

OKI Semiconductor

FEDL87V3104-03

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ML87V3104

LCD Display Controller with Embedded Display Memory

GENERAL DESCRIPTION

The ML87V3104 is an LCD graphic display controller intended for use in medium to small-sized equipment having such as QVGA grade medium-sized LCD panels, such as PDA or portable information terminals.

Since this LSI device has an internal display memory, use of this device reduces the component count. It is possible to set an easy to use configuration of the display memory size, such as 1024 × 1024 dots × 4 bits or 2048 × 256 dots × 8 bits, depending on the application at hand, and it is possible to access the image data without having to be concerned about address conversion.

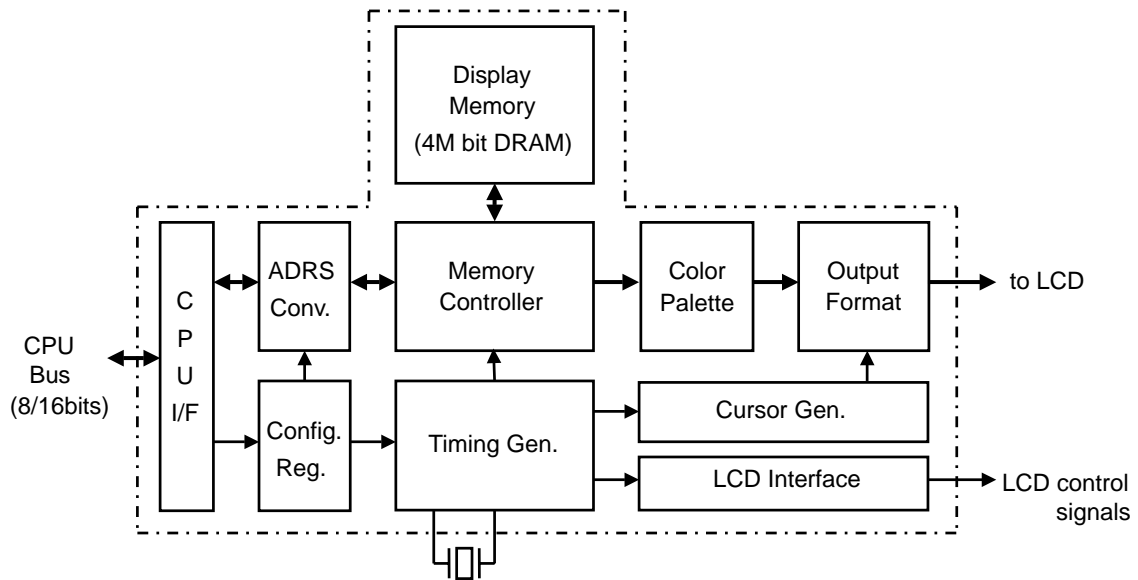
The area specified in the display memory can be output on the display.

The display data and the control information can be set by the host CPU.

FEATURES

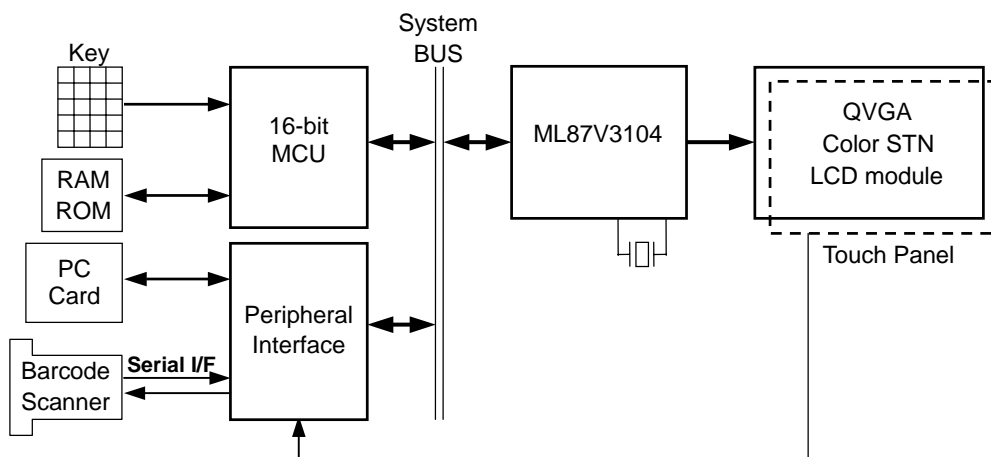
- Display memory: Horizontal 4096 dots, maximum, vertical 4096 dots, maximum (with restrictions)
- Display size: Horizontal 1024 dots, maximum, vertical 1024 dots, maximum (with restrictions)
suitable for QVGA (320 × 240) or HVGA (640 × 240, 480 × 320)
- Number of display colors: 16/256 Colors out of 4096 colors (pseudo-colors)
4096/65536 Colors (direct colors)
- Color palette: 256 Colors × 12 bits (R4, G4, B4)
- Output data: STN 4/8 bits parallel,
TFT 12 bits (R4, G4, B4) / 16 bits (R5, G6, B5)
- Display functions: Scroll (in units of 16 horizontal pixels and 1 vertical line),
Sub-screen display (any position, pseudo-color mode only)
Hardware cursor (16 × 16 × 2 bits)
- LCD Drive signals: Duty 1/64 to 1/1024, up to 16-gray levels,
Programmable AC driving signal (Toggle period can be specified.)
- Host CPU: 8/16 bits (68k- Series, 80-Series, RISCs of different companies, etc.)
- Embedded memory: 4M bit DRAM
- Operating frequency: 15 MHz, maximum
- Power supply voltages: 3.3 V ± 0.3 V
- Package: 100-Pin plastic TQFP (TQFP100-P-1414-0.50-K)

