



PCA9532

16-bit I²C-bus LED dimmer

Rev. 4.1 — 22 August 2016

Product data sheet

1. General description

The PCA9532 is a 16-bit I²C-bus and SMBus I/O expander optimized for dimming LEDs in 256 discrete steps for Red/Green/Blue (RGB) color mixing and back light applications.

The PCA9532 contains an internal oscillator with two user programmable blink rates and duty cycles coupled to the output PWM. The LED brightness is controlled by setting the blink rate high enough (> 100 Hz) that the blinking cannot be seen and then using the duty cycle to vary the amount of time the LED is on and thus the average current through the LED.

The initial setup sequence programs the two blink rates/duty cycles for each individual PWM. From then on, only one command from the bus master is required to turn individual LEDs ON, OFF, BLINK RATE 1 or BLINK RATE 2. Based on the programmed frequency and duty cycle, BLINK RATE 1 and BLINK RATE 2 will cause the LEDs to appear at a different brightness or blink at periods up to 1.69 second. The open-drain outputs directly drive the LEDs with maximum output sink current of 25 mA per bit and 200 mA per package (100 mA per octal).

To blink LEDs at periods greater than 1.69 second the bus master (MCU, MPU, DSP, chip set, etc.) must send repeated commands to turn the LED on and off as is currently done when using normal I/O expanders like the NXP Semiconductors PCF8575 or PCA9555. Any bits not used for controlling the LEDs can be used for General Purpose parallel Input/Output (GPIO) expansion, which provides a simple solution when additional I/O is needed for ACPI power switches, sensors, push-buttons, alarm monitoring, fans, etc.

The active LOW hardware reset pin ($\overline{\text{RESET}}$) and Power-On Reset (POR) initializes the registers to their default state, all zeroes, causing the bits to be set HIGH (LED off).

Three hardware address pins on the PCA9532 allow eight devices to operate on the same bus.

2. Features and benefits

- 16 LED drivers (on, off, flashing at a programmable rate)
- Two selectable, fully programmable blink rates (frequency and duty cycle) between 0.591 Hz and 152 Hz (1.69 second and 6.58 milliseconds)
- 256 brightness steps
- Input/outputs not used as LED drivers can be used as regular GPIOs
- Internal oscillator requires no external components
- I²C-bus interface logic compatible with SMBus
- Internal power-on reset



- Noise filter on SCL/SDA inputs
- Active LOW reset input
- 16 open-drain outputs directly drive LEDs to 25 mA
- Controlled edge rates to minimize ground bounce
- No glitch on power-up
- Supports hot insertion
- Low standby current
- Operating power supply voltage range of 2.3 V to 5.5 V
- 0 Hz to 400 kHz clock frequency
- ESD protection exceeds 2000 V HBM per JESD22-A114, 150 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: SO24, TSSOP24, HVQFN24

3. 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 | |
| PCA9532D | PCA9532D | SO24 | plastic small outline package; 24 leads; body width 7.5 mm | SOT137-1 |
| PCA9532PW | PCA9532PW | TSSOP24 | plastic thin shrink small outline package; 24 leads; body width 4.4 mm | SOT355-1 |
| PCA9532BS | 9532 | HVQFN24 | plastic thermal enhanced very thin quad flat package; no leads; 24 terminals; body 4 × 4 × 0.85 mm | SOT616-1 |

4. Block diagram

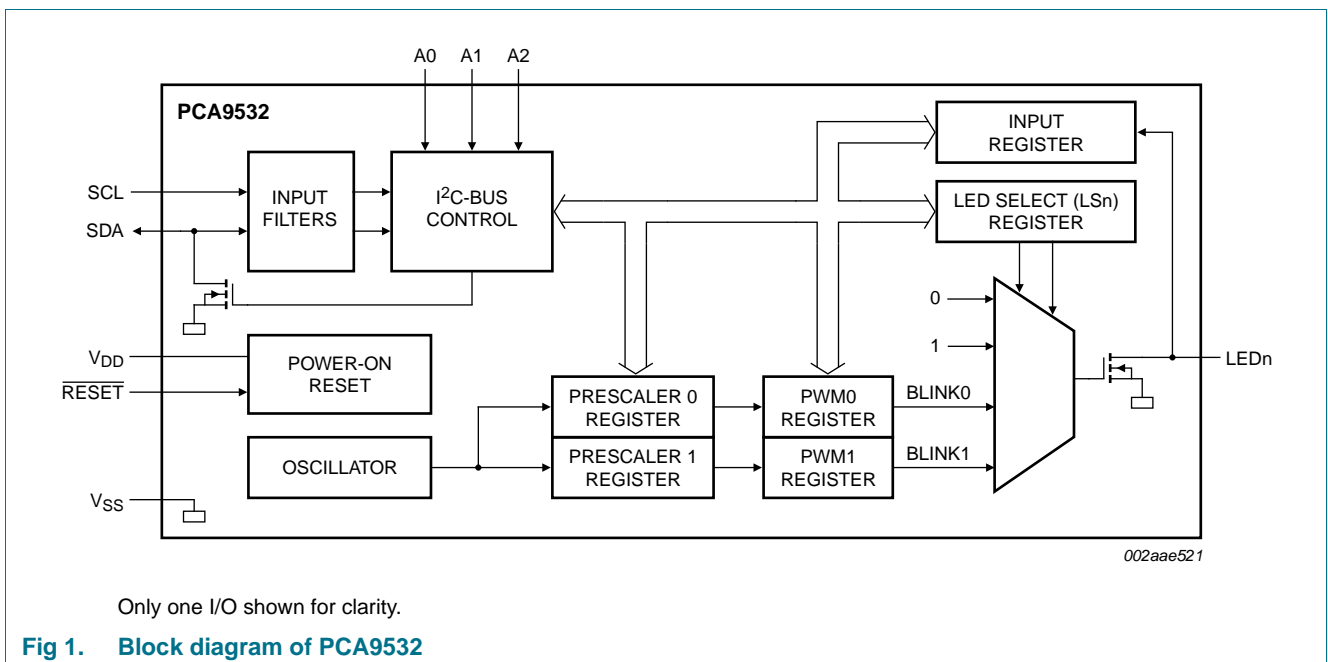
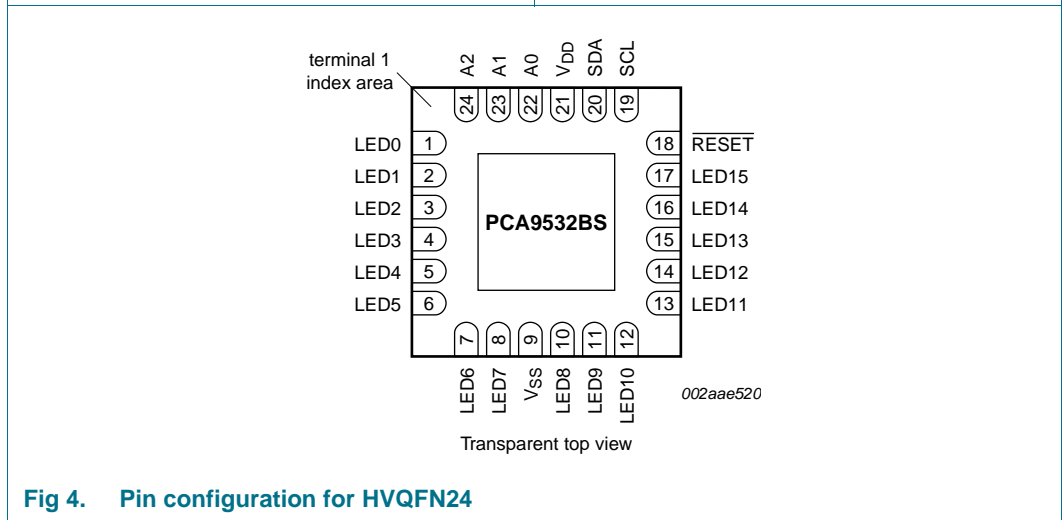
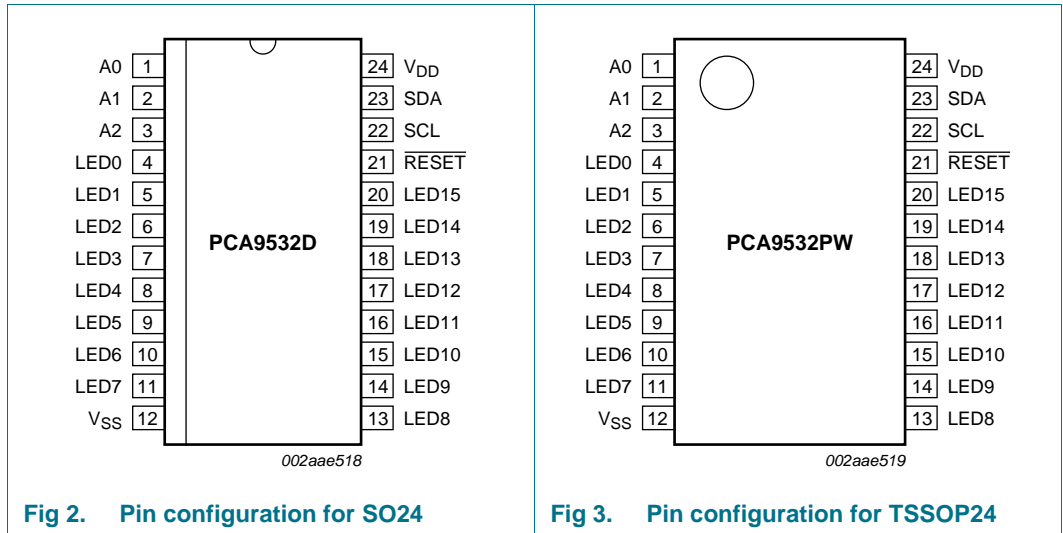


