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# PCA85134

Automotive 60 x 4 LCD segment driver for multiplex rates up to 1:4

Rev. 2 — 6 May 2014

Product data sheet

## 1. General description

The PCA85134 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 60 segments. It can be easily cascaded for larger LCD applications. The PCA85134 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-incremented addressing, by hardware subaddressing, and by display memory switching (static and duplex drive modes).

For a selection of NXP LCD segment drivers, see [Table 26 on page 45](#).

## 2. Features and benefits

- AEC-Q100 compliant for automotive applications
- Single-chip LCD controller and driver
- Selectable backplane drive configurations: static, 2, 3, or 4 backplane multiplexing
- 60 segment outputs allowing to drive:
  - ◆ 30 7-segment alphanumeric characters
  - ◆ 15 14-segment alphanumeric characters
  - ◆ Any graphics of up to 240 elements
- Cascading supported for larger applications
- 60 × 4-bit display data storage RAM
- Extended operating temperature range from –40 °C to +95 °C
- Wide LCD supply range: from 2.5 V for low threshold LCDs up to 8.0 V for high threshold twisted nematic LCDs
- Internal LCD bias generation with voltage follower buffers
- Selectable display bias configurations: static, 1/2, or 1/3
- Wide logic power supply range: from 1.8 V to 5.5 V
- LCD and logic supplies may be separated
- Low power consumption
- 400 kHz I<sup>2</sup>C-bus interface
- No external components required
- Display memory bank switching in static and duplex drive mode
- Versatile blinking modes
- Silicon gate CMOS process

1. The definition of the abbreviations and acronyms used in this data sheet can be found in [Section 21](#).



### 3. Ordering information

Table 1. Ordering information

| Type number | Package |  |          |
|-------------|---------|--|----------|
|             | Name    | Description  | Version  |
| PCA85134H   | LQFP80  | plastic low profile quad flat package; 80 leads; body 12 × 12 × 1.4 mm | SOT315-1 |

#### 3.1 Ordering options

Table 2. Ordering options

| Product type number | Orderable part number | Sales item (12NC) | Delivery form          | IC revision |
|---------------------|-----------------------|-------------------|------------------------|-------------|
| PCA85134H/Q900/1    | PCA85134H/Q900/1,1    | 935296068118      | tape and reel, 13 inch | 1           |

### 4. Marking

Table 3. Marking codes

| Type number      | Marking code  |
|------------------|---------------|
| PCA85134H/Q900/1 | PCA85134/Q900 |

5. Block diagram

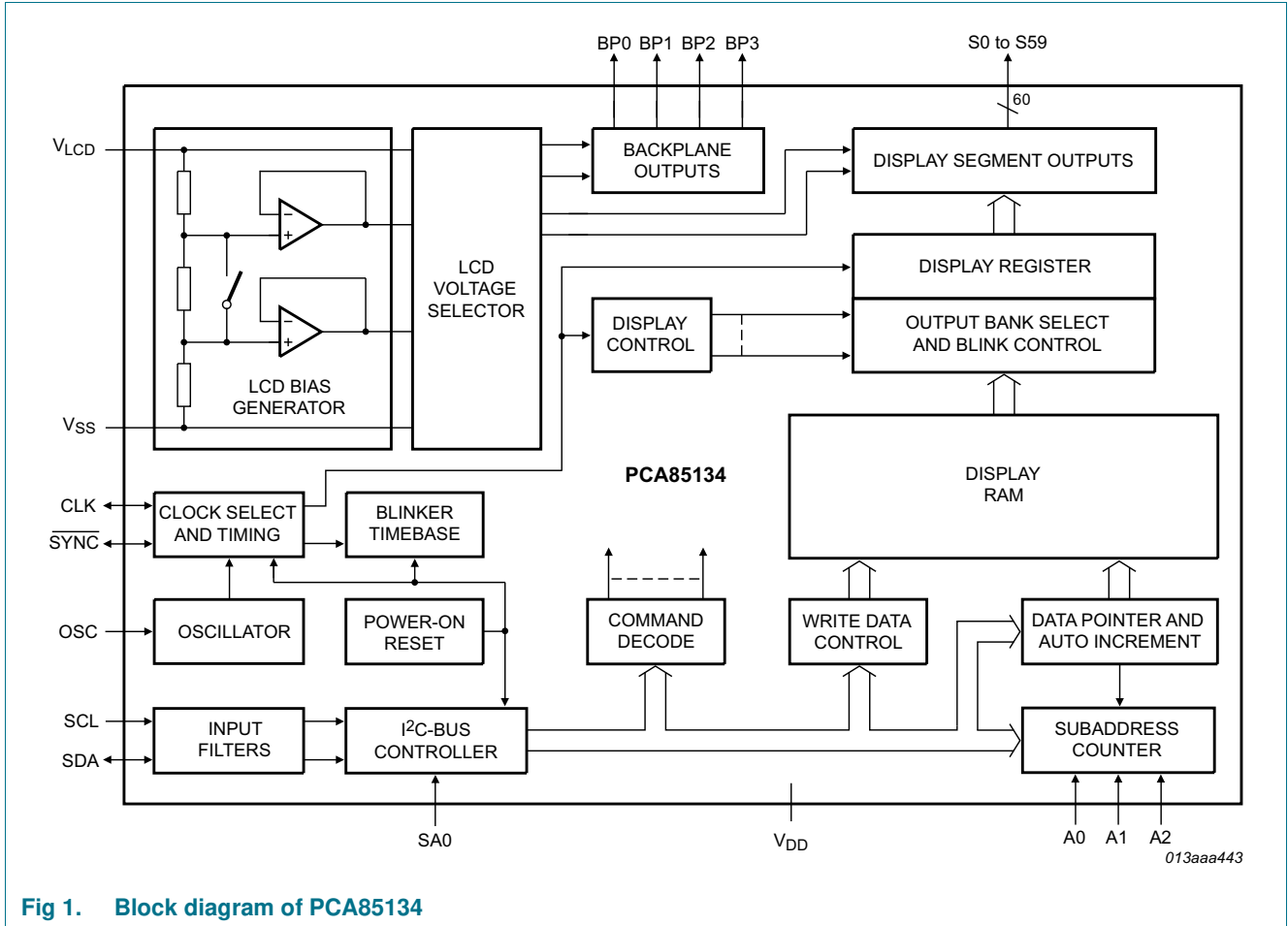
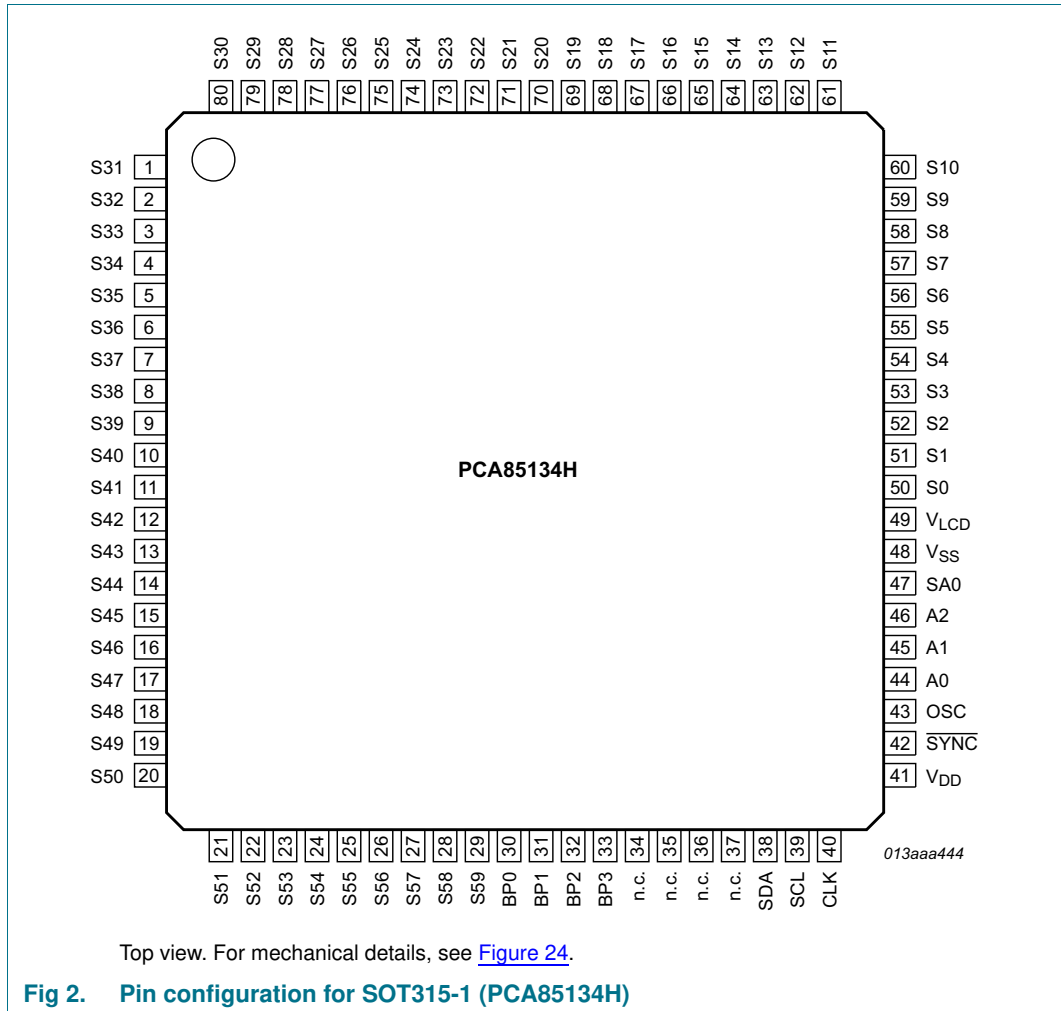


