



PCA9538

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

Rev. 6 — 6 February 2013

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 and benefits

- 8-bit I²C-bus GPIO with interrupt and reset
- Operating power supply voltage range of 2.3 V to 5.5 V
(5.0 V $\pm$ 10 % for PCA9538PW/Q900 AEC-Q100 compliant devices)
- 5 V tolerant I/Os
- Polarity Inversion register
- Active LOW interrupt output
- Active LOW reset input
- Low standby current
- Noise filter on SCL/SDA inputs
- No glitch on power-up



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

3. Ordering information

Table 1. Ordering information

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

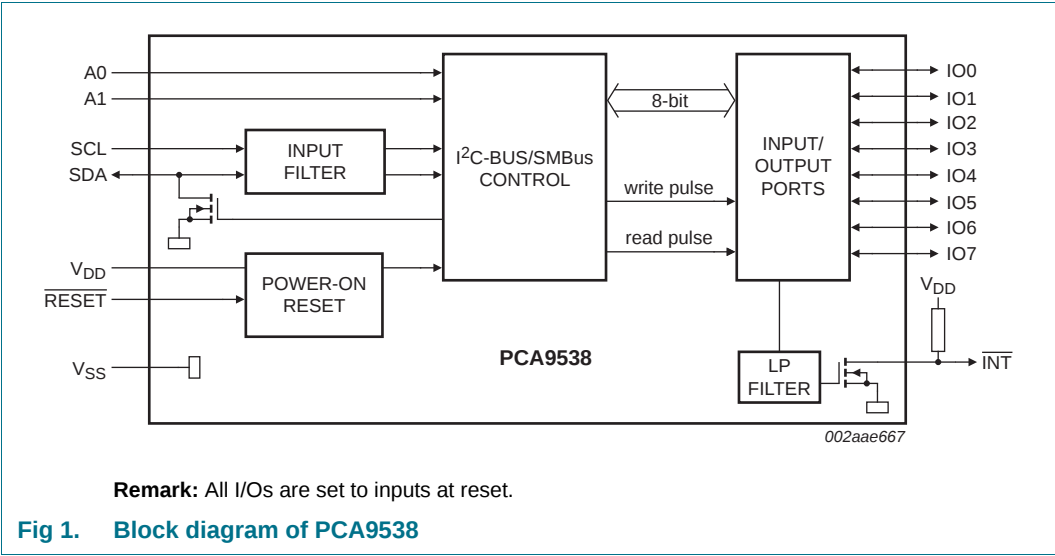
[1] PCA9538PW/Q900 is AEC-Q100 compliant. Contact i2c.support@nxp.com for PPAP.

3.1 Ordering options

Table 2. Ordering options

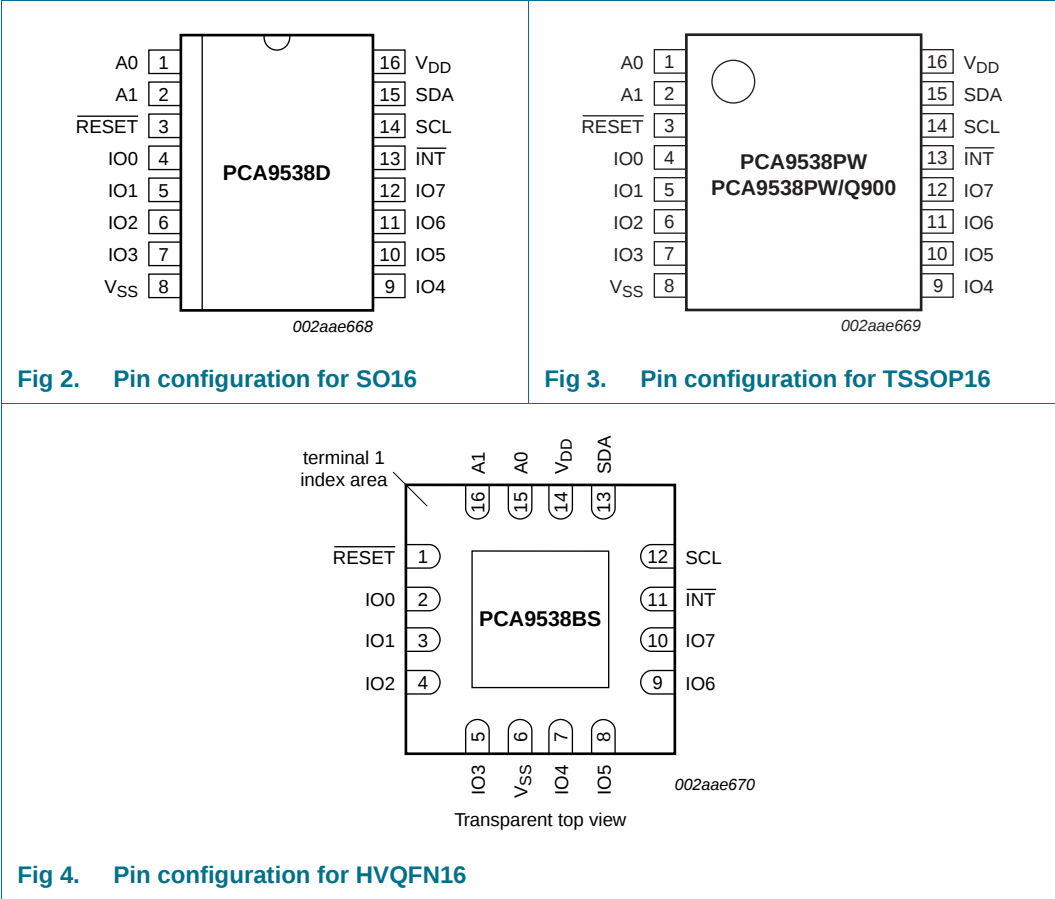
Type number	Orderable part number	Package	Packing method	Minimum order quantity	Temperature
PCA9538BS	PCA9538BS,118	HVQFN16	Reel pack, SMD, 13-inch	6000	T _{amb} = –40 °C to +85 °C
PCA9538D	PCA9538D,112	SO16	Tube, bulk pack	1920	T _{amb} = –40 °C to +85 °C
	PCA9538D,118	SO16	Reel pack, SMD, 13-inch	1000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

4. Block diagram



5. Pinning information

5.1 Pinning



5.2 Pin description

Table 3. Pin description

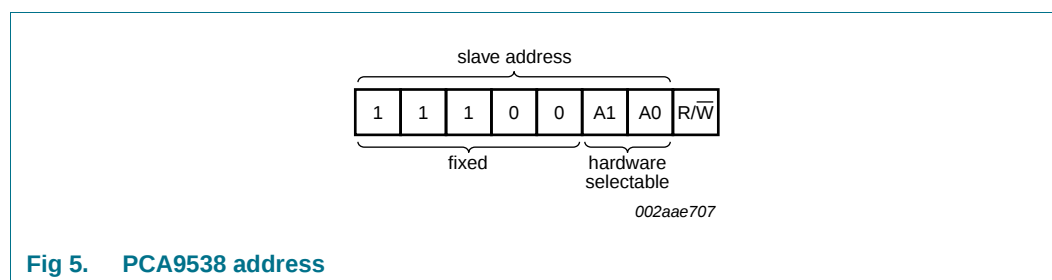
Symbol	Pin		Description
	SO16, TSSOP16	HVQFN16	
A0	1	15	address input 0
A1	2	16	address input 1
$\overline{\text{RESET}}$	3	1	active LOW reset input
IO0	4	2	input/output 0
IO1	5	3	input/output 1
IO2	6	4	input/output 2
IO3	7	5	input/output 3
V _{SS}	8	6 ^[1]	supply ground
IO4	9	7	input/output 4
IO5	10	8	input/output 5
IO6	11	9	input/output 6
IO7	12	10	input/output 7
$\overline{\text{INT}}$	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.

6. Functional description

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

6.1 Device address



6.2 Registers

6.2.1 Command byte

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

Table 4. Command byte

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

6.2.2 Register 0 - Input Port register

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

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

Table 5. Register 0 - Input Port register bit description

Legend: * default value.

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

6.2.3 Register 1 - Output Port register

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

Table 6. Register 1 - Output Port register bit description

Legend: * default value.

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

6.2.4 Register 2 - Polarity Inversion register

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

Table 7. Register 2 - Polarity Inversion register bit description

Legend: * default value.

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

6.2.5 Register 3 - Configuration register

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

Table 8. Register 3 - Configuration register bit description

Legend: * default value.

