



# PCA9698

40-bit Fm+ I<sup>2</sup>C-bus advanced I/O port with  $\overline{\text{RESET}}$ ,  $\overline{\text{OE}}$  and  $\overline{\text{INT}}$

Rev. 02 — 19 July 2006

Product data sheet

## 1. General description

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The PCA9698 provides 40-bit parallel input/output (I/O) port expansion for I<sup>2</sup>C-bus applications organized in 5 banks of 8 I/Os. At 5 V supply voltage, the outputs are capable of sourcing 10 mA and sinking 25 mA with a total package load of 1 A to allow direct driving of 40 LEDs. Any of the 40 I/O ports can be configured as an input or output.

The PCA9698 is the first GPIO device in a new Fast-mode Plus (Fm+) family. Fm+ devices offer higher frequency (up to 1 MHz) and longer, more densely populated bus operation (up to 4000 pF).

The device is fully configurable: output ports can be programmed to be totem-pole or open-drain and logic states can change at either the Acknowledge (bank change) or the Stop Command (global change), each input port can be masked to prevent it from generating interrupts when its state changes, I/O data logic state can be inverted when read by the system master.

An open-drain interrupt output pin ( $\overline{\text{INT}}$ ) allows monitoring of the input pins and is asserted each time a change occurs in one or several input ports (unless masked).

The Output Enable pin ( $\overline{\text{OE}}$ ) 3-states any I/O selected as output and can be used as an input signal to blink or dim LEDs (PWM with frequency > 80 Hz and change duty cycle).

A 'GPIO All Call' command allows to program multiple Advanced GPIOs at the same time even if they have different I<sup>2</sup>C-bus addresses. This allows optimal code programming when more than one device needs to be programmed with the same instruction or if all outputs need to be turned on or off at the same time (for example, LED test).

The Device ID, hard coded in the PCA9698, allows the system master to read manufacturer, part type and revision information.

The SMBus Alert feature allows the  $\overline{\text{SMBALERT}}$  pins of multiple devices with this feature to be connected together to form a wired-AND signal and to be used in conjunction with the SMBus Alert Response Address.

The internal Power-On Reset (POR) or hardware reset pin ( $\overline{\text{RESET}}$ ) initializes the 40 I/Os as inputs. Three address select pins configure one of 64 slave addresses.

The PCA9698 is available in 56-pin TSSOP and HVQFN packages and is specified over the -40 °C to +85 °C industrial temperature range.

## 2. Features

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- 1 MHz Fast-mode Plus I<sup>2</sup>C-bus serial interface
- Compliant with I<sup>2</sup>C-bus Fast-mode (400 kHz) and Standard-mode (100 kHz)

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- 2.3 V to 5.5 V operation with 5.5 V tolerant I/Os
- 40 configurable I/O pins that default to inputs at power-up
- Outputs:
  - ◆ Programmable totem-pole (10 mA source, 25 mA sink) or open-drain (25 mA sink) with controlled edge rate output structure. Default to totem-pole on power-up.
  - ◆ Active LOW Output Enable ( $\overline{\text{OE}}$ ) input pin 3-states all outputs. Polarity can be programmed to active HIGH through the I<sup>2</sup>C-bus. Defaults to  $\overline{\text{OE}}$  on power-up.
  - ◆ Output state change programmable on the Acknowledge or the STOP Command to update outputs byte-by-byte or all at the same time respectively. Defaults to Acknowledge on power-up.
- Inputs:
  - ◆ Open-drain active LOW Interrupt ( $\overline{\text{INT}}$ ) output pin allows monitoring of logic level change of pins programmed as inputs
  - ◆ Programmable Interrupt Mask Control for input pins that do not require an interrupt when their states change
  - ◆ Polarity Inverter register allows inversion of the polarity of the I/O pins when read
- Active LOW SMBus Alert ( $\overline{\text{SMBALERT}}$ ) output pin allows to initiate SMBus 'Alert Response Address' sequence. Own slave address sent when sequence initiated.
- Active LOW Reset ( $\overline{\text{RESET}}$ ) input pin resets device to power-up default state
- GPIO All Call address allows programming of more than one device at the same time with the same parameters
- 64 programmable slave addresses using 3 address pins
- Readable Device ID (manufacturer, device type and revision)
- Designed for live insertion in PICMG applications
  - ◆ Minimize line disturbance ( $I_{\text{OFF}}$  and power-up 3-state)
  - ◆ Signal transient rejection (50 ns noise filter and robust I<sup>2</sup>C-bus state machine)
- Low standby current
- -40 °C to +85 °C operation
- ESD protection exceeds 2000 V HBM per JESD22-A114, 200 V MM per JESD22-A115, and 1000 V CDM per JESD22-C101
- Latch-up testing is done to JEDEC Standard JESD78 which exceeds 100 mA
- Packages offered: TSSOP56, and HVQFN56

### 3. Applications

- Servers
- RAID systems
- Industrial control
- Medical equipment
- PLCs
- Cell phones
- Gaming machines
- Instrumentation and test measurement

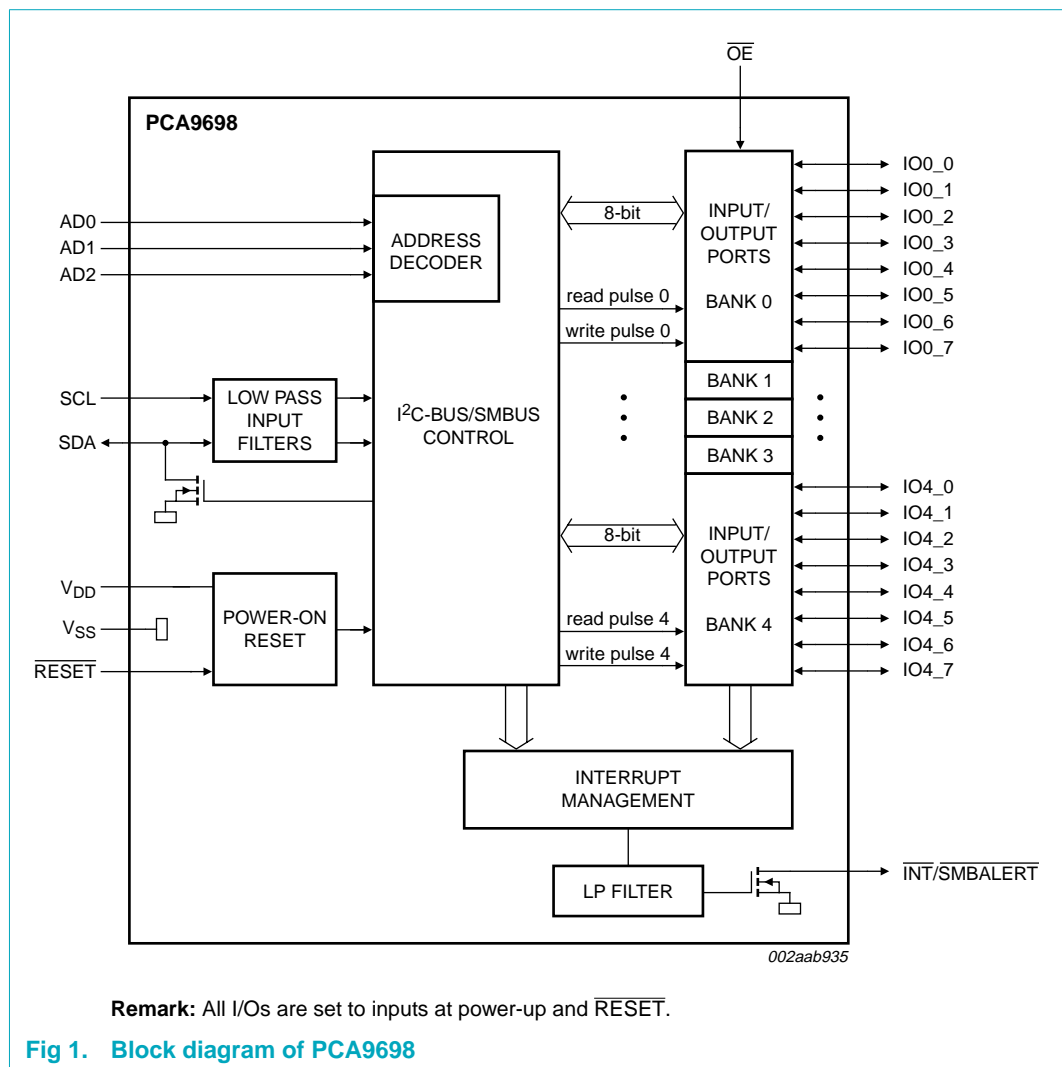
### 4. Ordering information

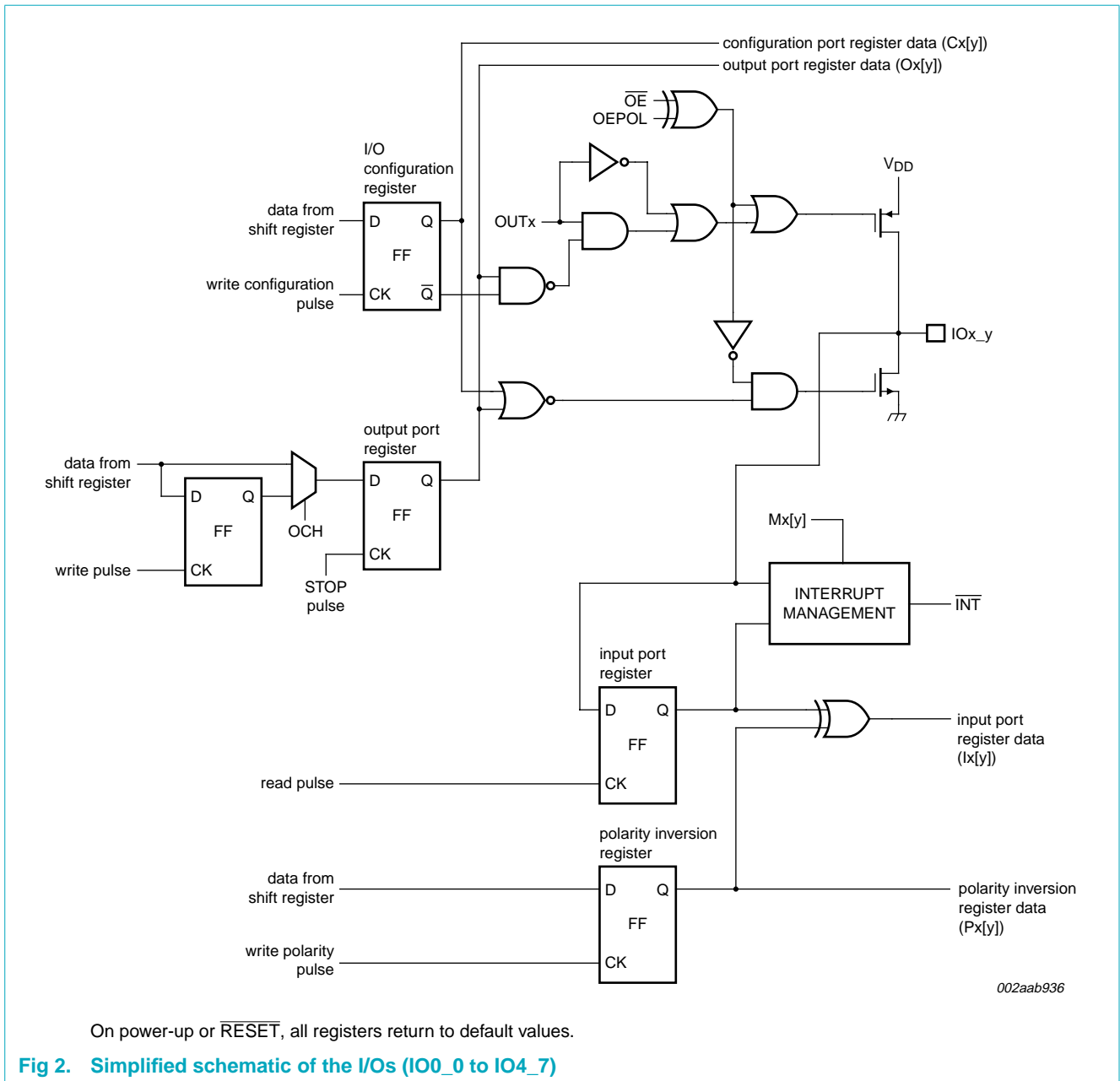
Table 1. Ordering information

$T_{amb} = -40\text{ }^{\circ}\text{C}$  to  $+85\text{ }^{\circ}\text{C}$

Type number	Topside mark	Package		Version
		Name	Description	
PCA9698DGG	PCA9698DGG	TSSOP56	plastic thin shrink small outline package; 56 leads; body width 6.1 mm	SOT364-1
PCA9698BS	PCA9698BS	HVQFN56	plastic thermal enhanced very thin quad flat package; no leads; 56 terminals; body $8 \times 8 \times 0.85$ mm	SOT684-1