Fig 1. Block diagram of PCA85134

## 6. Pinning information

### 6.1 Pinning



## 6.2 Pin description

**Table 4. Pin description**

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

| Symbol                   | Pin      | Type         | Description  |
|--------------------------|----------|--------------|--|
| S31 to S59               | 1 to 29  | output       | LCD segment output 31 to 59                                  |
| BP0 to BP3               | 30 to 33 | output       | LCD backplane output 0 to 3                                  |
| n.c.                     | 34 to 37 | -            | not connected; do not connect and do not use as feed through |
| SDA                      | 38       | input/output | I <sup>2</sup> C-bus serial data input and output            |
| SCL                      | 39       | input        | I <sup>2</sup> C-bus serial clock input                      |
| CLK                      | 40       | input/output | external clock input and internal clock output               |
| $V_{DD}$                 | 41       | supply       | supply voltage   |
| $\overline{\text{SYNC}}$ | 42       | input/output | cascade synchronization input and output (active LOW)        |
| OSC                      | 43       | input        | enable input for internal oscillator                         |
| A0 to A2                 | 44 to 46 | input        | subaddress counter input 0 to 2                              |
| SA0                      | 47       | input        | I <sup>2</sup> C-bus slave address input 0                   |
| $V_{SS}$                 | 48       | supply       | ground supply voltage  |
| $V_{LCD}$                | 49       | supply       | input of LCD supply voltage                                  |
| S0 to S30                | 50 to 80 | output       | LCD segment output 0 to 30                                   |

## 7. Functional description

The PCA85134 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 60 segments.

The display configurations possible with the PCA85134 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](#).

