PCA9538

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

Rev. 05 — 28 May 2009 Product data sheet

1. General description

The PCA9538 is a 16-pin CMOS device that provides 8 bits of General Purpose parallel Input/Output (GPIO) expansion with interrupt and reset for I²C-bus/SMBus applications and was developed to enhance the NXP Semiconductors family of I²C-bus I/O expanders. I/O expanders provide a simple solution when additional I/O is needed for ACPI power switches, sensors, push-buttons, LEDs, fans, etc.

The PCA9538 consists of an 8-bit Configuration register (input or output selection), 8-bit Input Port register, 8-bit Output Port register and an 8-bit Polarity Inversion register (active HIGH or active LOW operation). The system master can enable the I/Os as either inputs or outputs by writing to the I/O configuration bits. The data for each input or output is kept in the corresponding Input Port or Output Port register. The polarity of the Input Port register can be inverted with the Polarity Inversion register. All registers can be read by the system master.

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

The PCA9538 open-drain interrupt output ($\overline{\text{INT}}$) is activated when any input state differs from its corresponding Input Port register state and is used to indicate to the system master that an input state has changed. The power-on reset sets the registers to their default values and initializes the device state machine. The $\overline{\text{RESET}}$ pin causes the same reset/initialization to occur without de-powering the device.

Two hardware pins (A0 and A1) vary the fixed I²C-bus address and allow up to four devices to share the same I²C-bus/SMBus.

2. Features

- 8-bit I²C-bus GPIO with interrupt and reset
- Operating power supply voltage range of 2.3 V to 5.5 V
- 5 V tolerant I/Os
- Polarity Inversion register
- Active LOW interrupt output
- Active LOW reset input
- Low standby current
- Noise filter on SCL/SDA inputs
- No glitch on power-up
- Internal power-on reset

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- 8 I/O pins which default to 8 inputs
- 0 Hz to 400 kHz clock frequency
- ESD protection exceeds 2000 V HBM per JESD22-A114, 200 V MM per JESD22-A115 and 1000 V CDM per JESD22-C101
- Latch-up testing is done to JEDEC Standard JESD78 which exceeds 100 mA
- Offered in three different packages: SO16, TSSOP16 and HVQFN16

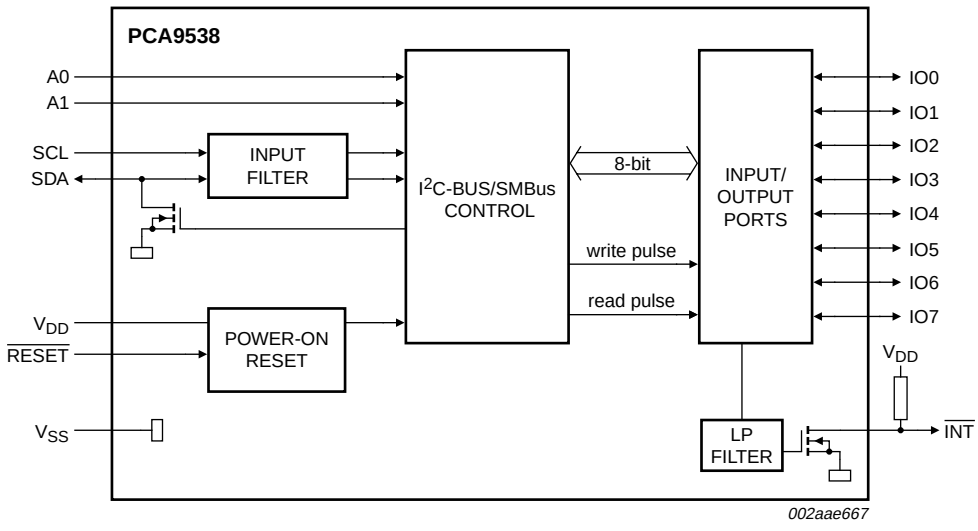
3. Ordering information

Table 1. Ordering information

T_{amb} = −40 °C to +85 °C

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

4. Block diagram



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

Fig 1. Block diagram of PCA9538

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5. Pinning information

5.1 Pinning

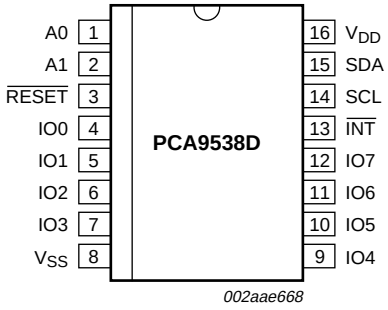


Fig 2. Pin configuration for SO16

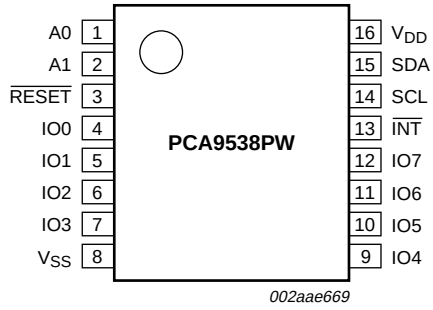


Fig 3. Pin configuration for TSSOP16

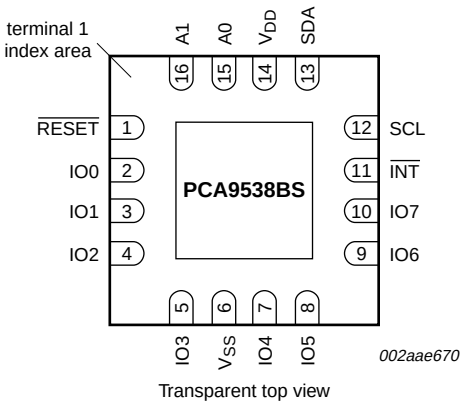


Fig 4. Pin configuration for HVQFN16

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5.2 Pin description

Table 2. Pin description

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

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

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6. Functional description

Refer to Figure 1 “Block diagram of PCA9538”.

6.1 Device address

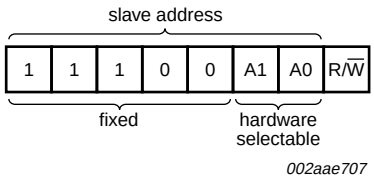


Fig 5. PCA9538 address

6.2 Registers

6.2.1 Command byte

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

Table 3. Command byte

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

6.2.2 Register 0 - Input Port register

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

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

Table 4. Register 0 - Input Port register bit description

*Legend: * default value.*

Bit	Symbol	Access	Value	Description
7	I7	read only	X*	value ‘X’ is determined by externally applied logic level
6	I6	read only	X*	
5	I5	read only	X*	
4	I4	read only	X*	
3	I3	read only	X*	
2	I2	read only	X*	
1	I1	read only	X*	
0	I0	read only	X*	

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6.2.3 Register 1 - Output Port register

