performed.

The I<sup>2</sup>C-bus master must interpret a non-acknowledge from the PCA9671 (at any time) as a 'Software Reset Abort'. The PCA9671 does not initiate a reset of its registers.

The unique sequence that initiates a Software Reset is described in [Figure 10](#).

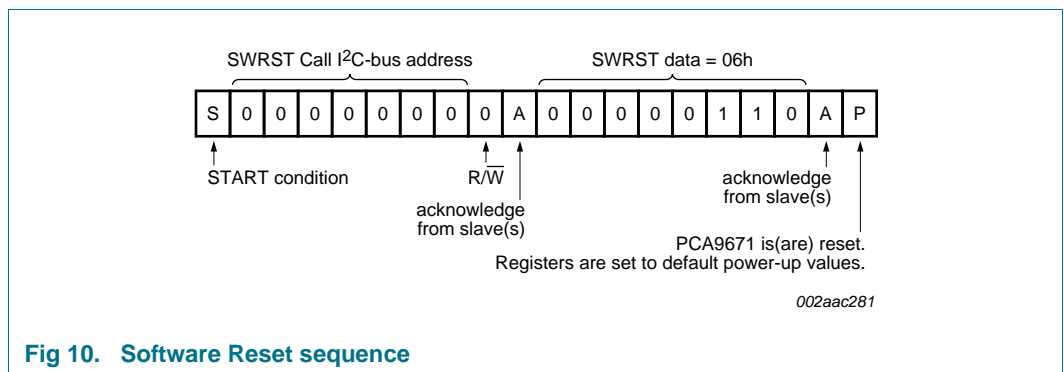


Fig 10. Software Reset sequence

### 7.2.2 Device ID (PCA9671 ID field)

The Device ID field is a 3-byte read-only (24 bits) word giving the following information:

- 8 bits with the manufacturer name, unique per manufacturer (for example, NXP Semiconductors).
- 13 bits with the part identification, assigned by manufacturer, the 7 MSBs with the category ID and the 6 LSBs with the feature ID (for example, PCA9671 16-bit quasi-output I/O expander).
- 3 bits with the die revision, assigned by manufacturer (for example, Rev X).

The Device ID is read-only, hardwired in the device and can be accessed as follows:

1. START command.
2. The master sends the Reserved Device ID I<sup>2</sup>C-bus address '1111 100' with the R/W bit set to logic 0 (write).
3. The master sends the I<sup>2</sup>C-bus slave address of the slave device it needs to identify. The LSB is a 'Don't care' value. Only one device must acknowledge this byte (the one that has the I<sup>2</sup>C-bus slave address).
4. The master sends a Re-START command.

**Remark:** A STOP command followed by a START command will reset the slave state machine and the Device ID read cannot be performed.

**Remark:** A STOP command or a Re-START command followed by an access to another slave device will reset the slave state machine and the Device ID read cannot be performed.

5. The master sends the Reserved Device ID I<sup>2</sup>C-bus address '1111 100' with the R/W bit set to logic 1 (read).
6. The device ID read can be done, starting with the 8 manufacturer bits (first byte + 4 MSB of the second byte), followed by the 13 part identification bits and then the 3 die revision bits (3 LSB of the third byte).
7. The master ends the reading sequence by NACKing the last byte, thus resetting the slave device state machine and allowing the master to send the STOP command.

**Remark:** The reading of the Device ID can be stopped anytime by sending a NACK command.

**Remark:** If the master continues to ACK the bytes after the third byte, the PCA9671 rolls back to the first byte and keeps sending the Device ID sequence until a NACK has been detected.

For the PCA9671, the Device ID is as shown in [Figure 11](#).

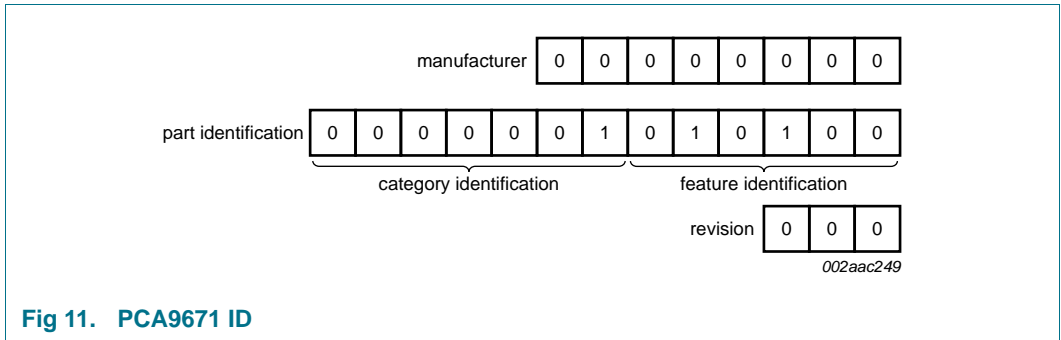


Fig 11. PCA9671 ID

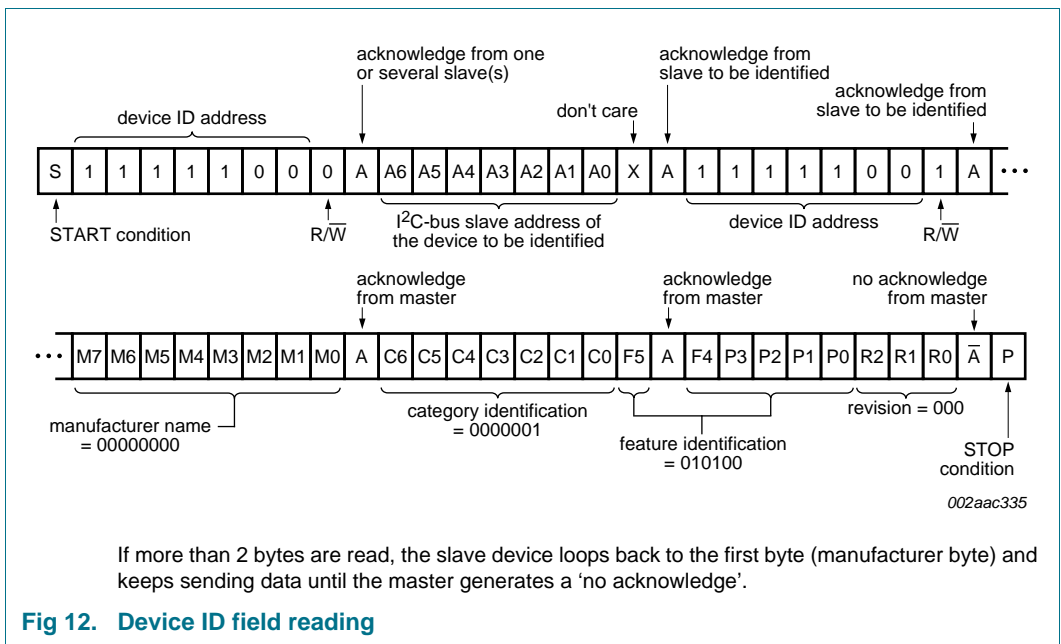


Fig 12. Device ID field reading

## 8. I/O programming

### 8.1 Quasi-bidirectional I/O architecture

The PCA9671's 16 ports (see [Figure 2](#)) are entirely independent and can be used either as input or output ports. Input data is transferred from the ports to the microcontroller in the Read mode (see [Figure 15](#)). Output data is transmitted to the ports in the Write mode (see [Figure 14](#)).

Every data transmission from the PCA9671 must consist of an even number of bytes, the first byte will be referred to as P07 to P00, and the second byte as P17 to P10. The third will be referred to as P07 to P00, and so on.

This quasi-bidirectional I/O can be used as an input or output without the use of a control signal for data directions. At power-on the I/Os are HIGH. In this mode only a current source ( $I_{OH}$ ) to  $V_{DD}$  is active. An additional strong pull-up to  $V_{DD}$  ( $I_{trt(pu)}$ ) allows fast rising edges into heavily loaded outputs. These devices turn on when an output is written HIGH, and are switched off by the negative edge of SCL. The I/Os should be HIGH before being used as inputs. After power-on, as all the I/Os are set HIGH, all of them can be used as inputs. Any change in setting of the I/Os as either inputs or outputs can be done with the write mode.