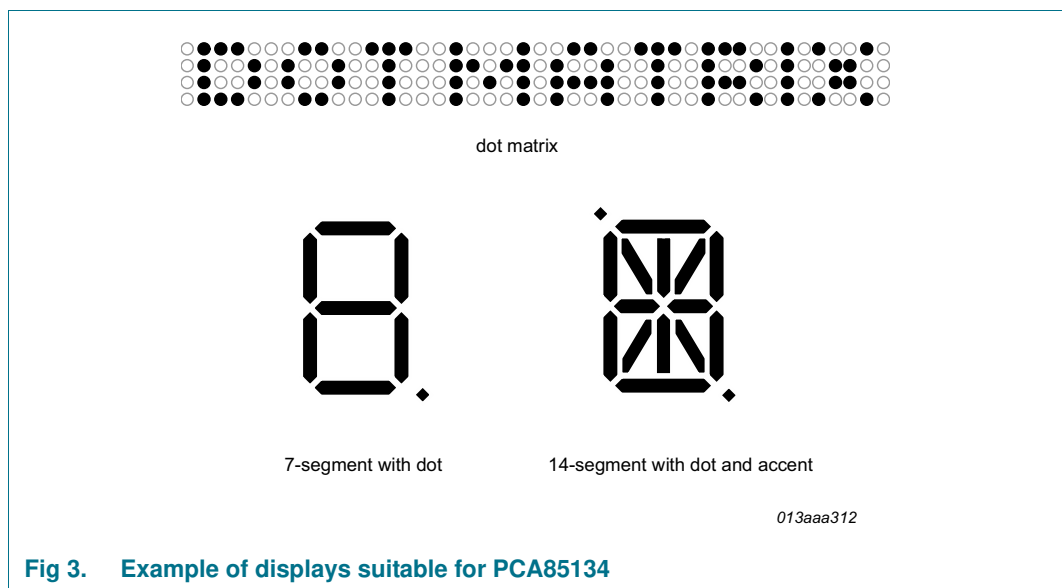


Fig 3. Example of displays suitable for PCA85134

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          | 240   | 30                       | 15                        | 240 (4 × 60)            |
| 3          | 180   | 22                       | 11                        | 180 (3 × 60)            |
| 2          | 120   | 15                       | 7                         | 120 (2 × 60)            |
| 1          | 60    | 7                        | 3                         | 60 (1 × 60)             |

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

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

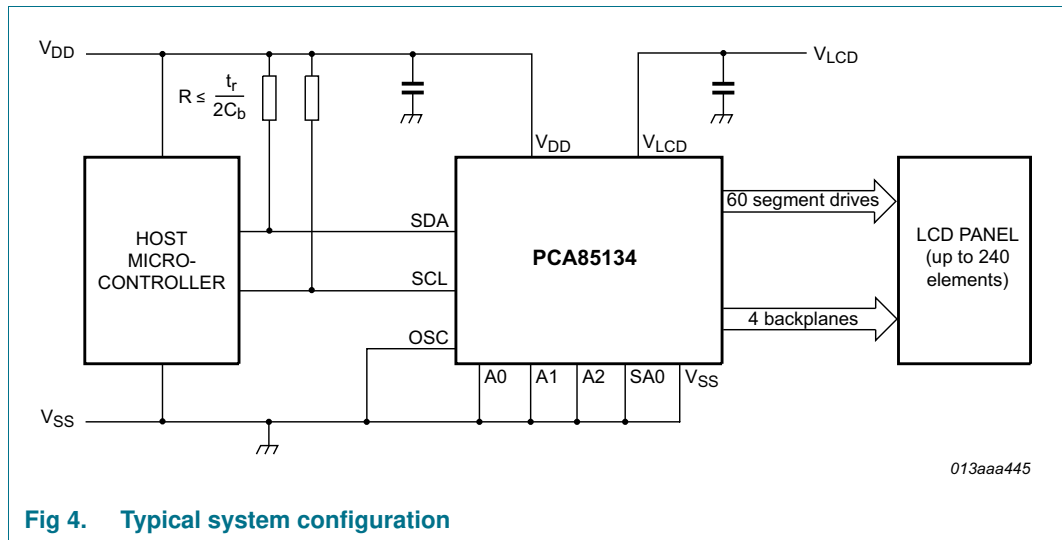


Fig 4. Typical system configuration

The host microcontroller maintains the 2-line I<sup>2</sup>C-bus communication channel with the PCA85134.

Biasing voltages for the multiplexed LCD waveforms are generated internally, removing the need for an external bias generator. The internal oscillator is selected by connecting pin OSC to V<sub>SS</sub>. The only other connections required to complete the system are the power supplies (pins V<sub>DD</sub>, V<sub>SS</sub>, and V<sub>LCD</sub>) and the LCD panel selected for the application.

### 7.1 Power-On Reset (POR)

At power-on the PCA85134 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 consisting of three impedances connected in series between V<sub>LCD</sub> and V<sub>SS</sub>. If the 1/2 bias voltage level for the 1:2 multiplex drive mode configuration is selected, the center impedance is bypassed by switch. The LCD voltage can be temperature compensated externally, using the supply to pin V<sub>LCD</sub>.



### 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](#):

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

Using [Equation 3](#), the discrimination for an LCD drive mode of 1:3 multiplex with 1/2 bias is  $\sqrt{3} = 1.732$  and the discrimination for an LCD drive mode of 1:4 multiplex with 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 (1/2 bias):  $V_{LCD} = \sqrt{6} \times V_{off(RMS)} = 2.449V_{off(RMS)}$
- 1:4 multiplex (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 1/3 bias is used.

$V_{LCD}$  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 is switched on or off, determines 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:

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

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

$V_{on(RMS)}$  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.

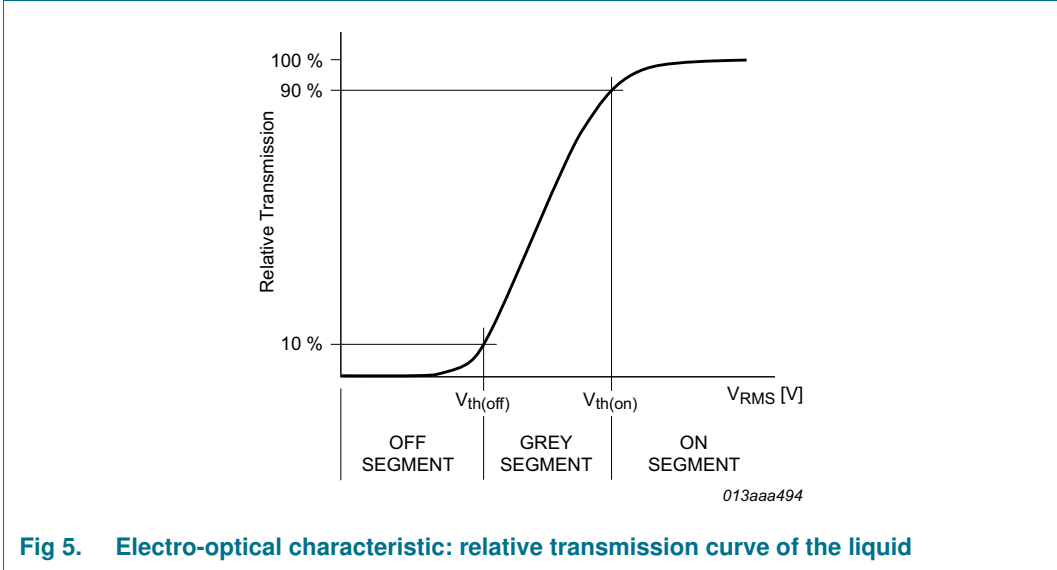


Fig 5. Electro-optical characteristic: relative transmission curve of the liquid

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](#).