Fig 1. Block diagram of PCA9532

5. Pinning information

5.1 Pinning



5.2 Pin description

Table 2. Pin description

| Symbol | Pin | | Description |
|---------------------------|------------------|------------------|--------------------------|
| | SO24, TSSOP24 | HVQFN24 | |
| A0 | 1 | 22 | address input 0 |
| A1 | 2 | 23 | address input 1 |
| A2 | 3 | 24 | address input 2 |
| LED0 | 4 | 1 | LED driver 0 |
| LED1 | 5 | 2 | LED driver 1 |
| LED2 | 6 | 3 | LED driver 2 |
| LED3 | 7 | 4 | LED driver 3 |
| LED4 | 8 | 5 | LED driver 4 |
| LED5 | 9 | 6 | LED driver 5 |
| LED6 | 10 | 7 | LED driver 6 |
| LED7 | 11 | 8 | LED driver 7 |
| V _{SS} | 12 | 9 ^[1] | supply ground |
| LED8 | 13 | 10 | LED driver 8 |
| LED9 | 14 | 11 | LED driver 9 |
| LED10 | 15 | 12 | LED driver 10 |
| LED11 | 16 | 13 | LED driver 11 |
| LED12 | 17 | 14 | LED driver 12 |
| LED13 | 18 | 15 | LED driver 13 |
| LED14 | 19 | 16 | LED driver 14 |
| LED15 | 20 | 17 | LED driver 15 |
| $\overline{\text{RESET}}$ | 21 | 18 | reset input (active LOW) |
| SCL | 22 | 19 | serial clock line |
| SDA | 23 | 20 | serial data line |
| V _{DD} | 24 | 21 | supply voltage |

- [1] HVQFN24 package die supply ground is connected to both V_{SS} pin and exposed center pad. 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 PCB in the thermal pad region.

6. Functional description

Refer to [Figure 1 “Block diagram of PCA9532”](#).

6.1 Device address

Following a START condition, the bus master must output the address of the slave it is accessing. The address of the PCA9532 is shown in [Figure 5](#). To conserve power, no internal pull-up resistors are incorporated on the hardware selectable address pins and they must be pulled HIGH or LOW.

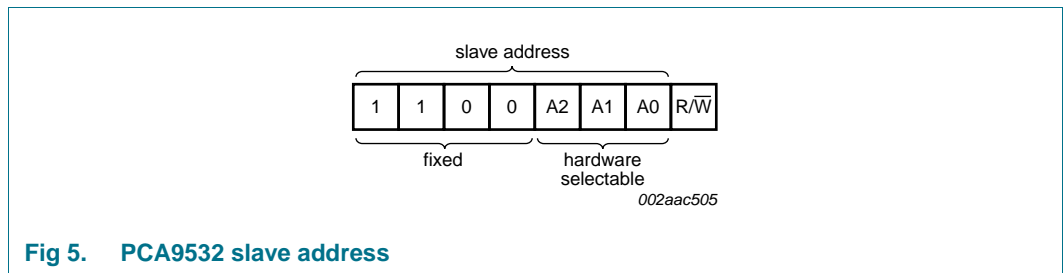
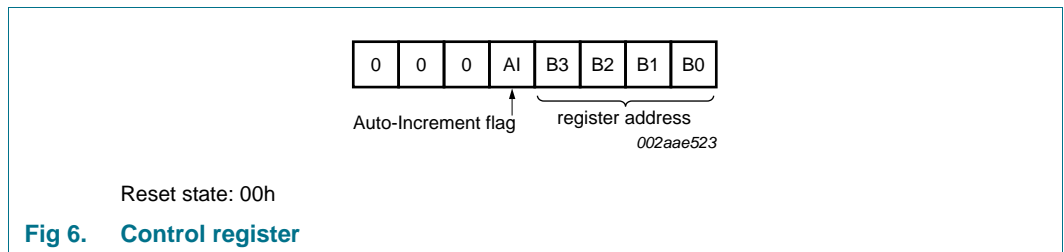


Fig 5. PCA9532 slave address

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

6.2 Control register

Following the successful acknowledgement of the slave address, the bus master will send a byte to the PCA9532, which will be stored in the Control register.



Reset state: 00h

Fig 6. Control register

The lowest 4 bits are used as a pointer to determine which register will be accessed.

If the Auto-Increment (AI) flag is set, the four low order bits of the Control register are automatically incremented after a read or write. This allows the user to program the registers sequentially. The contents of these bits will rollover to '0000' after the last register is accessed.

When Auto-Increment flag is set (AI = 1) and a read sequence is initiated, the sequence must start by reading a register different from the INPUT0 register (B3 B2 B1 B0 ≠ 0 0 0 0).

Only the 4 least significant bits are affected by the AI flag. Unused bits must be programmed with zeroes.

6.2.1 Control register definition

Table 3. Register summary

| B3 | B2 | B1 | B0 | Symbol | Access | Description |
|----|----|----|----|--------|------------|-------------------------|
| 0 | 0 | 0 | 0 | INPUT0 | read only | input register 0 |
| 0 | 0 | 0 | 1 | INPUT1 | read only | input register 1 |
| 0 | 0 | 1 | 0 | PSC0 | read/write | frequency prescaler 0 |
| 0 | 0 | 1 | 1 | PWM0 | read/write | PWM register 0 |
| 0 | 1 | 0 | 0 | PSC1 | read/write | frequency prescaler 1 |
| 0 | 1 | 0 | 1 | PWM1 | read/write | PWM register 1 |
| 0 | 1 | 1 | 0 | LS0 | read/write | LED0 to LED3 selector |
| 0 | 1 | 1 | 1 | LS1 | read/write | LED4 to LED7 selector |
| 1 | 0 | 0 | 0 | LS2 | read/write | LED8 to LED11 selector |
| 1 | 0 | 0 | 1 | LS3 | read/write | LED12 to LED15 selector |

6.3 Register descriptions

6.3.1 INPUT0 - Input register 0

The INPUT0 register reflects the state of the device pins (inputs 0 to 7). Writes to this register will be acknowledged but will have no effect.

Table 4. INPUT0 - Input register 0 description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|------|------|------|------|------|------|------|------|
| Symbol | LED7 | LED6 | LED5 | LED4 | LED3 | LED2 | LED1 | LED0 |
| Default | X | X | X | X | X | X | X | X |

Remark: The default value 'X' is determined by the externally applied logic level (normally logic 1) when used for directly driving LED with pull-up to V_{DD} .

6.3.2 INPUT1 - Input register 1

The INPUT1 register reflects the state of the device pins (inputs 8 to 15). Writes to this register will be acknowledged but will have no effect.

Table 5. INPUT1 - Input register 1 description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|-------|-------|-------|-------|-------|-------|------|------|
| Symbol | LED15 | LED14 | LED13 | LED12 | LED11 | LED10 | LED9 | LED8 |
| Default | X | X | X | X | X | X | X | X |

Remark: The default value 'X' is determined by the externally applied logic level (normally logic 1) when used for directly driving LED with pull-up to V_{DD} .

6.3.3 PCS0 - Frequency Prescaler 0

PSC0 is used to program the period of the PWM output.

The period of BLINK0 = (PSC0 + 1) / 152.

Table 6. PSC0 - Frequency Prescaler 0 register description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Symbol | PSC0[7] | PSC0[6] | PSC0[5] | PSC0[4] | PSC0[3] | PSC0[2] | PSC0[1] | PSC0[0] |
| Default | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

6.3.4 PWM0 - Pulse Width Modulation 0

The PWM0 register determines the duty cycle of BLINK0. The outputs are LOW (LED on) when the count is less than the value in PWM0 and HIGH (LED off) when it is greater. If PWM0 is programmed with 00h, then the PWM0 output is always HIGH (LED off).

The duty cycle of BLINK0 = PWM0 / 256.

Table 7. PWM0 - Pulse Width Modulation 0 register description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Symbol | PWM0 [7] | PWM0 [6] | PWM0 [5] | PWM0 [4] | PWM0 [3] | PWM0 [2] | PWM0 [1] | PWM0 [0] |
| Default | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

6.3.5 PCS1 - Frequency Prescaler 1

PSC1 is used to program the period of the PWM output.

The period of BLINK1 = (PSC1 + 1) / 152.

Table 8. PSC1 - Frequency Prescaler 1 register description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|---------|---------|---------|---------|---------|---------|---------|---------|
| Symbol | PSC1[7] | PSC1[6] | PSC1[5] | PSC1[4] | PSC1[3] | PSC1[2] | PSC1[1] | PSC1[0] |
| Default | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

6.3.6 PWM1 - Pulse Width Modulation 1

The PWM1 register determines the duty cycle of BLINK1. The outputs are LOW (LED on) when the count is less than the value in PWM1 and HIGH (LED off) when it is greater. If PWM1 is programmed with 00h, then the PWM1 output is always HIGH (LED off).