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

Table 5. Register 1 - Output Port register bit description

*Legend: * default value.*

Bit	Symbol	Access	Value	Description
7	O7	R	1*	reflects outgoing logic levels of pins defined as outputs by Register 3
6	O6	R	1*	
5	O5	R	1*	
4	O4	R	1*	
3	O3	R	1*	
2	O2	R	1*	
1	O1	R	1*	
0	O0	R	1*	

6.2.4 Register 2 - Polarity Inversion register

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

Table 6. Register 2 - Polarity Inversion register bit description

*Legend: * default value.*

Bit	Symbol	Access	Value	Description
7	N7	R/W	0*	inverts polarity of Input Port register data
6	N6	R/W	0*	0 = Input Port register data retained (default value)
5	N5	R/W	0*	1 = Input Port register data inverted
4	N4	R/W	0*	
3	N3	R/W	0*	
2	N2	R/W	0*	
1	N1	R/W	0*	
0	N0	R/W	0*	

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6.2.5 Register 3 - Configuration register

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

Table 7. Register 3 - Configuration register bit description

*Legend: * default value.*

Bit	Symbol	Access	Value	Description
7	C7	R/W	1*	configures the directions of the I/O pins 0 = corresponding port pin enabled as an output 1 = corresponding port pin configured as an input (default value)
6	C6	R/W	1*	
5	C5	R/W	1*	
4	C4	R/W	1*	
3	C3	R/W	1*	
2	C2	R/W	1*	
1	C1	R/W	1*	
0	C0	R/W	1*	

6.3 Power-on reset

When power is applied to V_{DD}, an internal Power-On Reset (POR) holds the PCA9538 in a reset condition until V_{DD} has reached V_{POR}. At that point, the reset condition is released and the PCA9538 registers and state machine will initialize to their default states. Thereafter, V_{DD} must be lowered below 0.2 V to reset the device.

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

6.4 $\overline{\text{RESET}}$ input

A reset can be accomplished by holding the $\overline{\text{RESET}}$ pin LOW for a minimum of $t_{w(rst)}$. The PCA9538 registers and SMBus/I²C-bus state machine will be held in their default state until the $\overline{\text{RESET}}$ input is once again HIGH. This input requires a pull-up resistor to V_{DD} if no active connection is used.

6.5 Interrupt output

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

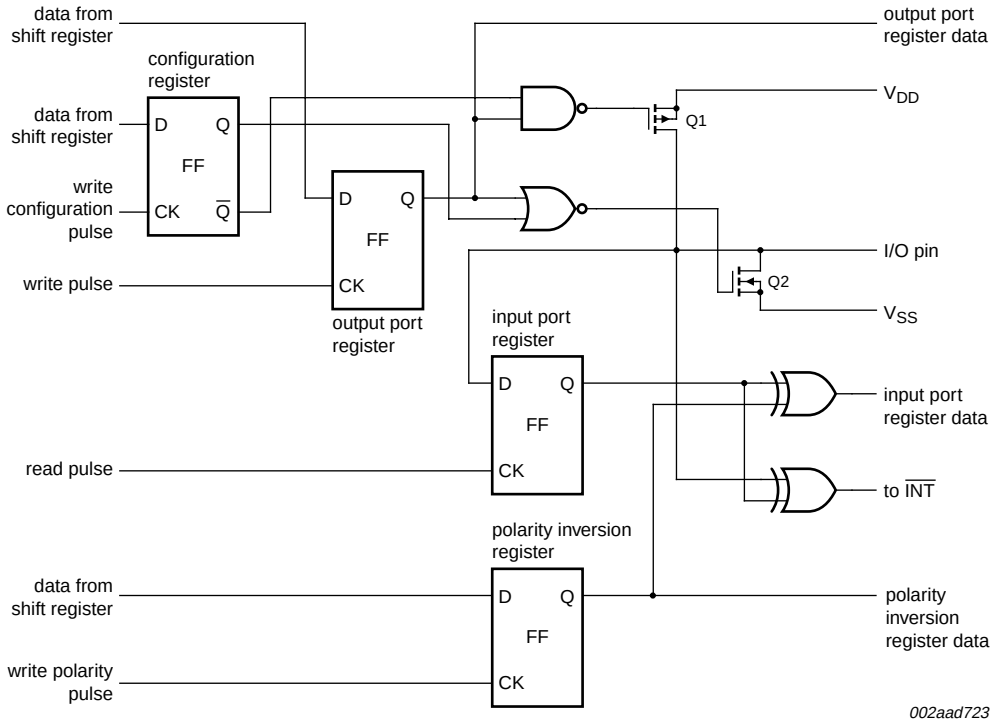
Note that changing an I/O from an output to an input may cause a false interrupt to occur if the state of the pin does not match the contents of the Input Port register.

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6.6 I/O port

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

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



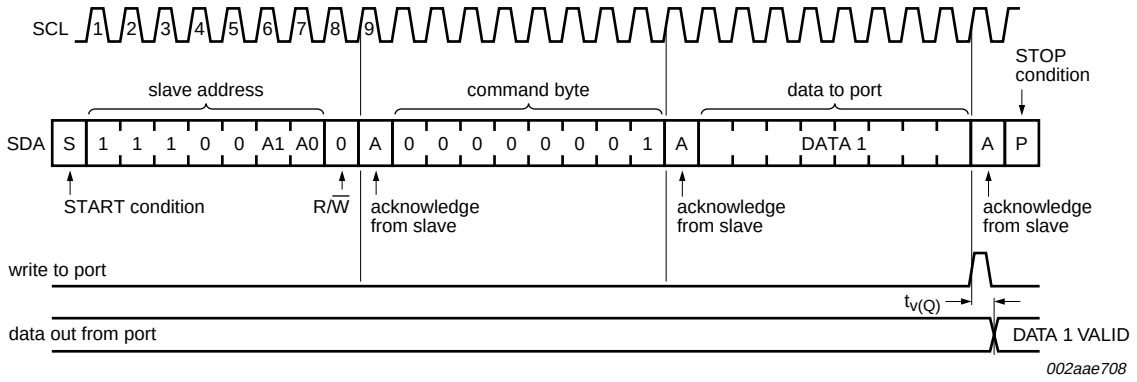
Remark: At power-on reset, all registers return to default values.

Fig 6. Simplified schematic of IO0 to IO7

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6.7 Bus transactions

Data is transmitted to the PCA9538 registers using the write mode as shown in Figure 7 and Figure 8. Data is read from the PCA9538 registers using the read mode as shown in Figure 9 and Figure 10. These devices do not implement an auto-increment function so once a command byte has been sent, the register which was addressed will continue to be accessed by reads until a new command byte has been sent.



Expanded diagram is shown in Figure 18.