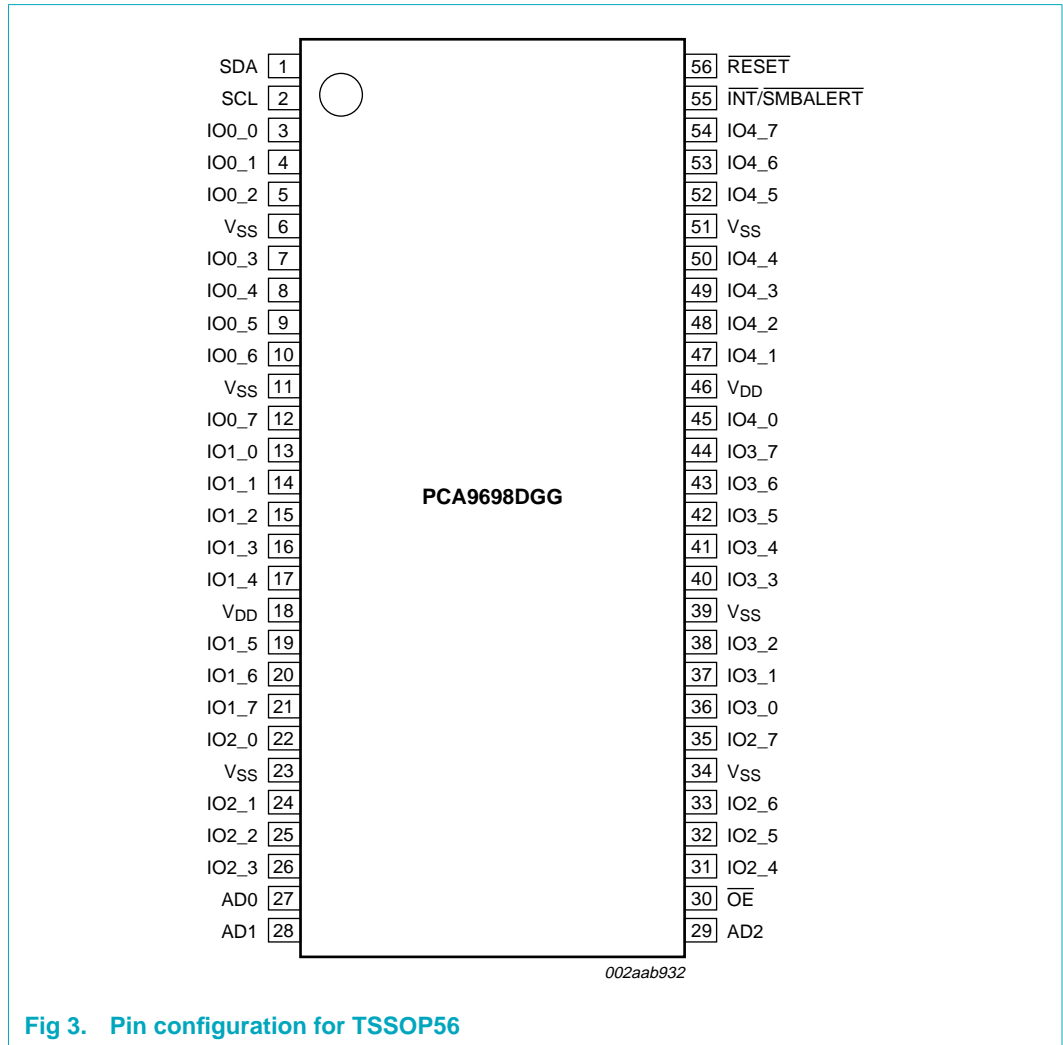
### 5. Block diagram





## 6. Pinning information

### 6.1 Pinning



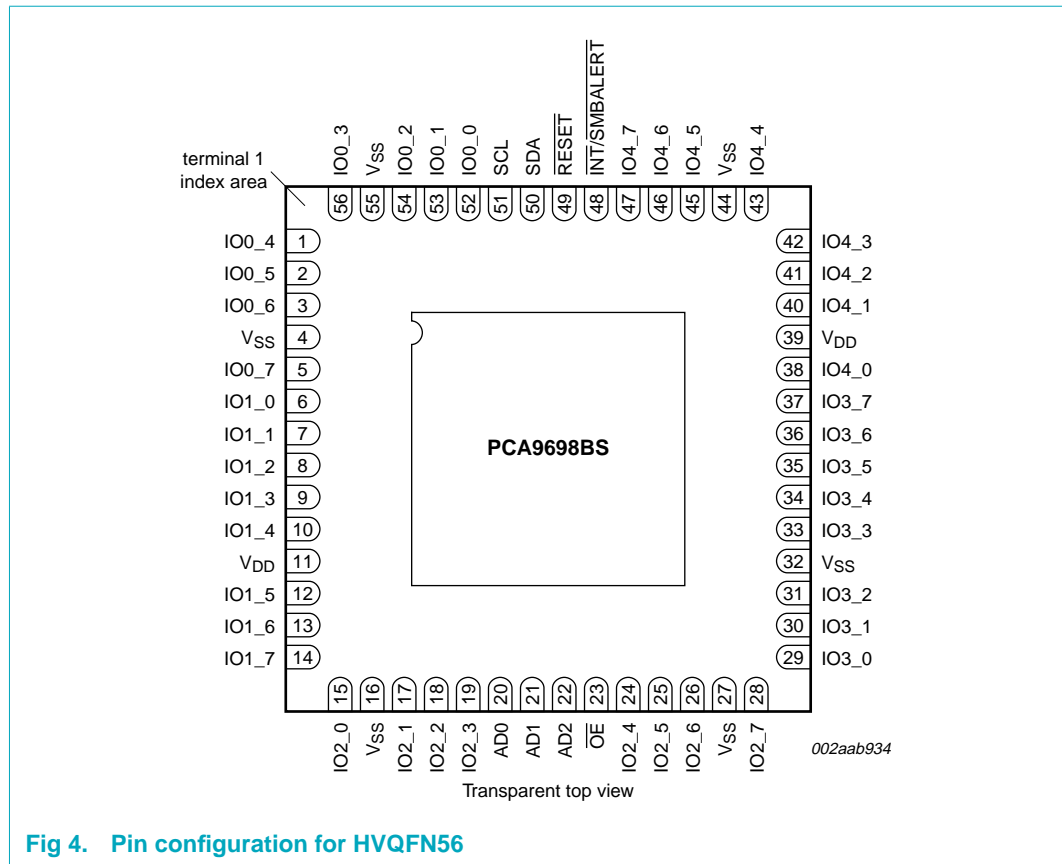


Fig 4. Pin configuration for HVQFN56

## 6.2 Pin description

Table 2. Pin description

Symbol	Pin		Type	Description
	TSSOP	HVQFN		
SDA	1	50	input/output	serial data line
SCL	2	51	input	serial clock line
IO0_0 to IO0_7	3, 4, 5, 7, 8, 9, 10, 12	52, 53, 54, 56, 1, 2, 3, 5	input/output	input/output bank 0
IO1_0 to IO1_7	13, 14, 15, 16, 17, 19, 20, 21	6, 7, 8, 9, 10, 12, 13, 14	input/output	input/output bank 1
IO2_0 to IO2_7	22, 24, 25, 26, 31, 32, 33, 35	15, 17, 18, 19, 24, 25, 26, 28	input/output	input/output bank 2
IO3_0 to IO3_7	36, 37, 38, 40, 41, 42, 43, 44	29, 30, 31, 33, 34, 35, 36, 37	input/output	input/output bank 3
IO4_0 to IO4_7	45, 47, 48, 49, 50, 52, 53, 54	38, 40, 41, 42, 43, 45, 46, 47	input/output	input/output bank 4
V <sub>SS</sub>	6, 11, 23, 34, 39, 51	4, 16, 27, 32, 44, 55 <sup>[1]</sup>	power supply	supply ground
V <sub>DD</sub>	18, 46	11, 39	power supply	supply voltage
AD0	27	20	input	address input 0
AD1	28	21	input	address input 1

**Table 2. Pin description ...continued**

Symbol	Pin		Type	Description
	TSSOP	HVQFN		
AD2	29	22	input	address input 2
$\overline{\text{OE}}$	30	23	input	active LOW output enable
$\overline{\text{INT/SMBALERT}}$	55	48	output	active LOW interrupt output/ active LOW SMBus alert output
$\overline{\text{RESET}}$	56	49	input	active LOW reset input

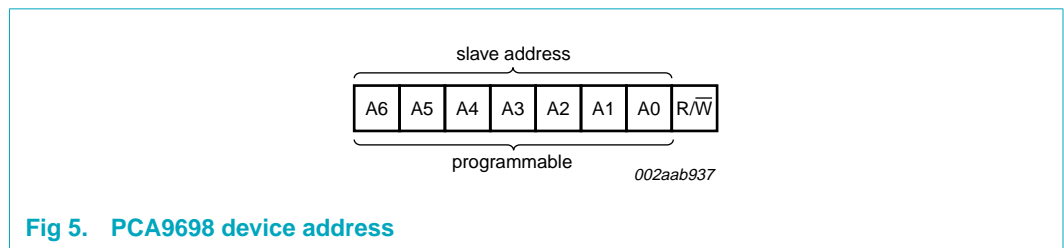
[1] HVQFN package die supply ground is connected to both V<sub>SS</sub> pins and exposed center pad. V<sub>SS</sub> pins must be connected to supply ground for proper device operation. For enhanced thermal, electrical, and board level performance, the exposed pad needs to be soldered to the board using 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.

## 7. Functional description

Refer to [Figure 1 “Block diagram of PCA9698”](#).

### 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 PCA9698 is shown in [Figure 5](#). 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 12 “PCA9698 address map”](#).



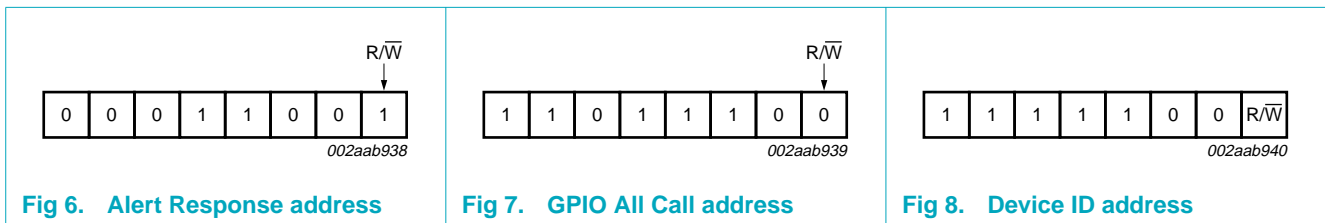
**Fig 5. PCA9698 device address**

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.

### 7.2 Alert response, GPIO All Call and Device ID addresses

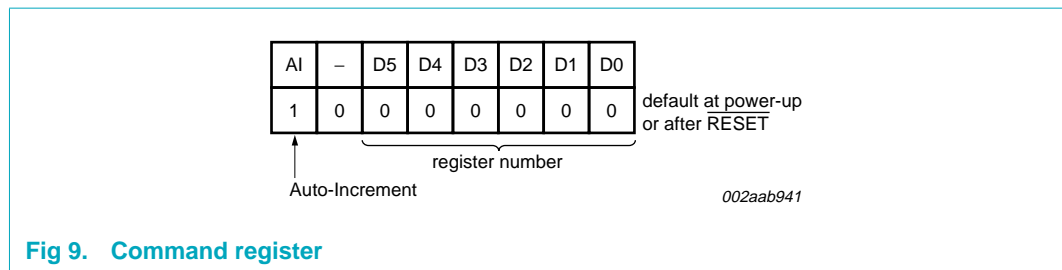
Three other different addresses can be sent to the PCA9698.

- Alert Response address: allows to perform an ‘SMBus Alert’ operation as defined in the SMBus specification. This address is always used to perform a Read operation. See [Section 7.11 “SMBus Alert output \(SMBALERT\)”](#) for more information.
- GPIO All Call address: allows to program several Advanced GPIO devices at the same time. This address is always used to perform a Write operation. See [Section 7.6 “GPIO All Call”](#) for more information.
- Device ID address: allows to read ID information from the device (manufacturer, part identification, revision). See [Section 7.5 “Device ID - PCA9698 ID field”](#) for more information.



### 7.3 Command register

Following the successful acknowledgement of the slave address +  $\overline{\text{R/W}}$  bit, the bus master will send a byte to the PCA9698, which will be stored in the Command register.



The lowest 6 bits are used as a pointer to determine which register will be accessed.

Registers are divided into 2 categories: 5-bank register category, and 1-bank register category.

Only a command register code with the 7 least significant bits equal to the 28 allowable values as defined in [Table 3 “Register summary”](#) will be acknowledged. Reserved or undefined command codes will not be acknowledged. At power-up, this register defaults to 80h, with the AI bit set to ‘1’, and the lowest 7 bits set to ‘0’.

During a write operation, the PCA9698 will acknowledge a byte sent to the OP, PI, IOC, MSK, OUTCONF, ALLBNK, and MODE registers, but will not acknowledge a byte sent to the IPx registers since these are read-only registers.



### 7.3.1 5-bank register category

- IP – Input registers
- OP – Output registers
- PI – Polarity Inversion registers
- IOC – I/O Configuration registers
- MSK – Mask interrupt registers

If the Auto-Increment flag is set (AI = 1), the 3 least significant bits are automatically incremented after a read or write. This allows the user to program and/or read the 5 register banks sequentially.

If more than 5 bytes of data are written and AI = 1, previous data in the selected registers will be overwritten or reread. Reserved registers are skipped and not accessed (refer to [Table 3](#)).

If the Auto-Increment flag is cleared (AI = 0), the 3 least significant bits are not incremented after data is read or written, only one register will be repeatedly read or written.

### 7.3.2 1-bank register category

- OUTCONF – Output Structure Configuration register
- ALLBNK – All Bank Control register
- MODE – Mode Selection register

If more than 1 byte of data is written or read, previous data in the same register is overwritten independently of the value of AI.

## 7.4 Register definitions

**Table 3. Register summary**

Reg #	D5	D4	D3	D2	D1	D0	Name	Type	Function
<b>Input Port registers</b>									
00h	0	0	0	0	0	0	IP0	read only	Input Port register bank 0
01h	0	0	0	0	0	1	IP1	read only	Input Port register bank 1
02h	0	0	0	0	1	0	IP2	read only	Input Port register bank 2
03h	0	0	0	0	1	1	IP3	read only	Input Port register bank 3
04h	0	0	0	1	0	0	IP4	read only	Input Port register bank 4
05h	0	0	0	1	0	1	-	-	reserved for future use
06h	0	0	0	1	1	0	-	-	reserved for future use
07h	0	0	0	1	1	1	-	-	reserved for future use

Table 3. Register summary ...continued

Reg #	D5	D4	D3	D2	D1	D0	Name	Type	Function
<b>Output Port registers</b>									
08h	0	0	1	0	0	0	OP0	read/write	Output Port register bank 0
09h	0	0	1	0	0	1	OP1	read/write	Output Port register bank 1
0Ah	0	0	1	0	1	0	OP2	read/write	Output Port register bank 2
0Bh	0	0	1	0	1	1	OP3	read/write	Output Port register bank 3
0Ch	0	0	1	1	0	0	OP4	read/write	Output Port register bank 4
0Dh	0	0	1	1	0	1	-	-	reserved for future use
0Eh	0	0	1	1	1	0	-	-	reserved for future use
0Fh	0	0	1	1	1	1	-	-	reserved for future use
<b>Polarity Inversion registers</b>									
10h	0	1	0	0	0	0	PI0	read/write	Polarity Inversion register bank 0
11h	0	1	0	0	0	1	PI1	read/write	Polarity Inversion register bank 1
12h	0	1	0	0	1	0	PI2	read/write	Polarity Inversion register bank 2
13h	0	1	0	0	1	1	PI3	read/write	Polarity Inversion register bank 3
14h	0	1	0	1	0	0	PI4	read/write	Polarity Inversion register bank 4
15h	0	1	0	1	0	1	-	-	reserved for future use
16h	0	1	0	1	1	0	-	-	reserved for future use
17h	0	1	0	1	1	1	-	-	reserved for future use
<b>I/O Configuration registers</b>									
18h	0	1	1	0	0	0	IOC0	read/write	I/O Configuration register bank 0
19h	0	1	1	0	0	1	IOC1	read/write	I/O Configuration register bank 1
1Ah	0	1	1	0	1	0	IOC2	read/write	I/O Configuration register bank 2
1Bh	0	1	1	0	1	1	IOC3	read/write	I/O Configuration register bank 3
1Ch	0	1	1	1	0	0	IOC4	read/write	I/O Configuration register bank 4
1Dh	0	1	1	1	0	1	-	-	reserved for future use
1Eh	0	1	1	1	1	0	-	-	reserved for future use
1Fh	0	1	1	1	1	1	-	-	reserved for future use
<b>Mask Interrupt registers</b>									
20h	1	0	0	0	0	0	MSK0	read/write	Mask interrupt register bank 0
21h	1	0	0	0	0	1	MSK1	read/write	Mask interrupt register bank 1
22h	1	0	0	0	1	0	MSK2	read/write	Mask interrupt register bank 2
23h	1	0	0	0	1	1	MSK3	read/write	Mask interrupt register bank 3
24h	1	0	0	1	0	0	MSK4	read/write	Mask interrupt register bank 4
25h	1	0	0	1	0	1	-	-	reserved for future use
26h	1	0	0	1	1	0	-	-	reserved for future use
27h	1	0	0	1	1	1	-	-	reserved for future use
<b>Miscellaneous</b>									
28h	1	0	1	0	0	0	OUTCONF	read/write	output structure configuration
29h	1	0	1	0	0	1	ALLBNK	read/write	control all banks
2Ah	1	0	1	0	1	0	MODE	read/write	PCA9698 mode selection

### 7.4.1 IP0 to IP4 - Input Port registers

These registers are read-only. They reflect the incoming logic levels of the port pins regardless of whether the pin is defined as an input or an output by the I/O Configuration register. If the corresponding Px[y] bit in the PI registers is set to 0, or the inverted incoming logic levels if the corresponding Px[y] bit in the PI register is set to 1. Writes to these registers have no effect.

**Table 4. IP0 to IP4 - Input Port registers (address 00h to 04h) bit description**

Legend: \* default value 'X' determined by the externally applied logic level.

Address	Register	Bit	Symbol	Access	Value	Description
00h	IP0	7 to 0	I0[7:0]	R	XXXX XXXX*	Input Port register bank 0
01h	IP1	7 to 0	I1[7:0]	R	XXXX XXXX*	Input Port register bank 1
02h	IP2	7 to 0	I2[7:0]	R	XXXX XXXX*	Input Port register bank 2
03h	IP3	7 to 0	I3[7:0]	R	XXXX XXXX*	Input Port register bank 3
04h	IP4	7 to 0	I4[7:0]	R	XXXX XXXX*	Input Port register bank 4

The Polarity Inversion register can invert the logic states of the port pins. The polarity of the corresponding bit is inverted when Px[y] bit in the PI register is set to 1. The polarity of the corresponding bit is not inverted when Px[y] bits in the PI register is set to 0.

### 7.4.2 OP0 to OP4 - Output Port registers

These registers reflect the outgoing logic levels of the pins defined as outputs by the I/O Configuration register. Bit values in these registers have no effect on pins defined as inputs. In turn, reads from these registers reflect the values that are in the flip-flops controlling the output selection, **not** the actual pin values.

$Ox[y] = 0$ : IOx\_y = 0 if IOx\_y defined as output (Cx[y] in IOC register = 0).

$Ox[y] = 1$ : IOx\_y = 1 if IOx\_y defined as output (Cx[y] in IOC register = 0).

Where 'x' refers to the bank number (0 to 4); 'y' refers to the bit number (0 to 7).

**Table 5. OP0 to OP4 - Output Port registers (address 08h to 0Ch) bit description**

Legend: \* default value.

Address	Register	Bit	Symbol	Access	Value	Description
08h	OP0	7 to 0	O0[7:0]	R/W	0000 0000*	Output Port register bank 0
09h	OP1	7 to 0	O1[7:0]	R/W	0000 0000*	Output Port register bank 1
0Ah	OP2	7 to 0	O2[7:0]	R/W	0000 0000*	Output Port register bank 2
0Bh	OP3	7 to 0	O3[7:0]	R/W	0000 0000*	Output Port register bank 3
0Ch	OP4	7 to 0	O4[7:0]	R/W	0000 0000*	Output Port register bank 4

### 7.4.3 PI0 to PI4 - Polarity Inversion registers

These registers allow inversion of the polarity of the corresponding Input Port register.