The duty cycle of BLINK1 = PWM1 / 256.

Table 9. PWM1 - Pulse Width Modulation 1 register description

| Bit | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Symbol | PWM1 [7] | PWM1 [6] | PWM1 [5] | PWM1 [4] | PWM1 [3] | PWM1 [2] | PWM1 [1] | PWM1 [0] |
| Default | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

6.3.7 LS0 to LS3 - LED selector registers

The LSn LED selector registers determine the source of the LED data.

- 00 = output is set high-impedance (LED off; default)
- 01 = output is set LOW (LED on)
- 10 = output blinks at PWM0 rate
- 11 = output blinks at PWM1 rate

Table 10. LS0 to LS3 - LED selector registers bit description

Legend: * default value.

| Register | Bit | Value | Description |
|--------------------------------------|-----|-------|----------------|
| LS0 - LED0 to LED3 selector | | | |
| LS0 | 7:6 | 00* | LED3 selected |
| | 5:4 | 00* | LED2 selected |
| | 3:2 | 00* | LED1 selected |
| | 1:0 | 00* | LED0 selected |
| LS1 - LED4 to LED7 selector | | | |
| LS1 | 7:6 | 00* | LED7 selected |
| | 5:4 | 00* | LED6 selected |
| | 3:2 | 00* | LED5 selected |
| | 1:0 | 00* | LED4 selected |
| LS2 - LED8 to LED11 selector | | | |
| LS2 | 7:6 | 00* | LED11 selected |
| | 5:4 | 00* | LED10 selected |
| | 3:2 | 00* | LED9 selected |
| | 1:0 | 00* | LED8 selected |
| LS3 - LED12 to LED15 selector | | | |
| LS3 | 7:6 | 00* | LED15 selected |
| | 5:4 | 00* | LED14 selected |
| | 3:2 | 00* | LED13 selected |
| | 1:0 | 00* | LED12 selected |

6.4 Pins used as GPIOs

LEDn pins not used to control LEDs can be used as General Purpose I/Os (GPIOs).

For use as input, set LEDn to high-impedance (00) and then read the pin state via the INPUT0 or INPUT1 register.

For use as output, connect external pull-up resistor to the pin and size it according to the DC recommended operating characteristics. LEDn output pin is HIGH when the output is programmed as high-impedance, and LOW when the output is programmed LOW through the 'LED selector' register. The output can be pulse-width controlled when PWM0 or PWM1 are used.

6.5 Power-on reset

When power is applied to V_{DD} , an internal Power-On Reset (POR) holds the PCA9532 in a reset condition until V_{DD} has reached V_{POR} . At that point, the reset condition is released and the PCA9532 registers are initialized to their default states, all the outputs in the OFF state. Thereafter, V_{DD} must be lowered below 0.2 V to reset the device.

6.6 External $\overline{\text{RESET}}$

A reset can be accomplished by holding the $\overline{\text{RESET}}$ pin LOW for a minimum of $t_{w(\text{rst})}$. The PCA9532 registers and I²C-bus state machine will be held in their default states 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.

7. Characteristics of the I²C-bus

The I²C-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.

7.1 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 7](#)).

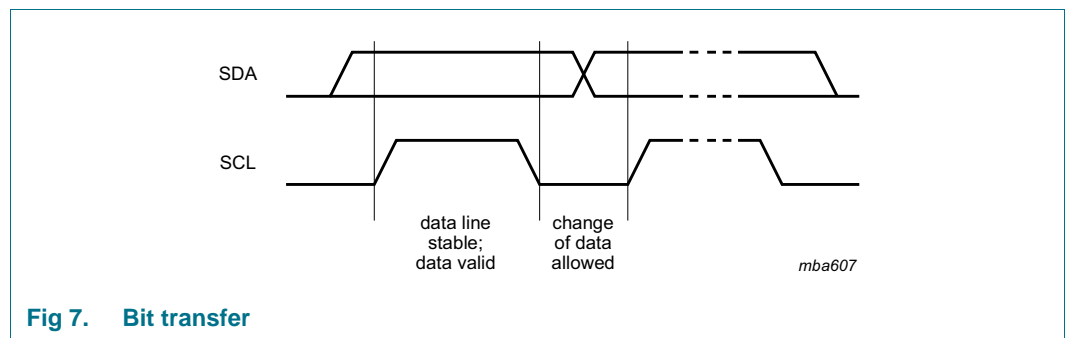


Fig 7. Bit transfer

7.1.1 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 8](#)).

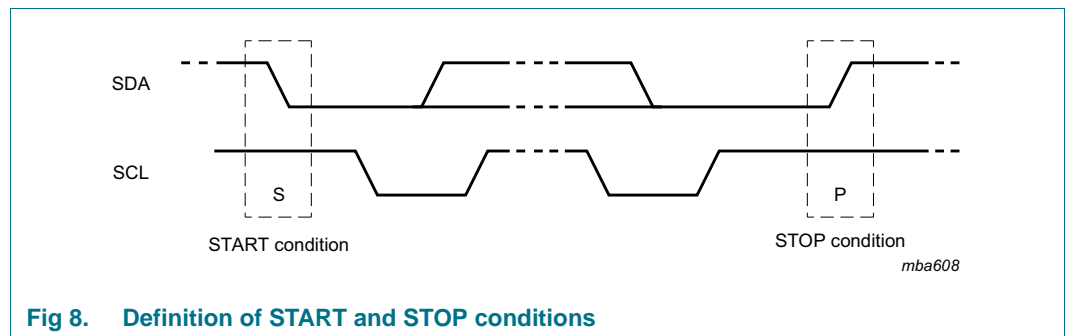


Fig 8. Definition of START and STOP conditions

7.2 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 9](#)).