BLOCK DIAGRAM



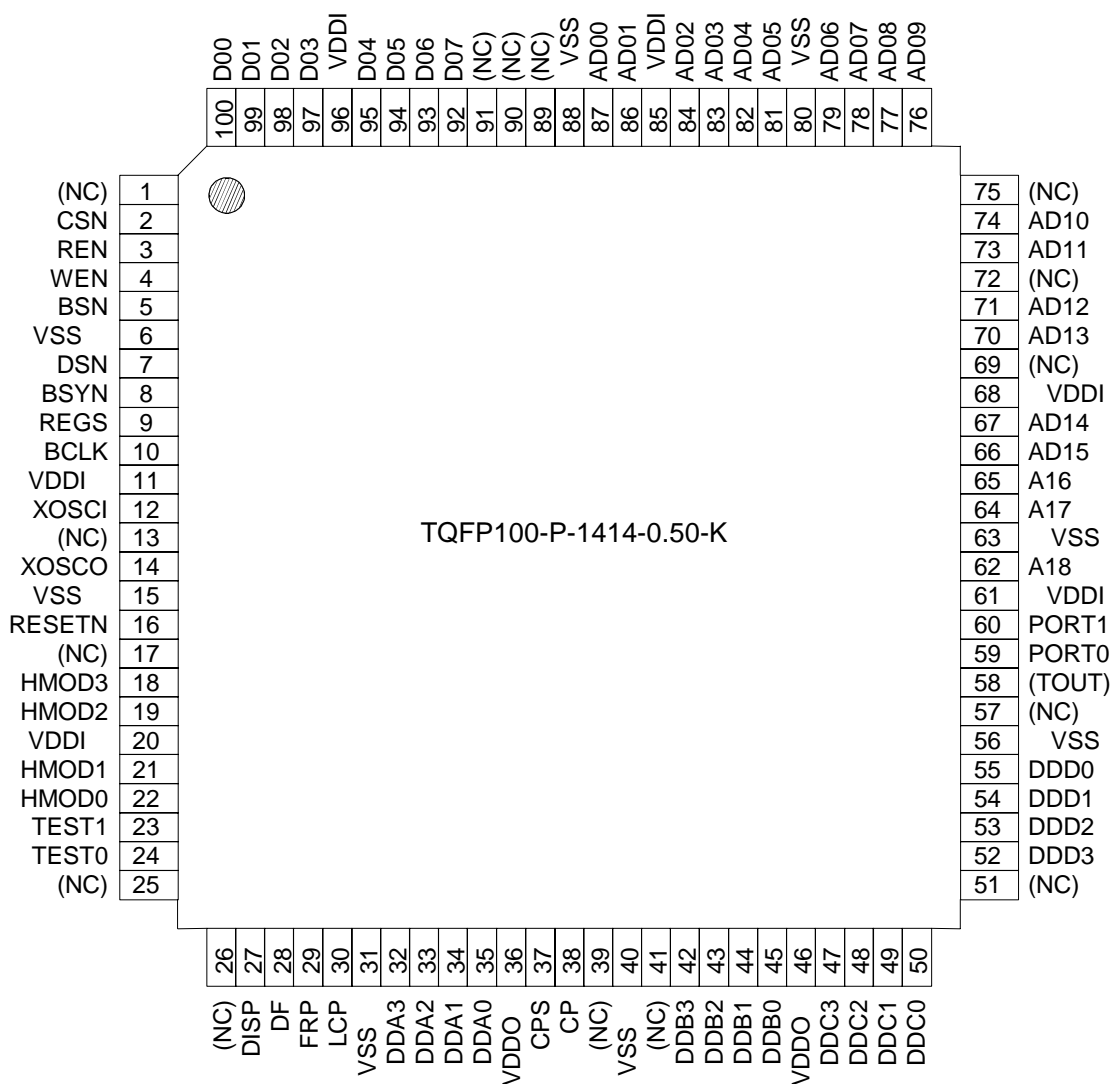
APPLICATION CIRCUIT

The following is an example of application to a handy terminal for POS systems.



PIN CONFIGURATION (TOP VIEW)

100-pin Plastic TQFP



NC: No-connection pins These pins should be left open during normal use.

Please supply the same voltage to all the "VDDI" pins, also "VDDO" pins.

