PCA8533

Universal LCD driver for low multiplex rates

Rev. 3 — 1 October 2012 Product data sheet

1. General description

The PCA8533 is a peripheral device which interfaces to almost any Liquid Crystal Display (LCD)[1] 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 PCA8533 is compatible with most microcontrollers and communicates via the two-line bidirectional I^2C-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).

2. Features and benefits

- Single-chip LCD controller and driver
- Selectable backplane drive configuration: static, 2, 3, or 4 backplane multiplexing
- Selectable display bias configuration: static, $\frac{1}{2}$, or $\frac{1}{3}$
- Internal LCD bias generation with voltage follower buffers
- 80 segment outputs allowing to drive:
  - 35 7-segment alphanumeric characters
  - 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 LCD supply range: from 2.5 V for low threshold LCDs up to 6.5 V for high threshold twisted nematic LCDs
- Low power consumption
- 400 kHz I^2C-bus interface
- CMOS compatible
- May be cascaded for large LCD applications (up to 5120 elements possible)
- No external components required
- Compatible with Chip-On-Glass (COG) technology
- Manufactured using silicon gate CMOS process

1. The definition of the abbreviations and acronyms used in this data sheet can be found in Section 17.

3. Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
PCA8533U	bare die	99 bumps; 5.28 x 1.4 x 0.38 mm	PCA8533-2

3.1 Ordering options

Table 2. Ordering options

Type number	IC revision	Sales item (12NC)	Delivery form
PCA8533U/2DD/2	2	935295243026	chip with bumps in tray

4. Marking

Table 3. Marking codes

Type number	Marking code
PCA8533U/2DD/2	PC8533-2

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5. Block diagram

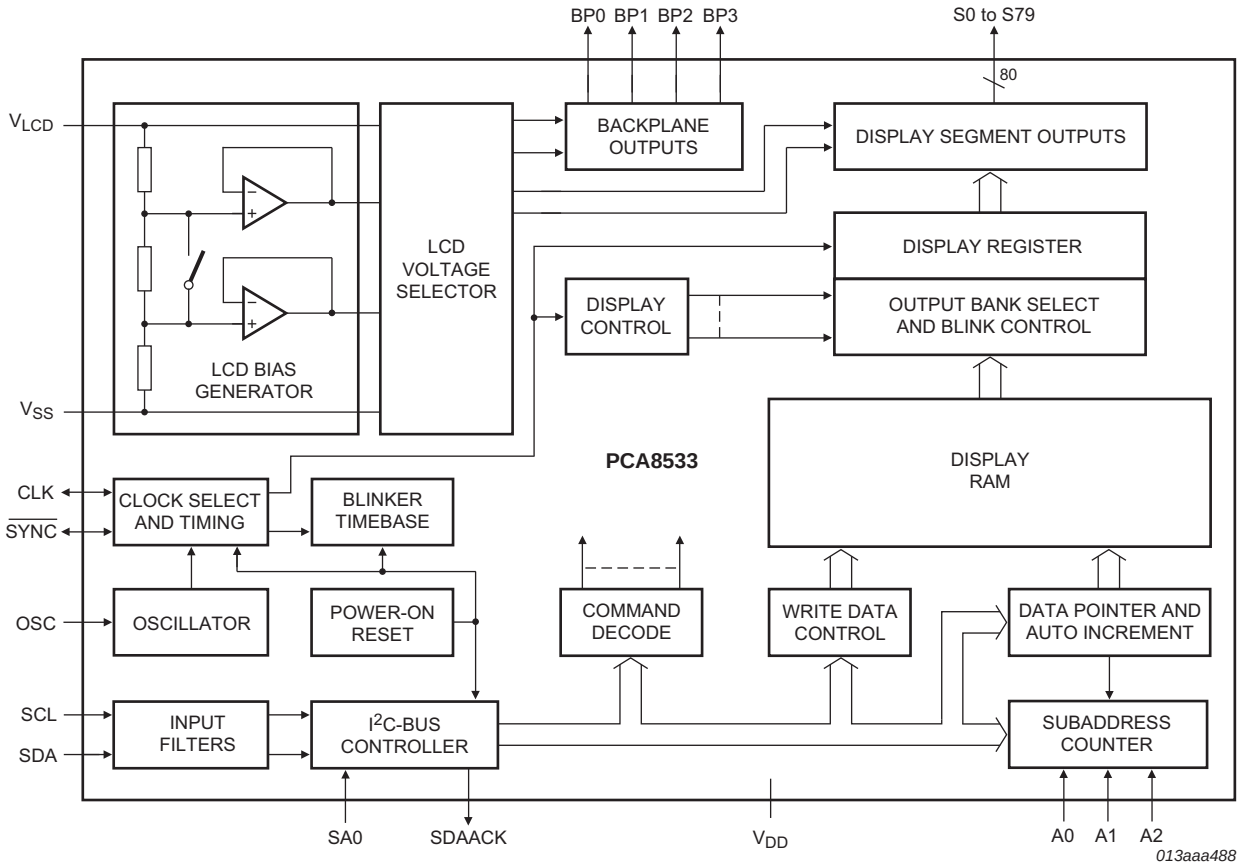


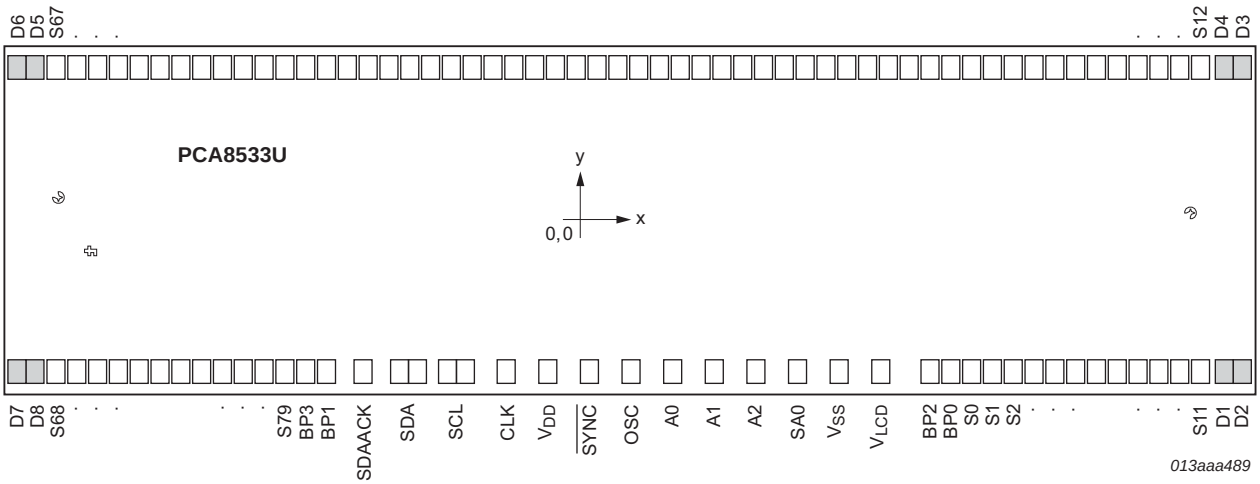
Fig 1. Block diagram of PCA8533

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6. Pinning information

6.1 Pinning



Viewed from active side. For mechanical details, see Figure 28.

Fig 2. Pin configuration for PCA8533U

6.2 Pin description

Table 4. Pin description overview

Symbol	Pin	Type	Description
SDAACK	1	output	I^2C-bus acknowledge
SDA	2 and 3	input/output	I^2C-bus serial data
SCL	4 and 5	input	I^2C-bus serial clock
CLK	6	input/output	clock input/output
V_{DD}	7	supply	supply voltage
$\overline{SYNC}$	8	input/output	cascade synchronization
OSC	9	input	oscillator select
A0, A1 and A2	10 to 12	input	subaddress
SA0	13	input	I^2C-bus slave address
V_{SS}[1]	14	supply	ground supply voltage
V_{LCD}	15	supply	LCD supply voltage
BP0, BP1, BP2 and BP3	17, 99, 16 and 98	output	LCD backplane output
S0 to S79	18 to 97	output	LCD segment output
D1, D2, D3, D4, D5, D6, D7, D8		-	dummy pins

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

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7. Functional description

The PCA8533 is a versatile peripheral device designed to interface between any microcontroller to a wide variety of LCD segment or dot-matrix displays. It can directly drive any static or multiplexed LCD containing up to four backplanes and up to 80 segments.

7.1 Commands of PCA8533

The five commands available to the PCA8533 are defined in Table 5.

Table 5. Definition of commands

Command	Operation code								Reference
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
mode-set	1	1	0	0	E	B	M[1:0]		Table 6
load-data-pointer	0	P[6:0]							Table 7
device-select	1	1	1	0	0	A[2:0]			Table 8
bank-select	1	1	1	1	1	0	I	O	Table 9
blink-select	1	1	1	1	0	AB	BF[1:0]		Table 10

7.1.1 Command: mode-set

The mode-set command allows configuring the multiplex mode, the bias levels and enabling or disabling the display.

Table 6. Mode-set command bit description

Bit	Symbol	Value	Description
7 to 4	-	1100	fixed value
3	E		**display status**[1]
		0	disabled (blank)[2]
		1	enabled
2	B		**LCD bias configuration**[3]
		0	$\frac{1}{3}$ bias
		1	$\frac{1}{2}$ bias
1 to 0	M[1:0]		**LCD drive mode selection**
		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_{LCD}.

[3] Not applicable for static drive mode.

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7.1.2 Command: load-data-pointer

The load-data-pointer command defines the display RAM address where the following display data will be sent to.

Table 7. Load-data-pointer command bit description

See Section 7.6.1.

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

7.1.3 Command: device-select

The device-select command allows defining the subaddress counter value.

Table 8. Device-select command bit description

See Section 7.6.2.

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

7.1.4 Command: bank-select

The bank-select command controls where data is written to RAM and where it is displayed from.

Table 9. Bank-select command bit description[1]

See Section 7.6.5.1 and Section 7.6.5.2.

Bit	Symbol	Value	Description	
			Static	**1:2 multiplex**
7 to 2	-	111110	fixed value	
1	I		**Input bank selection**: 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		**Output bank selection**: 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.

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7.1.5 Command: blink-select

The blink-select command allows configuring the blink mode and the blink frequency.

Table 10. Blink-select command bit description

See Section 7.1.5.1.

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

[1] Only normal blinking can be selected in multiplexer 1:3 or 1:4 drive modes.

[2] For the blink frequency, see Table 11.

7.1.5.1 Blinking

The display blink capabilities of the PCA8533 are very versatile. The whole display can blink at frequencies selected by the blink-select command (see Table 10). The blink frequencies are fractions of the clock frequency. The ratios between the clock and blink frequencies depend on the blink mode selected (see Table 11).

Table 11. Blink frequencies

Blink mode	Normal operating mode ratio	Nominal blink frequency of f_{clk} (typical f_{clk} = 1.536 kHz)	Unit
Off	-	blinking off	Hz
1	$\frac{f_{clk}}{768}$	2	Hz
2	$\frac{f_{clk}}{1536}$	1	Hz
3	$\frac{f_{clk}}{3072}$	0.5	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 segments can blink by selectively changing the display RAM data at fixed time intervals.

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 6).

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7.2 Power-On Reset (POR)

At power-on, the PCA8533 resets to the following starting conditions:

1. All backplane outputs are set to V_{LCD}.
2. All segment outputs are set to V_{LCD}.
3. The selected drive mode is: 1:4 multiplex with $\frac{1}{3}$ bias.
4. Blinking is switched off.
5. Input and output bank selectors are reset.
6. The I^2C-bus interface is initialized.
7. The data pointer and the subaddress counter are cleared (set to logic 0).
8. The display is disabled (bit E = 0, see Table 6)

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

7.3 Possible display configurations

The display configurations possible with the PCA8533 depend on the required number of active backplane outputs. A selection of display configurations is given in Table 12.

