



# PCA85133

Automotive LCD driver for low multiplex rates

Rev. 3 — 4 July 2014

Product data sheet

## 1. General description

The PCA85133 is a peripheral device which interfaces to almost any Liquid Crystal Display (LCD)<sup>1</sup> with low multiplex rates. It generates the drive signals for any static or multiplexed LCD containing up to four backplanes and up to 80 segments and can easily be cascaded for larger LCD applications. The PCA85133 is compatible with most microcontrollers and communicates via the two-line bidirectional I<sup>2</sup>C-bus. Communication overheads are minimized by a display RAM with auto-incremental addressing, by hardware subaddressing, and by display memory switching (static and duplex drive modes).

For a selection of NXP LCD segment drivers, see [Table 27 on page 46](#).

## 2. Features and benefits

- AEC-Q100 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
- Selectable frame frequency: 82 Hz or 110 Hz
- Internal LCD bias generation with voltage-follower buffers
- 80 segment drives:
  - ◆ Up to 40 7-segment alphanumeric characters
  - ◆ Up to 20 14-segment alphanumeric characters
  - ◆ Any graphics of up to 320 elements
- 80 × 4 bit RAM for display data storage
- Auto-incremental display data loading across device subaddress boundaries
- Display memory bank switching in static and duplex drive modes
- Versatile blinking modes
- Independent supplies possible for LCD and logic voltages
- Wide power supply range: from 1.8 V to 5.5 V
- Wide logic LCD supply range:
  - ◆ From 2.5 V for low-threshold LCDs
  - ◆ Up to 8.0 V for guest-host LCDs and high-threshold twisted nematic LCDs
- Low power consumption
- 400 kHz I<sup>2</sup>C-bus interface
- Extended temperature range up to 95 °C
- May be cascaded for large LCD applications (up to 5120 segments possible)

1. The definition of the abbreviations and acronyms used in this data sheet can be found in [Section 20](#).



- No external components needed
- Compatible with Chip-On-Glass (COG) technology
- Manufactured using silicon gate CMOS process

### 3. Ordering information

Table 1. Ordering information

| Type number | Package  |                                  |          |
|-------------|----------|----------------------------------|----------|
|             | Name     | Description                      | Version  |
| PCA85133U   | bare die | 110 bumps; 4.16 × 1.07 × 0.40 mm | PCA85133 |

#### 3.1 Ordering options

Table 2. Ordering options

| Product type number | Orderable part number | Sales item (12NC) | Delivery form <sup>[1]</sup> | IC revision |
|---------------------|-----------------------|-------------------|------------------------------|-------------|
| PCA85133U/2DA/Q1    | PCA85133U/2DA/Q1Z     | 935290456033      | chip with hard bumps in tray | 1           |
| PCA85133U/2DB/Q1    | PCA85133U/2DB/Q1Z     | 935290457033      | chip with soft bumps in tray | 1           |

[1] Bump hardness, see [Table 24 on page 43](#).

### 4. Marking

Table 3. Marking codes

| Type number      | Marking code |
|------------------|--------------|
| PCA85133U/2DA/Q1 | PC85133-1    |
| PCA85133U/2DB/Q1 | PC85133-1    |

5. Block diagram

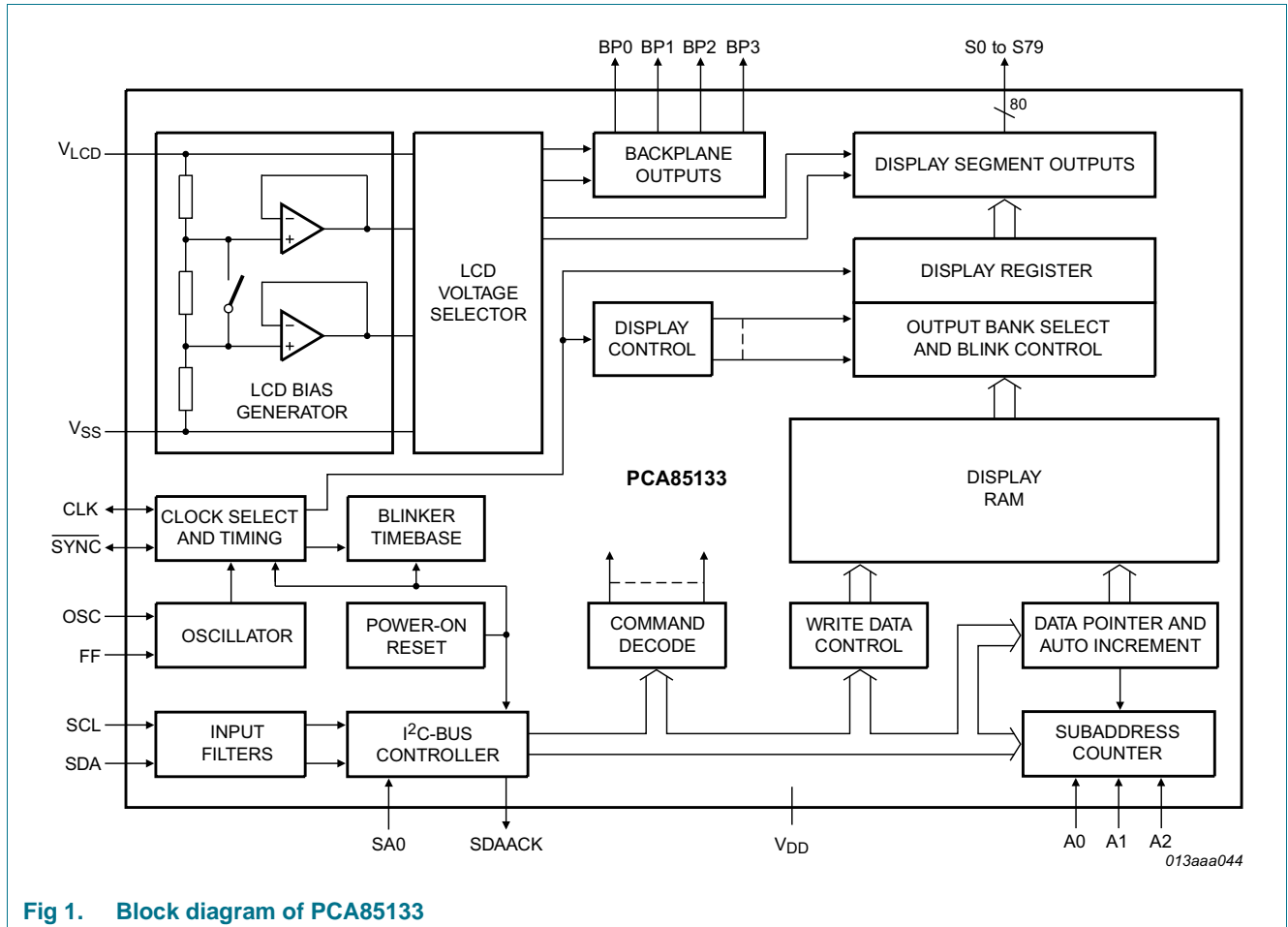
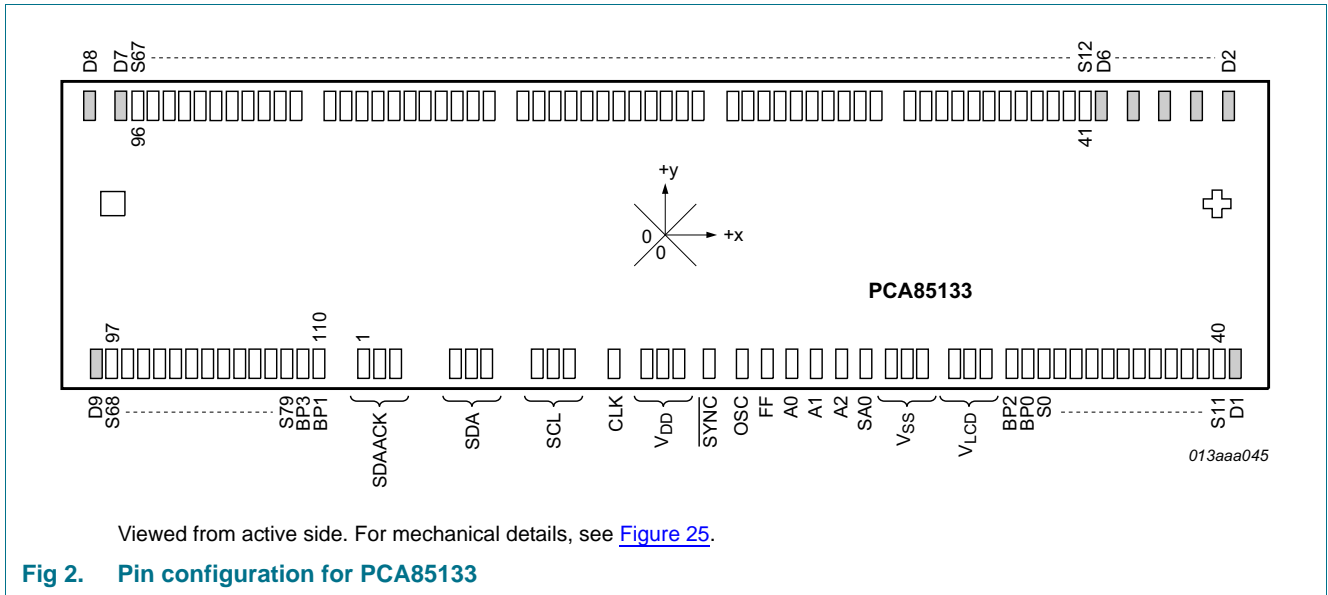


Fig 1. Block diagram of PCA85133

## 6. Pinning information

### 6.1 Pinning



### 6.2 Pin description

**Table 4. Pin description overview**

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

| Symbol                  | Pin                 | Description                              |
|-------------------------|---------------------|--|
| SDAACK                  | 1 to 3              | I <sup>2</sup> C-bus acknowledge output  |
| SDA                     | 4 to 6              | I <sup>2</sup> C-bus serial data input   |
| SCL                     | 7 to 9              | I <sup>2</sup> C-bus serial clock input  |
| CLK                     | 10                  | clock input and output                   |
| $V_{DD}$                | 11 to 13            | supply voltage                           |
| SYNC                    | 14                  | cascade synchronization input and output |
| OSC                     | 15                  | oscillator select                        |
| FF                      | 16                  | frame frequency select                   |
| A0, A1, and A2          | 17 to 19            | subaddress input                         |
| SA0                     | 20                  | I <sup>2</sup> C-bus slave address input |
| $V_{SS}$ <sup>[1]</sup> | 21 to 23            | ground supply voltage                    |
| $V_{LCD}$               | 24 to 26            | LCD supply voltage                       |
| BP2, BP0, BP3, and BP1  | 27, 28, 109 and 110 | LCD backplane output                     |
| S0 to S79               | 29 to 108           | LCD segment output                       |
| D1 to D9                | -                   | dummy pins                               |

[1] The substrate (rear side of the die) is at  $V_{SS}$  potential and should be electrically isolated.

## 7. Functional description

The PCA85133 is a versatile peripheral device designed to interface between any microcontroller to a wide variety of LCD segment or dot matrix displays (see [Figure 3](#)). It can directly drive any static or multiplexed LCD containing up to four backplanes and up to 80 segments.

The display configurations possible with the PCA85133 depend on the required number of active backplane outputs. A selection of display configurations is given in [Table 5](#).

All of the display configurations given in [Table 5](#) can be implemented in a typical system as shown in [Figure 4](#).

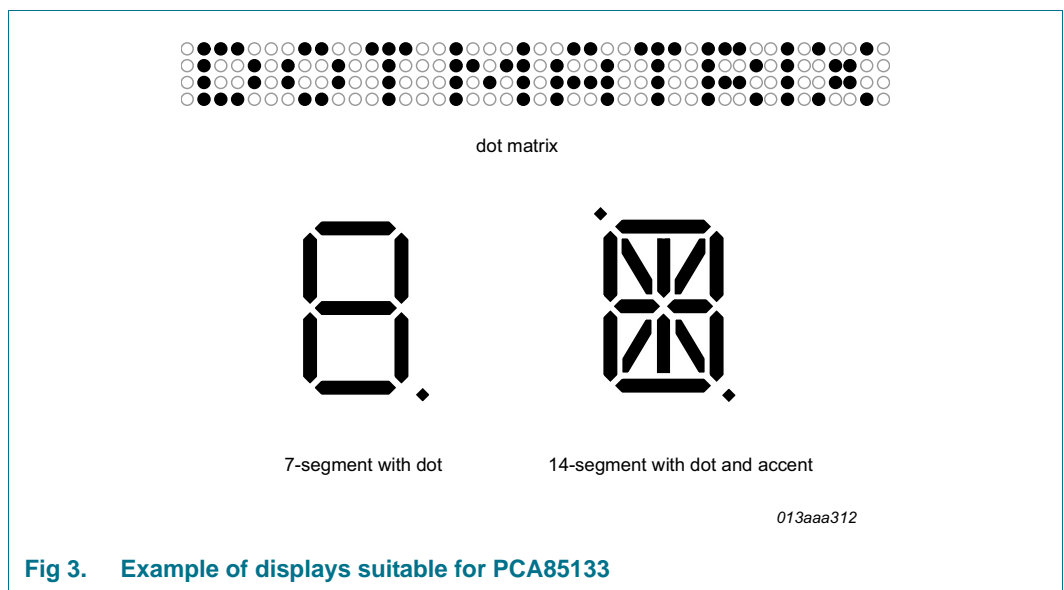


Fig 3. Example of displays suitable for PCA85133

Table 5. Selection of possible display configurations

| Number of  |       |                          |                           |                         |
|------------|-------|--------------------------|---------------------------|-------------------------|
| Backplanes | Icons | Digits/Characters        |                           | Dot matrix/<br>Elements |
|            |       | 7-segment <sup>[1]</sup> | 14-segment <sup>[2]</sup> |                         |
| 4          | 320   | 40                       | 20                        | 320 (4 × 80)            |
| 3          | 240   | 30                       | 15                        | 240 (3 × 80)            |
| 2          | 160   | 20                       | 10                        | 160 (2 × 80)            |
| 1          | 80    | 10                       | 5                         | 80 (1 × 80)             |

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

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

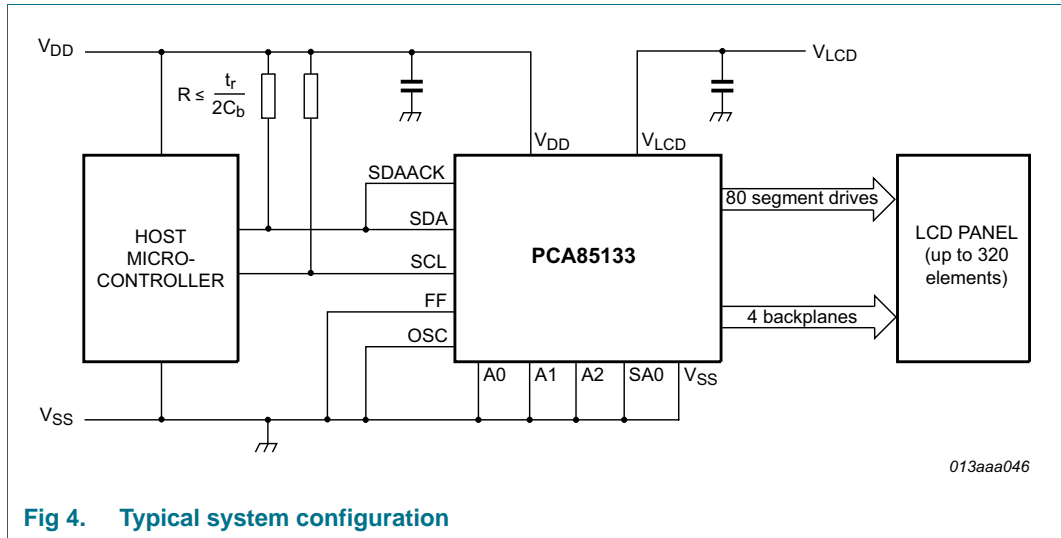


Fig 4. Typical system configuration

The host microcontroller maintains the 2-line I<sup>2</sup>C-bus communication channel with the PCA85133. The internal oscillator is enabled by connecting pin OSC to pin V<sub>SS</sub>. 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<sub>DD</sub>, V<sub>SS</sub>, and V<sub>LCD</sub>) and the LCD panel chosen for the application.

### 7.1 Power-on reset

At power-on the PCA85133 resets to the following starting conditions:

- All backplane and segment outputs are set to V<sub>LCD</sub>
- The selected drive mode is 1:4 multiplex with 1/3 bias
- Blinking is switched off
- Input and output bank selectors are reset
- The I<sup>2</sup>C-bus interface is initialized
- The data pointer and the subaddress counter are cleared (set to logic 0)
- The display is disabled (bit E = 0, see [Table 12](#))

**Remark:** Do not transfer data on the I<sup>2</sup>C-bus for at least 1 ms after a power-on to allow the reset action to complete.

### 7.2 LCD bias generator

Fractional LCD biasing voltages are obtained from an internal voltage divider of three impedances connected between pins V<sub>LCD</sub> and V<sub>SS</sub>. The center impedance is bypassed by switch if the 1/2 bias voltage level for the 1:2 multiplex drive mode configuration is selected.

### 7.3 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 mode-set command from the command decoder. 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 6](#).

Discrimination is a term which is defined as the ratio of the on and off RMS voltage across a segment. It can be thought of as a measurement of contrast.

**Table 6. 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                             | $\infty$                               |
| 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 by  $\frac{1}{1+a}$ , where the values for a are

a = 1 for  $\frac{1}{2}$  bias

a = 2 for  $\frac{1}{3}$  bias

The RMS on-state voltage ( $V_{on(RMS)}$ ) for the LCD is calculated with [Equation 1](#):

$$V_{on(RMS)} = V_{LCD} \sqrt{\frac{a^2 + 2a + n}{n \times (1 + a)^2}} \tag{1}$$

where the values for n are

n = 1 for static drive mode

n = 2 for 1:2 multiplex drive mode

n = 3 for 1:3 multiplex drive mode

n = 4 for 1:4 multiplex drive mode

The RMS off-state voltage ( $V_{off(RMS)}$ ) for the LCD is calculated with [Equation 2](#):

$$V_{off(RMS)} = V_{LCD} \sqrt{\frac{a^2 - 2a + n}{n \times (1 + a)^2}} \tag{2}$$

Discrimination is the ratio of  $V_{on(RMS)}$  to  $V_{off(RMS)}$  and is determined from [Equation 3](#):

$$D = \frac{V_{on(RMS)}}{V_{off(RMS)}} = \sqrt{\frac{a^2 + 2a + n}{a^2 - 2a + n}} \tag{3}$$

Using [Equation 3](#), 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.

It should be noted that  $V_{LCD}$  is sometimes referred as the LCD operating voltage.