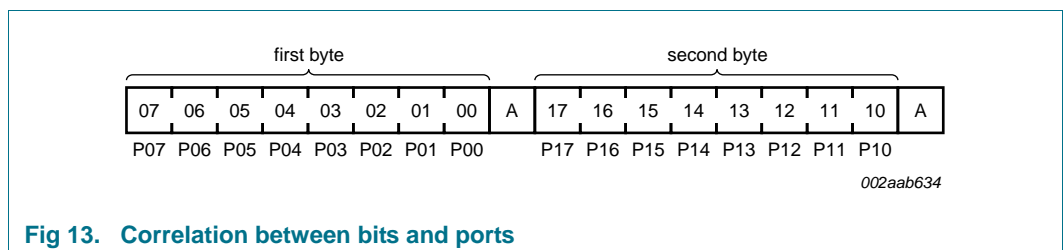
**Remark:** If a HIGH is applied to an I/O which has been written earlier to LOW, a large current ( $I_{OL}$ ) will flow to  $V_{SS}$ .

### 8.2 Writing to the port (Output mode)

To write, the master (microcontroller) first addresses the slave device. By setting the last bit of the byte containing the slave address to logic 0 the Write mode is entered. The PCA9671 acknowledges and the master sends the first data byte for P07 to P00. After the first data byte is acknowledged by the PCA9671, the second data byte P17 to P10 is sent by the master. Once again, the PCA9671 acknowledges the receipt of the data. Each 8-bit data is presented on the port lines after it has been acknowledged by the PCA9671.

The number of data bytes that can be sent successively is not limited. After every two bytes, the previous data is overwritten.

The first data byte in every pair refers to Port 0 (P07 to P00), whereas the second data byte in every pair refers to Port 1 (P17 to P10). See [Figure 13](#).



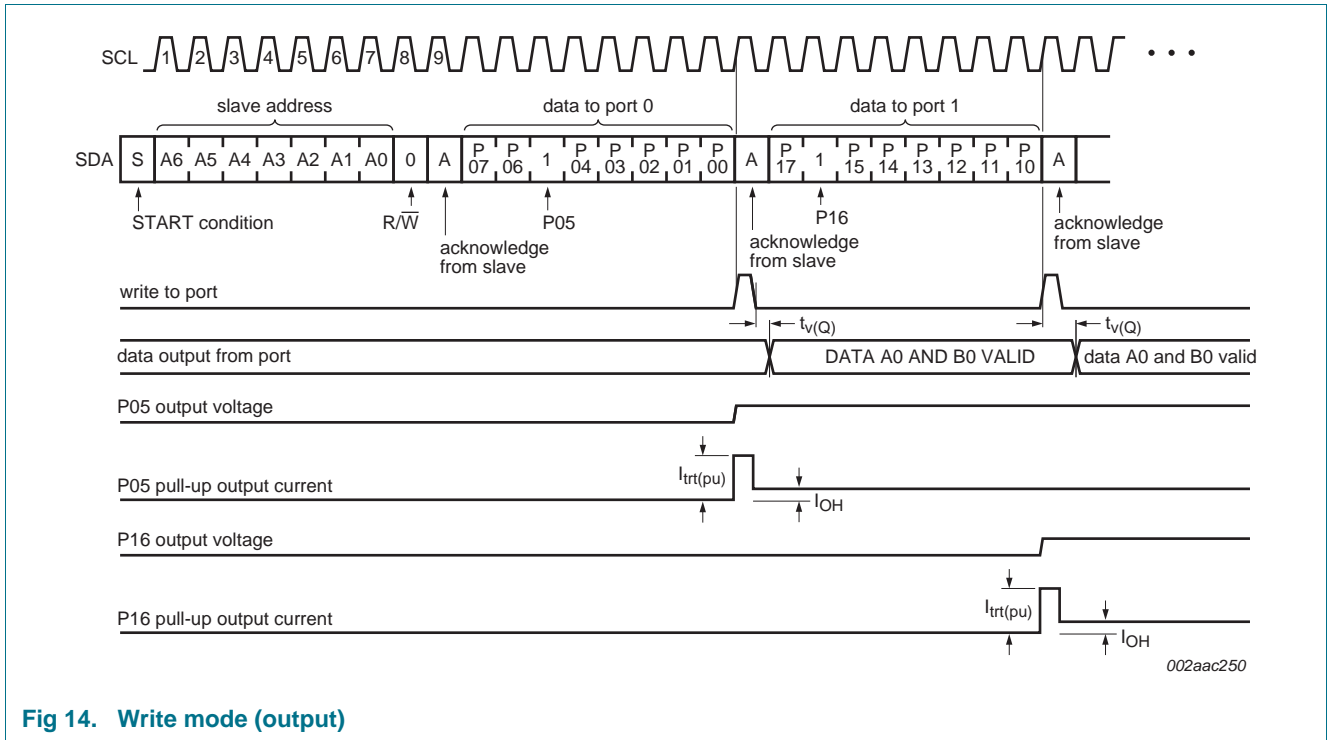
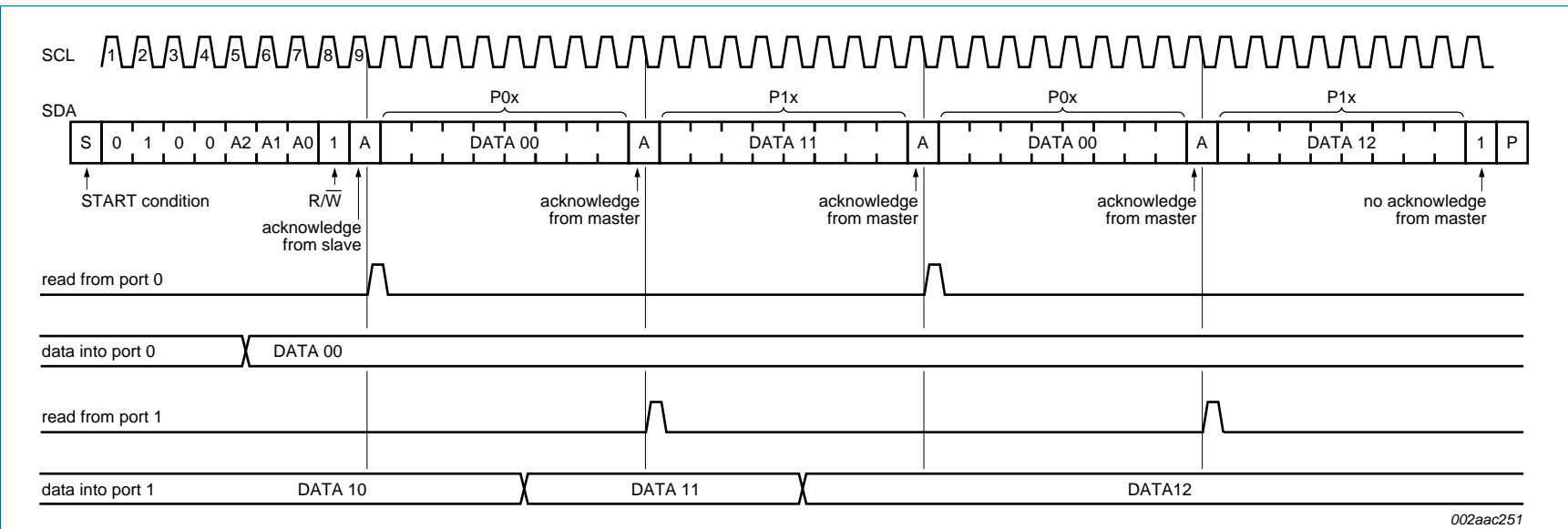


Fig 14. Write mode (output)

