

PCA8551

Automotive 36 × 4 LCD segment driver

Rev. 3.1 — 3 May 2021

Product data sheet

1 General description

PCA8551 is an ultra low-power LCD segment driver with 4 backplane- and 36 segment-driver outputs, with either an I²C- (PCA8551A) or an SPI-bus (PCA8551B) interface. It comprises an internal oscillator, bias generation, instruction decoding, and display controller.

For a selection of NXP LCD segment drivers, see [Table 23](#).

2 Features and benefits

- AEC-Q100 grade 2 up to 105 °C compliant for automotive applications
- Single chip LCD controller and driver
- Selectable backplane drive configuration: static, 2, 3, or 4 backplane multiplexing
- Selectable display bias configuration: static, 1/2, or 1/3
- Internal LCD bias generation with buffers
- 36 segment drives:
 - Up to 18 7-segment numeric characters
 - Up to 9 14-segment alphanumeric characters
 - Any graphics of up to 144 segments/elements
- Auto-incrementing display data and instruction loading
- Versatile blinking modes
- Independent supplies of V_{LCD} and V_{DD}
- Power supply ranges:
 - 1.8 V to 5.5 V for V_{LCD}
 - 1.8 V to 5.5 V for V_{DD}
- Ultra low-power consumption
- 400 kHz I²C-bus interface (PCA8551A)
- 5 MHz SPI-bus interface (PCA8551B)
- Internally generated or externally supplied clock signal

3 Applications

- Displays integrated
 - in a car instrument cluster
 - in a control indicator
- Battery operated applications
- Healthcare devices



4 Ordering information

Table 1. Ordering Information

| Product type Number | Topside mark | Package | | |
|---------------------|--------------|---------|--|----------|
| | | Name | Description | Version |
| PCA8551ATT/A | PCA8551A | TSSOP48 | plastic thin shrink small outline package; 48 leads; body width 6.1 mm | SOT362-1 |
| PCA8551BTT/A | PCA8551B | TSSOP48 | plastic thin shrink small outline package; 48 leads; body width 6.1 mm | SOT362-1 |

4.1 Ordering options

Table 2. Ordering options

| Product type Number | Orderable part number | Package | Packing method | Minimum order quantity | Temperature |
|---------------------|------------------------------|---------|-----------------|------------------------|--------------------------------------|
| PCA8551ATT/A | PCA8551ATT/AJ ^[1] | TSSOP48 | Reel 13" Q1 NDP | 2000 | T _{amb} = -40 °C to +105 °C |
| | PCA8551ATT/AY ^[2] | TSSOP48 | Reel 13" Q1 DP | 2000 | T _{amb} = -40 °C to +105 °C |
| PCA8551BTT/A | PCA8551BTT/AJ ^[1] | TSSOP48 | Reel 13" Q1 NDP | 2000 | T _{amb} = -40 °C to +105 °C |
| | PCA8551BTT/AY ^[2] | TSSOP48 | Reel 13" Q1 DP | 2000 | T _{amb} = -40 °C to +105 °C |

[1] Not recommend for new design - will be discontinued in mid 2021 - use new version with improved package.

[2] Improved package - refer to PCN 202005038F01.

5 Block diagram

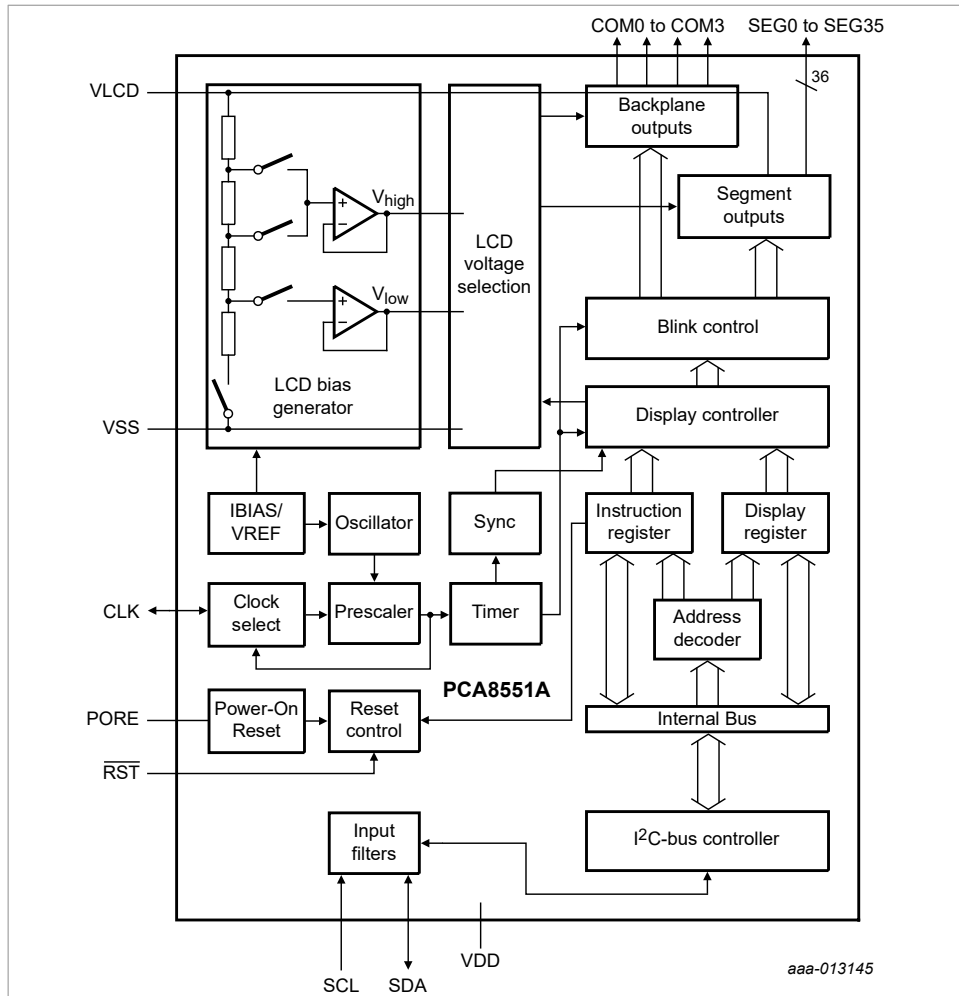


Figure 1. Block diagram of PCA8551A

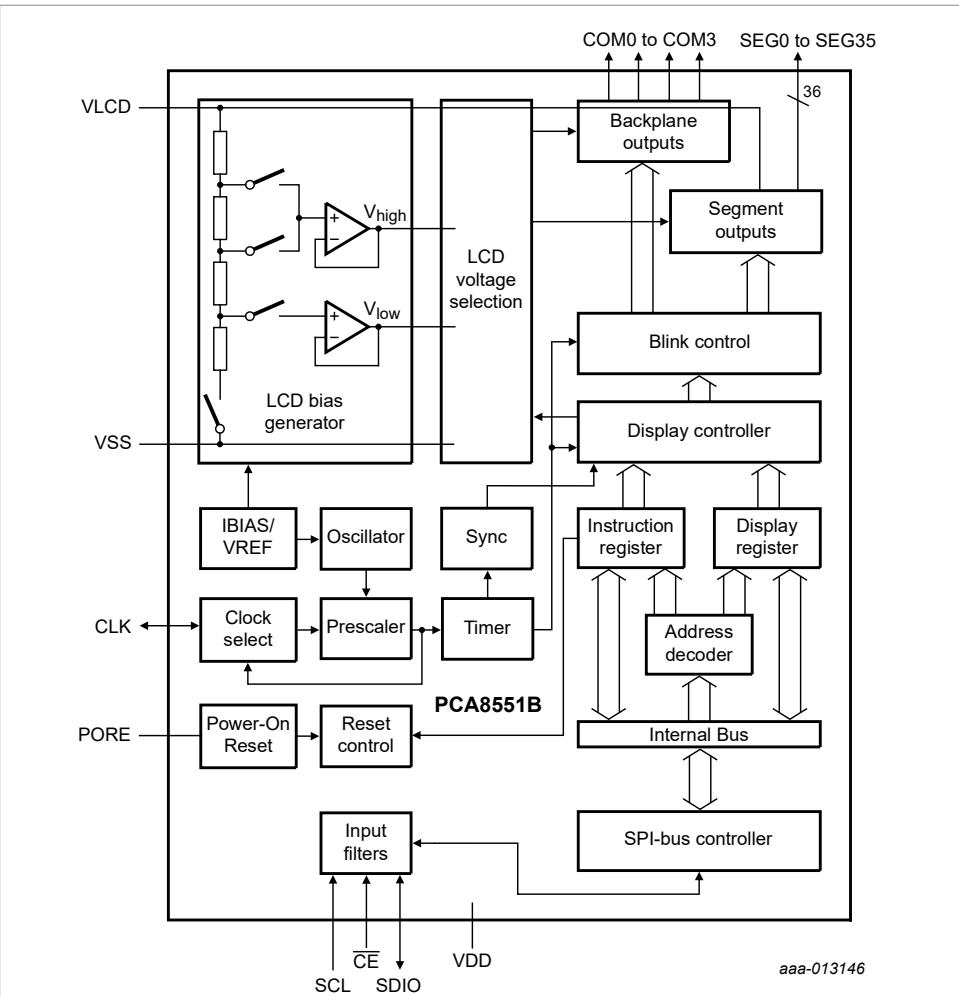
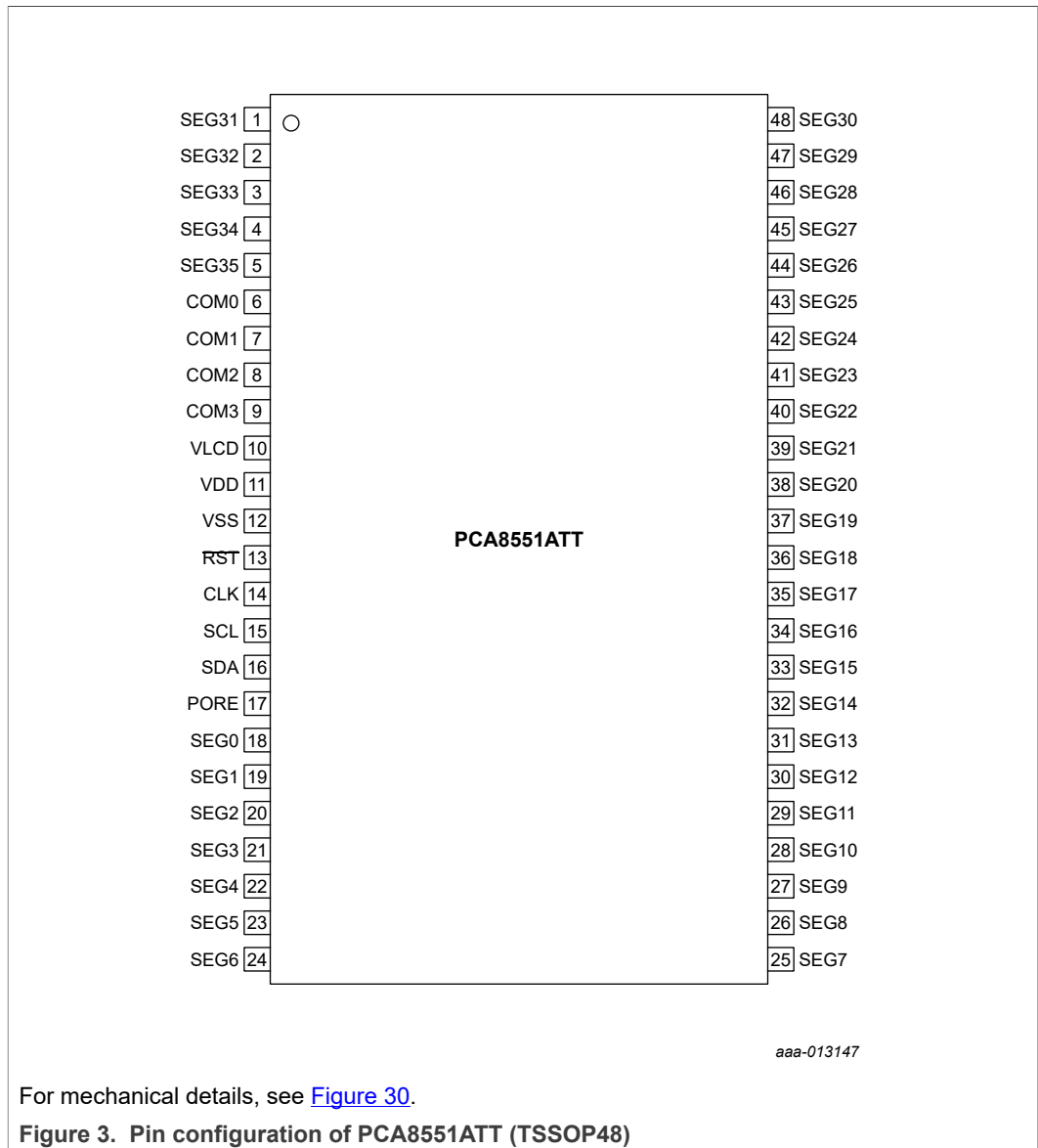
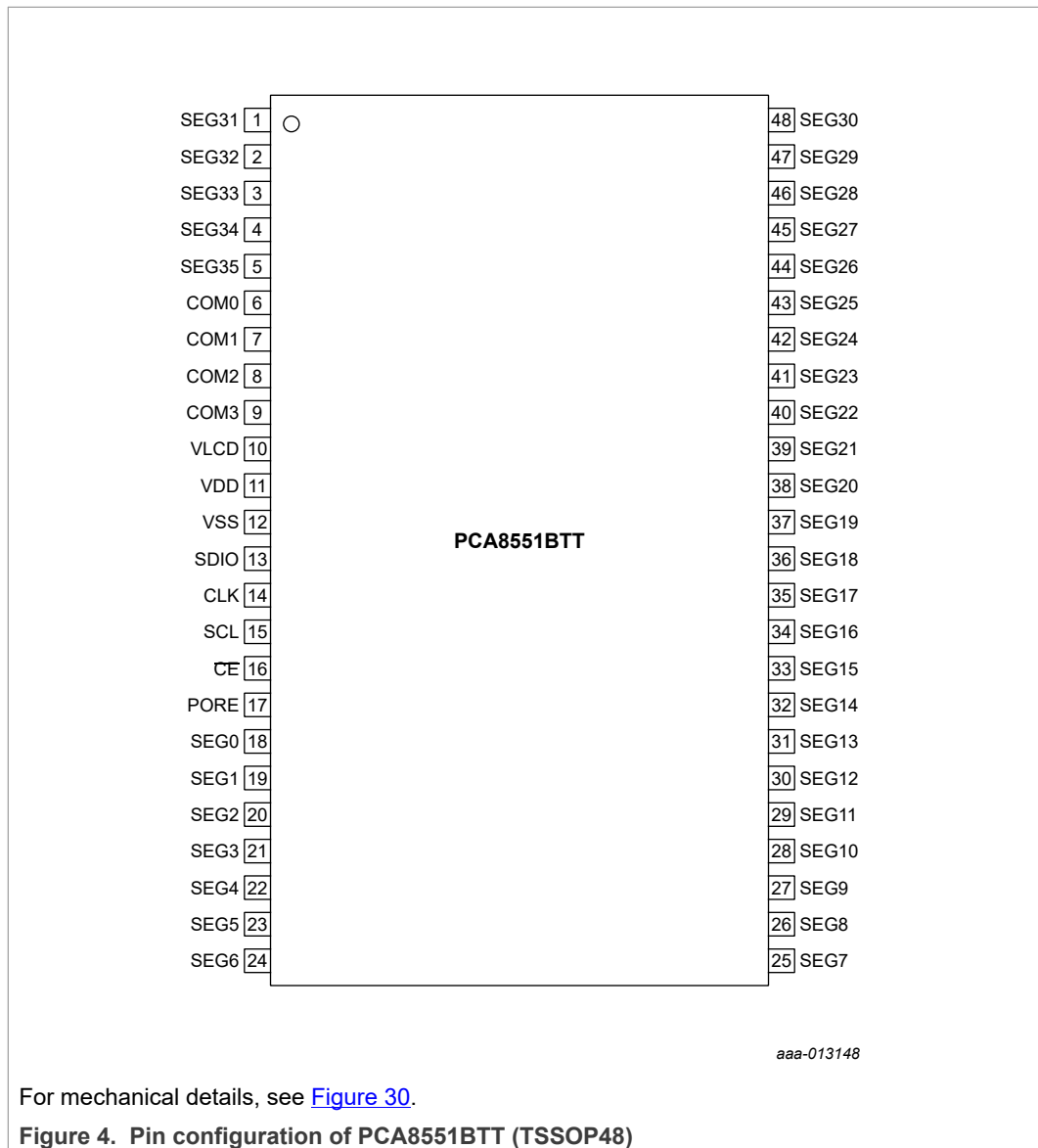


Figure 2. Block diagram of PCA8551B

6 Pinning information

6.1 Pinning





6.2 Pin description

Table 3. Pin description

Input or input/output pins must always be at a defined level (V_{SS} or V_{DD}) unless otherwise specified.

| Pin | Symbol | Type | Description | |
|---|--|---------------------------------|---|-------------------------------|
| 1 to 5, 18 to 48 | SEG0 to SEG35 | output | LCD segment outputs | |
| 6 to 9 | COM0 to COM3 | output | LCD backplane outputs | |
| 10 | VLCD | supply | LCD supply voltage | |
| 11 | VDD | supply | supply voltage | |
| 12 | VSS | supply | ground supply | |
| 14 | CLK | input/output | internal oscillator output, external oscillator input ^[1] <ul style="list-style-type: none"> • must be left open if unused | |
| 15 | SCL | input | serial clock input | |
| 17 | PORE ^[2] | input | Power-On Reset (POR) enable <ul style="list-style-type: none"> • connect to V_{DD} for enabling POR • connect to V_{SS} (or leave open) for disabling POR | |
| Pin layout depending on product and bus type | | | | |
| | PCA8551ATT (I²C-bus) | PCA8551BTT (SPI-bus) | | |
| 13 | RST | - | input | reset input, active LOW |
| | - | SDIO | input/output | serial data input/output |
| 16 | SDA | - | input/output | serial data line |
| | - | CE | input | chip enable input, active LOW |

[1] Can be configured by command, see [Table 5](#).