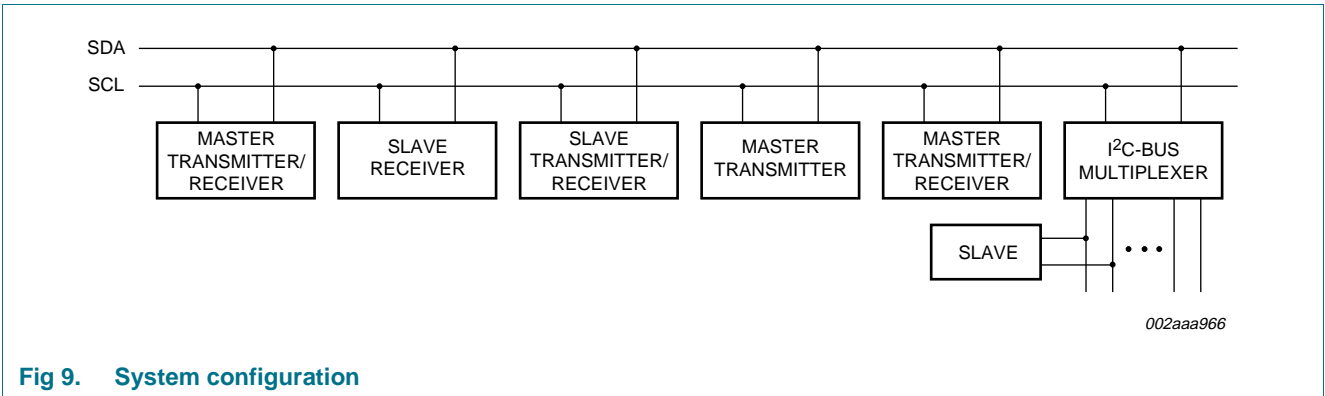


Fig 9. System configuration

7.3 Acknowledge

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

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

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

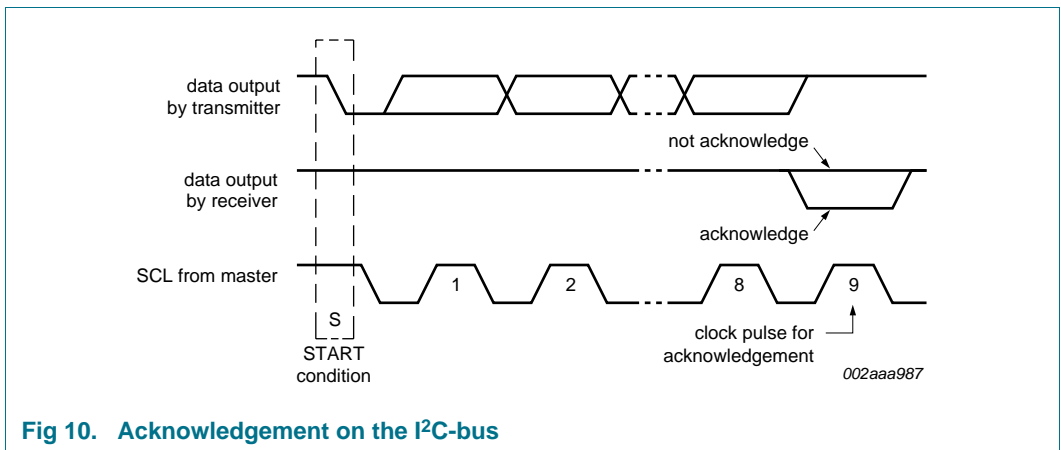
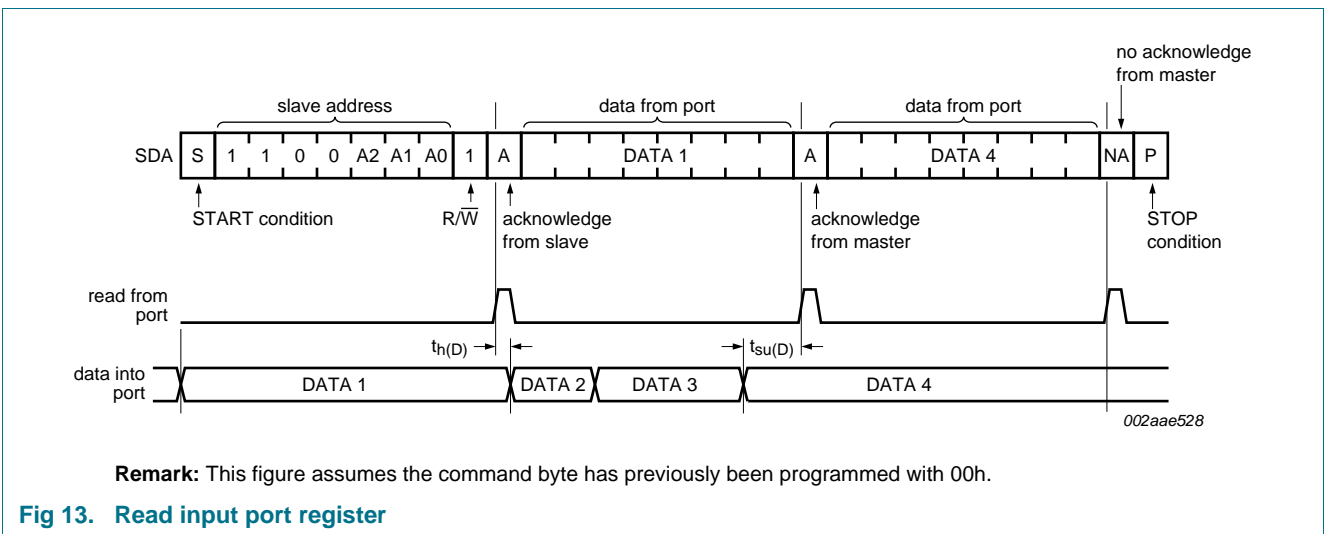
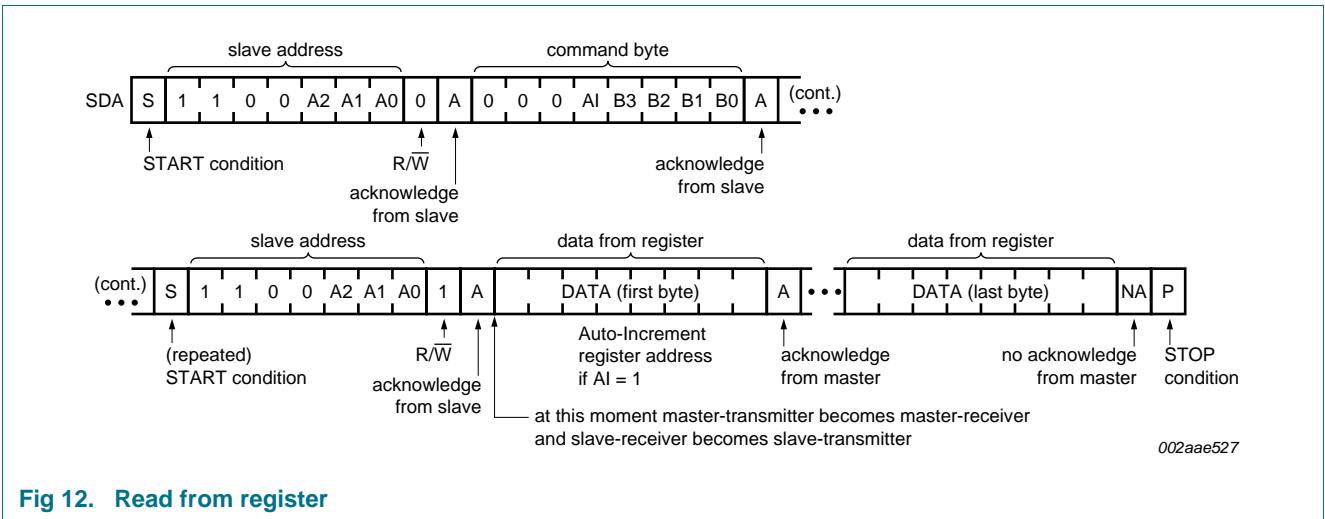
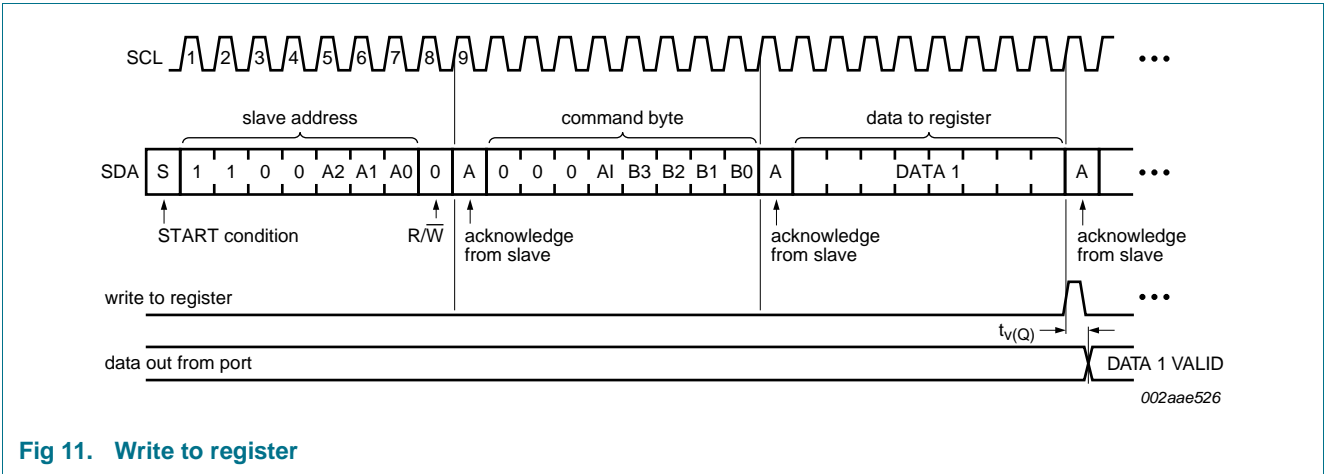
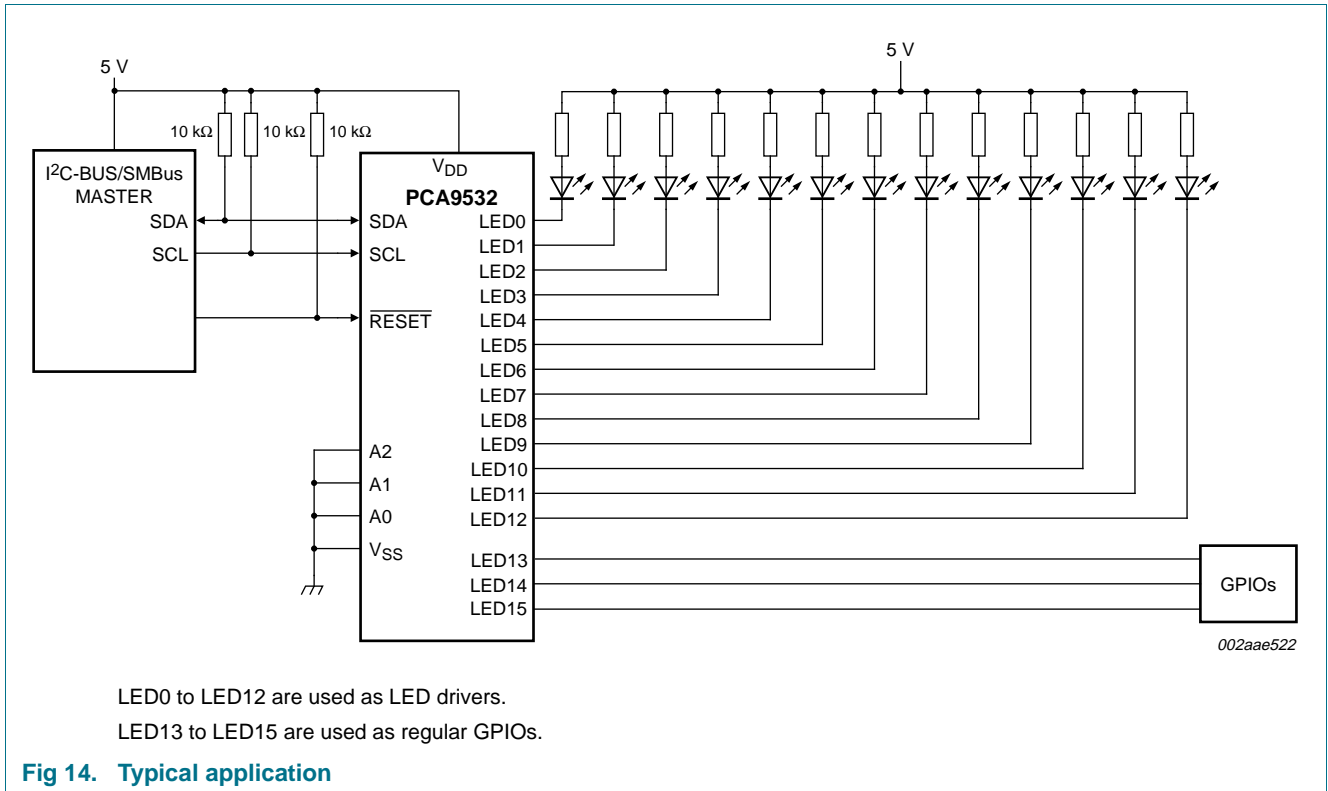