All of the display configurations given in Table 12 can be implemented in a typical system as shown in Figure 4.

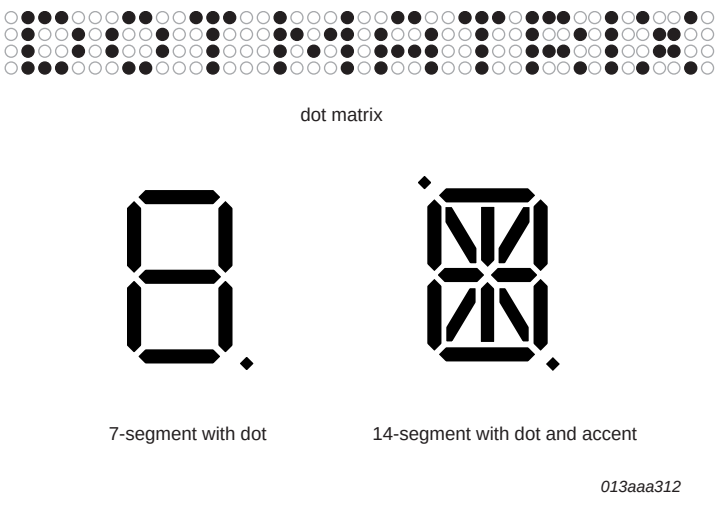


Fig 3. Example of displays suitable for PCA8533

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Table 12. Selection of possible display configurations

Number of				
Backplanes	**Icons**	**Digits/Characters**		**Dot matrix/ Elements**
		7-segment[1]	**14-segment[2]**	
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.

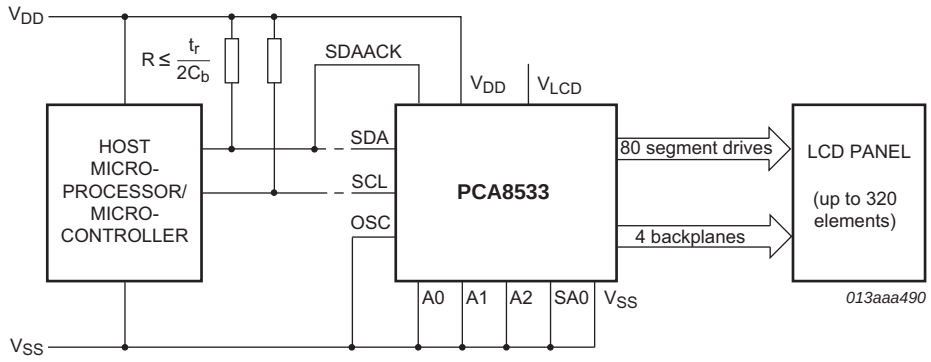


Fig 4. Typical system configuration

The host microcontroller maintains the 2-line I^{2}C-bus communication channel with the PCA8533. The internal oscillator is enabled by connecting pin OSC to pin V_{SS}. The appropriate biasing voltages for the multiplexed LCD waveforms are generated internally. The only other connections required to complete the system are the power supplies (V_{DD}, V_{SS}, and V_{LCD}) and the LCD panel chosen for the application.

7.3.1 LCD bias generator

Fractional LCD biasing voltages are obtained from an internal voltage divider of three impedances connected between pins V_{LCD} and V_{SS}. The center impedance is bypassed by switch if the ½ bias voltage level for the 1:2 multiplex drive mode configuration is selected.

7.3.2 Display register

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

7.3.3 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 13.

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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 13. Biasing characteristics

LCD drive mode	Number of:		LCD bias configuration	$\frac{V_{off(RMS)}}{V_{LCD}}$	$\frac{V_{on(RMS)}}{V_{LCD}}$	$D = \frac{V_{on(RMS)}}{V_{off(RMS)}}$
	Backplanes	Levels				
static	1	2	static	0	1	∞
1:2 multiplex	2	3	½	0.354	0.791	2.236
1:2 multiplex	2	4	⅓	0.333	0.745	2.236
1:3 multiplex	3	4	⅓	0.333	0.638	1.915
1:4 multiplex	4	4	⅓	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 ½ 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 ½ bias

a = 2 for ⅓ bias

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

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

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:

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

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

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

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Using Equation 3, the discrimination for an LCD drive mode of 1:3 multiplex with ½ bias is $\sqrt{3} = 1.732$ and the discrimination for an LCD drive mode of 1:4 multiplex with ½ 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 (½ bias): $V_{LCD} = \sqrt{6} \times V_{off(RMS)} = 2.449 V_{off(RMS)}$
- 1:4 multiplex (½ bias): $V_{LCD} = \left[\frac{(4 \times \sqrt{3})}{3}\right] = 2.309 V_{off(RMS)}$

These compare with $V_{LCD} = 3V_{off(RMS)}$ when ⅓ bias is used.

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

7.3.3.1 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:

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

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

$V_{on(RMS)}$ 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 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.

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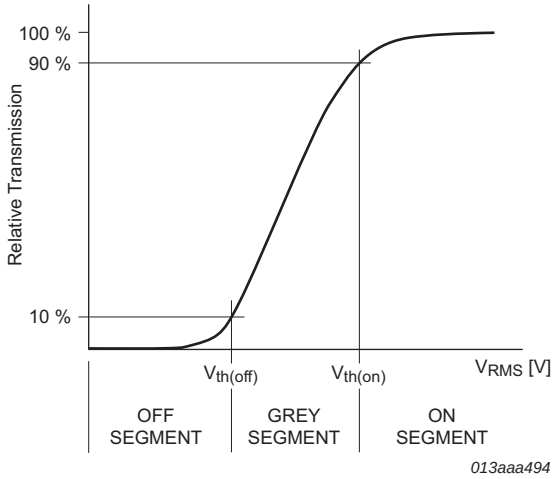


Fig 5. Electro-optical characteristic: relative transmission curve of the liquid

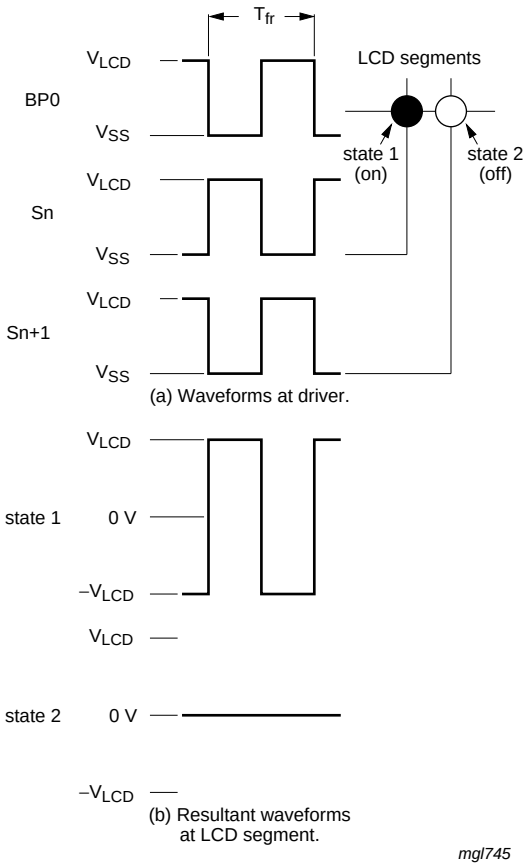
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7.3.4 LCD drive mode waveforms

7.3.4.1 Static drive mode

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



$V_{state1}(t) = V_{Sn}(t) - V_{BP0}(t)$.

$V_{on(RMS)} = V_{LCD}$.

$V_{state2}(t) = V_{(Sn+1)}(t) - V_{BP0}(t)$.

$V_{off(RMS)} = 0$ V.

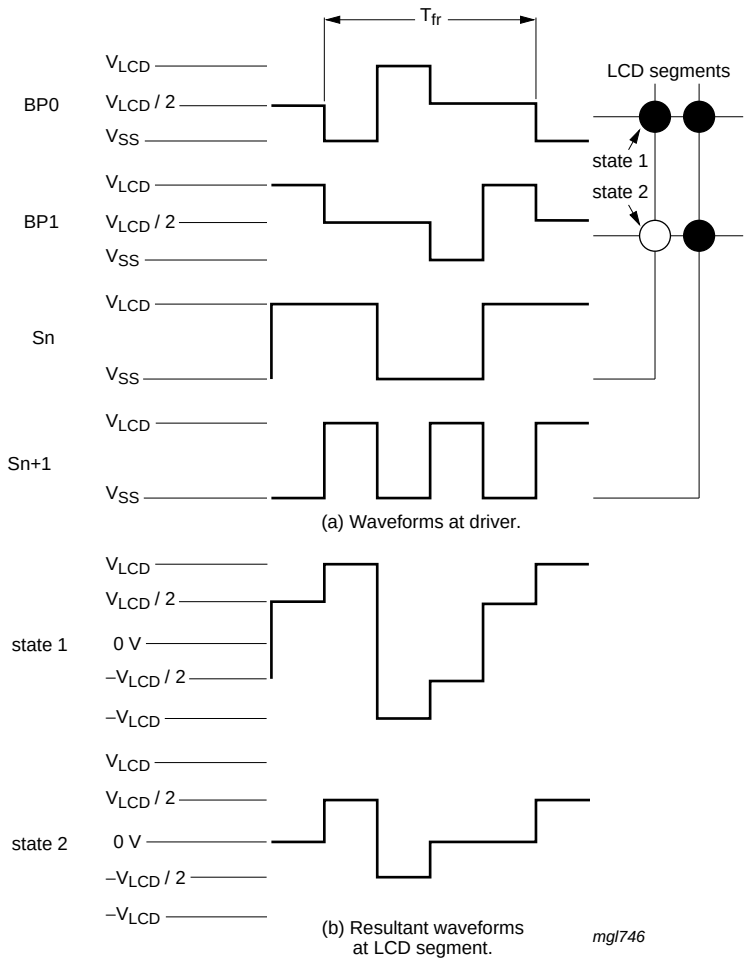
Fig 6. Static drive mode waveforms

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7.3.4.2 1:2 multiplex drive mode

The 1:2 multiplex drive mode is used when two backplanes are provided in the LCD. This mode allows fractional LCD bias voltages of ½ bias or ⅓ bias as shown in Figure 7 and Figure 8.



$V_{state1}(t) = V_{Sn}(t) - V_{BP0}(t)$.

$V_{on(RMS)} = 0.791V_{LCD}$.