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

6.3 Power-on reset

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

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

6.4 RESET input

A reset can be accomplished by holding the $\overline{\text{RESET}}$ pin LOW for a minimum of $t_{w(\text{rst})}$. The PCA9538 registers and SMBus/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

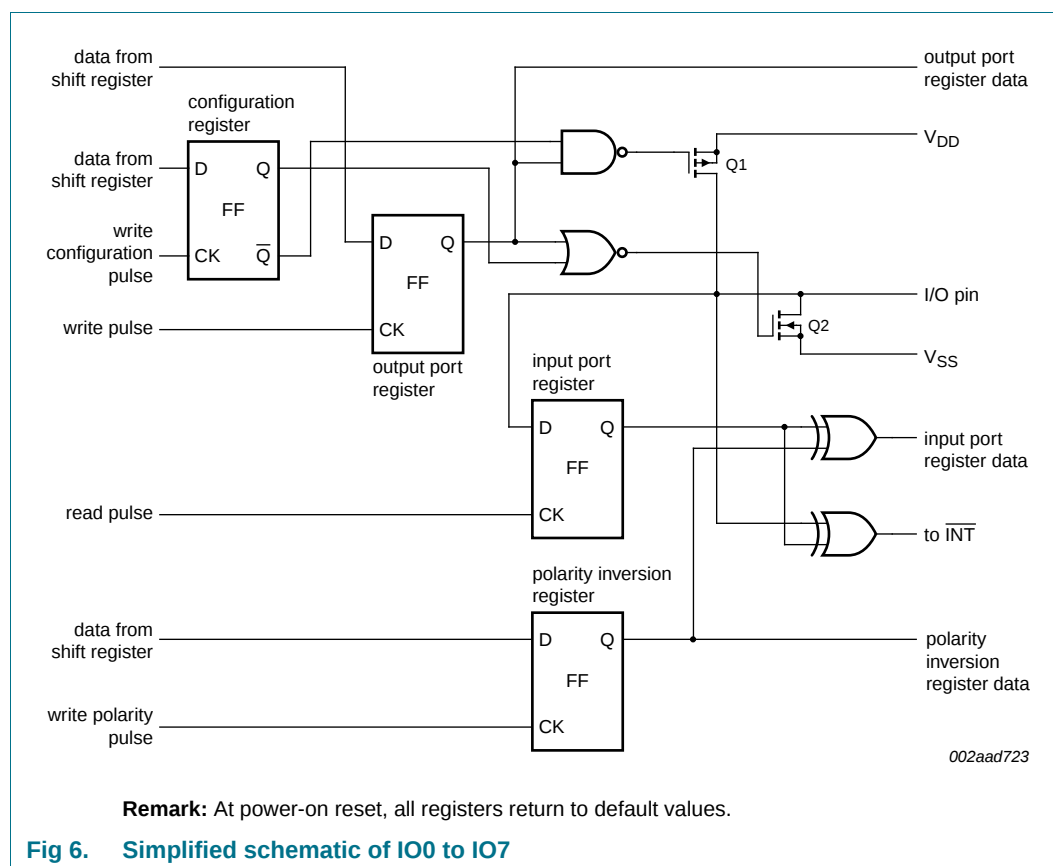
The open-drain interrupt output ($\overline{\text{INT}}$) is activated when one of the port pins changes state and the pin is configured as an input. The interrupt is de-activated when the input returns to its previous state or the Input Port register is read.

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.

6.6 I/O port

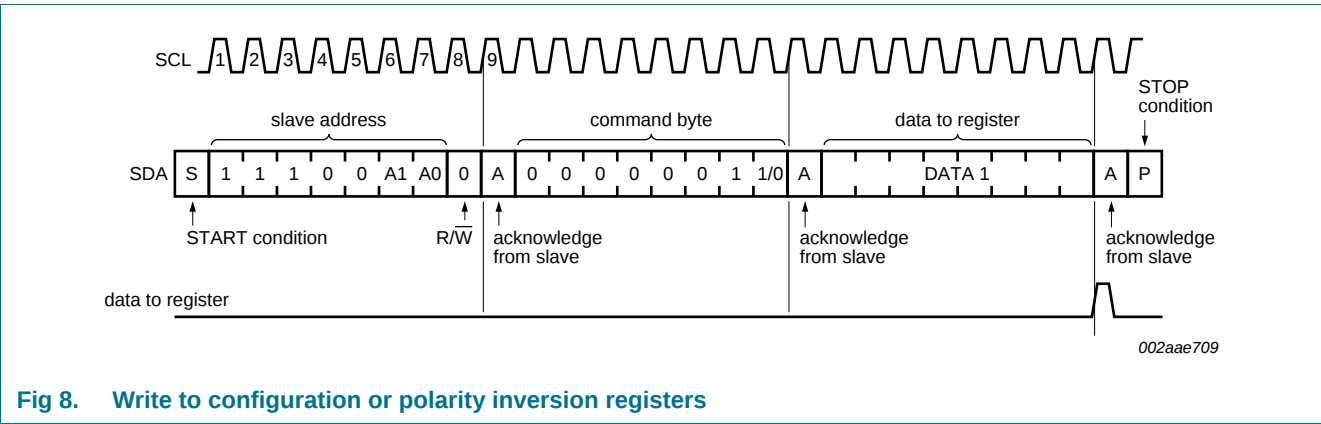
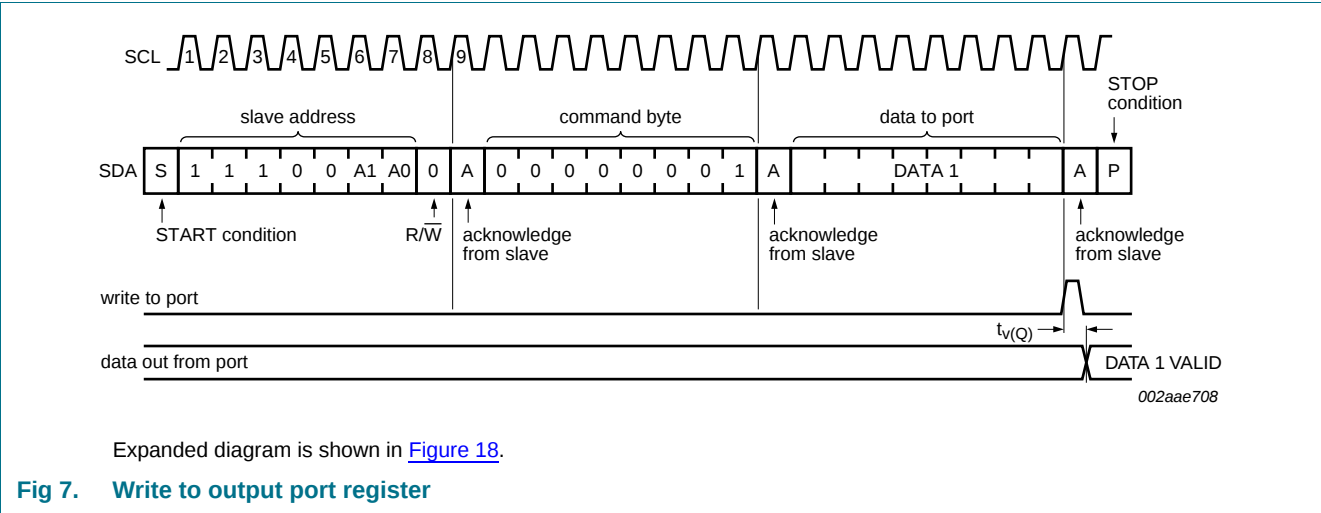
When an I/O is configured as an input, FETs Q1 and Q2 are off, creating a high-impedance input. The input voltage may be raised above V_{DD} to a maximum of 5.5 V.

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



6.7 Bus transactions

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



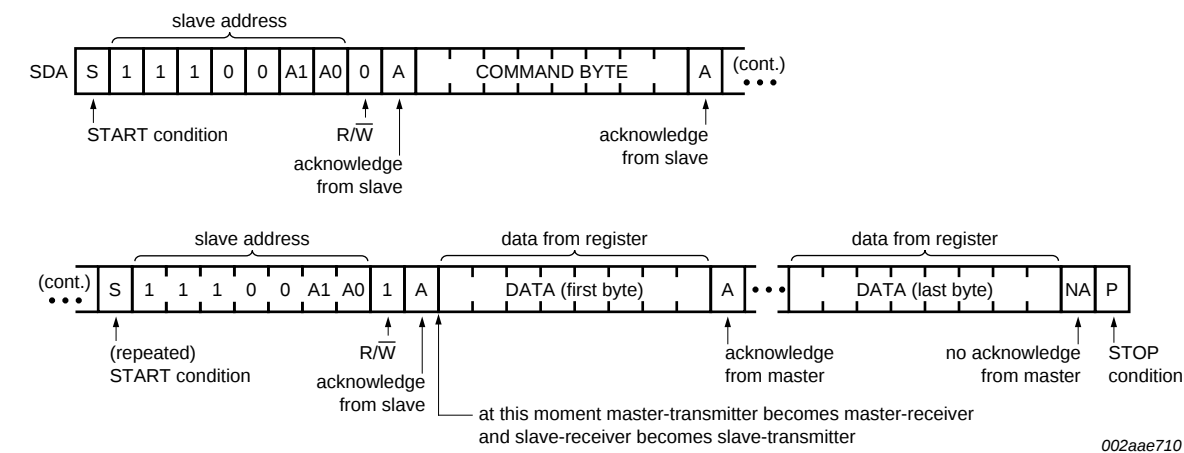
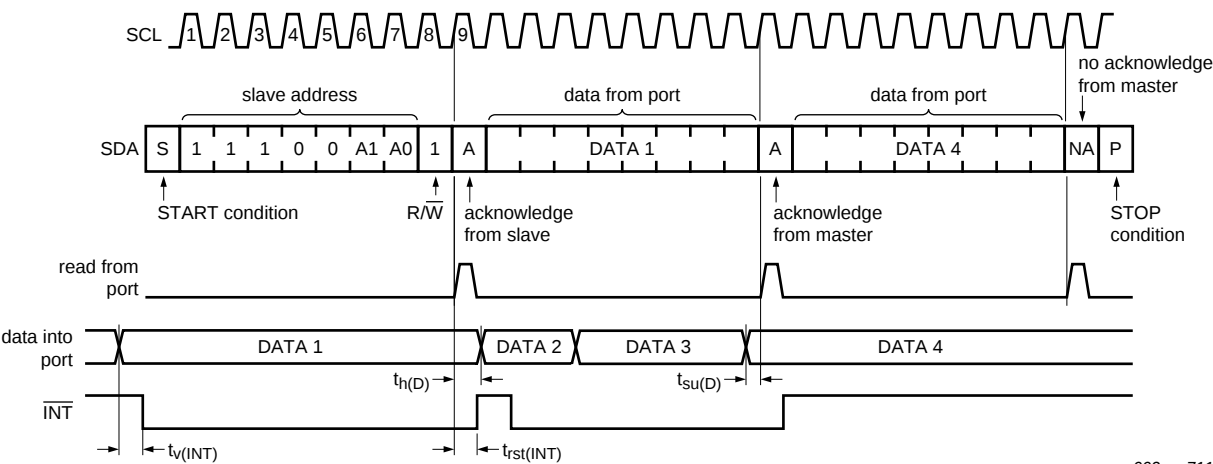