Fig 7. Write to output port register

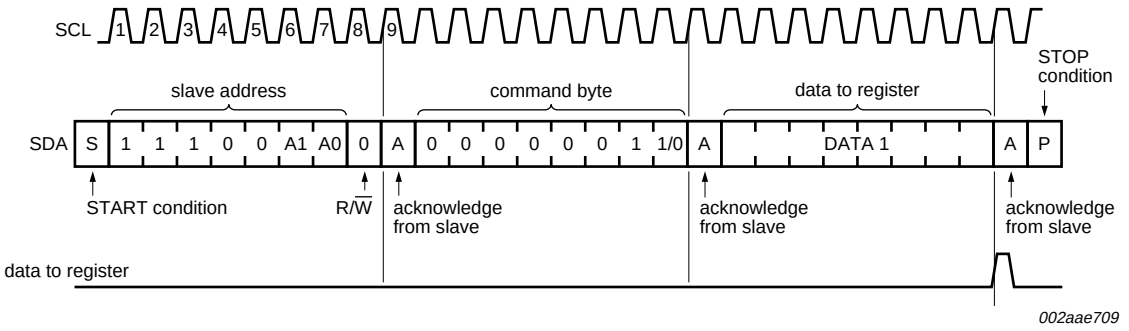


Fig 8. Write to configuration or polarity inversion registers

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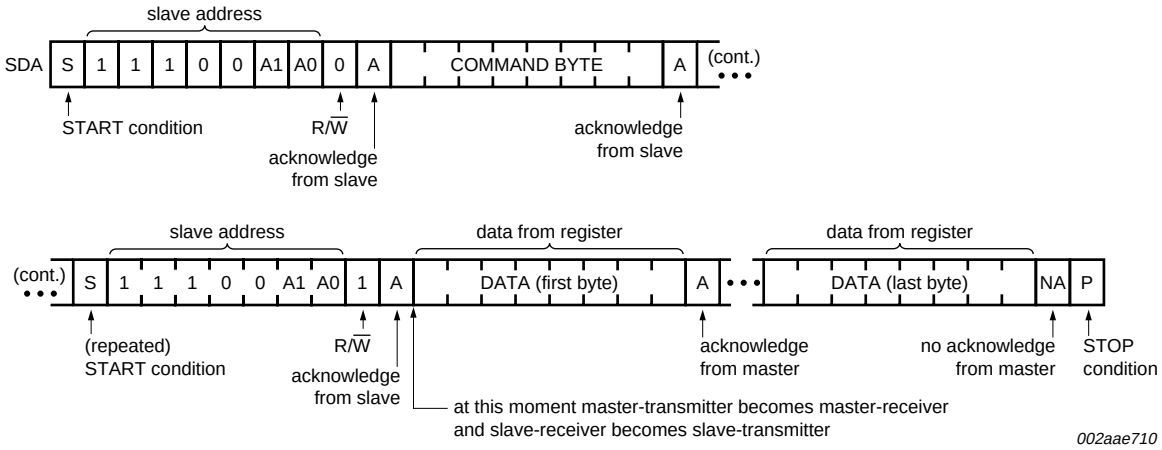
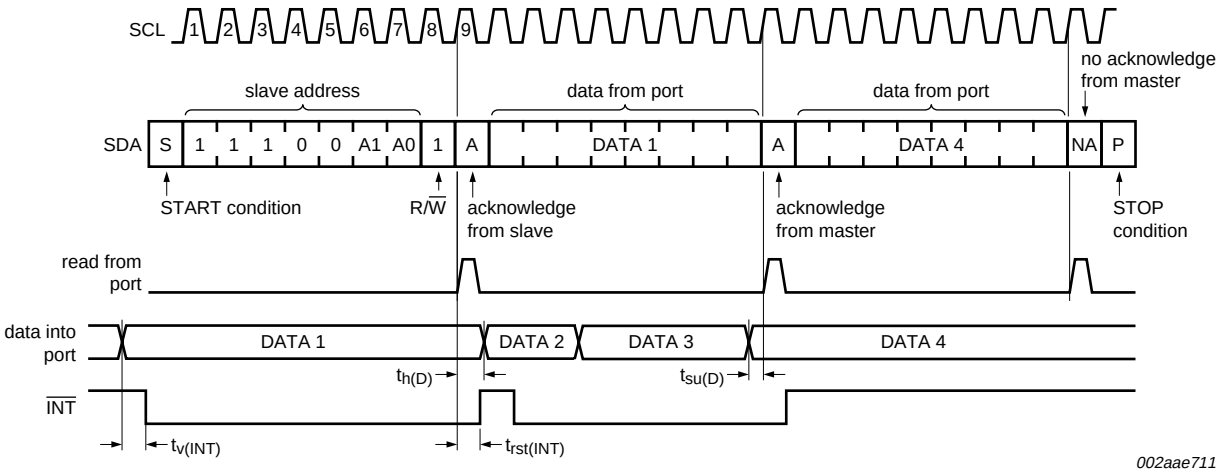


Fig 9. Read from register



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

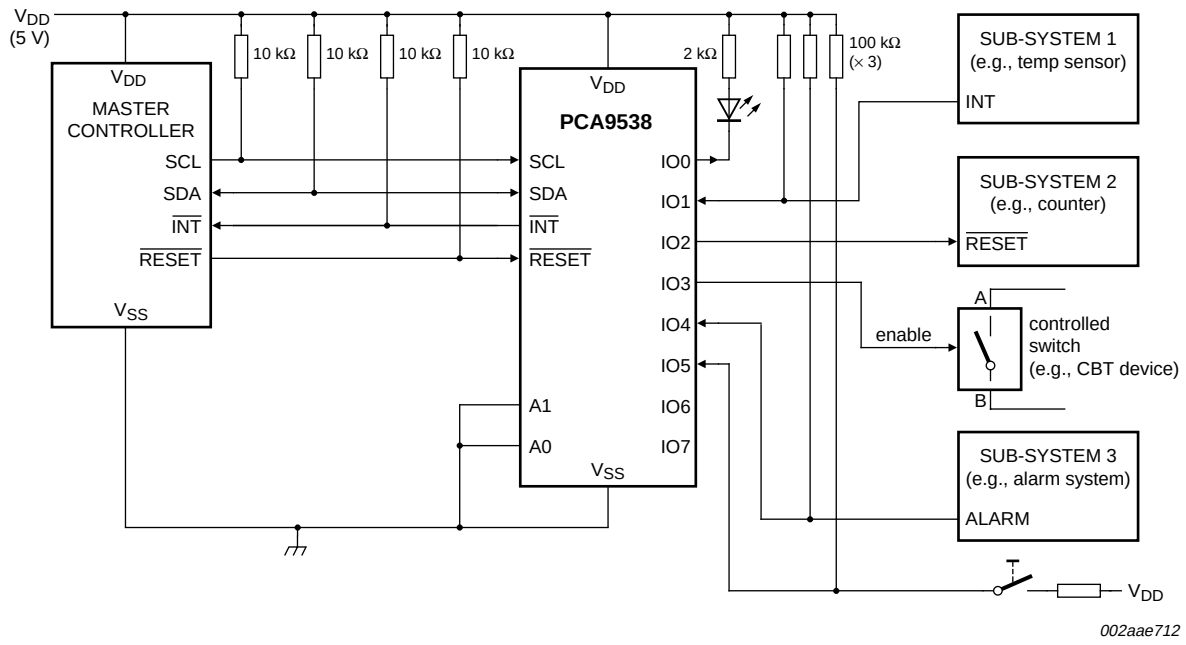
Transfer of data can be stopped at any moment by a STOP condition.