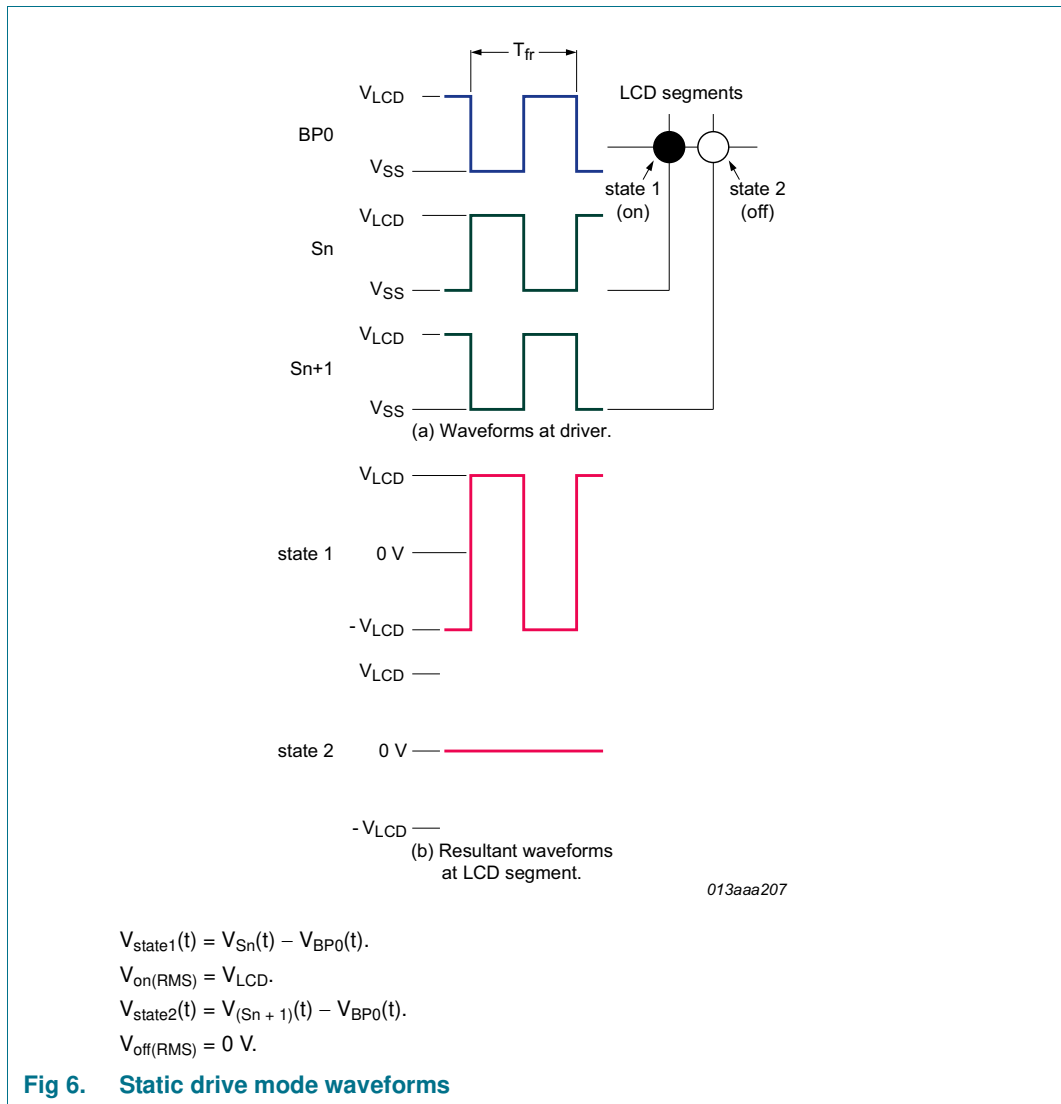


Fig 6. Static drive mode waveforms

7.4.2 1:2 Multiplex drive mode

When two backplanes are provided in the LCD, the 1:2 multiplex mode applies. The PCA85134 allows the use of 1/2 bias or 1/3 bias in this mode as shown in Figure 7 and Figure 8.