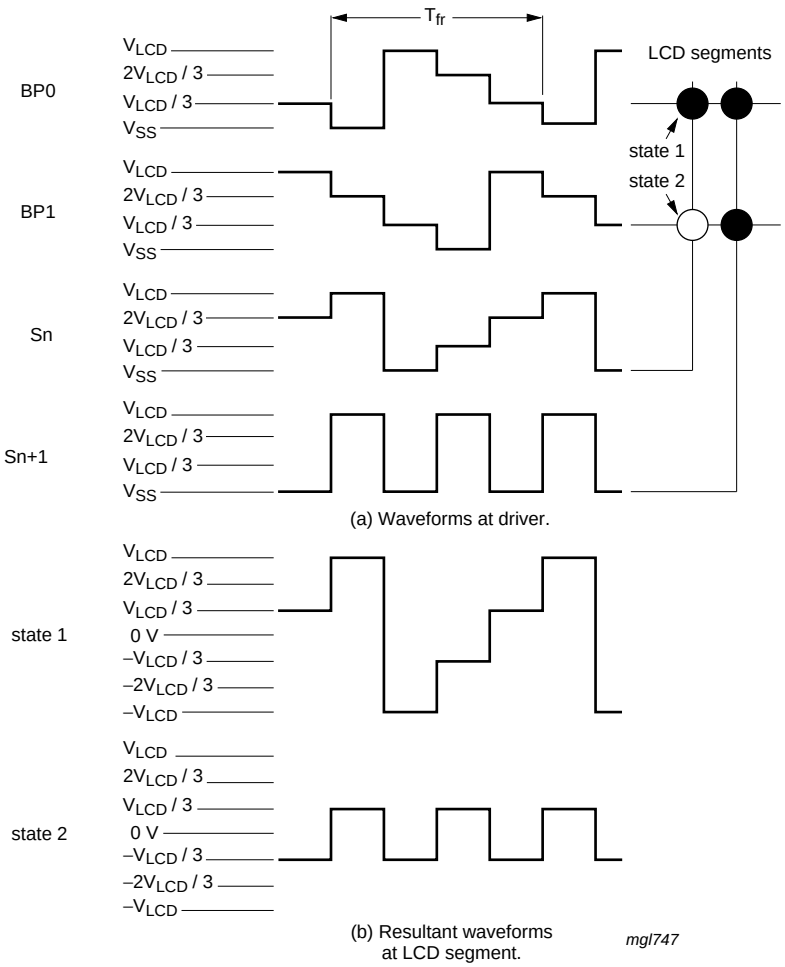
$V_{state2}(t) = V_{Sn}(t) - V_{BP1}(t)$.

$V_{off(RMS)} = 0.354V_{LCD}$.

Fig 7. Waveforms for the 1:2 multiplex drive mode with ½ bias

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$V_{state1}(t) = V_{Sn}(t) - V_{BP0}(t)$.

$V_{on(RMS)} = 0.745V_{LCD}$.

$V_{state2}(t) = V_{Sn}(t) - V_{BP1}(t)$.

$V_{off(RMS)} = 0.333V_{LCD}$.

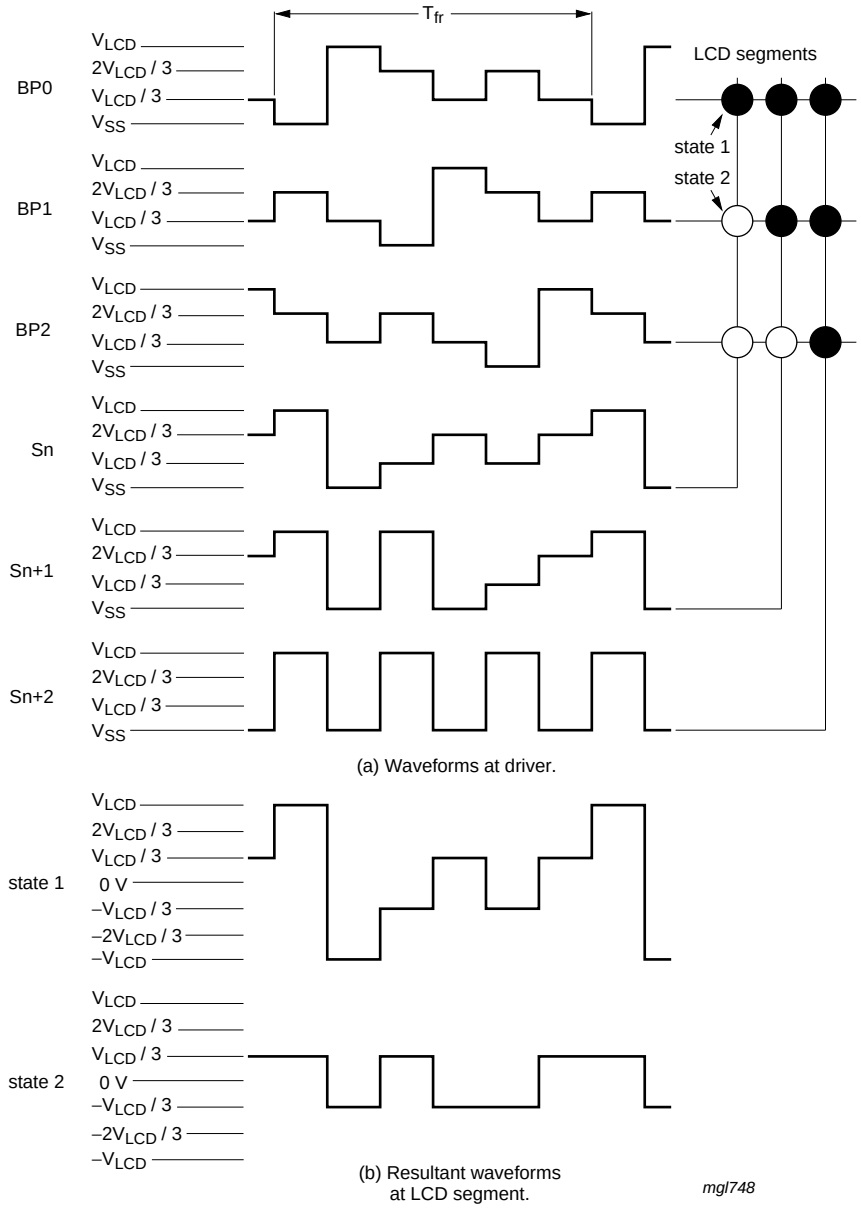
Fig 8. Waveforms for the 1:2 multiplex drive mode with ⅓ bias

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7.3.4.3 1:3 multiplex drive mode

The 1:3 multiplex drive mode is used when three backplanes are provided in the LCD as shown in Figure 9.



$V_{state1}(t) = V_{Sn}(t) - V_{BP0}(t)$.

$V_{on(RMS)} = 0.638V_{LCD}$.

$V_{state2}(t) = V_{Sn}(t) - V_{BP1}(t)$.

$V_{off(RMS)} = 0.333V_{LCD}$.

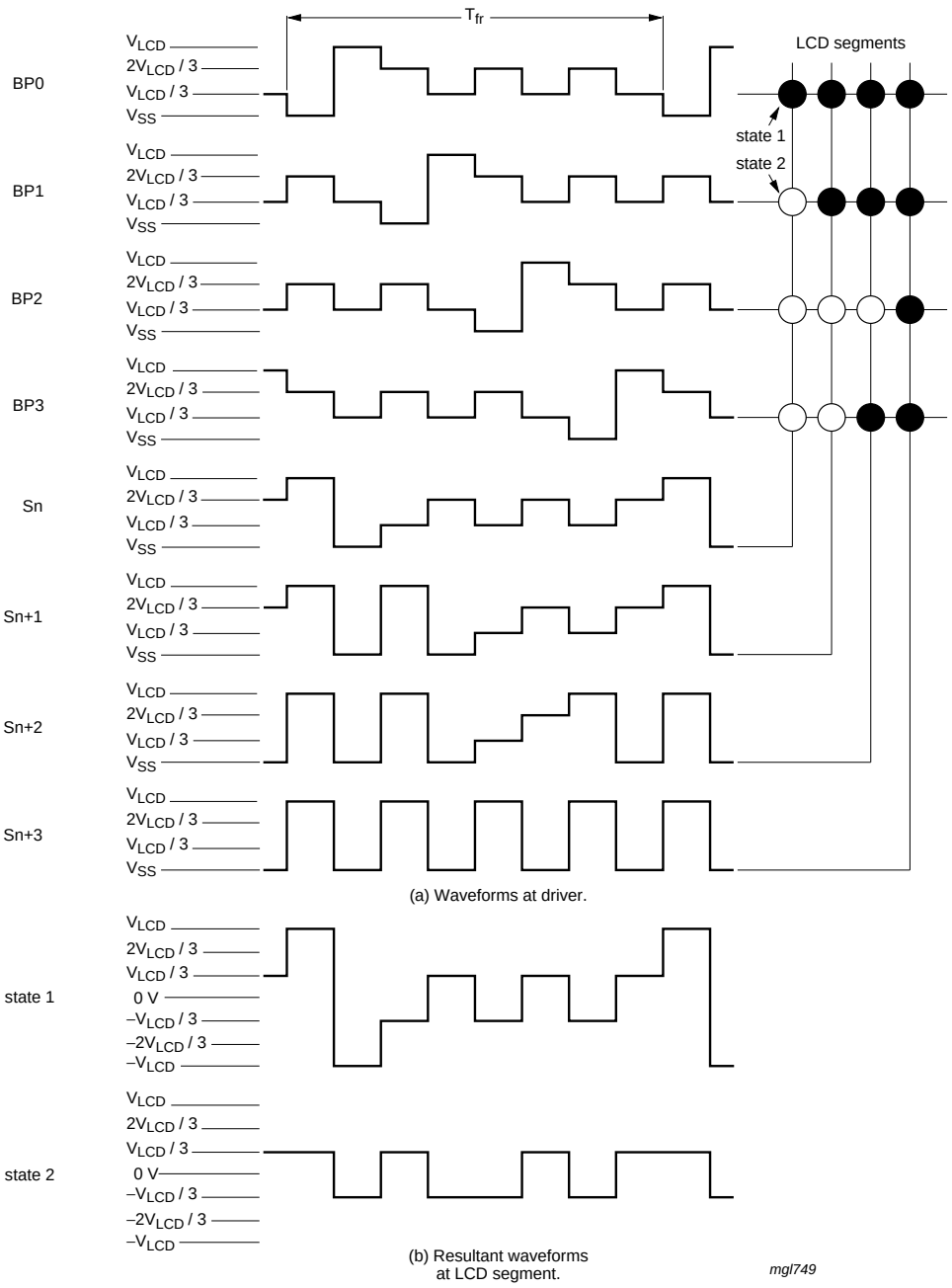
Fig 9. Waveforms for the 1:3 multiplex drive mode with ⅓ bias

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7.3.4.4 1:4 multiplex drive mode

The 1:4 multiplex drive mode is used when four backplanes are provided in the LCD as shown in Figure 10.



$V_{state1}(t) = V_{Sn}(t) - V_{BP0}(t)$.

$V_{on(RMS)} = 0.577V_{LCD}$.

$V_{state2}(t) = V_{Sn}(t) - V_{BP1}(t)$.

$V_{off(RMS)} = 0.333V_{LCD}$.

Fig 10. Waveforms for the 1:4 multiplex drive mode with ⅓ bias

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7.4 Oscillator

The internal logic and the LCD drive signals of the PCA8533 are timed by a frequency f_{clk}, which either is derived from the built-in oscillator frequency f_{osc} or equals an external clock frequency $f_{clk(ext)}$.

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

The clock frequency f_{clk} determines the LCD frame frequency f_{fr} (see Table 14) and is calculated as follows:

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

Table 14. LCD frame frequency

Nominal clock frequency (Hz)	LCD frame frequency (Hz)
1536	64

7.4.1 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 cascaded PCA8533 in the system.

7.4.2 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.

7.4.3 Timing

The PCA8533 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 synchronization signal ($\overline{SYNC}$) maintains the correct timing relationship between all PCA8533 in the system. The timing also generates the LCD frame signal (f_{fr}) whose frequency is derived as an integer division of the clock frequency f_{clk} (see Table 14), applied to pin CLK from either the internal or an external clock.

7.5 Backplane and segment outputs

7.5.1 Backplane outputs

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

- In 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, BP1 and BP3 respectively carry the same signals and can also be paired to increase the drive capabilities.