### 7.3.1 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 5](#). For a good contrast performance, the following rules should be followed:

$$V_{on(RMS)} \geq V_{th(on)} \tag{4}$$

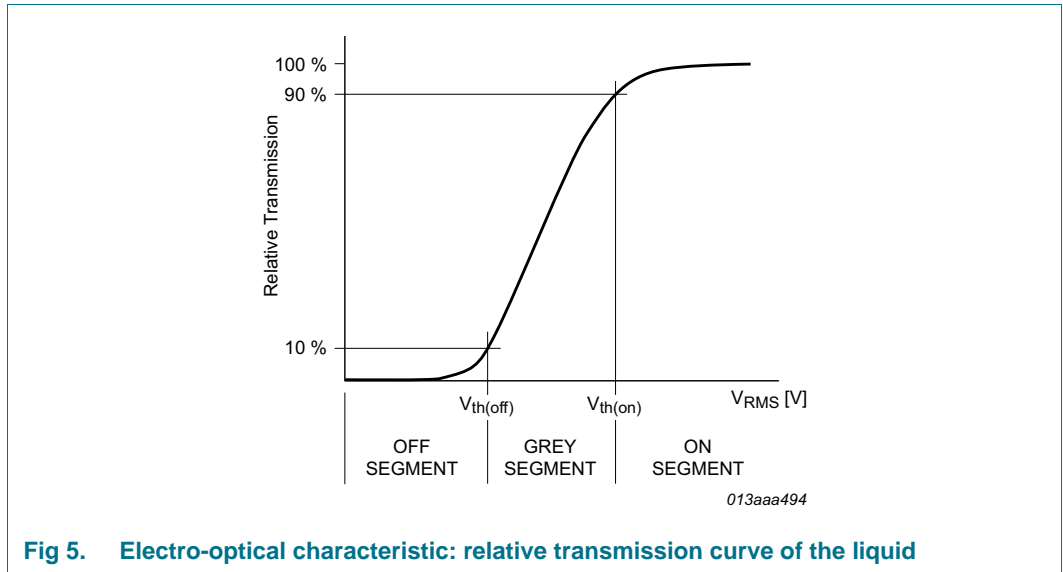
$$V_{off(RMS)} \leq V_{th(off)} \tag{5}$$

$V_{on(RMS)}$  and  $V_{off(RMS)}$  are properties of the display driver and are affected by the selection of a, n (see [Equation 1](#) to [Equation 3](#)) 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 just 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.





7.4 LCD drive mode waveforms

7.4.1 Static drive mode

The static LCD drive mode is used when a single backplane is provided in the LCD. Backplane and segment drive waveforms for this mode are shown in [Figure 6](#).

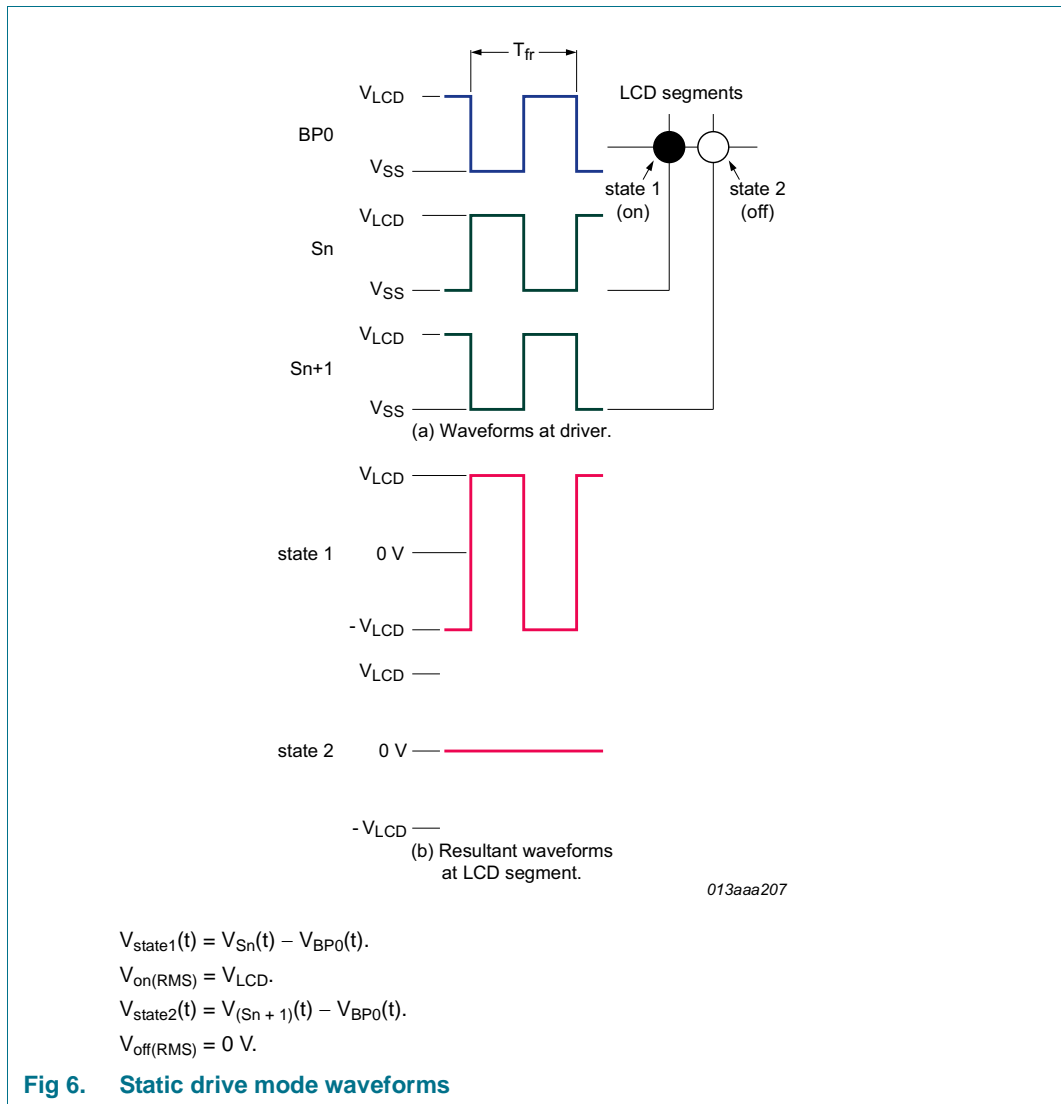


Fig 6. Static drive mode waveforms

7.4.2 1:2 Multiplex drive mode

When two backplanes are provided in the LCD, the 1:2 multiplex mode applies. The PCA85133 allows the use of 1/2 bias or 1/3 bias in this mode as shown in Figure 7 and Figure 8.

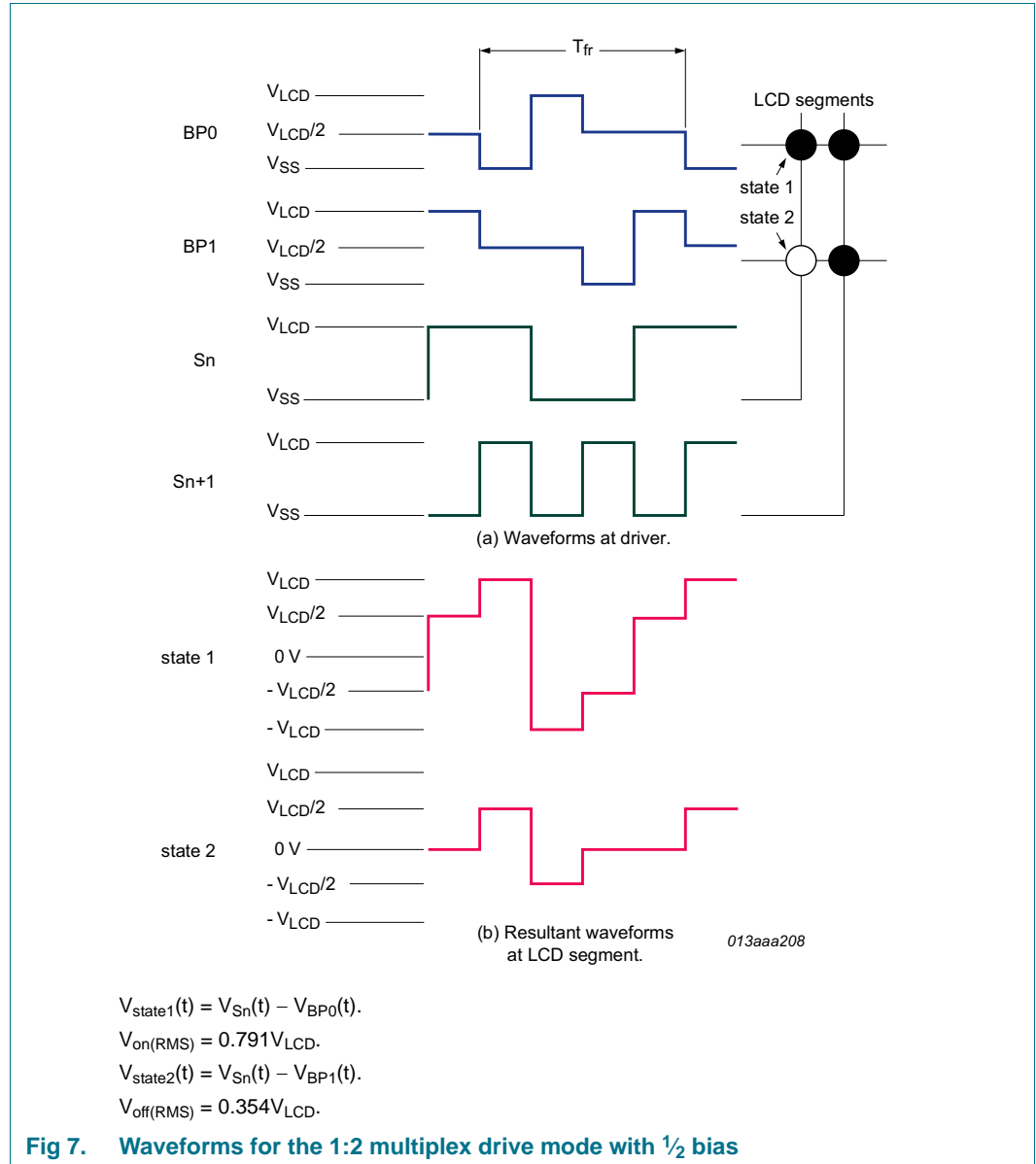


Fig 7. Waveforms for the 1:2 multiplex drive mode with 1/2 bias

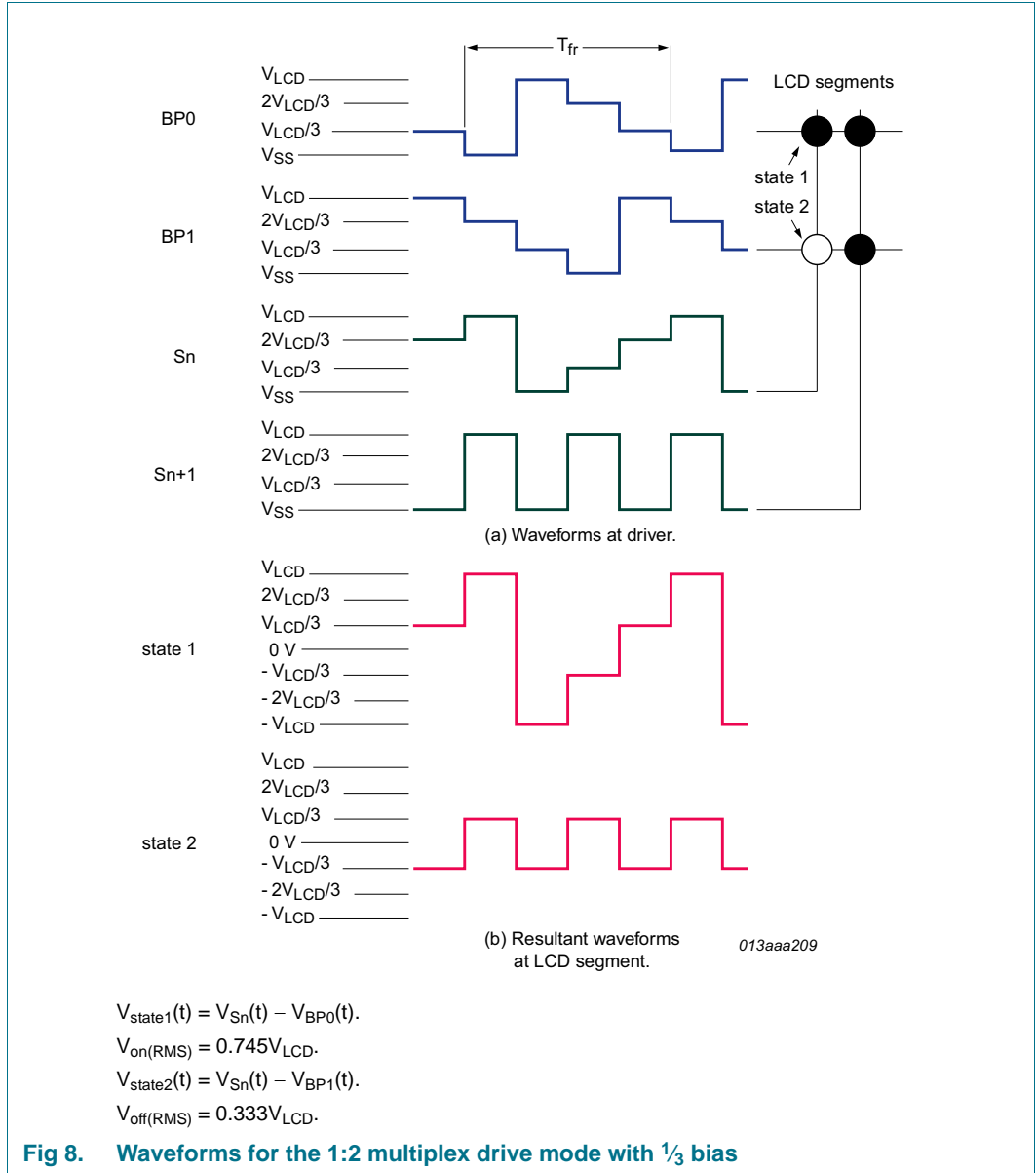


Fig 8. Waveforms for the 1:2 multiplex drive mode with 1/3 bias

7.4.3 1:3 Multiplex drive mode

When three backplanes are provided in the LCD, the 1:3 multiplex drive mode applies, as shown in Figure 9.

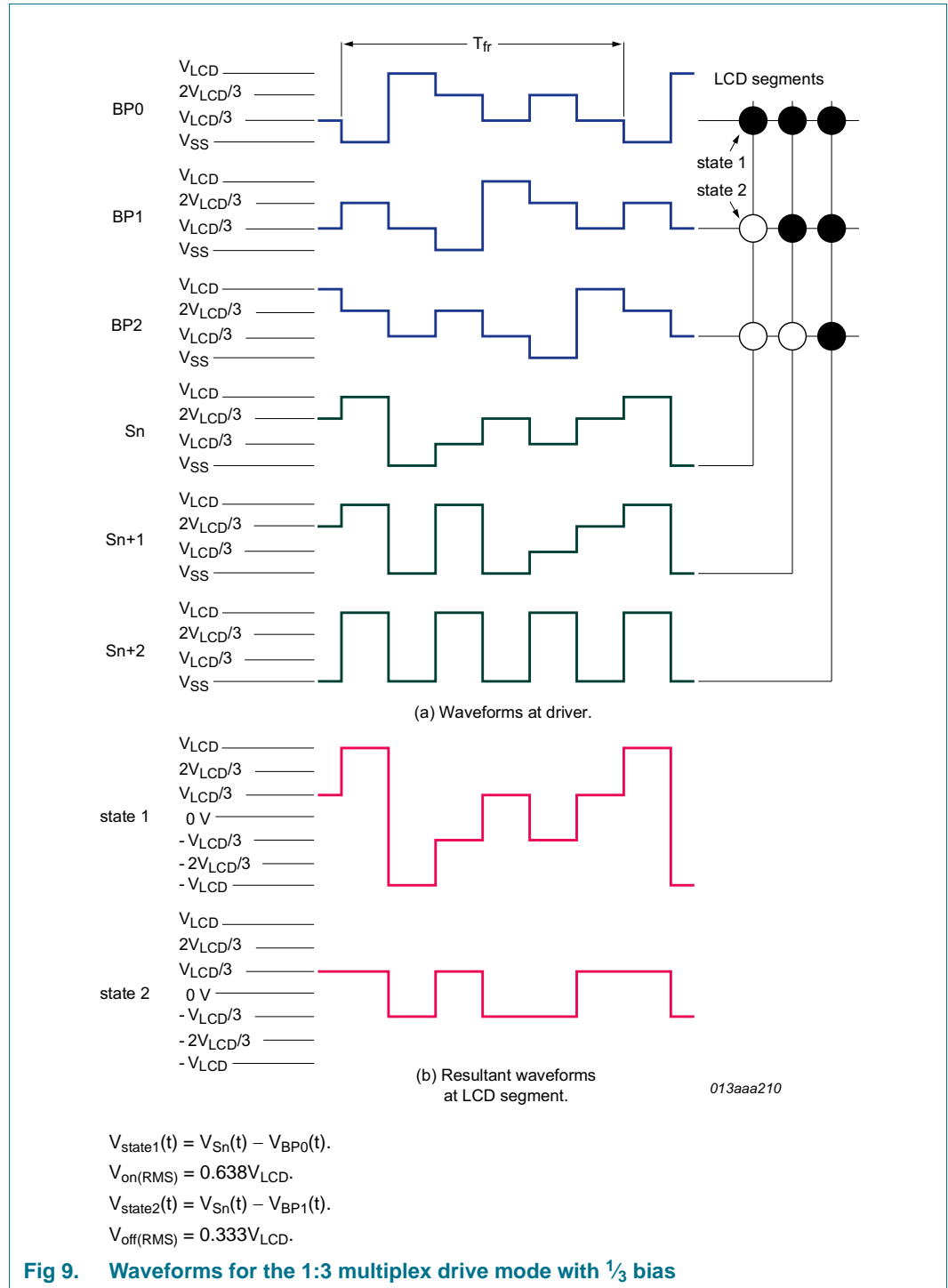


Fig 9. Waveforms for the 1:3 multiplex drive mode with 1/3 bias

7.4.4 1:4 Multiplex drive mode

When four backplanes are provided in the LCD, the 1:4 multiplex drive mode applies, as shown in Figure 10.