### 8.3 Reading from a port (Input mode)

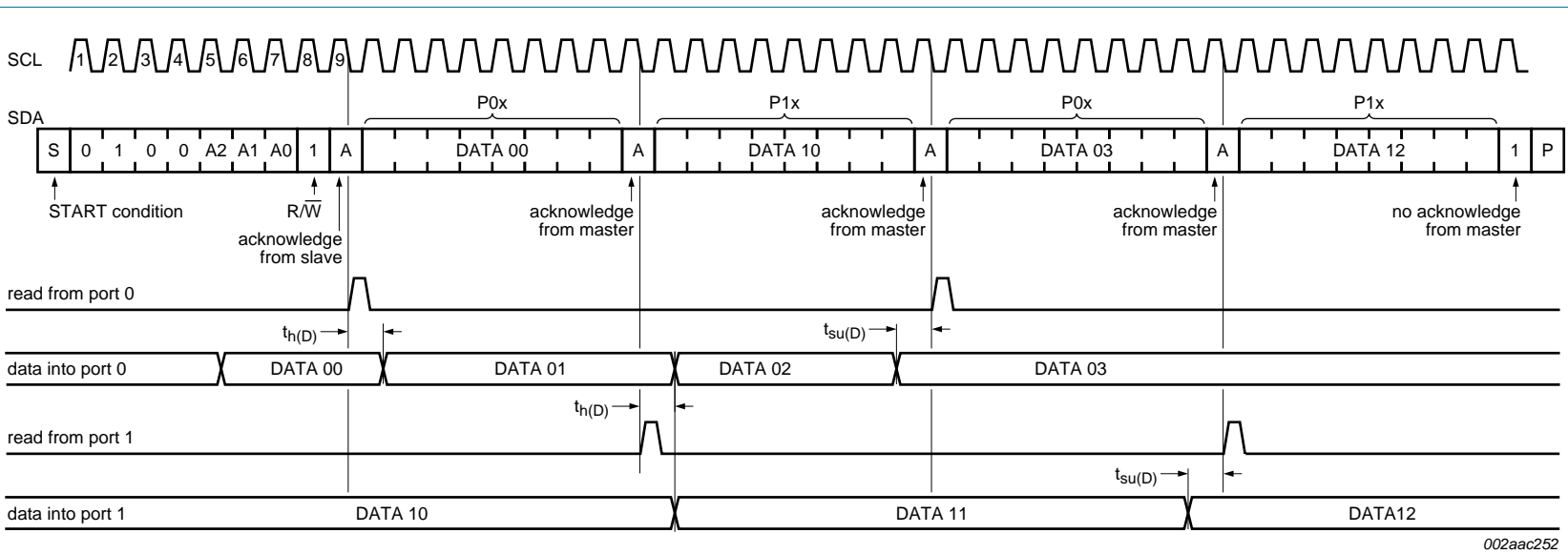
All ports programmed as input should be set to logic 1. To read, the master (microcontroller) first addresses the slave device after it receives the interrupt. By setting the last bit of the byte containing the slave address to logic 1 the Read mode is entered. The data bytes that follow on the SDA are the values on the ports.

If the data on the input port changes faster than the master can read, this data may be lost.



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).

**Fig 15. Read input port register, scenario 1**



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).

Fig 16. Read input port register, scenario 2

## 8.4 Power-on reset

When power is applied to  $V_{DD}$ , an internal Power-On Reset (POR) holds the PCA9671 in a reset condition until  $V_{DD}$  has reached  $V_{POR}$ . At that point, the reset condition is released and the PCA9671 registers and I<sup>2</sup>C-bus/SMBus state machine will initialize to their default states. Thereafter  $V_{DD}$  must be lowered below 0.2 V to reset the device.

## 8.5 RESET input

A reset can be accomplished by holding the  $\overline{\text{RESET}}$  pin LOW for a minimum of  $t_{w(\text{rst})}$ . The PCA9671 registers and I<sup>2</sup>C-bus state machine will be held in their default state until the RESET input is once again HIGH.

# 9. Characteristics of the I<sup>2</sup>C-bus

The I<sup>2</sup>C-bus is for 2-way, 2-line communication between different ICs or modules. The two 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.

## 9.1 Bit transfer

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as control signals (see [Figure 17](#)).

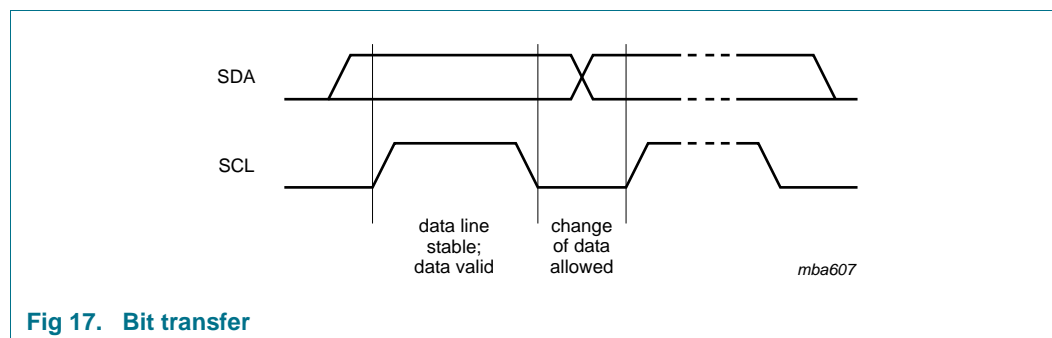


Fig 17. Bit transfer

### 9.1.1 START and STOP conditions

Both data and clock lines remain HIGH when the bus is not busy. A HIGH-to-LOW transition of the data line while the clock is HIGH is defined as the START condition (S). A LOW-to-HIGH transition of the data line while the clock is HIGH is defined as the STOP condition (P) (see [Figure 18](#)).



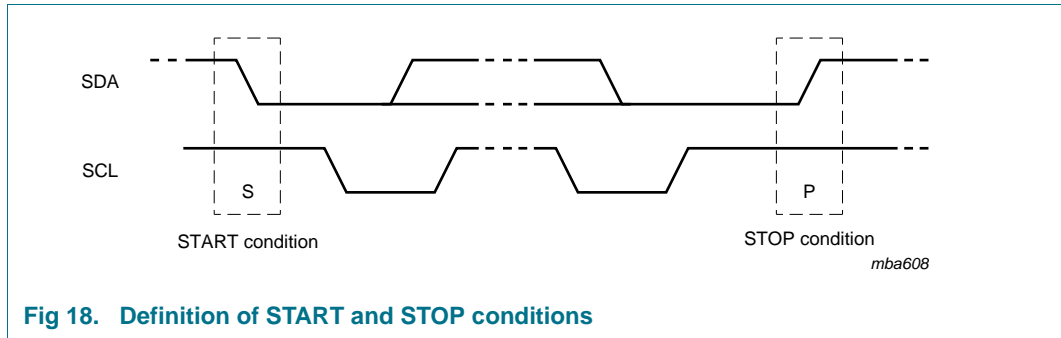


Fig 18. Definition of START and STOP conditions

### 9.2 System configuration

A device generating a message is a ‘transmitter’; a device receiving is the ‘receiver’. The device that controls the message is the ‘master’ and the devices which are controlled by the master are the ‘slaves’ (see [Figure 19](#)).