[2] A series resistance between V_{DD} and the pin must not exceed 1 kΩ to ensure proper functionality, see [Section 15.3](#).

7 Functional description

7.1 Registers of the PCA8551

The registers of the PCA8551 are arranged in bytes with 8 bit, addressed by an address pointer. [Table 4](#) depicts the layout.

Table 4. Registers of the PCA8551

Bits labeled as 0 must always be written with logic 0; bits labeled as - are ignored by the device.

| Register name | Address | Bits | | | | | | | | Reference |
|-------------------------------|---------|---------|-------|-------|---------|----------|---------|-------|-------|-------------------------|
| | AP[4:0] | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Command registers | | | | | | | | | | |
| Software_reset | 00h | SR[7:0] | | | | | | | | Table 8 |
| Device_ctrl | 01h | 0 | 0 | 0 | FF[2:0] | | | OSC | COE | Table 5 |
| Display_ctrl_1 | 02h | 0 | 0 | 0 | BOOST | MUX[1:0] | | B | DE | Table 6 |
| Display_ctrl_2 | 03h | 0 | 0 | 0 | 0 | 0 | BL[1:0] | | INV | Table 7 |
| Display data registers | | | | | | | | | | |
| COM0 | 04h | SEG7 | SEG6 | SEG5 | SEG4 | SEG3 | SEG2 | SEG1 | SEG0 | Table 9 |
| | 05h | SEG15 | SEG14 | SEG13 | SEG12 | SEG11 | SEG10 | SEG9 | SEG8 | |
| | 06h | SEG23 | SEG22 | SEG21 | SEG20 | SEG19 | SEG18 | SEG17 | SEG16 | |
| | 07h | SEG31 | SEG30 | SEG29 | SEG28 | SEG27 | SEG26 | SEG25 | SEG24 | |
| | 08h | - | - | - | - | SEG35 | SEG34 | SEG33 | SEG32 | |
| COM1 | 09h | SEG7 | SEG6 | SEG5 | SEG4 | SEG3 | SEG2 | SEG1 | SEG0 | |
| | 0Ah | SEG15 | SEG14 | SEG13 | SEG12 | SEG11 | SEG10 | SEG9 | SEG8 | |
| | 0Bh | SEG23 | SEG22 | SEG21 | SEG20 | SEG19 | SEG18 | SEG17 | SEG16 | |
| | 0Ch | SEG31 | SEG30 | SEG29 | SEG28 | SEG27 | SEG26 | SEG25 | SEG24 | |
| | 0Dh | - | - | - | - | SEG35 | SEG34 | SEG33 | SEG32 | |
| COM2 | 0Eh | SEG7 | SEG6 | SEG5 | SEG4 | SEG3 | SEG2 | SEG1 | SEG0 | |
| | 0Fh | SEG15 | SEG14 | SEG13 | SEG12 | SEG11 | SEG10 | SEG9 | SEG8 | |
| | 10h | SEG23 | SEG22 | SEG21 | SEG20 | SEG19 | SEG18 | SEG17 | SEG16 | |
| | 11h | SEG31 | SEG30 | SEG29 | SEG28 | SEG27 | SEG26 | SEG25 | SEG24 | |
| | 12h | - | - | - | - | SEG35 | SEG34 | SEG33 | SEG32 | |
| COM3 | 13h | SEG7 | SEG6 | SEG5 | SEG4 | SEG3 | SEG2 | SEG1 | SEG0 | |
| | 14h | SEG15 | SEG14 | SEG13 | SEG12 | SEG11 | SEG10 | SEG9 | SEG8 | |
| | 15h | SEG23 | SEG22 | SEG21 | SEG20 | SEG19 | SEG18 | SEG17 | SEG16 | |
| | 16h | SEG31 | SEG30 | SEG29 | SEG28 | SEG27 | SEG26 | SEG25 | SEG24 | |
| | 17h | - | - | - | - | SEG35 | SEG34 | SEG33 | SEG32 | |

For writing to the registers, send the address byte first, then write the data to the register (see [Section 10.1.4](#) and [Section 10.2.1](#)). The address byte works as an address pointer. For the succeeding registers, the address pointer is automatically incremented by 1 (see

Figure 5) and all following data are written into these register addresses. After register 18h, the auto-incrementing will stop and subsequent data are ignored.

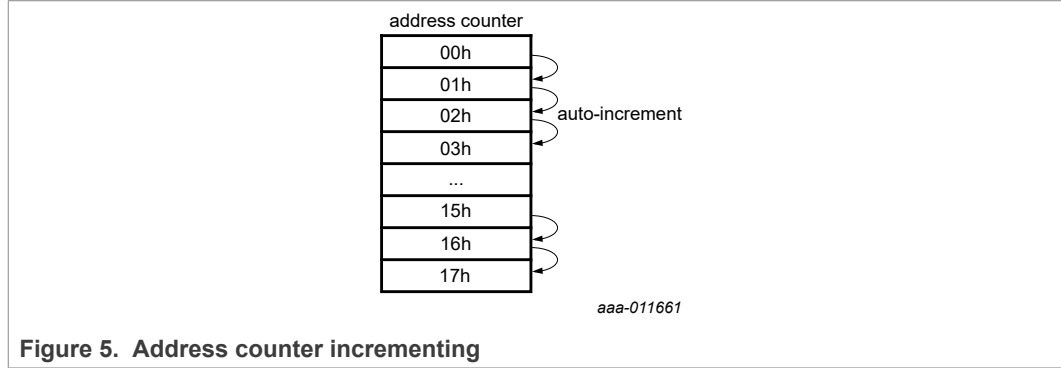


Figure 5. Address counter incrementing

7.2 Command registers of the PCA8551

7.2.1 Command: Device_ctrl

The Device_ctrl command sets the device into a defined state. It should be executed before enabling the display (see bit DE in Table 6).

Table 5. Device_ctrl - device control command register (address 01h) bit description

| Bit | Symbol | Value | Description |
|--------|---------|--------------------|--|
| 7 to 5 | - | 000 | default value |
| 4 to 2 | FF[2:0] | | frame frequency selection |
| | | 000 | $f_{fr} = 32 \text{ Hz}$ |
| | | 001 ^[1] | $f_{fr} = 64 \text{ Hz}$ |
| | | 010 | $f_{fr} = 96 \text{ Hz}$ |
| | | 011 | $f_{fr} = 128 \text{ Hz}$ |
| | | 100 | $f_{fr} = 160 \text{ Hz}$ |
| | | 101 | $f_{fr} = 192 \text{ Hz}$ |
| | | 110 | $f_{fr} = 224 \text{ Hz}$ |
| 1 | OSC | | internal oscillator control |
| | | 0 ^[1] | enabled |
| | | 1 | disabled |
| 0 | COE | | clock output enable |
| | | 0 ^[1] | clock signal not available on pin CLK; pin CLK is in 3-state |
| | | 1 | clock signal available on pin CLK |

[1] Default value.

7.2.1.1 Internal oscillator and clock output

Bit OSC enables or disables the internal oscillator. When the internal oscillator is used, bit COE allows making the clock signal available on pin CLK. If this is not intended, pin CLK should be left open. The design ensures that the duty cycle of the clock output is 50 : 50 (% HIGH-level time : % LOW-level time).

In applications where an external clock has to be applied to the PCA8551, bit OSC must be set logic 1 and COE logic 0. In this case pin CLK becomes an input.

In power-down mode (see [Section 7.3.1](#))

- if pin CLK is configured as an output, there is no signal on CLK
- if pin CLK is configured as an input, the signal on CLK can be removed.

Remark: A clock signal must always be supplied to the device if the display is enabled (see bit DE in [Table 6](#)). Removing the clock may freeze the LCD in a DC state, which is not suitable for the liquid crystal.

7.2.2 Command: Display_ctrl_1

The Display_ctrl_1 command allows configuring the basic display set-up.

Table 6. Display_ctrl_1 - display control command 1 register (address 02h) bit description

| Bit | Symbol | Value | Description |
|--------|------------------|-------------------|---|
| 7 to 5 | - | 000 | default value |
| 4 | BOOST | | large display mode support |
| | | 0 ^[1] | standard power drive scheme |
| | | 1 | enhanced power drive scheme for higher display loads |
| 3 to 2 | MUX[1:0] | | multiplex drive mode selection |
| | | 00 ^[1] | 1:4 multiplex drive mode; COM0 to COM3 ($n_{MUX} = 4$) |
| | | 01 | 1:3 multiplex drive mode; COM0 to COM2 ($n_{MUX} = 3$) |
| | | 10 | 1:2 multiplex drive mode; COM0 and COM1 ($n_{MUX} = 2$) |
| | | 11 | static drive mode; COM0 ($n_{MUX} = 1$) |
| 1 | B ^[2] | | bias mode selection |
| | | 0 ^[1] | $\frac{1}{3}$ bias ($a_{bias} = 2$) |
| | | 1 | $\frac{1}{2}$ bias ($a_{bias} = 1$) |
| 0 | DE | | display enable ^[3] |
| | | 0 ^[1] | display disabled; device is in power-down mode |
| | | 1 | display enabled; device is in power-on mode |

[1] Default value.

[2] Not applicable for static drive mode.

[3] See [Section 7.3.1](#).

7.2.2.1 Enhanced power drive mode

By setting the BOOST bit to logic 1, the driving capability of the display signals is increased to cope with large displays with a higher effective capacitance. Setting this bit increases the current consumption on V_{LCD}.

7.2.2.2 Multiplex drive mode

MUX[1:0] sets the multiplex driving scheme and the associated backplane drive signals, which are active. For further details, see [Section 8.2](#).

7.2.3 Command: Display_ctrl_2

Table 7. Display_ctrl_2 - display control command 2 register (address 03h) bit description

| Bit | Symbol | Value | Description |
|--------|---------|-------------------|--|
| 7 to 3 | - | 00000 | default value |
| 2 to 1 | BL[1:0] | | blink control |
| | | 00 ^[1] | blinking off |
| | | 01 | blinking on, f _{blink} = 0.5 Hz |
| | | 10 | blinking on, f _{blink} = 1 Hz |
| | | 11 | blinking on, f _{blink} = 2 Hz |
| 0 | INV | | inversion mode selection |
| | | 0 ^[1] | line inversion (driving scheme A) |
| | | 1 | frame inversion (driving scheme B) |

[1] Default value.

7.2.3.1 Blinking

The whole display blinks at frequencies selected by the blink control bits BL[1:0], see [Table 7](#). The blink frequencies are derived from the clock frequency. During the blank-out phase of the blinking period, the display is turned off.

If an external clock with frequency f_{clk(ext)} is used, the blinking frequency is determined by [Equation 1](#). For notation, see [Section 8.2](#).

$$f_{blink(ef f)} = \frac{2^{n_{MUX}} \times f_{fr} \times f_{blink}}{f_{clk(ext)}} \quad (1)$$

7.2.3.2 Line inversion (driving scheme A) and frame inversion (driving scheme B)

The waveforms used to drive LCD inherently produce a DC voltage across the display cell. The PCA8551 compensates for the DC voltage by inverting the waveforms on alternate frames or alternate lines. The choice of compensation method is determined with the INV bit.

7.3 Starting and resetting the PCA8551

If the internal Power-On Reset (POR) is enabled by connecting pin PORE to V_{DD} , the chip resets automatically when V_{DD} rises above the minimum supply voltage. No further action is required.

If the internal POR is disabled by connecting pin PORE to V_{SS} , the chip must be reset by driving the \overline{RST} pin (PCA8551A only) to logic 0 for at least 10 μs , see [Figure 6](#).

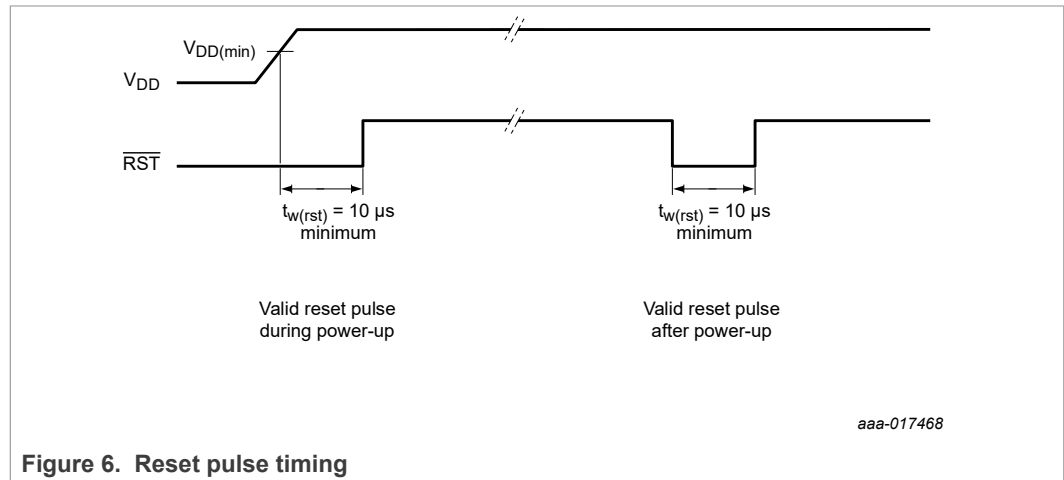


Figure 6. Reset pulse timing

Alternatively a software reset can be applied (see [Section 7.3.4](#)).

Following a reset, the register 00h has to be rewritten with 0h by the next command byte or the address pointer AP[4:0] has to be set to the required address after a new START procedure. See also application information in [Section 15](#).

7.3.1 Power-down mode

After a reset, the PCA8551 remains in power-down mode. In power-down mode the oscillator is switched off and there is no output on pin CLK. The register settings remain unchanged and the bus remains active. To enable the PCA8551, bit DE (command Display_ctrl_1, see [Table 6](#)) must be set to logic 1.

7.3.2 Power-On Reset (POR)

If pin PORE is connected to V_{DD} , the PCA8551 comprises an internal POR, which puts the device into the following starting conditions:

- All backplane and segment outputs are set to V_{SS}
- The selected drive mode is: 1:4 multiplex with $\frac{1}{3}$ bias
- Blinking is switched off
- The address pointer is cleared (set to logic 0)
- The display and the internal oscillator are disabled
- The display registers are set to logic 0
- The bus interface is initialized

Remark: The internal POR can be disabled by connecting pin PORE to V_{SS} . In this case, the internal registers are not defined and require a hardware reset according to [Section 7.3.3](#) or a software reset, see [Section 7.3.4](#).

Remark: For power-on with a slowly starting power supply, see [Section 15.1](#).

7.3.3 Hardware reset: RST pin (only PCA8551A)

At power-on the PCA8551A can be reset to the following starting conditions by pulling pin RST low:

- All backplane and segment outputs are set to V_{SS}
- The selected drive mode is: 1:4 multiplex with $\frac{1}{3}$ bias
- Blinking is switched off
- The address pointer is cleared (set to logic 0)
- The display and the internal oscillator are disabled
- The display registers are set to logic 0

Remark: The hardware reset overrides the POR see [Section 7.3.2](#).

7.3.4 Command: Software_reset

The internal registers including the display registers and the address pointer (set to logic 0) of the device are reset by the Software_reset command.

Table 8. Software_reset - software reset command register (address 00h) bit description

| Bit | Symbol | Value | Description |
|--------|------------------------|--------------------------|-----------------------|
| 7 to 0 | SR[7:0] ^[1] | | software reset |
| | | 0000 0000 ^[2] | no reset |
| | | 0010 1100 | software reset |

[1] Software_reset only generates a reset pulse, therefore this register always reads back as 00h.

[2] Default value.

7.4 Display data register mapping

The example in [Table 9](#) and [Figure 7](#) illustrates the segment and backplane mapping of the display in relation to the display RAM.

For example, in 1:4 multiplex drive mode, the backplanes are served by signals COM0 to COM3 and the segments are driven by signals SEG0 to SEG35. Contents of addresses 04h to 08h are allocated to the first row (COM0) starting with the LSB driving the leftmost element and moving forward to the right with increasing bit position. If a bit is logic 0, the element is off, if it is logic 1 the element is turned on. All register content is LSB to MSB left to right. Addresses 09h to 0Dh serve COM1 signals, addresses 0Eh to 12h serve COM2 signals, and addresses 13h to 17h serve COM3 signals.

For displays with fewer segments/elements the unused bits are ignored.