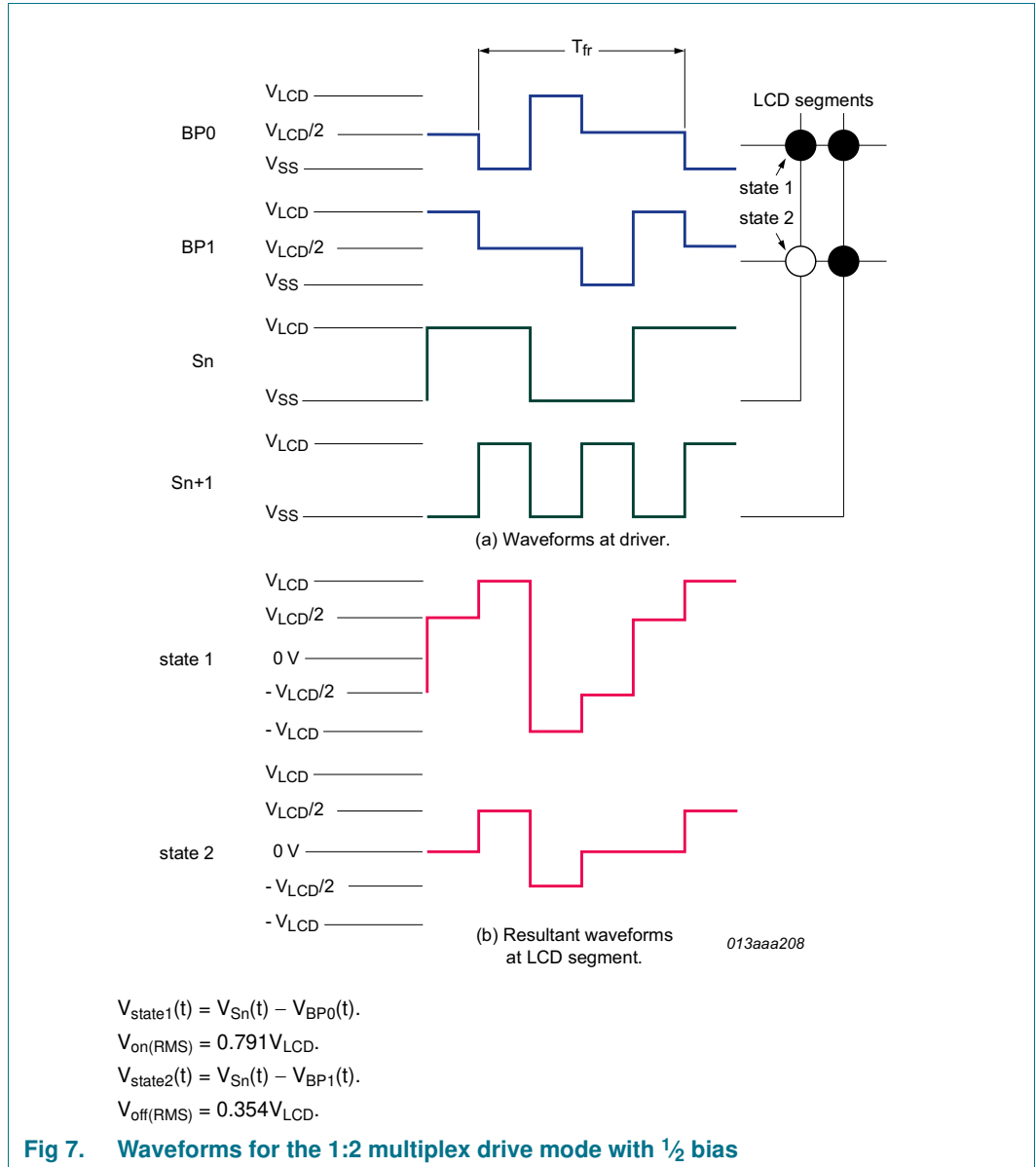


Fig 7. Waveforms for the 1:2 multiplex drive mode with 1/2 bias

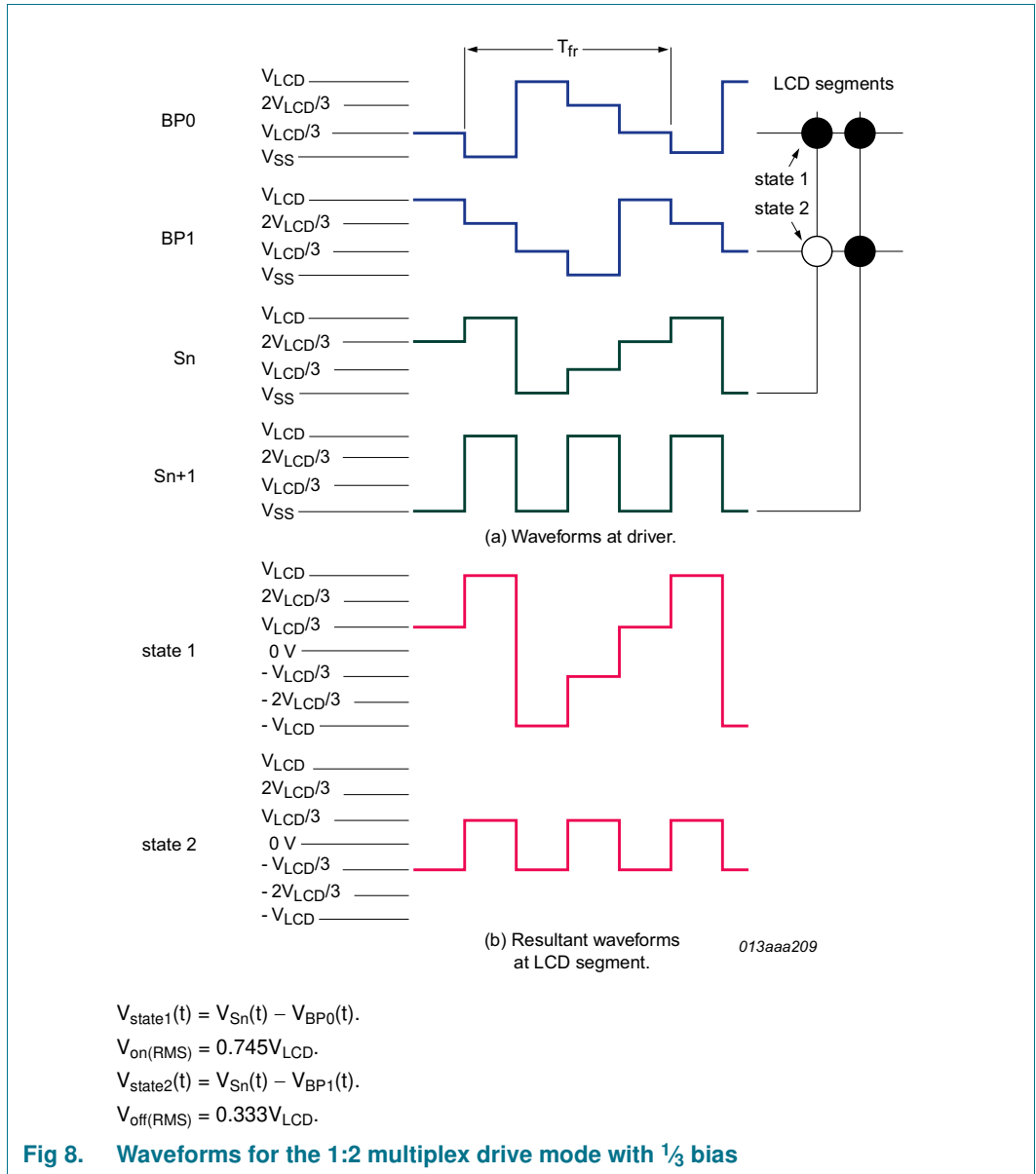


Fig 8. Waveforms for the 1:2 multiplex drive mode with 1/3 bias

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.