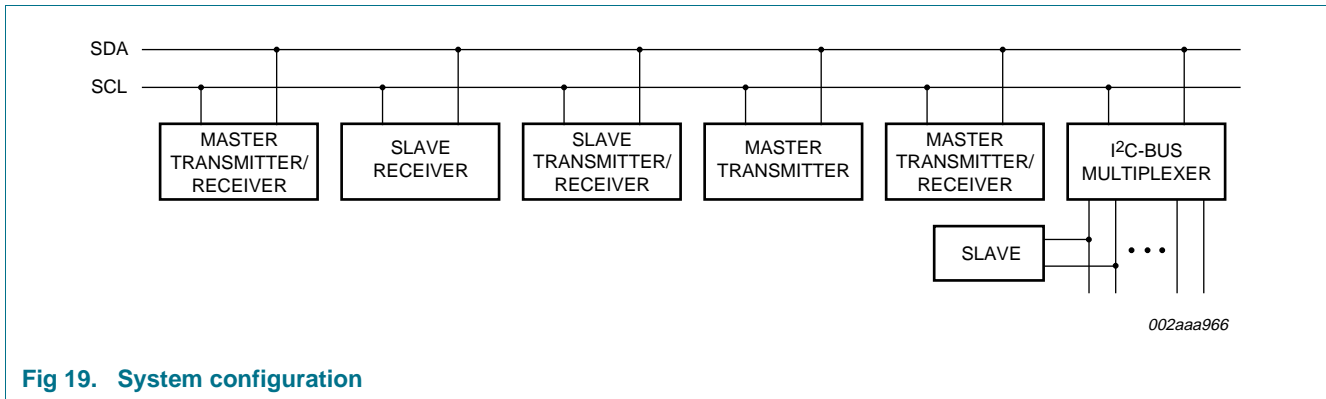


Fig 19. System configuration

### 9.3 Acknowledge

The number of data bytes transferred between the START and the STOP conditions from transmitter to receiver is not limited. Each byte of eight bits is followed by one acknowledge bit. The acknowledge bit is a HIGH level put on the bus by the transmitter, whereas the master generates an extra acknowledge related clock pulse.

A slave receiver which is addressed must generate an acknowledge after the reception of each byte. Also a master must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter. The device that acknowledges has to pull down the SDA line during the acknowledge clock pulse, so that the SDA line is stable LOW during the HIGH period of the acknowledge related clock pulse; set-up and hold times must be taken into account.

A master receiver must signal an end of data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this event, the transmitter must leave the data line HIGH to enable the master to generate a STOP condition.

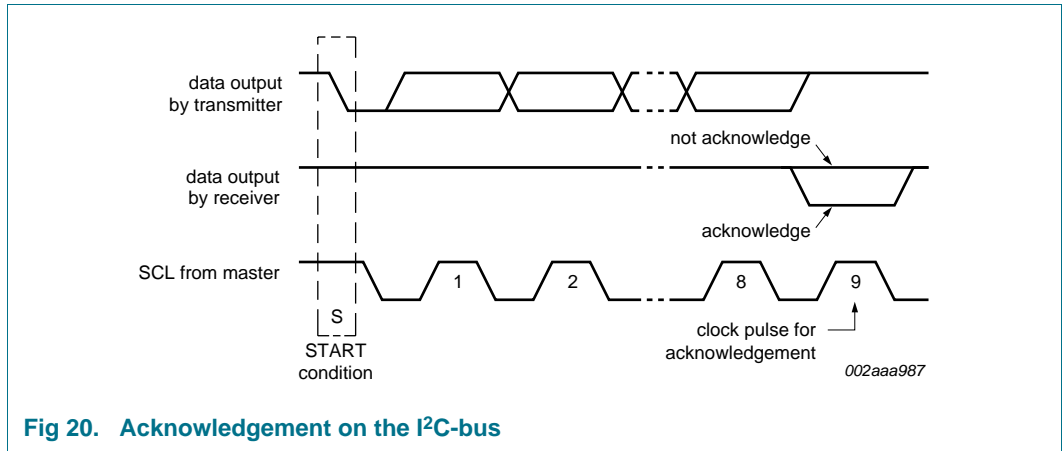


Fig 20. Acknowledgement on the I<sup>2</sup>C-bus

## 10. Application design-in information

### 10.1 Bidirectional I/O expander applications

In the 8-bit I/O expander application shown in [Figure 21](#), P00 and P01 are inputs, and P02 to P07 are outputs. When used in this configuration, during a write, the input (P00 and P01) must be written as HIGH so the external devices fully control the input ports. The desired HIGH or LOW logic levels may be written to the I/Os used as outputs (P02 to P07). During a read, the logic levels of the external devices driving the input ports (P00 and P01) and the previous written logic level to the output ports (P02 to P07) will be read.

The GPIO also has a reset line ( $\overline{\text{RESET}}$ ) that can be connected to an output pin of the microprocessor. Since the device does not have an interrupt output, changes of the I/Os can be monitored by reading the input registers. If both a  $\overline{\text{RESET}}$  and  $\overline{\text{INT}}$  are needed, use the PCA9673.

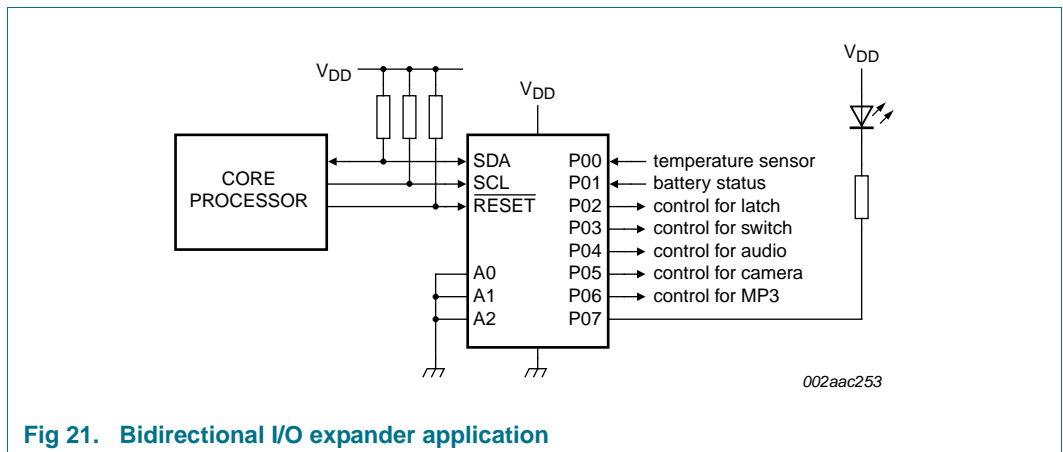


Fig 21. Bidirectional I/O expander application

### 10.2 High current-drive load applications

The GPIO has a maximum sinking current of 25 mA per bit. In applications requiring additional drive, two port pins in the same octal may be connected together to sink up to 50 mA current. Both bits must then always be turned on or off together. Up to 8 pins (one octal) can be connected together to drive 200 mA.

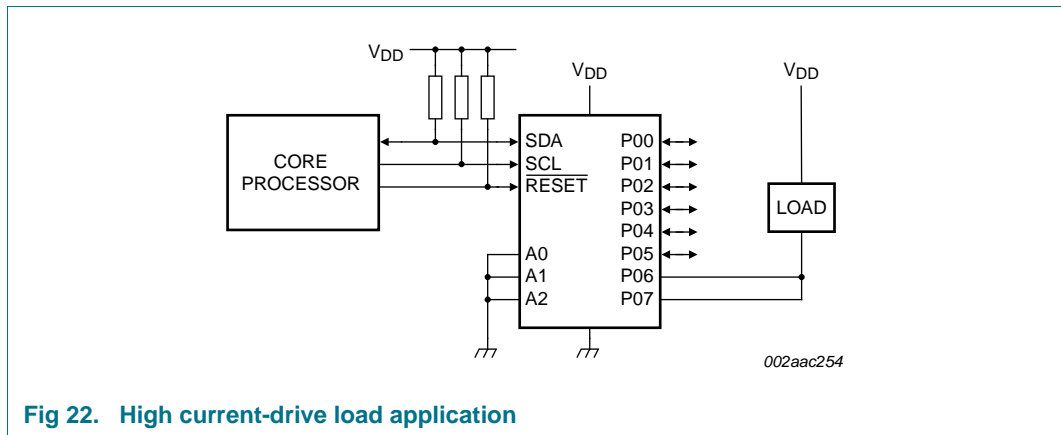


Fig 22. High current-drive load application

## 11. Limiting values

Table 4. 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                 | V    |
| I <sub>DD</sub>  | supply current               |            | -                     | ±100               | mA   |
| I <sub>SS</sub>  | ground supply current        |            | -                     | ±600               | mA   |
| V <sub>I</sub>   | input voltage                |            | V <sub>SS</sub> - 0.5 | 5.5                | V    |
| I <sub>I</sub>   | input current                |            | -                     | ±20                | mA   |
| I <sub>O</sub>   | output current               |            | -                     | ±50 <sup>[1]</sup> | mA   |
| P <sub>tot</sub> | total power dissipation      |            | -                     | 600                | mW   |
| P/out            | power dissipation per output |            | -                     | 200                | mW   |
| T <sub>stg</sub> | storage temperature          |            | -65                   | +150               | °C   |
| T <sub>amb</sub> | ambient temperature          | operating  | -40                   | +85                | °C   |

[1] Total package (maximum) output current is 600 mA.