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- 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.

7.5.2 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.

7.6 Display RAM

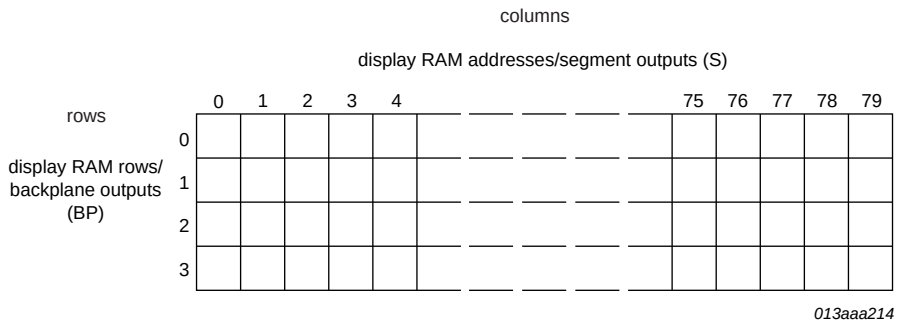
The display RAM is a static 80 × 4 bit RAM which stores LCD data.

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.



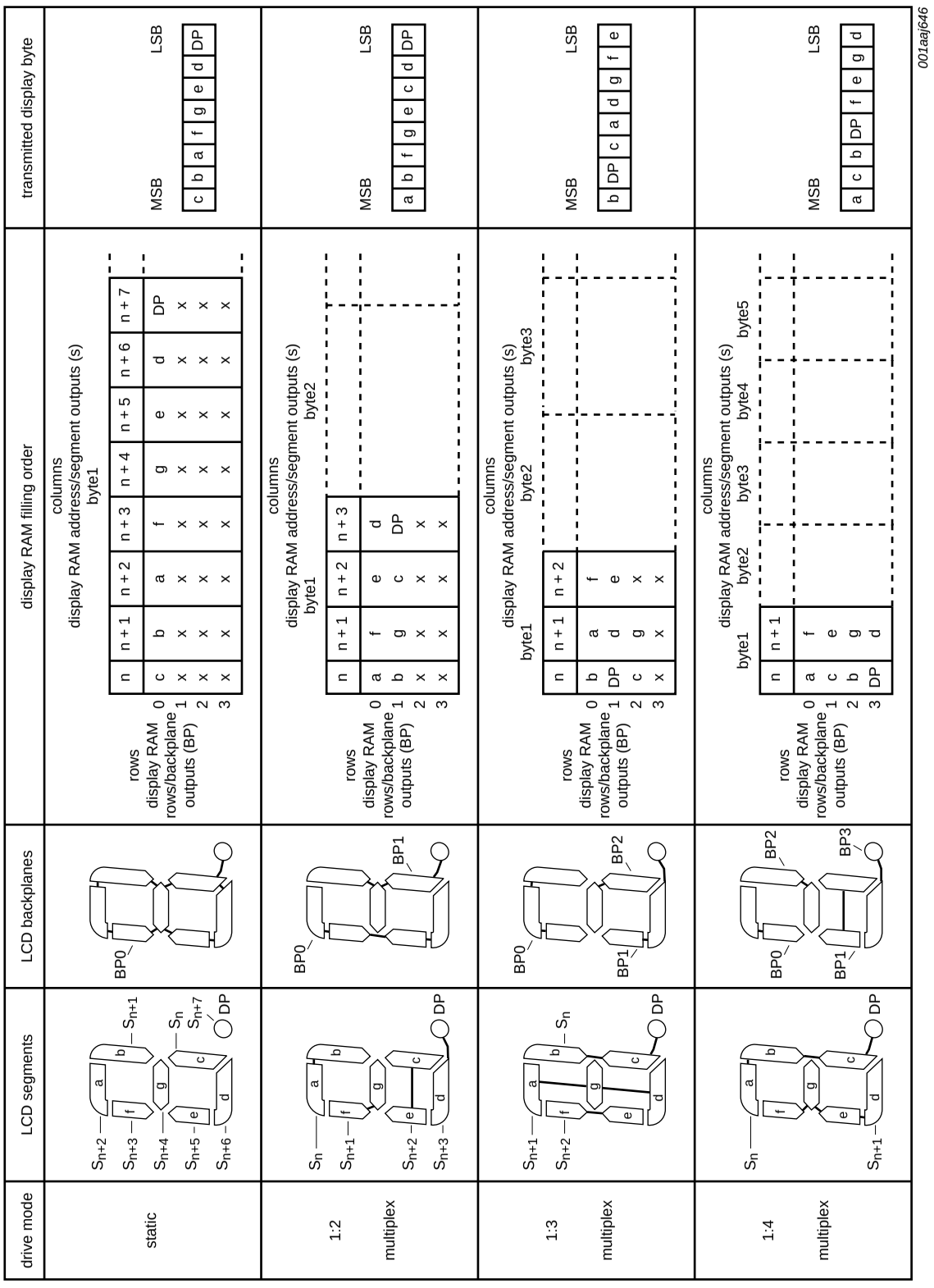
The display RAM bitmap shows the direct relationship between the display RAM addresses and the segment outputs and between the bits in a RAM word and the backplane outputs.

Fig 11. Display RAM bitmap

When display data is transmitted to the PCA8533, 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.

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x = data bit unchanged

Fig 12. Relationships between LCD layout, drive mode, display RAM filling order, and display data transmitted over the I²C-bus

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- 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 two successive 4-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 7.6.3).
- 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.

7.6.1 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 7). 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^2C-bus data access is terminated early, then the state of the data pointer is unknown. So, the data pointer must be rewritten before further RAM accesses.

7.6.2 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 8). 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 PCA8533 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 while the device is being accessed on the I^2C-bus interface.

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7.6.3 RAM writing in 1:3 multiplex drive mode

In 1:3 multiplex drive mode, the RAM is written as shown in Table 15 (see Figure 12 as well).

Table 15. Standard RAM filling in 1:3 multiplex drive mode

*Assumption: BP2/S2, BP2/S5, BP2/S8 and so on, **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 16.

Table 16. Entire RAM filling by rewriting in 1:3 multiplex drive mode

*Assumption: BP2/S2, BP2/S5, BP2/S8 and so on, **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 16 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
- The data-pointer (see Section 7.6.1 on page 21) has to be set to the address of bit a1
- In the second write, bits b7 to b0 are written, overwriting bits a1 and a0 with bits b7 and b6
- The data-pointer has to be set to the address of bit b1
- 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.

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7.6.4 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 PCA8533 is part of a cascade, the additional bits fall into the next device that also generates the acknowledge signal. If the PCA8533 is a single device or the last device in a cascade, the additional bits will be discarded and no acknowledge signal will be generated.

7.6.5 Bank selection

7.6.5.1 Output bank selector

The output bank selector (see Table 9) 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 PCA8533 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.

7.6.5.2 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 9). The input bank selector functions independently to the output bank selector.

7.6.5.3 RAM bank switching

The PCA8533 includes a RAM bank switching feature in the static and 1:2 multiplex drive modes. A bank can be thought of as one RAM row or a collection of RAM rows (see Figure 13). The RAM bank switching gives the provision for preparing display information in an alternative bank and to be able to switch to it once it is complete.

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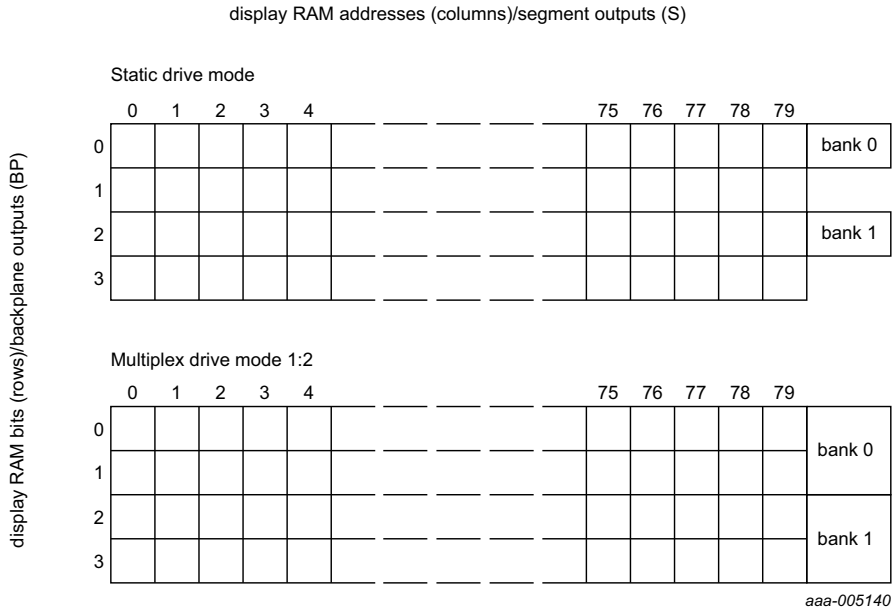


Fig 13. RAM banks in static and multiplex driving mode 1:2

There are two banks; bank 0 and bank 1. Figure 13 shows the location of these banks relative to the RAM map. Input and output banks can be set independently from one another with the Bank-select command (see Table 9 on page 6). Figure 14 shows the concept.

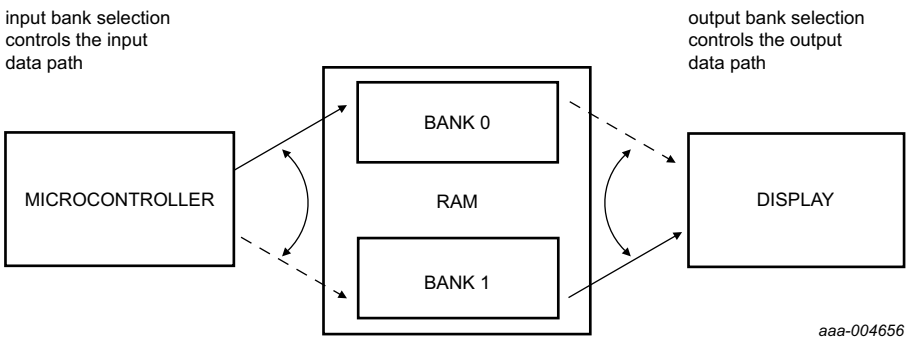


Fig 14. Bank selection

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.

In Figure 15 an example is shown for 1:2 multiplex drive mode where the displayed data is read from the first two rows of the memory (bank 0), while the transmitted data is stored in the second two rows of the memory (bank 1).

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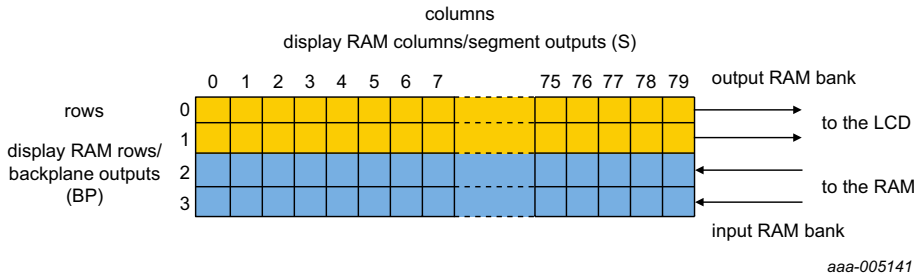


Fig 15. Example of the Bank-select command with multiplex drive mode 1:2

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8. I²C-bus interface

8.1 Characteristics of the I²C-bus

The I²C-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 PCA8533, the SDA line becomes fully I²C-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 PCA8533 cannot 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 I²C-bus master has to be set up in such a way that it ignores the acknowledge cycle.[2]

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

8.1.1 Bit transfer

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time will be interpreted as a control signal; see Figure 16.