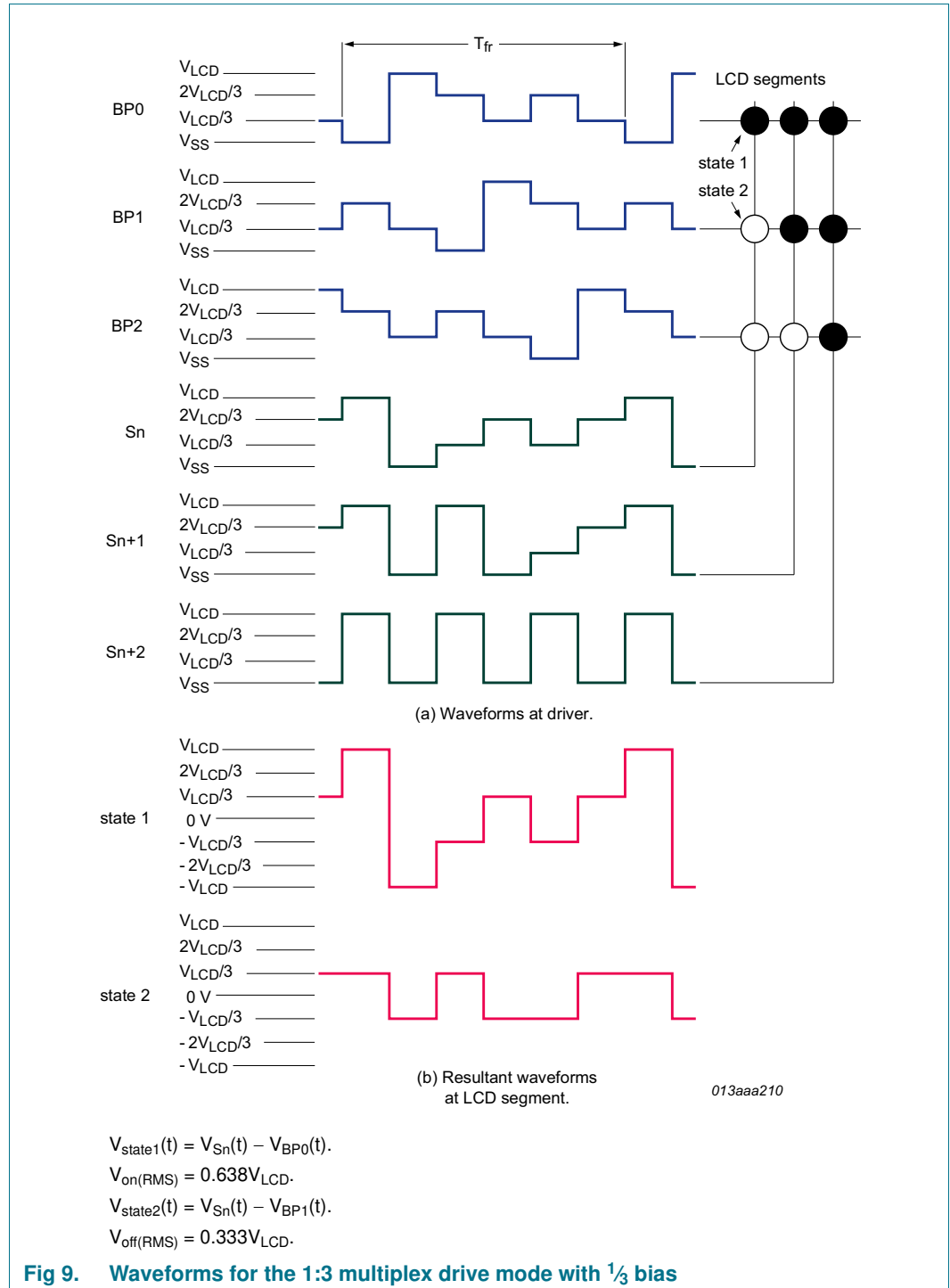


Fig 9. Waveforms for the 1:3 multiplex drive mode with 1/3 bias

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.