$Px[y] = 0$ : The corresponding Input Port register data polarity is retained.

$Px[y] = 1$ : The corresponding Input Port register data polarity is inverted.

Where 'x' refers to the bank number (0 to 4); 'y' refers to the bit number (0 to 7).

**Table 6. PI0 to PI4 - Polarity Inversion registers (address 10h to 14h) bit description**

Legend: \* default value.

Address	Register	Bit	Symbol	Access	Value	Description
10h	PI0	7 to 0	P0[7:0]	R/W	0000 0000*	Polarity Inversion register bank 0
11h	PI1	7 to 0	P1[7:0]	R/W	0000 0000*	Polarity Inversion register bank 1
12h	PI2	7 to 0	P2[7:0]	R/W	0000 0000*	Polarity Inversion register bank 2
13h	PI3	7 to 0	P3[7:0]	R/W	0000 0000*	Polarity Inversion register bank 3
14h	PI4	7 to 0	P4[7:0]	R/W	0000 0000*	Polarity Inversion register bank 4

### 7.4.4 IOC0 to IOC4 - I/O Configuration registers

These registers configure the direction of the I/O pins.

$Cx[y] = 0$ : The corresponding port pin is an output.

$Cx[y] = 1$ : The corresponding port pin is an input.

Where 'x' refers to the bank number (0 to 4); 'y' refers to the bit number (0 to 7).

**Table 7. IOC0 to IOC4 - I/O Configuration registers (address 18h to 1Ch) bit description**

Legend: \* default value.

Address	Register	Bit	Symbol	Access	Value	Description
18h	IOC0	7 to 0	C0[7:0]	R/W	1111 1111*	I/O Configuration register bank 0
19h	IOC1	7 to 0	C1[7:0]	R/W	1111 1111*	I/O Configuration register bank 1
1Ah	IOC2	7 to 0	C2[7:0]	R/W	1111 1111*	I/O Configuration register bank 2
1Bh	IOC3	7 to 0	C3[7:0]	R/W	1111 1111*	I/O Configuration register bank 3
1Ch	IOC4	7 to 0	C4[7:0]	R/W	1111 1111*	I/O Configuration register bank 4

### 7.4.5 MSK0 to MSK4 - Mask interrupt registers

These registers mask the interrupt due to a change in the I/O pins configured as inputs. 'x' refers to the bank number (0 to 4); 'y' refers to the bit number (0 to 7).

Mx[y] = 0: A level change at the I/O will generate an interrupt if IOx\_y defined as input (Cx[y] in IOC register = 1).

Mx[y] = 1: A level change in the input port will not generate an interrupt if IOx\_y defined as input (Cx[y] in IOC register = 1).

**Table 8. MSK0 to MSK4 - Mask interrupt registers (address 20h to 24h) bit description**

Legend: \* default value.

Address	Register	Bit	Symbol	Access	Value	Description
20h	MSK0	7 to 0	M0[7:0]	R/W	1111 1111*	Mask Interrupt register bank 0
21h	MSK1	7 to 0	M1[7:0]	R/W	1111 1111*	Mask Interrupt register bank 1
22h	MSK2	7 to 0	M2[7:0]	R/W	1111 1111*	Mask Interrupt register bank 2
23h	MSK3	7 to 0	M3[7:0]	R/W	1111 1111*	Mask Interrupt register bank 3
24h	MSK4	7 to 0	M4[7:0]	R/W	1111 1111*	Mask Interrupt register bank 4

### 7.4.6 OUTCONF - output structure configuration register

**Table 9. OUTCONF - output structure configuration register (address 28h) description**

Bit	7	6	5	4	3	2	1	0
Symbol	OUT4	OUT3	OUT2	OUT1	OUT067	OUT045	OUT023	OUT001
Default	1	1	1	1	1	1	1	1

This register controls the configuration of the output ports as open-drain or totem-pole.

The 4 least significant bits control the output architecture for bank 0, 2 bits at a time.

OUT001 controls the output structure for IO0\_0 and IO0\_1

OUT023 controls the output structure for IO0\_2 and IO0\_3

OUT045 controls the output structure for IO0\_4 and IO0\_5

OUT067 controls the output structure for IO0\_6 and IO0\_7

The 4 most significant bits control the output architectures for bank 1 to bank 4, each bit controlling one bank.

OUT1 controls the output structure for bank 1 (IO1\_0 to IO1\_7)

OUT2 controls the output structure for bank 2 (IO2\_0 to IO2\_7)

OUT3 controls the output structure for bank 3 (IO3\_0 to IO3\_7)

OUT4 controls the output structure for bank 4 (IO4\_0 to IO4\_7)

OUTx = 0: The I/Os are configured with an open-drain structure.

OUTx = 1: The I/Os are configured with a totem-pole structure.

### 7.4.7 ALLBNK - All Bank control register

Table 10. ALLBNK - All Bank control register (address 29h) description

Bit	7	6	5	4	3	2	1	0
Symbol	BSEL	X	X	B4	B3	B2	B1	B0
Default	1	0	0	0	0	0	0	0

This register allows all the I/Os configured as outputs to be programmed with the same logic value. This programming is applied to all the banks or a selection of banks.

When this register is programmed, values in the Output Port registers are not changed and do not reflect the states of I/Os configured as outputs anymore.

- B0 to B4 controls the logic level to be applied to Bank 0 to Bank 4, respectively.
  - Bx = 0: All the I/Os configured as outputs in the corresponding Bank x are programmed with 0s.
  - Bx = 1: All the I/Os configured as outputs in the corresponding Bank x are programmed with 1s.
- Bit 5 and bit 6 are not used and can be programmed to either '1' or '0'.
- BSEL is a filter bit that allows programming of some banks only, and not the others.
  - BSEL = 0:
    - When Bx = 0, all the I/Os configured as output in the corresponding Bank x are programmed with 0s.
    - When Bx = 1, all the I/Os configured as output in the corresponding Bank x are programmed with their actual value from the corresponding output register.
  - BSEL = 1:
    - When Bx = 0, all the I/Os configured as output in the corresponding Bank x are programmed with their actual value from the corresponding output register.
    - When Bx = 1, all the I/Os configured as output in the corresponding Bank x are programmed with 1s.

#### 7.4.7.1 Examples

- If ALLBNK = 0XX0 0000:
  - All I/Os configured as outputs in Bank 0 to Bank 4 will be programmed with 0s, overwriting values programmed in the five Output Port registers.
- If ALLBNK = 1XX1 1111:
  - All I/Os configured as outputs in Bank 0 to Bank 4 will be programmed with 1s, overwriting values programmed in the five Output Port registers.
- If ALLBNK = 0XX0 0110:
  - All I/Os configured as outputs in Banks 0, 3, and 4 only will be programmed with 0s, overwriting values programmed in the Output Port registers 0, 3, and 4, while I/Os configured as outputs in Bank 1 and Bank 2 are programmed with values in Output Port registers 1 and 2.

- If ALLBNK = 1XX0 1100:

All I/Os configured as outputs in Bank 2 and 3 will be programmed with 1s, overwriting values programmed in the Output Port registers 2 and 3, while I/Os configured as outputs in Bank 0, 1, and 4 are programmed with values in Output Port registers 0, 1, and 4.

#### 7.4.8 MODE - PCA9698 mode selection register

Table 11. MODE - mode selection register (address 2Ah) description

Bit	7	6	5	4	3	2	1	0
Symbol	X	X	X	SMBA	IOAC	X	OCH	OEPOL
Default	0	0	0	0	0	0	1	0

This register allows programming of the PCA9698 modes.

- OEPOL bit controls the polarity of  $\overline{\text{OE}}$  pin.
  - OEPOL = 0:  $\overline{\text{OE}}$  pin is active LOW.
  - OEPOL = 1:  $\overline{\text{OE}}$  pin is active HIGH (equivalent to OE pin).
- OCH bit selects the I<sup>2</sup>C-bus event where the state of the I/Os configured as outputs change.
  - OCH = 0: outputs change on STOP command.
  - OCH = 1: outputs change on ACK.
- IOAC bit controls the ability of the device to respond to a 'GPIO All Call' command (see [Section 7.6 "GPIO All Call"](#) for more information), allowing programming of more than one device at the same time.
  - IOAC = 0: The device cannot respond to a 'GPIO All Call' command.
  - IOAC = 1: The device can respond to a 'GPIO All Call' command.

**Remark:** The 'GPIO ALL CALL' command defined for the PCA9698 is different from the I<sup>2</sup>C-bus protocol 'General Call' command.
- SMBA bit controls the capability of the PCA9698 to respond to a SMBAlert command.
  - SMBA = 0: PCA9698 does not respond to an Alert Response Address.
  - SMBA = 1: PCA9698 responds to an Alert Response Address. Bits 5, 6 and 7 are reserved and must be programmed with 0s.
- Unused bits (bits 2, 5, 6 and 7) must be programmed with 0s for proper device operation.

## 7.5 Device ID - PCA9698 ID field

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

- 12 bits with the manufacturer name, unique per manufacturer (e.g., Philips)
- 9 bits with the part identification, assigned by manufacturer (e.g., PCA9698)
- 3 bits with the die revision, assigned by manufacturer (e.g., RevX)

The Device ID is read-only, hard-wired 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 followed by the R $\overline{\text{W}}$  bit set to '0' (write): '1111 1000'.
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.

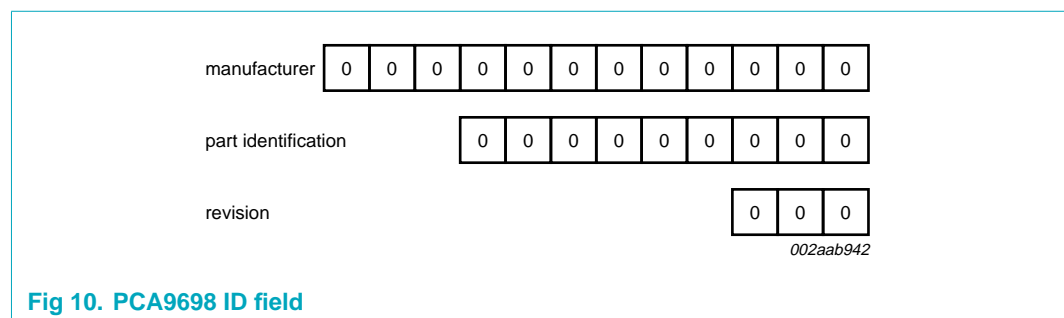
**Remark:** A STOP command followed by a START command will reset the slave state machine and the Device ID Read cannot be performed. Also, a STOP command or a Re-START command followed by an access to another slave device will reset the slave state machine and the Device ID Read cannot be performed.

5. The master sends the Reserved Device ID I<sup>2</sup>C-bus address followed by the R $\overline{\text{W}}$  bit set to '1' (read): '1111 1001'.
6. The Device ID Read can be done, starting with the 12 manufacturer bits (first byte + 4 MSBs of the second byte), followed by the 9 part identification bits (4 LSBs of the second byte + 5 MSBs of the third byte), and then the 3 die revision bits (3 LSBs 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.

If the master continues to ACK the bytes after the third byte, the PCA9698 rolls back to the first byte and keeps sending the Device ID sequence until a NACK has been detected.

For the PCA9698, the Device ID is as shown in [Figure 10](#).



**Fig 10. PCA9698 ID field**



## 7.6 GPIO All Call

A 'GPIO All Call' command allows the programming of multiple advanced GPIOs with different I<sup>2</sup>C-bus addresses at the same time. This allows to optimize code programming when the master needs to send the same instruction to several devices. To respond to such a command and sequence, the PCA9698 needs to have its IOAC bit (register 2Ah, bit 3) set to 1. Devices that have this bit set to 0 do not participate in any 'GPIO All Call' sequence.

The 'GPIO All Call' command can be performed only for a write operation and cannot be used in conjunction with a read operation.

- Master initiates a command sequence with the START command, the 'GPIO All Call' command associated with a Write command: Start – 1101 110 + Write
- All the devices that are programmed to respond to this command will acknowledge
- The master then sends the data and all the devices that are programmed to respond acknowledge the byte(s)
- The master ends the sequence by sending a STOP or Repeated START command.

If the master initiates a 'GPIO All Call' sequence with a Read command, none of the slave devices acknowledge.

## 7.7 Output state change on ACK or STOP

State change of the I/Os programmed as outputs can be done either:

- during the ACK phase every time an Output Port register is modified. The output state is then updated one-by-one (at a bank level): OCH bit = 1 (register 2Ah, bit 1)
- at a STOP command allowing all the outputs to change at the exact same moment: OCH bit = 0 (register 2Ah, bit 1).

Change of the outputs at the STOP command allows synchronizing of all the programmed banks in a single device, and also allows synchronizing outputs of more than one PCA9698.

**Example 1:** Only one PCA9698 is used on the I<sup>2</sup>C-bus and all the outputs need to change at the same time.

- OCH bit (Mode Selection Register, bit 1) must be equal to '0'.
- The master accesses the device and programs the Output Port register(s) that has (have) to be changed (up to 5 ports).
- When done, the master must generate a STOP command.
- At the STOP command, the PCA9698 will update the Output Port register(s) that has (have) been programmed and change the output states all at the same time.

**Example 2:** More than one PCA9698 is used on the I<sup>2</sup>C-bus and all the outputs need to change at the same time.

- OCH bit (Mode Selection Register, bit 1) must be equal to '0' in all the devices.
- The master device must access the devices one-by-one.
- Access to each device must be separated by a Re-START command.

- When all the devices have been accessed, the master must generate a STOP command.
- At the STOP command, all the PCA9698s that have been accessed will update their Output Port registers that have been programmed and change the output states all at the same time.

**Remark:** After programming a PCA9698, its state machine will be in a 'wait-for-STOP-condition' until a STOP condition is received to update the Output Port registers. Since this state machine will be in a 'wait-state', the part will not respond to its own address until this state machine gets out to the idle condition, which means that the device can be programmed only once and is not addressable again until a STOP condition has been received.

**Remark:** The PCA9698 has one level of buffers to store 5 bytes of data, and the actual Output Port registers will get updated on the STOP condition. If the master sends more than 5 bytes of data (with AI = 1), the data in the buffer will get overwritten.

## 7.8 Power-on reset

When power is applied to  $V_{DD}$ , an internal Power-On Reset (POR) holds the PCA9698 in a reset condition until  $V_{DD}$  has reached  $V_{POR}$ . At that point, the reset condition is released and the PCA9698 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.

## 7.9 $\overline{\text{RESET}}$ input

A reset can be accomplished by holding the  $\overline{\text{RESET}}$  pin LOW for a minimum of  $t_{w(\text{rst})}$ . The PCA9698 registers and 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.

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

The open-drain active LOW interrupt is activated when one of the port pins changes state and the port pin is configured as an input and the interrupt on it is not masked. The interrupt is deactivated when the port pin input returns to its previous state or the Input Port register is read.

It is highly recommended to program the MSK register, and the IOC registers during the initialization sequence after power-up, since any change to them during Normal mode operation may cause undesirable interrupt events to happen.

**Remark:** 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.

Only a Read of the Input Port register that contains the bit(s) image of the input(s) that generated the interrupt clears the interrupt condition.

If more than one input register changed state before a read of the Input Port register is initiated, the interrupt is cleared when all the input registers containing all the inputs that changed are read.

Example: If IO0\_5, IO2\_3, and IO3\_7 change state at the same time, the interrupt is cleared only when INREG0, INREG2, and INREG3 are read.

### 7.11 SMBus Alert output ( $\overline{\text{SMBALERT}}$ )

The interrupt output pin ( $\overline{\text{INT}}$ ) can also be used as an Alert line ( $\overline{\text{SMBALERT}}$ ).

The  $\overline{\text{SMBALERT}}$  pins of multiple devices with this feature can be connected together to form a wired-AND signal and can be used in conjunction with the SMBus Alert Response Address. 'SMBus Alert' message is 2 bytes long and allows the master to determine which device generated the Alert ( $\overline{\text{SMBALERT}}$  going LOW).

When SMBA bit = 1 (register 2Ah, bit 4), the PCA9698 supports the SMBus Alert function and its  $\overline{\text{INT/SMBALERT}}$  pin may be connected as an SMBus Alert signal.