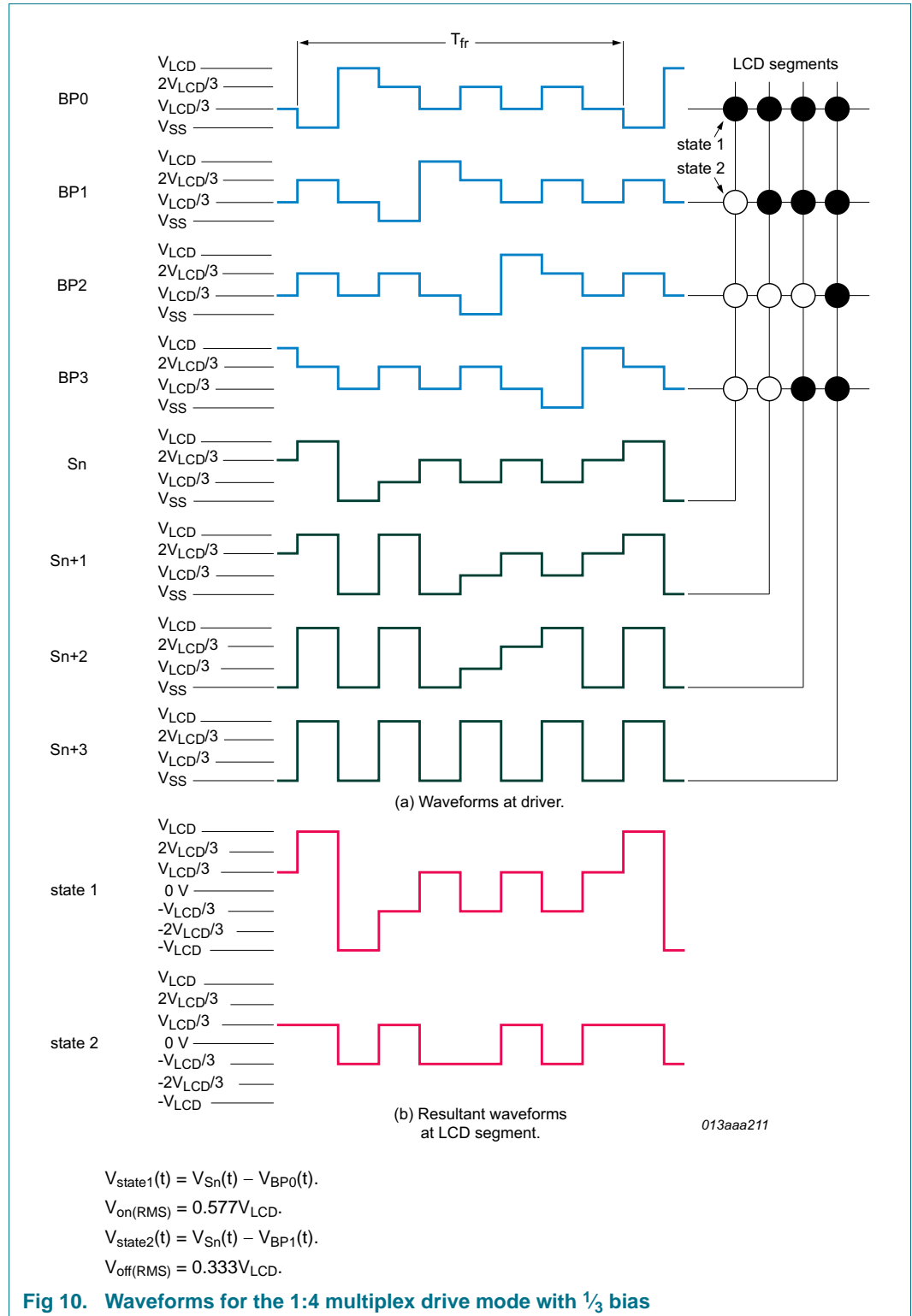


Fig 10. Waveforms for the 1:4 multiplex drive mode with 1/3 bias

### 7.5 Oscillator

The internal logic and the LCD drive signals of the PCA85133 are timed by a frequency  $f_{clk}$  which either is derived from the built-in oscillator frequency  $f_{osc}$ :

$$f_{clk} = \frac{f_{osc}}{64} \tag{6}$$

or equals an external clock frequency  $f_{clk(ext)}$ :

$$f_{clk} = f_{clk(ext)} \tag{7}$$

#### 7.5.1 Internal clock

The internal oscillator is enabled by connecting pin OSC to  $V_{SS}$ . In this case the output from pin CLK provides the clock signal for any cascaded PCA85133 in the system.

#### 7.5.2 External clock

Connecting pin OSC to  $V_{DD}$  enables an external clock source. Pin CLK then becomes the external clock input.

**Remark:** A clock signal must always be supplied to the device; removing the clock may freeze the LCD in a DC state, which is not suitable for the liquid crystal.

### 7.6 Timing and frame frequency

The clock frequency  $f_{clk}$  determines the LCD frame frequency  $f_{fr}$  and is calculated as follows:

$$f_{fr} = \frac{f_{clk}}{24} \tag{8}$$

The internal clock frequency  $f_{clk}$  can be selected using pin FF. As a result 2 frame frequencies are available: 82 Hz or 110 Hz (typical), see [Table 7](#).

**Table 7. LCD frame frequencies**

| Pin FF tied to <sup>[1]</sup> | Typical clock frequency (Hz) | LCD frame frequency (Hz) |
|-------------------------------|------------------------------|--------------------------|
| $V_{DD}$                      | 1970                         | 82                       |
| $V_{SS}$                      | 2640                         | 110                      |

[1] FF has no effect when an external clock is used but must not be left floating.

The timing of the PCA85133 organizes the internal data flow of the device. This includes the transfer of display data from the display RAM to the display segment outputs. In cascaded applications, the synchronization signal (SYNC) maintains the correct timing relationship between all the PCA85133 in the system.

### 7.7 Display register

The display register holds the display data while the corresponding multiplex signals are generated.

## 7.8 Segment outputs

The LCD drive section includes 80 segment outputs (S0 to S79) which must be connected directly to the LCD. The segment output signals are generated in accordance with the multiplexed backplane signals and with data residing in the display register. When less than 80 segment outputs are required the unused segment outputs must be left open-circuit.

## 7.9 Backplane outputs

The LCD drive section includes four backplane outputs: BP0 to BP3. The backplane output signals are generated in accordance with the selected LCD drive mode.

- In the 1:4 multiplex drive mode BP0 to BP3 must be connected directly to the LCD.

If less than four backplane outputs are required the unused outputs can be left open-circuit.

- In 1:3 multiplex drive mode: BP3 carries the same signal as BP1; therefore, these two adjacent outputs can be tied together to give enhanced drive capabilities.
- In 1:2 multiplex drive mode: BP0 and BP2, respectively, BP1 and BP3 carry the same signals and can 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.

## 7.10 Display RAM

The display RAM is a static  $80 \times 4$  bit RAM which stores LCD data.

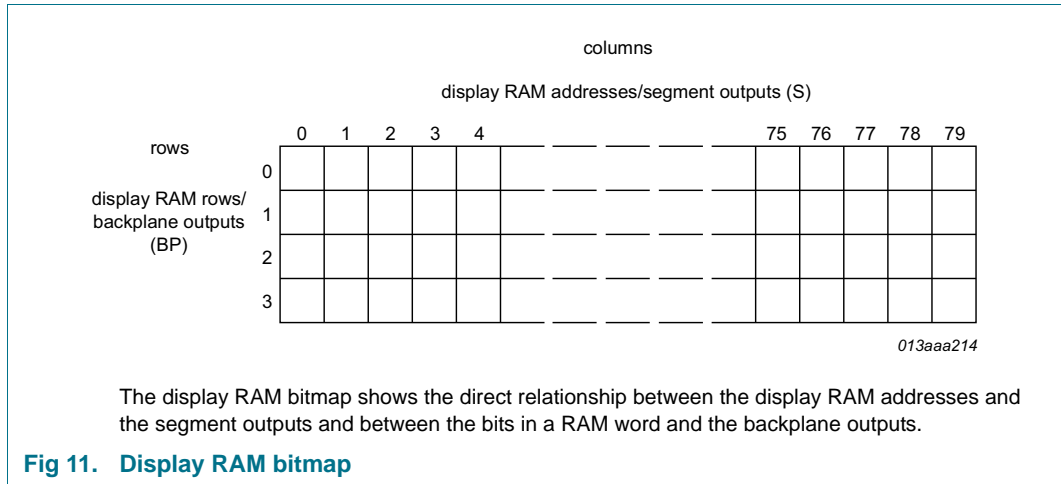
There is a one-to-one correspondence between

- the bits in the RAM bitmap and the LCD elements
- the RAM columns and the segment outputs
- the RAM rows and the backplane outputs.

A logic 1 in the RAM bitmap indicates the on-state of the corresponding LCD element; similarly, a logic 0 indicates the off-state.

The display RAM bit map, [Figure 11](#), shows rows 0 to 3 which correspond with the backplane outputs BP0 to BP3, and columns 0 to 79 which correspond with the segment outputs S0 to S79. In multiplexed LCD applications the segment data of the first, second, third and fourth row of the display RAM are time-multiplexed with BP0, BP1, BP2, and BP3 respectively.





When display data is transmitted to the PCA85133, the received display bytes are stored in the display RAM in accordance with the selected LCD drive mode. The data is stored as it arrives and depending on the current multiplex drive mode the bits are stored singularly, in pairs, triples or quadruples. To illustrate the filling order, an example of a 7-segment display showing all drive modes is given in [Figure 12](#); the RAM filling organization depicted applies equally to other LCD types.

The following applies to [Figure 12](#):

- In static drive mode the eight transmitted data bits are placed into row 0 as one byte.
- In 1:2 multiplex drive mode the eight transmitted data bits are placed in pairs into row 0 and 1 as four successive 2-bit RAM words.
- In 1:3 multiplex drive mode the eight bits are placed in triples into row 0, 1, and 2 as three successive 3-bit RAM words, with bit 3 of the third address left unchanged. It is not recommended to use this bit in a display because of the difficult addressing. This last bit may, if necessary, be controlled by an additional transfer to this address, but care should be taken to avoid overwriting adjacent data because always full bytes are transmitted (see [Section 7.10.3](#)).
- In 1:4 multiplex drive mode, the eight transmitted data bits are placed in quadruples into row 0, 1, 2, and 3 as two successive 4-bit RAM words.

| drive mode       | LCD segments | LCD backplanes | display RAM filling order  | transmitted display byte |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|------------------|--------------|----------------|--|--------------------------|-------|-------|------------------|------------------|------------------|-------|----------------|-------|------------------|---|----------------|---|---|--------------|---|----|--------------|----|---|---|---|---|----|---|---|----|---|---|---|---|---|---|---|---|---|---|----|---|--|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|----|
| static           |              |                | <p>columns<br/>display RAM address/segment outputs (s)<br/>byte1</p> <table border="1"> <tr> <td></td> <td>n</td> <td>n + 1</td> <td>n + 2</td> <td>n + 3</td> <td>n + 4</td> <td>n + 5</td> <td>n + 6</td> <td>n + 7</td> </tr> <tr> <td>rows display RAM</td> <td>0</td> <td>c</td> <td>b</td> <td>a</td> <td>f</td> <td>g</td> <td>e</td> <td>d</td> <td>DP</td> </tr> <tr> <td>rows/backplane</td> <td>1</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> </tr> <tr> <td>outputs (BP)</td> <td>2</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> </tr> <tr> <td></td> <td>3</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> </tr> </table> |                          | n     | n + 1 | n + 2            | n + 3            | n + 4            | n + 5 | n + 6          | n + 7 | rows display RAM | 0 | c              | b | a | f            | g | e  | d            | DP | rows/backplane  | 1 | x | x | x  | x   | x | x  | x | x | outputs (BP)  | 2 | x | x | x | x | x | x | x  | x |  | 3 | x | x | x | x | x | x | x | x | <p>MSB</p> <p>LSB</p> <table border="1"> <tr> <td>c</td> <td>b</td> <td>a</td> <td>f</td> <td>g</td> <td>e</td> <td>d</td> <td>DP</td> </tr> </table> | c | b | a | f | g | e | d | DP |
|                  | n            | n + 1          | n + 2  | n + 3                    | n + 4 | n + 5 | n + 6            | n + 7            |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows display RAM | 0            | c              | b  | a                        | f     | g     | e                | d                | DP               |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows/backplane   | 1            | x              | x  | x                        | x     | x     | x                | x                | x                |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| outputs (BP)     | 2            | x              | x  | x                        | x     | x     | x                | x                | x                |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | 3            | x              | x  | x                        | x     | x     | x                | x                | x                |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| c                | b            | a              | f  | g                        | e     | d     | DP               |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| 1:2 multiplex    |              |                | <p>columns<br/>display RAM address/segment outputs (s)<br/>byte1</p> <table border="1"> <tr> <td></td> <td>n</td> <td>n + 1</td> <td>n + 2</td> <td>n + 3</td> </tr> <tr> <td>rows display RAM</td> <td>0</td> <td>a</td> <td>f</td> <td>e</td> <td>d</td> </tr> <tr> <td>rows/backplane</td> <td>1</td> <td>b</td> <td>g</td> <td>c</td> <td>DP</td> </tr> <tr> <td>outputs (BP)</td> <td>2</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> </tr> <tr> <td></td> <td>3</td> <td>x</td> <td>x</td> <td>x</td> <td>x</td> </tr> </table>   |                          | n     | n + 1 | n + 2            | n + 3            | rows display RAM | 0     | a              | f     | e                | d | rows/backplane | 1 | b | g            | c | DP | outputs (BP) | 2  | x   | x | x | x |    | 3   | x | x  | x | x | <p>MSB</p> <p>LSB</p> <table border="1"> <tr> <td>a</td> <td>b</td> <td>f</td> <td>g</td> <td>e</td> <td>c</td> <td>d</td> <td>DP</td> </tr> </table> | a | b | f | g | e | c | d | DP |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | n            | n + 1          | n + 2  | n + 3                    |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows display RAM | 0            | a              | f  | e                        | d     |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows/backplane   | 1            | b              | g  | c                        | DP    |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| outputs (BP)     | 2            | x              | x  | x                        | x     |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | 3            | x              | x  | x                        | x     |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| a                | b            | f              | g  | e                        | c     | d     | DP               |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| 1:3 multiplex    |              |                | <p>columns<br/>display RAM address/segment outputs (s)<br/>byte1</p> <table border="1"> <tr> <td></td> <td>n</td> <td>n + 1</td> <td>n + 2</td> </tr> <tr> <td>rows display RAM</td> <td>0</td> <td>b</td> <td>a</td> <td>f</td> </tr> <tr> <td>rows/backplane</td> <td>1</td> <td>DP</td> <td>d</td> <td>e</td> </tr> <tr> <td>outputs (BP)</td> <td>2</td> <td>c</td> <td>g</td> <td>x</td> </tr> <tr> <td></td> <td>3</td> <td>x</td> <td>x</td> <td>x</td> </tr> </table>  |                          | n     | n + 1 | n + 2            | rows display RAM | 0                | b     | a              | f     | rows/backplane   | 1 | DP             | d | e | outputs (BP) | 2 | c  | g            | x  |   | 3 | x | x | x  | <p>MSB</p> <p>LSB</p> <table border="1"> <tr> <td>b</td> <td>DP</td> <td>c</td> <td>a</td> <td>d</td> <td>g</td> <td>f</td> <td>e</td> </tr> </table> | b | DP | c | a | d   | g | f | e |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | n            | n + 1          | n + 2  |                          |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows display RAM | 0            | b              | a  | f                        |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows/backplane   | 1            | DP             | d  | e                        |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| outputs (BP)     | 2            | c              | g  | x                        |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | 3            | x              | x  | x                        |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| b                | DP           | c              | a  | d                        | g     | f     | e                |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| 1:4 multiplex    |              |                | <p>columns<br/>display RAM address/segment outputs (s)<br/>byte1</p> <table border="1"> <tr> <td></td> <td>n</td> <td>n + 1</td> </tr> <tr> <td>rows display RAM</td> <td>0</td> <td>a</td> <td>f</td> </tr> <tr> <td>rows/backplane</td> <td>1</td> <td>c</td> <td>e</td> </tr> <tr> <td>outputs (BP)</td> <td>2</td> <td>b</td> <td>g</td> </tr> <tr> <td></td> <td>3</td> <td>DP</td> <td>d</td> </tr> </table>   |                          | n     | n + 1 | rows display RAM | 0                | a                | f     | rows/backplane | 1     | c                | e | outputs (BP)   | 2 | b | g            |   | 3  | DP           | d  | <p>MSB</p> <p>LSB</p> <table border="1"> <tr> <td>a</td> <td>c</td> <td>b</td> <td>DP</td> <td>f</td> <td>e</td> <td>g</td> <td>d</td> </tr> </table> | a | c | b | DP | f   | e | g  | d |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | n            | n + 1          |  |                          |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows display RAM | 0            | a              | f  |                          |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| rows/backplane   | 1            | c              | e  |                          |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| outputs (BP)     | 2            | b              | g  |                          |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
|                  | 3            | DP             | d  |                          |       |       |                  |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |
| a                | c            | b              | DP   | f                        | e     | g     | d                |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |

001aaj646

x = data bit unchanged

Fig 12. Relationships between LCD layout, drive mode, display RAM filling order, and display data transmitted over the I<sup>2</sup>C-bus

7.10.1 Data pointer

The addressing mechanism for the display RAM is realized using a data pointer. This allows the loading of an individual display data byte, or a series of display data bytes, into any location of the display RAM. The sequence commences with the initialization of the data pointer by the load-data-pointer command (see Table 13). Following this command, an arriving data byte is stored at the display RAM address indicated by the data pointer. The filling order is shown in Figure 12. After each byte is stored, the content of the data pointer is automatically incremented by a value dependent on the selected LCD drive mode:

- In static drive mode by eight
- In 1:2 multiplex drive mode by four
- In 1:3 multiplex drive mode by three
- In 1:4 multiplex drive mode by two

If an I<sup>2</sup>C-bus data access is terminated early then the state of the data pointer is unknown. Consequently, the data pointer must be rewritten prior to further RAM accesses.

7.10.2 Subaddress counter

The storage of display data is determined by the content of the subaddress counter. Storage is allowed only when the content of the subaddress counter match with the hardware subaddress applied to A0, A1, and A2. The subaddress counter value is defined by the device-select command (see Table 14). If the content of the subaddress counter and the hardware subaddress do not match, then data storage is inhibited but the data pointer is incremented as if data storage had taken place. The subaddress counter is also incremented when the data pointer overflows.

The storage arrangements described lead to extremely efficient data loading in cascaded applications. When a series of display bytes are sent to the display RAM, automatic wrap-over to the next PCA85133 occurs when the last RAM address is exceeded. Subaddressing across device boundaries is successful even if the change to the next device in the cascade occurs within a transmitted character.

The hardware subaddress must not be changed whilst the device is being accessed on the I<sup>2</sup>C-bus interface.

7.10.3 RAM writing in 1:3 multiplex drive mode

In 1:3 multiplex drive mode, the RAM is written as shown in Table 8 (see Figure 12 as well).

Table 8. Standard RAM filling in 1:3 multiplex drive mode

Assumption: BP2/S2, BP2/S5, BP2/S8 etc. **are not connected** to any elements on the display.

| Display RAM bits (rows)/backplane outputs (BPn) | Display RAM addresses (columns)/segment outputs (Sn) |    |    |    |    |    |    |    |    |    |   |
|---|--|----|----|----|----|----|----|----|----|----|---|
|   | 0  | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  | 9  | : |
| 0   | a7   | a4 | a1 | b7 | b4 | b1 | c7 | c4 | c1 | d7 | : |
| 1   | a6   | a3 | a0 | b6 | b3 | b0 | c6 | c3 | c0 | d6 | : |
| 2   | a5   | a2 | -  | b5 | b2 | -  | c5 | c2 | -  | d5 | : |
| 3   | -  | -  | -  | -  | -  | -  | -  | -  | -  | -  | : |

If the bit at position BP2/S2 would be written by a second byte transmitted, then the mapping of the segment bits would change as illustrated in [Table 9](#).