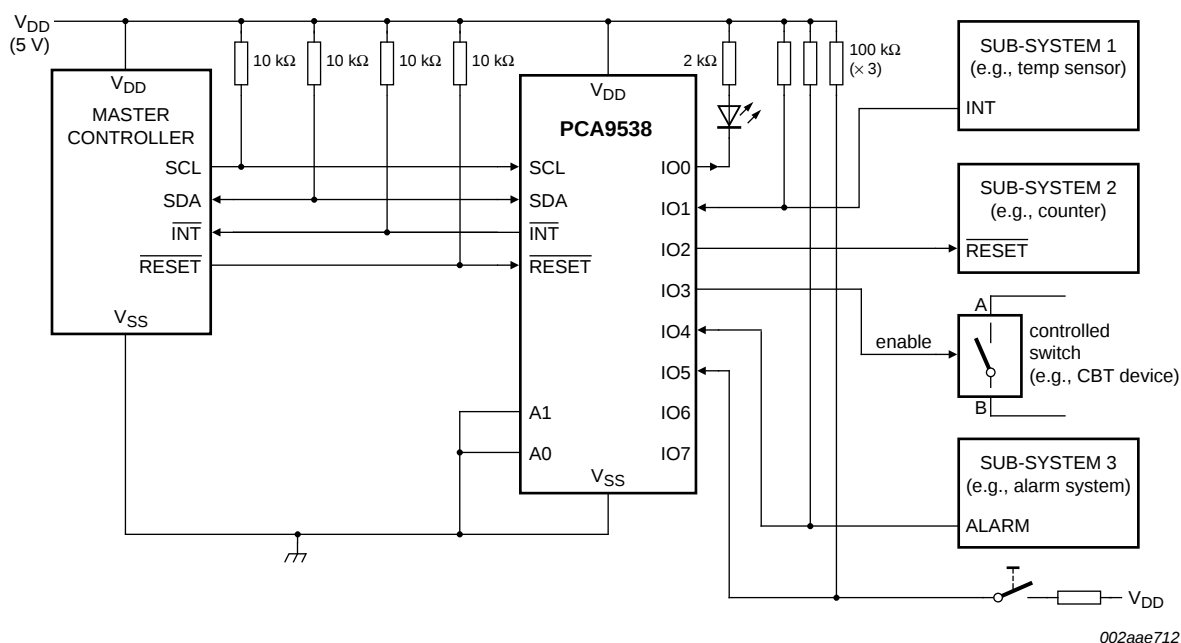
Fig 9. Read from register



This figure assumes the command byte has previously been programmed with 00h.
 Transfer of data can be stopped at any moment by a STOP condition.
 Expanded diagram is shown in [Figure 17](#).

Fig 10. Read input port register

7. Application design-in information



Device address is 1110 000x for this example.

IO0, IO2, IO3 configured as outputs.

IO1, IO4, IO5 configured as inputs.

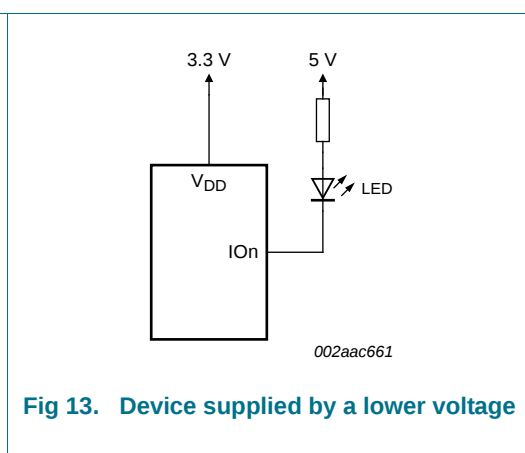
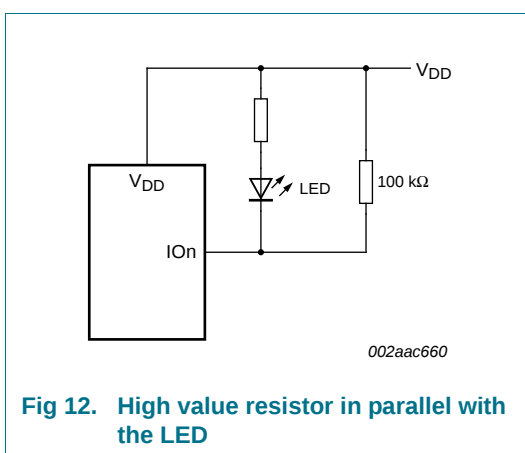
IO6, IO7 are not used and need 100 kΩ pull-up resistors to protect them from floating.

Fig 11. Typical application

7.1 Minimizing I_{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.



8. Limiting values

Table 9. 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			
		all devices except PCA9538PW/Q900	-40	+85	°C
		PCA9538PW/Q900	-40	+125	°C
T _{j(max)}	maximum junction temperature		-	+125	°C

9. Static characteristics

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

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

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supplies						
V_{DD}	supply voltage		2.3	-	5.5	V
I_{DD}	supply current	operating mode; $V_{DD} = 5.5 \text{ V}$; no load; $f_{SCL} = 100 \text{ kHz}$	-	104	175	μA
I_{stbL}	LOW-level standby current	Standby mode; $V_{DD} = 5.5 \text{ V}$; no load; $V_I = V_{SS}$; $f_{SCL} = 0 \text{ kHz}$; I/O = inputs	-	0.25	1	μA
I_{stbH}	HIGH-level standby current	Standby mode; $V_{DD} = 5.5 \text{ V}$; no load; $V_I = V_{DD}$; $f_{SCL} = 0 \text{ kHz}$; 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	-	+0.3 V_{DD}	V
V_{IH}	HIGH-level input voltage		0.7 V_{DD}	-	5.5	V
I_{OL}	LOW-level output current	$V_{OL} = 0.4 \text{ V}$	3	7	-	mA
I_L	leakage current	$V_I = V_{DD} = V_{SS}$	-1	-	+1	μA
C_i	input capacitance	$V_I = V_{SS}$	-	5	10	pF
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	$V_{OL} = 0.5 \text{ V}$				
		$V_{DD} = 2.3 \text{ V}$	[2] 8	10	-	mA
		$V_{DD} = 3.0 \text{ V}$	[2] 8	14	-	mA
		$V_{DD} = 4.5 \text{ V}$	[2] 8	17	-	mA
		$V_{OL} = 0.7 \text{ V}$				
		$V_{DD} = 2.3 \text{ V}$	[2] 10	13	-	mA
		$V_{DD} = 3.0 \text{ V}$	[2] 10	19	-	mA
		$V_{DD} = 4.5 \text{ V}$	[2] 10	24	-	mA
		$I_{OH} = -8 \text{ mA}$				
		$V_{DD} = 2.3 \text{ V}$	[3] 1.8	-	-	V
V_{OH}	HIGH-level output voltage	$V_{DD} = 3.0 \text{ V}$	[3] 2.6	-	-	V
		$V_{DD} = 4.5 \text{ V}$	[3] 4.1	-	-	V
		$I_{OH} = -10 \text{ mA}$				
		$V_{DD} = 2.3 \text{ V}$	[3] 1.7	-	-	V
		$V_{DD} = 3.0 \text{ V}$	[3] 2.5	-	-	V
		$V_{DD} = 4.5 \text{ V}$	[3] 4.0	-	-	V
		I_{LI}	-1	-	+1	μA
		C_i	-	5	10	pF

Table 10. Static characteristics for all devices except PCA9538PW/Q900 ...continued $V_{DD} = 2.3 \text{ V to } 5.5 \text{ V}$; $V_{SS} = 0 \text{ V}$; $T_{amb} = -40 \text{ }^{\circ}\text{C to } +85 \text{ }^{\circ}\text{C}$; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Interrupt $\overline{\text{INT}}$						
I_{OL}	LOW-level output current	$V_{OL} = 0.4 \text{ V}$	3	13	-	mA
Select inputs A0, A1, $\overline{\text{RESET}}$						
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.