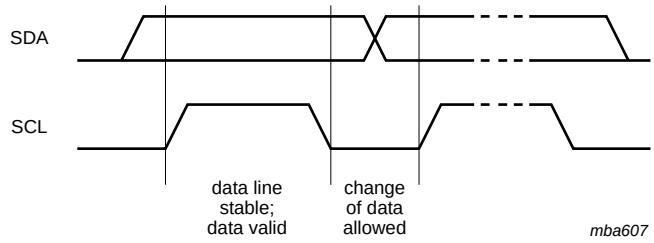


Fig 16. Bit transfer

8.1.2 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).

2. For further information, please consider the NXP application note: Ref. 1 “AN10170”.

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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 shown in Figure 17.

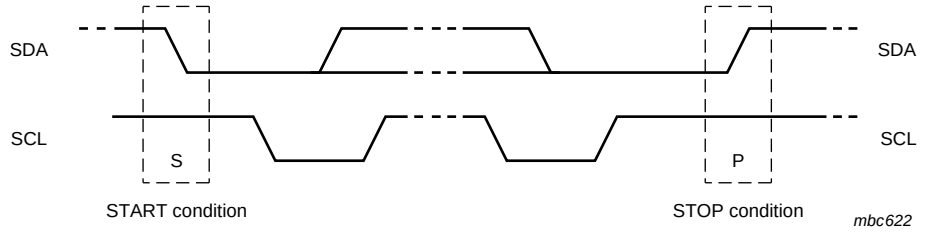


Fig 17. Definition of START and STOP conditions

8.1.3 System configuration

A device generating a message is a transmitter; a device receiving a message is a receiver. The device that controls the message is the master and the devices which are controlled by the master are the slaves; see Figure 18.

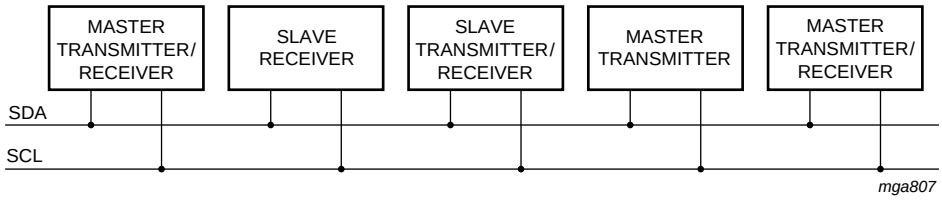


Fig 18. System configuration

8.1.4 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 considered).
- 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^2C-bus is illustrated in Figure 19.

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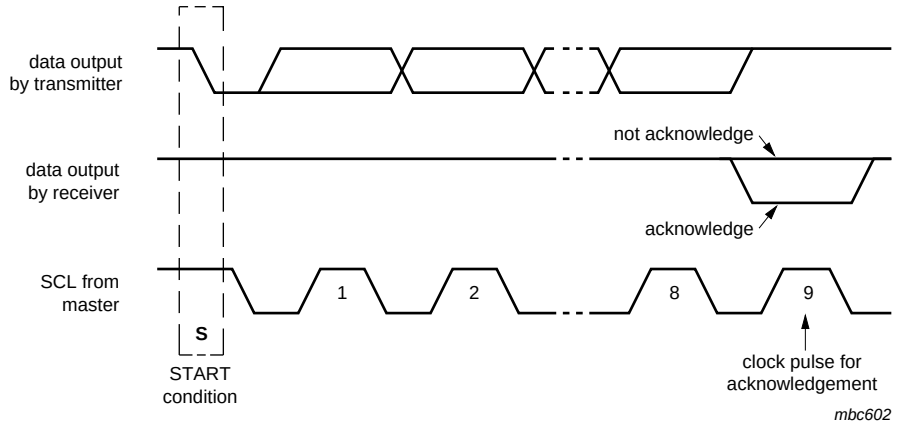


Fig 19. Acknowledgement on the I²C-bus

8.1.5 I²C-bus controller

The PCA8533 acts as an I²C-bus slave receiver. It does not initiate I²C-bus transfers or transmit data to an I²C-bus master receiver. The only data output from the PCA8533 is the acknowledge signal of the selected device. Device selection depends on the I²C-bus slave address, the transferred command data and the hardware subaddress.

In single device applications, the hardware subaddress inputs A0, A1, and A2 are normally tied to V_{SS} which defines the hardware subaddress 0. In multiple device applications A0, A1, and A2 are tied to V_{SS} or V_{DD} using a binary coding scheme, so that no two devices with a common I²C-bus slave address have the same hardware subaddress.

8.1.6 Input filters

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

8.1.7 I²C-bus protocol

Two I²C-bus slave addresses (0111 000 and 0111 001) are reserved for the PCA8533.

The PCA8533 slave address is illustrated in Table 17.

Table 17. I²C slave address byte

Bit	Slave address							
	7	6	5	4	3	2	1	0
	MSB							LSB
	0	1	1	1	0	0	SA0	R/$\overline{W}$

The least significant bit of the slave address that a PCA8533 will respond to is defined by the level tied to its SA0 input. The PCA8533 is a write-only device and does not respond to a read access. Having two reserved slave addresses allows the following on the same I²C-bus:

- Up to 16 PCA8533 for very large LCD applications
- The use of two types of LCD multiplex drive modes.

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The I²C-bus protocol is shown in Figure 20. The sequence is initiated with a START condition (S) from the I²C-bus master which is followed by one of two possible PCA8533 slave addresses available. All PCA8533 whose SA0 inputs correspond to bit 0 of the slave address respond by asserting an acknowledge in parallel. This I²C-bus transfer is ignored by all PCA8533 whose SA0 inputs are set to the alternative level.

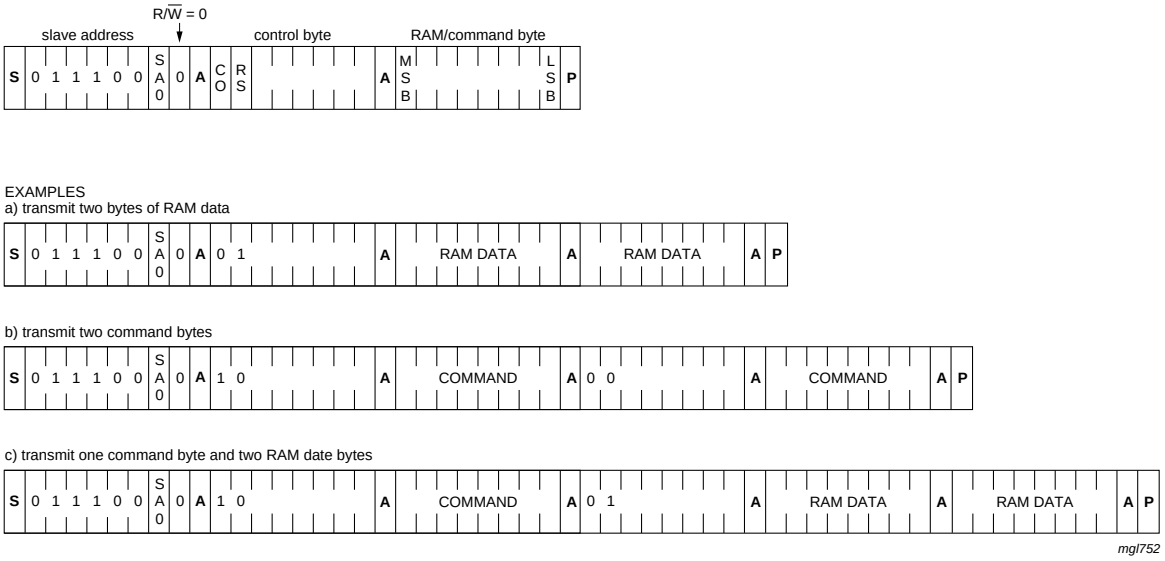


Fig 20. I²C-bus protocol

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 21 and Table 18). In this way, it is possible to configure the device and then fill the display RAM with little overhead.

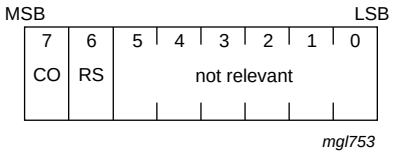


Fig 21. Control byte format

Table 18. Control byte description

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

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The command bytes and control bytes are also acknowledged by all addressed PCA8533 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; see Section 7.6.1 and Section 7.6.2.

The acknowledgement after each byte is made only by the (A0, A1, and A2) addressed PCA8533. After the last (display) byte, the I^2C-bus master asserts a STOP condition (P). Alternatively a START may be asserted to RESTART an I^2C-bus access.

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9. Internal circuitry

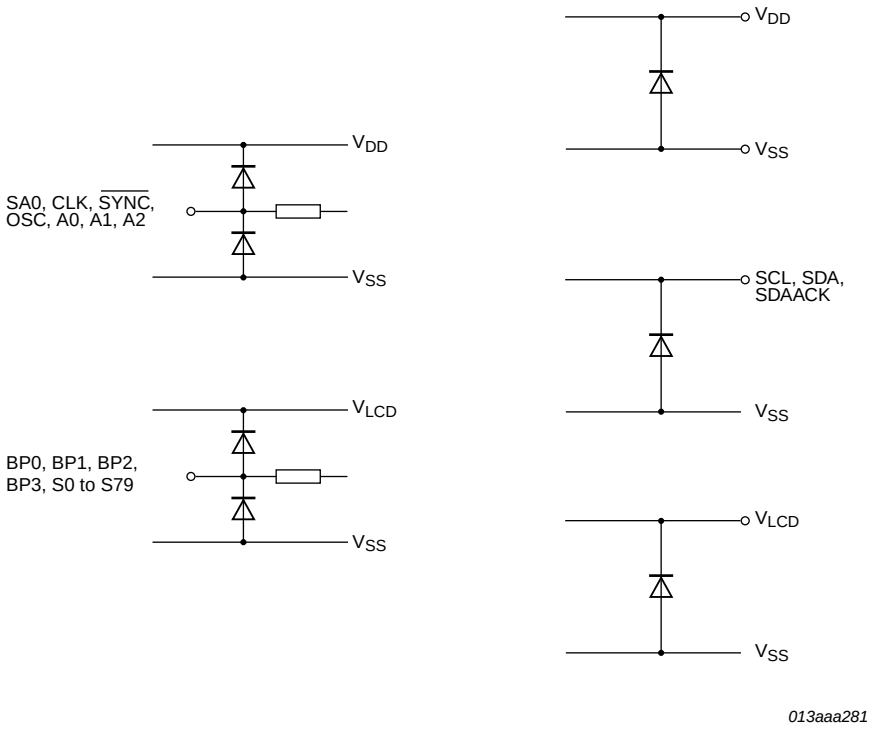


Fig 22. Device protection diagram

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10. Limiting values

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.

Table 19. Limiting values

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

Symbol	Parameter	Conditions		Min	Max	Unit
V_{DD}	supply voltage			−0.5	+6.5	V
V_{LCD}	LCD supply voltage			−0.5	+7.5	V
$V_{i(n)}$	voltage on any input	V_{DD}-related inputs		−0.5	+6.5	V
$V_{o(n)}$	voltage on any output	V_{LCD}-related outputs		−0.5	+7.5	V
I_I	input current			−10	+10	mA
I_O	output current			−10	+10	mA
I_{DD}	supply current			−50	+50	mA
I_{SS}	ground supply current			−50	+50	mA
$I_{DD(LCD)}$	LCD supply current			−50	+50	mA
P_{tot}	total power dissipation			-	400	mW
P/out	power dissipation per output			-	100	mW
V_{ESD}	electrostatic discharge voltage	HBM	[1]	-	±5000	V
		MM	[2]	-	±200	V
I_{lu}	latch-up current		[3]	-	200	mA
T_{stg}	storage temperature		[4]	−65	+150	°C
T_{amb}	ambient temperature	operating device		−40	+85	°C

[1] Pass level; Human Body Model (HBM), according to Ref. 6 “JESD22-A114”.