PIN DESCRIPTIONS

Table P1. List of pins and their descriptions

Pin	Symbol	I/O	Type	Description
27	DISP	O	4mA drive	LCD Display enable
28	DF	O	4mA drive	LCD AC driving signal pin
29	FRP	O	4mA drive	LCD Frame pulse
30	LCP	O	4mA drive	LCD Line clock pulse
32-35	DDA3 - 0	O	4mA drive 3-state	LCD Data A
37	CPS	O	4mA drive	LCD Data clock pulse 2 or Data Strobe
38	CP	O	4mA drive	LCD Data clock pulse
42-45	DDB3 - 0	O	4mA drive 3-state	LCD Data B
47-50	DDC3 - 0	O	4mA drive 3-state	LCD Data C
52-55	DDD3 - 0	O	4mA drive 3-state	LCD Data D
59, 60	PORT0, 1	I/O	LVTTL / 4mA drive	General purpose I/O port (input / output direction can be set for each pin)
62, 64, 65	A18 - 16	I	LVTTL	Host address bus
66, 67, 70, 71 73, 74, 76-79 81-84, 86, 87	AD15 - 00	I/O	LVTTL / 4mA drive	Host address/data multiplexed bus
92-95, 97-100	D07 - 00	I/O	LVTTL / 4mA drive	Host data bus
2	CSN	I	LVTTL, Schmitt	Chip select (active "L")
3	REN	I	LVTTL, Schmitt	Read enable (active "L")
4	WEN	I	LVTTL, Schmitt	Write enable (active "L")
5	BSN	I	LVTTL, Schmitt	Bus start/address strobe (active "L")
7	DSN	I	LVTTL, Schmitt	Data strobe (active "L")
8	BSYN	O	8mA drive 3-state	Busy/wait (active "L", 3-stated)
10	BCLK	I	LVTTL, Schmitt	Bus clock
9	REGS	I	LVTTL, Schmitt	Register select
12	XOSCI	I	X'tal oscillation buffer	Clock oscillator input (built-in feedback resistor)
14	XOSCO	O		Clock oscillator output
16	RESETN	I	LVTTL	System reset (active "L")
18, 19, 21, 22	HMOD3 - 0	I	LVTTL	Host mode select
23, 24	TEST1, 0	I	LVTTL	Test mode select (normally tied to "L")
58	(TOUT)	O	2mA drive	(Test output. Not used.)
11, 20, 61, 68, 85, 96	VDDI	—	Power Supply	Power supply for the internal core and I/O
36, 46	VDDO	—	Power Supply	Power supply for the LCD interface signal outputs
6, 15, 31, 40, 56, 63, 80, 88	VSS	—	Power Supply	Common ground

FUNCTIONAL DESCRIPTION

1. Display Memory

The address and data configuration of the display memory is specified by making control register settings. When the defined memory size is smaller than the internal DRAM (4M bits), the page mode operation is started automatically, making it possible to specify the display address in units of a page and to access the host CPU (a maximum of 256 pages). Even when the address space of the host CPU bus is smaller than the display memory space, the entire area can be accessed using the page mode.

There are limitations on the LCD drive mode depending on the display memory data width. (See Section 3.1.)

Note that the LCD control timings must be defined before accessing the display memory. (See Section 3.1.2)

- Control registers:

IMASZX [#03h: bit 3-0]: Display memory horizontal size (2^n) (Table F1.1)

IMASZY [#03h: bit 7-4]: Display memory vertical size (2^n) (Table F1.1)

IMDBPP [#02h: bit 1-0]: Number of bits per pixel (Table F1.2)

HSTPGA [#3Bh]: Page number for host access

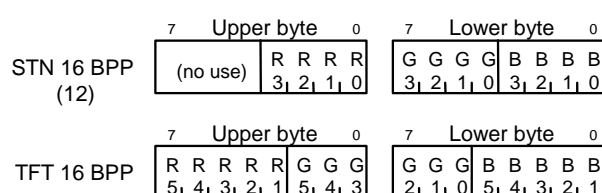
Table F1.1 Display memory size selection

IMASZY	Vertical size (lines)	IMASZX	Horizontal size (pixels)
0000	64	0000	64
0001	128	0001	128
0010	256	0010	256
0011	512	0011	512
0100	1024	0100	1024
0101	2048	0101	2048
0110	4096	0110	4096
0111	(Reserved)	0111	(Reserved)
1XXX	(Reserved)	1XXX	(Reserved)

Table F1.2 Display memory data width

IMDBPP	Number of bits (bits / pixel)	Number of simultaneously displayed colors		Applicable LCD type
		Color mode	Monochrome mode	
00X	—	—	—	—
010	4	Pseudo color	16/4096	16
011	8		256/4096	256
100	16 ^{*1}	Direct color	4096	—
			65536	—

*1: Correspondence between the display memory data and the color data in the 16BPP mode.



Example 1: When IMASZX = “100”, IMASZY = “100”, and IMDBPP = “010”:
The memory size is 1024 horizontal pixels, 1024 vertical lines and 4 bits/pixel.

$$1024 \times 1024 \times 4 = 4\text{M bits}$$

The memory can be accessed using 19 host address bits (10 horizontal bits plus 9 vertical bits) with the host data width being 8 bits (in 2-pixel packed format).

Example 2: When IMASZX = “010”, IMASZY = “010”, and IMDBPP = “011”:
The memory size is 256 horizontal pixels, 256 vertical lines with 8 bits/pixel and 8 pages.

$$256 \times 256 \times 8 = 512\text{K bits} (< 4\text{M bits})$$

$$4\text{M bits}/512 \text{ K bits} = 8 \text{ pages}$$

The memory can be accessed using 16 host address bits (8 horizontal bits plus 8 vertical bits) and the lower 3 bits of the page register, with the host data width being 8 bits (in 2-pixel packed format).