When a master device senses that an 'SMBus Alert' condition is present on the ALERT line ( $\overline{\text{SMBALERT}}$  pin of the PCA9698 and/or other devices going LOW):

- It accesses the slave device(s) through the Alert Response Address (ARA) associated with a Read Command: Start – 0001 100 +  $\overline{\text{R/W}} = 1$ .
- If the PCA9698 is the device that generated the 'SMBus Alert' condition (and its SMBA bit = 1), it will acknowledge the SMBus Alert command and respond by transmitting its slave address on the SDA line. The 8<sup>th</sup> bit (LSB) of the slave address byte will be a zero.
- The device will acknowledge an ARA command only if the  $\overline{\text{SMBALERT}}$  signal has been previously asserted ( $\overline{\text{SMBALERT}} = \text{LOW}$ ).
- If more than one device pulls its  $\overline{\text{SMBALERT}}$  pin LOW, the highest priority (lowest I<sup>2</sup>C-bus address) device will win communication rights via standard I<sup>2</sup>C-bus arbitration during the slave address transfer.
- If the PCA9698 wins the arbitration, its  $\overline{\text{SMBALERT}}$  pin will become inactive (will go HIGH) at the completion of the slave address transmission (9<sup>th</sup> clock pulse, NACK phase).
- If the PCA9698 loses the arbitration, its  $\overline{\text{SMBALERT}}$  pin will remain active (will stay LOW).
- The master ends the sequence by sending a NACK and then STOP command.
- If the  $\overline{\text{SMBALERT}}$  is still LOW after transfer is complete, it means that more than one device made the request. Another full transaction is then required.

**Remark:** If the master initiates an 'SMBus Alert' sequence with a Write Command, none of the slave devices acknowledge. The  $\overline{\text{SMBALERT}}$  is open-drain and requires a pull-up resistor to  $V_{\text{DD}}$ .

**Remark:** If the master sends an ACK after reading the I<sup>2</sup>C-bus slave address, the slave device keeps sending '1's until a NACK is received.

### 7.12 Output enable input ( $\overline{\text{OE}}$ )

The configurable active LOW or active HIGH output enable pin allows to enable or disable all the I/Os at the same time.

- When a LOW level is applied to the  $\overline{\text{OE}}$  pin, with OEPOL = 0 (register 2Ah, bit 4) or a HIGH level is applied to the  $\overline{\text{OE}}$  pin, with OEPOL = 1 (register 2Ah, bit 0), all the I/Os configured as outputs are enabled and the logic value programmed in their respective OP registers is applied to the pins.
- When a HIGH level is applied to the  $\overline{\text{OE}}$  pin, with OEPOL = 0 (register 2Ah, bit 0) or a LOW level is applied to the  $\overline{\text{OE}}$  pin, with OEPOL = 1 (register 2Ah, bit 0), all the I/Os configured as outputs are 3-stated.

For applications requiring LED blinking with brightness control, this pin can be used to control the brightness by applying a high frequency PWM signal on the  $\overline{\text{OE}}$  pin. LEDs can be blinked using the Output Port registers and can be dimmed using the PWM signal on the  $\overline{\text{OE}}$  pin thus controlling the brightness by adjusting the duty cycle.

Default is OEPOL = 0, so if the  $\overline{\text{OE}}$  pin is held HIGH, the outputs are disabled. The  $\overline{\text{OE}}$  pin needs to be pulled LOW or OEPOL changed to '1' to enable the outputs.

It is recommended to define the required polarity of the  $\overline{\text{OE}}$  input by programming the value of OEPOL before programming the configuration registers (IOC register).

### 7.13 Live insertion

The PCA9698 is fully specified for live-insertion applications using  $I_{\text{OFF}}$ , power-up 3-states, robust state machine, and 50 ns noise filter. The  $I_{\text{OFF}}$  circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down. The power-up 3-states circuitry places the outputs in the high-impedance state during power-up and power-down, which prevents driver conflict and bus contention.

The robust state machine does not respond until it sees a valid START condition and the 50 ns noise filter will filter out any insertion glitches. The PCA9698 will not cause corruption of active data on the bus nor will the device be damaged or cause damage to devices already on the bus when similar featured devices are being used.

### 7.14 Standby

The PCA9698 goes into standby when the I<sup>2</sup>C-bus is idle. Standby supply current is lower than 1.0  $\mu\text{A}$  (typical).

## 7.15 Address map

Table 12. PCA9698 address map

AD2	AD1	AD0	A6	A5	A4	A3	A2	A1	A0	Address
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
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

Table 12. PCA9698 address map ...continued

AD2	AD1	AD0	A6	A5	A4	A3	A2	A1	A0	Address
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	AEnh
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
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	1	E0h
SCL	V <sub>SS</sub>	SDA	1	1	1	0	0	1	0	E2h
SCL	V <sub>DD</sub>	SCL	1	1	1	0	0	1	1	E4h
SCL	V <sub>DD</sub>	SDA	1	1	1	0	1	0	0	E6h
SDA	V <sub>SS</sub>	SCL	1	1	1	0	1	0	1	E8h
SDA	V <sub>SS</sub>	SDA	1	1	1	0	1	1	0	EAh
SDA	V <sub>DD</sub>	SCL	1	1	1	0	1	1	1	ECh
SDA	V <sub>DD</sub>	SDA	1	1	1	0	0	0	1	EEnh

## 8. 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.

### 8.1 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 11](#)).

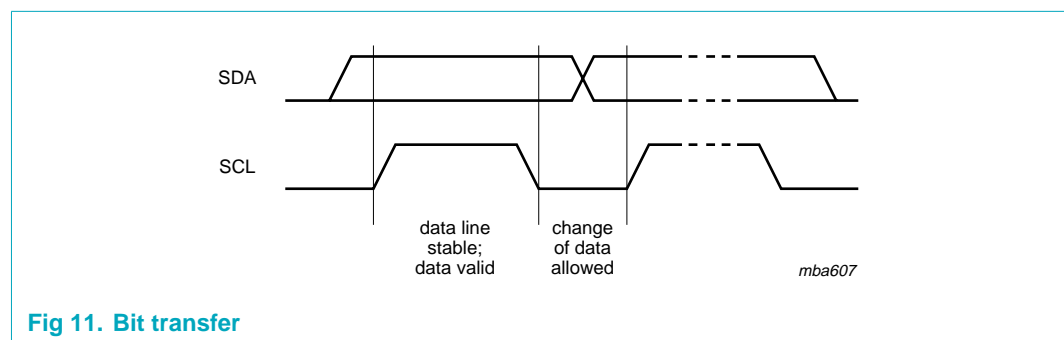


Fig 11. Bit transfer

#### 8.1.1 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 12](#).)

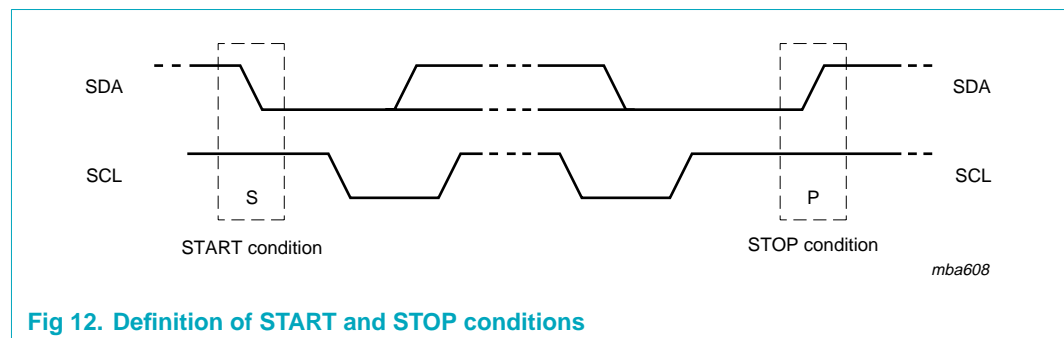


Fig 12. Definition of START and STOP conditions

### 8.2 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 13](#)).

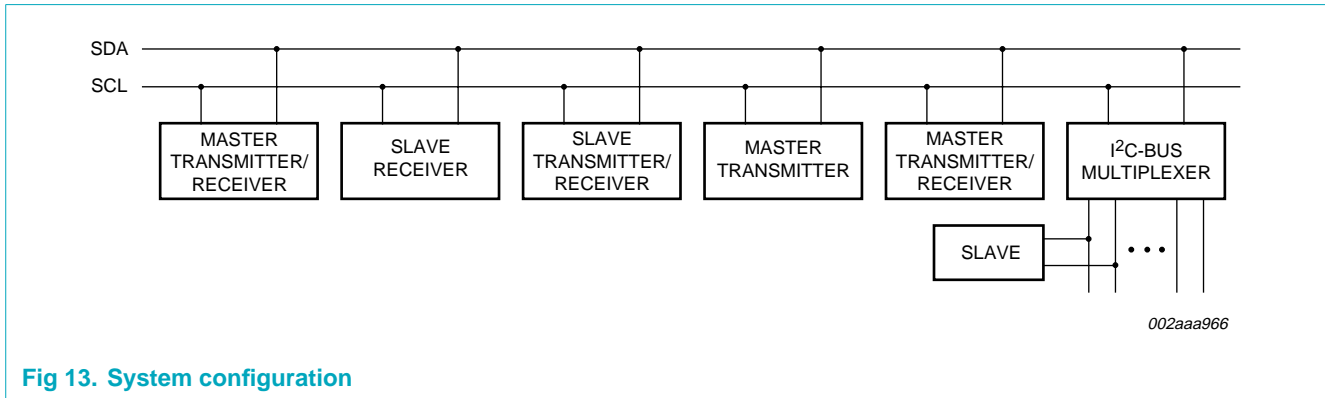


Fig 13. System configuration

### 8.3 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; setup 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.

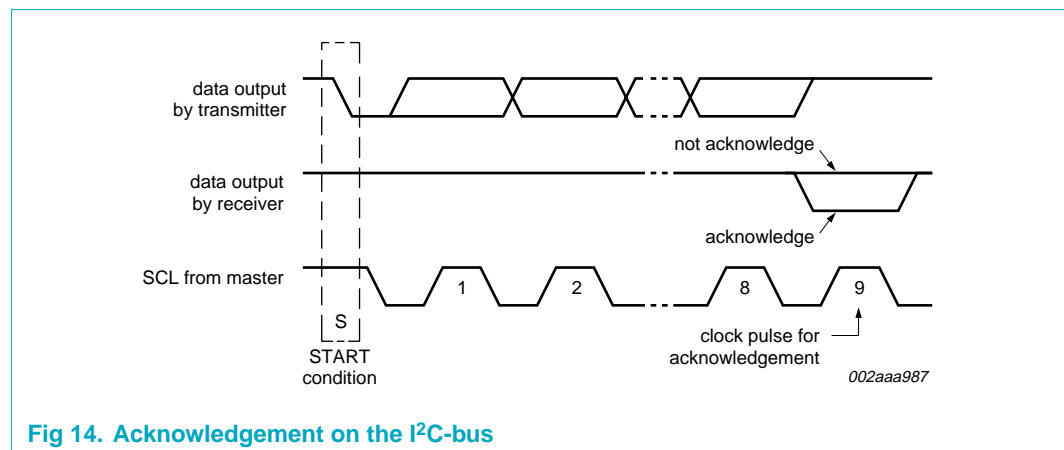


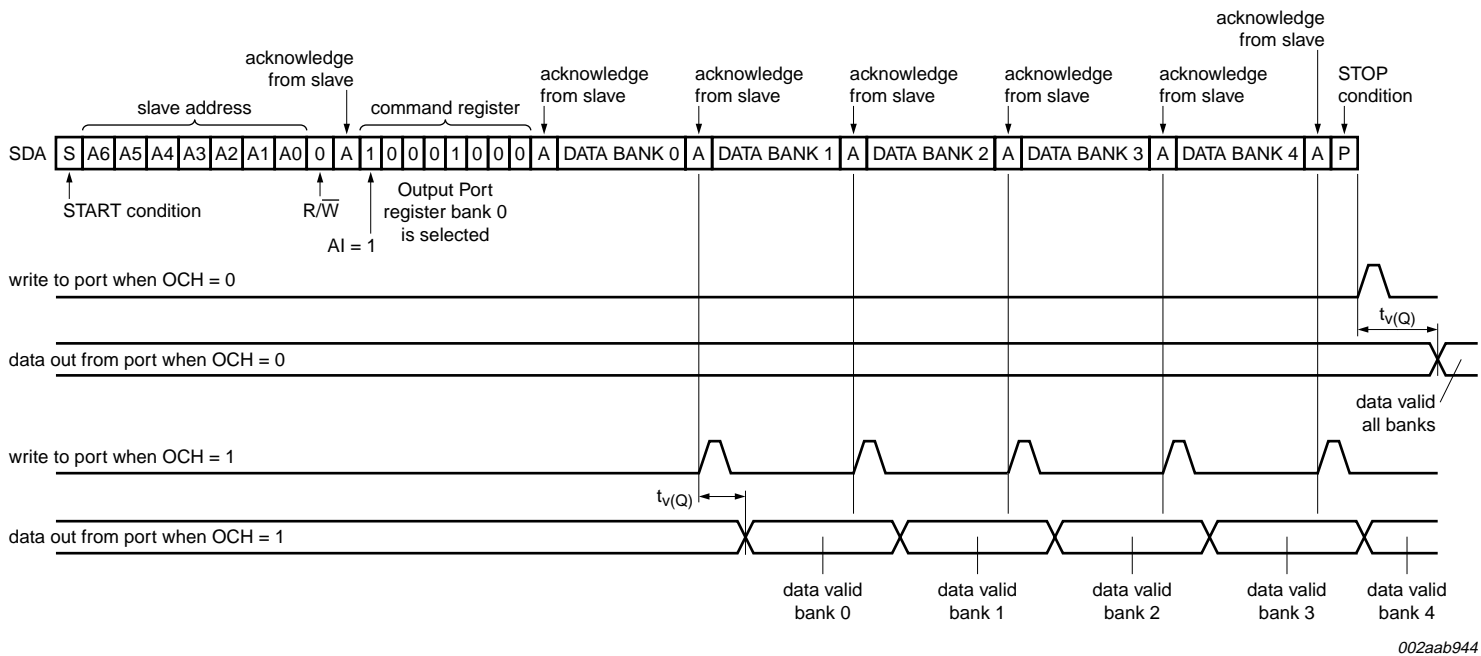
Fig 14. Acknowledgement on the I<sup>2</sup>C-bus



#### 8.4 Bus transactions

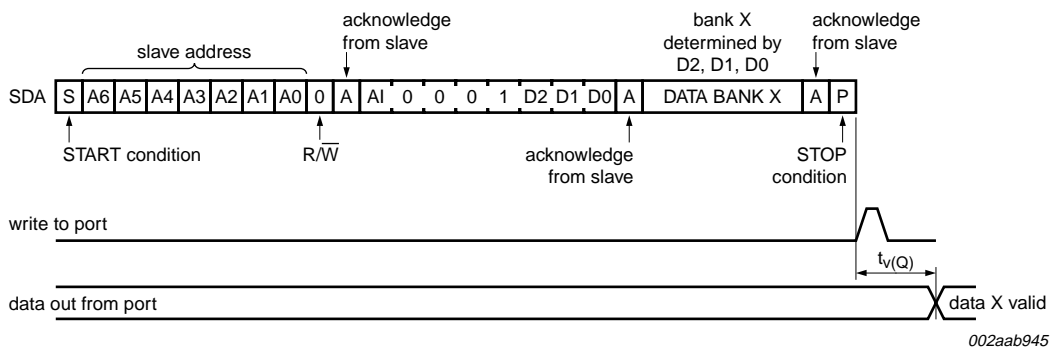
Data is transmitted to the PCA9698 registers using 'Write Byte' transfers (see [Figure 15](#), [Figure 16](#), [Figure 17](#), and [Figure 18](#)).

Data is read from the PCA9698 registers using 'Read Byte' and 'Receive Byte' transfers (see [Figure 19](#) and [Figure 20](#)).