**Table 9. Entire RAM filling by rewriting in 1:3 multiplex drive mode**

Assumption: BP2/S2, BP2/S5, BP2/S8 etc. **are connected** to elements on the display.

| Display RAM bits (rows)/ backplane outputs (BPn) | Display RAM addresses (columns)/segment outputs (Sn) |    |       |    |       |    |       |    |       |    |   |
|--|--|----|-------|----|-------|----|-------|----|-------|----|---|
|  | 0  | 1  | 2     | 3  | 4     | 5  | 6     | 7  | 8     | 9  | : |
| 0  | a7   | a4 | a1/b7 | b4 | b1/c7 | c4 | c1/d7 | d4 | d1/e7 | e4 | : |
| 1  | a6   | a3 | a0/b6 | b3 | b0/c6 | c3 | c0/d6 | d3 | d0/e6 | e3 | : |
| 2  | a5   | a2 | b5    | b2 | c5    | c2 | d5    | d2 | e5    | e2 | : |
| 3  | -  | -  | -     | -  | -     | -  | -     | -  | -     | -  | : |

In the case described in [Table 9](#) the RAM has to be written entirely and BP2/S2, BP2/S5, BP2/S8 etc. have to be connected to elements on the display. This can be achieved by a combination of writing and rewriting the RAM like follows:

- In the first write to the RAM, bits a7 to a0 are written.
- In the second write, bits b7 to b0 are written, overwriting bits a1 and a0 with bits b7 and b6.
- In the third write, bits c7 to c0 are written, overwriting bits b1 and b0 with bits c7 and c6.

Depending on the method of writing to the RAM (standard or entire filling by rewriting), some elements remain unused or can be used, but it has to be considered in the module layout process as well as in the driver software design.

**7.10.4 Writing over the RAM address boundary**

In all multiplex drive modes, depending on the setting of the data pointer, it is possible to fill the RAM over the RAM address boundary. If the PCA85133 is part of a cascade the additional bits fall into the next device that also generates the acknowledge signal. If the PCA85133 is a single device or the last device in a cascade the additional bits will be discarded and no acknowledge signal will be generated.

**7.10.5 Output bank selector**

The output bank selector (see [Table 15](#)) selects one of the four rows per display RAM address for transfer to the display register. The actual row selected depends on the selected LCD drive mode in operation and on the instant in the multiplex sequence.

- In 1:4 multiplex mode, all RAM addresses of row 0 are selected, these are followed by the contents of row 1, 2, and then 3
- In 1:3 multiplex mode, rows 0, 1, and 2 are selected sequentially
- In 1:2 multiplex mode, rows 0 and 1 are selected
- In static mode, row 0 is selected

The PCA85133 includes a RAM bank switching feature in the static and 1:2 multiplex drive modes. In the static drive mode, the bank-select command may request the contents of row 2 to be selected for display instead of the contents of row 0. In the 1:2 multiplex

mode, the contents of rows 2 and 3 may be selected instead of rows 0 and 1. This gives the provision for preparing display information in an alternative bank and to be able to switch to it once it is assembled.

**7.10.6 Input bank selector**

The input bank selector loads display data into the display RAM in accordance with the selected LCD drive configuration. Display data can be loaded in row 2 in static drive mode or in rows 2 and 3 in 1:2 multiplex drive mode by using the bank-select command (see [Table 15](#)). The input bank selector functions independently to the output bank selector.

**7.11 Blinking**

The display blink capabilities of the PCA85133 are very versatile. The whole display can blink at frequencies selected by the blink-select command (see [Table 16](#)). The blink frequencies are derived from the clock frequency. The ratios between the clock and blink frequencies depend on the blink mode selected (see [Table 10](#)).

**Table 10. Blink frequencies**

| Blink mode | Operating mode ratio   | Blink frequency with respect to f <sub>clk</sub> (typical) |                              | Unit |
|------------|------------------------|--|------------------------------|------|
|            |                        | f <sub>clk</sub> = 1.970 kHz                               | f <sub>clk</sub> = 2.640 kHz |      |
| off        | -                      | blinking off   | blinking off                 | Hz   |
| 1          | $\frac{f_{clk}}{768}$  | 2.5  | 3.5                          | Hz   |
| 2          | $\frac{f_{clk}}{1536}$ | 1.3  | 1.7                          | Hz   |
| 3          | $\frac{f_{clk}}{3072}$ | 0.6  | 0.9                          | Hz   |

An additional feature is for an arbitrary selection of LCD segments to blink. This applies to the static and 1:2 multiplex drive modes and can be implemented without any communication overheads. By means of the output bank selector, the displayed RAM banks are exchanged with alternate RAM banks at the blink frequency. This mode can also be specified by the blink-select command.

In the 1:3 and 1:4 multiplex modes, where no alternate RAM bank is available, groups of LCD segments can blink by selectively changing the display RAM data at fixed time intervals.

If the entire display can blink at a frequency other than the typical blink frequency. This can be effectively performed by resetting and setting the display enable bit E at the required rate using the mode-set command (see [Table 12](#)).

**7.12 Command decoder**

The command decoder identifies command bytes that arrive on the I<sup>2</sup>C-bus. The commands available to the PCA85133 are defined in [Table 11](#).

**Table 11. Definition of commands**

| Command           | Operation code |        |   |   |   |        |         |                          | Reference                |
|-------------------|----------------|--------|---|---|---|--------|---------|--------------------------|--------------------------|
|                   | 7              | 6      | 5 | 4 | 3 | 2      | 1       | 0                        |                          |
| mode-set          | 1              | 1      | 0 | 0 | E | B      | M[1:0]  |                          | <a href="#">Table 12</a> |
| load-data-pointer | 0              | P[6:0] |   |   |   |        |         |                          | <a href="#">Table 13</a> |
| device-select     | 1              | 1      | 1 | 0 | 0 | A[2:0] |         | <a href="#">Table 14</a> |                          |
| bank-select       | 1              | 1      | 1 | 1 | 1 | 0      | I       | O                        | <a href="#">Table 15</a> |
| blink-select      | 1              | 1      | 1 | 1 | 0 | AB     | BF[1:0] |                          | <a href="#">Table 16</a> |

**Table 12. Mode-set command bit description**

| Bit    | Symbol | Value | Description                                  |
|--------|--------|-------|--|
| 7 to 4 | -      | 1100  | fixed value                                  |
| 3      | E      |       | <b>display status</b> <sup>[1]</sup>         |
|        |        | 0     | disabled (blank) <sup>[2]</sup>              |
|        |        | 1     | enabled                                      |
| 2      | B      |       | <b>LCD bias configuration</b> <sup>[3]</sup> |
|        |        | 0     | 1/3 bias                                     |
|        |        | 1     | 1/2 bias                                     |
| 1 to 0 | M[1:0] |       | <b>LCD drive mode selection</b>              |
|        |        | 01    | static; 1 backplane                          |
|        |        | 10    | 1:2 multiplex; 2 backplanes                  |
|        |        | 11    | 1:3 multiplex; 3 backplanes                  |
|        |        | 00    | 1:4 multiplex; 4 backplanes                  |

[1] The possibility to disable the display allows implementation of blinking under external control.

[2] The display is disabled by setting all backplane and segment outputs to V<sub>LCD</sub>.

[3] Not applicable for static drive mode.

**Table 13. Load-data-pointer command bit description**

See [Section 7.10.1](#).

| Bit    | Symbol | Value              | Description   |
|--------|--------|--------------------|---|
| 7      | -      | 0                  | fixed value   |
| 6 to 0 | P[6:0] | 0000000 to 1001111 | <b>data pointer</b><br>7-bit binary value of 0 to 79, transferred to the data pointer to define one of 80 display RAM addresses |

**Table 14. Device-select command bit description**

See [Section 7.10.2](#).

| Bit    | Symbol | Value      | Description   |
|--------|--------|------------|---|
| 7 to 3 | -      | 11100      | fixed value   |
| 2 to 0 | A[2:0] | 000 to 111 | <b>device selection</b><br>3-bit binary value of 0 to 7, transferred to the subaddress counter to define one of 8 hardware subaddresses |

**Table 15. Bank-select command bit description<sup>[1]</sup>**

See [Section 7.10.5](#) and [Section 7.10.6](#).

| Bit    | Symbol | Value  | Description   |                      |
|--------|--------|--------|---|----------------------|
|        |        |        | <b>Static</b>   | <b>1:2 multiplex</b> |
| 7 to 2 | -      | 111110 | fixed value   |                      |
| 1      | I      |        | <b>input bank selection:</b> storage of arriving display data |                      |
|        |        | 0      | RAM row 0   | RAM rows 0 and 1     |
|        |        | 1      | RAM row 2   | RAM rows 2 and 3     |
| 0      | O      |        | <b>output bank selection:</b> retrieval of LCD display data   |                      |
|        |        | 0      | RAM row 0   | RAM rows 0 and 1     |
|        |        | 1      | RAM row 2   | RAM rows 2 and 3     |

[1] The bank-select command has no effect in 1:3 or 1:4 multiplex drive modes.

**Table 16. Blink-select command bit description**

See [Section 7.11](#).

| Bit    | Symbol  | Value | Description                                    |  |
|--------|---------|-------|--|--|
| 7 to 3 | -       | 11110 | fixed value                                    |  |
| 2      | AB      |       | <b>blink mode selection<sup>[1]</sup></b>      |  |
|        |         | 0     | normal blinking                                |  |
|        |         | 1     | blinking by alternating display RAM banks      |  |
| 1 to 0 | BF[1:0] |       | <b>blink frequency selection<sup>[2]</sup></b> |  |
|        |         | 00    | off  |  |
|        |         | 01    | 1  |  |
|        |         | 10    | 2  |  |
|        |         | 11    | 3  |  |

[1] Normal blinking can only be selected in multiplex drive mode 1:3 or 1:4.

[2] For the blink frequencies, see [Table 10](#).

### 7.13 Display controller

The display controller executes the commands identified by the command decoder. It contains the status registers and coordinates their effects. The display controller also loads the display data into the display RAM as required by the storage order.

## 8. Characteristics of the I<sup>2</sup>C-bus

The I<sup>2</sup>C-bus is for bidirectional, two-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.

By connecting pin SDAACK to pin SDA on the PCA85133, the SDA line becomes fully I<sup>2</sup>C-bus compatible. In COG applications where the track resistance from the SDAACK pin to the system SDA line can be significant, possibly a voltage divider is generated by the bus pull-up resistor and the Indium Tin Oxide (ITO) track resistance. As a consequence it may be possible that the acknowledge generated by the PCA85133 can't be interpreted as logic 0 by the master. In COG applications where the acknowledge cycle is required, it is therefore necessary to minimize the track resistance from the SDAACK pin to the system SDA line to guarantee a valid LOW level.

By separating the acknowledge output from the serial data line (having the SDAACK open circuit) design efforts to generate a valid acknowledge level can be avoided. However, in that case the I<sup>2</sup>C-bus master has to be set up in such a way that it ignores the acknowledge cycle.<sup>2</sup>

The following definition assumes SDA and SDAACK are connected and refers to the pair as SDA.

### 8.1 Bit transfer

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as a control signal (see [Figure 13](#)).

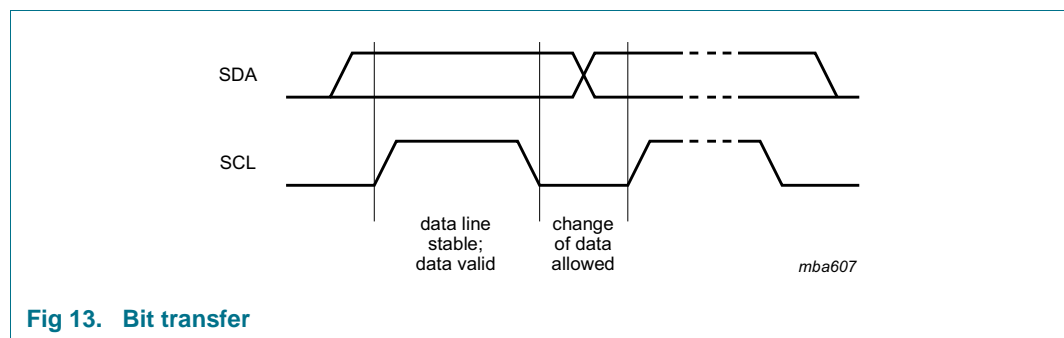


Fig 13. Bit transfer

### 8.2 START and STOP conditions

Both data and clock lines remain HIGH when the bus is not busy.

A HIGH-to-LOW change of the data line, while the clock is HIGH, is defined as the START condition (S).

A LOW-to-HIGH change of the data line, while the clock is HIGH, is defined as the STOP condition (P).

2. For further information, please consider the NXP application note: [Ref. 1 "AN10170"](#).



The START and STOP conditions are shown in [Figure 14](#).

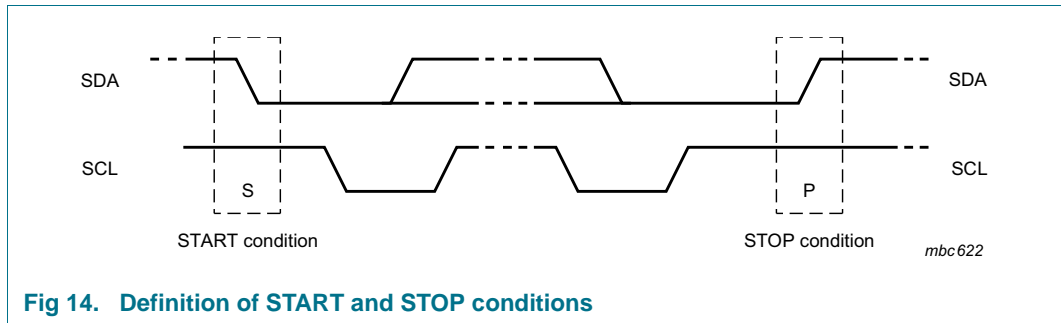


Fig 14. Definition of START and STOP conditions

### 8.3 System configuration

A device generating a message is a transmitter, a device receiving a message is the receiver. The device that controls the message is the master; and the devices which are controlled by the master are the slaves. The system configuration is shown in [Figure 15](#).

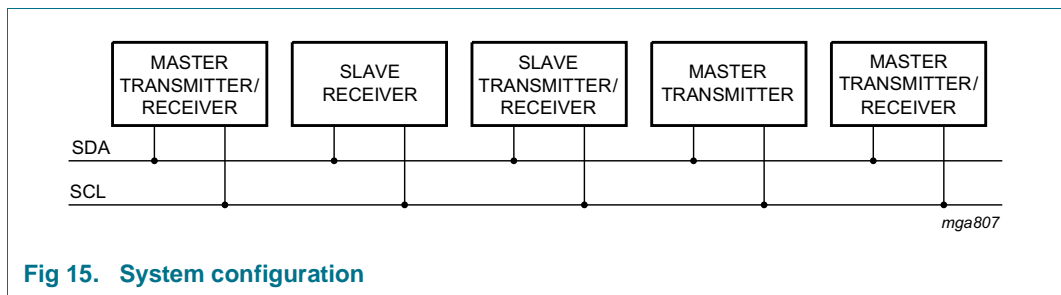


Fig 15. System configuration

### 8.4 Acknowledge

The number of data bytes transferred between the START and STOP conditions from transmitter to receiver is unlimited. Each byte of eight bits is followed by an acknowledge cycle.

- A slave receiver, which is addressed, must generate an acknowledge after the reception of each byte.
- A master receiver must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter.
- The device that acknowledges must 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 consideration).
- 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.

Acknowledgement on the I<sup>2</sup>C-bus is shown in [Figure 16](#).

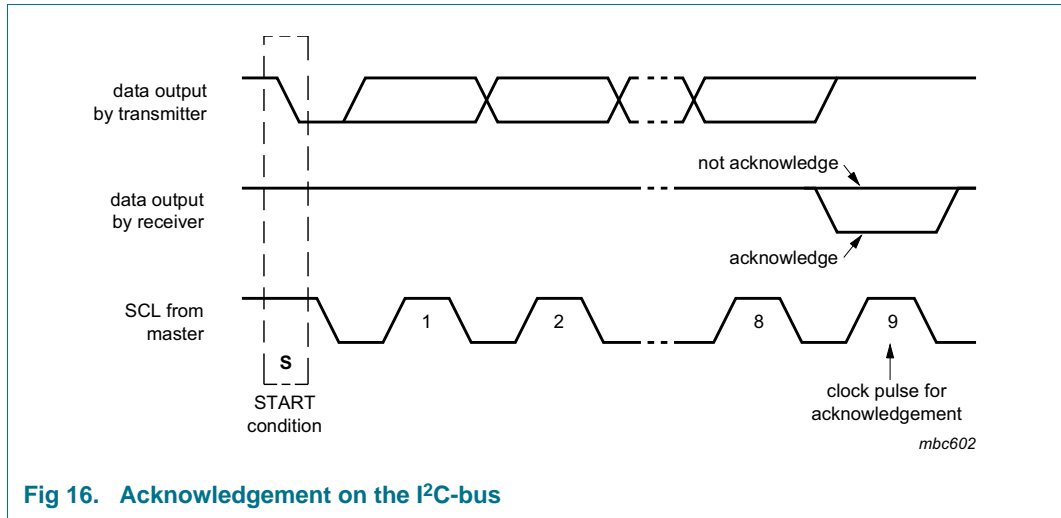


Fig 16. Acknowledgement on the I<sup>2</sup>C-bus

### 8.5 I<sup>2</sup>C-bus controller

The PCA85133 acts as an I<sup>2</sup>C-bus slave receiver. It does not initiate I<sup>2</sup>C-bus transfers or transmit data to an I<sup>2</sup>C-bus master receiver. The only data output from the PCA85133 are the acknowledge signals from the selected devices. Device selection depends on the I<sup>2</sup>C-bus slave address, on the transferred command data, and on the hardware subaddress.

In single device applications, the hardware subaddress inputs A0, A1, and A2 are normally tied to V<sub>SS</sub> which defines the hardware subaddress 0. In multiple device applications A0, A1, and A2 are tied to V<sub>SS</sub> or V<sub>DD</sub> using a binary coding scheme, so that no two devices with a common I<sup>2</sup>C-bus slave address have the same hardware subaddress.

### 8.6 Input filters

To enhance noise immunity in electrically adverse environments, RC low-pass filters are provided on the SDA and SCL lines.

### 8.7 I<sup>2</sup>C-bus protocol

Two I<sup>2</sup>C-bus slave addresses (0111 000 and 0111 001) are used to address the PCA85133. The entire I<sup>2</sup>C-bus slave address byte is shown in [Table 17](#).

Table 17. I<sup>2</sup>C slave address byte

| Bit | Slave address |   |   |   |   |   |     | 0   |
|-----|---------------|---|---|---|---|---|-----|-----|
|     | 7             | 6 | 5 | 4 | 3 | 2 | 1   |     |
|     | MSB           |   |   |   |   |   |     | LSB |
|     | 0             | 1 | 1 | 1 | 0 | 0 | SA0 | R/W |

The PCA85133 is a write-only device and will not respond to a read access, therefore bit 0 should always be logic 0. Bit 1 of the slave address byte that a PCA85133 will respond to, is defined by the level tied to its SA0 input (V<sub>SS</sub> for logic 0 and V<sub>DD</sub> for logic 1).