## 12. Static characteristics

**Table 5. Static characteristics**
 $V_{DD} = 2.3\text{ V to }5.5\text{ V}; V_{SS} = 0\text{ V}; T_{amb} = -40\text{ }^{\circ}\text{C to }+85\text{ }^{\circ}\text{C};$  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; no load;<br>$V_I = V_{DD}$ or $V_{SS}$ ; $f_{SCL} = 400\text{ kHz}$ | -            | 200  | 500           | $\mu\text{A}$ |
| $I_{stb}$                              | standby current                   | standby mode; no load;<br>$V_I = V_{DD}$ or $V_{SS}$                                | -            | 2.5  | 10            | $\mu\text{A}$ |
| $V_{POR}$                              | power-on reset voltage            |   | [1] -        | 1.8  | 2.0           | 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          | $V_{OL} = 0.4\text{ V}$   | 20           | -    | -             | mA            |
| $I_L$                                  | leakage current                   | $V_I = V_{DD}$ or $V_{SS}$  | -1           | -    | +1            | $\mu\text{A}$ |
| $C_i$                                  | input capacitance                 | $V_I = V_{SS}$  | -            | 4    | 10            | pF            |
| <b>I/Os; P00 to P07 and P10 to P17</b> |                                   |   |              |      |               |               |
| $I_{OL}$                               | LOW-level output current          | $V_{OL} = 0.5\text{ V}; V_{DD} = 2.3\text{ V}$                                      | [2] 12       | 27   | -             | mA            |
|  |                                   | $V_{OL} = 0.5\text{ V}; V_{DD} = 3.0\text{ V}$                                      | [2] 17       | 35   | -             | mA            |
|  |                                   | $V_{OL} = 0.5\text{ V}; V_{DD} = 4.5\text{ V}$                                      | [2] 25       | 42   | -             | mA            |
| $I_{OL(tot)}$                          | total LOW-level output current    | $V_{OL} = 0.5\text{ V}; V_{DD} = 4.5\text{ V}$                                      | [2] -        | -    | 400           | mA            |
| $I_{OH}$                               | HIGH-level output current         | $V_{OH} = V_{SS}$   | -30          | -150 | -300          | $\mu\text{A}$ |
| $I_{trt(pu)}$                          | transient boosted pull-up current | $V_{OH} = V_{SS}$ ; see <a href="#">Figure 14</a>                                   | -0.5         | -1.0 | -             | mA            |
| $C_i$                                  | input capacitance                 |   | [3] -        | 4    | 10            | pF            |
| $C_o$                                  | output capacitance                |   | [3] -        | 4    | 10            | pF            |
| <b>Input RESET</b>                     |                                   |   |              |      |               |               |
| $V_{IL}$                               | LOW-level input voltage           |   | -0.5         | -    | +0.8          | V             |
| $V_{IH}$                               | HIGH-level input voltage          |   | 2            | -    | 5.5           | V             |
| $I_{LI}$                               | input leakage current             |   | -1           | -    | +1            | $\mu\text{A}$ |
| $C_i$                                  | input capacitance                 |   | -            | 3    | 5             | pF            |
| <b>Inputs AD0, AD1, AD2</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             |
| $I_{LI}$                               | input leakage current             |   | -1           | -    | +1            | $\mu\text{A}$ |
| $C_i$                                  | input capacitance                 |   | -            | 3    | 5             | pF            |

[1] The power-on reset circuit resets the I<sup>2</sup>C-bus logic with  $V_{DD} < V_{POR}$  and set all I/Os to logic 1 (with current source to  $V_{DD}$ ).

[2] Each bit must be limited to a maximum of 25 mA and the total package limited to 400 mA due to internal busing limits.

[3] The value is not tested, but verified on sampling basis.

### 13. Dynamic characteristics

**Table 6. Dynamic characteristics**

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

| Symbol   | Parameter   | Conditions | Standard-mode I <sup>2</sup> C-bus |      | Fast-mode I <sup>2</sup> C-bus |     | Fast-mode Plus I <sup>2</sup> C-bus |      | Unit |
|--|---|------------|------------------------------------|------|--------------------------------|-----|-------------------------------------|------|------|
|  |   |            | Min                                | Max  | Min                            | Max | Min                                 | Max  |      |
| f <sub>SCL</sub>   | SCL clock frequency   |            | 0                                  | 100  | 0                              | 400 | 0                                   | 1000 | kHz  |
| t <sub>BUF</sub>   | bus free time between a STOP and START condition                  |            | 4.7                                | -    | 1.3                            | -   | 0.5                                 | -    | μs   |
| t <sub>HD;STA</sub>  | hold time (repeated) START condition                              |            | 4.0                                | -    | 0.6                            | -   | 0.26                                | -    | μs   |
| t <sub>SU;STA</sub>  | set-up time for a repeated START condition                        |            | 4.7                                | -    | 0.6                            | -   | 0.26                                | -    | μs   |
| t <sub>SU;STO</sub>  | set-up time for STOP condition                                    |            | 4.0                                | -    | 0.6                            | -   | 0.26                                | -    | μs   |
| t <sub>HD;DAT</sub>  | data hold time  |            | 0                                  | -    | 0                              | -   | 0                                   | -    | ns   |
| t <sub>VD;ACK</sub>  | data valid acknowledge time                                       | [1]        | 0.3                                | 3.45 | 0.1                            | 0.9 | 0.05                                | 0.45 | μs   |
| t <sub>VD;DAT</sub>  | data valid time   | [2]        | 300                                | -    | 50                             | -   | 50                                  | 450  | ns   |
| t <sub>SU;DAT</sub>  | data set-up time  |            | 250                                | -    | 100                            | -   | 50                                  | -    | ns   |
| t <sub>LOW</sub>   | LOW period of the SCL clock                                       |            | 4.7                                | -    | 1.3                            | -   | 0.5                                 | -    | μs   |
| t <sub>HIGH</sub>  | HIGH period of the SCL clock                                      |            | 4.0                                | -    | 0.6                            | -   | 0.26                                | -    | μs   |
| t <sub>f</sub>   | fall time of both SDA and SCL signals                             | [4][5]     | -                                  | 300  | 20 + 0.1C <sub>b</sub> [3]     | 300 | -                                   | 120  | ns   |
| t <sub>r</sub>   | rise time of both SDA and SCL signals                             |            | -                                  | 1000 | 20 + 0.1C <sub>b</sub> [3]     | 300 | -                                   | 120  | ns   |
| t <sub>SP</sub>  | pulse width of spikes that must be suppressed by the input filter | [6]        | -                                  | 50   | -                              | 50  | -                                   | 50   | ns   |
| <b>Port timing; C<sub>L</sub> ≤ 100 pF (see Figure 15 and Figure 14)</b> |   |            |                                    |      |                                |     |                                     |      |      |
| t <sub>v(Q)</sub>  | data output valid time  |            | -                                  | 4    | -                              | 4   | -                                   | 4    | μs   |
| t <sub>su(D)</sub>   | data input set-up time  |            | 0                                  | -    | 0                              | -   | 0                                   | -    | μs   |
| t <sub>h(D)</sub>  | data input hold time  |            | 4                                  | -    | 4                              | -   | 4                                   | -    | μs   |
| <b>Reset timing (see Figure 24)</b>                                      |   |            |                                    |      |                                |     |                                     |      |      |
| t <sub>w(rst)</sub>  | reset pulse width   |            | 4                                  | -    | 4                              | -   | 4                                   | -    | ns   |
| t <sub>rec(rst)</sub>  | reset recovery time   |            | 0                                  | -    | 0                              | -   | 0                                   | -    | ns   |
| t <sub>rst</sub>   | reset time  |            | 100                                | -    | 100                            | -   | 100                                 | -    | ns   |