2. Display Control

2.1 Display section

The display section of the ML87V3104 is composed of the display memory, the cursor and cursor color registers, the color palette, the FRC table, and output format conversion section. (Fig. F2.1)

The color display in the case of 4 bits/pixel and 8 bits/pixel can be made using, respectively, 16 and 256 colors out of 4096 colors. (Pseudo-color mode)

Further, in the STN mode, the output is made after conversion into the gradation expression data in the FRC method.

In the case of 16 bits/pixel, the output is made directly without passing through the color palette. (Direct color mode)

In the STN mode, out of the total 16 bits, only 4 bits each of RGB (12 bits in all) will be valid and display 4096 colors can be made.

In the TFT mode, the 16 bits are divided into 5 bits of R, 6 bits of G, and 5 bits of B, making it possible to display 65536 colors.

Even the direct mode can also be used in the case of 8 bits/pixel.

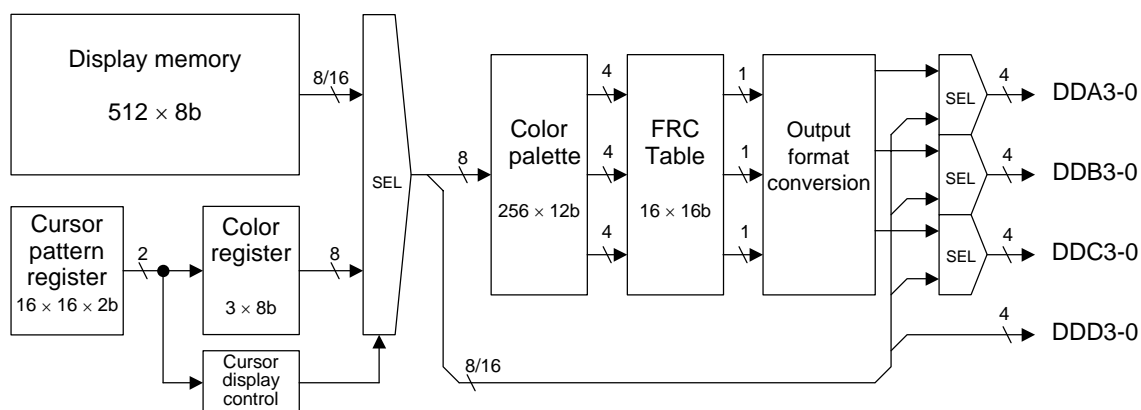


Fig. 2.1 The display section

2.2 Display screen composition

The display screen consists of the main screen with a size equal to the display size of the LCD panel, and a sub-screen displayed in a smaller area within the main screen. (Fig. F2.2.1)

In the case of a color LCD panel, one set of the three colors (RGB) is considered as one pixel. (Fig. F2.2.2)

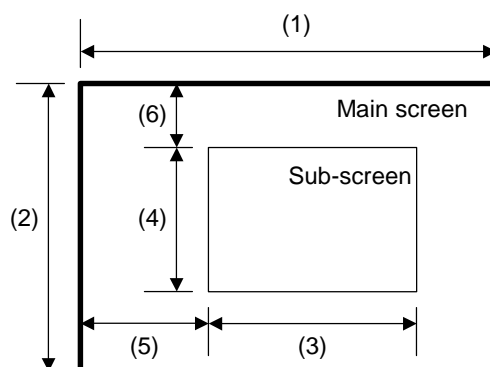


Fig. F2.2.1 The display screen composition

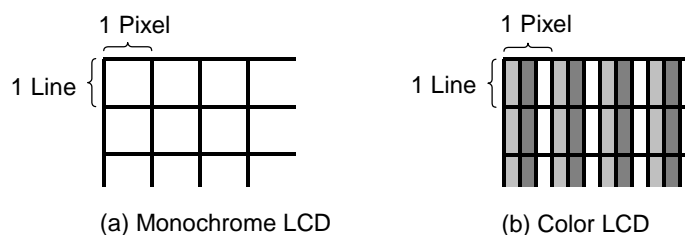


Fig. F2.2.2 The LCD panel dot composition

• Control registers:

- (1) MSCSZH [#21h, #20h]: Horizontal display size ≤ 1024 pixels
- (2) MSCSZV [#23h, #22h]: Vertical display size ≤ 1024 lines
- (3) SSCSZH [#25h, #24h]: Sub-screen horizontal display size $< (1)$
- (4) SSCSZV [#27h, #26h]: Sub-screen vertical display size $< (2)$
- (5) SDPOSH [#29h, #28h]: Sub-screen horizontal display position $< (1)$
- (6) SDPOSV [#2Bh, #2Ah]: Sub-screen vertical display position $< (2)$

2.3 Display functions

2.3.1 Main screen, sub-screen, and scrolling

The main screen and the sub-screen in the display screen (see Fig. F2.2.1) can respectively display the areas specified in the display memory. (Fig. F2.3.1)