Table 9. Register to segment and backplane mapping

| Backplanes ^[1] | Segments | | | | | | | | | |
|---------------------------------|----------------|-----|----------------|-----|----------------|-----|----------------|-----|----------------|-----|
| | SEG0 to SEG7 | | SEG8 to SEG15 | | SEG16 to SEG23 | | SEG24 to SEG31 | | SEG32 to SEG35 | |
| | LSB | MSB | LSB | MSB | LSB | MSB | LSB | MSB | LSB | MSB |
| 1:4 multiplex drive mode | | | | | | | | | | |
| COM0 | content of 04h | | content of 05h | | content of 06h | | content of 07h | | content of 08h | |

Table 9. Register to segment and backplane mapping...continued

| Backplanes ^[1] | Segments | | | | | | | | | |
|---------------------------------|----------------|-----|----------------|-----|----------------|-----|----------------|-----|----------------|-----|
| | SEG0 to SEG7 | | SEG8 to SEG15 | | SEG16 to SEG23 | | SEG24 to SEG31 | | SEG32 to SEG35 | |
| | LSB | MSB | LSB | MSB | LSB | MSB | LSB | MSB | LSB | MSB |
| COM1 | content of 09h | | content of 0Ah | | content of 0Bh | | content of 0Ch | | content of 0Dh | |
| COM2 | content of 0Eh | | content of 0Fh | | content of 10h | | content of 11h | | content of 12h | |
| COM3 | content of 13h | | content of 14h | | content of 15h | | content of 16h | | content of 17h | |
| 1:3 multiplex drive mode | | | | | | | | | | |
| COM0 | content of 04h | | content of 05h | | content of 06h | | content of 07h | | content of 08h | |
| COM1 | content of 09h | | content of 0Ah | | content of 0Bh | | content of 0Ch | | content of 0Dh | |
| COM2 | content of 0Eh | | content of 0Fh | | content of 10h | | content of 11h | | content of 12h | |
| 1:2 multiplex drive mode | | | | | | | | | | |
| COM0 | content of 04h | | content of 05h | | content of 06h | | content of 07h | | content of 08h | |
| COM1 | content of 09h | | content of 0Ah | | content of 0Bh | | content of 0Ch | | content of 0Dh | |
| static drive mode | | | | | | | | | | |
| COM0 | content of 04h | | content of 05h | | content of 06h | | content of 07h | | content of 08h | |

[1] See also [Section 8.3.1](#).

8 Possible display configurations

The possible display configurations of the PCA8551 depend on the number of active backplane outputs required. A selection of display configurations is shown in [Table 10](#). All of these configurations can be implemented in the typical systems shown in [Figure 9](#) or [Figure 10](#).

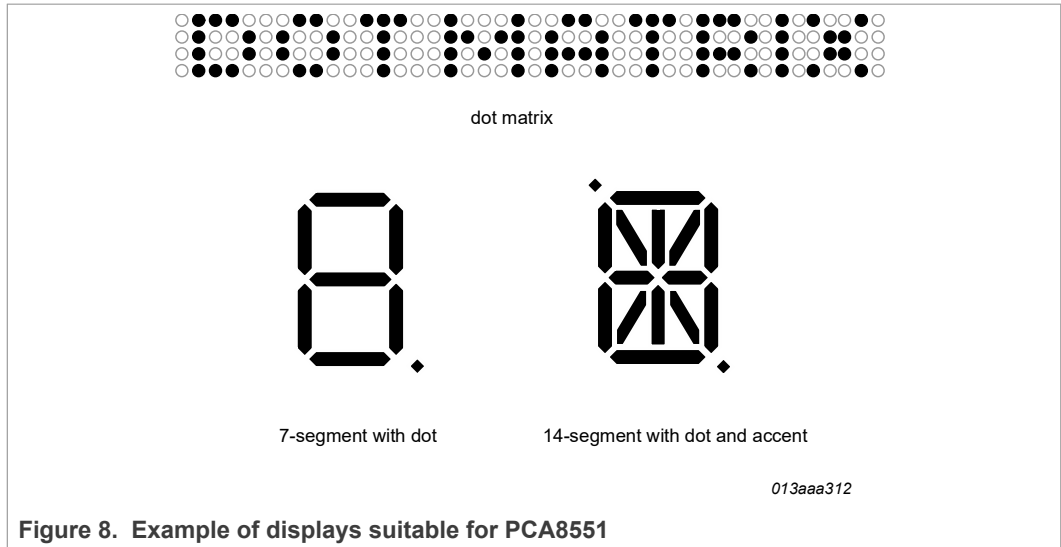


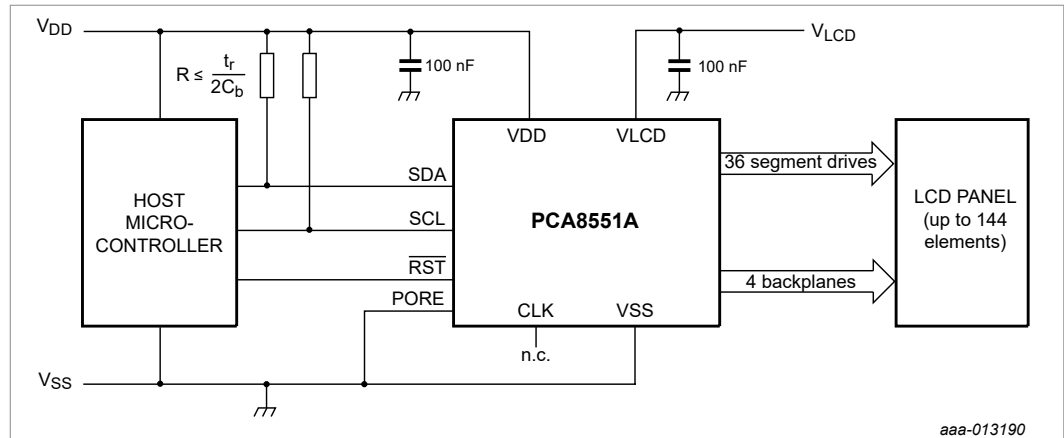
Figure 8. Example of displays suitable for PCA8551

Table 10. Selection of possible display configurations

| Number of Backplanes | Icons | Digits/Characters | | Dot matrix: segments/elements |
|----------------------|-------|--------------------------|---------------------------|-------------------------------|
| | | 7-segment ^[1] | 14-segment ^[2] | |
| 4 | 144 | 18 | 9 | 144 dots (4 × 36) |
| 3 | 108 | 13 | 6 | 108 dots (3 × 36) |
| 2 | 72 | 9 | 4 | 72 dots (2 × 36) |
| 1 | 36 | 4 | 2 | 36 dots (1 × 36) |

[1] 7 segment display has 8 segments/elements including the decimal point.

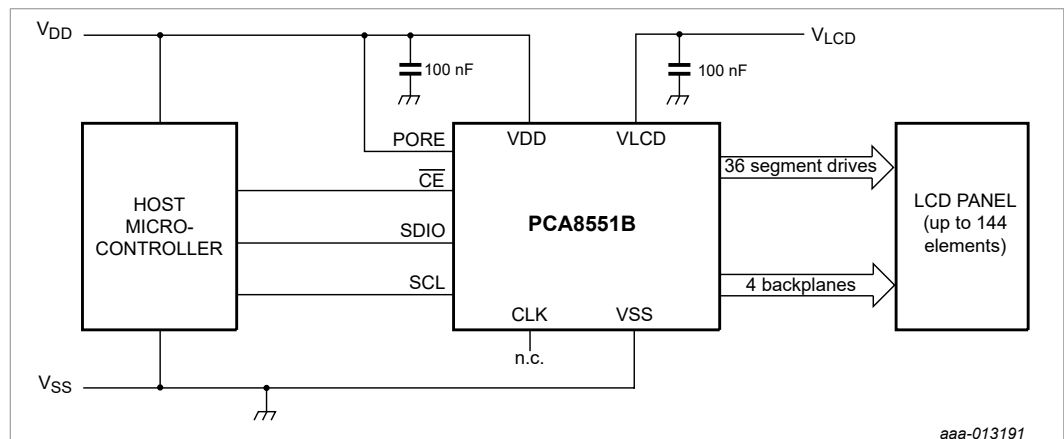
[2] 14 segment display has 16 segments/elements including decimal point and accent dot.



The resistance of the power lines must be kept to a minimum. A decoupling capacitor of at least 100 nF is recommended for the supplies.

Figure 9. Typical system configuration using I²C-bus, internal power-on reset disabled

The host microcontroller manages the 2-line I²C-bus communication channel with the PCA8551A. The internal oscillator is used and the internal POR is disabled in the example. The appropriate biasing voltages for the multiplexed LCD waveforms are generated internally. The only other connections required to complete the system are the reset, the power supplies (V_{DD}, V_{SS}, and V_{LCD}) and the LCD panel chosen for the application.



The resistance of the power lines must be kept to a minimum. A decoupling capacitor of at least 100 nF is recommended for the supplies.

Figure 10. Typical system configuration using SPI-bus, internal power-on reset enabled

The host microcontroller manages the 3-line SPI-bus communication channel with the PCA8551B. The internal oscillator is enabled. The appropriate biasing voltages for the multiplexed LCD waveforms are generated internally. The only other connections required to complete the system are the power supplies (V_{DD}, V_{SS}, and V_{LCD}) and the LCD panel chosen for the application.

8.1 LCD bias generator

Fractional LCD biasing voltages are obtained from an internal voltage divider of three impedances connected between V_{LCD} and V_{SS}. These intermediate levels are tapped

off at positions of $\frac{1}{3}$ and $\frac{2}{3}$, or $\frac{1}{2}$, depending on the bias mode chosen. To keep current consumption to a minimum, on-chip low-power buffers provide these levels to the display.

8.2 LCD voltage selector

The LCD voltage selector coordinates the multiplexing of the LCD in accordance with the selected LCD drive configuration. The operation of the voltage selector is controlled by the Display_ctrl_1 command (see [Table 6](#)). The biasing configurations that apply to the preferred modes of operation, together with the biasing characteristics as functions of V_{LCD} and the resulting discrimination ratios (D) are given in [Table 11](#).

Table 11. Biasing characteristics

| LCD drive mode | Number of: | | LCD bias configuration | $\frac{V_{off(RMS)}}{V_{LCD}}$ | $\frac{V_{on(RMS)}}{V_{LCD}}$ | $D = \frac{V_{on(RMS)}}{V_{off(RMS)}}$ |
|----------------|------------|--------|------------------------|--------------------------------|-------------------------------|--|
| | Backplanes | Levels | | | | |
| static | 1 | 2 | static | 0 | 1 | ∞ |
| 1:2 multiplex | 2 | 3 | $\frac{1}{2}$ | 0.354 | 0.791 | 2.236 |
| 1:2 multiplex | 2 | 4 | $\frac{1}{3}$ | 0.333 | 0.745 | 2.236 |
| 1:3 multiplex | 3 | 4 | $\frac{1}{3}$ | 0.333 | 0.638 | 1.915 |
| 1:4 multiplex | 4 | 4 | $\frac{1}{3}$ | 0.333 | 0.577 | 1.732 |

A practical value for V_{LCD} is determined by equating $V_{off(RMS)}$ with a defined LCD threshold voltage ($V_{th(off)}$), typically when the LCD exhibits approximately 10 % contrast. In the static drive mode, a suitable choice is $V_{LCD} > 3V_{th(off)}$.

Multiplex drive modes of 1:3 and 1:4 with $\frac{1}{2}$ bias are possible but the discrimination and hence the contrast ratios are smaller.

Bias is calculated with [Equation 2](#)

$$\frac{1}{1+a_{bias}} \quad (2)$$

The values for a_{bias} are:

$$a_{bias} = 1 \text{ for } \frac{1}{2} \text{ bias}$$

$$a_{bias} = 2 \text{ for } \frac{1}{3} \text{ bias}$$

The RMS on-state voltage ($V_{on(RMS)}$) for the LCD is calculated with [Equation 3](#):

$$V_{on(RMS)} = \frac{V_{LCD}}{n_{MUX}} \sqrt{\frac{a_{bias}^2 + 2a_{bias} + n_{MUX}}{(1+a_{bias})^2}} \quad (3)$$

where the values for n are

$$n_{MUX} = 1 \text{ for static drive mode}$$

$$n_{MUX} = 2 \text{ for 1:2 multiplex drive mode}$$

$$n_{MUX} = 3 \text{ for 1:3 multiplex drive mode}$$

$$n_{MUX} = 4 \text{ for 1:4 multiplex drive mode}$$

The RMS off-state voltage ($V_{off(RMS)}$) for the LCD is calculated with [Equation 4](#):

$$V_{off(RMS)} = \frac{V_{LCD}}{n_{MUX}} \sqrt{\frac{a_{bias}^2 - 2a_{bias} + n_{MUX}}{(1+a_{bias})^2}} \quad (4)$$

Discrimination is a term which is defined as the ratio of the on and off RMS voltages ($V_{on(RMS)}$ to $V_{off(RMS)}$) across a segment. It can be thought of as a measurement of contrast. Discrimination is determined from [Equation 5](#):

$$D = \frac{V_{on(RMS)}}{V_{off(RMS)}} = \sqrt{\frac{a_{bias}^2 + 2a_{bias} + n_{MUX}}{a_{bias}^2 - 2a_{bias} + n_{MUX}}} \quad (5)$$

Using [Equation 5](#), the discrimination for an LCD drive mode of 1:3 multiplex with $\frac{1}{2}$ bias is $\sqrt{3} = 1.732$ and the discrimination for an LCD drive mode of 1:4 multiplex with $\frac{1}{2}$ bias is $\frac{\sqrt{21}}{3} = 1.528$.

The advantage of these LCD drive modes is a reduction of the LCD full scale voltage V_{LCD} as follows:

- 1:3 multiplex ($\frac{1}{2}$ bias): $V_{LCD} = \sqrt{6} \times V_{off(RMS)} = 2.449V_{off(RMS)}$
- 1:4 multiplex ($\frac{1}{2}$ bias): $V_{LCD} = \left[\frac{4 \times \sqrt{3}}{3} \right] = 2.309V_{off(RMS)}$

These compare with $V_{LCD} = 3V_{off(RMS)}$ when $\frac{1}{3}$ bias is used.

V_{LCD} is sometimes referred as the LCD operating voltage.

8.2.1 Electro-optical performance

Suitable values for $V_{on(RMS)}$ and $V_{off(RMS)}$ are dependent on the LCD liquid used. The RMS voltage, at which a pixel will be switched on or off, determine the transmissibility of the pixel.

For any given liquid, there are two threshold values defined. One point is at 10 % relative transmission (at $V_{th(off)}$) and the other at 90 % relative transmission (at $V_{th(on)}$), see [Figure 11](#). For a good contrast performance, the following rules should be followed:

$$V_{on(RMS)} \geq V_{th(on)} \quad (6)$$

$$V_{off(RMS)} \leq V_{th(off)} \quad (7)$$

$V_{on(RMS)}$ (see [Equation 3](#)) and $V_{off(RMS)}$ (see [Equation 5](#)) are properties of the display driver and are affected by the selection of a_{bias} , n_{MUX} , and the V_{LCD} voltage.

$V_{th(off)}$ and $V_{th(on)}$ are properties of the LCD liquid and can be provided by the module manufacturer. $V_{th(off)}$ is sometimes named V_{th} . $V_{th(on)}$ is sometimes named saturation voltage V_{sat} .

It is important to match the module properties to those of the driver in order to achieve optimum performance.