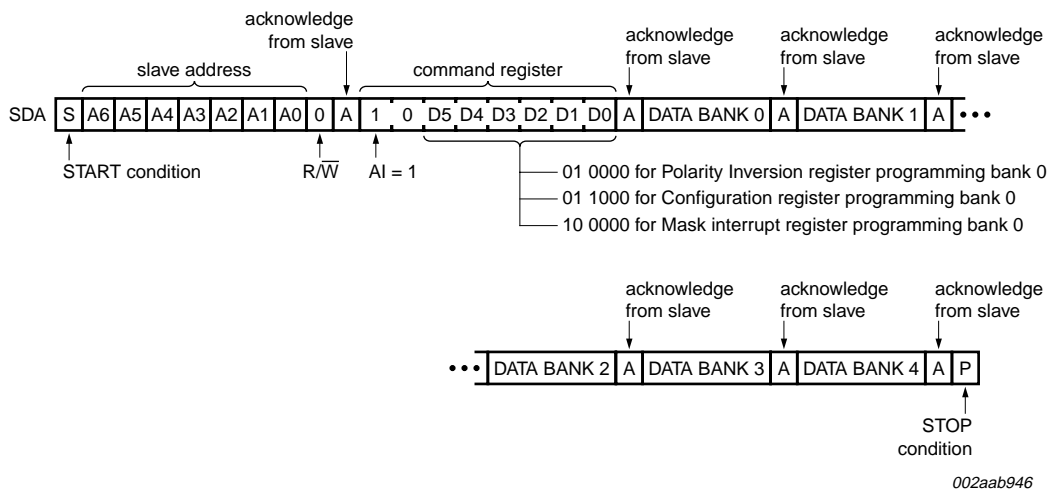
$\overline{\text{OE}}$  is LOW (with OEPOL = 0) or HIGH (with OEPOL = 1) to observe a change in the outputs.  
 If more than 5 bytes are written, previous data are overwritten.

Fig 15. Write to the 5 output ports



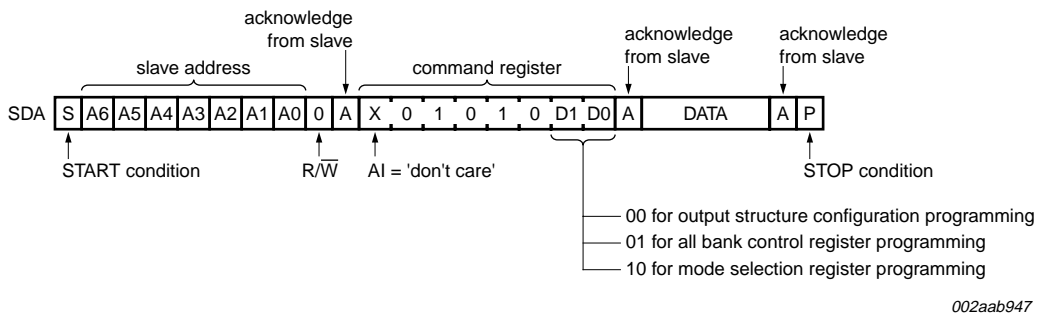
$\overline{\text{OE}}$  is LOW (with OEPOL = 0) or HIGH (with OEPOL = 1) to observe a change in the outputs.  
 OCH = 0. When OCH = 1, the change in the port happens at the acknowledge phase.  
 Two, three, or four adjacent banks can be programmed by using the Auto-Increment feature (AI = 1) and change at the corresponding output port becomes effective at the STOP command when OCH = 0, or at each acknowledge when OCH = 1.

Fig 16. Write to a specific output port



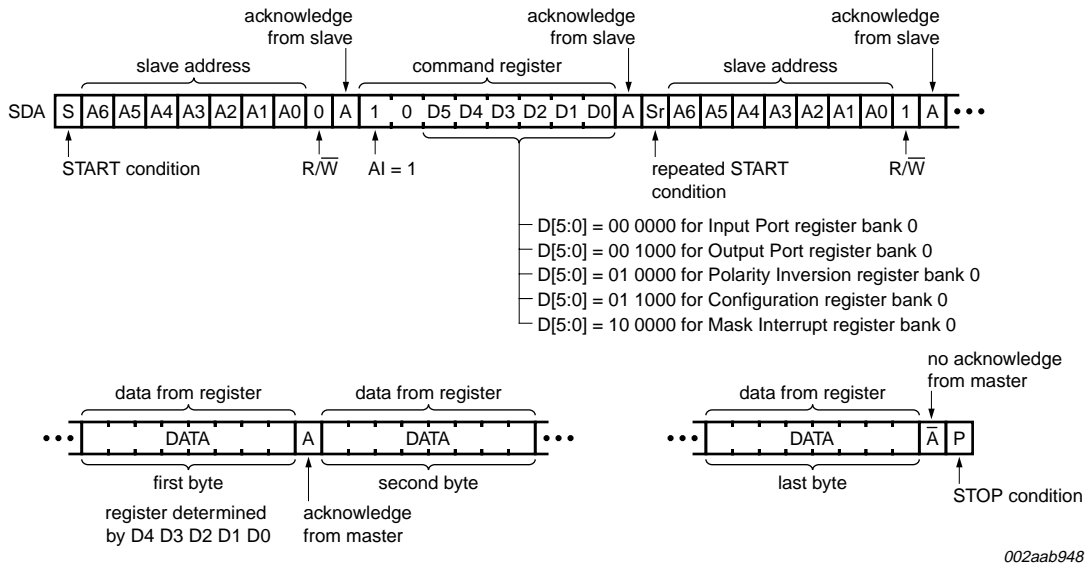
The programming becomes effective at the Acknowledge.  
 Less than 5 bytes can be programmed by using the same scheme. 'D5 D4 D3 D2 D1 D0' refers to the first register to be programmed.  
 If more than 5 bytes are written, previous data are overwritten (the sixth configuration register will roll over to the first addressed configuration register, the sixth Polarity Inversion register will roll over to the first addressed Polarity Inversion register, the sixth Mask interrupt register will roll over to the first addressed Mask interrupt register).

Fig 17. Write to the I/O Configuration, Polarity Inversion, or Mask interrupt registers (5 banks)



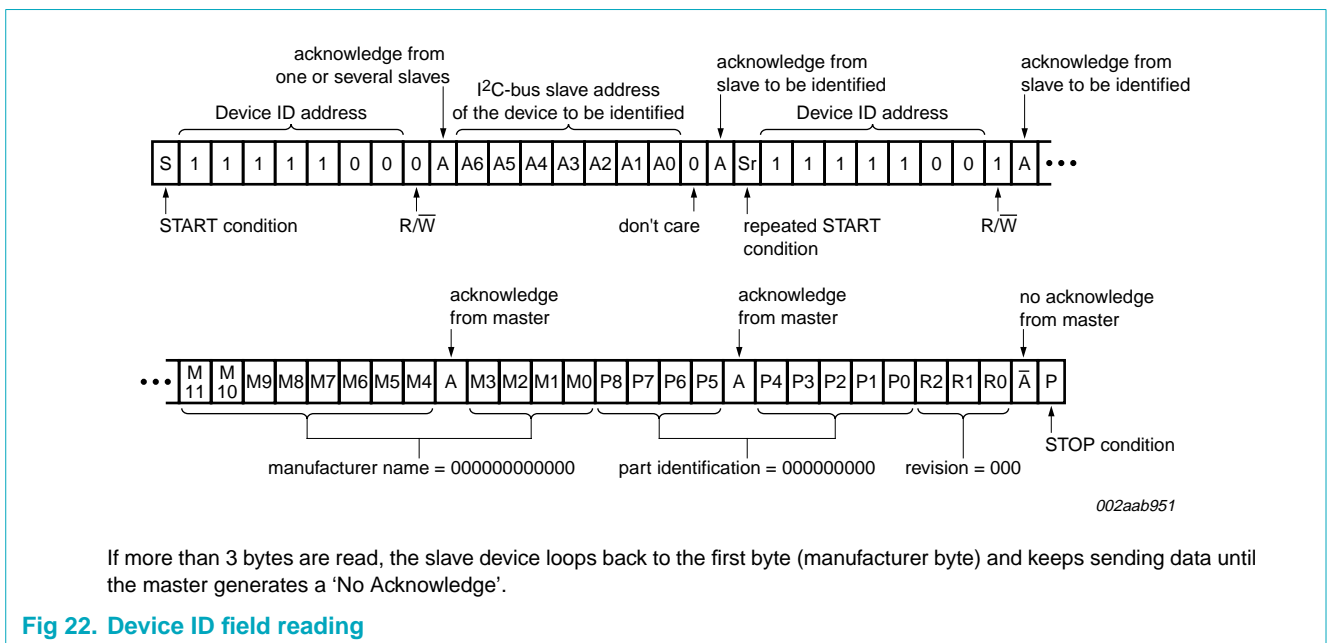
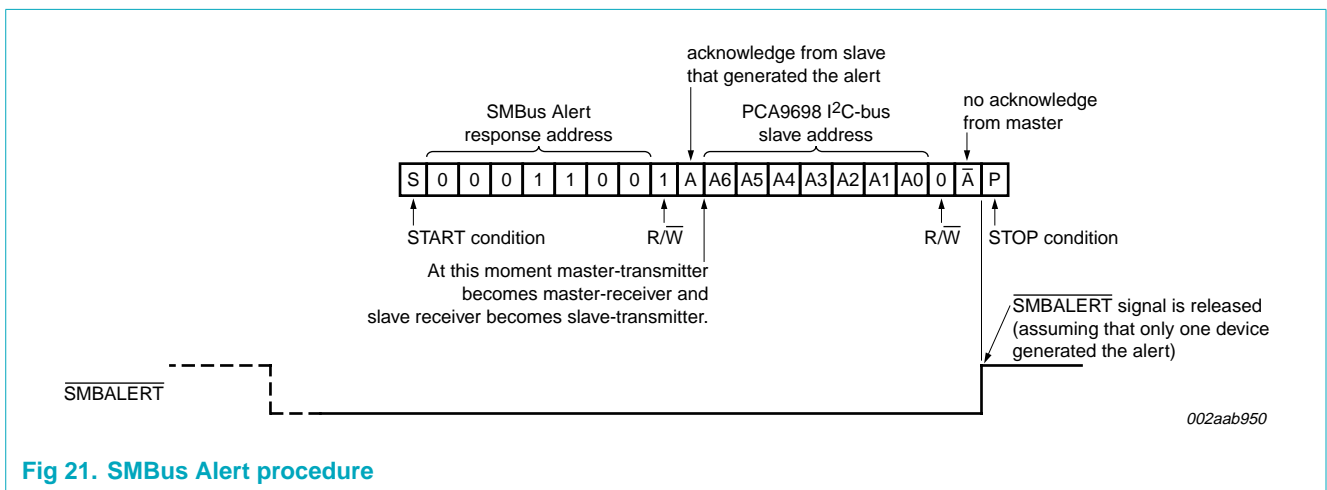
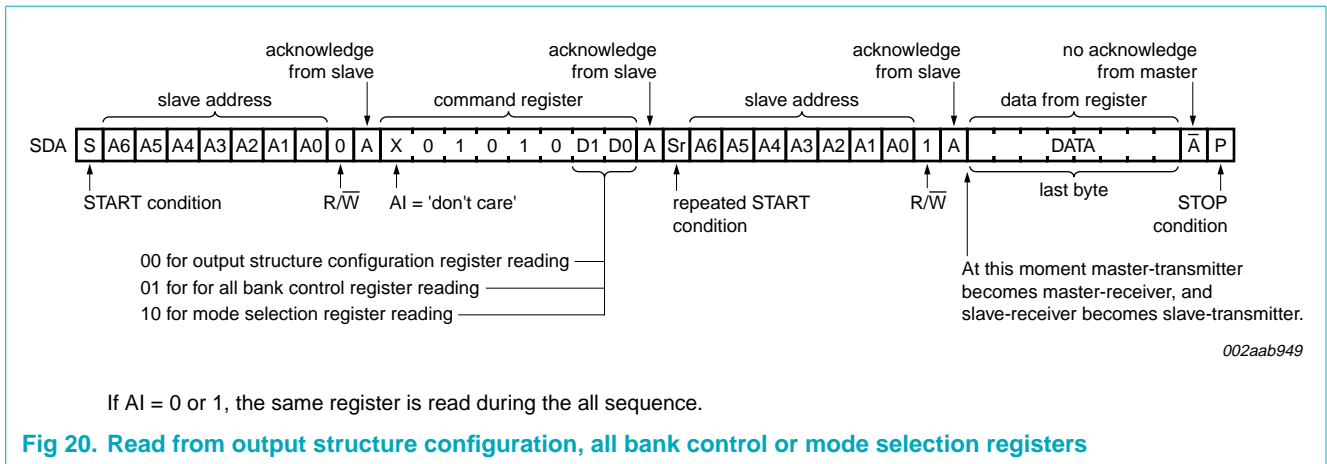
The programming becomes effective at the Acknowledge.  
 If more than 1 byte is written, previous data is overwritten.

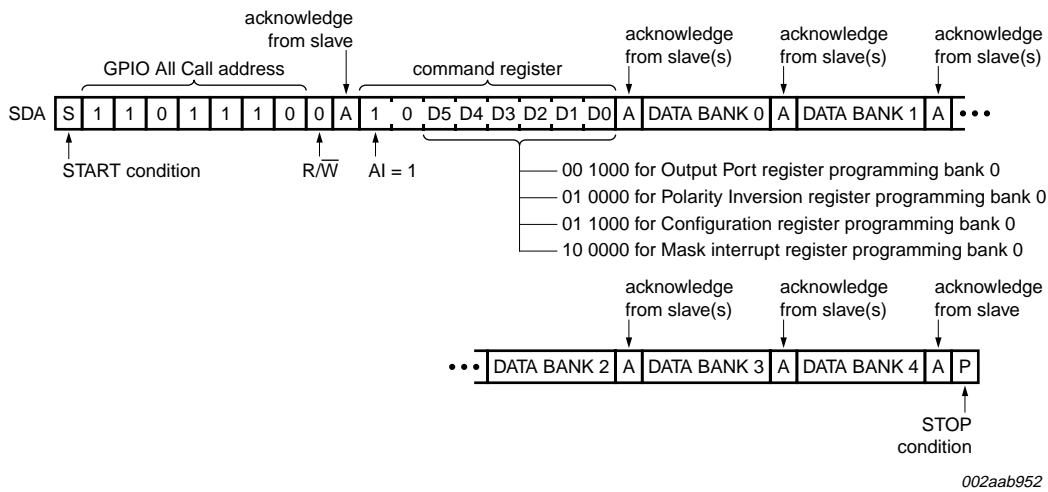
Fig 18. Write to the output structure configuration, all bank control, or mode selection



If AI = 0, the same register is read during the whole sequence.  
 If AI = 1, the register value is incremented after each read. When the last register bank is read, it rolls over to the first byte of the category (see category definition in [Section 7.3 "Command register"](#)).  
 The  $\overline{\text{INT}}$  signal is released only when the last register containing an input that changed has been read. For example, when IO2\_4 and IO4\_7 change at the same time and an Input Port register read sequence is initiated, starting with IP0,  $\overline{\text{INT}}$  is released after IP4 is read (and not after IP2 is read).

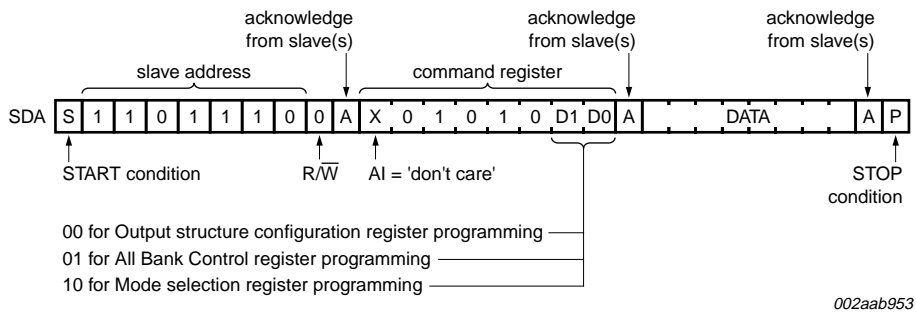
Fig 19. Read from Input Port, Output Port, I/O Configuration, Polarity Inversion, or Mask interrupt registers





Only slave devices with bit IOAC = 1 answer to the GPIO All Call transaction.  
 Output Port register programming becomes effective at the STOP command if OCH = 0, at each acknowledge if OCH = 1.  
 Configuration, Polarity Inversion, and Mask interrupt registers become effective at the acknowledge.  
 Less than 5 bytes can be programmed by using the same scheme.  
 'D5 D4 D3 D2 D1 D0' refers to the first register to be programmed.  
 If more than 5 bytes are written, previous data are overwritten (the sixth Configuration register will roll over to the first addressed Configuration register, the sixth Polarity Inversion register will roll over to the first addressed Polarity Inversion register, the sixth Mask interrupt register will roll over to the first addressed Mask interrupt register).