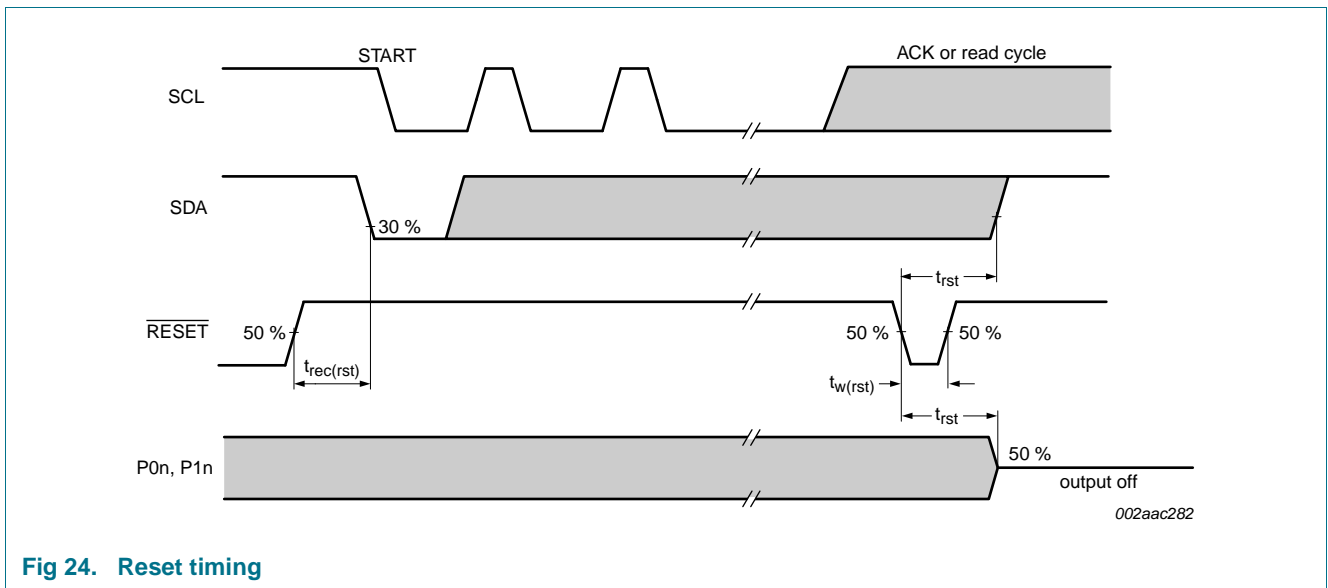
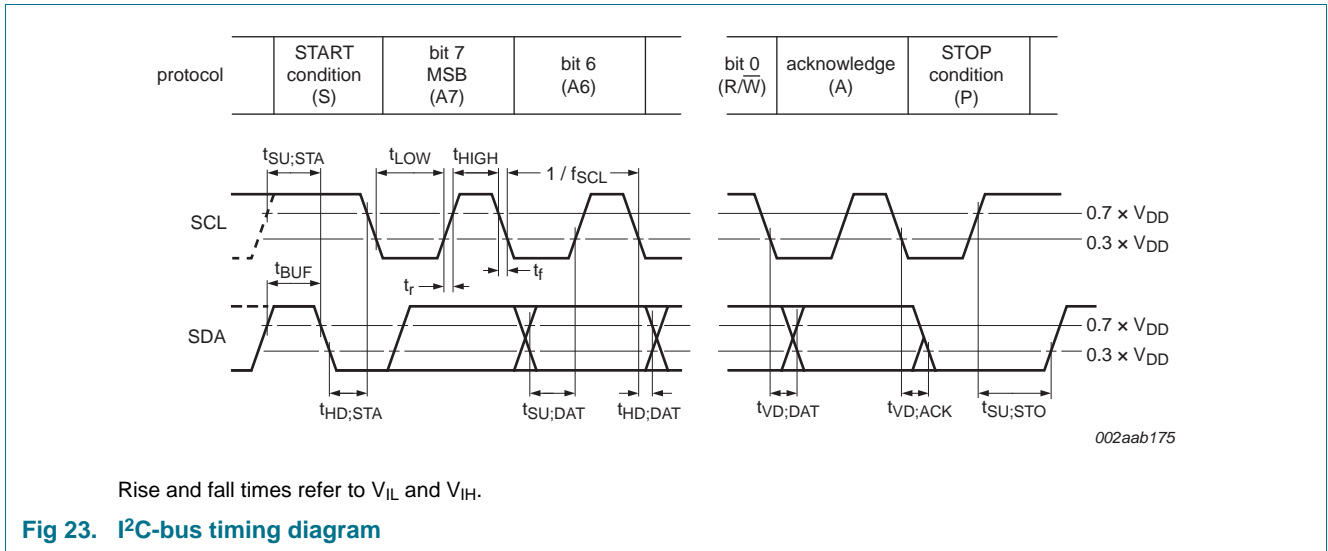
[1] t<sub>VD;ACK</sub> = time for Acknowledgement signal from SCL LOW to SDA (out) LOW.

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

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

[4] A master device must internally provide a hold time of at least 300 ns for the SDA signal (refer to the V<sub>IL</sub> of the SCL signal) in order to bridge the undefined region SCL's falling edge.

- [5] The maximum  $t_r$  for the SDA and SCL bus lines is specified at 300 ns. The maximum fall time for the SDA output stage  $t_f$  is specified at 250 ns. This allows series protection resistors to be connected between the SDA and the SCL pins and the SDA/SCL bus lines without exceeding the maximum specified  $t_r$ .
- [6] Input filters on the SDA and SCL inputs suppress noise spikes less than 50 ns.