Expanded diagram is shown in Figure 17.

Fig 10. Read input port register

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7. Application design-in information



Device address is 1110 000x for this example.

IO0, IO2, IO3 configured as outputs.

IO1, IO4, IO5 configured as inputs.

IO6, IO7 are not used and need 100 kΩ pull-up resistors to protect them from floating.

Fig 11. Typical application

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

When the I/Os are used to control LEDs, they are normally connected to V_{DD} through a resistor as shown in Figure 11. Since the LED acts as a diode, when the LED is off the I/O V_I is about 1.2 V less than V_{DD}. The supply current, I_{DD}, increases as V_I becomes lower than V_{DD}.

Designs needing to minimize current consumption, such as battery power applications, should consider maintaining the I/O pins greater than or equal to V_{DD} when the LED is off. Figure 12 shows a high value resistor in parallel with the LED. Figure 13 shows V_{DD} less than the LED supply voltage by at least 1.2 V. Both of these methods maintain the I/O V_I at or above V_{DD} and prevents additional supply current consumption when the LED is off.

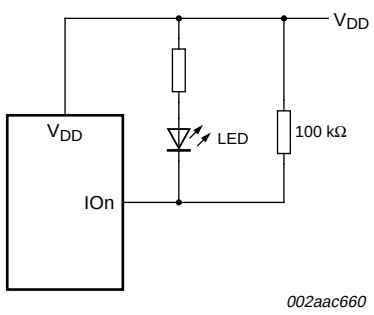


Fig 12. High value resistor in parallel with the LED

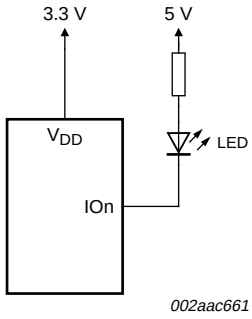


Fig 13. Device supplied by a lower voltage

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8. Limiting values

Table 8. Limiting values

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

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

9. Static characteristics

Table 9. Static characteristics

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

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Supplies							
V_{DD}	supply voltage			2.3	-	5.5	V
I_{DD}	supply current	operating mode; V_{DD} = 5.5 V; no load; f_{SCL} = 100 kHz		-	104	175	µA
I_{stbL}	LOW-level standby current	Standby mode; V_{DD} = 5.5 V; no load; $V_I = V_{SS}$; f_{SCL} = 0 kHz; I/O = inputs		-	0.25	1	µA
I_{stbH}	HIGH-level standby current	Standby mode; V_{DD} = 5.5 V; no load; $V_I = V_{DD}$; f_{SCL} = 0 kHz; I/O = inputs		-	0.25	1	µA
V_{POR}	power-on reset voltage	no load; $V_I = V_{DD}$ or V_{SS}	[1]	-	1.5	1.65	V
Input SCL; input/output SDA							
V_{IL}	LOW-level input voltage			–0.5	-	$+0.3V_{DD}$	V
V_{IH}	HIGH-level input voltage			$0.7V_{DD}$	-	5.5	V
I_{OL}	LOW-level output current	V_{OL} = 0.4 V		3	7	-	mA
I_L	leakage current	$V_I = V_{DD} = V_{SS}$		–1	-	+1	µA
C_i	input capacitance	$V_I = V_{SS}$		-	5	10	pF

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Table 9. Static characteristics *…continued*

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

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
I/Os							
V_{IL}	LOW-level input voltage			−0.5	-	+0.8	V
V_{IH}	HIGH-level input voltage			2.0	-	5.5	V
I_{OL}	LOW-level output current	V_{OL} = 0.5 V					
		V_{DD} = 2.3 V	[2]	8	10	-	mA
		V_{DD} = 3.0 V	[2]	8	14	-	mA
		V_{DD} = 4.5 V	[2]	8	17	-	mA
		V_{OL} = 0.7 V					
		V_{DD} = 2.3 V	[2]	10	13	-	mA
		V_{DD} = 3.0 V	[2]	10	19	-	mA
		V_{DD} = 4.5 V	[2]	10	24	-	mA
V_{OH}	HIGH-level output voltage	I_{OH} = −8 mA					
		V_{DD} = 2.3 V	[3]	1.8	-	-	V
		V_{DD} = 3.0 V	[3]	2.6	-	-	V
		V_{DD} = 4.5 V	[3]	4.1	-	-	V
		I_{OH} = −10 mA					
		V_{DD} = 2.3 V	[3]	1.7	-	-	V
		V_{DD} = 3.0 V	[3]	2.5	-	-	V
		V_{DD} = 4.5 V	[3]	4.0	-	-	V
I_{LI}	input leakage current	$V_I = V_{DD} = V_{SS}$		−1	-	+1	µA
C_i	input capacitance			-	5	10	pF
Interrupt $\overline{INT}$							
I_{OL}	LOW-level output current	V_{OL} = 0.4 V		3	13	-	mA
Select inputs A0, A1, $\overline{RESET}$							
V_{IL}	LOW-level input voltage			−0.5	-	+0.8	V
V_{IH}	HIGH-level input voltage			2.0	-	5.5	V
I_{LI}	input leakage current			−1	-	+1	µA

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

[2] Each I/O must be externally limited to a maximum of 25 mA and the device must be limited to a maximum current of 100 mA.

[3] The total current sourced by all I/Os must be limited to 85 mA.

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10. Dynamic characteristics

Table 10. Dynamic characteristics

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

[1] $t_{VD;ACK}$ = time for Acknowledgement signal from SCL LOW to SDA (out) LOW.

[2] $t_{VD;DAT}$ = minimum time for the SDA data out to be valid following SCL LOW.

[3] C_b = total capacitance of one bus line in pF.