Having two reserved slave addresses allows the following on the same I<sup>2</sup>C-bus:

- Up to 16 PCA85133 on the same I<sup>2</sup>C-bus for very large LCD applications
- The use of two types of LCD multiplex drive modes on the same I<sup>2</sup>C-bus

The I<sup>2</sup>C-bus protocol is shown in [Figure 17](#). The sequence is initiated with a START condition (S) from the I<sup>2</sup>C-bus master which is followed by one of the available PCA85133 slave addresses. All PCA85133 with the same SA0 level acknowledge in parallel to the slave address. All PCA85133 with the alternative SA0 level ignore the whole I<sup>2</sup>C-bus transfer.

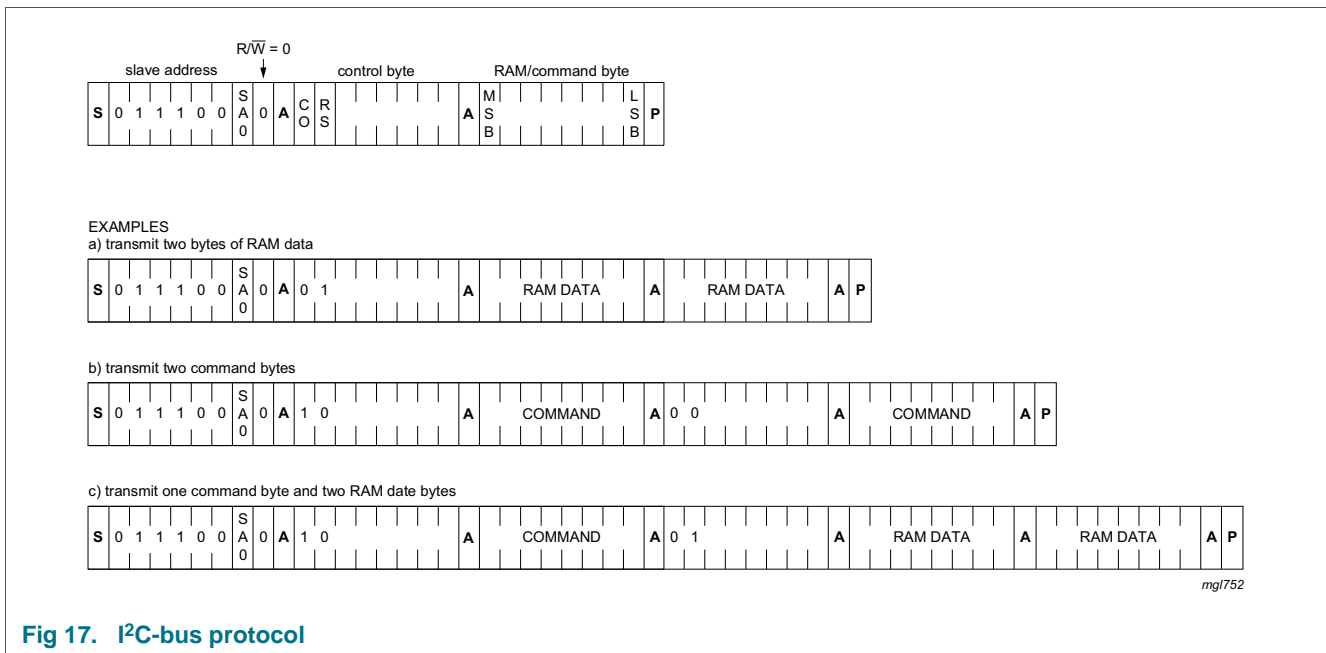


Fig 17. I<sup>2</sup>C-bus protocol

After acknowledgement, the control byte is sent, defining if the next byte is a RAM or command information. The control byte also defines if the next byte is a control byte or further RAM or command data (see [Figure 18](#) and [Table 18](#)). In this way it is possible to configure the device and then fill the display RAM with little overhead.

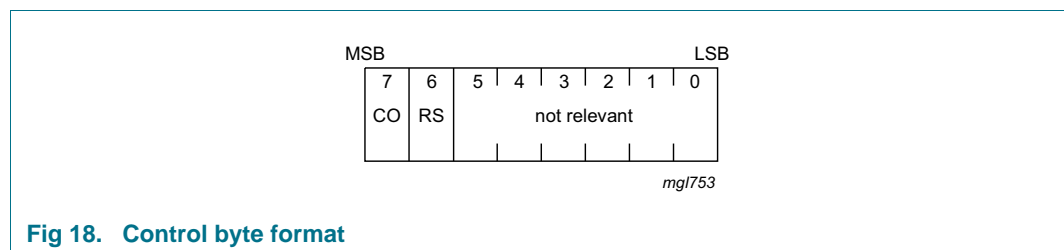


Fig 18. Control byte format

Table 18. Control byte description

| Bit    | Symbol | Value | Description               |
|--------|--------|-------|---------------------------|
| 7      | CO     |       | <b>continue bit</b>       |
|        |        | 0     | last control byte         |
|        |        | 1     | control bytes continue    |
| 6      | RS     |       | <b>register selection</b> |
|        |        | 0     | command register          |
|        |        | 1     | data register             |
| 5 to 0 | -      |       | not relevant              |

The command bytes and control bytes are also acknowledged by all addressed PCA85133 connected to the bus.

The display bytes are stored in the display RAM at the address specified by the data pointer and the subaddress counter. Both data pointer and subaddress counter are automatically updated.

The acknowledgement after each byte is made only by the (A0, A1, and A2) addressed PCA85133. After the last display byte, the I<sup>2</sup>C-bus master issues a STOP condition (P). Alternatively a START may be asserted to RESTART an I<sup>2</sup>C-bus access.

## 9. Internal circuitry

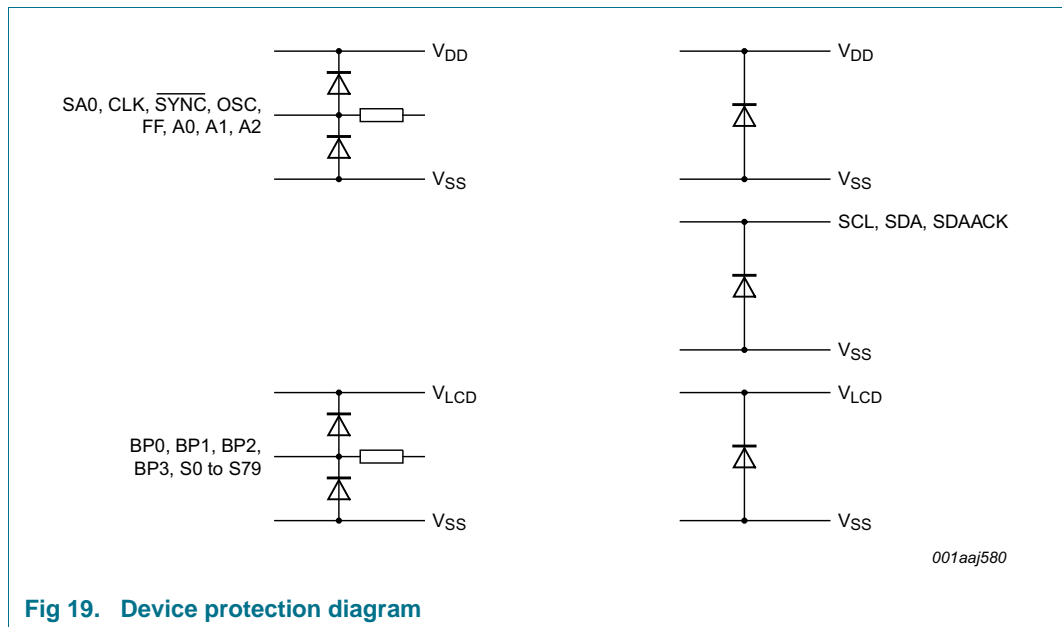


Fig 19. Device protection diagram

## 10. 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.

### CAUTION



Semiconductors are light sensitive. Exposure to light sources can cause the IC to malfunction. The IC must be protected against light. The protection must be applied to all sides of the IC.

## 11. Limiting values

**Table 19. Limiting values**

In accordance with the Absolute Maximum Rating System (IEC 60134).<sup>[1]</sup>

| Symbol               | Parameter                       | Conditions                       | Min            | Max   | Unit |    |
|----------------------|---------------------------------|----------------------------------|----------------|-------|------|----|
| V <sub>DD</sub>      | supply voltage                  |                                  | -0.5           | +6.5  | V    |    |
| V <sub>LCD</sub>     | LCD supply voltage              |                                  | -0.5           | +9.0  | V    |    |
| V <sub>i(n)</sub>    | voltage on any input            | V <sub>DD</sub> related inputs   | -0.5           | +6.5  | V    |    |
| V <sub>o(n)</sub>    | voltage on any output           | V <sub>LCD</sub> related outputs | -0.5           | +9.0  | V    |    |
| I <sub>I</sub>       | input current                   |                                  | -10            | +10   | mA   |    |
| I <sub>O</sub>       | output current                  |                                  | -10            | +10   | mA   |    |
| I <sub>DD</sub>      | supply current                  |                                  | -50            | +50   | mA   |    |
| I <sub>SS</sub>      | ground supply current           |                                  | -50            | +50   | mA   |    |
| I <sub>DD(LCD)</sub> | LCD supply current              |                                  | -50            | +50   | mA   |    |
| P <sub>tot</sub>     | total power dissipation         |                                  | -              | 400   | mW   |    |
| P/out                | power dissipation per output    |                                  | -              | 100   | mW   |    |
| V <sub>ESD</sub>     | electrostatic discharge voltage | Human Body Model <sup>[2]</sup>  | -              | ±4500 | V    |    |
|                      |                                 | Machine Model <sup>[3]</sup>     | -              | ±250  | V    |    |
| I <sub>lu</sub>      | latch-up current                |                                  | <sup>[4]</sup> | 200   | mA   |    |
| T <sub>stg</sub>     | storage temperature             |                                  | <sup>[5]</sup> | -65   | +150 | °C |
| T <sub>amb</sub>     | ambient temperature             | operating device                 | -40            | +95   | °C   |    |

[1] Stresses above these values listed may cause permanent damage to the device.

[2] Pass level; Human Body Model (HBM) according to [Ref. 8 "JESD22-A114"](#).

[3] Pass level; Machine Model (MM), according to [Ref. 9 "JESD22-A115"](#).

[4] Pass level; latch-up testing, according to [Ref. 10 "JESD78"](#) at maximum ambient temperature (T<sub>amb(max)</sub>).

[5] According to the store and transport requirements (see [Ref. 13 "UM10569"](#)) the devices have to be stored at a temperature of +8 °C to +45 °C and a humidity of 25 % to 75 %.

## 12. Static characteristics

**Table 20. Static characteristics**
 $V_{DD} = 1.8\text{ V to }5.5\text{ V}; V_{SS} = 0\text{ V}; V_{LCD} = 2.5\text{ V to }8.0\text{ V}; T_{amb} = -40\text{ }^{\circ}\text{C to }+95\text{ }^{\circ}\text{C};$  unless otherwise specified.

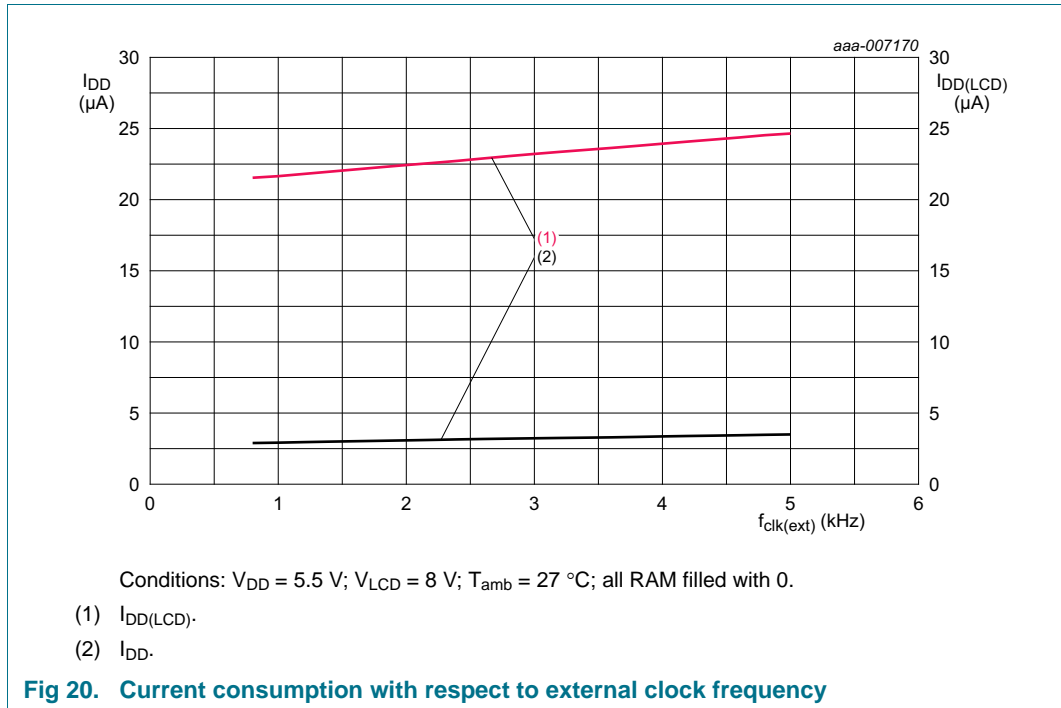
| Symbol                           | Parameter                           | Conditions   | Min                   | Typ | Max                   | Unit |
|----------------------------------|-------------------------------------|--|-----------------------|-----|-----------------------|------|
| <b>Supplies</b>                  |                                     |  |                       |     |                       |      |
| V <sub>DD</sub>                  | supply voltage                      | V <sub>LCD</sub> ≤ 6.5 V   | 1.8                   | -   | 5.5                   | V    |
|                                  |                                     | V <sub>LCD</sub> > 6.5 V   | 2.5                   | -   | 5.5                   | V    |
| V <sub>LCD</sub>                 | LCD supply voltage                  | V <sub>DD</sub> < 2.5 V  | 2.5                   | -   | 6.5                   | V    |
|                                  |                                     | V <sub>DD</sub> ≥ 2.5 V  | 2.5                   | -   | 8.0                   | V    |
| V <sub>POR</sub>                 | power-on reset voltage              |  | 1.0                   | 1.3 | 1.6                   | V    |
| I <sub>DD</sub>                  | supply current                      | f <sub>clk(ext)</sub> = 1536 Hz; see <a href="#">Figure 20</a>                                     | [1]                   | 3   | 6                     | μA   |
| I <sub>DD(LCD)</sub>             | LCD supply current                  | f <sub>clk(ext)</sub> = 1536 Hz; see <a href="#">Figure 20</a>                                     | [1]                   | 22  | 45                    | μA   |
| <b>Logic</b>                     |                                     |  |                       |     |                       |      |
| V <sub>I</sub>                   | input voltage                       |  | V <sub>SS</sub> - 0.5 | -   | V <sub>DD</sub> + 0.5 | V    |
| V <sub>IH</sub>                  | HIGH-level input voltage            | on pins CLK, SYNC, OSC, A0 to A2, SA0, FF  | 0.7V <sub>DD</sub>    | -   | V <sub>DD</sub>       | V    |
| V <sub>IL</sub>                  | LOW-level input voltage             | on pins CLK, SYNC, OSC, A0 to A2, SA0, FF  | V <sub>SS</sub>       | -   | 0.3V <sub>DD</sub>    | V    |
| V <sub>OH</sub>                  | HIGH-level output voltage           |  | 0.8V <sub>DD</sub>    | -   | -                     | V    |
| V <sub>OL</sub>                  | LOW-level output voltage            |  | -                     | -   | 0.2V <sub>DD</sub>    | V    |
| I <sub>OH</sub>                  | HIGH-level output current           | on pin CLK; V <sub>OH</sub> = 4.6 V; V <sub>DD</sub> = 5 V   | +1                    | -   | -                     | mA   |
| I <sub>OL</sub>                  | LOW-level output current            | on pin CLK, SYNC; V <sub>OL</sub> = 0.4 V; V <sub>DD</sub> = 5 V                                   | -                     | -   | -1                    | mA   |
| I <sub>L</sub>                   | leakage current                     | on pins OSC, CLK, SCL, SDA, A0 to A2, SA0, FF; V <sub>I</sub> = V <sub>DD</sub> or V <sub>SS</sub> | -1                    | -   | +1                    | μA   |
| C <sub>I</sub>                   | input capacitance                   |  | [3]                   | -   | 7                     | pF   |
| <b>I<sup>2</sup>C-bus[2]</b>     |                                     |  |                       |     |                       |      |
| <b>Input on pins SDA and SCL</b> |                                     |  |                       |     |                       |      |
| V <sub>I</sub>                   | input voltage                       |  | V <sub>SS</sub> - 0.5 | -   | 5.5                   | V    |
| V <sub>IH</sub>                  | HIGH-level input voltage            |  | 0.7V <sub>DD</sub>    | -   | 5.5                   | V    |
| V <sub>IL</sub>                  | LOW-level input voltage             |  | V <sub>SS</sub>       | -   | 0.3V <sub>DD</sub>    | V    |
| C <sub>I</sub>                   | input capacitance                   |  | [3]                   | -   | 7                     | pF   |
| I <sub>OL(SDA)</sub>             | LOW-level output current on pin SDA | V <sub>OL</sub> = 0.4 V; V <sub>DD</sub> = 5 V   | +3                    | -   | -                     | mA   |
| <b>LCD outputs</b>               |                                     |  |                       |     |                       |      |
| ΔV <sub>O</sub>                  | output voltage variation            | on pins BP0 to BP3; C <sub>bpl</sub> = 35 nF   | -100                  | -   | +100                  | mV   |
|                                  |                                     | on pins S0 to S79; C <sub>sgm</sub> = 5 nF   | -100                  | -   | +100                  | mV   |
| R <sub>O</sub>                   | output resistance                   | V <sub>LCD</sub> = 5 V   |                       |     |                       |      |
|                                  |                                     | on pins BP0 to BP3   | [4]                   | 1.5 | 10                    | kΩ   |
|                                  |                                     | on pins S0 to S79  | [4]                   | 6.0 | 13.5                  | kΩ   |

[1] LCD outputs are open-circuit; inputs at V<sub>SS</sub> or V<sub>DD</sub>; external clock with 50 % duty factor; I<sup>2</sup>C-bus inactive.

[2] The I<sup>2</sup>C-bus interface of PCA85133 is 5 V tolerant.

[3] Not tested, design specification only.

[4] Outputs measured individually and sequentially.