Fig 10. Acknowledgement on the I²C-bus

7.4 Bus transactions



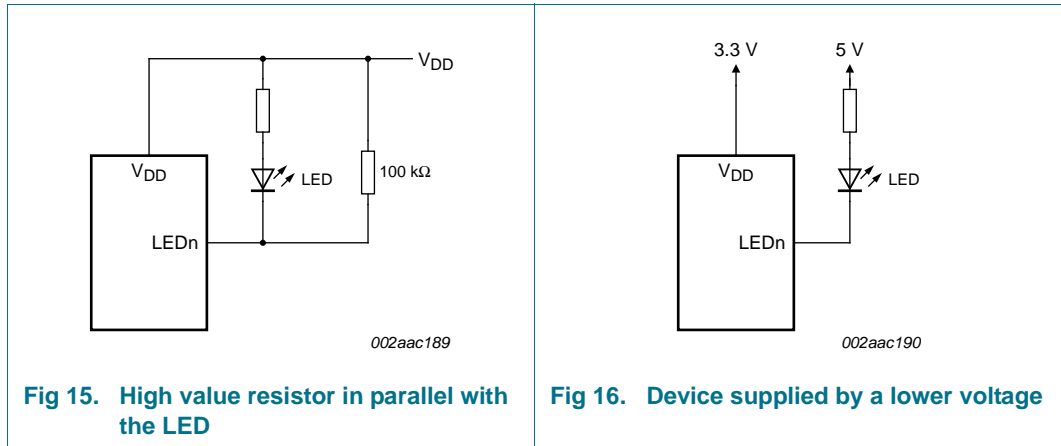
8. Application design-in information



8.1 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 14](#). 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} and is specified as ΔI_{DD} in [Table 13 “Static characteristics”](#).

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 15](#) shows a high value resistor in parallel with the LED. [Figure 16](#) 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.



8.2 Programming example

The following example will show how to set LED0 to LED3 on. It will then set LED4 and LED5 to blink at 1 Hz at a 50 % duty cycle. LED6 and LED7 will be set to be dimmed at 25 % of their maximum brightness (duty cycle = 25 %). LED8 to LED15 will be set to off.

Table 11. Programming PCA9532

| Program sequence | I ² C-bus |
|---|----------------------|
| START | S |
| PCA9532 address with A0 to A2 = LOW | C0h |
| PSC0 subaddress + Auto-Increment | 12h |
| Set prescaler PSC0 to achieve a period of 1 second: $Blink\ period = 1 = \frac{PSC0 + 1}{152}$ | 97h |
| PSC0 = 151 | |
| Set PWM0 duty cycle to 50 %: $\frac{PWM0}{256} = 0.5$ | 80h |
| PWM0 = 128 | |
| Set prescaler PCS1 to dim at maximum frequency: $Blink\ period = max$ | 00h |
| PSC1 = 0 | |
| Set PWM1 output duty cycle to 25 %: $\frac{PWM1}{256} = 0.25$ | 40h |
| PWM1 = 64 | |
| Set LED0 to LED3 on | 55h |
| Set LED4 and LED5 to PWM0, and LED6 or LED7 to PWM1 | FAh |
| Set LED8 to LED11 off | 00h |
| Set LED12 to LED15 off | 00h |
| STOP | P |

9. Limiting values

Table 12. 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 |
| V _{I/O} | voltage on an input/output pin | | V _{SS} - 0.5 | 5.5 | V |
| I _{O(LEDn)} | output current on pin LEDn | | - | ±25 | mA |
| I _{SS} | ground supply current | | - | 200 | mA |
| P _{tot} | total power dissipation | | - | 400 | mW |
| T _{stg} | storage temperature | | -65 | +150 | °C |
| T _{amb} | ambient temperature | operating | -40 | +85 | °C |

10. Static characteristics

Table 13. Static characteristics

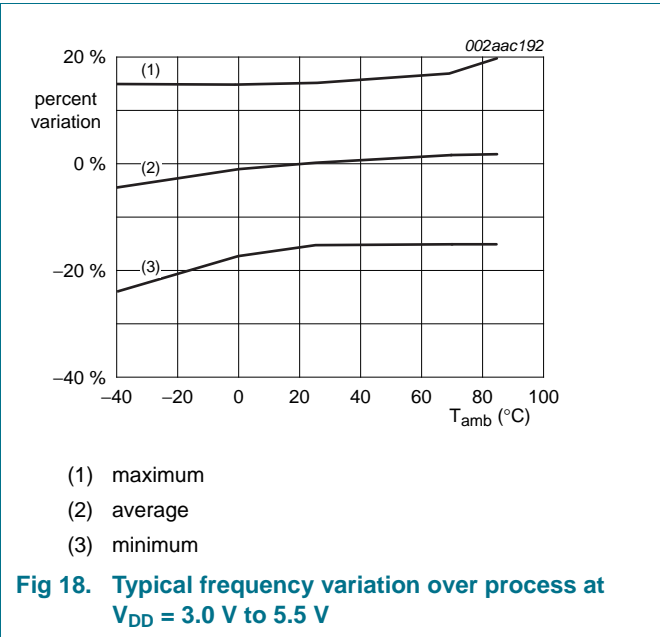
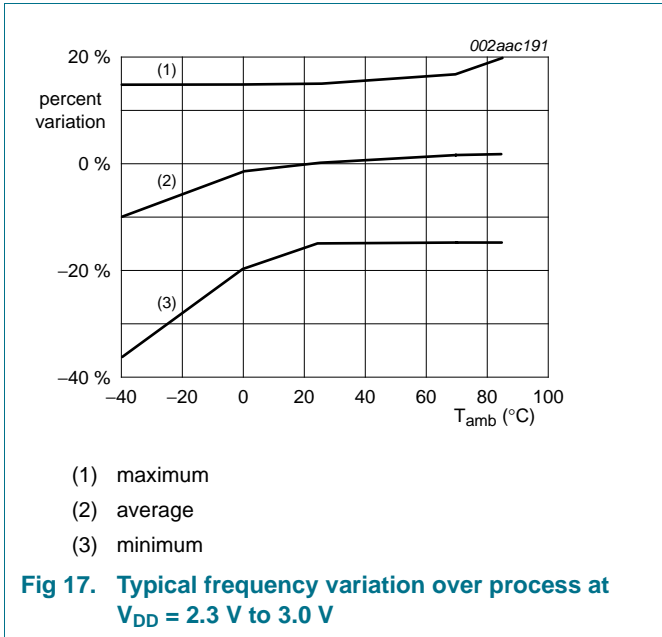
$V_{DD} = 2.3\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+85\text{ °C}$; unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ ^[1] | 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; $V_I = V_{DD}$ or V_{SS} ; $f_{SCL} = 100\text{ kHz}$ | - | 350 | 550 | μA |
| I_{stb} | standby current | Standby mode; $V_{DD} = 5.5\text{ V}$; no load; $V_I = V_{DD}$ or V_{SS} ; $f_{SCL} = 0\text{ kHz}$ | - | 2.1 | 5.0 | μA |
| ΔI_{DD} | additional quiescent supply current | Standby mode; $V_{DD} = 5.5\text{ V}$; every LED I/O at $V_I = 4.3\text{ V}$; $f_{SCL} = 0\text{ kHz}$ | - | - | 2 | mA |
| V_{POR} | power-on reset voltage | $V_{DD} = 3.3\text{ V}$; no load; $V_I = V_{DD}$ or V_{SS} | ^[2] - | 1.7 | 2.2 | 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 | 6.5 | - | mA |
| I_L | leakage current | $V_I = V_{DD} = V_{SS}$ | -1 | - | +1 | μA |
| C_i | input capacitance | $V_I = V_{SS}$ | - | 4.4 | 5 | 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 | $V_{OL} = 0.4\text{ V}$ | | | | |
| | | $V_{DD} = 2.3\text{ V}$ | ^[3] 9 | - | - | mA |
| | | $V_{DD} = 3.0\text{ V}$ | ^[3] 12 | - | - | mA |
| | | $V_{DD} = 5.0\text{ V}$ | ^[3] 15 | - | - | mA |
| | | $V_{OL} = 0.7\text{ V}$ | | | | |
| | | $V_{DD} = 2.3\text{ V}$ | ^[3] 15 | - | - | mA |
| | | $V_{DD} = 3.0\text{ V}$ | ^[3] 20 | - | - | mA |
| $V_{DD} = 5.0\text{ V}$ | ^[3] 25 | - | - | mA | | |
| I_{LI} | input leakage current | $V_{DD} = 3.6\text{ V}$; $V_I = 0\text{ V}$ or V_{DD} | -1 | - | +1 | μA |
| C_{io} | input/output capacitance | | - | 2.6 | 5 | pF |
| Select inputs A0, A1, A2; 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 |
| C_i | input capacitance | $V_I = V_{SS}$ | - | 2.3 | 5 | pF |

[1] Typical limits at $V_{DD} = 3.3\text{ V}$, $T_{amb} = 25\text{ °C}$.