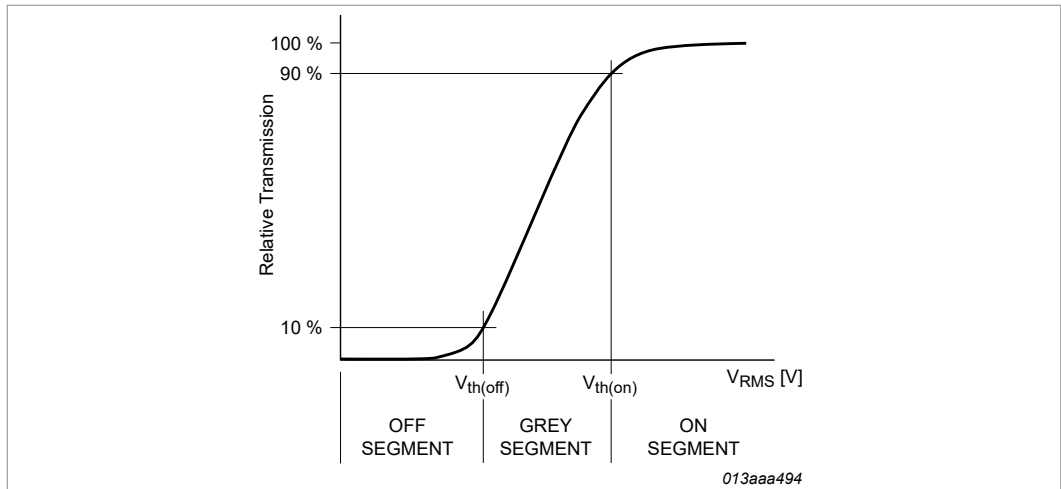
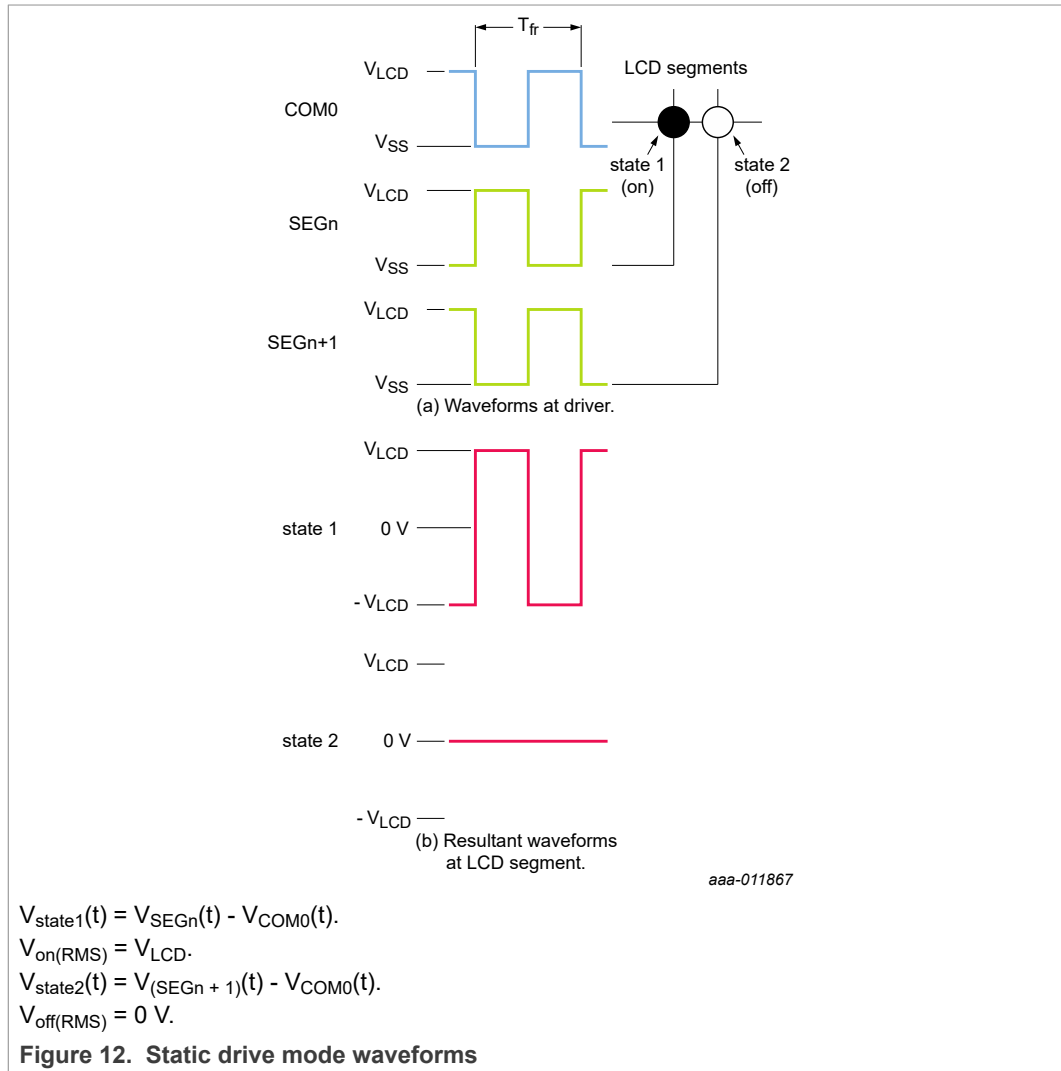


Figure 11. Electro-optical characteristic: relative transmission curve of the liquid

8.2.2 LCD drive mode waveforms

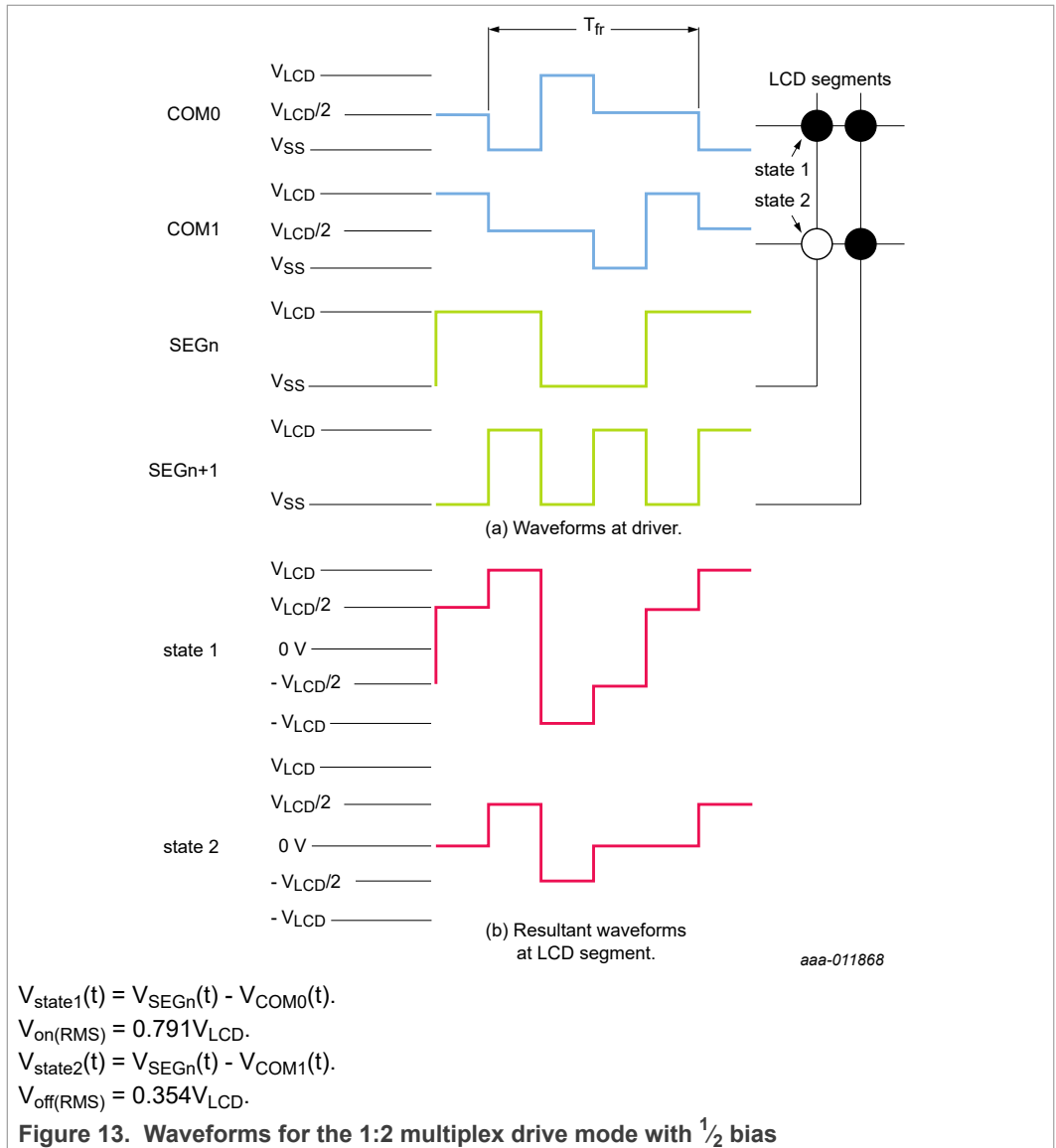
8.2.2.1 Static drive mode

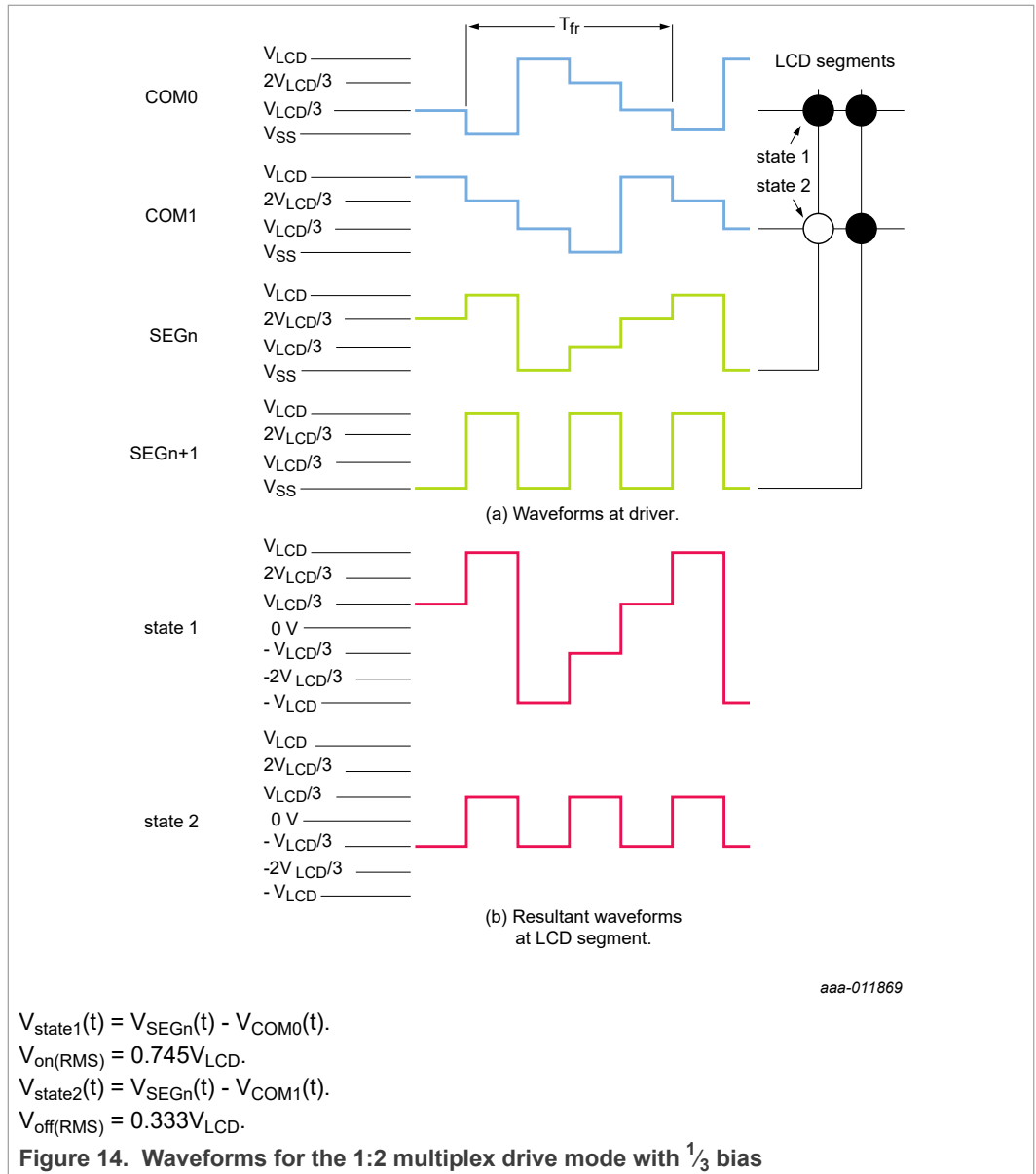
The static LCD drive mode is used when a single backplane is provided in the LCD. The backplane (COMn) and segment (SEGN) drive waveforms for this mode are shown in [Figure 12](#).



8.2.2.2 1:2 Multiplex drive mode

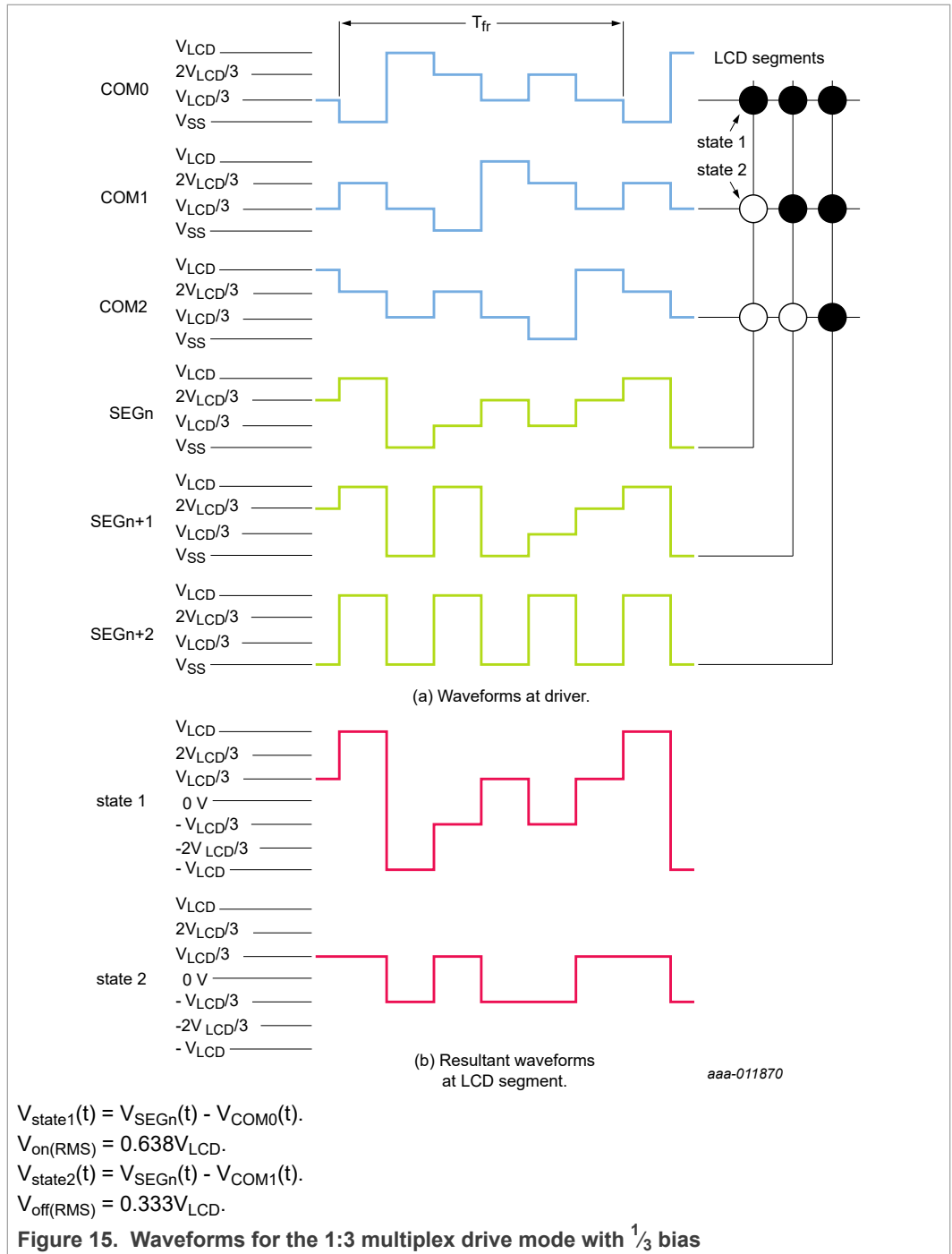
When two backplanes are provided in the LCD, the 1:2 multiplex mode applies. The PCA8551 allows the use of $\frac{1}{2}$ bias or $\frac{1}{3}$ bias in this mode as shown in [Figure 13](#) and [Figure 14](#).





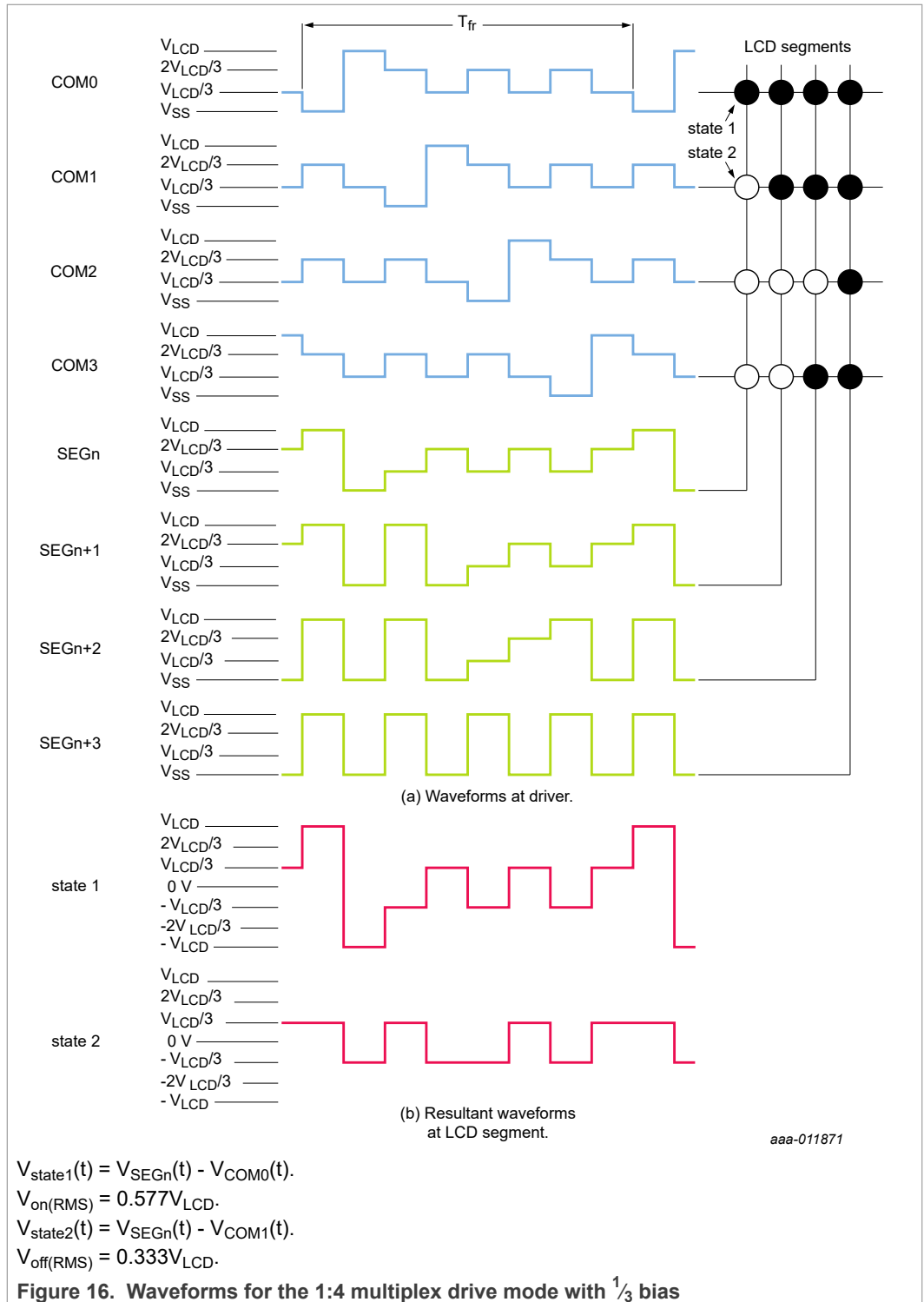
8.2.2.3 1:3 Multiplex drive mode

When three backplanes are provided in the LCD, the 1:3 multiplex drive mode applies, as shown in [Figure 15](#).