[2] Pass level; Machine Model (MM), according to Ref. 7 “JESD22-A115”.

[3] Pass level; latch-up testing according to Ref. 8 “JESD78” at maximum ambient temperature ($T_{amb(max)}$).

[4] According to the store and transport requirements (see Ref. 11 “UM10569”) the devices have to be stored at a temperature of +8 °C to +45 °C and a humidity of 25 % to 75 %.

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11. Static characteristics

Table 20. Static characteristics

V_{DD} = 1.8 V to 5.5 V; V_{SS} = 0 V; V_{LCD} = 2.5 V to 6.5 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Supplies							
V_{DD}	supply voltage			1.8	-	5.5	V
V_{LCD}	LCD supply voltage			2.5	-	6.5	V
V_{POR}	power-on reset voltage			1.0	1.3	1.6	V
I_{DD}	supply current	$f_{clk(ext)}$ = 1536 Hz	[1][2]	-	3	5	µA
$I_{DD(LCD)}$	LCD supply current	$f_{clk(ext)}$ = 1536 Hz	[1]	-	25	30	µA
Logic							
V_I	input voltage			V_{SS} − 0.5	-	V_{DD} + 0.5	V
V_{IL}	LOW-level input voltage	on pins CLK, $\overline{SYNC}$, OSC, A0 to A2, SA0		V_{SS}	-	0.3V_{DD}	V
V_{IH}	HIGH-level input voltage	on pins CLK, $\overline{SYNC}$, OSC, A0 to A2, SA0		0.7V_{DD}	-	V_{DD}	V
V_O	output voltage			−0.5	-	V_{DD} + 0.5	V
V_{OH}	HIGH-level output voltage			0.8V_{DD}	-	-	V
V_{OL}	LOW-level output voltage			-	-	0.2V_{DD}	V
I_L	leakage current	on pins OSC, CLK, SCL, SDA, A0 to A2, SA0; V_I = V_{DD} or V_{SS}		−1	-	+1	µA
I_{OL}	LOW-level output current	output sink current; on pins CLK, $\overline{SYNC}$; V_{OL} = 0.4 V; V_{DD} = 5 V		1	-	-	mA
I_{OH}	HIGH-level output current	output source current; on pin CLK; V_{OH} = 4.6 V; V_{DD} = 5 V		1	-	-	mA
C_I	input capacitance		[3]	-	-	7	pF
I^2C-bus[4]							
$I_{OL(SDA)}$	LOW-level output current on pin SDA	V_{OL} = 0.4 V; V_{DD} = 5 V		3	-	-	mA
Input on pins SDA and SCL							
V_I	input voltage			V_{SS} − 0.5	-	5.5	V
V_{IL}	LOW-level input voltage			V_{SS}	-	0.3V_{DD}	V
V_{IH}	HIGH-level input voltage			0.7V_{DD}	-	5.5	V
I_{LI}	input leakage current	V_I = V_{DD} or V_{SS}		−1	-	+1	µA
C_I	input capacitance		[3]	-	-	7	pF

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Table 20. Static characteristics *...continued*

V_{DD} = 1.8 V to 5.5 V; V_{SS} = 0 V; V_{LCD} = 2.5 V to 6.5 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
LCD outputs							
Output pins BP0 to BP3 and S0 to S79							
ΔV_O	output voltage variation	on pins BP0 to BP3; C_{bpl} = 35 nF	[5]	−100	-	+100	mV
		on pins S0 to S79; C_{sgm} = 5 nF	[6]	−100	-	+100	mV
R_O	output resistance	V_{LCD} = 5 V					
		on pins BP0 to BP3	[7]	-	1.5	10	kΩ
		on pins S0 to S79	[7]	-	6.0	13.5	kΩ

[1] LCD outputs are open-circuit; inputs at V_{SS} or V_{DD}; external clock with 50 % duty factor; I^2C-bus inactive.

[2] For typical values, see Figure 23.

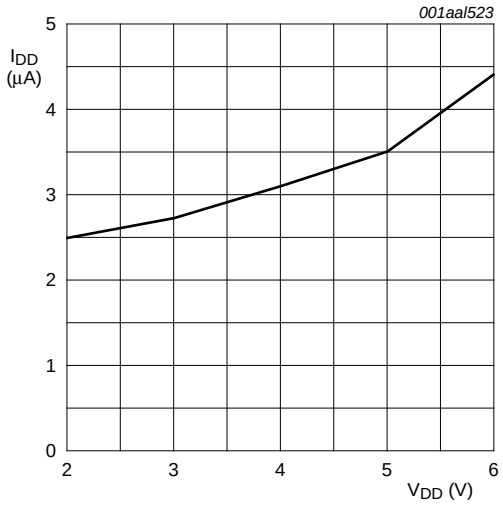
[3] Not tested, design specification only.

[4] The I^2C-bus interface of PCA8533 is 5 V tolerant.

[5] C_{bpl} = backplane capacitance.

[6] C_{sgm} = segment capacitance.

[7] Outputs measured individually and sequentially.



T_{amb} = 30 °C; 1:4 multiplex drive mode; V_{LCD} = 6.5 V; $f_{clk(ext)}$ = 1.536 kHz; all RAM written with logic 1; no display connected; I^2C-bus inactive.

Fig 23. Typical I_{DD} with respect to V_{DD}

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12. Dynamic characteristics

Table 21. Dynamic characteristics

V_{DD} = 1.8 V to 5.5 V; V_{SS} = 0 V; V_{LCD} = 2.5 V to 6.5 V; T_{amb} = −40 °C to +85 °C; unless otherwise specified.

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
Clock							
$f_{clk(int)}$	internal clock frequency		[1][2]	960	1536	3046	Hz
$f_{clk(ext)}$	external clock frequency		[1][2]	797	1536	3046	Hz
$t_{clk(H)}$	HIGH-level clock time			130	-	-	µs
$t_{clk(L)}$	LOW-level clock time			130	-	-	µs
Synchronization: input pin $\overline{SYNC}$							
$t_{PD(SYNC_N)}$	$\overline{SYNC}$ propagation delay			-	30	-	ns
t_{SYNC_NL}	$\overline{SYNC}$ LOW time			1	-	-	µs
Outputs: pins BP0 to BP3 and S0 to S79							
$t_{PD(drv)}$	driver propagation delay	V_{LCD} = 5 V		-	-	30	µs
I^2C-bus: timing[3]; see Figure 25							
Pin SCL							
f_{SCL}	SCL clock frequency			-	-	400	kHz
t_{LOW}	LOW period of the SCL clock			1.3	-	-	µs
t_{HIGH}	HIGH period of the SCL clock			0.6	-	-	µs
Pin SDA							
$t_{SU;DAT}$	data set-up time			100	-	-	ns
$t_{HD;DAT}$	data hold time			0	-	-	ns
Pins SCL and SDA							
t_{BUF}	bus free time between a STOP and START condition			1.3	-	-	µs
$t_{SU;STO}$	set-up time for STOP condition			0.6	-	-	µs
$t_{HD;STA}$	hold time (repeated) START condition			0.6	-	-	µs
$t_{SU;STA}$	set-up time for a repeated START condition			0.6	-	-	µs
t_r	rise time of both SDA and SCL signals	f_{SCL} = 400 kHz		-	-	0.3	µs
		f_{SCL} < 125 kHz		-	-	1.0	µs
t_f	fall time of both SDA and SCL signals			-	-	0.3	µs
C_b	capacitive load for each bus line			-	-	400	pF
$t_{w(spike)}$	spike pulse width	on bus		-	-	50	ns

[1] Typical output duty cycle of 50 %.

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

[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}.

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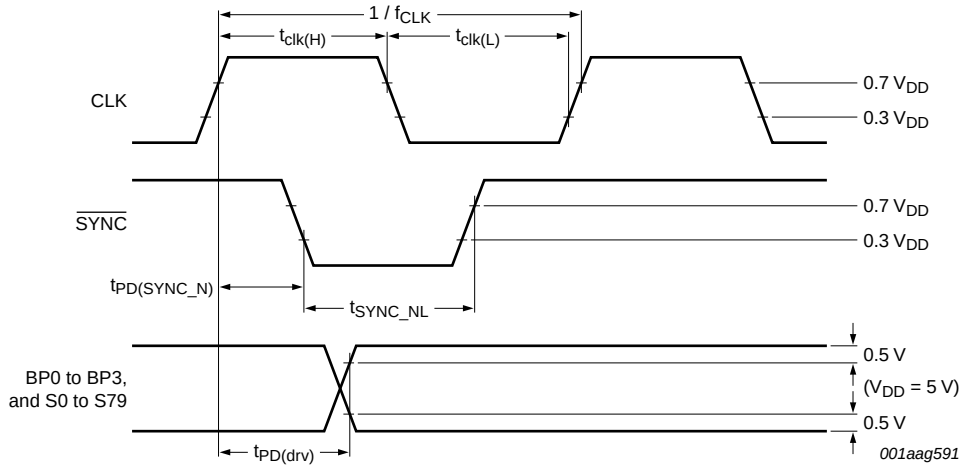


Fig 24. Driver timing waveforms

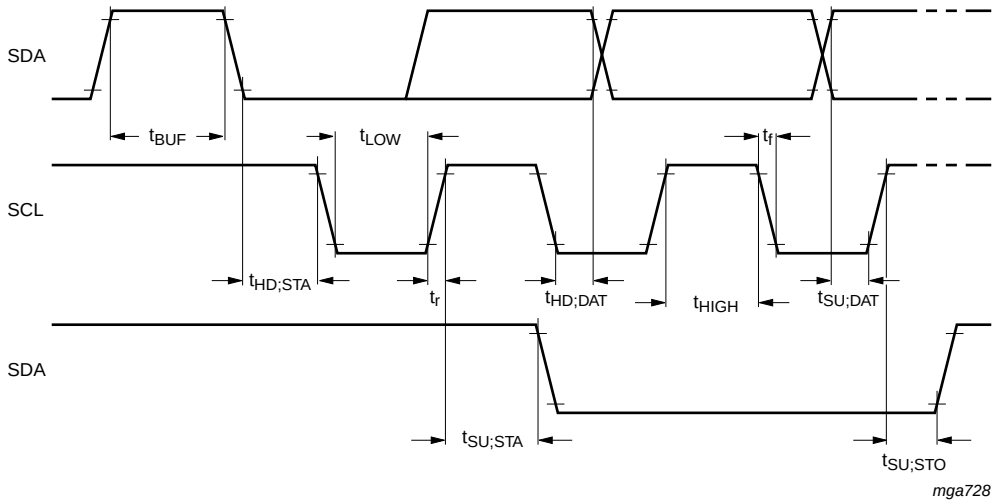


Fig 25. I²C-bus timing waveforms

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13. Application information

13.1 Cascaded operation

Large display configurations of up to sixteen PCA8533 can be recognized on the same I^2C-bus by using the 3-bit hardware subaddress (A0, A1 and A2) and the programmable I^2C-bus slave address (SA0).

Table 22. Addressing cascaded PCA8533

Cluster	Bit SA0	Pin			Device
		A2	A1	A0	
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 PCA8533 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 PCA8533 of the cascade contribute additional segment outputs, but their backplane outputs are left open-circuit (see Figure 26).