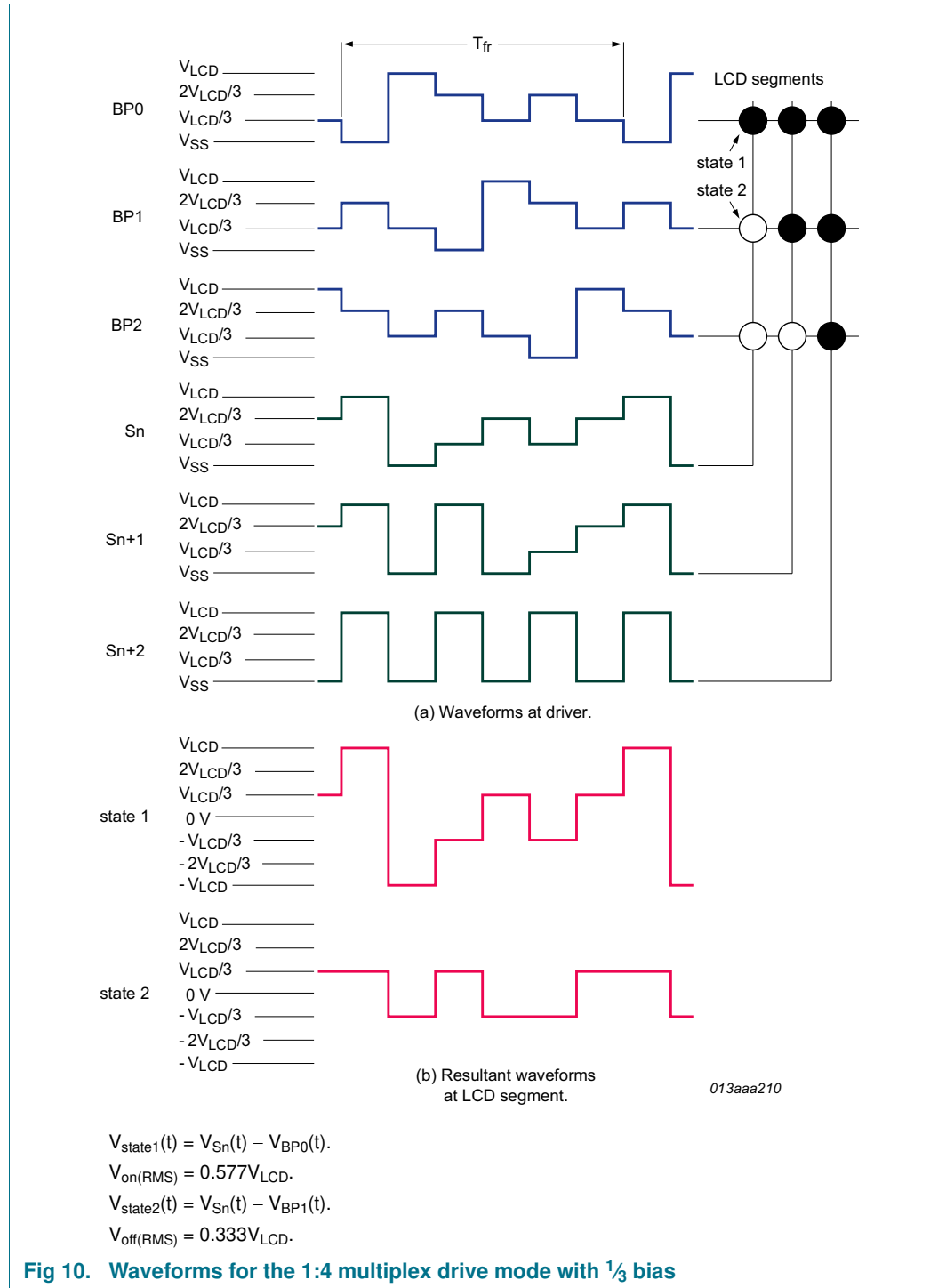


Fig 10. Waveforms for the 1:4 multiplex drive mode with 1/3 bias



### 7.5 Oscillator

The internal logic and the LCD drive signals of the PCA85134 are timed by the frequency  $f_{clk}$ . It equals either the built-in oscillator frequency  $f_{osc}$  or the external clock frequency  $f_{clk(ext)}$ . The clock frequency  $f_{clk}$  determines the LCD frame frequency ( $f_{fr}$ ).

#### 7.5.1 Internal clock

The internal oscillator is enabled by connecting pin OSC to pin  $V_{SS}$ . In this case, the output from pin CLK is the clock signal for any cascaded PCA85134 in the system.

#### 7.5.2 External clock

Pin CLK is enabled as an external clock input by connecting pin OSC to  $V_{DD}$ .

**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 PCA85134 timing controls 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 correct timing relationship between each PCA85134 in the system is maintained by the synchronization signal at pin  $\overline{SYNC}$ . The timing also generates the LCD frame signal whose frequency is derived from the clock frequency. The frame signal frequency is a fixed division of the clock frequency from either the internal or an external clock.

Table 7. LCD frame frequencies

| Operating mode ratio          | Frame frequency with respect to $f_{clk}$ (typical) | Unit |
|-------------------------------|---|------|
|                               | $f_{clk} = 1970 \text{ Hz}$                         |      |
| $f_{fr} = \frac{f_{clk}}{24}$ | 82  | Hz   |

### 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 60 segment outputs (S0 to S59) which should be connected directly to the LCD. The segment output signals are generated based on the multiplexed backplane signals and with data resident in the display register. When less than 60 segment outputs are required, the unused segment outputs must be left open-circuit.



| 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<br>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<br>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<br>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                |                  |                  |       |                |       |                  |   |                |   |   |              |   |    |              |    |   |   |   |   |    |   |   |    |   |   |   |   |   |   |   |   |   |   |    |   |  |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |   |    |

001aa646

x = data bit unchanged.

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

When display data is transmitted to the PCA85134, the display bytes received are stored in the display RAM in accordance with the selected LCD multiplex drive mode. The data is stored as it arrives and depending on the current multiplex drive mode, data is 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 row 1 as four successive 2-bit RAM words.
- In 1:3 multiplex drive mode the eight bits are placed in triples into row 0, row 1, and row 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, row 1, row 2, and row 3 as two successive 4-bit RAM words.

### 7.10.1 Data pointer

The addressing mechanism for the display RAM is realized using the 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 11](#)). 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 terminates early, then the state of the data pointer is unknown. Consequently, the data pointer must be rewritten before 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 matches 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.

In cascaded applications each PCA85134 in the cascade must be addressed separately. Initially, the first PCA85134 is selected by sending the device-select command matching the first hardware subaddress. Then the data pointer is set to the preferred display RAM address by sending the load-data-pointer command.

Once the display RAM of the first PCA85134 has been written, the second PCA85134 is selected by sending the device-select command again. This time however the command matches the hardware subaddress of the second device. Next the load-data-pointer command is sent to select the preferred display RAM address of the second PCA85134.

This last step is very important because during writing data to the first PCA85134, the data pointer of the second PCA85134 is incremented. In addition, the hardware subaddress should not be changed while 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 and so on, 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 Bank selector

### 7.10.4.1 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 particular 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  $\overline{\text{SYNC}}$  signal resets these sequences to the following starting points:

- row 3 for 1:4 multiplex
- row 2 for 1:3 multiplex
- row 1 for 1:2 multiplex
- row 0 for static mode

The PCA85134 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.

### 7.10.4.2 Input bank selector

The input bank selector loads display data into the display data 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 blinking capabilities of the PCA85134 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 ratio between the clock and blink frequency depends on the blink mode selected (see [Table 10](#)).

**Table 10. Blink frequencies**

| Blink mode | Operating mode ratio               | Blink frequency with respect to $f_{clk}$ (typical) | Unit |
|------------|------------------------------------|---|------|
|            |                                    | $f_{clk} = 1970 \text{ Hz}$                         |      |
| off        | -                                  | blinking off  | Hz   |
| 1          | $f_{blink} = \frac{f_{clk}}{768}$  | 2.5   | Hz   |
| 2          | $f_{blink} = \frac{f_{clk}}{1536}$ | 1.3   | Hz   |
| 3          | $f_{blink} = \frac{f_{clk}}{3072}$ | 0.6   | 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. With 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 elements can blink by selectively changing the display RAM data at fixed time intervals.