8.2.2.4 1:4 Multiplex drive mode

When four backplanes are provided in the LCD, the 1:4 multiplex drive mode applies as shown in [Figure 16](#).



8.3 Backplane and segment outputs

8.3.1 Backplane outputs

The LCD drive section includes four backplane outputs COM0 to COM3, which must be directly connected to the LCD. The backplane output signals are generated in accordance with the selected LCD drive mode. If less than four backplane outputs are required, the unused outputs can be left open-circuit.

- In 1:3 multiplex drive mode, COM3 carries the same signal as COM1, therefore these two outputs can be tied together to give enhanced drive capabilities
- In 1:2 multiplex drive mode, COM0 and COM2, respectively, COM1 and COM3 all carry the same signals and may also be paired to increase the drive capabilities
- In static drive mode, the same signal is carried by all four backplane outputs and they can be connected in parallel for very high drive requirements

8.3.2 Segment outputs

The LCD drive section includes 36 segment outputs SEG0 to SEG35, which must be directly connected to the LCD. The segment output signals are generated in accordance with the multiplexed backplane signals and with data residing in the display registers. When less than 36 segment outputs are required, the unused segment outputs must be left open-circuit.

9 Power Sequencing

9.1 Power-on

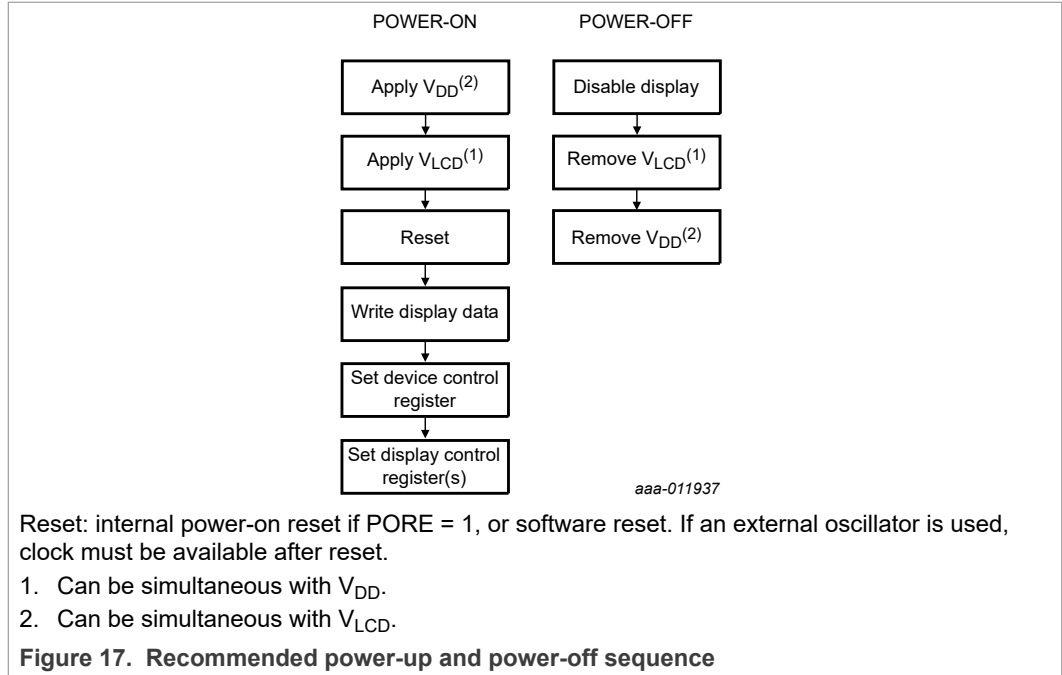
To avoid unwanted artifacts on the display, V_{LCD} must never be asserted before V_{DD} , it is permitted to assert V_{DD} and V_{LCD} at the same time.

9.2 Power-off

Before turning the power to the device off, the display must be disabled by setting bit DE to logic 0. To avoid unwanted artifacts on the display, V_{LCD} must never be connected, while V_{DD} is switched off. It is permitted to switch off V_{DD} and V_{LCD} simultaneously.

9.3 Power sequences

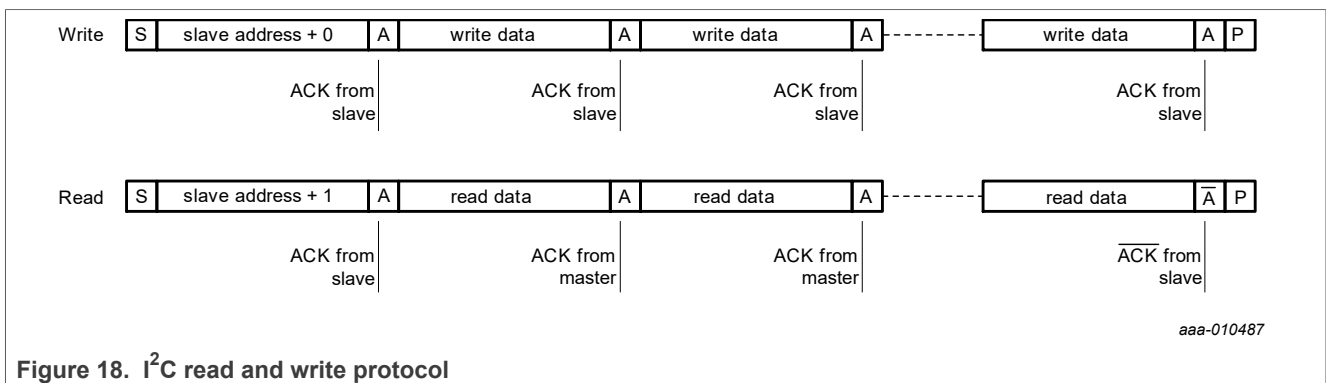
[Figure 17](#) depicts the recommended power-up and power-off sequence.



10 Bus interfaces

10.1 I²C-bus interface of the PCA8551A

The I²C-bus is for bidirectional, two-line communication between different ICs. 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. Data transfer may be initiated only when the bus is not busy. Both data and clock lines remain HIGH when the bus is not busy. The PCA8551A acts as a slave receiver when being written to and as a slave transmitter when being read from.



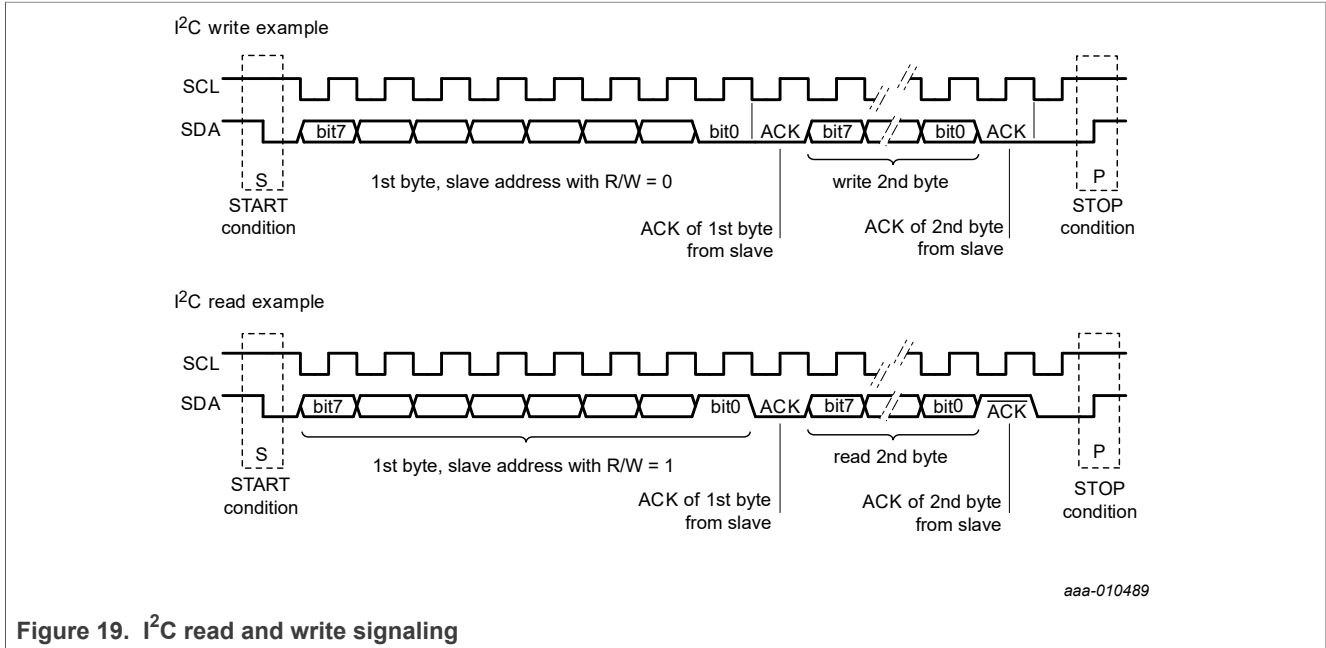


Figure 19. I²C read and write signaling

10.1.1 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 are interpreted as STOP or START conditions.

10.1.2 START and STOP conditions

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 19](#)).

10.1.3 Acknowledge

Each byte of 8 bits is followed by an acknowledge cycle. An acknowledge is defined as logic 0. A not-acknowledge is defined as logic 1.

When written to, the slave will generate an acknowledge after the reception of each byte. After the acknowledge, another byte may be transmitted. It is also possible to send a STOP or START condition.

When read from, the master receiver must generate an acknowledge after the reception of each byte. When the master receiver no longer requires bytes to be transmitted, it must generate a not-acknowledge. After the not-acknowledge, either a STOP or START condition must be sent.

Remark: The PCA8551A omits the not-acknowledge. After the last byte read, the end of transmission is indicated by a STOP or START condition from the master.

A detailed description of the I²C-bus specification is given in [\[5\]](#).

10.1.4 I²C interface protocol

The PCA8551A uses the I²C interface for data transfer. Interpretation of the data is determined by the interface protocol.

10.1.4.1 Write protocol

After the I²C slave address is transmitted, the PCA8551A requires that the register address pointer is defined. It can take the value 00h to 17h. Values outside of that range will result in the transfer being ignored, however the slave will still respond with acknowledge pulses.

After the register address has been transmitted, write data is transmitted. The minimum number of data write bytes is 0 and the maximum number is unlimited. After each write, the address pointer increments by one. After address 17h, the address pointer stops incrementing at 18h.

- I²C START condition
- I²C slave address + write
- start register pointer
- write data
- write data
- :
- write data
- I²C STOP condition; an I²C RE-START condition is also possible.

10.1.4.2 Read protocol

When reading the PCA8551A, reading starts at the current position of the address pointer. The address pointer for read data should first be defined by a write sequence.

- I²C START condition
- I²C slave address + write
- start address pointer
- I²C STOP condition; an I²C RE-START condition is also possible.

After setting the address pointer, a read can be executed. After the I²C slave address is transmitted, the PCA8551A will immediately output read data. After each read, the address pointer increments by one. After address 17h, the address pointer stops incrementing at 18h.

- I²C START condition
- I²C slave address + read
- read data (master sends acknowledge bit)
- read data (master sends acknowledge bit)
- :

10.1.4.3 I²C-bus slave address

Device selection depends on the I²C-bus slave address (see [Table 12](#)).

Table 12. I²C slave address byte

| | | Slave address | | | | | | | |
|-----|----------|---------------|---|---|---|---|---|----------|--|
| Bit | 7 MSB | 6 | 5 | 4 | 3 | 2 | 1 | 0 LSB | |
| | 0 | 1 | 1 | 1 | 0 | 0 | 0 | R/W | |

The least significant bit of the slave address byte is bit R/W (see Table 13).

Table 13. R/W-bit description

| R/W | Description |
|-----|-------------|
| 0 | write data |
| 1 | read data |

10.2 SPI-bus interface of the PCA8551B

Data transfer to the device is made via a 3-line SPI-bus (see Table 14). There is no dedicated output data line. The SPI-bus is initialized whenever the chip enable line pin \overline{CE} is pulled down.

Table 14. Serial interface

| Symbol | Function | Description |
|-----------------|---|---|
| \overline{CE} | chip enable input ^[1] ; active LOW | when HIGH, the interface is reset |
| SCL | serial clock input | input may be higher than V _{DD} |
| SDIO | serial data input/output | input data are sampled on the rising edge of SCL, output data are valid after the falling edge of SCL |

[1] The chip enable must not be wired permanently LOW.

10.2.1 Data transmission

The chip enable signal is used to identify the transmitted data. Each data transfer is a byte with the Most Significant Bit (MSB) sent first.

The transmission is controlled by the active LOW chip enable signal \overline{CE} . The first byte transmitted is the register address comprising of the address pointer and the R/W bit.

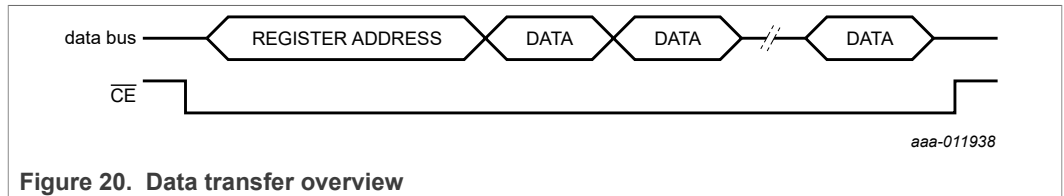


Figure 20. Data transfer overview

Table 15. Address byte definition

| Bit | Symbol | Value | Description |
|-----|--------|-------|-------------------------------------|
| 7 | R/W | | data read or write selection |
| | | 0 | write data |
| | | 1 | read data |

Table 15. Address byte definition...continued

| Bit | Symbol | Value | Description |
|--------|---------|------------|--|
| 6 to 5 | - | 00 | default value |
| 4 to 0 | AP[4:0] | | pointer to register start address |
| | | 00h to 17h | valid range; other addresses are ignored |

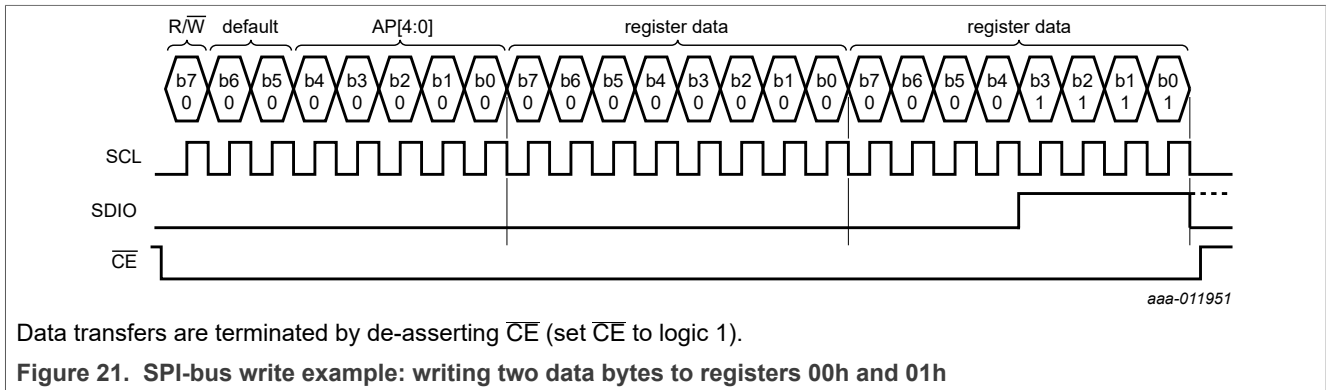
After the register address byte, the register contents follows with the address pointer being auto-incremented after every eighth bit sent (see [Section 7.1](#)).

10.2.1.1 Write protocol

After the \overline{CE} is set LOW, the PCA8551B requires that R/\overline{W} and the register address pointer is defined. It can take the value 00h to 17h. Values outside of that range will result in the transfer being ignored.

After the register address has been transmitted, write data is transmitted. The minimum number of data write bytes is 0 and the maximum number is unlimited. After each write, the address pointer increments by one. After address 17h, the address pointer stops incrementing at 18h.