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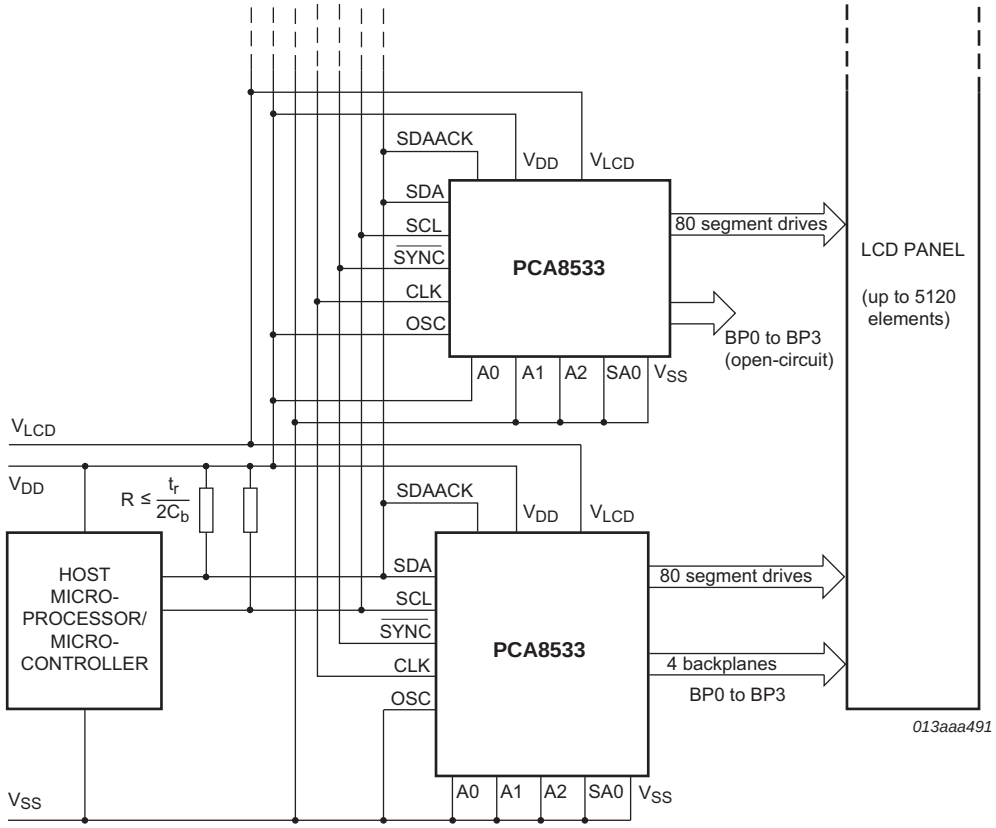


Fig 26. Cascaded PCA8533 configuration

The $\overline{\text{SYNC}}$ line is provided to maintain the correct synchronization between all cascaded PCA8533. This synchronization is guaranteed after the Power-On Reset (POR). The only time that $\overline{\text{SYNC}}$ is likely to be needed is if synchronization is accidentally lost (for example, by noise in adverse electrical environments, or by the definition of a multiplex mode when PCA8533 with different SA0 levels are cascaded).

$\overline{\text{SYNC}}$ is organized as an input/output pin; the output selection being realized as an open-drain driver with an internal pull-up resistor. A PCA8533 asserts the $\overline{\text{SYNC}}$ line at the onset of its last active backplane signal and monitors the $\overline{\text{SYNC}}$ line at all other times. Should synchronization in the cascade be lost, it is restored by the first PCA8533 to assert $\overline{\text{SYNC}}$. The timing relationships between the backplane waveforms and the $\overline{\text{SYNC}}$ signal for the various drive modes of the PCA8533 are shown in Figure 27.

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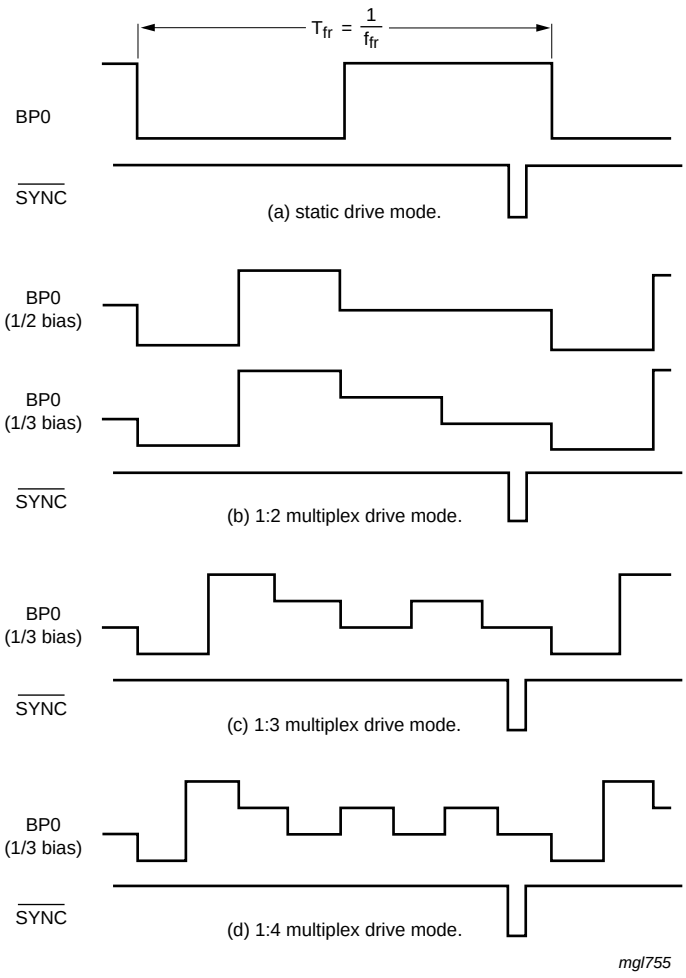


Fig 27. Synchronization of the cascade for the various PCA8533 drive modes

The contact resistance between the $\overline{\text{SYNC}}$ pins of cascaded devices must be controlled. If the resistance is too high, then the device is not able to synchronize properly. This is particularly applicable to COG applications. Table 23 shows the limiting values for contact resistance.

Table 23. $\overline{\text{SYNC}}$ contact resistance

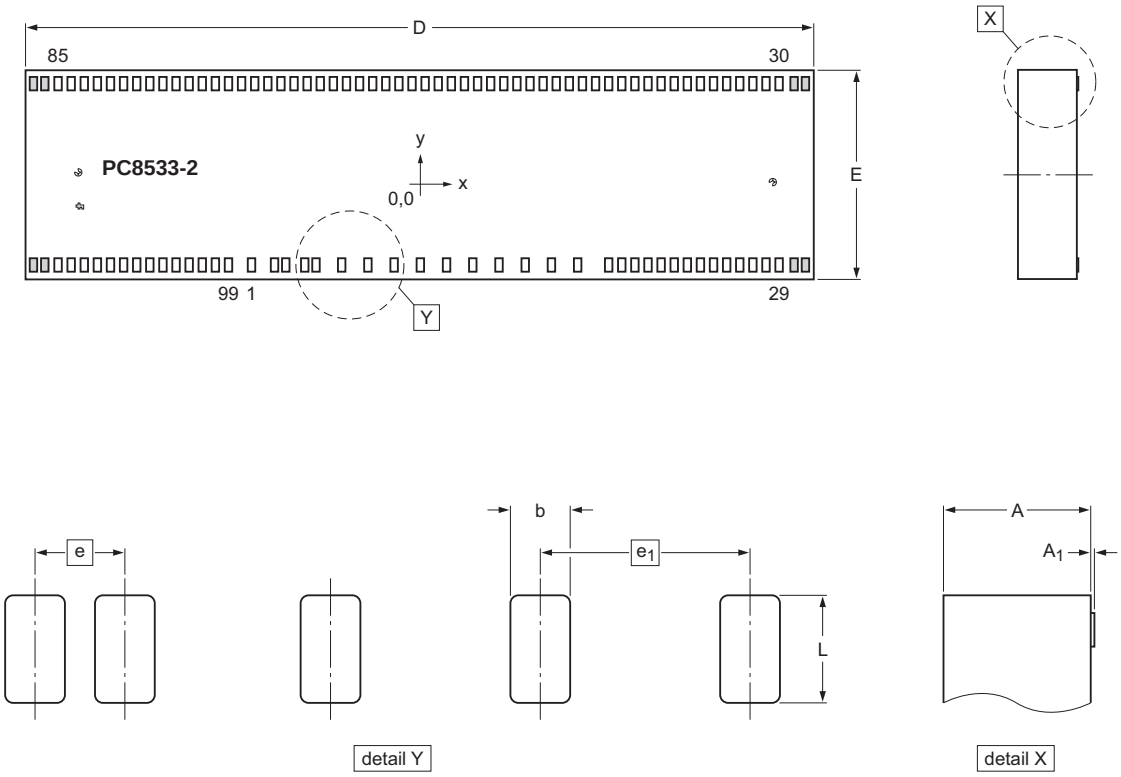
Number of devices	Maximum contact resistance
2	6000 Ω
3 to 5	2200 Ω
6 to 10	1200 Ω
11 to 16	700 Ω

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14. Bare die outline

Bare die; 99 bumps; 5.28 x 1.4 x 0.38 mm **PCA8533-2**



Dimensions (mm are the original dimensions)

Unit		A	A_1	b	D	E	$e^{(1)}$	$e_1{}^{(1)}$	L
mm	max		0.020	0.053				0.289	0.093
	nom	0.381	0.017	0.050	5.276	1.402			0.090
	min		0.014	0.047			0.08		0.087

Note
1. Dimension not drawn to scale

pca8533-2_do

Outline version	References				European projection	Issue date
	IEC	JEDEC	JEITA			
PCA8533-2						~~10-01-28~~ 11-03-21

Fig 28. Bare die outline of PCA8533-2

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Table 24. Bump locations

All x/y coordinates represent the position of the centre of each bump with respect to the center (x/y = 0) of the chip; see Figure 28.

Symbol	Bump	X (μm)	Y (μm)		Description
SDAACK	1	−1079.20	−594.40	[1]	I²C-bus acknowledge output
SDA	2	−839.20	−594.40	[1]	I²C-bus serial data input
SDA	3	−759.20	−594.40	[1]	
SCL	4	−599.20	−594.40		I²C-bus serial clock input
SCL	5	−519.20	−594.40		
CLK	6	−414.80	−594.40		clock input/output
V_{DD}	7	−284.80	−594.40		supply voltage
$\overline{SYNC}$	8	4.20	−594.40		cascade synchronization input/output
OSC	9	119.20	−594.40		oscillator select
A0	10	249.20	−594.40		subaddress input
A1	11	379.20	−594.40		
A2	12	581.20	−594.40		
SA0	13	711.20	−594.40		I²C-bus slave address input; bit 0
V_{SS}	14	841.20	−594.40		ground supply voltage
V_{LCD}	15	1099.60	−594.40		LCD supply voltage
BP2	16	1277.60	−594.40		LCD backplane output
BP0	17	1357.60	−594.40		
S0	18	1437.60	−594.40		LCD segment output
S1	19	1517.60	−594.40		
S2	20	1597.60	−594.40		
S3	21	1677.60	−594.40		
S4	22	1757.60	−594.40		
S5	23	1837.60	−594.40		
S6	24	1917.60	−594.40		
S7	25	1997.60	−594.40		
S8	26	2077.60	−594.40		
S9	27	2157.60	−594.40		
S10	28	2237.60	−594.40		
S11	29	2317.60	−594.40		
S12	30	2357.60	594.40		
S13	31	2277.60	594.40		
S14	32	2197.60	594.40		
S15	33	2117.60	594.40		
S16	34	2037.60	594.40		
S17	35	1957.60	594.40		
S18	36	1877.60	594.40		
S19	37	1797.60	594.40		
S20	38	1717.60	594.40		
S21	39	1637.60	594.40		

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Table 24. Bump locations

All x/y coordinates represent the position of the centre of each bump with respect to the center (x/y = 0) of the chip; see Figure 28.