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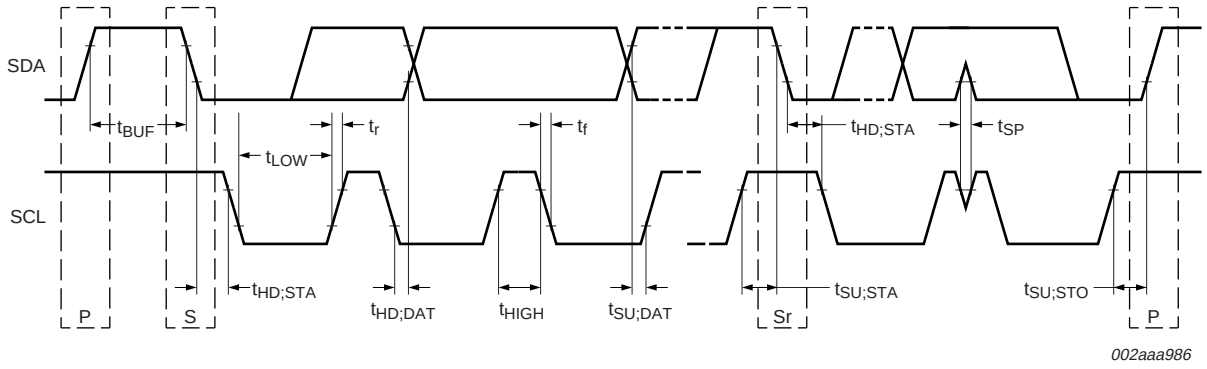
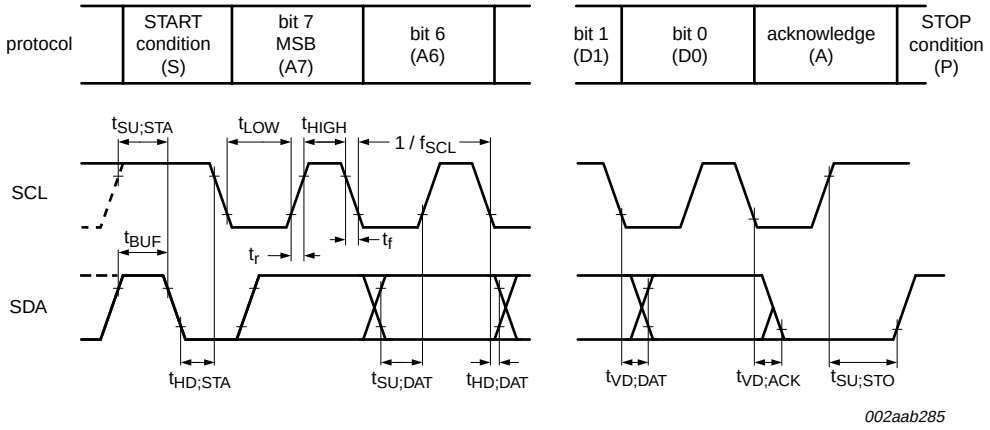


Fig 14. Definition of timing



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

Fig 15. I²C-bus timing diagram

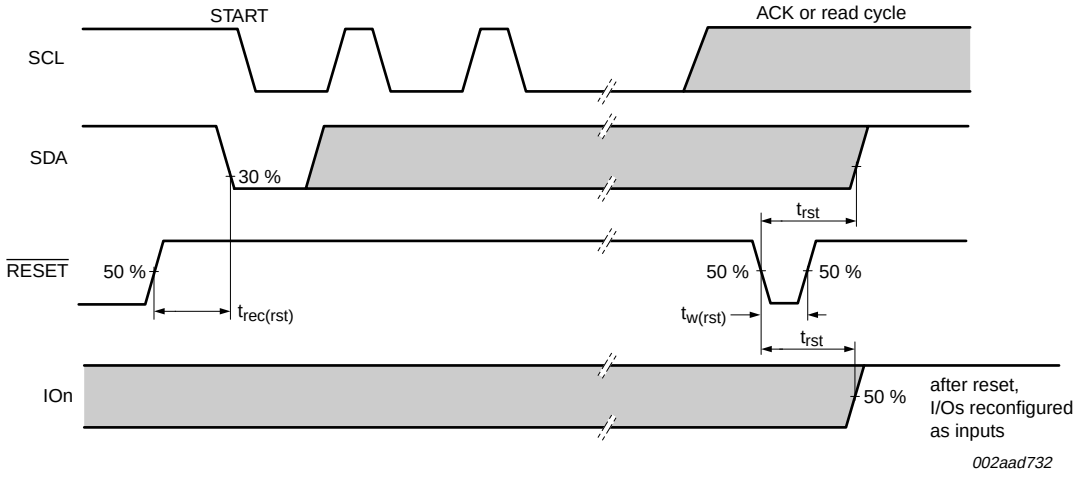


Fig 16. Definition of $\overline{\text{RESET}}$ timing

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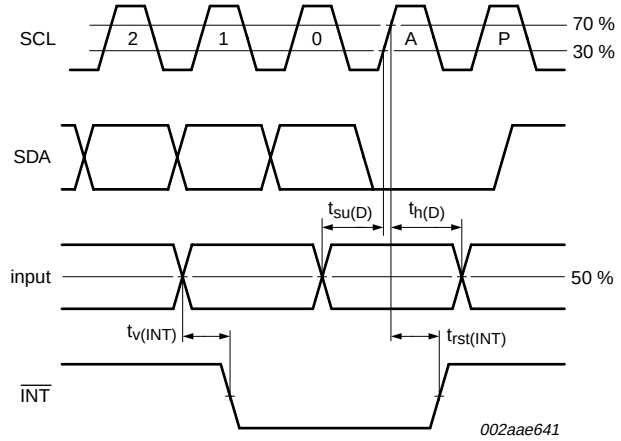


Fig 17. Expanded view of read input port register

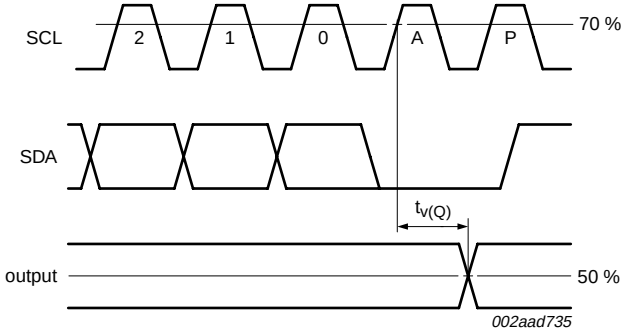
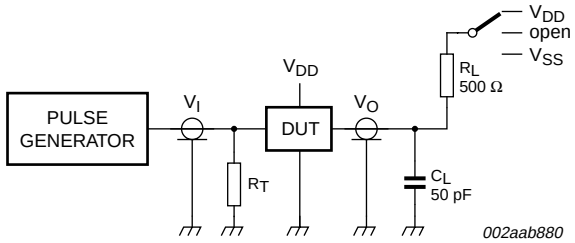


Fig 18. Expanded view of write to output port register

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11. Test information



R_L = load resistor.

C_L = load capacitance includes jig and probe capacitance.