- \overline{CE} set LOW
- $R/\overline{W} = 0$ and register address
- write data
- write data
- :
- write data
- \overline{CE} set HIGH

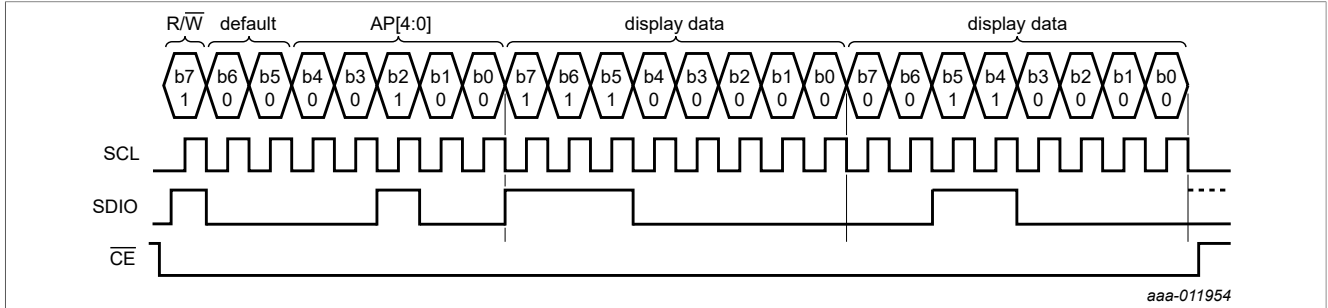


10.2.1.2 Read protocol

When reading the PCA8551B, reading starts at the defined position of the address pointer. After setting the address pointer, the read can be executed. After each read, the address pointer increments by one. After address 17h, the address pointer stops incrementing at 18h.

- \overline{CE} set LOW
- $R/\overline{W} = 1$ and register address
- read data
- read data
- :

- \overline{CE} set HIGH



Data transfers are terminated by de-asserting \overline{CE} (set \overline{CE} to logic 1).

Figure 22. SPI-bus read example: reading two data bytes from registers 04h and 05h

10.3 EMC detection

The PCA8551 is ruggedized against EMC susceptibility; however it is not possible to cover all cases. To detect if a severe EMC event has occurred, it is possible to check the responsiveness of the device by reading its registers.

11 Internal circuitry

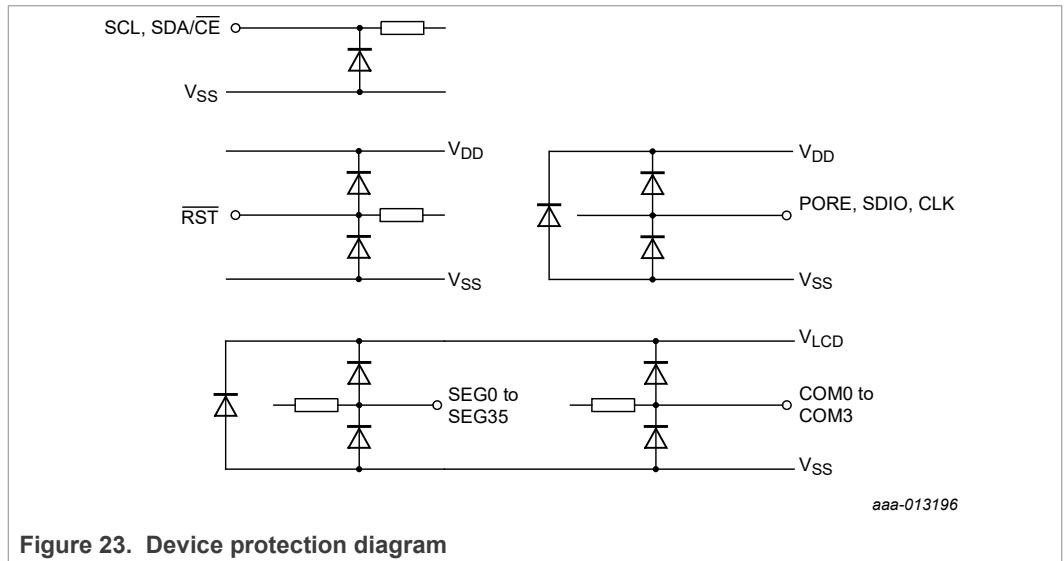



Figure 23. Device protection diagram

12 Safety notes

CAUTION



This device is sensitive to ElectroStatic Discharge (ESD). Observe precautions for handling electrostatic sensitive devices. Such precautions are described in the *ANSI/ESD S20.20*, *IEC/ST 61340-5*, *JESD625-A* or equivalent standards.

CAUTION



Static voltages across the liquid crystal display can build up when the LCD supply voltage (V_{LCD}) is on while the IC supply voltage (V_{DD}) is off, or vice versa. This may cause unwanted display artifacts. To avoid such artifacts, V_{LCD} and V_{DD} must be applied or removed together.

13 Limiting values

Table 16. Limiting values

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

| Symbol | Parameter | Conditions | Min | Max | Unit | |
|---------------|---------------------------------|-----------------------------------|------|------|--------|----|
| V_{DD} | supply voltage | | -0.5 | +6.5 | V | |
| V_{LCD} | LCD supply voltage | | -0.5 | +6.5 | V | |
| V_I | input voltage | | -0.5 | +6.5 | V | |
| V_O | output voltage | | -0.5 | +6.5 | V | |
| I_I | input current | | -10 | +10 | mA | |
| I_O | output current | | -10 | +10 | mA | |
| I_{DD} | supply current | | -50 | +50 | mA | |
| $I_{DD(LCD)}$ | LCD supply current | | -50 | +50 | mA | |
| I_{SS} | ground supply current | | -50 | +50 | mA | |
| P_{tot} | total power dissipation | | - | 100 | mW | |
| P_o | output power | | - | 100 | mW | |
| V_{ESD} | electrostatic discharge voltage | HBM | [1] | | | |
| | | on pins SCL, SDA, \overline{CE} | | - | ±2 000 | V |
| | | on all other pins | | - | ±3 500 | V |
| | | CDM | [2] | | | |
| | | on corner pins | | - | 750 | V |
| | on all other pins | | - | 500 | V | |
| I_{lu} | latch-up current | | [3] | - | 200 | mA |
| T_{stg} | storage temperature | | [4] | -55 | +150 | °C |
| T_{amb} | ambient temperature | operating device | | -40 | +105 | °C |

[1] Pass level; Human Body Model (HBM), according to [1].

[2] Pass level; Charged-Device Model (CDM), according to [2].

[3] Pass level; latch-up testing according to [3] at maximum ambient temperature ($T_{amb(max)}$).

[4] According to the store and transport requirements (see [6]) the devices have to be stored at a temperature of +8 °C to +45 °C and a humidity of 25 % to 75 %.

14 Characteristics

Table 17. Electrical characteristics
 $V_{DD} = 1.8\text{ V to }5.5\text{ V}; V_{SS} = 0\text{ V}; V_{LCD} = 1.8\text{ V to }5.5\text{ V}; T_{amb} = -40\text{ }^{\circ}\text{C to }+105\text{ }^{\circ}\text{C};$ unless otherwise specified.

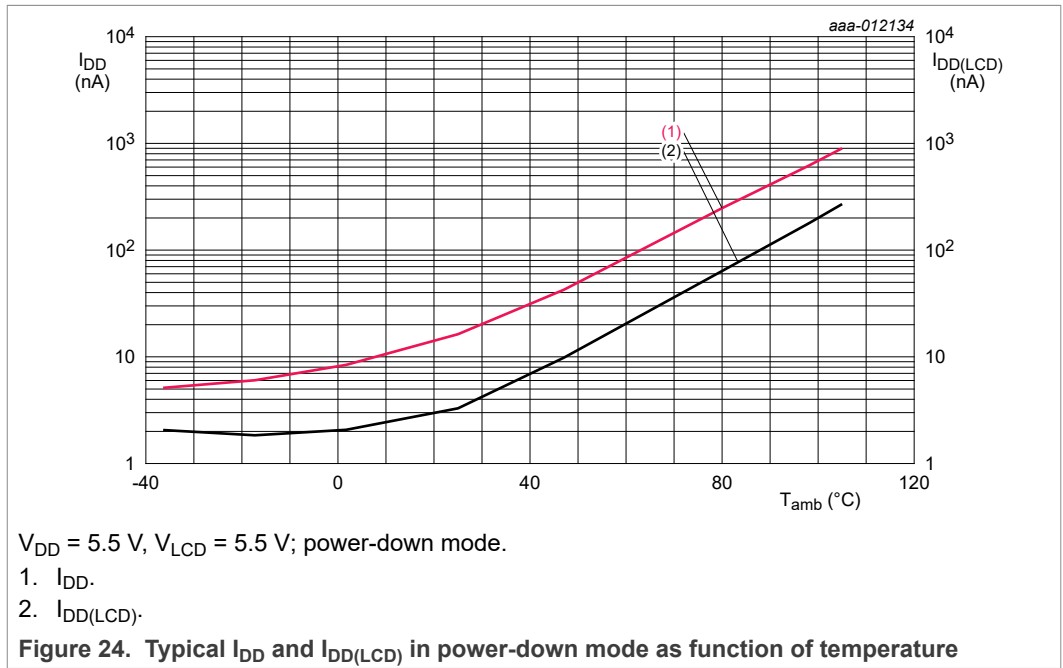
| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|--|---------------------------------|---|-----------------|-----|-------------|---------------|
| Supplies | | | | | | |
| V_{DD} | supply voltage | | 1.8 | - | 5.5 | V |
| V_{LCD} | LCD supply voltage | | 1.8 | - | 5.5 | V |
| I_{DD} | supply current | $f_{fr} = 64\text{ Hz};$ no bus activity | | | | |
| | | $V_{DD} = 3.3\text{ V}; T_{amb} = 25\text{ }^{\circ}\text{C}$ | - | 0.6 | - | μA |
| | | $V_{DD} = 5.5\text{ V}; T_{amb} = 105\text{ }^{\circ}\text{C}$ | - | 1.8 | 3.0 | μA |
| $I_{DD(LCD)}$ | LCD supply current | $f_{fr} = 64\text{ Hz};$ no bus activity | [1] | | | |
| | | $V_{LCD} = 5.5\text{ V}; T_{amb} = 105\text{ }^{\circ}\text{C};$ BOOST = 0; no display load | - | 3.7 | 4.7 | μA |
| | | $V_{LCD} = 3.3\text{ V}; T_{amb} = 25\text{ }^{\circ}\text{C}$ | | | | |
| | | BOOST = 0; no display load | - | 2.5 | - | μA |
| | | BOOST = 0; display enabled; display load $C_L = 1.4\text{ nF}$ | - | 4.5 | - | μA |
| | | BOOST = 1; display enabled; display load $C_L = 1.4\text{ nF}$ | - | 5.5 | - | μA |
| V_{IL} | LOW-level input voltage | | V_{SS} | - | $0.3V_{DD}$ | V |
| V_{IH} | HIGH-level input voltage | | [2] $0.7V_{DD}$ | - | V_{DD} | V |
| I_{OL} | LOW-level output current | output sink current; $V_{OL} = 0.4\text{ V}; V_{DD} = 5\text{ V}$ | | | | |
| | | on pin CLK | 2 | - | - | mA |
| | | on pin SDIO | 2 | - | - | mA |
| | | on pin SDA | 3 | - | - | mA |
| I_{OH} | HIGH-level output current | output source current; on pins SDIO, CLK; $V_{OH} = 4.6\text{ V}; V_{DD} = 5\text{ V}$ | 2 | - | - | mA |
| I_L | leakage current | any input pin except for $\overline{\text{RST}}$ | - | 0 | - | nA |
| | | after ESD event | -1 000 | - | +1 000 | nA |
| $R_{pu(RST_n)}$ | pull-up resistance on pin RST_N | | - | 100 | - | k Ω |
| LCD outputs (pins SEG0 to SEG17 and COM0 to COM3) | | | | | | |
| ΔV_o | output voltage variation | $V_{LCD} = 5\text{ V}$ | -100 | - | +100 | mV |

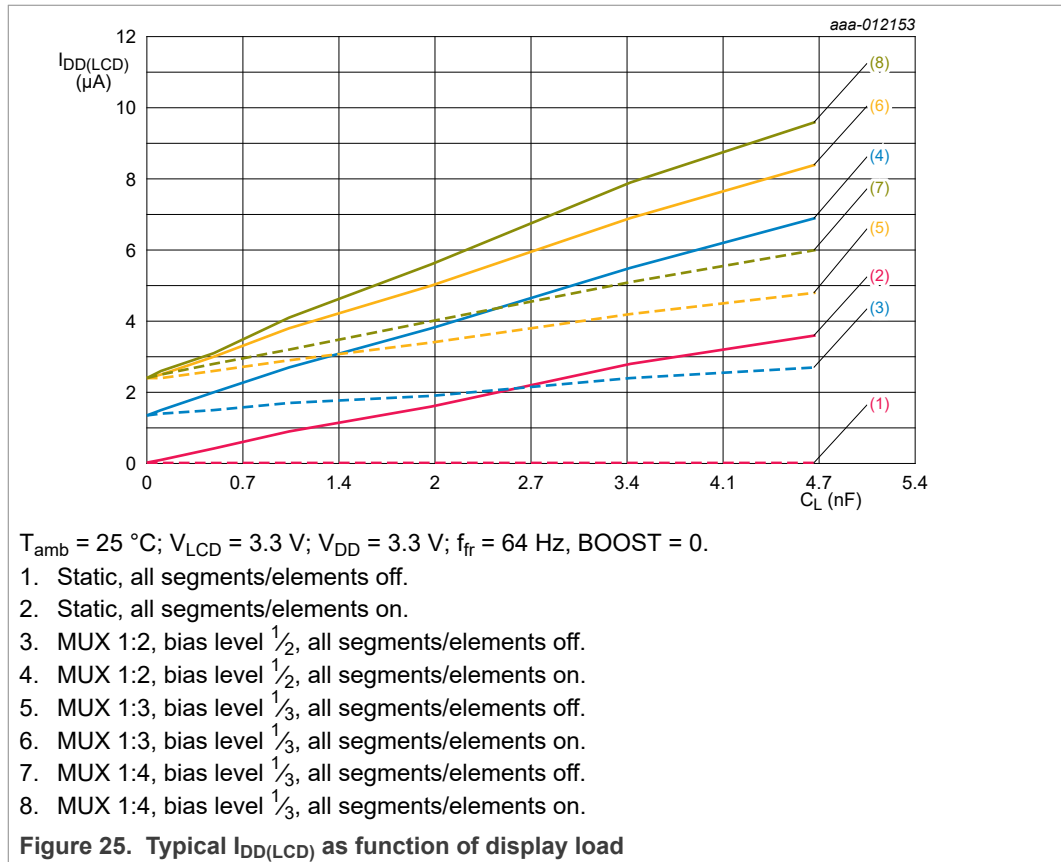
Table 17. Electrical characteristics...continued

$V_{DD} = 1.8\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $V_{LCD} = 1.8\text{ V to }5.5\text{ V}$; $T_{amb} = -40\text{ }^{\circ}\text{C to }+105\text{ }^{\circ}\text{C}$; unless otherwise specified.

| Symbol | Parameter | Conditions | | Min | Typ | Max | Unit |
|--------|-------------------|------------------------|-----|-----|-----|-----|------------|
| R_o | output resistance | $V_{LCD} = 5\text{ V}$ | [3] | - | 1.5 | 3 | k Ω |

- [1] For typical values, also see [Figure 24](#) to [Figure 26](#).
- [2] I²C pins SCL and SDA have no diode to V_{DD} and may be driven up to 5.5 V.
- [3] Outputs measured one at a time.





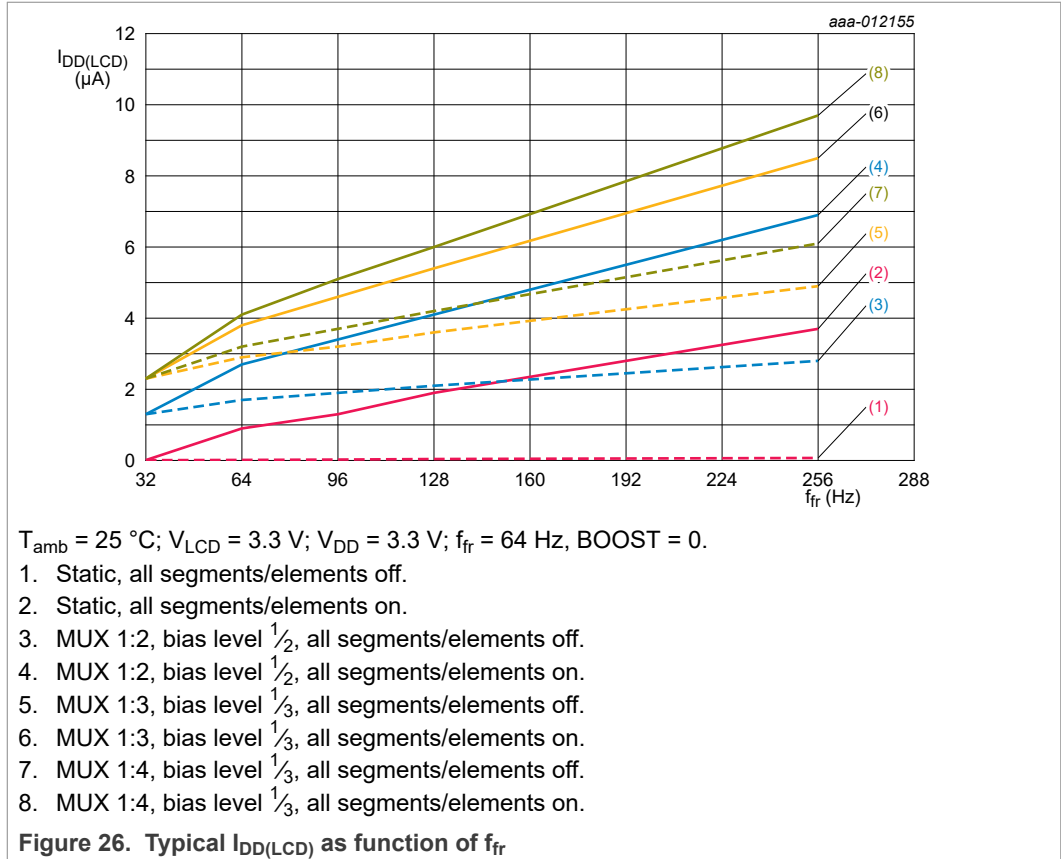


Table 18. Frequency characteristics

$V_{DD} = 1.8\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $V_{LCD} = 1.8\text{ V to }5.5\text{ V}$; $T_{amb} = -40\text{ }^{\circ}C\text{ to }+105\text{ }^{\circ}C$; unless otherwise specified.