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

[3] Each I/O must be externally limited to a maximum of 25 mA and each octal ([LED0 to LED7] and [LED8 to LED15]) must be limited to a maximum current of 100 mA for a device total of 200 mA.



11. Dynamic characteristics

Table 14. 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] | - | 600 | - | 600 ns |
| t _{VD;DAT} | data valid time | LOW-level | [2] | - | 600 | - | 600 ns |
| | | HIGH-level | [2] | - | 1500 | - | 600 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 |
| Reset | | | | | | | |
| t _{w(rst)} | reset pulse width | | 10 | - | 10 | - | ns |
| t _{rec(rst)} | reset recovery time | | 0 | - | 0 | - | ns |
| t _{rst} | reset time | | [4][5] | 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 SDA data output to be valid following SCL LOW.

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

[4] Resetting the device while actively communicating on the bus may cause glitches or errant STOP conditions.

[5] Upon reset, the full delay will be the sum of t_{rst} and the RC time constant of the SDA bus.

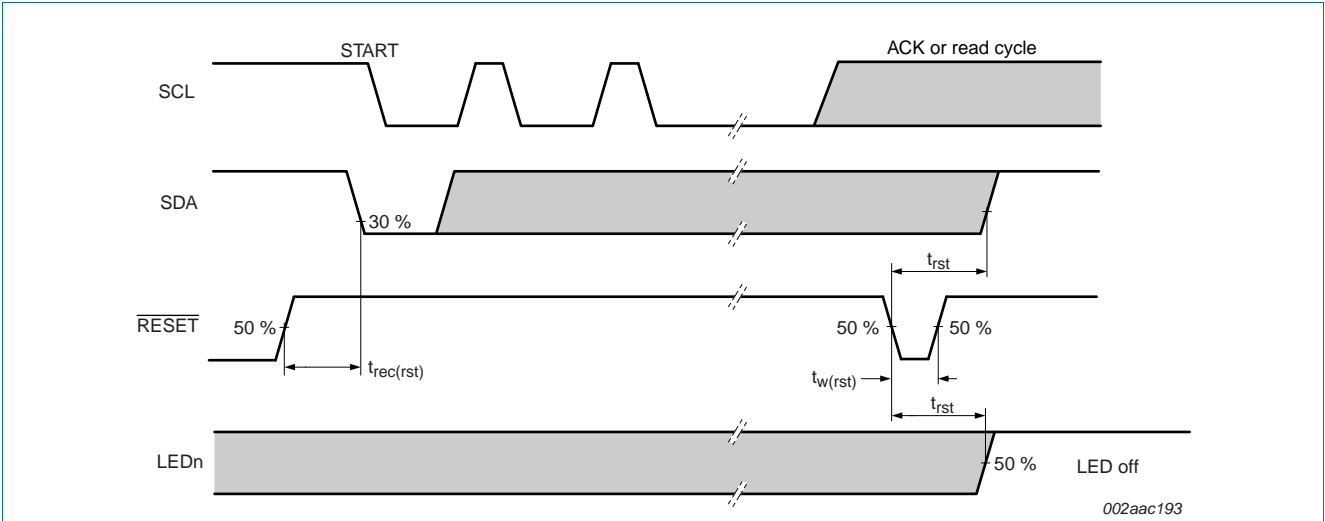


Fig 19. Definition of RESET timing

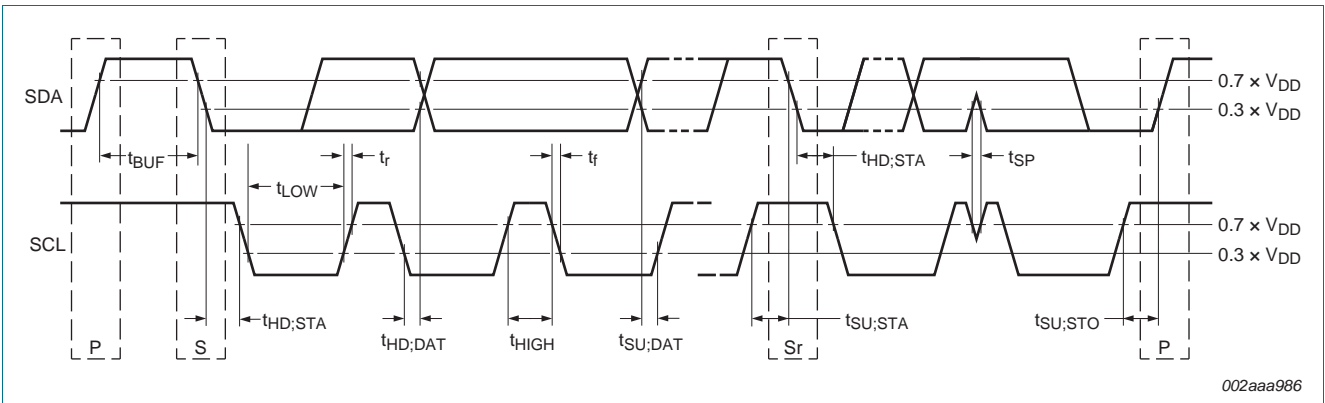


Fig 20. Definition of timing

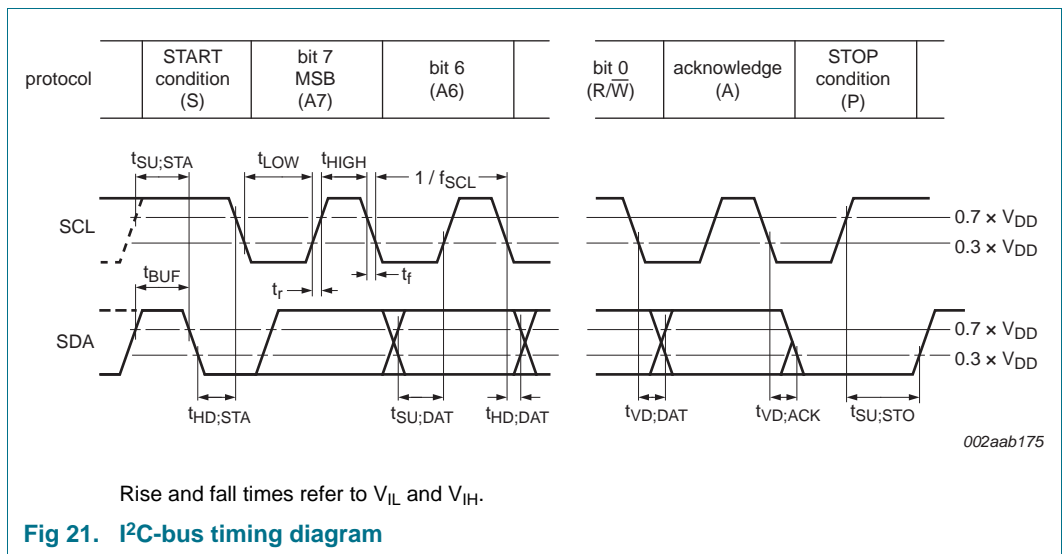
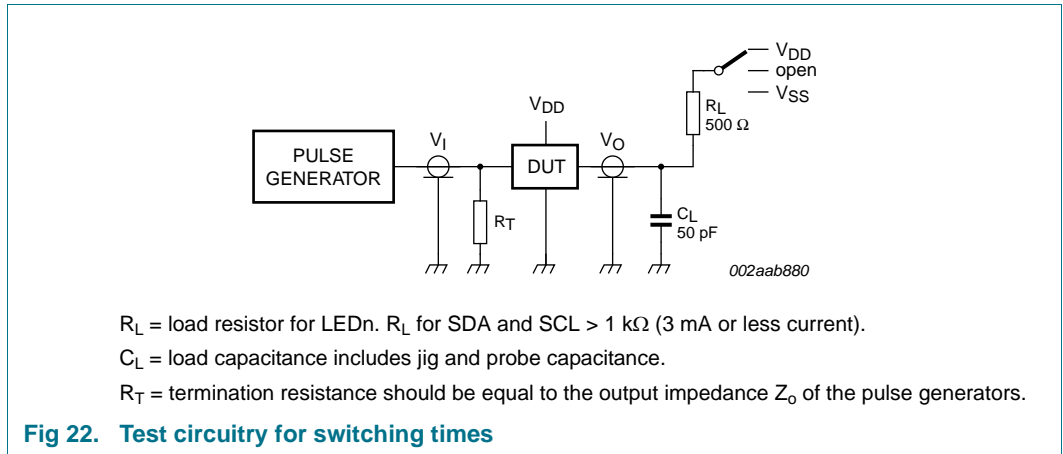