14. Package outline

SO24: plastic small outline package; 24 leads; body width 7.5 mm

SOT137-1

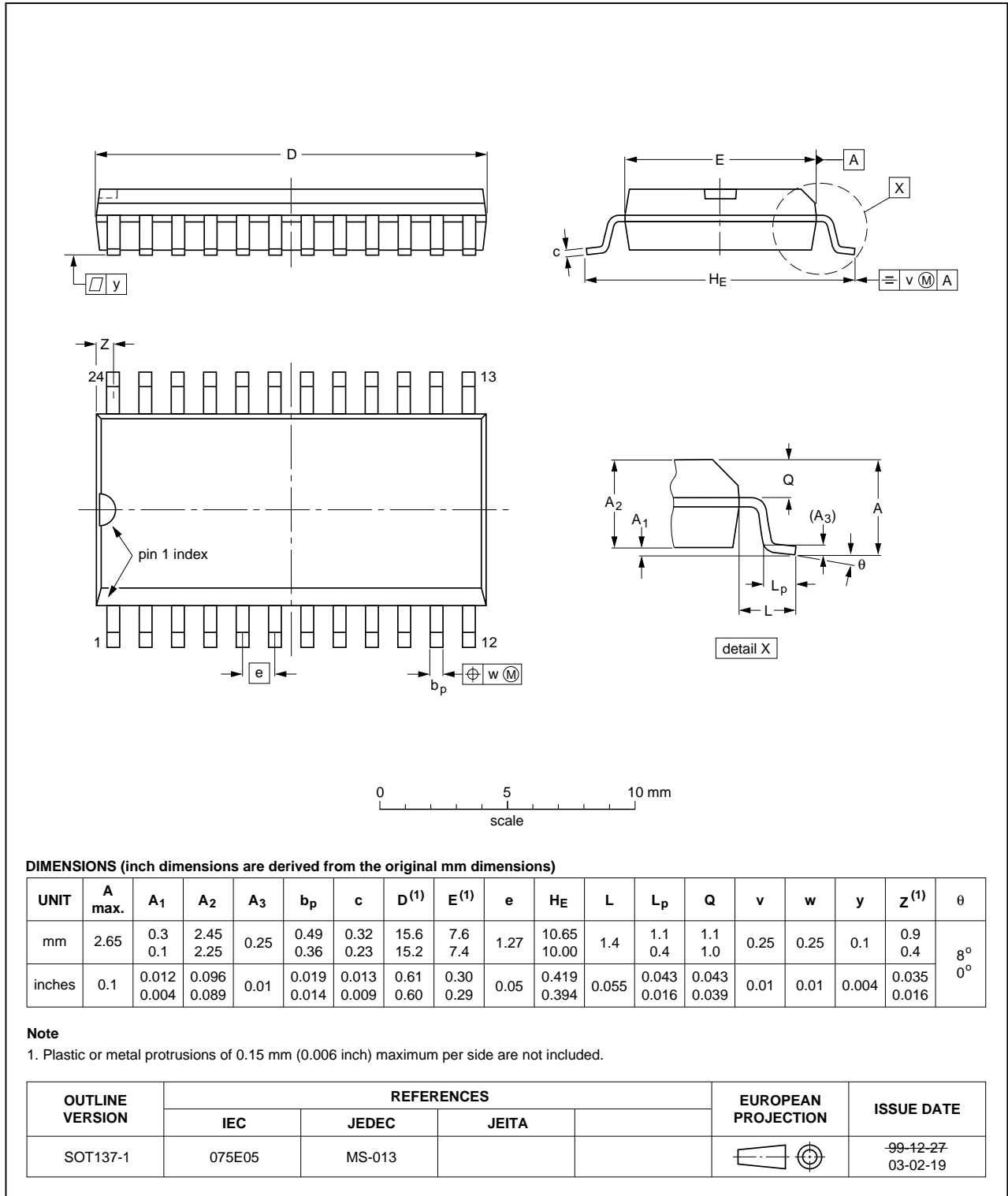


Fig 25. Package outline SOT137-1 (SO24)

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

SOT355-1



Fig 26. Package outline SOT355-1 (TSSOP24)



DHVQFN24: plastic dual in-line compatible thermal enhanced very thin quad flat package; no leads; 24 terminals; body 3.5 x 5.5 x 0.85 mm

SOT815-1

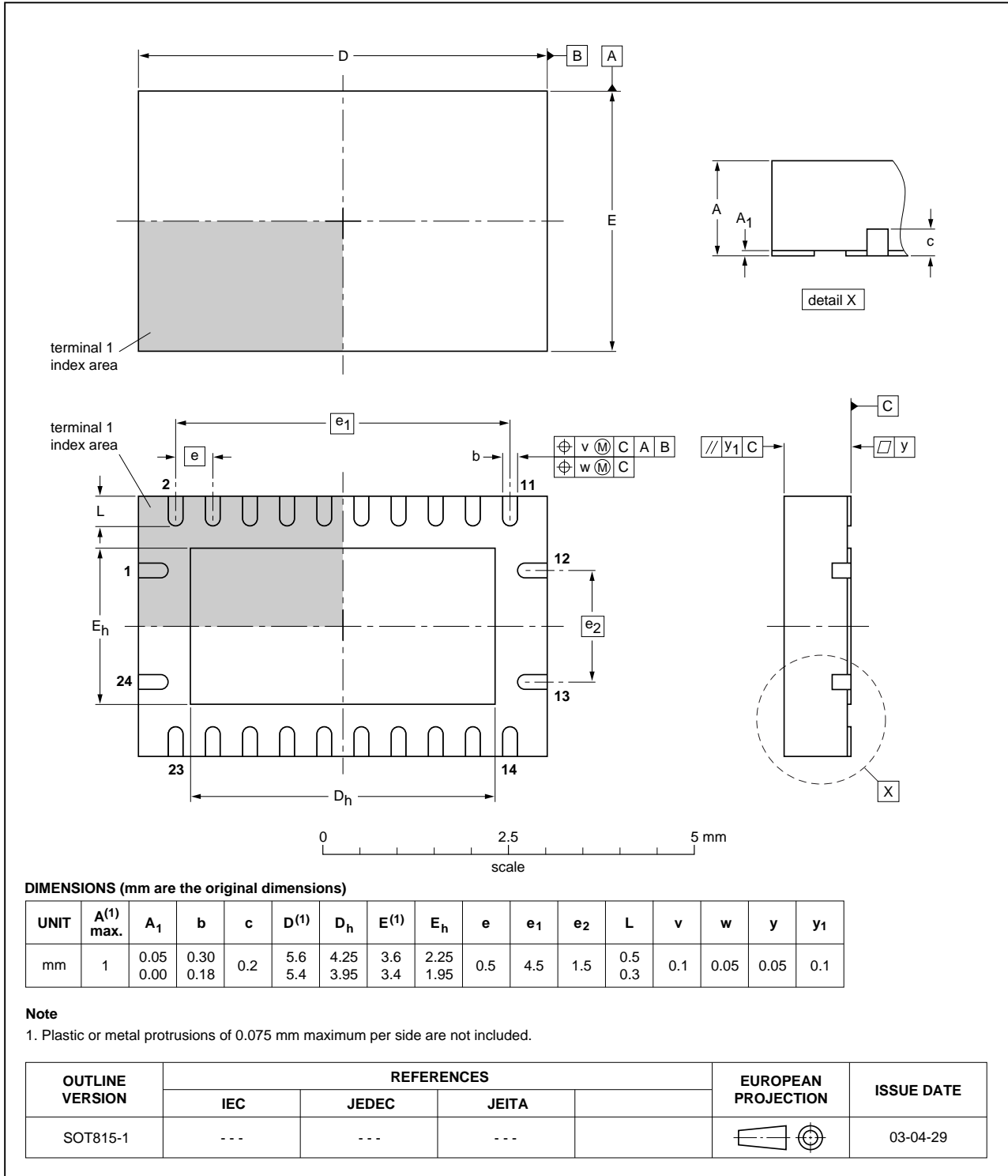


Fig 27. Package outline SOT815-1 (DHVQFN24)

HVQFN24: plastic thermal enhanced very thin quad flat package; no leads; 24 terminals; body 4 x 4 x 0.85 mm