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|----------------|--------------------------|---|-------|------|------|---------|
| f_{fr} | frame frequency | FF[2:0] = 000 | - | 32 | - | Hz |
| | | FF[2:0] = 001 | 42 | 64 | 86 | Hz |
| | | FF[2:0] = 010 | - | 96 | - | Hz |
| | | FF[2:0] = 011 | - | 128 | - | Hz |
| | | FF[2:0] = 100 | - | 160 | - | Hz |
| | | FF[2:0] = 101 | - | 192 | - | Hz |
| | | FF[2:0] = 110 | - | 224 | - | Hz |
| | | FF[2:0] = 111 | - | 256 | - | Hz |
| $f_{clk(int)}$ | internal clock frequency | $f_{fr} = 64\text{ Hz}$, $n_{MUX} = 4$ | [1] - | 1024 | - | Hz |
| $f_{clk(ext)}$ | external clock frequency | | [1] - | - | 4096 | Hz |
| $t_{clk(H)}$ | HIGH-level clock time | external clock | 60 | - | - | μs |
| $t_{clk(L)}$ | LOW-level clock time | external clock | 60 | - | - | μs |
| $t_{w(rst)}$ | reset pulse width | on pin RST | 10 | - | - | μs |

[1] $f_{clk(int)} = 2 \cdot f_{fr} \cdot n_{MUX}$ or $f_{clk(ext)} = 2 \cdot f_{fr} \cdot n_{MUX}$ respectively (see Table 5 and Table 6).

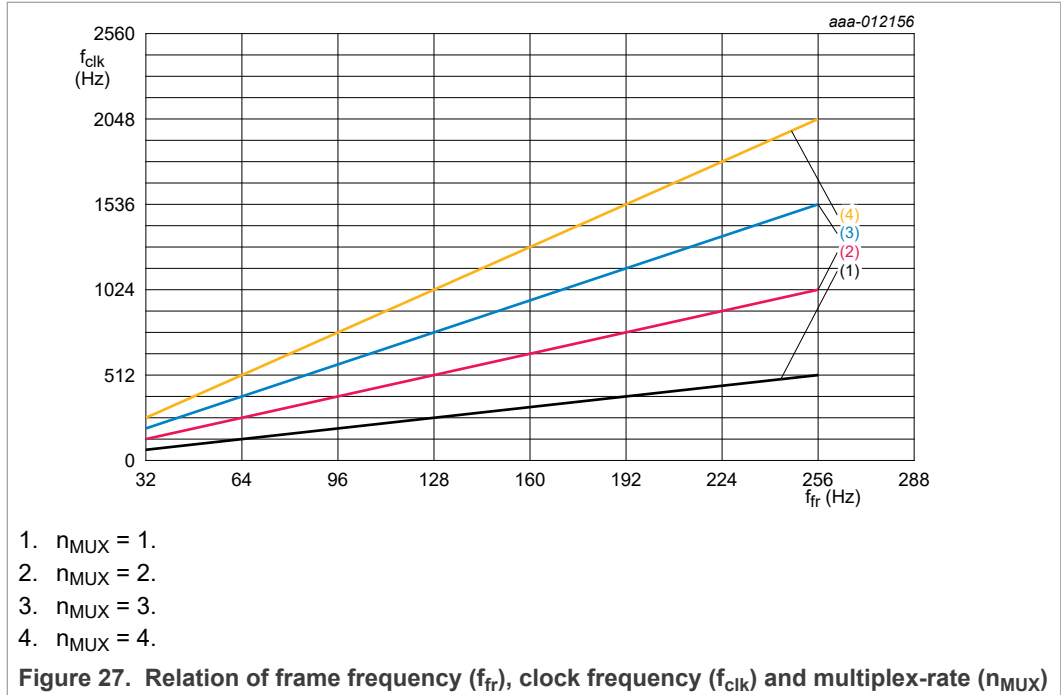


Table 19. I²C-bus characteristics

$V_{DD} = 1.8\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$; unless otherwise specified; all timing values are valid within the operating supply voltage and T_{amb} range and are referenced to V_{IL} and V_{IH} with an input voltage swing of V_{SS} to V_{DD} .^[1]

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-------------------------|--|------------|-----|-----|-----|---------------|
| Pin SCL | | | | | | |
| f_{SCL} | SCL clock frequency | | - | - | 400 | kHz |
| t_{LOW} | LOW period of the SCL clock | | 1.3 | - | - | μs |
| t_{HIGH} | HIGH period of the SCL clock | | 0.6 | - | - | μs |
| Pin SDA | | | | | | |
| $t_{SU;DAT}$ | data set-up time | | 100 | - | - | ns |
| $t_{HD;DAT}$ | data hold time | | 0 | - | - | ns |
| Pins SCL and SDA | | | | | | |
| t_{BUF} | bus free time between a STOP and START condition | | 1.3 | - | - | μs |
| $t_{SU;STO}$ | set-up time for STOP condition | | 0.6 | - | - | μs |
| $t_{HD;STA}$ | hold time (repeated) START condition | | 0.6 | - | - | μs |
| $t_{SU;STA}$ | set-up time for a repeated START condition | | 0.6 | - | - | μs |

Table 19. I²C-bus characteristics...continued

$V_{DD} = 1.8\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$; unless otherwise specified; all timing values are valid within the operating supply voltage and T_{amb} range and are referenced to V_{IL} and V_{IH} with an input voltage swing of V_{SS} to V_{DD} .^[1]

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|-----------------------|---------------------------------------|-----------------------------|-----|-----|-----|---------------|
| t_r | rise time of both SDA and SCL signals | $f_{SCL} = 400\text{ kHz}$ | - | - | 0.3 | μs |
| t_f | fall time of both SDA and SCL signals | | - | - | 0.3 | μs |
| C_b | capacitive load for each bus line | | - | - | 400 | pF |
| $t_{w(\text{spike})}$ | spike pulse width | on the I ² C-bus | - | - | 50 | ns |

[1] The I²C-bus interface of PCA8551A is 5 V tolerant.

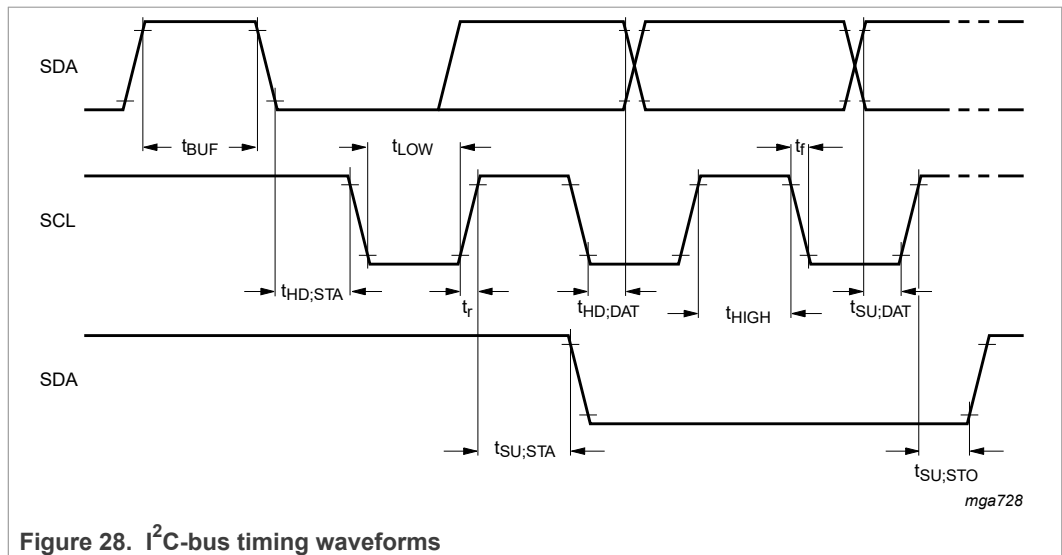


Figure 28. I²C-bus timing waveforms

Table 20. SPI-bus characteristics

$V_{DD} = 1.8\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$; unless otherwise specified; all timing values are valid within the operating supply voltage and T_{amb} range and are referenced to V_{IL} and V_{IH} with an input voltage swing of V_{SS} to V_{DD} .

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|----------------|------------------------------|------------|-----|-----|-----|------|
| Pin SCL | | | | | | |
| f_{SCL} | SCL clock frequency | | - | - | 5 | MHz |
| t_{LOW} | LOW period of the SCL clock | | 150 | - | - | ns |
| t_{HIGH} | HIGH period of the SCL clock | | 80 | - | - | ns |
| t_r | rise time | | - | - | 100 | ns |
| t_f | fall time | | - | - | 100 | ns |
| Pin CE | | | | | | |

Table 20. SPI-bus characteristics...continued

$V_{DD} = 1.8\text{ V to }5.5\text{ V}$; $V_{SS} = 0\text{ V}$; $T_{amb} = -40\text{ °C to }+105\text{ °C}$; unless otherwise specified; all timing values are valid within the operating supply voltage and T_{amb} range and are referenced to V_{IL} and V_{IH} with an input voltage swing of V_{SS} to V_{DD} .

| Symbol | Parameter | Conditions | Min | Typ | Max | Unit |
|------------------|---------------------------------|----------------------|-----|-----|-----|------|
| $t_{su(CE_N)}$ | CE_N set-up time | | 30 | - | - | ns |
| $t_{h(CE_N)}$ | CE_N hold time | | 10 | - | - | ns |
| $t_{rec(CE_N)}$ | CE_N recovery time | | 70 | - | - | ns |
| Pin SDIO | | | | | | |
| t_{su} | set-up time | write data | 5 | - | - | ns |
| t_h | hold time | write data | 50 | - | - | ns |
| $t_{d(R)SDIO}$ | SDIO read delay time | $C_L = 50\text{ pF}$ | - | - | 150 | ns |
| $t_{dis(SDIO)}$ | SDIO disable time | no load | - | - | 50 | ns |
| $t_t(SDI-SDO)$ | transition time from SDI to SDO | write to read mode | 0 | - | - | ns |

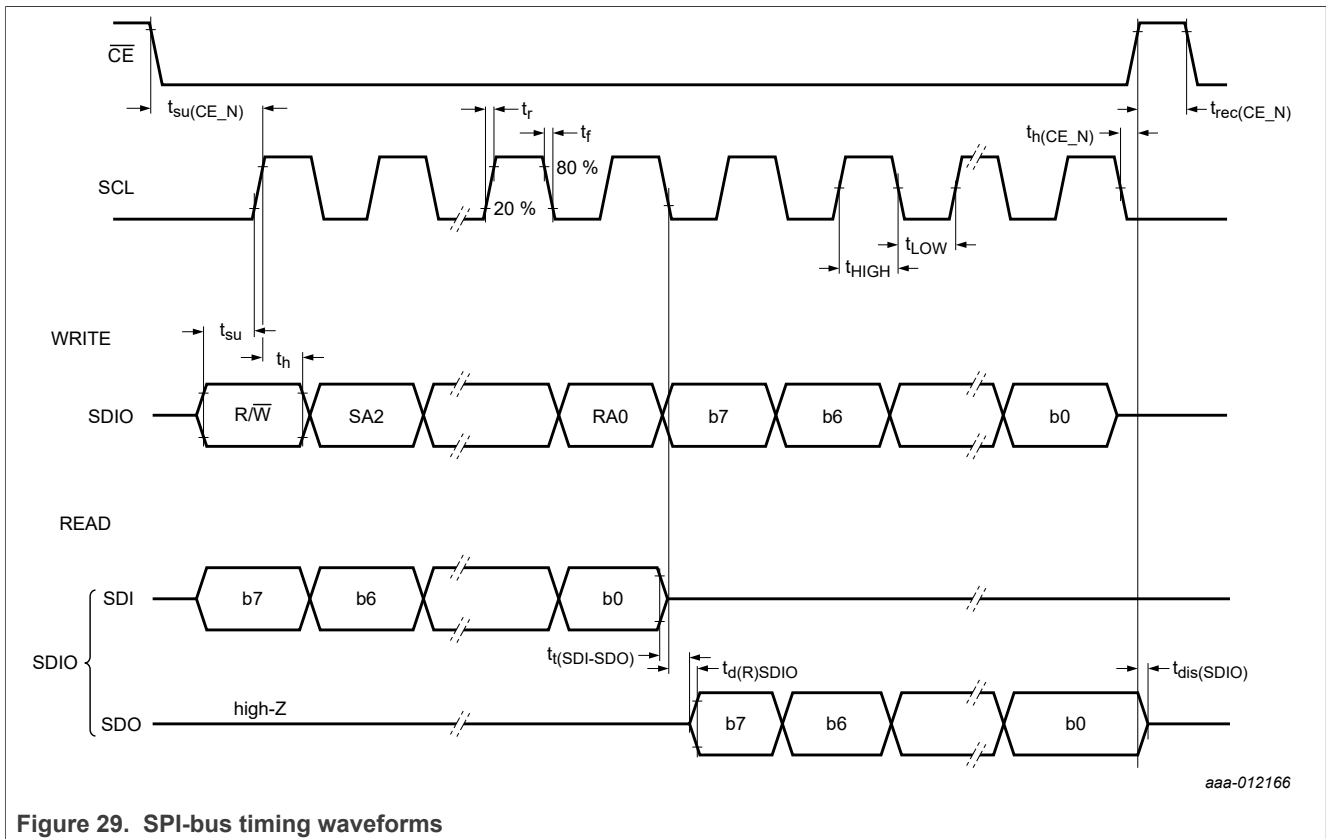


Figure 29. SPI-bus timing waveforms

15 Application information

15.1 Power-on Reset

The built-in POR block acts on the rising edge of the V_{DD} supply voltage. Depending on the V_{DD} rising edge in the application, the POR may not work properly. Therefore to ensure proper device operation it is required to send nine clock pulses immediately after power-on (see also UM10204).

15.2 I²C acknowledge after power-on

If the bus does not show an acknowledge at the first access, the command should be sent a second time.

15.3 Resistors on I/O pins

The pin PORE comprises an internal, latching pull-down device, which keeps the input at a low potential when left open. If the input is supposed to be at logic 0 potential, this pin can be either connected to V_{SS} or left open.

In case the pin is supposed to be at logic 1 potential, it must be connected to V_{DD} to avoid any cross-current during power-up. A series resistance between V_{DD} and PORE must not exceed 1 k Ω to ensure proper functionality.

16 Test information

16.1 Quality information

This product has been qualified in accordance with the Automotive Electronics Council (AEC) standard *Q100 - Failure mechanism based stress test qualification for integrated circuits*, and is suitable for use in automotive applications.

17 Package outline

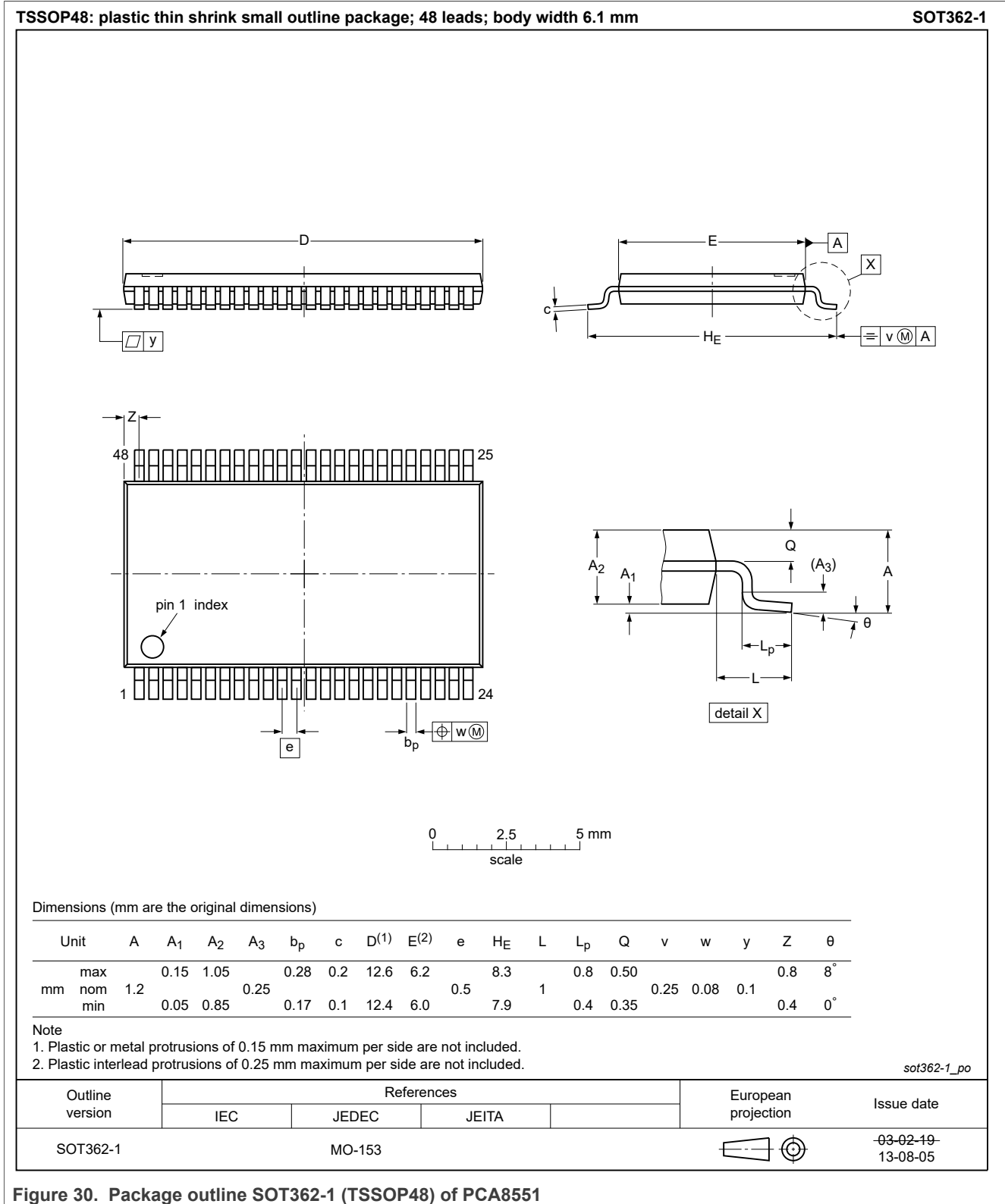


Figure 30. Package outline SOT362-1 (TSSOP48) of PCA8551

18 Handling information

All input and output pins are protected against ElectroStatic Discharge (ESD) under normal handling. When handling Metal-Oxide Semiconductor (MOS) devices ensure that all normal precautions are taken as described in *JESD625-A*, *IEC 61340-5* or equivalent standards.