The entire display can blink at a frequency other than the nominal 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 PCA85134 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 <sup>[2]</sup>  | disabled (blank) <sup>[3]</sup>              |
|        |        | 1                 | enable                                       |
| 2      | B      |                   | <b>LCD bias configuration</b> <sup>[4]</sup> |
|        |        | 0 <sup>[2]</sup>  | 1/3 bias                                     |
|        |        | 1                 | 1/2 bias                                     |
| 1 to 0 | M[1:0] |                   | <b>LCD drive mode selection</b>              |
|        |        | 01                | static; one backplane                        |
|        |        | 10                | 1:2 multiplex; two backplanes                |
|        |        | 11                | 1:3 multiplex; three backplanes              |
|        |        | 00 <sup>[2]</sup> | 1:4 multiplex; four backplanes               |

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

[2] Default value.

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

[4] Not applicable for static drive mode.

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

See [Section 7.10.1 on page 19](#).

| Bit    | Symbol | Value                             | Description  |
|--------|--------|-----------------------------------|--|
| 7      | -      | 0                                 | fixed value  |
| 6 to 0 | P[6:0] | 0000000 <sup>[1]</sup> to 0111011 | 7-bit binary value, 0 to 59; transferred to the data pointer to define one of 60 display RAM addresses |

[1] Default value.

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

See [Section 7.10.2 on page 19](#).

| Bit    | Symbol | Value                     | Description  |
|--------|--------|---------------------------|--|
| 7 to 3 | -      | 11100                     | fixed value  |
| 2 to 0 | A[2:0] | 000 <sup>[1]</sup> to 111 | 3-bit binary value, 0 to 7; transferred to the subaddress counter to define one of eight hardware subaddresses |

[1] Default value.



**Table 15. Bank-select command bit description**See [Section 7.10.4 on page 21](#).

| Bit    | Symbol | Value            | Description   |                              |
|--------|--------|------------------|---|------------------------------|
|        |        |                  | Static  | 1:2 multiplex <sup>[1]</sup> |
| 7 to 2 | -      | 111110           | fixed value   |                              |
| 1      | I      |                  | <b>input bank selection:</b> storage of arriving display data |                              |
|        |        | 0 <sup>[2]</sup> | 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 <sup>[2]</sup> | 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.

[2] Default value.

**Table 16. Blink-select command bit description**See [Section 7.11 on page 21](#).

| Bit    | Symbol  | Value             | Description                                    |
|--------|---------|-------------------|--|
| 7 to 3 | -       | 11110             | fixed value                                    |
| 2      | AB      |                   | <b>blink mode selection</b>                    |
|        |         | 0 <sup>[1]</sup>  | normal blinking <sup>[2]</sup>                 |
|        |         | 1                 | alternate RAM bank blinking <sup>[3]</sup>     |
| 1 to 0 | BF[1:0] |                   | <b>blink frequency selection<sup>[4]</sup></b> |
|        |         | 00 <sup>[1]</sup> | off  |
|        |         | 01                | 1  |
|        |         | 10                | 2  |
|        |         | 11                | 3  |

[1] Default value.

[2] Normal blinking is assumed when the LCD multiplex drive modes 1:3 or 1:4 are selected.

[3] Alternate RAM bank blinking does not apply in 1:3 and 1:4 multiplex drive modes.

[4] 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 of the PCA85134 and coordinates their effects. The display controller is also responsible for loading display data into the display RAM in the correct filling 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.

### 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. Bit transfer is illustrated in [Figure 13](#).

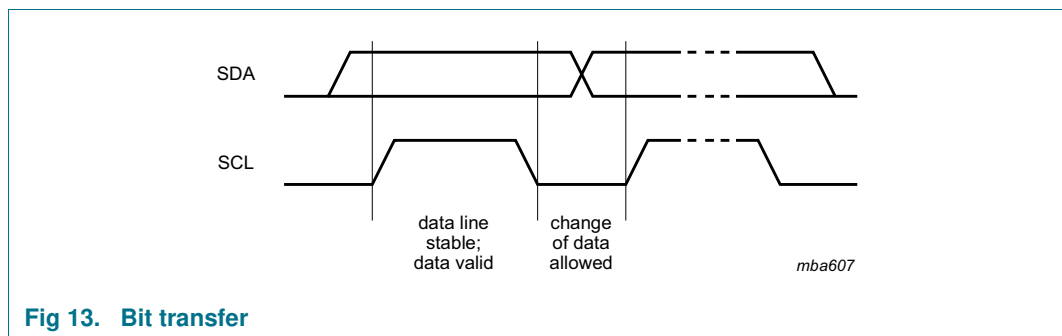


Fig 13. Bit transfer

#### 8.1.1 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).

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

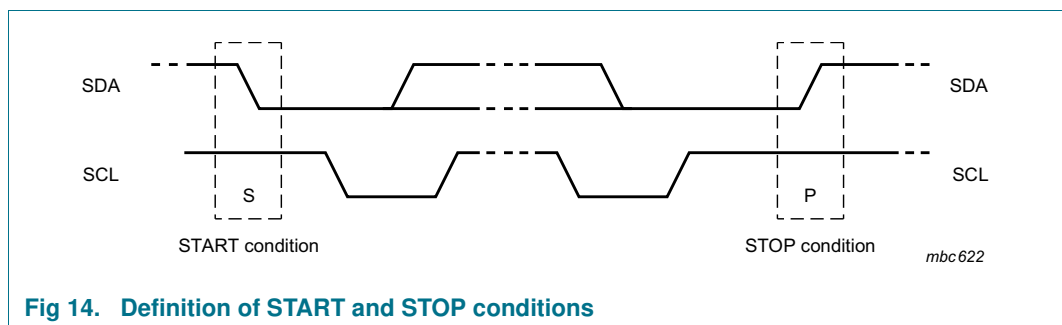


Fig 14. Definition of START and STOP conditions

### 8.2 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](#).