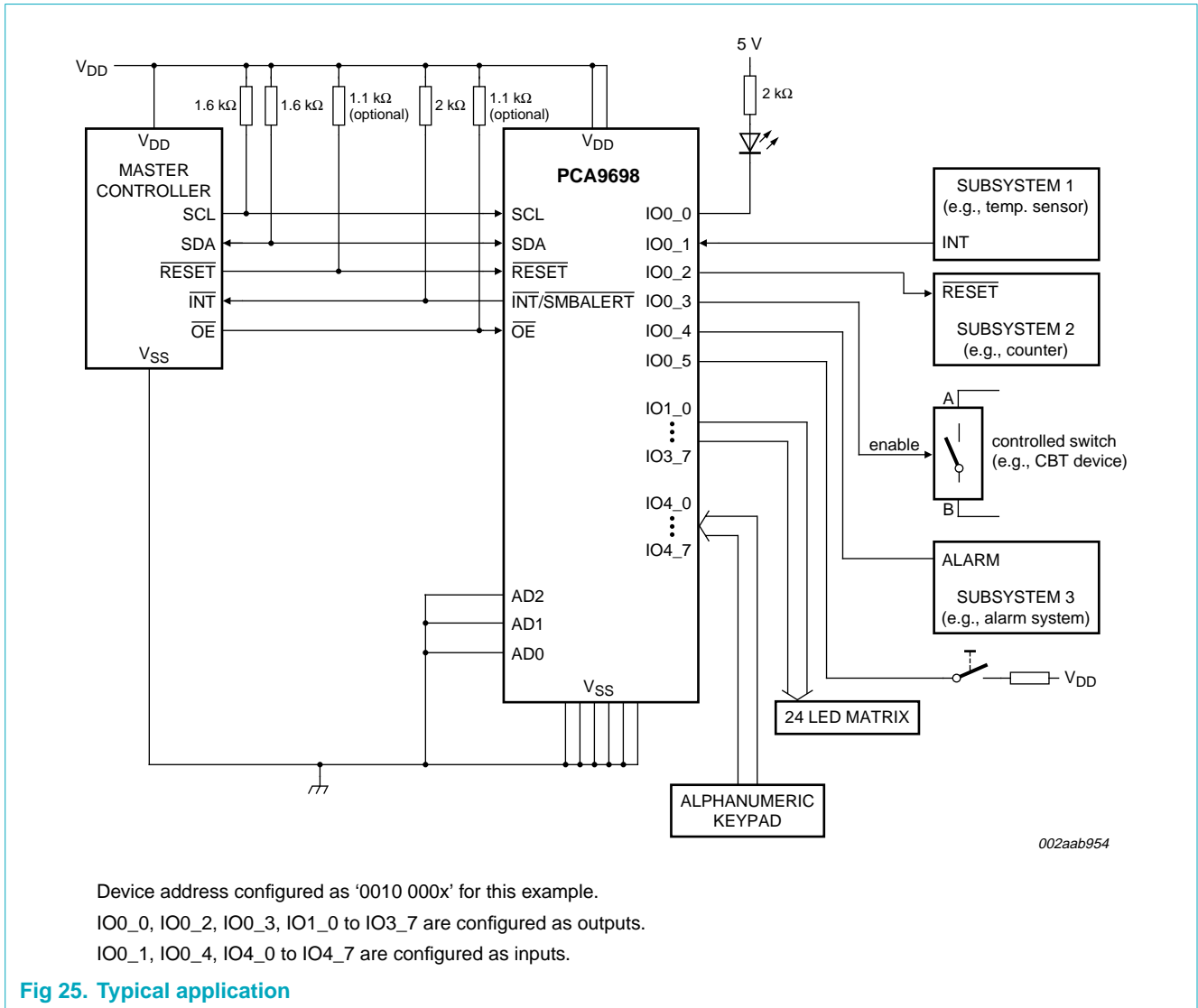
Fig 23. GPIO All Call write to the Output Port, I/O Configuration, Polarity Inversion, or Mask interrupt registers



Only slave devices with bit 0 IOAC = 1 answer the GPIO All Call transaction.  
 The programming becomes effective at the acknowledge.  
 If more than 1 byte is written, previous data is overwritten.

Fig 24. GPIO All Call write to the Output structure configuration, All Bank Control, or Mode selection registers

9. Application design-in information



002aab954

## 10. Limiting values

**Table 13. 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
V <sub>I</sub>	input voltage		V <sub>SS</sub> - 0.5	5.5	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(I0x_y)</sub>	output current on pin IOx_y		-20	+50	mA
I <sub>DD</sub>	supply current		-	500	mA
I <sub>SS</sub>	ground supply current		-	1100	mA
P <sub>tot</sub>	total power dissipation		-	500	mW
T <sub>stg</sub>	storage temperature		-65	+150	°C
T <sub>amb</sub>	ambient temperature	operating	-40	+85	°C
T <sub>j</sub>	junction temperature	operating	-	125	°C
		storage	-	150	°C



## 11. Static characteristics

**Table 14. 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; $f_{SCL} = 1 \text{ MHz}$ ; AD0, AD1, AD2 = static H or L					
		$V_{DD} = 2.3 \text{ V}$	-	135	200	$\mu\text{A}$	
		$V_{DD} = 3.3 \text{ V}$	-	250	400	$\mu\text{A}$	
		$V_{DD} = 5.5 \text{ V}$	-	550	800	$\mu\text{A}$	
$I_{stb}$	standby current	no load; $f_{SCL} = 0 \text{ kHz}$ ; I/O = inputs; $V_I = V_{DD}$					
		$V_{DD} = 2.3 \text{ V}$	-	0.15	11	$\mu\text{A}$	
		$V_{DD} = 3.3 \text{ V}$	-	0.25	12	$\mu\text{A}$	
		$V_{DD} = 5.5 \text{ V}$	-	0.75	15.5	$\mu\text{A}$	
$V_{POR}$	power-on reset voltage	no load; $V_I = V_{DD}$ or $V_{SS}$	[1]	-	1.70	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	$V_I = V_{SS}$	-	5	10	pF	
<b>I/Os</b>							
$V_{IL}$	LOW-level input voltage		-0.5	-	+0.3 $V_{DD}$	V	
$V_{IH}$	HIGH-level input voltage		2	-	5.5	V	
$I_{OL}$	LOW-level output current	$V_{OL} = 0.5 \text{ V}$ ; $V_{DD} = 2.3 \text{ V}$	[2]	12	-	-	mA
		$V_{OL} = 0.5 \text{ V}$ ; $V_{DD} = 3.0 \text{ V}$	[2]	17	-	-	mA
		$V_{OL} = 0.5 \text{ V}$ ; $V_{DD} = 4.5 \text{ V}$	[2]	25	-	-	mA
$I_{OL(tot)}$	total LOW-level output current	$V_{OL} = 0.5 \text{ V}$ ; $V_{DD} = 4.5 \text{ V}$					
		TSSOP56 package	[2]	-	-	0.86	A
		HVQFN56 package	[2]	-	-	1.0	A
$V_{OH}$	HIGH-level output voltage	$I_{OH} = -10 \text{ mA}$ ; $V_{DD} = 2.3 \text{ V}$	1.6	-	-	V	
		$I_{OH} = -10 \text{ mA}$ ; $V_{DD} = 3.0 \text{ V}$	2.3	-	-	V	
		$I_{OH} = -10 \text{ mA}$ ; $V_{DD} = 4.5 \text{ V}$	4.0	-	-	V	
$I_{LIH}$	HIGH-level input leakage current	$V_{DD} = 3.6 \text{ V}$ ; $V_{I/O} = V_{DD}$	-1	-	+1	$\mu\text{A}$	
$I_{LIL}$	LOW-level input leakage current	$V_{DD} = 5.5 \text{ V}$ ; $V_{I/O} = V_{SS}$	-1	-	+1	$\mu\text{A}$	
$C_i$	input capacitance		-	6	7	pF	
$C_o$	output capacitance		-	6	7	pF	

**Table 14. Static characteristics**

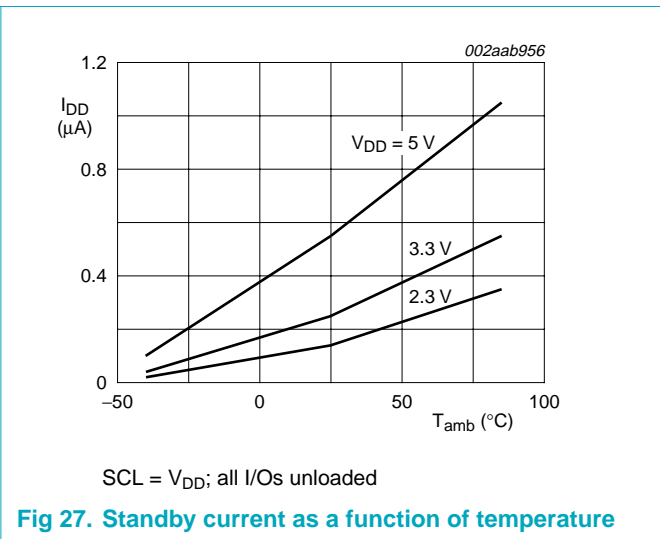
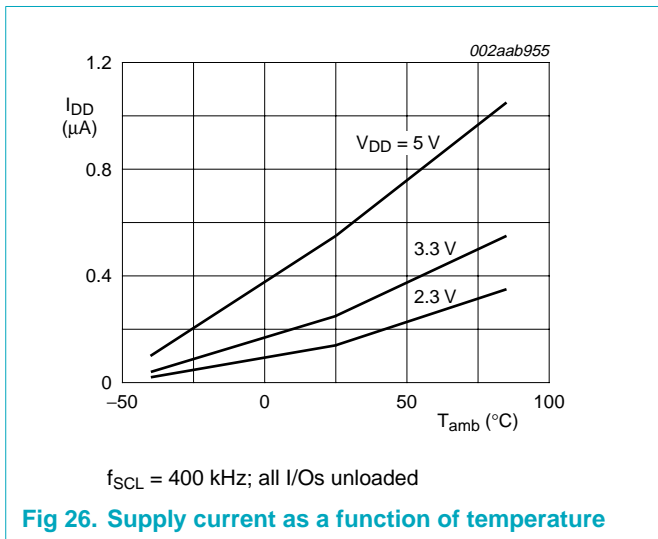
$V_{DD} = 2.3 \text{ V to } 5.5 \text{ V}$ ;  $V_{SS} = 0 \text{ V}$ ;  $T_{amb} = -40 \text{ }^\circ\text{C to } +85 \text{ }^\circ\text{C}$ ; unless otherwise specified.

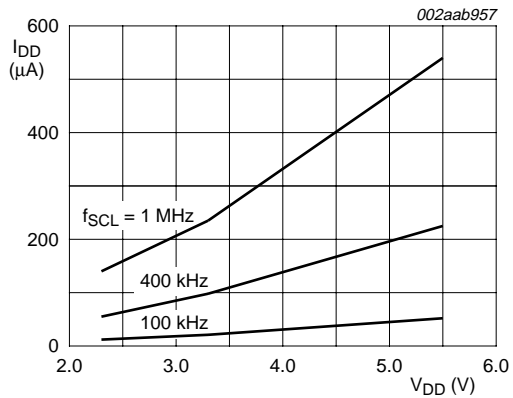
Symbol	Parameter	Conditions	Min	Typ	Max	Unit
<b>Interrupt <math>\overline{\text{INT}}</math></b>						
$I_{OL}$	LOW-level output current	$V_{OL} = 0.4 \text{ V}$	6	-	-	mA
$C_o$	output capacitance		-	3	5	pF
<b>Inputs <math>\overline{\text{RESET}}</math> and <math>\overline{\text{OE}}</math></b>						
$V_{IL}$	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	$\mu\text{A}$
$I_{OH}$	HIGH-level output 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	5	pF

[1]  $V_{DD}$  must be lowered to 0.2 V in order to reset part.

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

### 11.1 Performance curves





All I/Os unloaded; address pins static HIGH or LOW

Fig 28. Supply current as a function of supply voltage

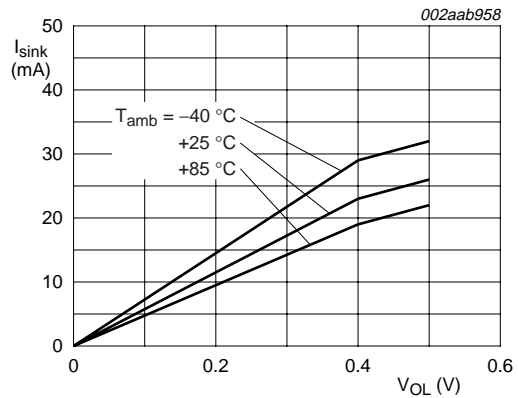


Fig 29. I/O sink current as a function of LOW-level output voltage ( $V_{DD} = 2.3 \text{ V}$ )

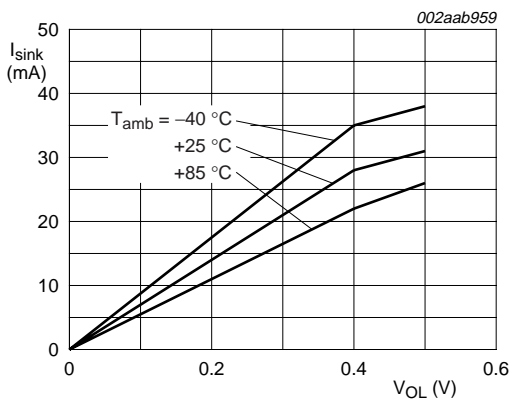


Fig 30. I/O sink current as a function of LOW-level output voltage ( $V_{DD} = 3.0 \text{ V}$ )

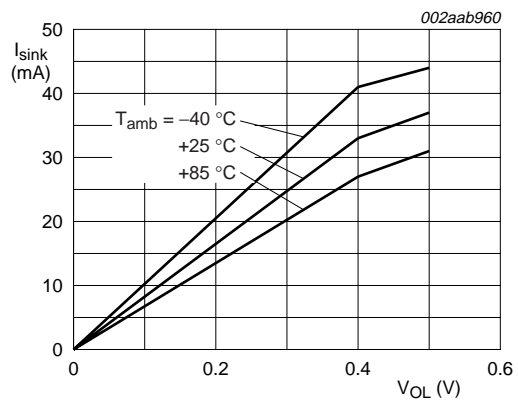


Fig 31. I/O sink current as a function of LOW-level output voltage ( $V_{DD} = 4.5 \text{ V}$ )

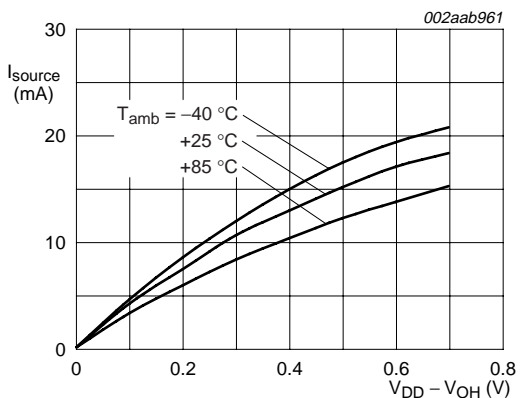


Fig 32. I/O source current as a function of HIGH-level output voltage ( $V_{DD} = 2 \text{ V}$ )

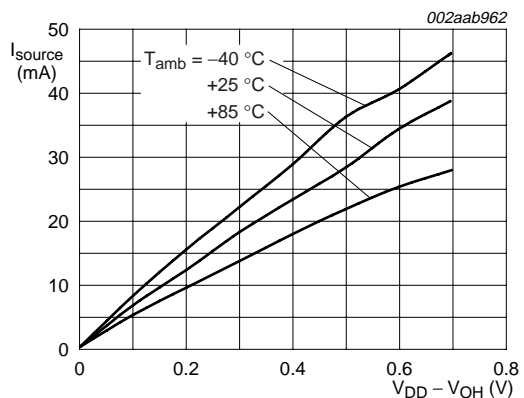


Fig 33. I/O source current as a function of HIGH-level output voltage ( $V_{DD} = 3.3 \text{ V}$ )