### 13. Dynamic characteristics

**Table 21. Dynamic characteristics**
 $V_{DD} = 1.8\text{ V to }5.5\text{ V}; V_{SS} = 0\text{ V}; V_{LCD} = 2.5\text{ V to }8.0\text{ V}; T_{amb} = -40\text{ }^{\circ}\text{C to }+95\text{ }^{\circ}\text{C};$  unless otherwise specified.

| Symbol  | Parameter                    | Conditions                                  | Min  | Typ  | Max  | Unit |
|---|------------------------------|---|------|------|------|------|
| <b>Clock</b>  |                              |   |      |      |      |      |
| Internal: output pin CLK                              |                              |   |      |      |      |      |
| f <sub>clk</sub>                                      | clock frequency              | FF = V <sub>DD</sub> <a href="#">[1][2]</a> | 1440 | 1970 | 2640 | Hz   |
|   |                              | FF = V <sub>SS</sub> <a href="#">[1][2]</a> | 1920 | 2640 | 3600 | Hz   |
| f <sub>fr</sub>                                       | frame frequency              | FF = V <sub>DD</sub>                        | 60   | 82   | 110  | Hz   |
|   |                              | FF = V <sub>SS</sub>                        | 80   | 110  | 150  | Hz   |
| External: input pin CLK                               |                              |   |      |      |      |      |
| f <sub>clk(ext)</sub>                                 | external clock frequency     | <a href="#">[2]</a>                         | 800  | -    | 5000 | Hz   |
| t <sub>clk(H)</sub>                                   | HIGH-level clock time        |   | 90   | -    | -    | μs   |
| t <sub>clk(L)</sub>                                   | LOW-level clock time         |   | 90   | -    | -    | μs   |
| <b>Synchronization: input pin SYNC</b>                |                              |   |      |      |      |      |
| t <sub>PD(SYNC_N)</sub>                               | SYNC propagation delay       |   | -    | 30   | -    | ns   |
| t <sub>SYNC_NL</sub>                                  | SYNC LOW time                |   | 1    | -    | -    | μs   |
| <b>Outputs: pins BP0 to BP3 and S0 to S79</b>         |                              |   |      |      |      |      |
| t <sub>PD(drv)</sub>                                  | driver propagation delay     | V <sub>LCD</sub> = 5 V                      | -    | -    | 30   | μs   |
| <b>I<sup>2</sup>C-bus: timing</b> <a href="#">[3]</a> |                              |   |      |      |      |      |
| Pin SCL   |                              |   |      |      |      |      |
| f <sub>SCL</sub>                                      | SCL clock frequency          |   | -    | -    | 400  | kHz  |
| t <sub>HIGH</sub>                                     | HIGH period of the SCL clock |   | 0.6  | -    | -    | μs   |
| t <sub>LOW</sub>                                      | LOW period of the SCL clock  |   | 1.3  | -    | -    | μs   |
| Pin SDA   |                              |   |      |      |      |      |
| t <sub>SU;DAT</sub>                                   | data set-up time             |   | 100  | -    | -    | ns   |
| t <sub>HD;DAT</sub>                                   | data hold time               |   | 0    | -    | -    | ns   |

**Table 21. Dynamic characteristics ...continued**

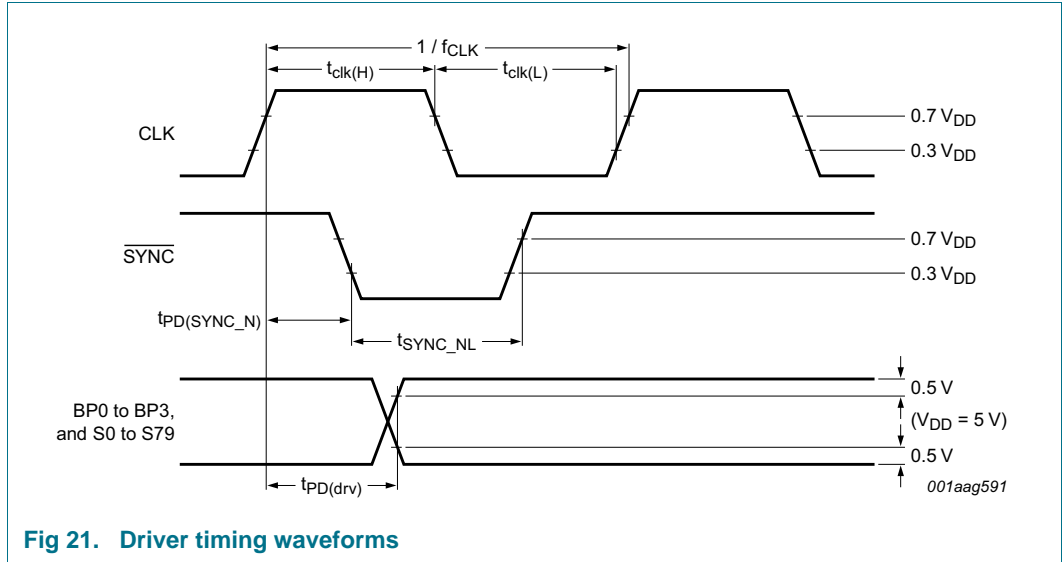
$V_{DD} = 1.8\text{ V to }5.5\text{ V}$ ;  $V_{SS} = 0\text{ V}$ ;  $V_{LCD} = 2.5\text{ V to }8.0\text{ V}$ ;  $T_{amb} = -40\text{ }^{\circ}\text{C to }+95\text{ }^{\circ}\text{C}$ ; unless otherwise specified.

| Symbol                | Parameter  | Conditions                 | Min | Typ | Max | Unit          |
|-----------------------|--|----------------------------|-----|-----|-----|---------------|
| Pins SCL and SDA      |  |                            |     |     |     |               |
| $t_{BUF}$             | bus free time between a STOP and START condition |                            | 1.3 | -   | -   | $\mu\text{s}$ |
| $t_{SU,STO}$          | set-up time for STOP condition                   |                            | 0.6 | -   | -   | $\mu\text{s}$ |
| $t_{HD,STA}$          | hold time (repeated) START condition             |                            | 0.6 | -   | -   | $\mu\text{s}$ |
| $t_{SU,STA}$          | set-up time for a repeated START condition       |                            | 0.6 | -   | -   | $\mu\text{s}$ |
| $t_r$                 | rise time of both SDA and SCL signals            | $f_{SCL} = 400\text{ kHz}$ | -   | -   | 0.3 | $\mu\text{s}$ |
|                       |  | $f_{SCL} < 125\text{ kHz}$ | -   | -   | 1.0 | $\mu\text{s}$ |
| $t_f$                 | fall time of both SDA and SCL signals            |                            | -   | -   | 0.3 | $\mu\text{s}$ |
| $C_b$                 | capacitive load for each bus line                |                            | -   | -   | 400 | $\text{pF}$   |
| $t_{w(\text{spike})}$ | spike pulse width                                | on bus                     | -   | -   | 50  | $\text{ns}$   |

[1] Typical output duty cycle of 50 %.

[2] The corresponding frame frequency is  $f_{fr} = \frac{f_{clk}}{24}$ .

[3] All timing values are valid within the operating supply voltage and ambient temperature range and are referenced to  $V_{IL}$  and  $V_{IH}$  with an input voltage swing of  $V_{SS}$  to  $V_{DD}$ . For I<sup>2</sup>C-bus timings see [Figure 22](#).



**Fig 21. Driver timing waveforms**

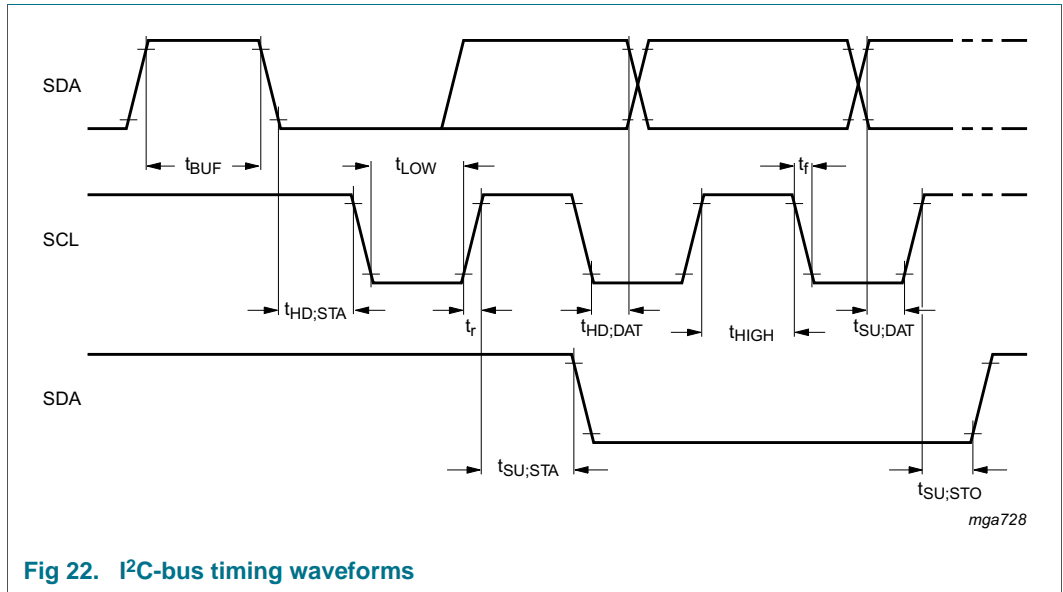


Fig 22. I<sup>2</sup>C-bus timing waveforms

## 14. Application information

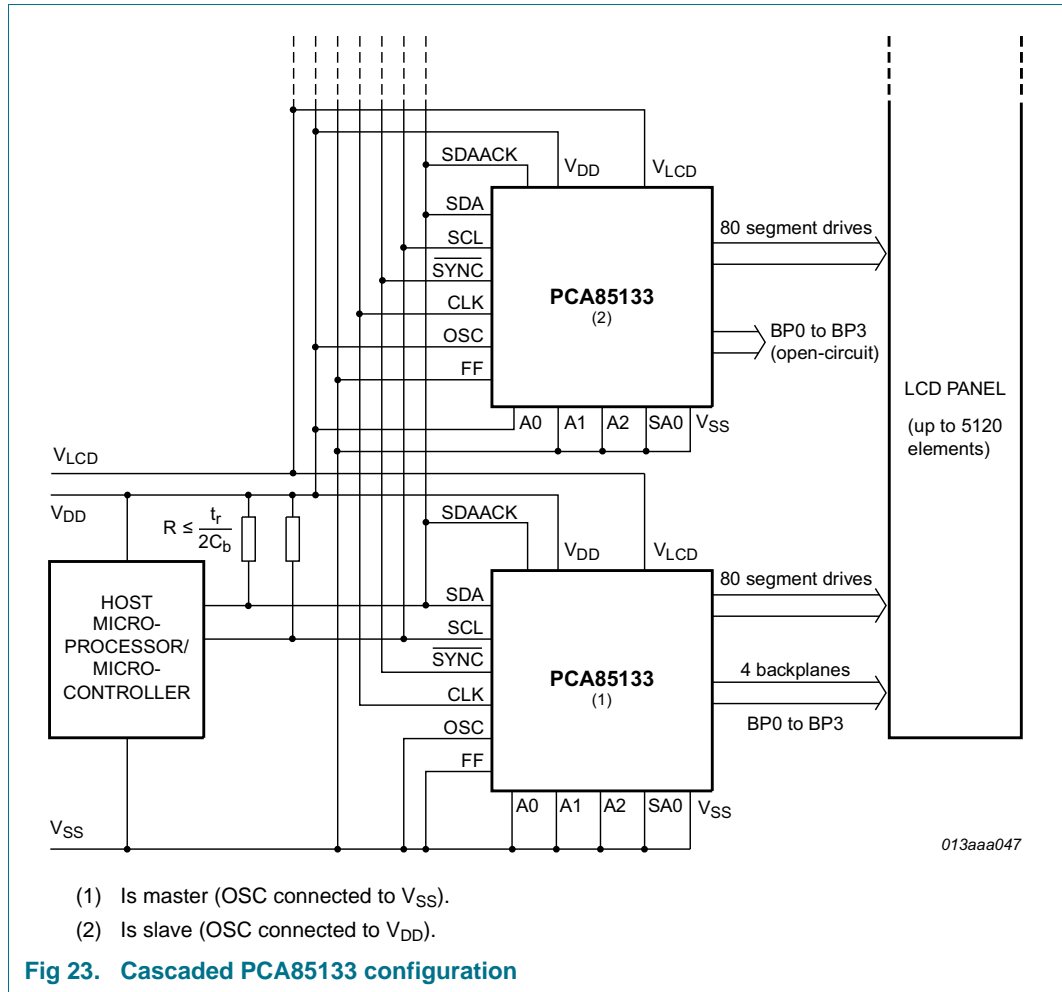
### 14.1 Cascaded operation

In large display configurations up to 16 PCA85133 can be recognized on the same I<sup>2</sup>C-bus by using the 3-bit hardware subaddress (A0, A1, and A2) and the programmable I<sup>2</sup>C-bus slave address (SA0).

**Table 22. Addressing cascaded PCA85133**

| Cluster | Bit SA0 | Pin A2 | Pin A1 | Pin A0 | Device |
|---------|---------|--------|--------|--------|--------|
| 1       | 0       | 0      | 0      | 0      | 0      |
|         |         | 0      | 0      | 1      | 1      |
|         |         | 0      | 1      | 0      | 2      |
|         |         | 0      | 1      | 1      | 3      |
|         |         | 1      | 0      | 0      | 4      |
|         |         | 1      | 0      | 1      | 5      |
|         |         | 1      | 1      | 0      | 6      |
|         |         | 1      | 1      | 1      | 7      |
| 2       | 1       | 0      | 0      | 0      | 8      |
|         |         | 0      | 0      | 1      | 9      |
|         |         | 0      | 1      | 0      | 10     |
|         |         | 0      | 1      | 1      | 11     |
|         |         | 1      | 0      | 0      | 12     |
|         |         | 1      | 0      | 1      | 13     |
|         |         | 1      | 1      | 0      | 14     |
|         |         | 1      | 1      | 1      | 15     |

When cascaded PCA85133 are synchronized, they can share the backplane signals from one of the devices in the cascade. Such an arrangement is cost-effective in large LCD applications since the backplane outputs of only one device need to be through-plated to the backplane electrodes of the display. The other PCA85133 of the cascade contribute additional segment outputs. The backplanes can either be connected together to enhance the drive capability or some can be left open-circuit (such as the ones from the slave in [Figure 23](#)) or just some of the master and some of the slave will be taken to facilitate the layout of the display.

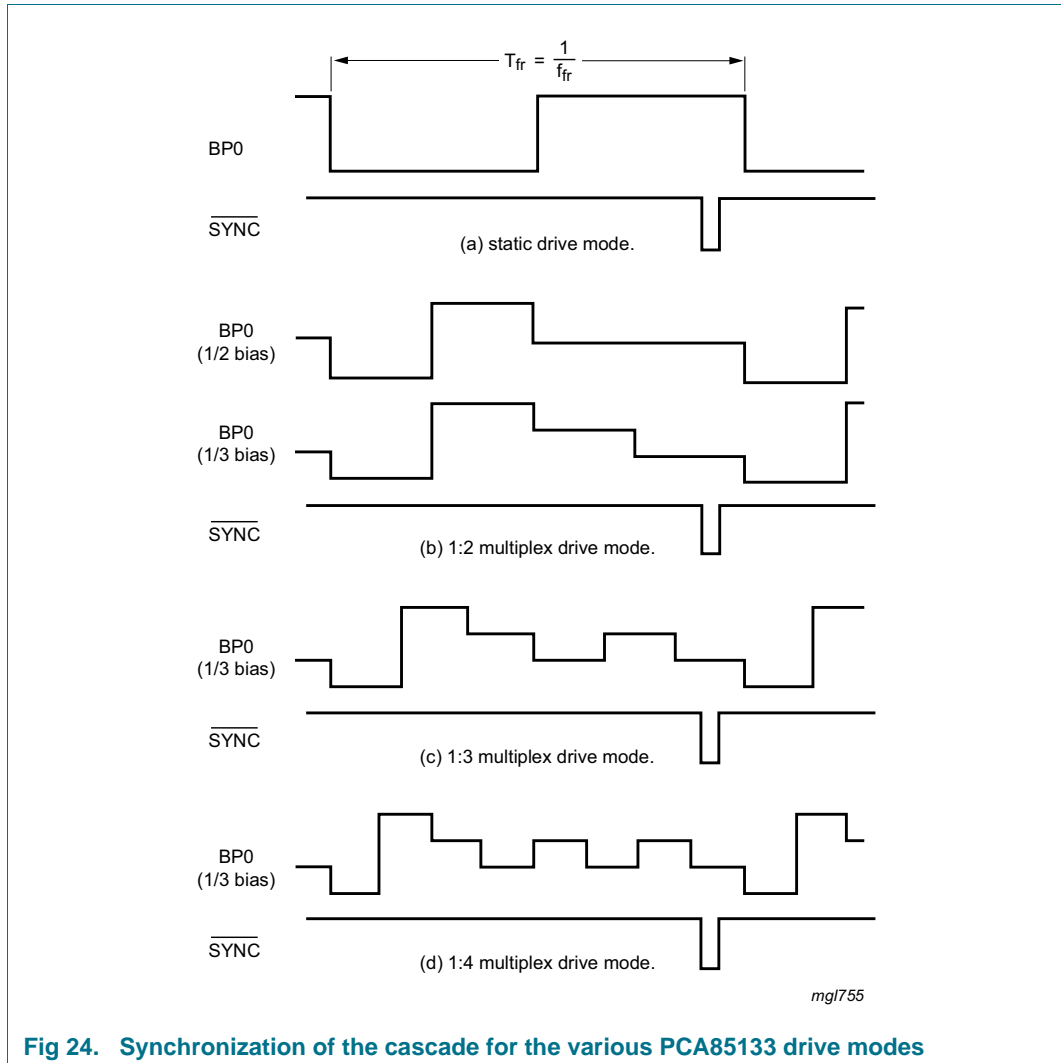


For display sizes that are not multiple of 320 elements, a mixed cascaded system can be considered containing only devices like PCA85133 and PCA85132. Depending on the application, one must take care of the software command and pin connection compatibility.

Only one master but multiple slaves are allowed in a cascade. All devices in the cascade have to use the same clock whether it is supplied externally or provided by the master.

The SYNC line is provided to maintain the correct synchronization between all cascaded PCA85133. This synchronization is guaranteed after the power-on reset. The only time that SYNC is likely to be needed is if synchronization is accidentally lost (e.g. by noise in adverse electrical environments or by the definition of a multiplex drive mode when PCA85133 with different SA0 levels are cascaded).

SYNC is organized as an input/output pin; The output selection is realized as an open-drain driver with an internal pull-up resistor. A PCA85133 asserts the SYNC line at the onset of its last active backplane signal and monitors the SYNC line at all other times. If synchronization in the cascade is lost, it is restored by the first PCA85133 to assert SYNC. The timing relationships between the backplane waveforms and the SYNC signal for the various drive modes of the PCA85133 are shown in [Figure 24](#).



**Fig 24. Synchronization of the cascade for the various PCA85133 drive modes**

The contact resistance between the SYNC pins of cascaded devices must be controlled. If the resistance is too high, then the device will not be able to synchronize properly. This is particularly applicable to COG applications.