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

Fig 19. Test circuitry for switching times

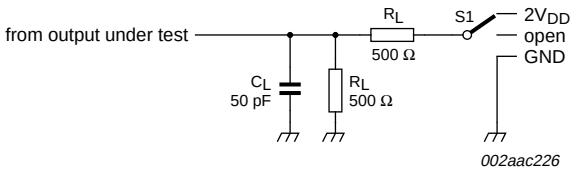


Fig 20. Test circuit

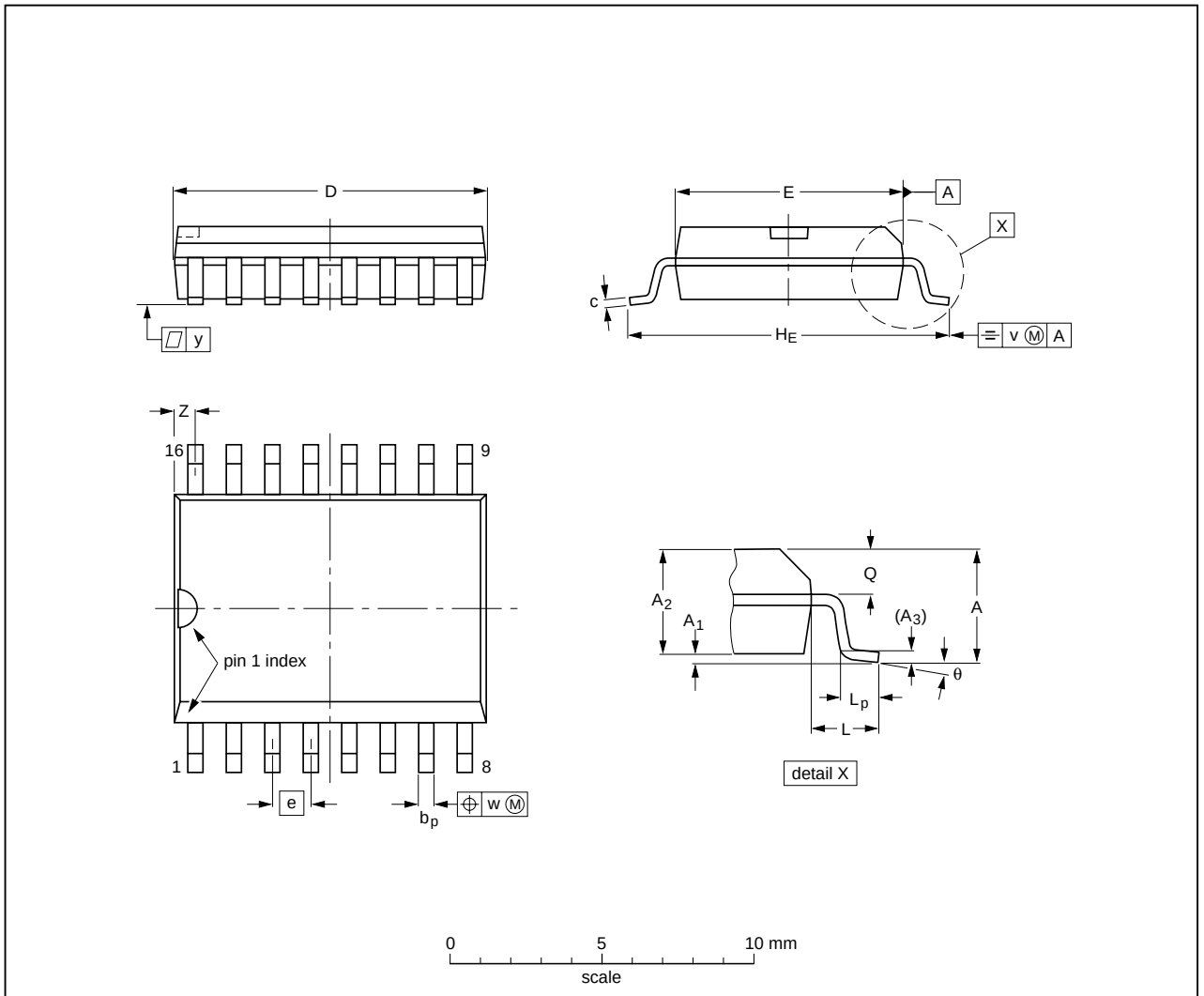
Table 11. Test data

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

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12. Package outline

SO16: plastic small outline package; 16 leads; body width 7.5 mm **SOT162-1**



DIMENSIONS (inch dimensions are derived from the original mm dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	D (1)	E (1)	e	H_E	L	L_p	Q	v	w	y	Z (1)	θ
mm	2.65	0.3 0.1	2.45 2.25	0.25	0.49 0.36	0.32 0.23	10.5 10.1	7.6 7.4	1.27	10.65 10.00	1.4	1.1 0.4	1.1 1.0	0.25	0.25	0.1	0.9 0.4	8^o 0^o
inches	0.1	0.012 0.004	0.096 0.089	0.01	0.019 0.014	0.013 0.009	0.41 0.40	0.30 0.29	0.05	0.419 0.394	0.055	0.043 0.016	0.043 0.039	0.01	0.01	0.004	0.035 0.016	

Note

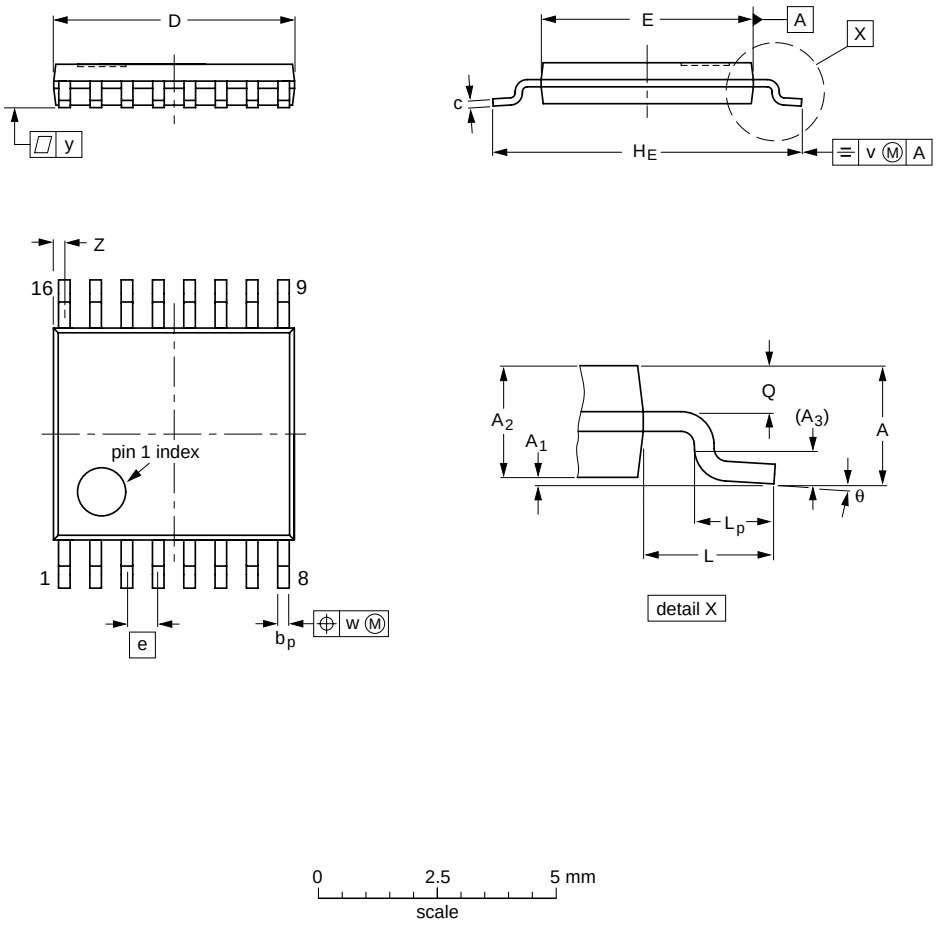
1. Plastic or metal protrusions of 0.15 mm (0.006 inch) maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT162-1	075E03	MS-013				~~99-12-27~~ 03-02-19