Table 11. Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device $V_{DD} = 5.0 \text{ V} \pm 10 \%$; $V_{SS} = 0 \text{ V}$; $T_{amb} = -40 \text{ }^{\circ}\text{C to } +125 \text{ }^{\circ}\text{C}$; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Supplies						
V_{DD}	supply voltage		4.5	-	5.5	V
I_{DD}	supply current	operating mode; $V_{DD} = 5.5 \text{ V}$; no load; $f_{SCL} = 100 \text{ kHz}$	-	104	175	μA
I_{stbL}	LOW-level standby current	Standby mode; $V_{DD} = 5.5 \text{ V}$; no load; $V_I = V_{SS}$; $f_{SCL} = 0 \text{ kHz}$; I/O = inputs	-	0.25	1	μA
I_{stbH}	HIGH-level standby current	Standby mode; $V_{DD} = 5.5 \text{ V}$; no load; $V_I = V_{DD}$; $f_{SCL} = 0 \text{ kHz}$; 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	-	+0.3 V_{DD}	V
V_{IH}	HIGH-level input voltage		0.7 V_{DD}	-	5.5	V
I_{OL}	LOW-level output current	$V_{OL} = 0.4 \text{ V}$	3	7	-	mA
I_L	leakage current	$V_I = V_{DD} = V_{SS}$	-1	-	+1	μA
C_i	input capacitance	$V_I = V_{SS}$	-	5	10	pF
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	$V_{DD} = 4.5 \text{ V}$				
		$V_{OL} = 0.5 \text{ V}$	[2] 8	17	-	mA
		$V_{OL} = 0.7 \text{ V}$	[2] 10	24	-	mA
V_{OH}	HIGH-level output voltage	$V_{DD} = 4.5 \text{ V}$				
		$I_{OH} = -8 \text{ mA}$	[3] 4.1	-	-	V
		$I_{OH} = -10 \text{ mA}$	[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

Table 11. Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device ...continued $V_{DD} = 5.0\text{ V} \pm 10\%$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ }^{\circ}\text{C}$ to $+125\text{ }^{\circ}\text{C}$; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Interrupt $\overline{\text{INT}}$						
I_{OL}	LOW-level output current	$V_{OL} = 0.4\text{ V}$	3	13	-	mA
Select inputs A0, A1, $\overline{\text{RESET}}$						
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.

10. Dynamic characteristics

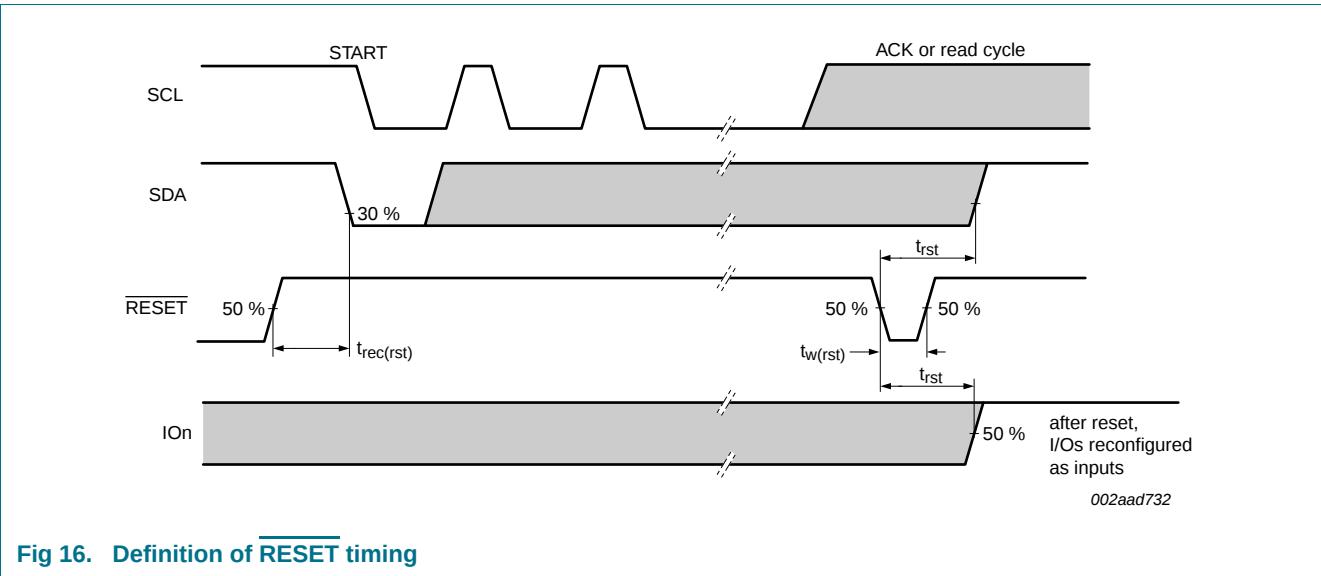
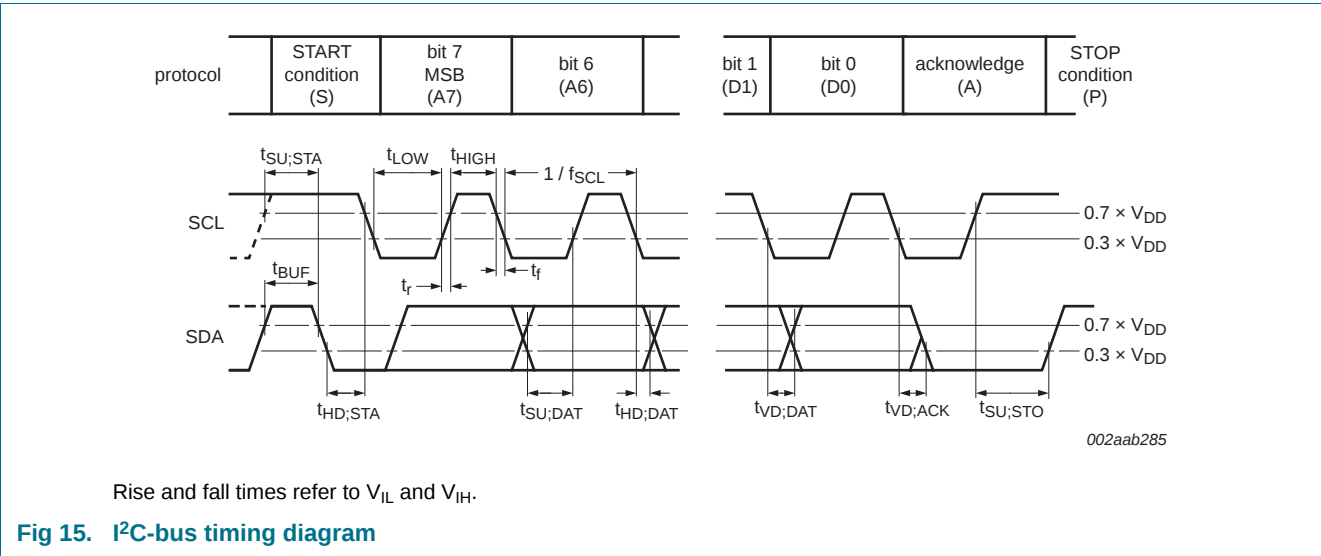
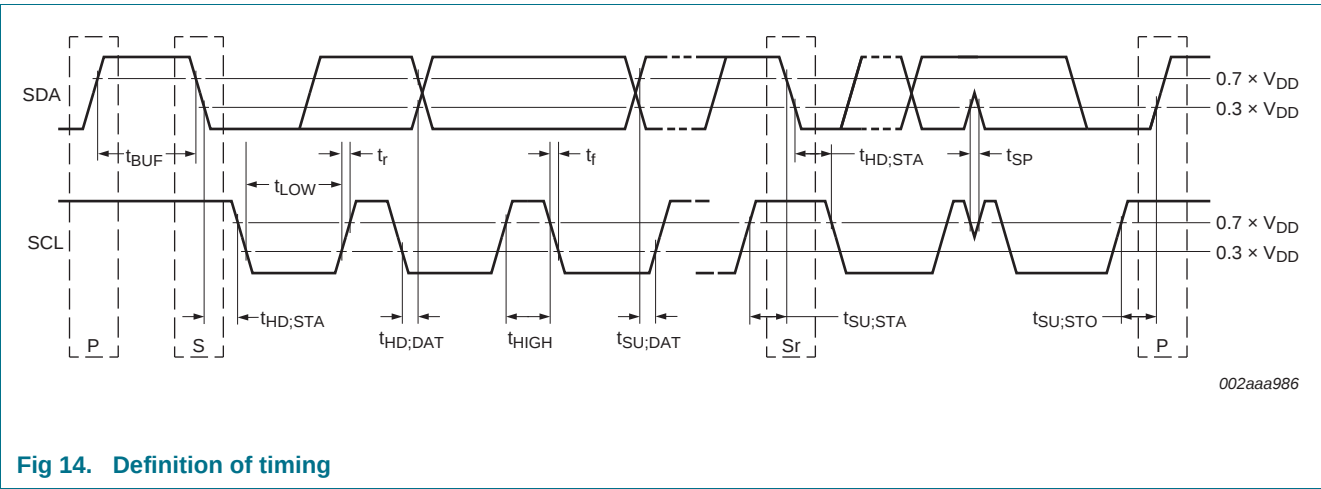
Table 12. Dynamic characteristics