19 Packing information

19.1 Tape and reel information

For tape and reel packing information, see [\[4\]](#).

20 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"*.

20.1 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.

20.2 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

20.3 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

20.4 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 31](#)) 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 21](#) and [Table 22](#)

Table 21. SnPb eutectic process (from J-STD-020D)

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

Table 22. Lead-free process (from J-STD-020D)

| 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 31](#).

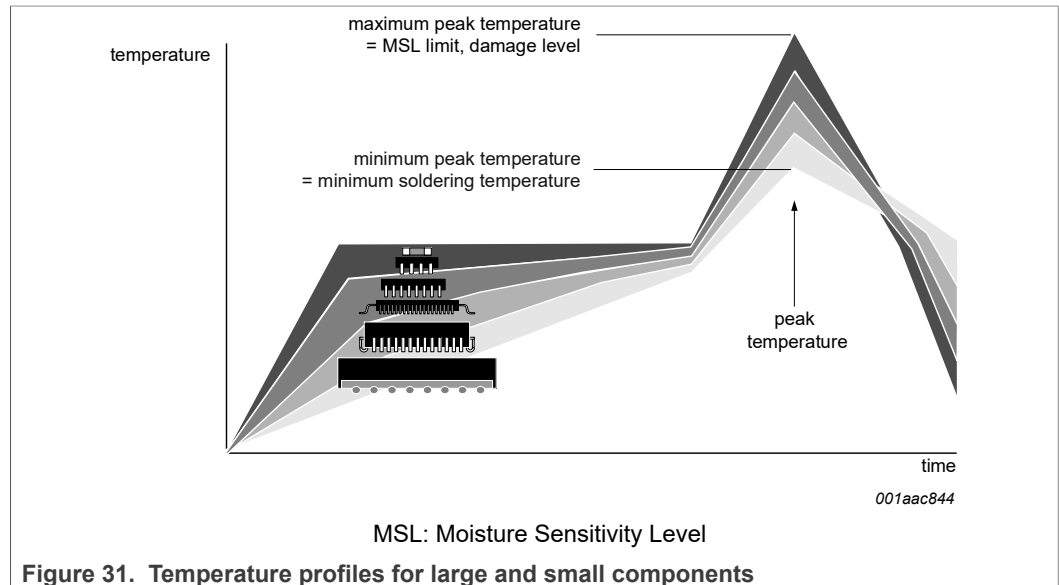


Figure 31. Temperature profiles for large and small components

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

21 Footprint information

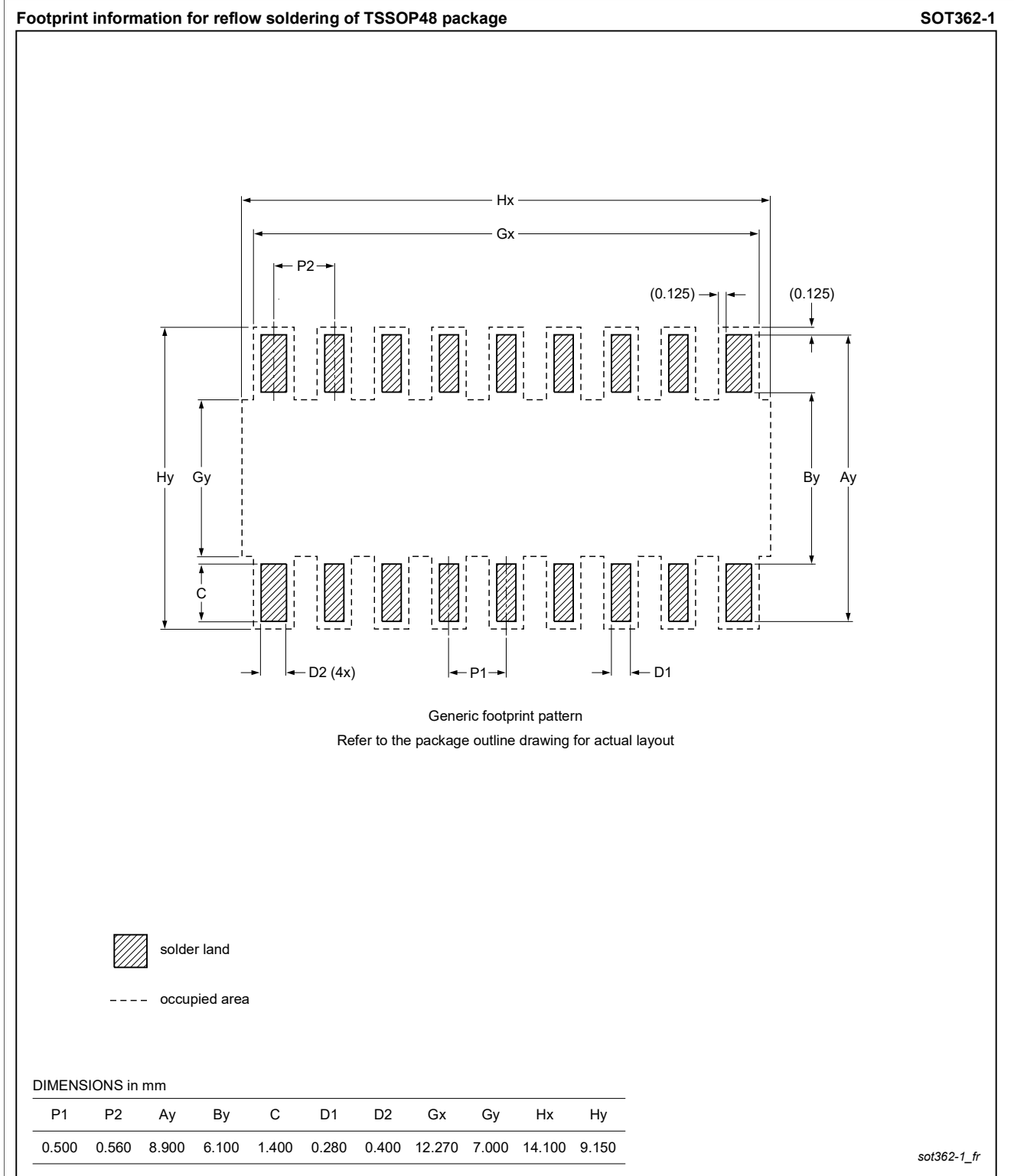


Figure 32. Footprint information for reflow soldering of SOT362-1 (TSSOP48) of PCA8551

22 Appendix

22.1 LCD segment driver selection

Table 23. Selection of LCD segment drivers

| Type name | Number of elements at MUX | | | | | | | V _{DD} (V) | V _{LCD} (V) | f _{fr} (Hz) | V _{LCD} (V) charge pump | V _{LCD} (V) temperature compensat. | T _{amb} (°C) | Interface | Package | AEC-Q100 |
|------------|---------------------------|-----|-----|-----|-----|-----|-----|---------------------|----------------------|--------------------------|-------------------------------------|--|-----------------------|------------------------|----------|----------|
| | 1:1 | 1:2 | 1:3 | 1:4 | 1:6 | 1:8 | 1:9 | | | | | | | | | |
| PCA8553DTT | 40 | 80 | 120 | 160 | - | - | - | 1.8 to 5.5 | 1.8 to 5.5 | 32 to 256 ^[1] | N | N | -40 to 105 | I ² C / SPI | TSSOP56 | Y |
| PCA8546ATT | - | - | - | 176 | - | - | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | N | N | -40 to 95 | I ² C | TSSOP56 | Y |
| PCA8546BTT | - | - | - | 176 | - | - | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | N | N | -40 to 95 | SPI | TSSOP56 | Y |
| PCA8547AHT | 44 | 88 | - | 176 | - | - | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 95 | I ² C | TQFP64 | Y |
| PCA8547BHT | 44 | 88 | - | 176 | - | - | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 95 | SPI | TQFP64 | Y |
| PCF85134HL | 60 | 120 | 180 | 240 | - | - | - | 1.8 to 5.5 | 2.5 to 6.5 | 82 | N | N | -40 to 85 | I ² C | LQFP80 | N |
| PCA85134H | 60 | 120 | 180 | 240 | - | - | - | 1.8 to 5.5 | 2.5 to 8 | 82 | N | N | -40 to 95 | I ² C | LQFP80 | Y |
| PCA8543AHL | 60 | 120 | - | 240 | - | - | - | 2.5 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 105 | I ² C | LQFP80 | Y |
| PCF8545ATT | - | - | - | 176 | 252 | 320 | - | 1.8 to 5.5 | 2.5 to 5.5 | 60 to 300 ^[1] | N | N | -40 to 85 | I ² C | TSSOP56 | N |
| PCF8545BTT | - | - | - | 176 | 252 | 320 | - | 1.8 to 5.5 | 2.5 to 5.5 | 60 to 300 ^[1] | N | N | -40 to 85 | SPI | TSSOP56 | N |
| PCF8536AT | - | - | - | 176 | 252 | 320 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | N | N | -40 to 85 | I ² C | TSSOP56 | N |
| PCF8536BT | - | - | - | 176 | 252 | 320 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | N | N | -40 to 85 | SPI | TSSOP56 | N |
| PCA8536AT | - | - | - | 176 | 252 | 320 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | N | N | -40 to 95 | I ² C | TSSOP56 | Y |
| PCA8536BT | - | - | - | 176 | 252 | 320 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | N | N | -40 to 95 | SPI | TSSOP56 | Y |
| PCF8537AH | 44 | 88 | - | 176 | 276 | 352 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 85 | I ² C | TQFP64 | N |
| PCF8537BH | 44 | 88 | - | 176 | 276 | 352 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 85 | SPI | TQFP64 | N |
| PCA8537AH | 44 | 88 | - | 176 | 276 | 352 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 95 | I ² C | TQFP64 | Y |
| PCA8537BH | 44 | 88 | - | 176 | 276 | 352 | - | 1.8 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 95 | SPI | TQFP64 | Y |
| PCA9620H | 60 | 120 | - | 240 | 320 | 480 | - | 2.5 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 105 | I ² C | LQFP80 | Y |
| PCA9620U | 60 | 120 | - | 240 | 320 | 480 | - | 2.5 to 5.5 | 2.5 to 9 | 60 to 300 ^[1] | Y | Y | -40 to 105 | I ² C | Bare die | Y |
| PCF8576DU | 40 | 80 | 120 | 160 | - | - | - | 1.8 to 5.5 | 2.5 to 6.5 | 77 | N | N | -40 to 85 | I ² C | Bare die | N |

Table 23. Selection of LCD segment drivers...continued

| Type name | Number of elements at MUX | | | | | | | V _{DD} (V) | V _{LCD} (V) | f _{fr} (Hz) | V _{LCD} (V) charge pump | V _{LCD} (V) temperature compensat. | T _{amb} (°C) | Interface | Package | AEC- Q100 |
|------------|---------------------------|-----|-----|-----|-----|-----|-----|---------------------|----------------------|---------------------------|--|---|-----------------------|------------------------|----------|--------------|
| | 1:1 | 1:2 | 1:3 | 1:4 | 1:6 | 1:8 | 1:9 | | | | | | | | | |
| PCF8576EUG | 40 | 80 | 120 | 160 | - | - | - | 1.8 to 5.5 | 2.5 to 6.5 | 77 | N | N | -40 to 85 | I ² C | Bare die | N |
| PCA8576FUG | 40 | 80 | 120 | 160 | - | - | - | 1.8 to 5.5 | 2.5 to 8 | 200 | N | N | -40 to 105 | I ² C | Bare die | Y |
| PCF85133U | 80 | 160 | 240 | 320 | - | - | - | 1.8 to 5.5 | 2.5 to 6.5 | 82, 110 ^[2] | N | N | -40 to 85 | I ² C | Bare die | N |
| PCA85133U | 80 | 160 | 240 | 320 | - | - | - | 1.8 to 5.5 | 2.5 to 8 | 82, 110 ^[2] | N | N | -40 to 95 | I ² C | Bare die | Y |
| PCA85233UG | 80 | 160 | 240 | 320 | - | - | - | 1.8 to 5.5 | 2.5 to 8 | 150, 220 ^[2] | N | N | -40 to 105 | I ² C | Bare die | Y |
| PCF85132U | 160 | 320 | 480 | 640 | - | - | - | 1.8 to 5.5 | 1.8 to 8 | 60 to 90 ^[1] | N | N | -40 to 85 | I ² C | Bare die | N |
| PCA8530DUG | 102 | 204 | - | 408 | - | - | - | 2.5 to 5.5 | 4 to 12 | 45 to 300 ^[1] | Y | Y | -40 to 105 | I ² C / SPI | Bare die | Y |
| PCA85132U | 160 | 320 | 480 | 640 | - | - | - | 1.8 to 5.5 | 1.8 to 8 | 60 to 90 ^[1] | N | N | -40 to 95 | I ² C | Bare die | Y |
| PCA85232U | 160 | 320 | 480 | 640 | - | - | - | 1.8 to 5.5 | 1.8 to 8 | 117 to 176 ^[1] | N | N | -40 to 95 | I ² C | Bare die | Y |
| PCF8538UG | 102 | 204 | - | 408 | 612 | 816 | 918 | 2.5 to 5.5 | 4 to 12 | 45 to 300 ^[1] | Y | Y | -40 to 85 | I ² C / SPI | Bare die | N |
| PCA8538UG | 102 | 204 | - | 408 | 612 | 816 | 918 | 2.5 to 5.5 | 4 to 12 | 45 to 300 ^[1] | Y | Y | -40 to 105 | I ² C / SPI | Bare die | Y |

[1] Software programmable.

[2] Hardware selectable.

23 Abbreviations

Table 24. Abbreviations

| Acronym | Description |
|------------------|-------------------------------|
| CDM | Charged-Device Model |
| DC | Direct Current |
| EMC | ElectroMagnetic Compatibility |
| ESD | ElectroStatic Discharge |
| HBM | Human Body Model |
| I ² C | Inter-Integrated Circuit bus |
| IC | Integrated Circuit |
| LCD | Liquid Crystal Display |
| LSB | Least Significant Bit |
| MSB | Most Significant Bit |
| MSL | Moisture Sensitivity Level |
| MUX | Multiplexer |
| PCB | Printed-Circuit Board |
| POR | Power-On Reset |
| RC | Resistance-Capacitance |
| RMS | Root Mean Square |
| SCL | Serial CLock line |
| SDA | Serial DAta line |
| SMD | Surface-Mount Device |
| SPI | Serial Peripheral Interface |

24 References

- [1] JESD22-A114 Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)
- [2] JESD22-C101 Field-Induced Charged-Device Model Test Method for Electrostatic-Discharge-Withstand Thresholds of Microelectronic Components
- [3] JESD78 IC Latch-Up Test
- [4] SOT362-1_118 TSSOP48; Reel pack; SMD, 13", packing information
- [5] UM10204 I²C-bus specification and user manual
- [6] UM10569 Store and transport requirements

25 Revision history

Table 25. Revision history

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|----------------|--|--------------------|---------------|-------------|
| PCA8551 v.3.1 | 20210503 | Product data sheet | 202005038F01 | PCA8551 v.3 |
| Modifications: | <ul style="list-style-type: none"> • Section 4: Added "Y" parts with improved package | | | |
| PCA8551 v.3 | 20210420 | Product data sheet | 202104032I | PCA8551 v.2 |
| Modifications: | <ul style="list-style-type: none"> • Updated ordering information to new format • Section 7.3: Added "See also application information..." • Section 7.3.2: Added "The bus interface is initialized" • Section 7.3.3: Removed "The bus interface is initialized" • Updated Section 15.1 | | | |
| PCA8551 v.2 | 20150324 | Product data sheet | - | PCA8551 v.1 |
| Modifications: | <ul style="list-style-type: none"> • Fixed typo • Added Figure 6 | | | |
| PCA8551 v.1 | 20150213 | Product data sheet | - | - |

26 Legal information

26.1 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".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

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