Fig 21. Package outline SOT162-1 (SO16)

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TSSOP16: plastic thin shrink small outline package; 16 leads; body width 4.4 mm **SOT403-1**



DIMENSIONS (mm are the original dimensions)

UNIT	A max.	A_1	A_2	A_3	b_p	c	D (1)	E (2)	e	H_E	L	L_p	Q	v	w	y	Z (1)	θ
mm	1.1	0.15 0.05	0.95 0.80	0.25	0.30 0.19	0.2 0.1	5.1 4.9	4.5 4.3	0.65	6.6 6.2	1	0.75 0.50	0.4 0.3	0.2	0.13	0.1	0.40 0.06	8° 0°

Notes

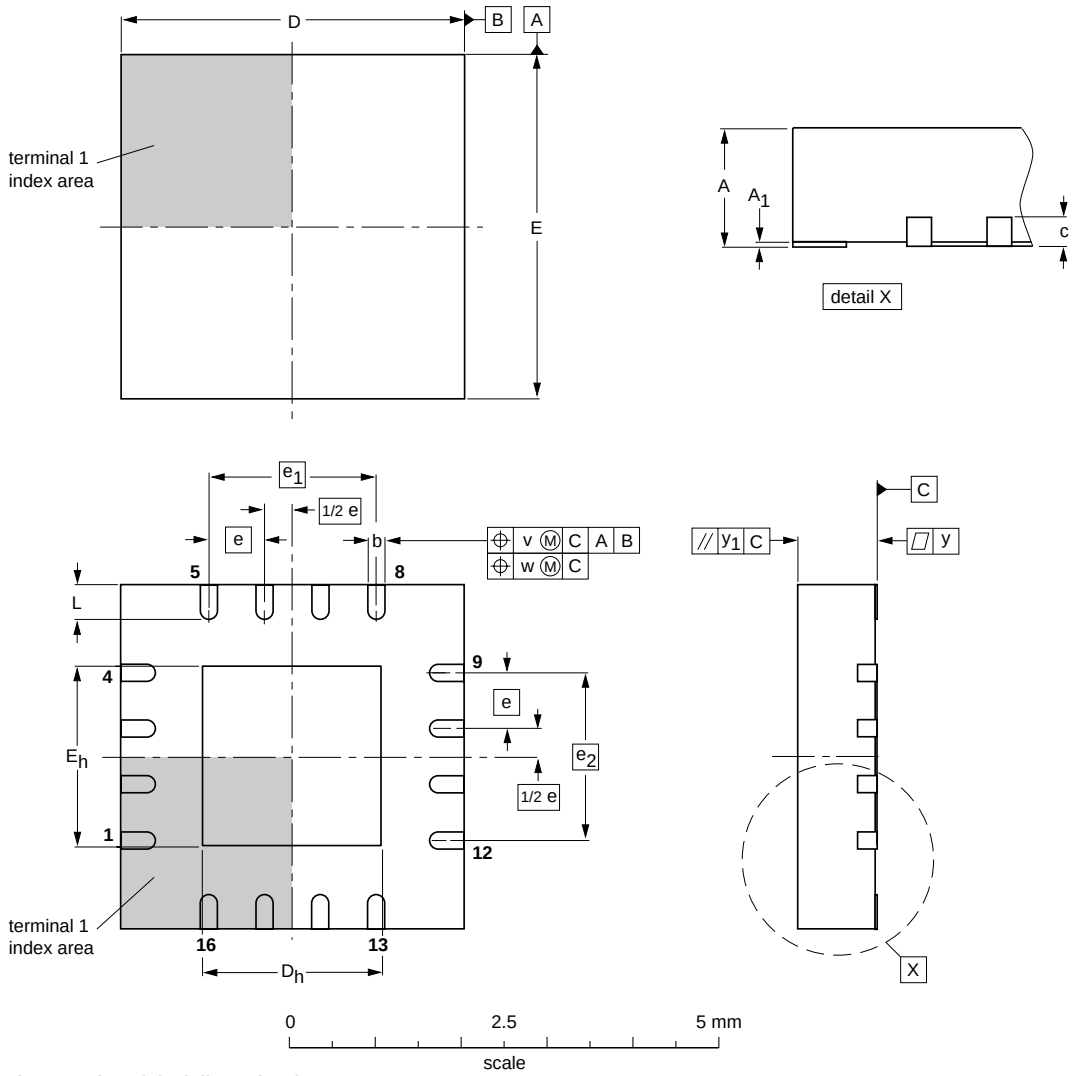
1. Plastic or metal protrusions of 0.15 mm maximum per side are not included.
2. Plastic interlead protrusions of 0.25 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT403-1		MO-153				~~99-12-27~~ 03-02-18

Fig 22. Package outline SOT403-1 (TSSOP16)

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HVQFN16: plastic thermal enhanced very thin quad flat package; no leads; 16 terminals; body 4 x 4 x 0.85 mm **SOT629-1**



DIMENSIONS (mm are the original dimensions)

UNIT	A(1) max.	A_1	b	c	D(1)	D_h	E(1)	E_h	e	e_1	e_2	L	v	w	y	y_1
mm	1	0.05 0.00	0.38 0.23	0.2	4.1 3.9	2.25 1.95	4.1 3.9	2.25 1.95	0.65	1.95	1.95	0.75 0.50	0.1	0.05	0.05	0.1

Note

1. Plastic or metal protrusions of 0.075 mm maximum per side are not included.

OUTLINE VERSION	REFERENCES				EUROPEAN PROJECTION	ISSUE DATE
	IEC	JEDEC	JEITA			
SOT629-1	- - -	MO-220	- - -			~~01-08-08~~ 02-10-22

Fig 23. Package outline SOT629-1 (HVQFN16)

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13. Handling information

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

14. Soldering of SMD packages

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

14.1 Introduction to soldering

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

14.2 Wave and reflow soldering

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

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

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

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

Key characteristics in both wave and reflow soldering are:

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

14.3 Wave soldering

Key characteristics in wave soldering are:

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

14.4 Reflow soldering

Key characteristics in reflow soldering are:

- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see Figure 24) than a SnPb process, thus reducing the process window
- Solder paste printing issues including smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature) and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic). In addition, the peak temperature must be low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with Table 12 and 13

Table 12. SnPb eutectic process (from J-STD-020C)