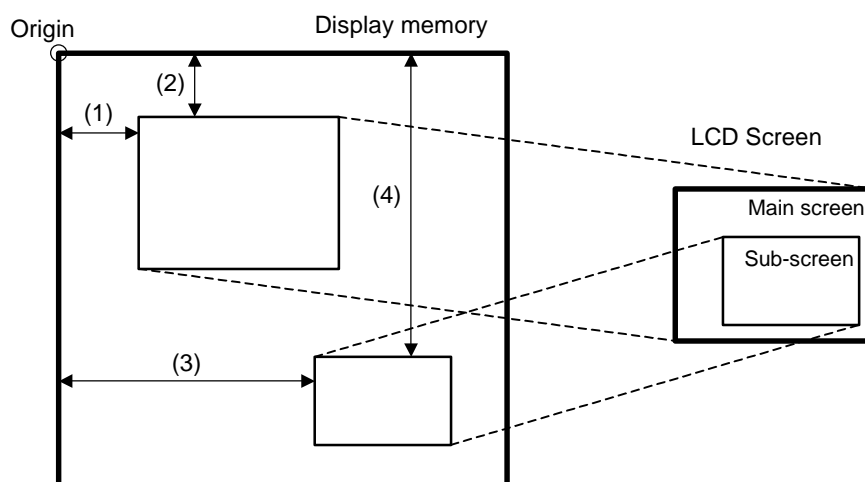


Fig. F2.3.1 The display screen composition

- Control registers:

- (1) MDPSTX [#31h, #30h]: Starting horizontal address of reading out the main screen display area
- (2) MDPSTY [#33h, #32h]: Starting vertical address of reading out the main screen display area
- (3) SDPSTX [#35h, #34h]: Starting horizontal address of reading out the sub-screen display area
- (4) SDPSTY [#37h, #36h]: Starting vertical address of reading out the sub-screen display area
- (5) MDPPGA [#38h]: Page number of the main screen display area
- (6) SDPPGA [#39h]: Page number of the sub-screen display area

The starting addresses of reading out the display memory can be specified for the separate main screen and sub-screen in units of 16 horizontal pixels and one vertical line. In addition, by successively over-writing by the host CPU, it is possible to realize scrolling of the display screen.

The sub-screen is always displayed by superimposing on the main screen.

2.3.2 Screen mode

It is possible to select the method of placing the LCD panel by setting the screen mode.

It is possible to specify the landscape (horizontal screen) or portrait (vertical screen), and to specify the left/right and top/bottom reversal of the displayed image.

- Control register:

SCRMOD [#02h; bit6-4]: Screen mode

Table F2.3.2 The screen modes

SCRMOD	Screen mode		
000	Landscape (longer horizontal side)	Normal	
001		Left/right flip	
010		Top/bottom flip	
011		Left/right and top/bottom flip	
100	Portrait (longer vertical side)	Normal	
101		Top/bottom flip	
110		Left/right flip	
111		Left/right and top/bottom flip	

: LCD data output scanning direction

Note: The screen mode definition has a difference between Landscape and Portrait.

2.4 Cursor

2.4.1 Cursor display

It is possible to display the cursor on the screen. It is also possible to select whether or not to display the cursor, and when cursor display is selected, it is always displayed in the front-most screen. This LSI has a pattern register for the display of a cursor with a size of 16 pixels \times 16 lines \times 2 bits in which it is possible to write the cursor shape. Displaying the cursor has no effect on the display memory.

The cursor display color can be specified by the contents of the 2-bit (4-value) cursor pattern register for each pixel. One of the four values is “transparent”, and that pixel is not displayed when this value is specified. The other 3 values respectively correspond to the 8-bit cursor color registers (CSCOL1 to CSCOL3), and the specified value is converted to the actually displayed pixel data from the color palette common to the display memory output.

2.4.2 Cursor display position

The cursor display position is specified in terms of the position in the screen of the cursor origin (the top left corner of the cursor).

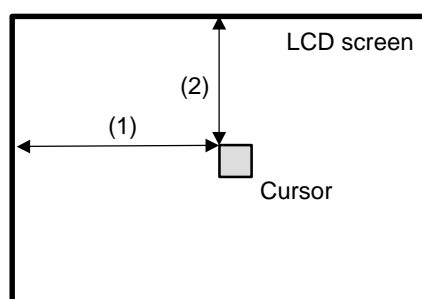


Fig. F2.4.2 The cursor position

- Control registers:

- (1) CSPOSH [#2Dh, #2Ch]: Cursor display horizontal position
- (2) CSPOSV [#2Fh, #2Eh]: Cursor display vertical position
- (3) CSDENB [#2Fh; bit7]: Cursor display enable ('0': disable, '1': enable)

2.4.3 Cursor color register

The display data of the cursor is determined corresponding to the cursor data by the contents of the 8-bit cursor color register. The number of valid bits depends on the number of bits per pixel (IMDBPP).