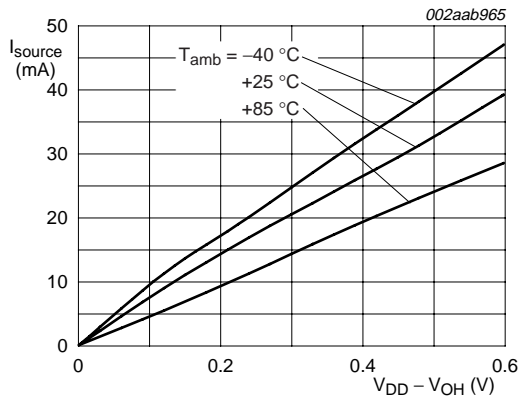
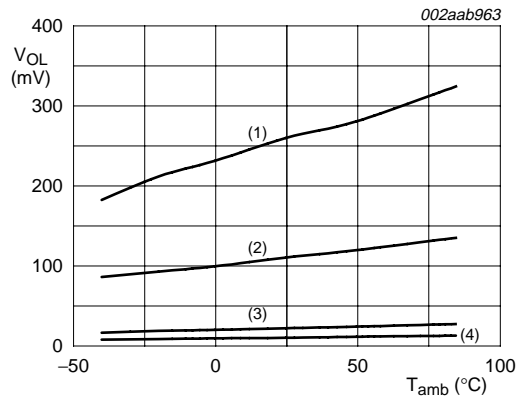
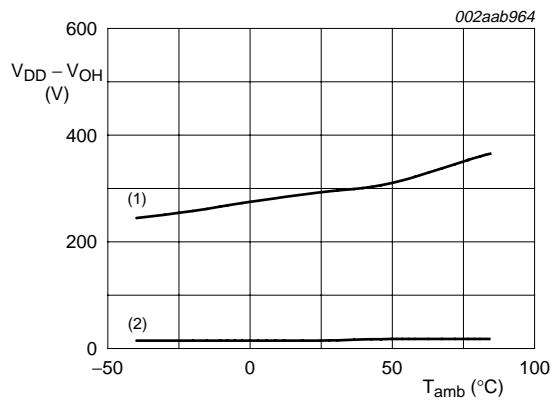


Fig 34. I/O source current as a function of HIGH-level output voltage ( $V_{\text{DD}} = 5\text{ V}$ )



- (1)  $V_{\text{DD}} = 5\text{ V}$ ;  $I_{\text{sink}} = 10\text{ mA}$
- (2)  $V_{\text{DD}} = 2.3\text{ V}$ ;  $I_{\text{sink}} = 10\text{ mA}$
- (3)  $V_{\text{DD}} = 5\text{ V}$ ;  $I_{\text{sink}} = 1\text{ mA}$
- (4)  $V_{\text{DD}} = 2.3\text{ V}$ ;  $I_{\text{sink}} = 1\text{ mA}$

Fig 35. I/O LOW-level output voltage as a function of temperature



- (1)  $V_{\text{DD}} = 2.3\text{ V}$ ;  $I_{\text{source}} = 10\text{ mA}$
- (2)  $V_{\text{DD}} = 5\text{ V}$ ;  $I_{\text{source}} = 10\text{ mA}$

Fig 36. HIGH-level output voltage as a function of temperature

## 12. Dynamic characteristics

Table 15. Dynamic characteristics

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	[3]	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>V D;ACK</sub>	data valid acknowledge time	[1]	0.1	3.45	0.1	0.9	0.05	0.45	μs
t <sub>V D;DAT</sub>	data valid time	[2]	300	-	75	-	75	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][6]	-	300	20 + 0.1C <sub>b</sub> [5]	300	-	120	ns
t <sub>r</sub>	rise time of both SDA and SCL signals	[4][6]	-	1000	20 + 0.1C <sub>b</sub> [5]	300	-	120	ns
t <sub>SP</sub>	pulse width of spikes that must be suppressed by the input filter	[7]	-	50	-	50	-	50	ns

### Port timing

t <sub>en</sub>	enable time	output	-	80	-	80	-	80	ns
t <sub>dis</sub>	disable time	output	-	40	-	40	-	40	ns
t <sub>V(Q)</sub>	data output valid time		-	250	-	250	-	250	ns
t <sub>su(D)</sub>	data input setup time		100	-	100	-	100	-	ns
t <sub>h(D)</sub>	data input hold time		250	-	250	-	250	-	ns

### Interrupt timing

t <sub>V(INT_N)</sub>	valid time on pin $\overline{\text{INT}}$		-	4	-	4	-	4	μs
t <sub>rst(INT_N)</sub>	reset time on pin $\overline{\text{INT}}$		-	4	-	4	-	4	μs

### Reset

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>V D;ACK</sub> = time for Acknowledgement signal from SCL LOW to SDA (out) LOW.

- [2]  $t_{\text{VD;DAT}}$  = minimum time for SDA data out to be valid following SCL LOW.
- [3] Minimum SCL clock frequency is limited by the bus time-out feature, which resets the serial bus interface if either SDA or SCL is held LOW for a minimum of 25 ms. Disable bus time-out feature for DC operation.
- [4] A master device must internally provide a hold time of at least 300 ns for the SDA signal (refer to the  $V_{\text{IL}}$  of the SCL signal) in order to bridge the undefined region of SCL's falling edge.
- [5]  $C_b$  = total capacitance of one bus line in pF.
- [6] The maximum  $t_f$  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  $t_f$ .
- [7] Input filters on the SDA and SCL inputs suppress noise spikes less than 50 ns.

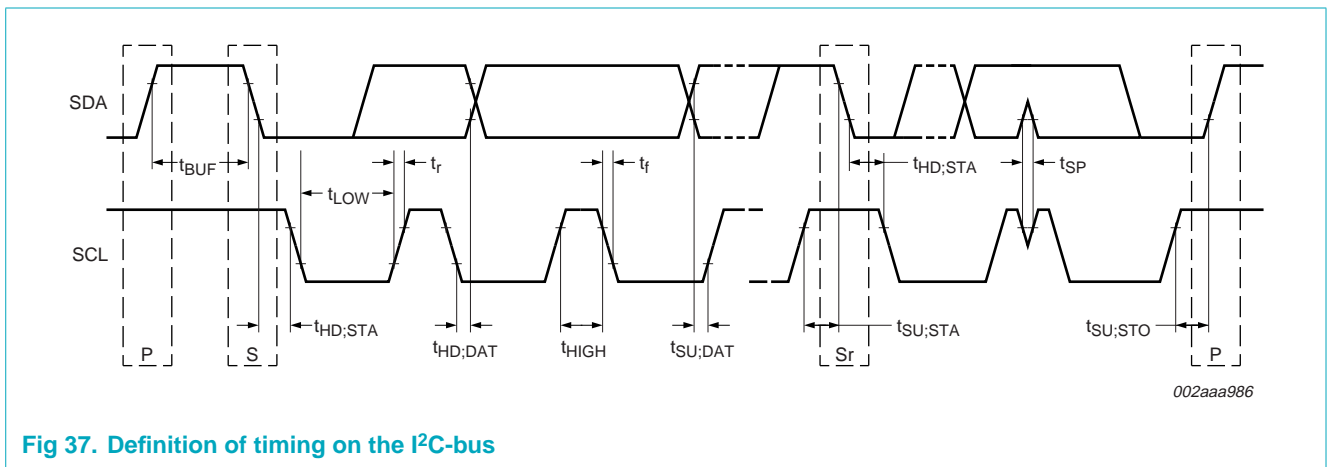


Fig 37. Definition of timing on the I<sup>2</sup>C-bus

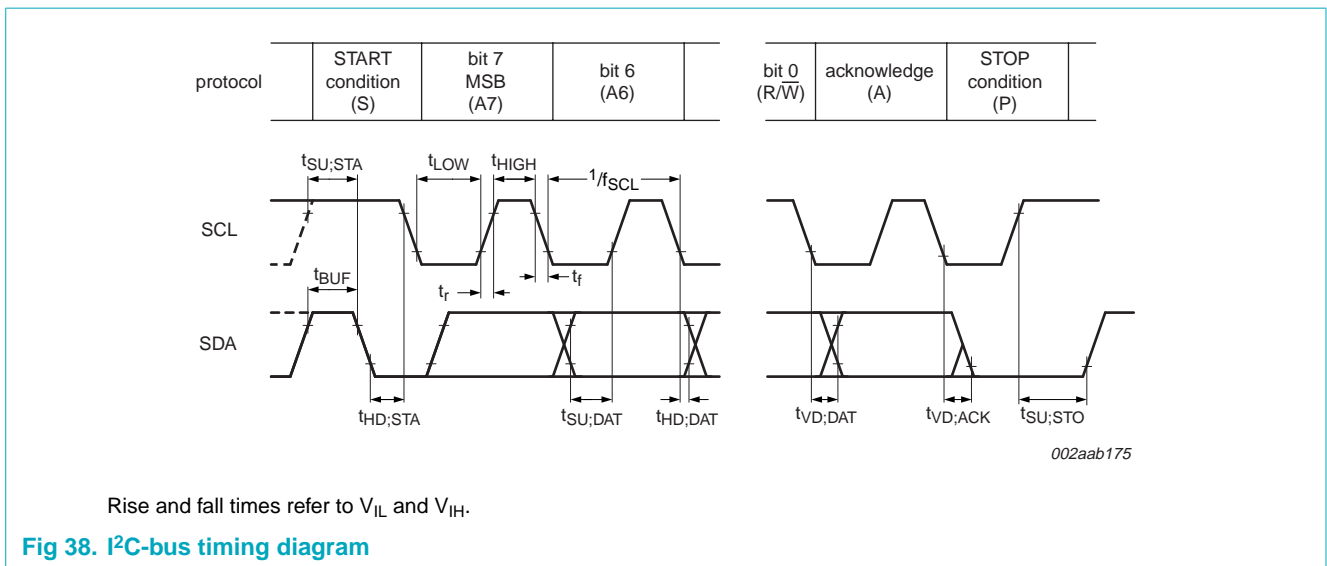


Fig 38. I<sup>2</sup>C-bus timing diagram

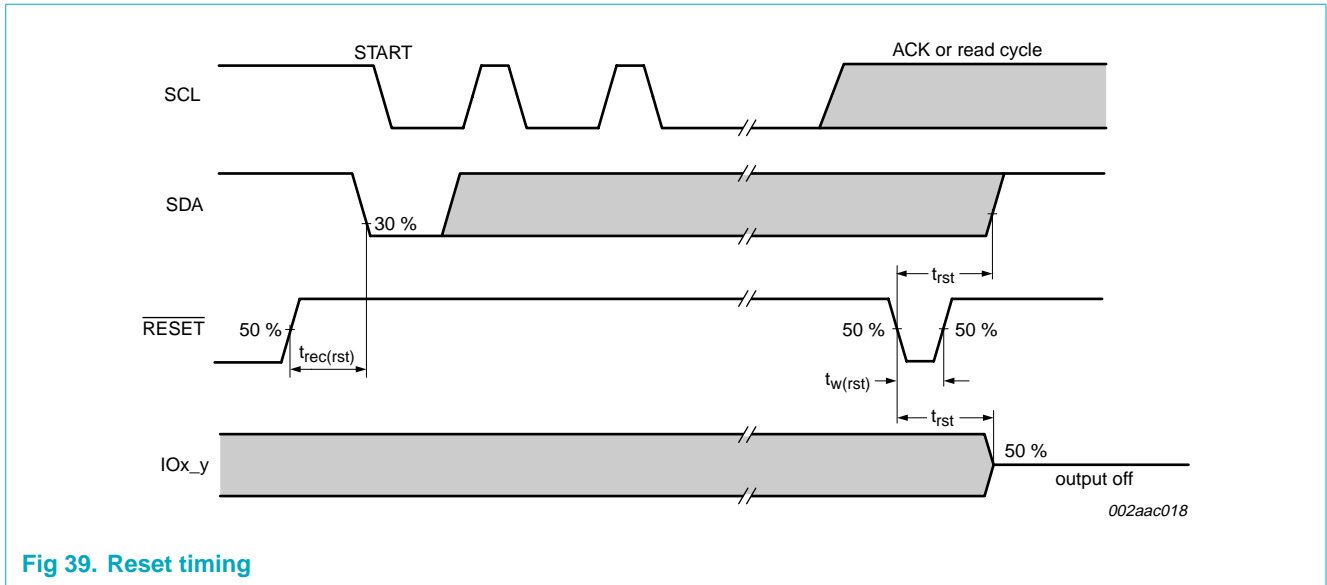


Fig 39. Reset timing

### 13. Test information

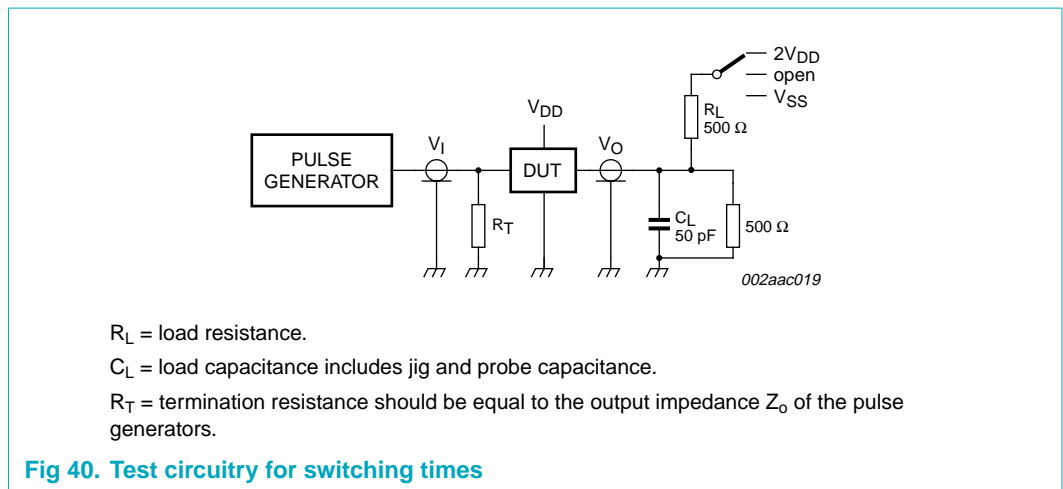


Fig 40. Test circuitry for switching times

14. Package outline

TSSOP56: plastic thin shrink small outline package; 56 leads; body width 6.1 mm

SOT364-1

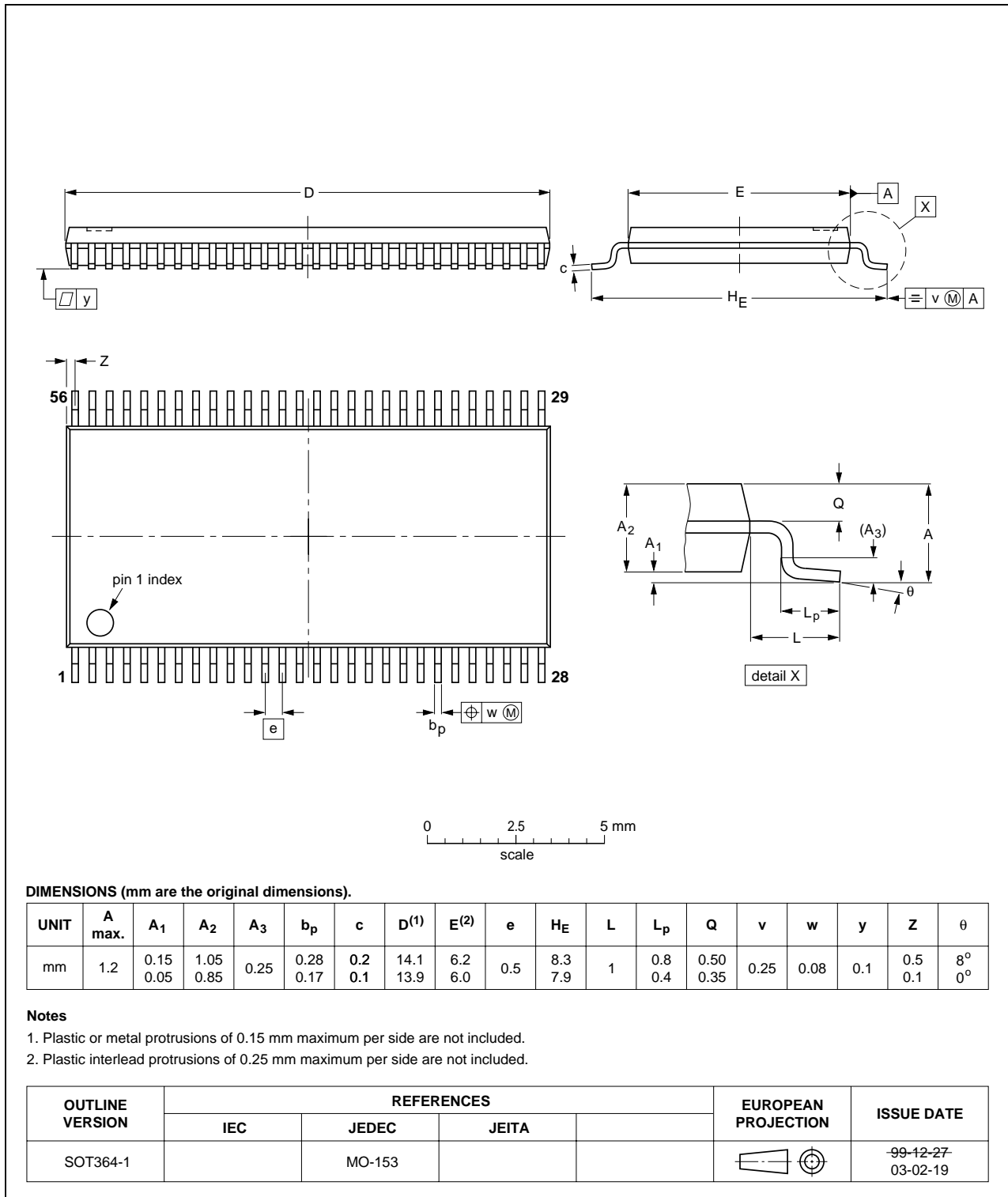


Fig 41. Package outline SOT364-1 (TSSOP56)