## 15. Test information

### 15.1 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.

16. Bare die outline

Bare die; 110 bumps; 4.16 x 1.07 x 0.40 mm

PCA85133

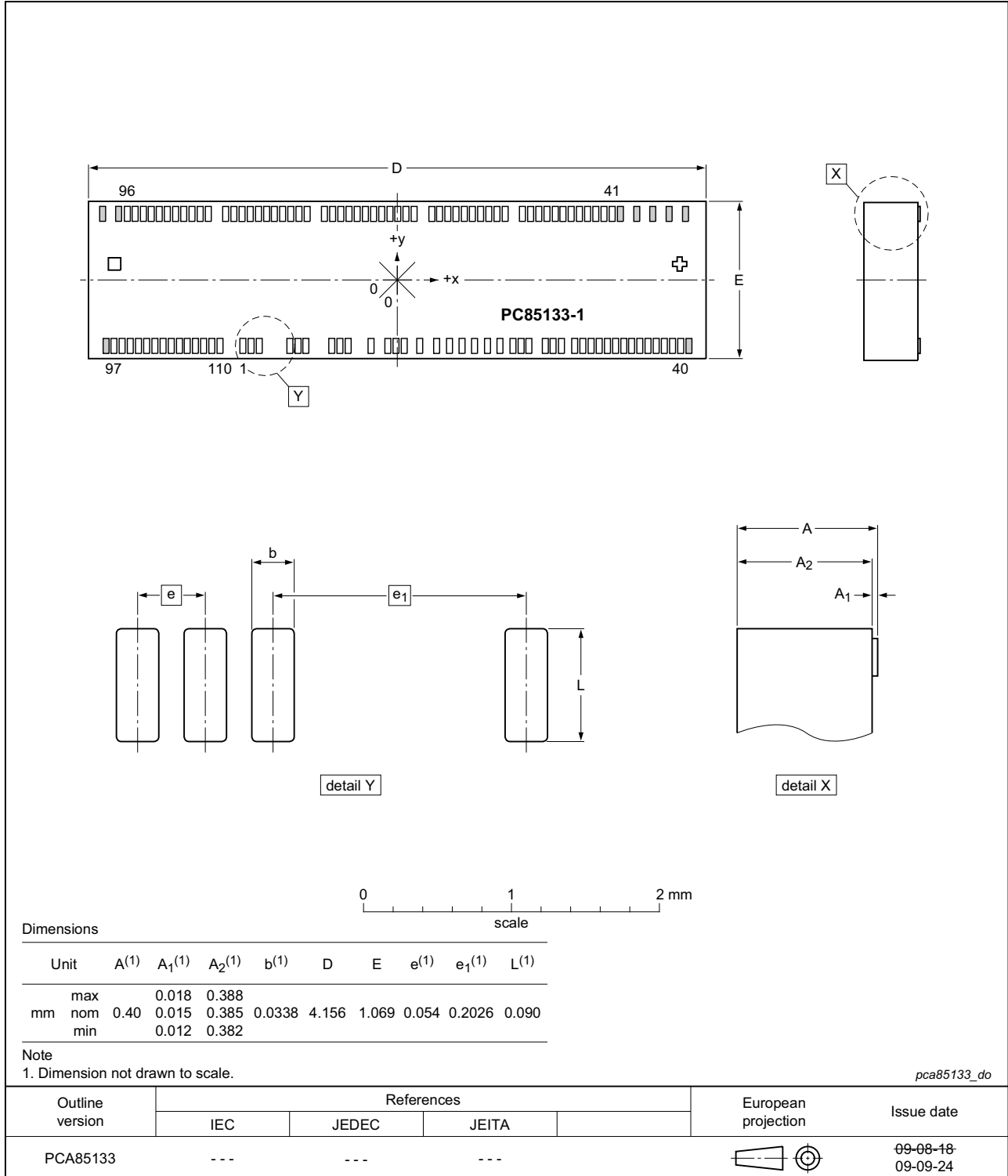


Fig 25. Bare die outline of PCA85133

**Table 23. Bump locations**

All x/y coordinates represent the position of the center of each bump with respect to the center (x/y = 0) of the chip; see [Figure 25](#).

| Symbol           | Bump | X (μm)   | Y (μm) |     | Description                                     |
|------------------|------|----------|--------|-----|---|
| SDAACK           | 1    | -1022.67 | -436.5 | [1] | I <sup>2</sup> C-bus acknowledge output         |
| SDAACK           | 2    | -968.67  | -436.5 |     |   |
| SDAACK           | 3    | -914.67  | -436.5 |     |   |
| SDA              | 4    | -712.17  | -436.5 | [1] | I <sup>2</sup> C-bus serial data input          |
| SDA              | 5    | -658.17  | -436.5 |     |   |
| SDA              | 6    | -604.17  | -436.5 |     |   |
| SCL              | 7    | -433.17  | -436.5 |     | I <sup>2</sup> C-bus serial clock input         |
| SCL              | 8    | -379.17  | -436.5 |     |   |
| SCL              | 9    | -325.17  | -436.5 |     |   |
| CLK              | 10   | -173.52  | -436.5 |     | clock input/output                              |
| V <sub>DD</sub>  | 11   | -61.47   | -436.5 |     | supply voltage                                  |
| V <sub>DD</sub>  | 12   | -7.47    | -436.5 |     |   |
| V <sub>DD</sub>  | 13   | 46.53    | -436.5 |     |   |
| SYNC             | 14   | 149.58   | -436.5 |     | cascade synchronization input/output            |
| OSC              | 15   | 262.08   | -436.5 |     | oscillator select                               |
| FF               | 16   | 345.78   | -436.5 |     | frame frequency select                          |
| A0               | 17   | 429.48   | -436.5 |     | subaddress input                                |
| A1               | 18   | 513.18   | -436.5 |     |   |
| A2               | 19   | 596.88   | -436.5 |     |   |
| SA0              | 20   | 680.58   | -436.5 |     | I <sup>2</sup> C-bus slave address input; bit 0 |
| V <sub>SS</sub>  | 21   | 765.63   | -436.5 |     | ground supply voltage                           |
| V <sub>SS</sub>  | 22   | 819.63   | -436.5 |     |   |
| V <sub>SS</sub>  | 23   | 873.63   | -436.5 |     |   |
| V <sub>LCD</sub> | 24   | 979.83   | -436.5 |     | LCD supply voltage                              |
| V <sub>LCD</sub> | 25   | 1033.83  | -436.5 |     |   |
| V <sub>LCD</sub> | 26   | 1087.83  | -436.5 |     |   |
| BP2              | 27   | 1176.03  | -436.5 |     | LCD backplane output                            |
| BPO              | 28   | 1230.03  | -436.5 |     |   |
| S0               | 29   | 1284.03  | -436.5 |     | LCD segment output                              |
| S1               | 30   | 1338.03  | -436.5 |     |   |
| S2               | 31   | 1392.03  | -436.5 |     |   |
| S3               | 32   | 1446.03  | -436.5 |     |   |
| S4               | 33   | 1500.03  | -436.5 |     |   |
| S5               | 34   | 1554.03  | -436.5 |     |   |
| S6               | 35   | 1608.03  | -436.5 |     |   |
| S7               | 36   | 1662.03  | -436.5 |     |   |
| S8               | 37   | 1716.03  | -436.5 |     |   |
| S9               | 38   | 1770.03  | -436.5 |     |   |



**Table 23. Bump locations**

All x/y coordinates represent the position of the center of each bump with respect to the center (x/y = 0) of the chip; see [Figure 25](#).

| Symbol | Bump | X (μm)   | Y (μm) | Description        |
|--------|------|----------|--------|--------------------|
| S10    | 39   | 1 824.03 | -436.5 | LCD segment output |
| S11    | 40   | 1 878.03 | -436.5 |                    |
| S12    | 41   | 1 423.53 | 436.5  |                    |
| S13    | 42   | 1 369.53 | 436.5  |                    |
| S14    | 43   | 1 315.53 | 436.5  |                    |
| S15    | 44   | 1 261.53 | 436.5  |                    |
| S16    | 45   | 1 207.53 | 436.5  |                    |
| S17    | 46   | 1 153.53 | 436.5  |                    |
| S18    | 47   | 1 099.53 | 436.5  |                    |
| S19    | 48   | 1 045.53 | 436.5  |                    |
| S20    | 49   | 991.53   | 436.5  |                    |
| S21    | 50   | 937.53   | 436.5  |                    |
| S22    | 51   | 883.53   | 436.5  |                    |
| S23    | 52   | 829.53   | 436.5  |                    |
| S24    | 53   | 714.06   | 436.5  |                    |
| S25    | 54   | 660.06   | 436.5  |                    |
| S26    | 55   | 606.06   | 436.5  |                    |
| S27    | 56   | 552.06   | 436.5  |                    |
| S28    | 57   | 498.06   | 436.5  |                    |
| S29    | 58   | 444.06   | 436.5  |                    |
| S30    | 59   | 390.06   | 436.5  |                    |
| S31    | 60   | 336.06   | 436.5  |                    |
| S32    | 61   | 282.06   | 436.5  |                    |
| S33    | 62   | 228.06   | 436.5  |                    |
| S34    | 63   | 112.59   | 436.5  |                    |
| S35    | 64   | 58.59    | 436.5  |                    |
| S36    | 65   | 4.59     | 436.5  |                    |
| S37    | 66   | -49.41   | 436.5  |                    |
| S38    | 67   | -103.41  | 436.5  |                    |
| S39    | 68   | -157.41  | 436.5  |                    |
| S40    | 69   | -211.41  | 436.5  |                    |
| S41    | 70   | -265.41  | 436.5  |                    |
| S42    | 71   | -319.41  | 436.5  |                    |
| S43    | 72   | -373.41  | 436.5  |                    |
| S44    | 73   | -427.41  | 436.5  |                    |
| S45    | 74   | -481.41  | 436.5  |                    |
| S46    | 75   | -596.88  | 436.5  |                    |
| S47    | 76   | -650.88  | 436.5  |                    |
| S48    | 77   | -704.88  | 436.5  |                    |

**Table 23. Bump locations**

All x/y coordinates represent the position of the center of each bump with respect to the center (x/y = 0) of the chip; see [Figure 25](#).

| Symbol | Bump | X (μm)   | Y (μm) | Description          |
|--------|------|----------|--------|----------------------|
| S49    | 78   | -758.88  | 436.5  | LCD segment output   |
| S50    | 79   | -812.88  | 436.5  |                      |
| S51    | 80   | -866.88  | 436.5  |                      |
| S52    | 81   | -920.88  | 436.5  |                      |
| S53    | 82   | -974.88  | 436.5  |                      |
| S54    | 83   | -1028.88 | 436.5  |                      |
| S55    | 84   | -1082.88 | 436.5  |                      |
| S56    | 85   | -1136.88 | 436.5  |                      |
| S57    | 86   | -1252.35 | 436.5  |                      |
| S58    | 87   | -1306.35 | 436.5  |                      |
| S59    | 88   | -1360.35 | 436.5  |                      |
| S60    | 89   | -1414.35 | 436.5  |                      |
| S61    | 90   | -1468.35 | 436.5  |                      |
| S62    | 91   | -1522.35 | 436.5  |                      |
| S63    | 92   | -1576.35 | 436.5  |                      |
| S64    | 93   | -1630.35 | 436.5  |                      |
| S65    | 94   | -1684.35 | 436.5  |                      |
| S66    | 95   | -1738.35 | 436.5  |                      |
| S67    | 96   | -1792.35 | 436.5  |                      |
| S68    | 97   | -1876.05 | -436.5 |                      |
| S69    | 98   | -1822.05 | -436.5 |                      |
| S70    | 99   | -1768.05 | -436.5 |                      |
| S71    | 100  | -1714.05 | -436.5 |                      |
| S72    | 101  | -1660.05 | -436.5 |                      |
| S73    | 102  | -1606.05 | -436.5 |                      |
| S74    | 103  | -1552.05 | -436.5 |                      |
| S75    | 104  | -1498.05 | -436.5 |                      |
| S76    | 105  | -1444.05 | -436.5 |                      |
| S77    | 106  | -1390.05 | -436.5 |                      |
| S78    | 107  | -1336.05 | -436.5 |                      |
| S79    | 108  | -1282.05 | -436.5 |                      |
| BP3    | 109  | -1228.05 | -436.5 | LCD backplane output |
| BP1    | 110  | -1174.05 | -436.5 |                      |

**Table 23. Bump locations**

All x/y coordinates represent the position of the center of each bump with respect to the center (x/y = 0) of the chip; see [Figure 25](#).

| Symbol | Bump | X (μm)   | Y (μm) | Description |
|--------|------|----------|--------|-------------|
| D1     | -    | 1932.03  | -436.5 | [2]         |
| D2     | -    | 1909.53  | 436.5  |             |
| D3     | -    | 1801.53  | 436.5  |             |
| D4     | -    | 1693.53  | 436.5  |             |
| D5     | -    | 1585.53  | 436.5  |             |
| D6     | -    | 1477.53  | 436.5  |             |
| D7     | -    | -1846.35 | 436.5  |             |
| D8     | -    | -1953    | 436.5  | dummy pad   |
| D9     | -    | -1930.05 | -436.5 |             |

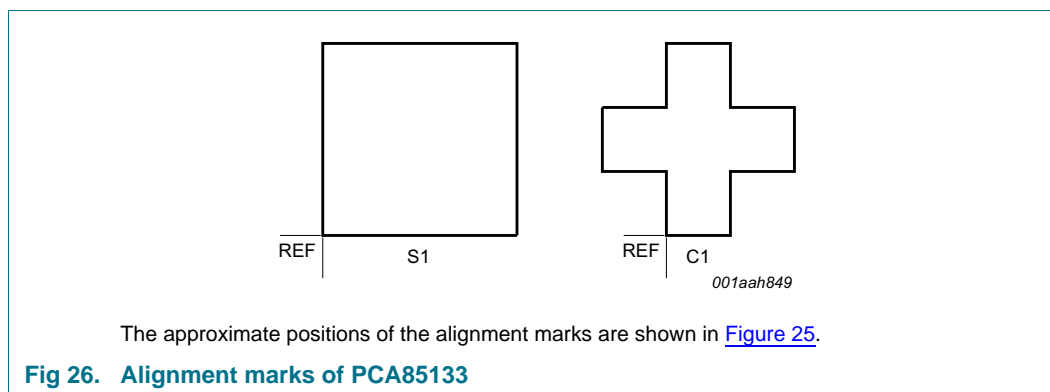
[1] For most applications SDA and SDAACK are shorted together; see [Section 8](#).

[2] The dummy pads are connected to V<sub>SS</sub> but are not tested.

**Table 24. Gold bump hardness**

| Type number      | Min | Max | Unit <sup>[1]</sup> |
|------------------|-----|-----|---------------------|
| PCA85133U/2DA/Q1 | 60  | 120 | HV                  |
| PCA85133U/2DB/Q1 | 35  | 80  | HV                  |

[1] Pressure of diamond head: 10 g to 50 g.



**Fig 26. Alignment marks of PCA85133**

**Table 25. Alignment mark locations**

All x/y coordinates represent the position of the REF point (see [Figure 26](#)) with respect to the center (x/y = 0) of the chip; see [Figure 25](#).

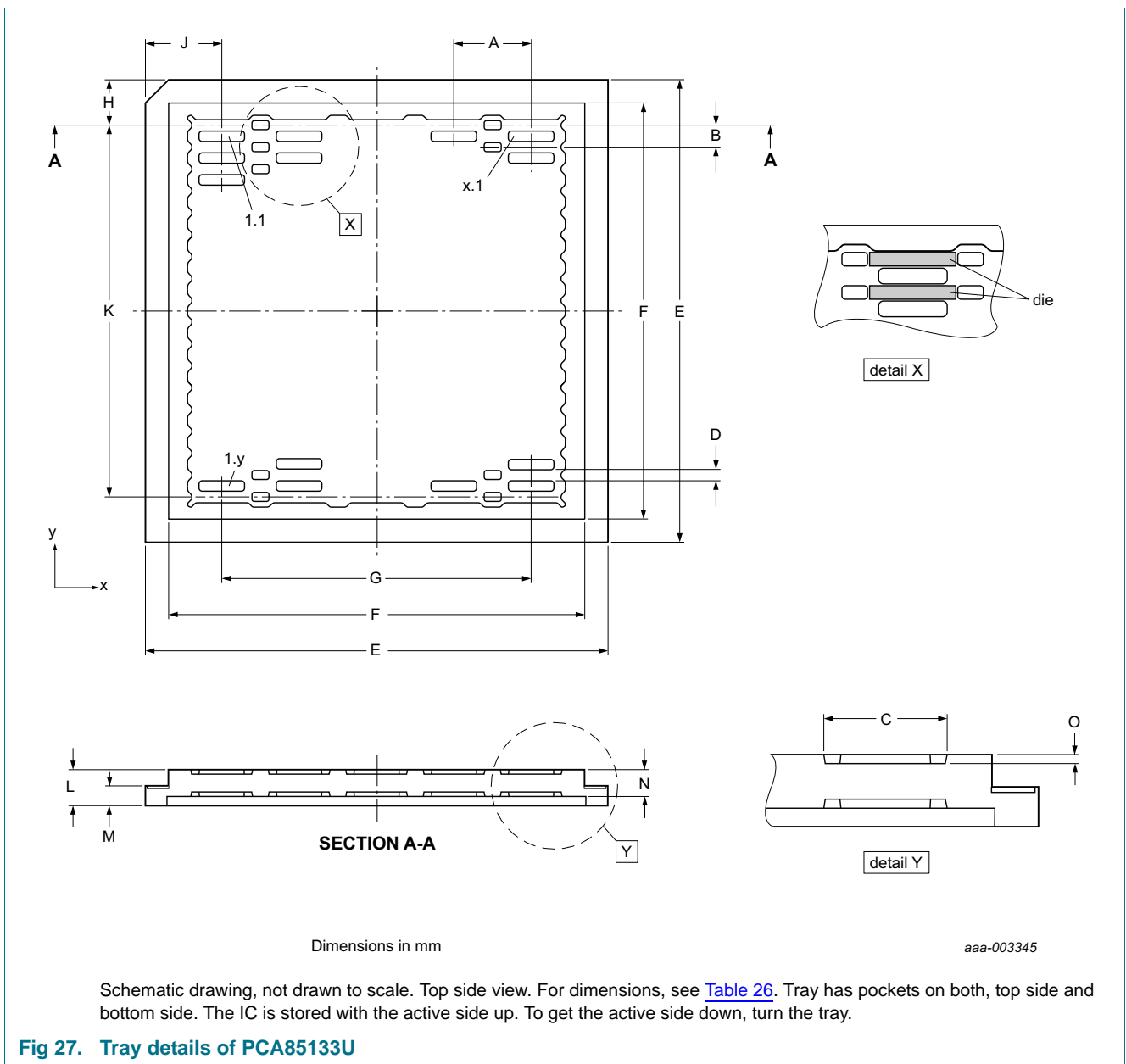
| Symbol | Size (μm) | X (μm)  | Y (μm) |
|--------|-----------|---------|--------|
| S1     | 81 × 81   | -1916.1 | 45     |
| C1     | 81 × 81   | 1855.8  | 45     |

### 17. 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.

### 18. Packing information

#### 18.1 Packing information on the tray



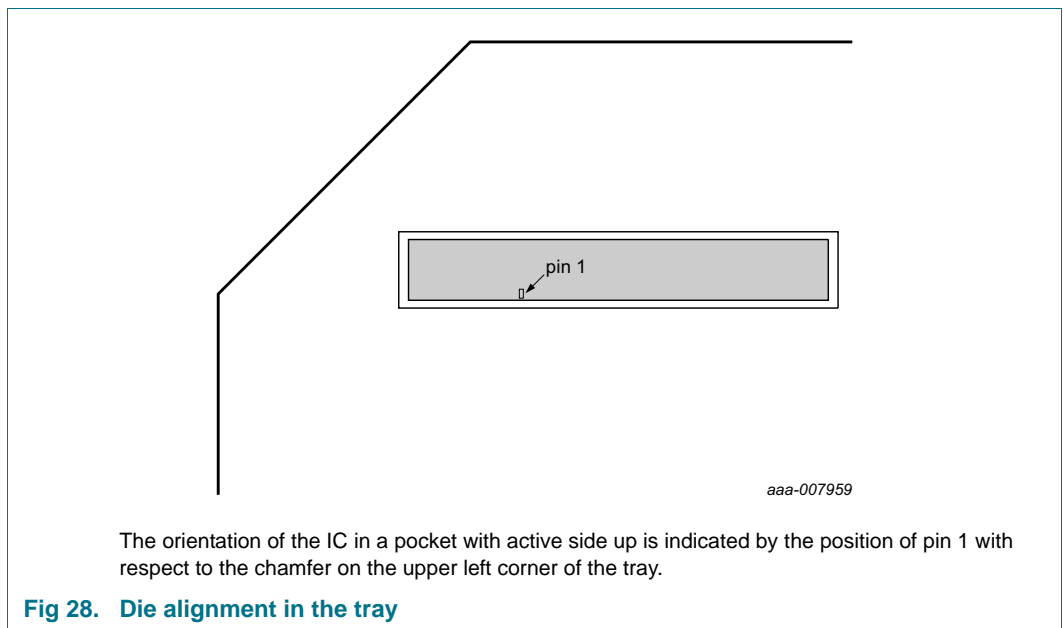
Schematic drawing, not drawn to scale. Top side view. For dimensions, see [Table 26](#). Tray has pockets on both, top side and bottom side. The IC is stored with the active side up. To get the active side down, turn the tray.