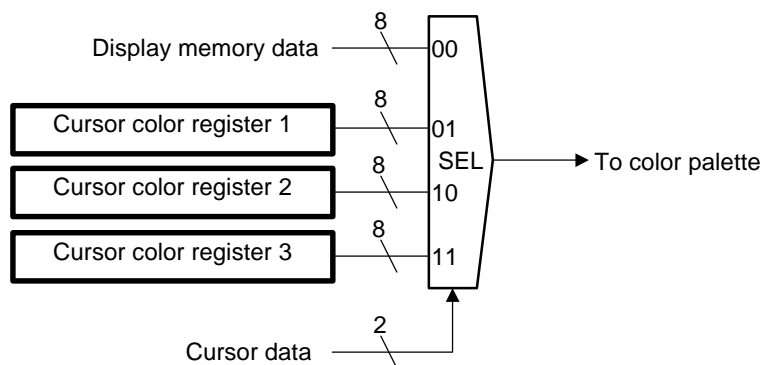


Fig. F2.4.3 The cursor color register

- Control registers:

- CSCOL1 [#1Dh]: Cursor color register 1
- CSCOL2 [#1Eh]: Cursor color register 2
- CSCOL3 [#1Fh]: Cursor color register 3

Valid bits:

- Bits 3 to 0 for 4BPP
- Bits 7 to 0 for 8BPP

2.4.4 Cursor pattern register

The cursor pattern (shape) can be prepared by writing data in the 16 x 16 x 2-bit cursor pattern register. The data is accessed in the 4-pixel packed format. (Fig. F2.4.4)

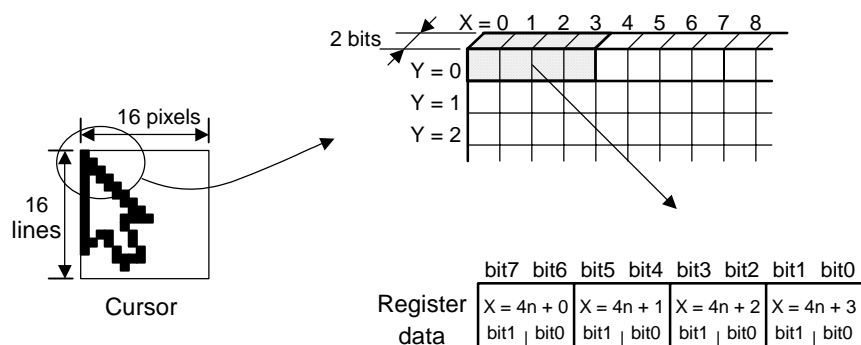


Fig. F2.4.4 The cursor pattern register

- Control registers:

- CSPTAY [#18h; bit5-2]: Cursor pattern register address Y (4 bits)
- CSPTAX [#18h; bit1-0]: Cursor pattern register address X (higher 2 bits)
- CSPTD0 [#19h; bit7-6]: Cursor pattern register data (X address = 4n+0)
- CSPTD1 [#19h; bit5-4]: Cursor pattern register data (X address = 4n+1)
- CSPTD2 [#19h; bit3-2]: Cursor pattern register data (X address = 4n+2)
- CSPTD3 [#19h; bit1-0]: Cursor pattern register data (X address = 4n+3)

2.5 Color palette

The data written in the display memory is converted into the actual color data output to the LCD panel by the color palette. (Pseudo-color mode) The color palette contains 4-bit × 3-color (R, G, B) (= 12 bits) registers corresponding to each of the 256 entries addresses.

The correspondence between the display memory data and the color palette entry is established as shown in Table F2.5 depending on the data width of the display memory. The color palette cannot be used in the direct color mode (16BPP).

Table F2.5 The display memory data vs. the color palette entries

Display memory data ^{*1}		Color palette entry
8 BPP	4 BPP	
00	0	00
01	1	01
02	2	02
03	3	03
04	4	04
05	5	05
06	6	06
07	7	07
08	8	08
09	9	09
0A	A	0A
0B	B	0B
0C	C	0C
0D	D	0D
0E	E	0E
0F	F	0F
10	—	10
11	—	11
12	—	12
13	—	13
14	—	14
⋮	⋮	⋮
FC	—	FC
FD	—	FD
FE	—	FE
FF	—	FF

*1: A hyphen “—” indicates that the data value is not used.

• Control registers:

COLPTA [#10h]:	Color palette entry address
COLPDR [#11h; bit7-4]:	Color palette data R
COLPDG [#12h; bit7-4]:	Color palette data G
COLPDB [#13h; bit7-4]:	Color palette data B

2.6 Gray level control

In the case of an STN type LCD panel, the FRC (Frame Rate Control) method is used for the multiple gray level display. By controlling the blinking pattern of the dot, it is possible to express intermediate gray levels in a quasi manner.

Taking 16 frames as one period, it is possible to express up to 16 gray levels.

The dot blinking pattern is set in the 16-word x 16-bit FRC table. The 4-bit table address corresponds to the gray levels from 0 to 15. The 16-bit table data expresses the dot blinking patterns corresponding to the different gray levels, and the dot display is switched for each frame sequentially from the MSB to the LSB, with the operation being repeated at a period of 16 frames.

In the case of a color STN panel, the FRC pattern is the same for all colors.