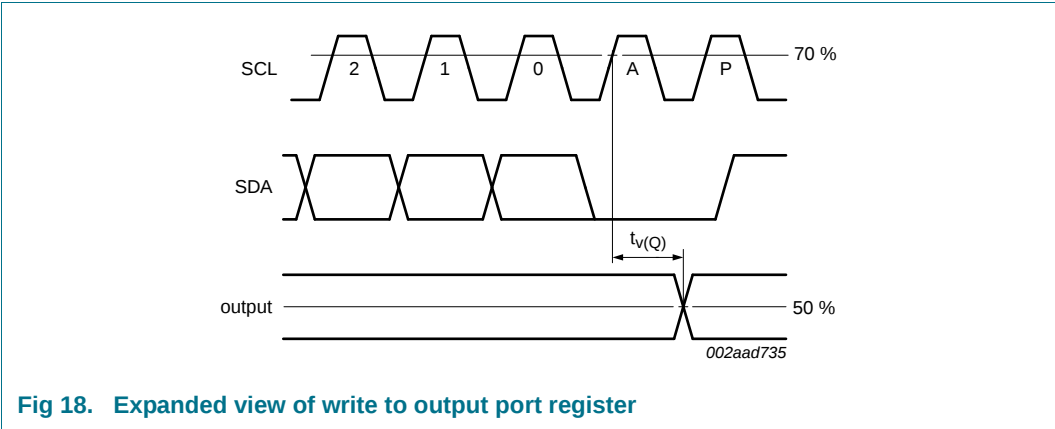
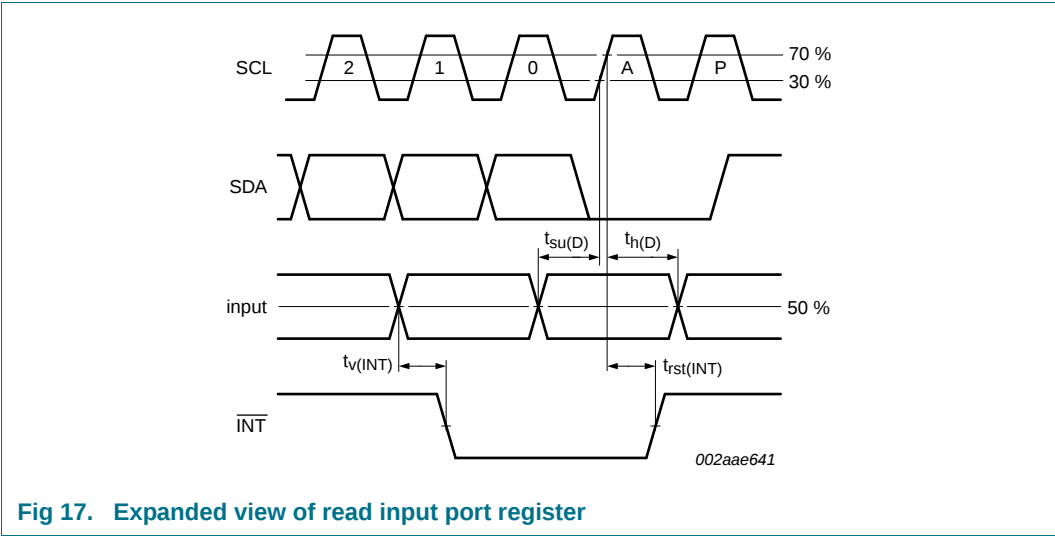
Symbol	Parameter	Conditions	Standard-mode I ² C-bus		Fast-mode I ² C-bus		Unit
			Min	Max	Min	Max	
f _{SCL}	SCL clock frequency		0	100	0	400	kHz
t _{BUF}	bus free time between a STOP and START condition		4.7	-	1.3	-	μs
t _{HD,STA}	hold time (repeated) START condition		4.0	-	0.6	-	μs
t _{SU,STA}	set-up 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 $\overline{\text{INT}}$		-	4	-	4	μs
t _{rst(INT)}	reset time on pin $\overline{\text{INT}}$		-	4	-	4	μs
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.





11. Test information

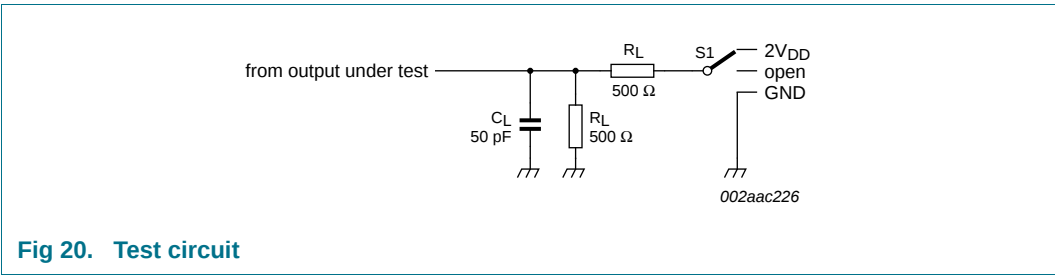
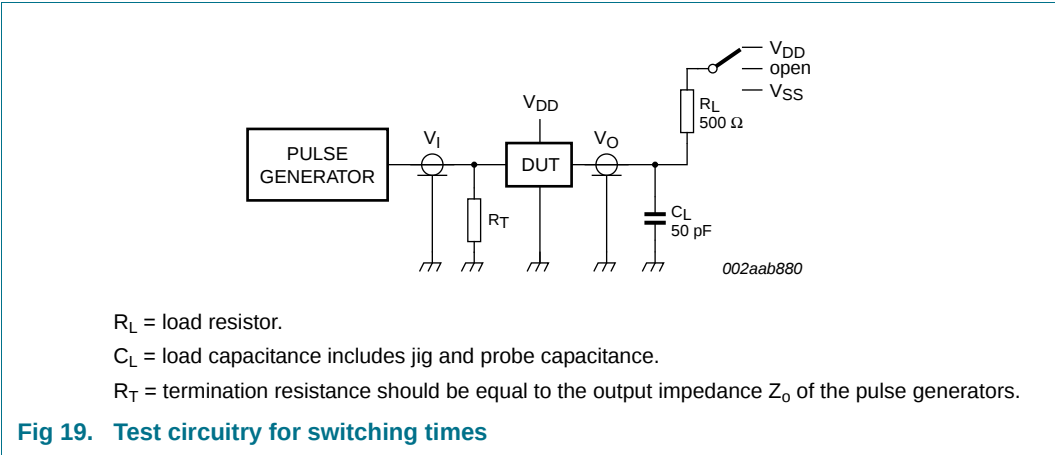


Table 13. Test data

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

12. Package outline

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

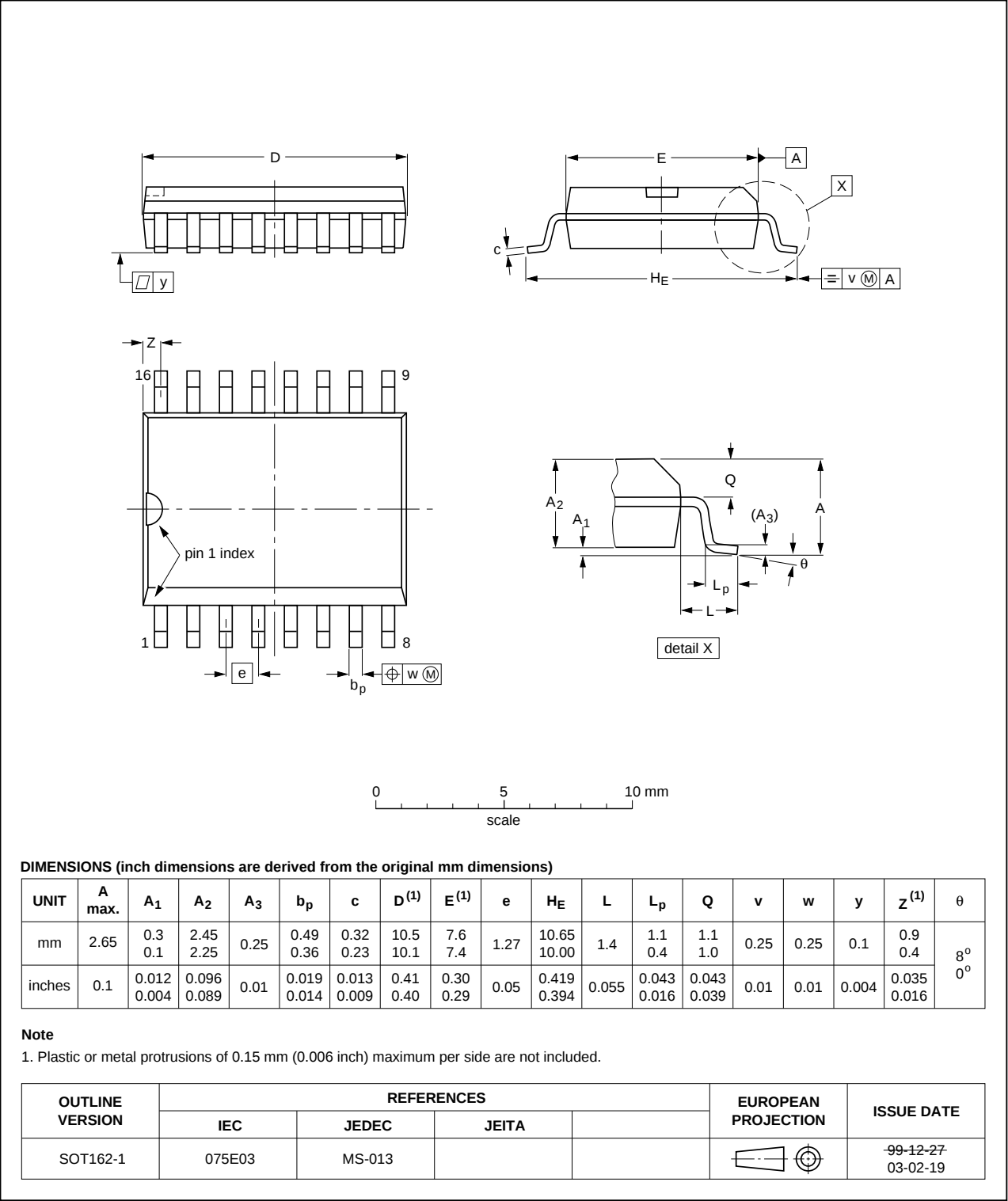


Fig 21. Package outline SOT162-1 (SO16)