**Fig 27. Tray details of PCA85133U**

**Table 26. Specification of 3 inch tray details**

Tray details are shown in [Figure 27](#). Nominal values without production tolerances.

| Tray details      |     |      |      |      |      |      |             |     |      |     |     |     |      |      |
|-------------------|-----|------|------|------|------|------|-------------|-----|------|-----|-----|-----|------|------|
| Dimensions        |     |      |      |      |      |      |             |     |      |     |     |     |      |      |
| A                 | B   | C    | D    | E    | F    | G    | H           | J   | K    | L   | M   | N   | O    | Unit |
| 6.0               | 2.5 | 4.26 | 1.17 | 76.0 | 68.0 | 60.0 | 6.75        | 8.0 | 62.5 | 4.2 | 2.6 | 3.2 | 0.48 | mm   |
| Number of pockets |     |      |      |      |      |      |             |     |      |     |     |     |      |      |
| x direction       |     |      |      |      |      |      | y direction |     |      |     |     |     |      |      |
| 11                |     |      |      |      |      |      | 26          |     |      |     |     |     |      |      |



## 19. Appendix

## 19.1 LCD segment driver selection

Table 27. Selection of LCD segment drivers

| Type name  | Number of elements at MUX |     |     |     |     |     |     | V <sub>DD</sub> (V) | V <sub>LCD</sub> (V) | f <sub>fr</sub> (Hz)     | V <sub>LCD</sub> (V)<br>charge<br>pump | V <sub>LCD</sub> (V)<br>temperature<br>compensat. | T <sub>amb</sub> (°C) | Interface              | Package  | AEC-<br>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 <sup>[1]</sup> | N                                      | N   | -40 to 105            | I <sup>2</sup> C / SPI | TSSOP56  | Y            |
| PCA8546ATT | -                         | -   | -   | 176 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 95             | I <sup>2</sup> C       | TSSOP56  | Y            |
| PCA8546BTT | -                         | -   | -   | 176 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 95             | SPI                    | TSSOP56  | Y            |
| PCA8547AHT | 44                        | 88  | -   | 176 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | Y                                      | Y   | -40 to 95             | I <sup>2</sup> C       | TQFP64   | Y            |
| PCA8547BHT | 44                        | 88  | -   | 176 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | 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 <sup>2</sup> C       | LQFP80   | N            |
| PCA85134H  | 60                        | 120 | 180 | 240 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 8             | 82                       | N                                      | N   | -40 to 95             | I <sup>2</sup> C       | LQFP80   | Y            |
| PCA8543AHL | 60                        | 120 | -   | 240 | -   | -   | -   | 2.5 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | Y                                      | Y   | -40 to 105            | I <sup>2</sup> C       | LQFP80   | Y            |
| PCF8545ATT | -                         | -   | -   | 176 | 252 | 320 | -   | 1.8 to 5.5          | 2.5 to 5.5           | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 85             | I <sup>2</sup> C       | TSSOP56  | N            |
| PCF8545BTT | -                         | -   | -   | 176 | 252 | 320 | -   | 1.8 to 5.5          | 2.5 to 5.5           | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 85             | SPI                    | TSSOP56  | N            |
| PCF8536AT  | -                         | -   | -   | 176 | 252 | 320 | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 85             | I <sup>2</sup> C       | TSSOP56  | N            |
| PCF8536BT  | -                         | -   | -   | 176 | 252 | 320 | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 85             | SPI                    | TSSOP56  | N            |
| PCA8536AT  | -                         | -   | -   | 176 | 252 | 320 | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | N                                      | N   | -40 to 95             | I <sup>2</sup> C       | TSSOP56  | Y            |
| PCA8536BT  | -                         | -   | -   | 176 | 252 | 320 | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | 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 <sup>[1]</sup> | Y                                      | Y   | -40 to 85             | I <sup>2</sup> C       | TQFP64   | N            |
| PCF8537BH  | 44                        | 88  | -   | 176 | 276 | 352 | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | 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 <sup>[1]</sup> | Y                                      | Y   | -40 to 95             | I <sup>2</sup> C       | TQFP64   | Y            |
| PCA8537BH  | 44                        | 88  | -   | 176 | 276 | 352 | -   | 1.8 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | 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 <sup>[1]</sup> | Y                                      | Y   | -40 to 105            | I <sup>2</sup> C       | LQFP80   | Y            |
| PCA9620U   | 60                        | 120 | -   | 240 | 320 | 480 | -   | 2.5 to 5.5          | 2.5 to 9             | 60 to 300 <sup>[1]</sup> | Y                                      | Y   | -40 to 105            | I <sup>2</sup> 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 <sup>2</sup> C       | Bare die | N            |
| PCF8576EUG | 40                        | 80  | 120 | 160 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 6.5           | 77                       | N                                      | N   | -40 to 85             | I <sup>2</sup> 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 <sup>2</sup> C       | Bare die | Y            |
| PCF85133U  | 80                        | 160 | 240 | 320 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 6.5           | 82, 110 <sup>[2]</sup>   | N                                      | N   | -40 to 85             | I <sup>2</sup> C       | Bare die | N            |
| PCA85133U  | 80                        | 160 | 240 | 320 | -   | -   | -   | 1.8 to 5.5          | 2.5 to 8             | 82, 110 <sup>[2]</sup>   | N                                      | N   | -40 to 95             | I <sup>2</sup> C       | Bare die | Y            |

Table 27. Selection of LCD segment drivers ...continued

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

[1] Software programmable.

[2] Hardware selectable.

## 20. Abbreviations

Table 28. Abbreviations

| Acronym          | Description                             |
|------------------|---|
| CMOS             | Complementary Metal-Oxide Semiconductor |
| COG              | Chip-On-Glass                           |
| DC               | Direct Current                          |
| HBM              | Human Body Model                        |
| I <sup>2</sup> C | Inter-Integrated Circuit                |
| IC               | Integrated Circuit                      |
| ITO              | Indium Tin Oxide                        |
| LCD              | Liquid Crystal Display                  |
| MM               | Machine Model                           |
| RAM              | Random Access Memory                    |
| RC               | Resistance-Capacitance                  |
| RMS              | Root Mean Square                        |

## 21. References

- [1] **AN10170** — Design guidelines for COG modules with NXP monochrome LCD drivers
- [2] **AN10706** — Handling bare die
- [3] **AN10853** — ESD and EMC sensitivity of IC
- [4] **AN11267** — EMC and system level ESD design guidelines for LCD drivers
- [5] **AN11494** — Cascading NXP LCD segment drivers
- [6] **IEC 60134** — Rating systems for electronic tubes and valves and analogous semiconductor devices
- [7] **IEC 61340-5** — Protection of electronic devices from electrostatic phenomena
- [8] **JESD22-A114** — Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)
- [9] **JESD22-A115** — Electrostatic Discharge (ESD) Sensitivity Testing Machine Model (MM)
- [10] **JESD78** — IC Latch-Up Test
- [11] **JESD625-A** — Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices
- [12] **UM10204** — I<sup>2</sup>C-bus specification and user manual
- [13] **UM10569** — Store and transport requirements



## 22. Revision history

Table 29. Revision history

| Document ID    | Release date   | Data sheet status  | Change notice | Supersedes   |
|----------------|--|--------------------|---------------|--------------|
| PCA85133 v.3   | 20140704   | Product data sheet | -             | PCA85133 v.2 |
| Modifications: | <ul style="list-style-type: none"> <li>• The format of this data sheet has been redesigned to comply with the new identity guidelines of NXP Semiconductors.</li> <li>• Legal texts have been adapted to the new company name where appropriate.</li> <li>• Adjusted <math>I_{DD}</math> and <math>I_{DD(LCD)}</math> values in <a href="#">Table 20</a></li> <li>• Added graph <a href="#">Figure 20 "Current consumption with respect to external clock frequency"</a></li> <li>• Removed ITO resistance table in <a href="#">Section 14</a></li> <li>• Changed product type and ordering information (<a href="#">Section 3</a>)</li> <li>• Changed tray information (<a href="#">Section 18</a>)</li> <li>• Improved description of bit E</li> </ul> |                    |               |              |
| PCA85133 v.2   | 20110704   | Product data sheet | -             | PCA85133_1   |
| PCA85133_1     | 20091023   | Product data sheet | -             | -            |

## 23. Legal information

### 23.1 Data sheet status

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

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

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

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

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## 25. Tables

|           |   |    |
|-----------|---|----|
| Table 1.  | Ordering information  | 2  |
| Table 2.  | Ordering options  | 2  |
| Table 3.  | Marking codes   | 2  |
| Table 4.  | Pin description overview                                    | 4  |
| Table 5.  | Selection of possible display configurations                | 5  |
| Table 6.  | Biasing characteristics                                     | 7  |
| Table 7.  | LCD frame frequencies                                       | 15 |
| Table 8.  | Standard RAM filling in 1:3 multiplex drive mode            | 19 |
| Table 9.  | Entire RAM filling by rewriting in 1:3 multiplex drive mode | 20 |
| Table 10. | Blink frequencies   | 21 |
| Table 11. | Definition of commands                                      | 22 |
| Table 12. | Mode-set command bit description                            | 22 |
| Table 13. | Load-data-pointer command bit description                   | 22 |
| Table 14. | Device-select command bit description                       | 22 |
| Table 15. | Bank-select command bit description <a href="#">[1]</a>     | 23 |
| Table 16. | Blink-select command bit description                        | 23 |
| Table 17. | I <sup>2</sup> C slave address byte                         | 26 |
| Table 18. | Control byte description                                    | 28 |
| Table 19. | Limiting values   | 30 |
| Table 20. | Static characteristics                                      | 31 |
| Table 21. | Dynamic characteristics                                     | 33 |
| Table 22. | Addressing cascaded PCA85133                                | 36 |
| Table 23. | Bump locations  | 40 |
| Table 24. | Gold bump hardness  | 43 |
| Table 25. | Alignment mark locations                                    | 43 |
| Table 26. | Specification of 3 inch tray details                        | 45 |
| Table 27. | Selection of LCD segment drivers                            | 46 |
| Table 28. | Abbreviations   | 48 |
| Table 29. | Revision history  | 49 |

26. Figures

Fig 1. Block diagram of PCA85133 .....3  
 Fig 2. Pin configuration for PCA85133 .....4  
 Fig 3. Example of displays suitable for PCA85133 .....5  
 Fig 4. Typical system configuration .....6  
 Fig 5. Electro-optical characteristic: relative transmission curve of the liquid. ....9  
 Fig 6. Static drive mode waveforms .....10  
 Fig 7. Waveforms for the 1:2 multiplex drive mode with  $\frac{1}{2}$  bias .....11  
 Fig 8. Waveforms for the 1:2 multiplex drive mode with  $\frac{1}{3}$  bias .....12  
 Fig 9. Waveforms for the 1:3 multiplex drive mode with  $\frac{1}{3}$  bias .....13  
 Fig 10. Waveforms for the 1:4 multiplex drive mode with  $\frac{1}{3}$  bias .....14  
 Fig 11. Display RAM bitmap .....17  
 Fig 12. Relationships between LCD layout, drive mode, display RAM filling order, and display data transmitted over the I<sup>2</sup>C-bus .....18  
 Fig 13. Bit transfer .....24  
 Fig 14. Definition of START and STOP conditions. ....25  
 Fig 15. System configuration .....25  
 Fig 16. Acknowledgement on the I<sup>2</sup>C-bus .....26  
 Fig 17. I<sup>2</sup>C-bus protocol. ....27  
 Fig 18. Control byte format .....27  
 Fig 19. Device protection diagram .....28  
 Fig 20. Current consumption with respect to external clock frequency .....32  
 Fig 21. Driver timing waveforms .....34  
 Fig 22. I<sup>2</sup>C-bus timing waveforms .....35  
 Fig 23. Cascaded PCA85133 configuration. ....37  
 Fig 24. Synchronization of the cascade for the various PCA85133 drive modes. ....38  
 Fig 25. Bare die outline of PCA85133 .....39  
 Fig 26. Alignment marks of PCA85133 .....43  
 Fig 27. Tray details of PCA85133U .....44  
 Fig 28. Die alignment in the tray .....45

## 27. Contents

|           |  |           |           |                                       |           |
|-----------|--|-----------|-----------|---------------------------------------|-----------|
| <b>1</b>  | <b>General description</b> .....                       | <b>1</b>  | <b>11</b> | <b>Limiting values</b> .....          | <b>30</b> |
| <b>2</b>  | <b>Features and benefits</b> .....                     | <b>1</b>  | <b>12</b> | <b>Static characteristics</b> .....   | <b>31</b> |
| <b>3</b>  | <b>Ordering information</b> .....                      | <b>2</b>  | <b>13</b> | <b>Dynamic characteristics</b> .....  | <b>33</b> |
| 3.1       | Ordering options .....                                 | 2         | <b>14</b> | <b>Application information</b> .....  | <b>36</b> |
| <b>4</b>  | <b>Marking</b> .....                                   | <b>2</b>  | 14.1      | Cascaded operation .....              | 36        |
| <b>5</b>  | <b>Block diagram</b> .....                             | <b>3</b>  | <b>15</b> | <b>Test information</b> .....         | <b>38</b> |
| <b>6</b>  | <b>Pinning information</b> .....                       | <b>4</b>  | 15.1      | Quality information .....             | 38        |
| 6.1       | Pinning .....  | 4         | <b>16</b> | <b>Bare die outline</b> .....         | <b>39</b> |
| 6.2       | Pin description .....                                  | 4         | <b>17</b> | <b>Handling information</b> .....     | <b>44</b> |
| <b>7</b>  | <b>Functional description</b> .....                    | <b>5</b>  | <b>18</b> | <b>Packing information</b> .....      | <b>44</b> |
| 7.1       | Power-on reset .....                                   | 6         | 18.1      | Packing information on the tray ..... | 44        |
| 7.2       | LCD bias generator .....                               | 6         | <b>19</b> | <b>Appendix</b> .....                 | <b>46</b> |
| 7.3       | LCD voltage selector .....                             | 7         | 19.1      | LCD segment driver selection .....    | 46        |
| 7.3.1     | Electro-optical performance .....                      | 8         | <b>20</b> | <b>Abbreviations</b> .....            | <b>48</b> |
| 7.4       | LCD drive mode waveforms .....                         | 10        | <b>21</b> | <b>References</b> .....               | <b>48</b> |
| 7.4.1     | Static drive mode .....                                | 10        | <b>22</b> | <b>Revision history</b> .....         | <b>49</b> |
| 7.4.2     | 1:2 Multiplex drive mode .....                         | 11        | <b>23</b> | <b>Legal information</b> .....        | <b>50</b> |
| 7.4.3     | 1:3 Multiplex drive mode .....                         | 13        | 23.1      | Data sheet status .....               | 50        |
| 7.4.4     | 1:4 Multiplex drive mode .....                         | 14        | 23.2      | Definitions .....                     | 50        |
| 7.5       | Oscillator .....                                       | 15        | 23.3      | Disclaimers .....                     | 50        |
| 7.5.1     | Internal clock .....                                   | 15        | 23.4      | Trademarks .....                      | 51        |
| 7.5.2     | External clock .....                                   | 15        | <b>24</b> | <b>Contact information</b> .....      | <b>51</b> |
| 7.6       | Timing and frame frequency .....                       | 15        | <b>25</b> | <b>Tables</b> .....                   | <b>52</b> |
| 7.7       | Display register .....                                 | 15        | <b>26</b> | <b>Figures</b> .....                  | <b>53</b> |
| 7.8       | Segment outputs .....                                  | 16        | <b>27</b> | <b>Contents</b> .....                 | <b>54</b> |
| 7.9       | Backplane outputs .....                                | 16        |           |                                       |           |
| 7.10      | Display RAM .....                                      | 16        |           |                                       |           |
| 7.10.1    | Data pointer .....                                     | 19        |           |                                       |           |
| 7.10.2    | Subaddress counter .....                               | 19        |           |                                       |           |
| 7.10.3    | RAM writing in 1:3 multiplex drive mode .....          | 19        |           |                                       |           |
| 7.10.4    | Writing over the RAM address boundary .....            | 20        |           |                                       |           |
| 7.10.5    | Output bank selector .....                             | 20        |           |                                       |           |
| 7.10.6    | Input bank selector .....                              | 21        |           |                                       |           |
| 7.11      | Blinking .....   | 21        |           |                                       |           |
| 7.12      | Command decoder .....                                  | 21        |           |                                       |           |
| 7.13      | Display controller .....                               | 23        |           |                                       |           |
| <b>8</b>  | <b>Characteristics of the I<sup>2</sup>C-bus</b> ..... | <b>24</b> |           |                                       |           |
| 8.1       | Bit transfer .....                                     | 24        |           |                                       |           |
| 8.2       | START and STOP conditions .....                        | 24        |           |                                       |           |
| 8.3       | System configuration .....                             | 25        |           |                                       |           |
| 8.4       | Acknowledge .....                                      | 25        |           |                                       |           |
| 8.5       | I <sup>2</sup> C-bus controller .....                  | 26        |           |                                       |           |
| 8.6       | Input filters .....                                    | 26        |           |                                       |           |
| 8.7       | I <sup>2</sup> C-bus protocol .....                    | 26        |           |                                       |           |
| <b>9</b>  | <b>Internal circuitry</b> .....                        | <b>28</b> |           |                                       |           |
| <b>10</b> | <b>Safety notes</b> .....                              | <b>29</b> |           |                                       |           |

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