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

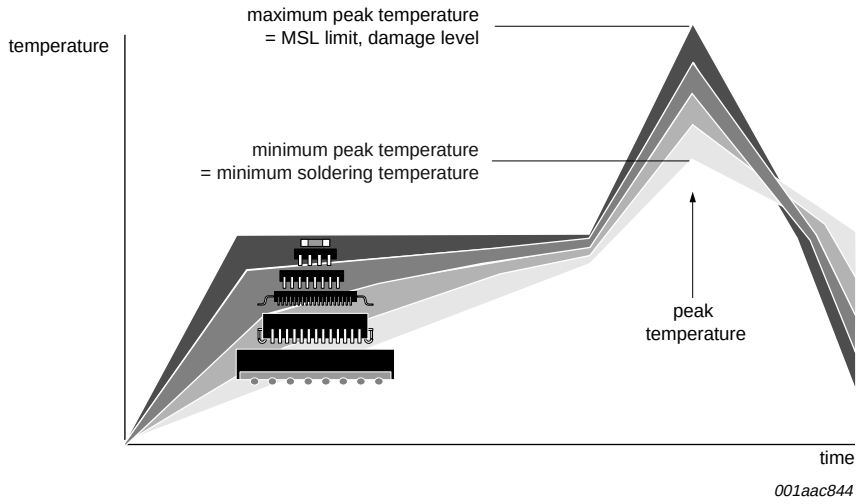
Table 13. Lead-free process (from J-STD-020C)

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

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

Studies have shown that small packages reach higher temperatures during reflow soldering, see Figure 24.

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MSL: Moisture Sensitivity Level

Fig 24. Temperature profiles for large and small components

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

15. Abbreviations

Table 14. Abbreviations

Acronym	Description
ACPI	Advanced Configuration and Power Interface
CBT	Cross-Bar Technology
CDM	Charged-Device Model
CMOS	Complementary Metal-Oxide Semiconductor
DUT	Device Under Test
ESD	ElectroStatic Discharge
FET	Field-Effect Transistor
FF	Flip-Flop
GPIO	General Purpose Input/Output
HBM	Human Body Model
I²C-bus	Inter-Integrated Circuit bus
I/O	Input/Output
LED	Light Emitting Diode
LP	Low-Pass
MM	Machine Model
POR	Power-On Reset
SMBus	System Management Bus

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16. Revision history

Table 15. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
PCA9538_5	20090528	Product data sheet	-	PCA9538_4

Modifications:

- The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors.
- Legal texts have been adapted to the new company name where appropriate.
- Pin names changed from “I/On” to “IOn”
- Table 2 “Pin description”: added Table note [1] and its reference at HVQFN16 pin 6.
- Section 6.4 “RESET input”, 1st sentence: changed symbol from “t_W” to “$t_{w(rst)}$”.
- Figure 7 “Write to output port register”: changed symbol from “t_{pv}” to “$t_{v(Q)}$”
- Figure 10 “Read input port register”:
  - changed symbol from “t_{ph}” to “$t_{h(D)}$”
  - changed symbol from “t_{ps}” to “$t_{su(D)}$”
  - changed symbol from “t_{iv}” to “$t_{v(INT)}$”
  - changed symbol from “t_{ir}” to “$t_{rst(INT)}$”
- Figure 12: changed signal name from “LEDx” to “IOn”
- Figure 13: changed signal name from “LEDx” to “IOn”
- Table 8 “Limiting values”:
  - parameter description for symbol $V_{I/O}$ changed from “DC output current on an I/O” to “voltage on an input/output pin”
  - symbol/parameter changed from “$I_{I/O}$, DC output current on an I/O” to “$I_{O(IOn)}$, output current on pin IOn”
  - parameter description for symbol I_{SS} changed from “supply current” to “ground supply current”
- Table 9 “Static characteristics”:
  - sub-section “Supplies”: symbol/parameter changed from “I_{stbl}, Standby current” to “I_{stbL}, LOW-level standby current”
  - sub-section “Supplies”: symbol/parameter changed from “I_{stbh}, Standby current” to “I_{stbH}, HIGH-level standby current”
  - sub-section “Input SCL; input/output SDA”: Typ value for I_{OL} changed from “<tbd>” to “7 mA”
  - sub-section “I/Os”: symbol “I_{IL}” (input leakage current) changed to “I_{LI}”
  - sub-section “Interrupt $\overline{INT}$”: Typ value for I_{OL} changed from “<tbd>” to “13 mA”
- Table 10 “Dynamic characteristics”: parameter description for symbol f_{SCL} changed from “operating frequency” to “SCL clock frequency”
- Table 10 “Dynamic characteristics”, sub-section “Port timing”:
  - symbol/parameter changed from “t_{PV}, Output data valid” to “$t_{v(Q)}$, data output valid time”
  - symbol/parameter changed from “t_{PS}, Input data setup time” to “$t_{su(D)}$, data input set-up time”
  - symbol/parameter changed from “t_{PH}, Input data hold time” to “$t_{h(D)}$, data input hold time”
- Table 10 “Dynamic characteristics”, sub-section “Interrupt timing”:
  - symbol/parameter changed from “t_{IV}, Interrupt valid” to “$t_{v(INT)}$, valid time on pin $\overline{INT}$”
  - symbol/parameter changed from “t_{IR}, Interrupt reset” to “$t_{rst(INT)}$, reset time on pin $\overline{INT}$”
- Table 10 “Dynamic characteristics”, sub-section “$\overline{RESET}$”:
  - symbol/parameter changed from “t_W, Reset pulse width” to “$t_{w(rst)}$, reset pulse width”
  - symbol/parameter changed from “t_{REC}, Reset recovery time” to “$t_{rec(rst)}$, reset recovery time”
  - symbol/parameter changed from “t_{RESET}, Time to reset” to “t_{rst}, reset time”

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Table 15. Revision history *...continued*

Document ID	Release date	Data sheet status	Change notice	Supersedes
Modifications: (continued)	• Figure 16 “Definition of RESET timing”: – symbol changed from “t_W” to “$t_{w(rst)}$” – symbol changed from “t_{REC}” to “$t_{rec(rst)}$” – symbol changed from “t_{RESET}” to “t_{rst}” • Figure 17 “Expanded view of read input port register”: – symbol changed from “t_{PS}” to “$t_{su(D)}$” – symbol changed from “t_{PH}” to “$t_{h(D)}$” – symbol changed from “t_{IV}” to “$t_{v(INT)}$” – symbol changed from “t_{IR}” to “$t_{rst(INT)}$” • Figure 18 “Expanded view of write to output port register”: symbol changed from “t_{PV}” to “$t_{v(Q)}$” • (old) Figure 19, “Test circuit” replaced with Figure 20 “Test circuit” and Table 11 “Test data”; symbol “t_{pv}” changed to “$t_{v(Q)}$” • Added soldering information • Added Section 15 “Abbreviations”			
PCA9538_4	20060921	Product data sheet	-	PCA9538_3
PCA9538_3 (9397 750 14176)	20041005	Product data sheet	-	PCA9538_2
PCA9538_2 (9397 750 14049)	20040930	Objective data sheet	-	PCA9538_1
PCA9538_1 (9397 750 12881)	20040820	Objective data sheet	-	-

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17. Legal information

17.1 Data sheet status

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

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

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Date of release: 28 May 2009
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