Symbol	Bump	X (μm)	Y (μm)	Description
S22	40	1557.60	594.40	LCD segment output
S23	41	1477.60	594.40	
S24	42	1317.60	594.40	
S25	43	1237.60	594.40	
S26	44	1157.60	594.40	
S27	45	1077.60	594.40	
S28	46	997.60	594.40	
S29	47	917.60	594.40	
S30	48	837.60	594.40	
S31	49	757.60	594.40	
S32	50	677.60	594.40	
S33	51	597.60	594.40	
S34	52	437.60	594.40	
S35	53	357.60	594.40	
S36	54	277.60	594.40	
S37	55	197.60	594.40	
S38	56	117.60	594.40	
S39	57	37.60	594.40	
S40	58	−42.40	594.40	
S41	59	−122.40	594.40	
S42	60	−202.40	594.40	
S43	61	−282.40	594.40	
S44	62	−362.40	594.40	
S45	63	−442.40	594.40	
S46	64	−602.40	594.40	
S47	65	−682.40	594.40	
S48	66	−762.40	594.40	
S49	67	−842.40	594.40	
S50	68	−922.40	594.40	
S51	69	−1002.40	594.40	
S52	70	−1082.40	594.40	
S53	71	−1162.40	594.40	
S54	72	−1242.40	594.40	
S55	73	−1322.40	594.40	
S56	74	−1402.40	594.40	
S57	75	−1562.40	594.40	
S58	76	−1642.40	594.40	
S59	77	−1722.40	594.40	
S60	78	−1802.40	594.40	

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Table 24. Bump locations

All x/y coordinates represent the position of the centre of each bump with respect to the center (x/y = 0) of the chip; see Figure 28.

Symbol	Bump	X (μm)	Y (μm)		Description
S61	79	−1882.40	594.40		LCD segment output
S62	80	−1962.40	594.40		
S63	81	−2042.40	594.40		
S64	82	−2122.40	594.40		
S65	83	−2202.40	594.40		
S66	84	−2282.40	594.40		
S67	85	−2362.40	594.40		
S68	86	−2322.40	−594.40		
S69	87	−2242.40	−594.40		
S70	88	−2162.40	−594.40		
S71	89	−2082.40	−594.40		
S72	90	−2002.40	−594.40		
S73	91	−1922.40	−594.40		
S74	92	−1842.40	−594.40		
S75	93	−1762.40	−594.40		
S76	94	−1682.40	−594.40		
S77	95	−1602.40	−594.40		
S78	96	−1522.40	−594.40		
S79	97	−1442.40	−594.40		
BP3	98	−1362.40	−594.40		LCD backplane output
BP1	99	−1282.40	−594.40		
D1	-	2469.70	−594.40	[2]	dummy bump
D2	-	2549.70	−594.40		
D3	-	2517.60	594.40		
D4	-	2437.60	594.40		
D5	-	−2442.30	594.40		
D6	-	−2522.30	594.40		
D7	-	−2554.40	−594.40		
D8	-	−2474.40	−594.40		

[1] For most applications SDA and SDAACK are shorted together; see Section 8.1.

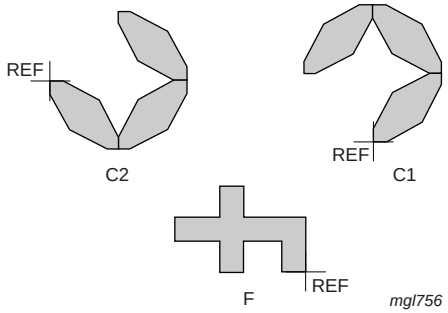
[2] The dummy bumps are connected to the adjacent segments but are not tested.

Table 25. Alignment mark locations

Symbol	X (μm)	Y (μm)
C1	2300.5	55.0
C2	−2320.2	107.0
F	−2208.3	−165.4

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The positions of the alignment marks are shown in Figure 2 and Figure 28.

Fig 29. Alignment marks of PCA8533

15. 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.

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16. Packing information

16.1 Tray information

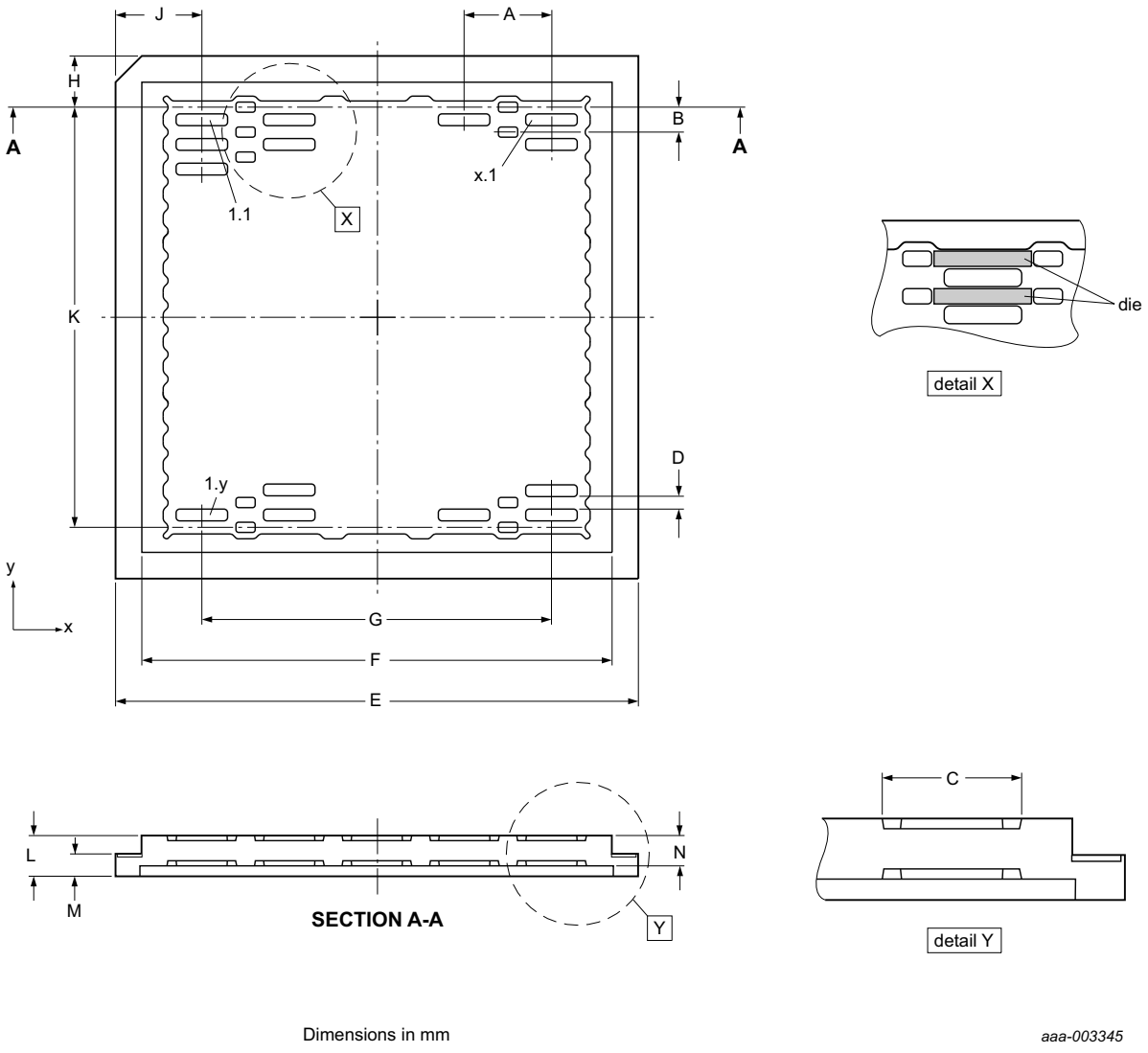


Fig 30. Tray details

Table 26. Description of tray details

Tray details are shown in Figure 30.

Tray details													
Dimensions													
A	B	C	D	E	F	G	H	J	K	L	M	N	Unit
7.0	2.4	5.38	1.50	50.8	45.72	35.0	5.0	7.9	40.8	3.96	2.18	2.49	mm
Number of pockets													
x direction							y direction						
6							18						

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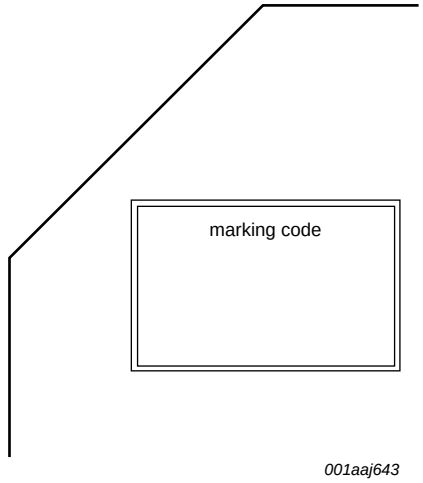


Fig 31. Tray alignment

The orientation of the IC in a pocket is indicated by the position of the IC type name on the die surface with respect to the chamfer on the upper left corner of the tray. Refer to Figure 28 for the orientation and position of the type name on the die surface.

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17. Abbreviations

Table 27. Abbreviations

Acronym	Description
CMOS	Complementary Metal-Oxide Semiconductor
COG	Chip-On-Glass
DC	Direct Current
ESD	ElectroStatic Discharge
HBM	Human Body Model
I^2C	Inter-Integrated Circuit bus
IC	Integrated Circuit
ITO	Indium Tin Oxide
LCD	Liquid Crystal Display
LSB	Least Significant Bit
MM	Machine Model
MOS	Metal-Oxide Semiconductor
MSB	Most Significant Bit
POR	Power-On Reset
RC	Resistance-Capacitance
RAM	Random Access Memory
RMS	Root Mean Square
SCL	Serial CLock line
SDA	Serial DAta line

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18. 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] **IEC 60134 —** Rating systems for electronic tubes and valves and analogous semiconductor devices

[5] **IEC 61340-5 —** Protection of electronic devices from electrostatic phenomena

[6] **JESD22-A114 —** Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)

[7] **JESD22-A115 —** Electrostatic Discharge (ESD) Sensitivity Testing Machine Model (MM)

[8] **JESD78 —** IC Latch-Up Test

[9] **JESD625-A —** Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices

[10] **UM10204 —** I^2C-bus specification and user manual

[11] **UM10569 —** Store and transport requirements

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19. Revision history

Table 28. Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
PCA8533 v.3	20121001	Product data sheet	-	PCA8533 v.2
Modifications:	• Adjusted values for I_{DD} and $I_{DD(LCD)}$ in Table 20 • Changed tray information (Section 16.1) • Added ordering options (Section 3.1) • Enhanced display RAM description (Section 7.6) • Improved description of bit E (Table 6)			
PCA8533 v.2	20110629	Product data sheet	-	PCA8533 v.1
PCA8533 v.1	20110427	Product data sheet	-	-

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20. Legal information

20.1 Data sheet status

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

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

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

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

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