- Control registers:

FRCTBA [#15h; bit3-0]: FRC table address

FRCTBD [#17h, #16h]: FRC table data

Table F2.6 The FRC table (initial value)

Table address (gradation)	FRC table (displayed in the sequence 15, 14, ..., 1, 0)															
	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
3	0	0	0	0	1	0	0	0	0	1	0	0	0	0	1	0
4	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1
5	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
6	0	1	0	0	1	0	0	1	0	1	0	0	1	0	0	1
7	1	0	1	0	1	0	1	0	1	0	1	0	0	1	0	0
8	0	1	0	1	0	1	0	1	0	1	0	1	1	0	1	1
9	1	0	1	1	0	1	1	0	1	0	1	1	0	1	1	0
10	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1
11	1	1	1	0	1	1	1	0	1	1	1	0	1	1	1	0
12	1	1	1	1	0	1	1	1	1	0	1	1	1	1	0	1
13	1	1	1	1	1	0	1	1	1	1	1	1	1	0	1	1
14	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Note: This table shows the initial value set after a reset, and is not one assuming any specific LCD panel specifications. Set the values in this table to suit the characteristics of the LCD panel being used.

3. LCD Interface

3.1 LCD driving method

3.1.1 LCD driving mode

The ML87V3104 is suitable for various types of LCD panels, and allows the LCD driving mode to be selected by setting the control registers.

The number of valid data bits in the LCD interface varies depending on the driving mode. The output data signals that are not used will be maintained in the high-impedance state. Further, there are some restrictions on the selection of the display memory data width (bits per pixel) depending on the driving mode. (Table F3.1)

• Control registers:

LCDMOD [#00h; bit7-4]: LCD panel operation mode

LCDDAT [#00h; bit3-0]: LCD panel interface data width

Table F3.1 LCD driving modes

LCDMOD	LCDDAT	LCD driving mode			Output data				Display memory BPP
					DDA	DDB	DDC	DDD	
0000	000	Color STN	Pseudo-color	4 bits	O	Z	Z	Z	4, 8
	010			8 bits	O	O	Z	Z	
	100			4 bits, 2 phase	O	Z	Z	Z	
0001	000		Direct color	4 bits	O	Z	Z	Z	16(12)
	010			8 bits	O	O	Z	Z	
	100			4 bits, 2 phase	O	Z	Z	Z	
0100	000	Monochrome STN	4 bits	O	Z	Z	Z	4	
	010		8 bits	O	O	Z	Z		
	100		4 bits, 2 phase	O	Z	Z	Z		
1000	000	Color TFT	Pseudo-color	12 bits	O	O	O	Z	4, 8
1001	001		Direct color	16 bits	O	O	O	O	16

BPP: bits per pixel

'O': 4 bits are active.

'Z': 4 bits are in a high impedance state.

3.1.2 LCD control timing

The LCD control timing is determined by the LCP (line clock pulse) signal and the FRP (frame pulse) signal. It is also possible to set the polarities of these pulses individually.

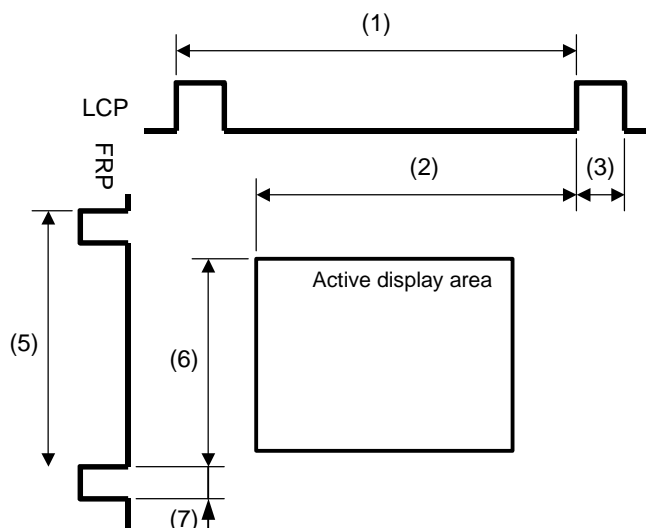


Fig. F3.1.2 LCD drive timing

• Control registers:

- (1) LCPCYC [#05h, #04h]: (LCP signal period – 1)
 In units of a CP clock in the STN color 4-bit mode
 In units of 2 CP clocks in the STN color 8-bit mode or 4-bit 2-phase mode
 In units of 4 CP clocks in the STN monochrome 4-bit mode
 In units of 8 CP clocks in the STN monochrome 8-bit mode or 4-bit 2-phase mode
 In units of a CP clock in the TFT color mode
- (2) LCPSTA [#07h, #06h]: LCP start timing, in units of a CP clock
- (3) LCPWID [#07h; bit7-4]: (LCP pulse width – 1), in units of $4 \times$ CP clocks
- (4) LCPPOL [#05h; bit7]: LCP pulse polarity, '0': Positive, '1': Negative
- (5) FRPCYC [#09h, #08h]: FRP signal period, in units of a line, $(5) \geq (6)+2$
- (6) FRPSTA [#0Bh, #0Ah]: FRP start timing, in units of a line
- (7) FRPWID [#0Bh; bit7-4]: (FRP pulse width – 1), in units of a line
- (8) FRPPOL [#09h; bit7]: FRP pulse polarity, '0': Positive, '1': Negative

Note: The internal memory gets started by setting above registers. These must be set at first after the power up or the internal memory cannot be accessed.