Fig 21. I²C-bus timing diagram

12. Test information



13. Package outline

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

SOT137-1

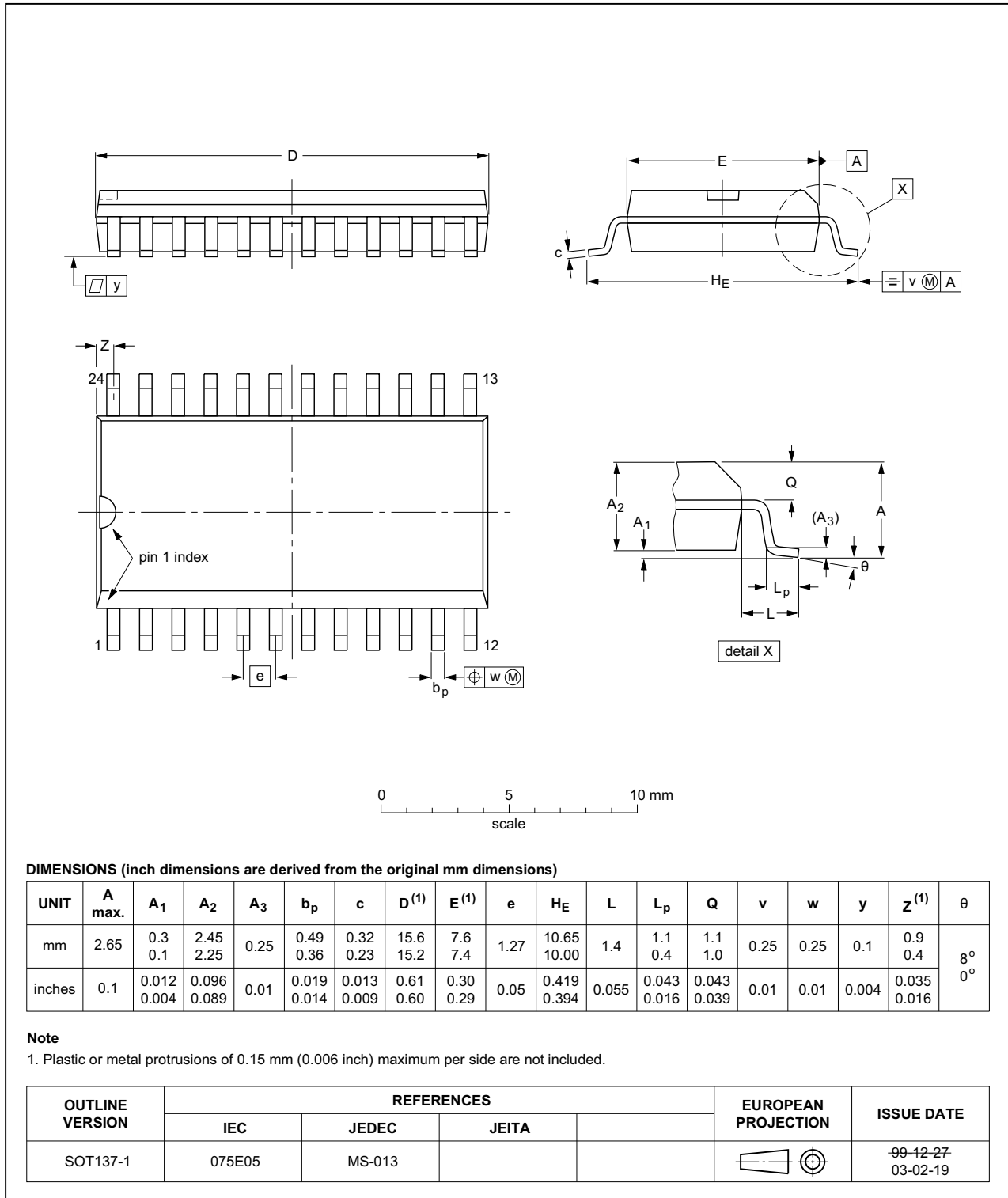


Fig 23. Package outline SOT137-1 (SO24)

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

SOT355-1

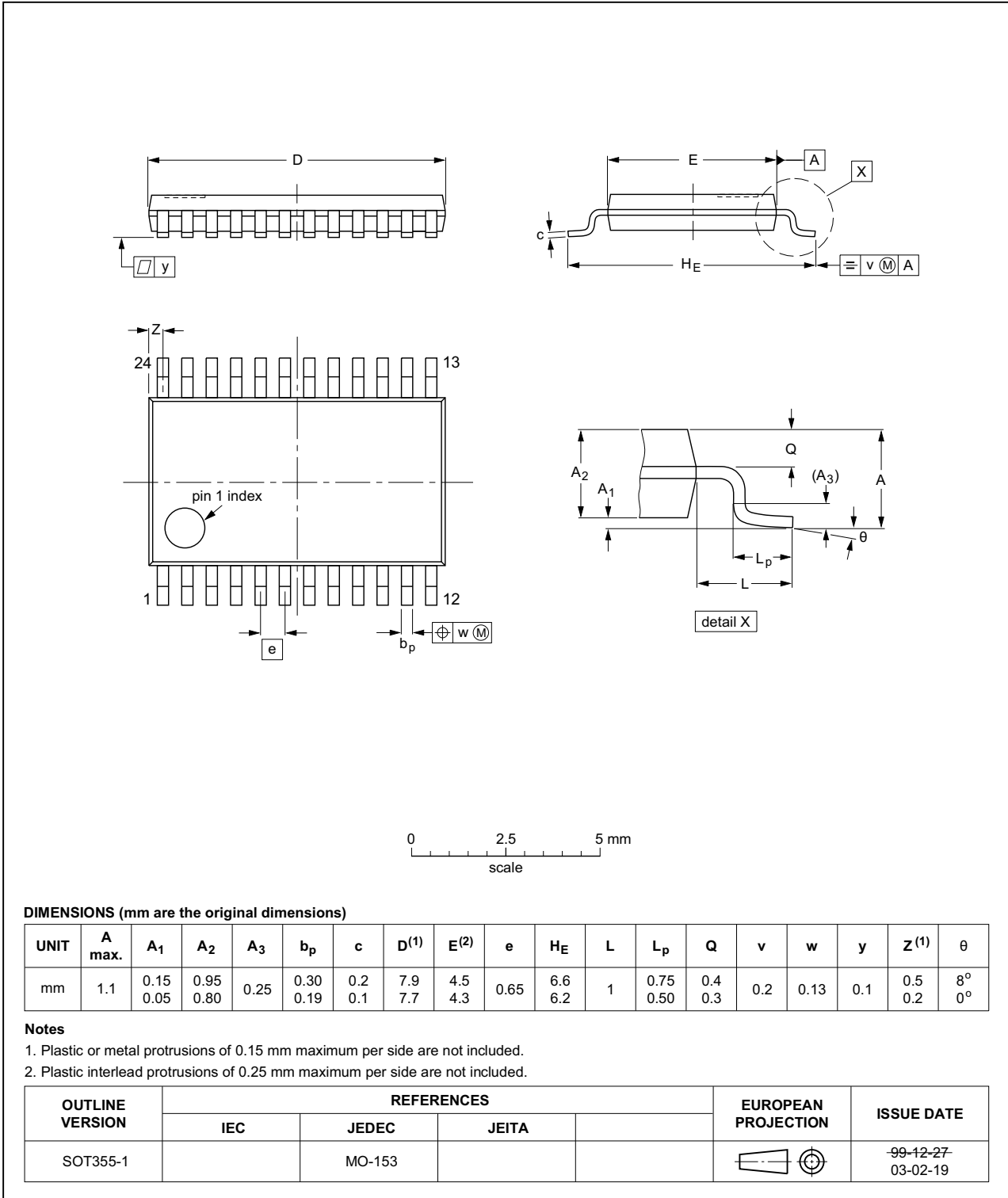


Fig 24. Package outline SOT355-1 (TSSOP24)