HVQFN56: plastic thermal enhanced very thin quad flat package; no leads;  
56 terminals; body 8 x 8 x 0.85 mm

SOT684-1

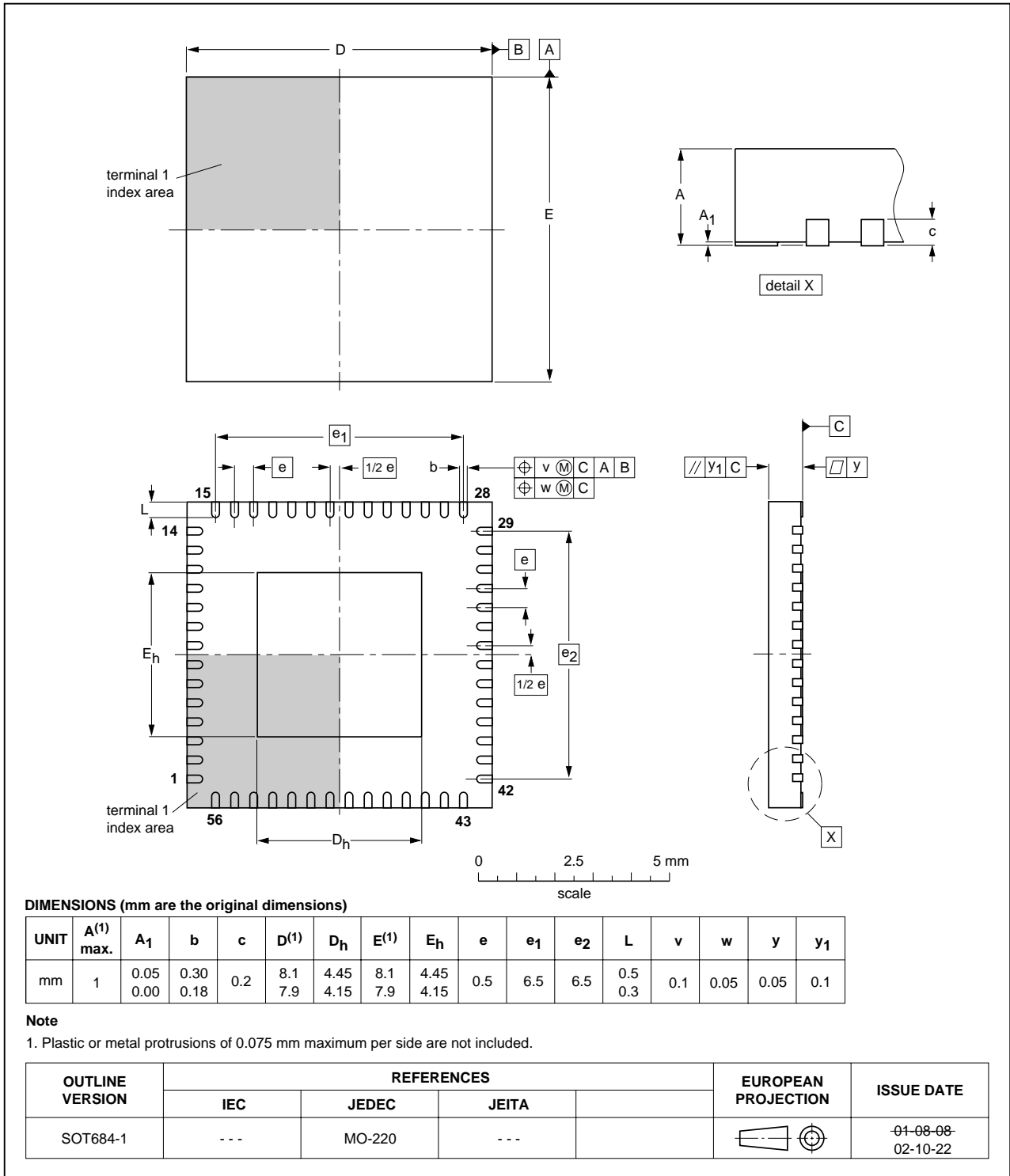


Fig 42. Package outline SOT684-1 (HVQFN56)

## 15. Handling information

Inputs and outputs are protected against electrostatic discharge in normal handling. However, to be completely safe you must take normal precautions appropriate to handling integrated circuits.

## 16. Soldering

### 16.1 Introduction to soldering surface mount packages

There is no soldering method that is ideal for all surface mount IC packages. Wave soldering can still be used for certain surface mount ICs, but it is not suitable for fine pitch SMDs. In these situations reflow soldering is recommended.

### 16.2 Reflow soldering

Reflow soldering requires solder paste (a suspension of fine solder particles, flux and binding agent) to be applied to the printed-circuit board by screen printing, stencilling or pressure-syringe dispensing before package placement. Driven by legislation and environmental forces the worldwide use of lead-free solder pastes is increasing.

Several methods exist for reflowing; for example, convection or convection/infrared heating in a conveyor type oven. Throughput times (preheating, soldering and cooling) vary between 100 seconds and 200 seconds depending on heating method.

Typical reflow temperatures range from 215 °C to 260 °C depending on solder paste material. The peak top-surface temperature of the packages should be kept below:

**Table 16. SnPb eutectic process - package peak reflow temperatures (from J-STD-020C July 2004)**

Package thickness	Volume mm <sup>3</sup> < 350	Volume mm <sup>3</sup> ≥ 350
< 2.5 mm	240 °C + 0/-5 °C	225 °C + 0/-5 °C
≥ 2.5 mm	225 °C + 0/-5 °C	225 °C + 0/-5 °C

**Table 17. Pb-free process - package peak reflow temperatures (from J-STD-020C July 2004)**

Package thickness	Volume mm <sup>3</sup> < 350	Volume mm <sup>3</sup> 350 to 2000	Volume mm <sup>3</sup> > 2000
< 1.6 mm	260 °C + 0 °C	260 °C + 0 °C	260 °C + 0 °C
1.6 mm to 2.5 mm	260 °C + 0 °C	250 °C + 0 °C	245 °C + 0 °C
≥ 2.5 mm	250 °C + 0 °C	245 °C + 0 °C	245 °C + 0 °C

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

### 16.3 Wave soldering

Conventional single wave soldering is not recommended for surface mount devices (SMDs) or printed-circuit boards with a high component density, as solder bridging and non-wetting can present major problems.

To overcome these problems the double-wave soldering method was specifically developed.

If wave soldering is used the following conditions must be observed for optimal results:

- Use a double-wave soldering method comprising a turbulent wave with high upward pressure followed by a smooth laminar wave.
- For packages with leads on two sides and a pitch (e):
  - larger than or equal to 1.27 mm, the footprint longitudinal axis is **preferred** to be parallel to the transport direction of the printed-circuit board;
  - smaller than 1.27 mm, the footprint longitudinal axis **must** be parallel to the transport direction of the printed-circuit board.

The footprint must incorporate solder thieves at the downstream end.

- For packages with leads on four sides, the footprint must be placed at a 45° angle to the transport direction of the printed-circuit board. The footprint must incorporate solder thieves downstream and at the side corners.

During placement and before soldering, the package must be fixed with a droplet of adhesive. The adhesive can be applied by screen printing, pin transfer or syringe dispensing. The package can be soldered after the adhesive is cured.

Typical dwell time of the leads in the wave ranges from 3 seconds to 4 seconds at 250 °C or 265 °C, depending on solder material applied, SnPb or Pb-free respectively.

A mildly-activated flux will eliminate the need for removal of corrosive residues in most applications.

## 16.4 Manual soldering

Fix the component by first soldering two diagonally-opposite end leads. Use a low voltage (24 V or less) soldering iron applied to the flat part of the lead. Contact time must be limited to 10 seconds at up to 300 °C.

When using a dedicated tool, all other leads can be soldered in one operation within 2 seconds to 5 seconds between 270 °C and 320 °C.

## 16.5 Package related soldering information

**Table 18. Suitability of surface mount IC packages for wave and reflow soldering methods**

Package <sup>[1]</sup>	Soldering method	
	Wave	Reflow <sup>[2]</sup>
BGA, HTSSON..T <sup>[3]</sup> , LBGA, LFBGA, SQFP, SSOP..T <sup>[3]</sup> , TFBGA, VFBGA, XSON	not suitable	suitable
DHVQFN, HBCC, HBGA, HLQFP, HSO, HSOP, HSQFP, HSSON, HTQFP, HTSSOP, HVQFN, HVSON, SMS	not suitable <sup>[4]</sup>	suitable
PLCC <sup>[5]</sup> , SO, SOJ	suitable	suitable
LQFP, QFP, TQFP	not recommended <sup>[5][6]</sup>	suitable
SSOP, TSSOP, VSO, VSSOP	not recommended <sup>[7]</sup>	suitable
CWQCCN..L <sup>[8]</sup> , PMFP <sup>[9]</sup> , WQCCN..L <sup>[8]</sup>	not suitable	not suitable

- [1] For more detailed information on the BGA packages refer to the *(LF)BGA Application Note (AN01026)*; order a copy from your Philips Semiconductors sales office.
- [2] All surface mount (SMD) packages are moisture sensitive. Depending upon the moisture content, the maximum temperature (with respect to time) and body size of the package, there is a risk that internal or external package cracks may occur due to vaporization of the moisture in them (the so called popcorn effect). For details, refer to the Drypack information in the *Data Handbook IC26; Integrated Circuit Packages; Section: Packing Methods*.
- [3] These transparent plastic packages are extremely sensitive to reflow soldering conditions and must on no account be processed through more than one soldering cycle or subjected to infrared reflow soldering with peak temperature exceeding  $217\text{ }^{\circ}\text{C} \pm 10\text{ }^{\circ}\text{C}$  measured in the atmosphere of the reflow oven. The package body peak temperature must be kept as low as possible.
- [4] These packages are not suitable for wave soldering. On versions with the heatsink on the bottom side, the solder cannot penetrate between the printed-circuit board and the heatsink. On versions with the heatsink on the top side, the solder might be deposited on the heatsink surface.
- [5] If wave soldering is considered, then the package must be placed at a  $45^{\circ}$  angle to the solder wave direction. The package footprint must incorporate solder thieves downstream and at the side corners.
- [6] Wave soldering is suitable for LQFP, QFP and TQFP packages with a pitch (e) larger than 0.8 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.65 mm.
- [7] Wave soldering is suitable for SSOP, TSSOP, VSO and VSSOP packages with a pitch (e) equal to or larger than 0.65 mm; it is definitely not suitable for packages with a pitch (e) equal to or smaller than 0.5 mm.
- [8] Image sensor packages in principle should not be soldered. They are mounted in sockets or delivered pre-mounted on flex foil. However, the image sensor package can be mounted by the client on a flex foil by using a hot bar soldering process. The appropriate soldering profile can be provided on request.
- [9] Hot bar soldering or manual soldering is suitable for PMFP packages.

## 17. Abbreviations

**Table 19. Abbreviations**

Acronym	Description
CDM	Charged Device Model
DUT	Device Under Test
ESD	ElectroStatic Discharge
GPIO	General Purpose Input/Output
HBM	Human Body Model
I <sup>2</sup> C-bus	Inter-Integrated Circuit bus
LED	Light Emitting Diode
MM	Machine Model
PICMG	PCI Industrial Computer Manufacturers Group
PLC	Programmable Logic Controller
POR	Power-On Reset
PWM	Pulse Width Modulation
RAID	Redundant Array of Independent Discs
SMBus	System Management Bus

## 18. Revision history

Table 20. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
PCA9698_2	20060719	Product data sheet	-	PCA9698_1
Modifications:	<ul style="list-style-type: none"> <li>• Descriptive title of data sheet modified (added "Fm+")</li> <li>• <a href="#">Section 1 "General description"</a>: 2nd paragraph re-written</li> <li>• <a href="#">Table 12 "PCA9698 address map"</a>: filled fields for AD0 for addresses E0h through EEh</li> <li>• <a href="#">Table 14 "Static characteristics"</a>: added <a href="#">Table note 2</a> and references to it under subsection "I/Os", symbols <math>I_{OL}</math> and <math>I_{OL(tot)}</math></li> </ul>			
PCA9698_1 (9397 750 13751)	20060224	Product data sheet	-	-

## 19. Legal information

### 19.1 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.semiconductors.philips.com>.

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## 21. Contents

<b>1</b>	<b>General description</b> .....	<b>1</b>	<b>10</b>	<b>Limiting values</b> .....	<b>32</b>
<b>2</b>	<b>Features</b> .....	<b>1</b>	<b>11</b>	<b>Static characteristics</b> .....	<b>33</b>
<b>3</b>	<b>Applications</b> .....	<b>2</b>	11.1	Performance curves .....	34
<b>4</b>	<b>Ordering information</b> .....	<b>3</b>	<b>12</b>	<b>Dynamic characteristics</b> .....	<b>37</b>
<b>5</b>	<b>Block diagram</b> .....	<b>3</b>	<b>13</b>	<b>Test information</b> .....	<b>39</b>
<b>6</b>	<b>Pinning information</b> .....	<b>5</b>	<b>14</b>	<b>Package outline</b> .....	<b>40</b>
6.1	Pinning .....	5	<b>15</b>	<b>Handling information</b> .....	<b>42</b>
6.2	Pin description .....	6	<b>16</b>	<b>Soldering</b> .....	<b>42</b>
<b>7</b>	<b>Functional description</b> .....	<b>7</b>	16.1	Introduction to soldering surface mount	
7.1	Device address .....	7		packages .....	42
7.2	Alert response, GPIO All Call and Device ID		16.2	Reflow soldering .....	42
	addresses .....	8	16.3	Wave soldering .....	42
7.3	Command register .....	8	16.4	Manual soldering .....	43
7.3.1	5-bank register category .....	9	16.5	Package related soldering information .....	43
7.3.2	1-bank register category .....	9	<b>17</b>	<b>Abbreviations</b> .....	<b>44</b>
7.4	Register definitions .....	9	<b>18</b>	<b>Revision history</b> .....	<b>45</b>
7.4.1	IP0 to IP4 - Input Port registers .....	11	<b>19</b>	<b>Legal information</b> .....	<b>46</b>
7.4.2	OP0 to OP4 - Output Port registers .....	11	19.1	Data sheet status .....	46
7.4.3	PI0 to PI4 - Polarity Inversion registers .....	12	19.2	Definitions .....	46
7.4.4	IOC0 to IOC4 - I/O Configuration registers .....	12	19.3	Disclaimers .....	46
7.4.5	MSK0 to MSK4 - Mask interrupt registers .....	13	19.4	Trademarks .....	46
7.4.6	OUTCONF - output structure configuration		<b>20</b>	<b>Contact information</b> .....	<b>46</b>
	register .....	13	<b>21</b>	<b>Contents</b> .....	<b>47</b>
7.4.7	ALLBNK - All Bank control register .....	14			
7.4.7.1	Examples .....	14			
7.4.8	MODE - PCA9698 mode selection register .....	15			
7.5	Device ID - PCA9698 ID field .....	16			
7.6	GPIO All Call .....	17			
7.7	Output state change on ACK or STOP .....	17			
7.8	Power-on reset .....	18			
7.9	$\overline{\text{RESET}}$ input .....	18			
7.10	Interrupt output ( $\overline{\text{INT}}$ ) .....	18			
7.11	SMBus Alert output ( $\overline{\text{SMBALERT}}$ ) .....	19			
7.12	Output enable input ( $\overline{\text{OE}}$ ) .....	20			
7.13	Live insertion .....	20			
7.14	Standby .....	20			
7.15	Address map .....	21			
<b>8</b>	<b>Characteristics of the I<sup>2</sup>C-bus</b> .....	<b>23</b>			
8.1	Bit transfer .....	23			
8.1.1	START and STOP conditions .....	23			
8.2	System configuration .....	24			
8.3	Acknowledge .....	24			
8.4	Bus transactions .....	25			
<b>9</b>	<b>Application design-in information</b> .....	<b>31</b>			

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