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

SOT403-1

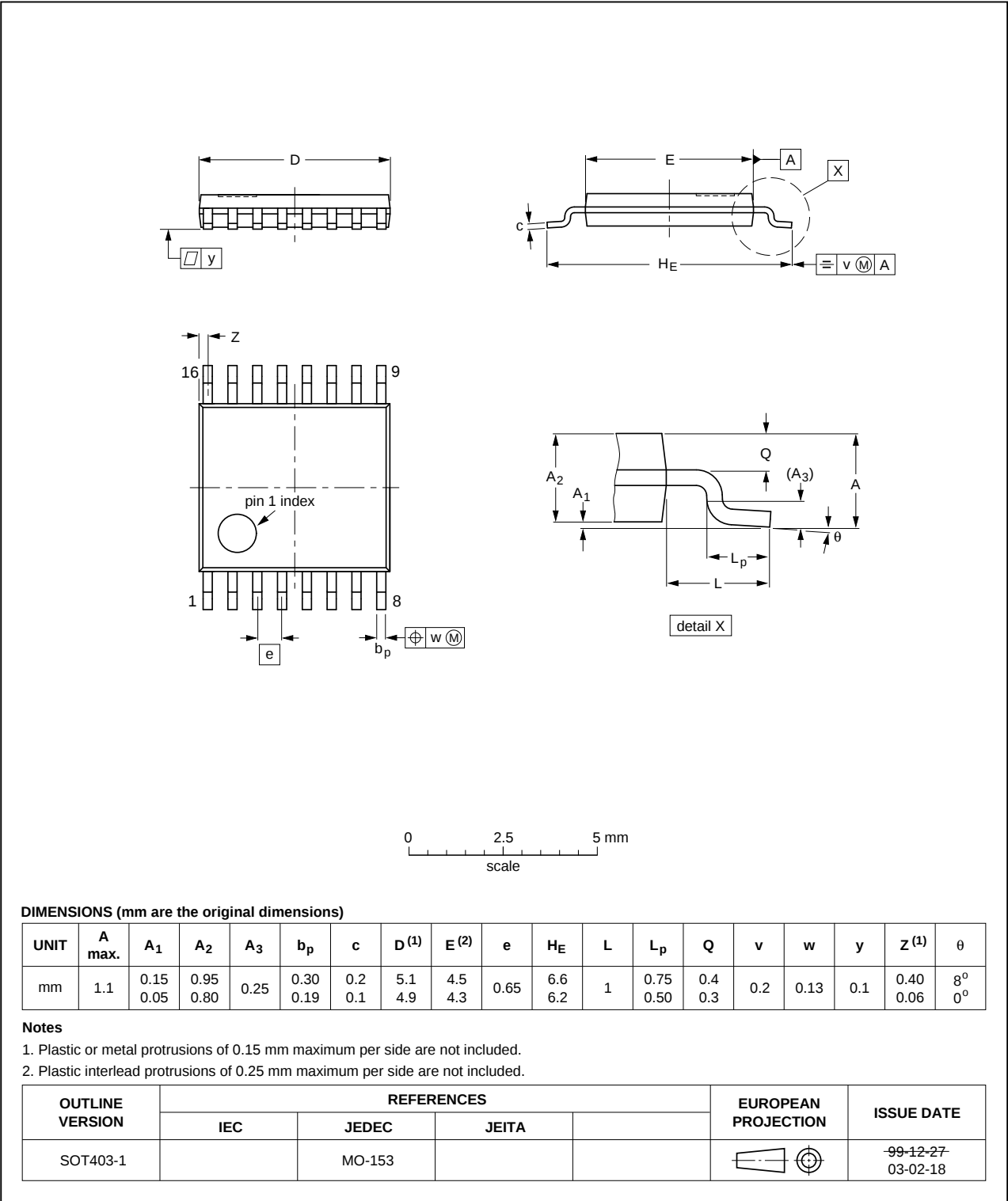


Fig 22. Package outline SOT403-1 (TSSOP16)

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

SOT629-1

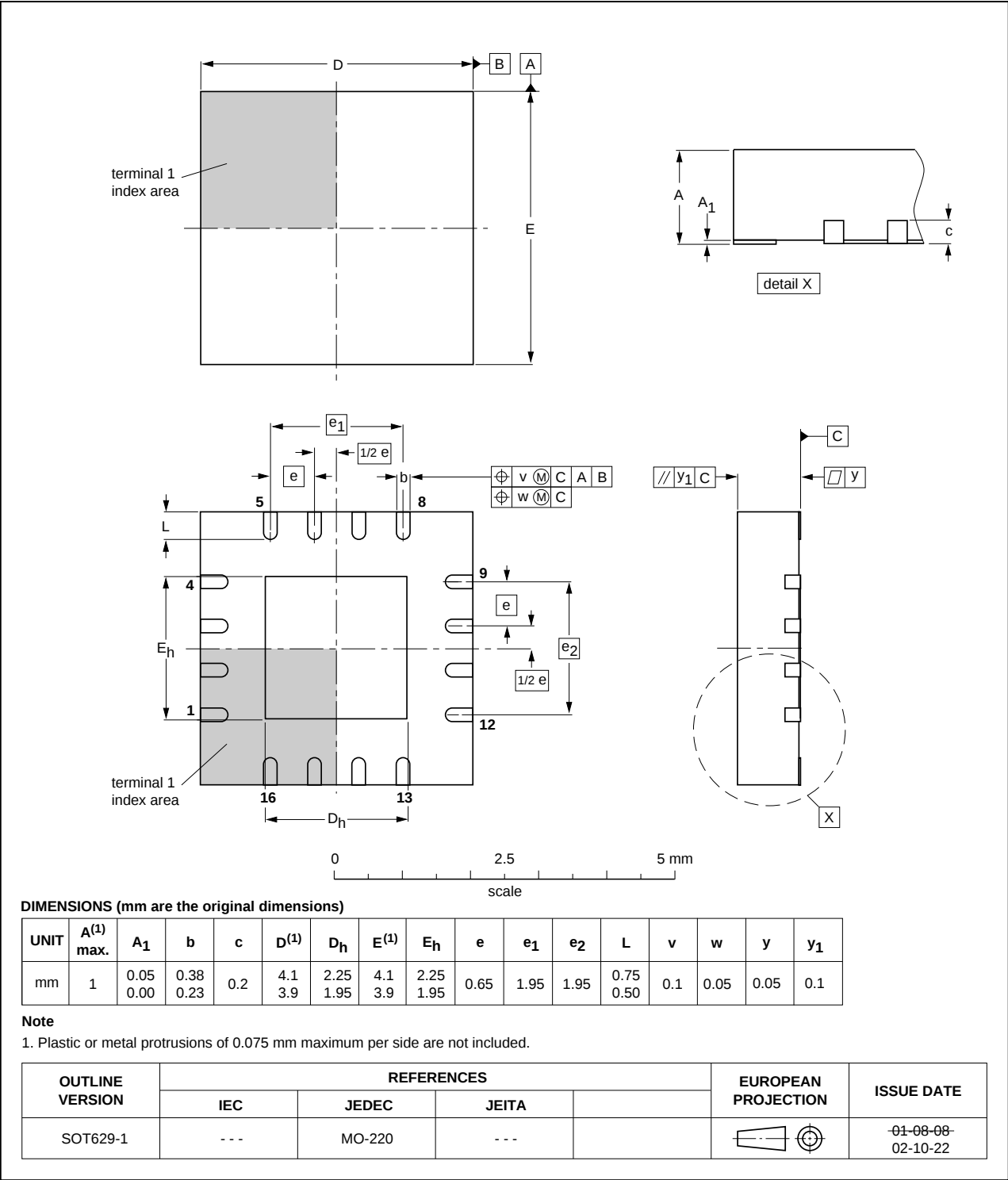


Fig 23. Package outline SOT629-1 (HVQFN16)

13. Handling information

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

14. Soldering of SMD packages

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

14.1 Introduction to soldering

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

14.2 Wave and reflow soldering

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

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

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

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

Key characteristics in both wave and reflow soldering are:

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

14.3 Wave soldering

Key characteristics in wave soldering are:

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

14.4 Reflow soldering

Key characteristics in reflow soldering are:

- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see [Figure 24](#)) than a SnPb process, thus reducing the process window
- Solder paste printing issues including smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature) and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic). In addition, the peak temperature must be low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with [Table 14](#) and [15](#)

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

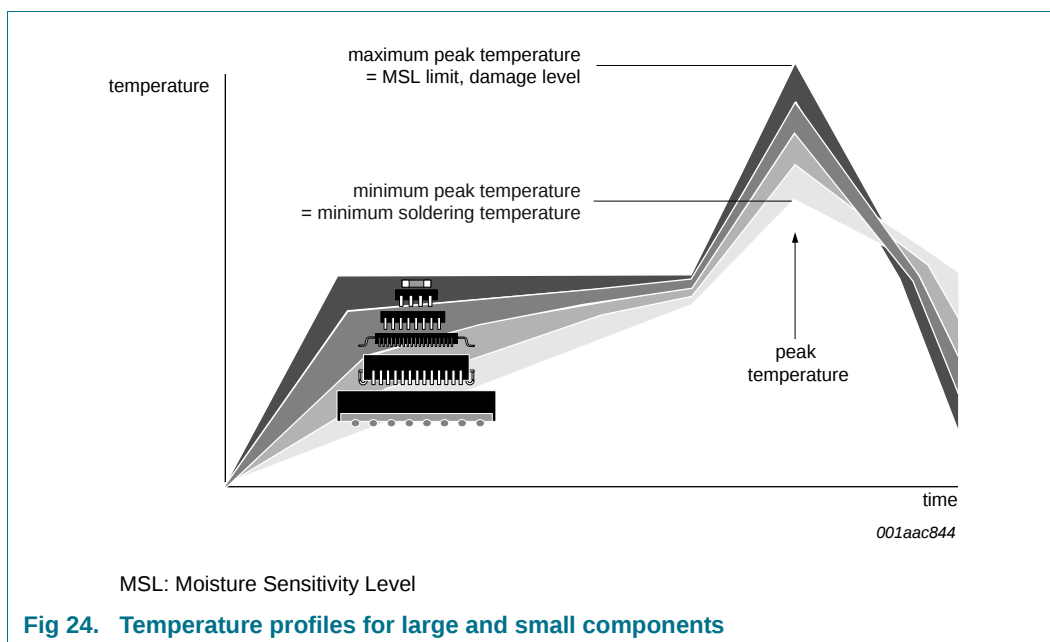
Package thickness (mm)	Package reflow temperature (°C)	
	Volume (mm ³)	
	< 350	≥ 350
< 2.5	235	220
≥ 2.5	220	220

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

Package thickness (mm)	Package reflow temperature (°C)		
	Volume (mm ³)		
	< 350	350 to 2000	> 2000
< 1.6	260	260	260
1.6 to 2.5	260	250	245
> 2.5	250	245	245

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

Studies have shown that small packages reach higher temperatures during reflow soldering, see [Figure 24](#).