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

SOT616-1

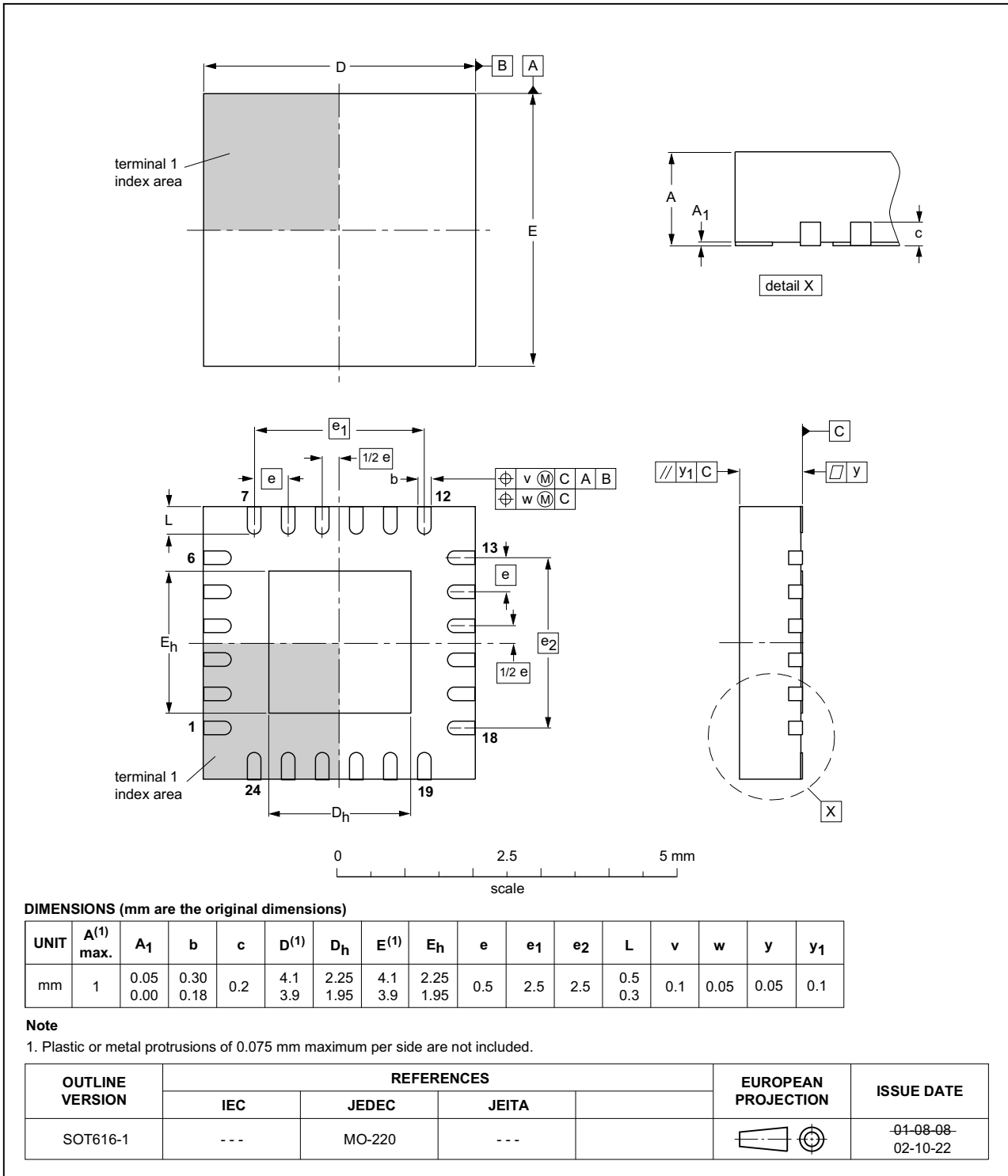


Fig 25. Package outline SOT616-1 (HVQFN24)

14. 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.

15. 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"*.

15.1 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.

15.2 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

15.3 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

15.4 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 26](#)) 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 15](#) and [16](#)

Table 15. SnPb eutectic process (from J-STD-020D)

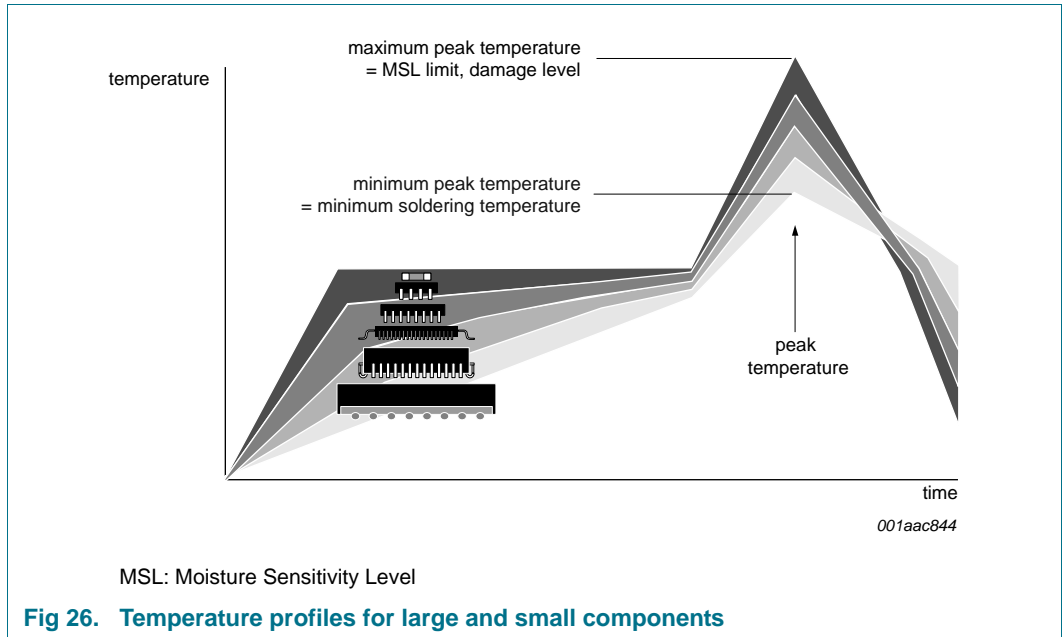
| Package thickness (mm) | Package reflow temperature (°C) | |
|------------------------|---------------------------------|-------|
| | Volume (mm ³) | |
| | < 350 | ≥ 350 |
| < 2.5 | 235 | 220 |
| ≥ 2.5 | 220 | 220 |

Table 16. Lead-free process (from J-STD-020D)

| 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 26](#).



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

16. Abbreviations

Table 17. Abbreviations

| Acronym | Description |
|----------------------|--|
| ACPI | Advanced Configuration and Power Interface |
| CDM | Charged Device Model |
| DSP | Digital Signal Processor |
| DUT | Device Under Test |
| ESD | ElectroStatic Discharge |
| GPIO | General Purpose Input/Output |
| HBM | Human Body Model |
| I ² C-bus | Inter-Integrated Circuit bus |
| LED | Light Emitting Diode |
| MCU | MicroController Unit |
| MM | Machine Model |
| MPU | MicroProcessor Unit |
| POR | Power-On Reset |
| RC | Resistor-Capacitor network |
| SMBus | System Management Bus |

17. Revision history

Table 18. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|-------------------------------|--|--------------------|---|------------|
| PCA9532 v.4.1 | 20160822 | Product data sheet | - | PCA9532_4 |
| Modifications: | <ul style="list-style-type: none"> • Table 1: Corrected topside mark for PCA9532PW. | | | |
| PCA9532_4 | 20090317 | Product data sheet | - | PCA9532_3 |
| Modifications: | <ul style="list-style-type: none"> • 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. • Section 5.1 "Pinning": replaced (old) Figure 1 with separate drawings for SO24 (Figure 2) and TSSOP24 (Figure 3) • Table 2 "Pin description": added Table note [1] and its reference at HVQFN24 pin 9, V_{SS} • Section 6.2 "Control register": <ul style="list-style-type: none"> – 2nd paragraph: changed from "The lowest 3 bits are ..." to "The lowest 4 bits are ..." – 4th paragraph: changed from "... by reading a register different from '0' ..." to "... by reading a register different from INPUT0 ..." • Section 6.6 "External RESET", 1st paragraph, 1st sentence: changed symbol from "t_w" to "t_{w(rst)}" • Figure 11 "Write to register": symbol changed from "t_{pv}" to "t_{v(Q)}" • Figure 13 "Read input port register": <ul style="list-style-type: none"> – Symbol changed from "t_{ph}" to "t_{h(D)}" – Symbol changed from "t_{ps}" to "t_{su(D)}" • Table 12 "Limiting values": changed symbol/parameter from "I_{I/O}, DC output current on an I/O" to "I_{O(LEDn)}, output current on pin LEDn" • Table 13 "Static characteristics": <ul style="list-style-type: none"> – Descriptive line below table title: 2nd sentence is moved to Table note [1], with its reference at column heading "Typ" – ΔI_{DD} parameter changed from "additional standby current" to "additional quiescent supply current" – Sub-section "I/Os": symbol changed from "I_L" to "I_{LI}" • Table 14 "Dynamic characteristics": <ul style="list-style-type: none"> – 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 set-up 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" – Symbol changed from "t_w" to "t_{w(rst)}" – Symbol changed from "t_{REC}" to "t_{rec(rst)}" – Symbol/parameter changed from "t_{RESET}, Time to reset" to "t_{rst}, reset time" • Figure 19 "Definition of RESET timing": <ul style="list-style-type: none"> – Symbol changed from "t_{REC}" to "t_{rec(rst)}" – Symbol changed from "t_{RESET}" to "t_{rst}" – Symbol changed from "t_w" to "t_{w(rst)}" – Symbol changed from "t_{RESET}" to "t_{rst}" • Updated handling information • Added soldering information | | | |
| PCA9532_3 | 20041001 | Product data sheet | - | PCA9532_2 |
| PCA9532_2 (9397 750 11459) | 20030502 | Product data | ECN 853-2398 29860 dated 24 Apr 2003 | PCA9532_1 |

Table 18. Revision history ...continued

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|-------------------------------|--------------|-------------------|---|------------|
| PCA9532_1 (9397 750 10874) | 20030226 | Product data | ECN 853-2398 29297 dated 12 Dec 2002 | - |

18. Legal information

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| Document status ^{[1][2]} | Product status ^[3] | Definition |
|-----------------------------------|-------------------------------|---|
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| Preliminary [short] data sheet | Qualification | This document contains data from the preliminary specification. |
| Product [short] data sheet | Production | This document contains the product specification. |

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

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

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