SOT616-1

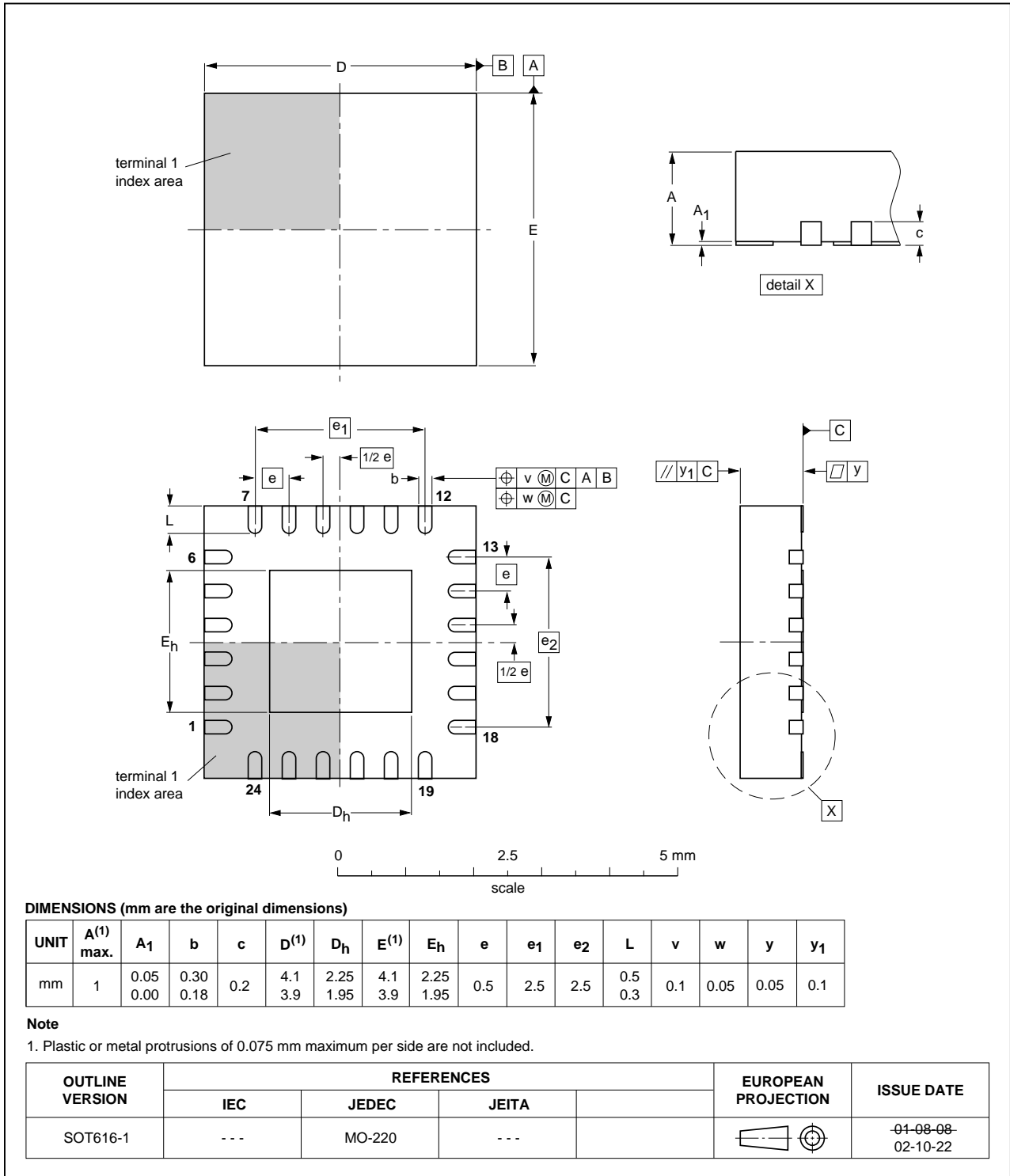


Fig 28. Package outline SOT616-1 (HVQFN24)

## 15. Handling information

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

## 16. 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"*.

### 16.1 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.

### 16.2 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

### 16.3 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

### 16.4 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 29](#)) 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 7](#) and [8](#)

**Table 7. SnPb eutectic process (from J-STD-020C)**

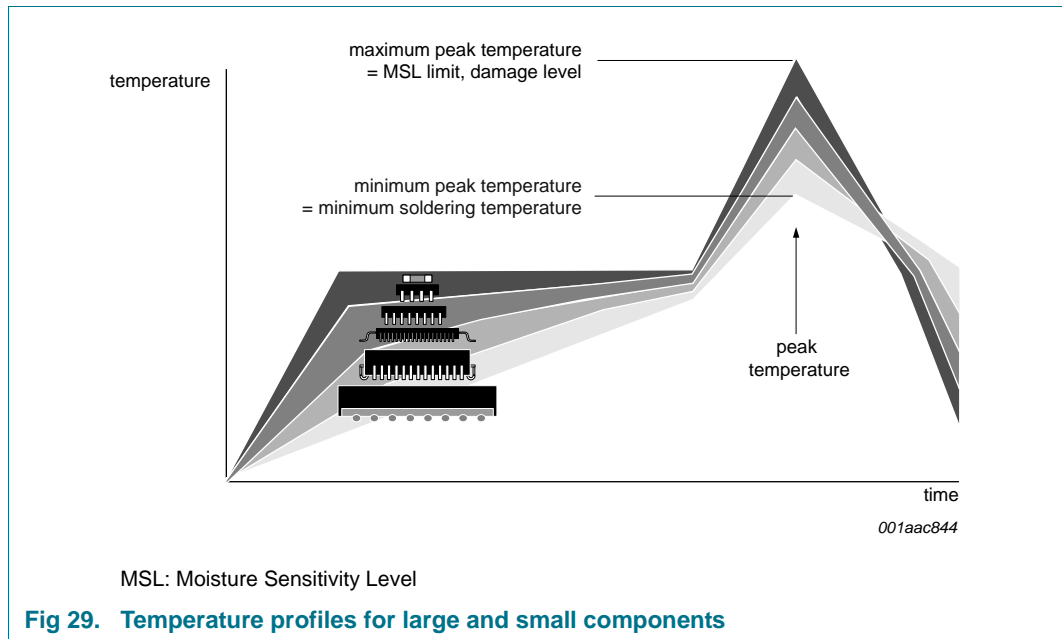
| Package thickness (mm) | Package reflow temperature (°C) |       |
|------------------------|---------------------------------|-------|
|                        | Volume (mm <sup>3</sup> )       |       |
|                        | < 350                           | ≥ 350 |
| < 2.5                 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

**Table 8. 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 29](#).



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

## 17. Abbreviations

**Table 9. Abbreviations**

| Acronym              | Description                             |
|----------------------|---|
| CDM                  | Charged Device Model                    |
| CMOS                 | Complementary Metal Oxide Semiconductor |
| ESD                  | ElectroStatic Discharge                 |
| GPIO                 | General Purpose Input/Output            |
| HBM                  | Human Body Model                        |
| I <sup>2</sup> C-bus | Inter-Integrated Circuit bus            |
| I/O                  | Input/Output                            |
| IC                   | Integrated Circuit                      |
| ID                   | Identification                          |
| LED                  | Light Emitting Diode                    |
| LSB                  | Least Significant Bit                   |
| MSB                  | Most Significant Bit                    |
| PLC                  | Programmable Logic Controller           |
| PWM                  | Pulse Width Modulation                  |
| RAID                 | Redundant Array of Independent Disks    |
| SMBus                | System Management Bus                   |

## 18. Revision history

Table 10. Revision history

| Document ID    | Release date  | Data sheet status  | Change notice | Supersedes  |
|----------------|---|--------------------|---------------|-------------|
| PCA9671 v.3    | 20110929  | Product data sheet | -             | PCA9671 v.2 |
| Modifications: | <ul style="list-style-type: none"> <li>• <a href="#">Section 2 “Features and benefits”</a>:               <ul style="list-style-type: none"> <li>– 13th bullet item: deleted phrase “200 V MM per JESD22-A115”</li> <li>– 15th bullet item: deleted “SSOP24, QSOP24”</li> </ul> </li> <li>• <a href="#">Table 1 “Ordering information”</a>: removed discontinued products               <ul style="list-style-type: none"> <li>– removed type number PCA9671DB (SSOP24)</li> <li>– removed type number PCA9671DK (SSOP24 [also known as QSOP24])</li> </ul> </li> <li>• <a href="#">Section 6.1 “Pinning”</a>:               <ul style="list-style-type: none"> <li>– deleted (old) Figure 5, Pin configuration for SSOP24 (QSOP24)</li> <li>– deleted (old) Figure 6, Pin configuration for SSOP24</li> </ul> </li> <li>• <a href="#">Table 2 “Pin description”</a>: deleted “SSOP24, QSOP24” from heading of second column</li> <li>• <a href="#">Figure 23 “I<sup>2</sup>C-bus timing diagram”</a> modified: added <math>0.7 \times V_{DD}</math> and <math>0.3 \times V_{DD}</math> level lines</li> <li>• <a href="#">Section 14 “Package outline”</a>:               <ul style="list-style-type: none"> <li>– deleted package outline SOT340-1 (SSOP24)</li> <li>– deleted package outline SOT556-1 (SSOP24)</li> </ul> </li> </ul> |                    |               |             |
| PCA9671 v.2    | 20100729  | Product data sheet | -             | PCA9671 v.1 |
| PCA9671 v.1    | 20061220  | Product data sheet | -             | -           |

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|-----------------------------------|-------------------------------|---|
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| 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".

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Date of release: 29 September 2011

Document identifier: PCA9671

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