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

15. Soldering: PCB footprints

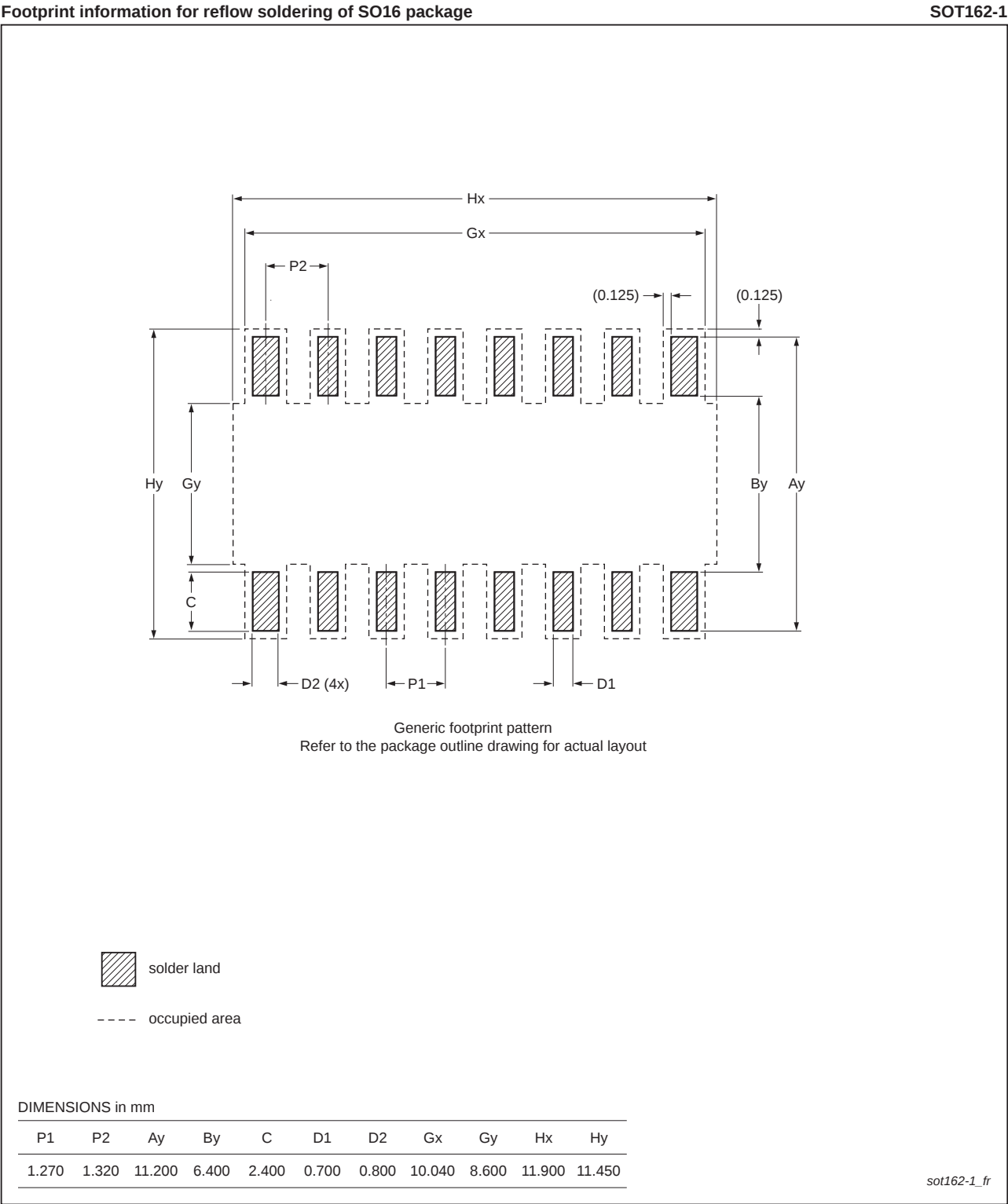


Fig 25. PCB footprint for SOT162-1 (SO16); reflow soldering

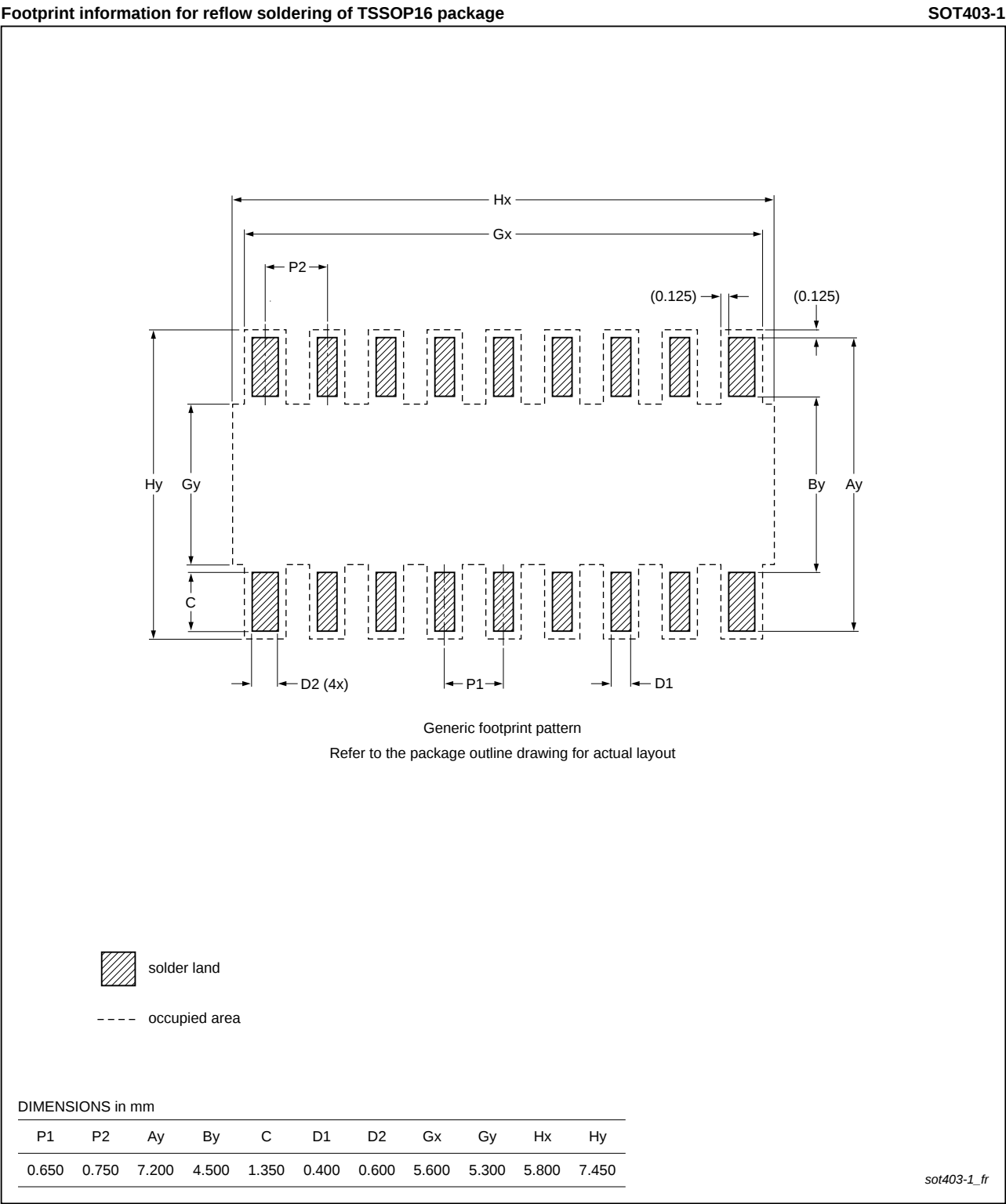


Fig 26. PCB footprint for SOT403-1 (TSSOP16); reflow soldering

Footprint information for reflow soldering of HVQFN16 package

SOT629-1

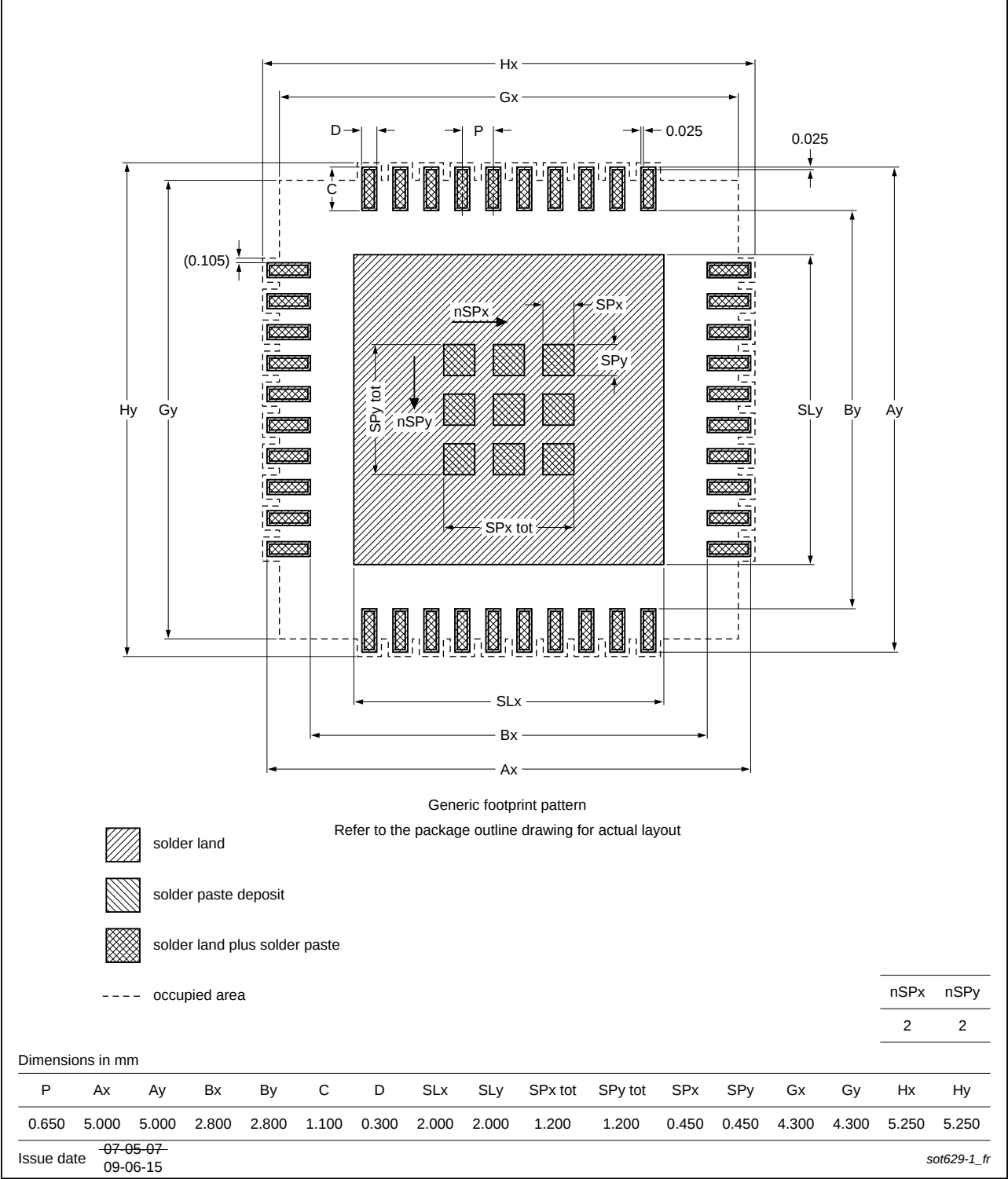


Fig 27. PCB footprint for SOT629-1 (HVQFN16); reflow soldering

16. Abbreviations

Table 16. Abbreviations

Acronym	Description
ACPI	Advanced Configuration and Power Interface
CBT	Cross-Bar Technology
CDM	Charged-Device Model
CMOS	Complementary Metal-Oxide Semiconductor
DUT	Device Under Test
ESD	ElectroStatic Discharge
FET	Field-Effect Transistor
FF	Flip-Flop
GPIO	General Purpose Input/Output
HBM	Human Body Model
I ² C-bus	Inter-Integrated Circuit bus
I/O	Input/Output
LED	Light Emitting Diode
LP	Low-Pass
POR	Power-On Reset
SMBus	System Management Bus

17. Revision history

Table 17. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
PCA9538 v.6	20130206	Product data sheet		PCA9538 v.5
Modifications:	• Section 2 “Features and benefits”: – Second bullet item: added phrase “(5.0 V $\pm$ 10 % for PCA9538PW/Q900 AEC-Q100 compliant devices)” – Thirteenth bullet item: deleted phrase “200 V MM per JESD22-A115” • Table 1 “Ordering information”: added type number PCA9538PW/Q900 (and Table note [1]) • Added Section 3.1 “Ordering options” • Figure 3 “Pin configuration for TSSOP16”: added “PCA9538PW/Q900” • Table 9 “Limiting values”, T_{amb}: added separate row for PCA9538PW/Q900 device limits • Table 10: appended “for all devices except PCA9538PW/Q900” to table title • Added Table 11 “Static characteristics for PCA9538PW/Q900 AEC-Q100 compliant device” • Figure 14 “Definition of timing” modified: added 0.3 $\times$ V_{DD} and 0.7 $\times$ V_{DD} reference lines • Figure 15 “I²C-bus timing diagram” modified: added 0.3 $\times$ V_{DD} and 0.7 $\times$ V_{DD} reference lines • Added Section 15 “Soldering: PCB footprints”			
PCA9538 v.5	20090528	Product data sheet	-	PCA9538 v.4
PCA9538 v.4	20060921	Product data sheet	-	PCA9538 v.3
PCA9538 v.3 (9397 750 14176)	20041005	Product data sheet	-	PCA9538 v.2
PCA9538 v.2 (9397 750 14049)	20040930	Objective data sheet	-	PCA9538 v.1
PCA9538 v.1 (9397 750 12881)	20040820	Objective data sheet	-	-

18. Legal information

18.1 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.

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

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20. Contents

1	General description	1	20	Contents	34
2	Features and benefits	1			
3	Ordering information	2			
3.1	Ordering options	2			
4	Block diagram	3			
5	Pinning information	4			
5.1	Pinning	4			
5.2	Pin description	5			
6	Functional description	6			
6.1	Device address	6			
6.2	Registers	6			
6.2.1	Command byte	6			
6.2.2	Register 0 - Input Port register	6			
6.2.3	Register 1 - Output Port register	7			
6.2.4	Register 2 - Polarity Inversion register	7			
6.2.5	Register 3 - Configuration register	8			
6.3	Power-on reset	8			
6.4	RESET input	8			
6.5	Interrupt output	8			
6.6	I/O port	9			
6.7	Bus transactions	10			
7	Application design-in information	12			
7.1	Minimizing I _{DD} when the I/Os are used to control LEDs	13			
8	Limiting values	13			
9	Static characteristics	14			
10	Dynamic characteristics	17			
11	Test information	20			
12	Package outline	21			
13	Handling information	24			
14	Soldering of SMD packages	24			
14.1	Introduction to soldering	24			
14.2	Wave and reflow soldering	24			
14.3	Wave soldering	24			
14.4	Reflow soldering	25			
15	Soldering: PCB footprints	27			
16	Abbreviations	30			
17	Revision history	31			
18	Legal information	32			
18.1	Data sheet status	32			
18.2	Definitions	32			
18.3	Disclaimers	32			
18.4	Trademarks	33			
19	Contact information	33			

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