3.1.3 LCD AC driving signal DF

The toggle period of the DF signal (AC driving signal) can be specified to be either one frame period or the period of the set number of lines.

- Control registers:

DFFALT [#0Dh; bit7]: DF signal toggle mode

DFLALT [#0Dh, #0Ch]: (DF signal toggle period – 1), in units of a line

DFFALT	DF toggle mode
0	Reversal at one frame periods
1	Reversal at periods of (DFLALT+1) line

3.1.4 LCD data clocks CP, CPS

It is possible to select whether or not to output the CP and CPS clock pulses during the invalid period (blanking period) of the LCD display data. In most cases, the appropriate setting is CPBLK = '1' for an STN LCD and CPBLK = '0' for a TFT LCD.

- Control register:

CPBLK [#01h; bit7]: Control of CP and CPS clock output during blanking

CPBLK	CP and CPS clock output during blanking
0	Active
1	Clock pulses are stopped

3.1.5 LCD data output control

Three types of control registers are provided in this LSI device for control of the LCD data output. The register COLOR_D can be used for changing R, G, B sequence in a color LCD. This is also valid in the frame sequential color mode.

The register DPDMOD is used for inverting the bits of the output data or for making the data all-zero or all-one. The register DPMENB can be used for stopping the display memory readout operation itself. At this time, even the LCD driving signals will be stopped. Further, it is also possible to specify the level of the DISP signal output. The register REFENB controls the refresh operation of the display memory (embedded DRAM). If the refresh operation is stopped, the entire contents of the display memory will be lost. Along with the register DPMENB, this register is useful for achieving low power consumption when no display is being made.

• Control registers:

COLOR_D [#01h; bit7]: Color arrangement sequence of the color LCD panel

COLOR_D	Color arrangement sequence
0 0 0	R, G, B, R, G, B, ...
0 0 1	G, B, R, G, B, R, ...
0 1 0	B, R, G, B, R, G, ...
1 0 1	R, B, G, R, B, G, ...
1 1 0	G, R, B, G, R, B, ...
1 1 1	B, G, R, B, G, R, ...

DPDMOD [#01h; bit3-2]: LCD data display mode

DPDMOD	LCD data display mode
0 0	Normal
0 1	Reverse
1 0	All '0'
1 1	All '1'

DPMENB [#01h; bit1-0]: Display memory readout control, definition of DISP signal output

DPMENB	Display memory readout	DISP signal
0 0	Memory readout stopped	DISP = 'L'
0 1	LCD drive stopped	DISP = 'H'
1 0	Memory readout operating	DISP = 'L'
1 1	LCD drive operating	DISP = 'H'

REFENB [#02h, bit7, 3]: Embedded DRAM refresh operation enable

REFENB		DRAM refresh operation
1	0	Fully stopped (sleep mode) ^{*1}
1	0	Operation only during blanking
	1	Always operating

*1: The contents of the display memory will be lost in the sleep mode.

3.1.6 Calculation of the display frame rate

The frame rate (the frame frequency) is determined by the periods of the LCD panel driving signals LCP and FRP, the clock frequency, and the LCD driving mode.

$$\text{Frame rate} = \text{FXOSC} / \{ (\text{FRPCYC}) \times (\text{LCPCYC}) \times (\text{TPX}) \}$$

Where,

FXOSC : External input clock frequency,

FRPCYC : Period (in units of a line) of the FRP (frame pulse) signal,

LCPCYC : Period (in units of a pixel) of the LCP (line pulse) signal,

TPX : TPX = 3/4 in the case of a color STN type LCD and TPX = 1 in all other cases.

Example: What is the input clock frequency for making the frame rate equal to 150 Hz in the case of a color STN QVGA (320 × 240) type LCD panel?

$$\text{FRPCYC} = 240 + 2 = 242$$

$$\text{LCPCYC} = 320 + 40 = 360$$

$$\text{FXOSC} = 150 \times 242 \times 360 \times 3/4 = \underline{9.8 \text{ MHz}}$$

3.2 LCD data output format

The valid output data signal and the data format are determined depending on the LCD driving mode.

3.2.1 Color STN, 4-bit mode

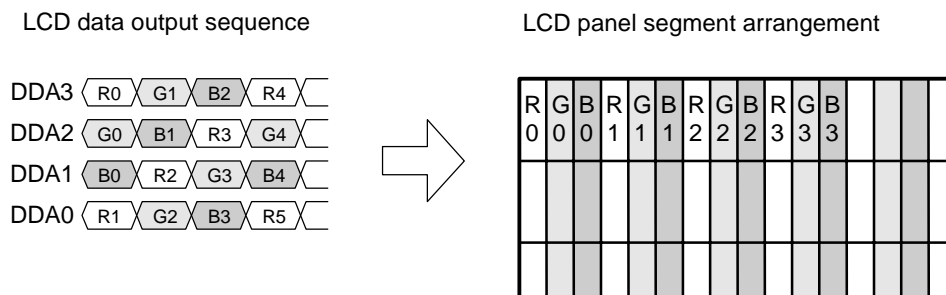


Fig. F3.2.1 Color STN, 4-bit mode

3.2.2 Color STN, 8-bit mode

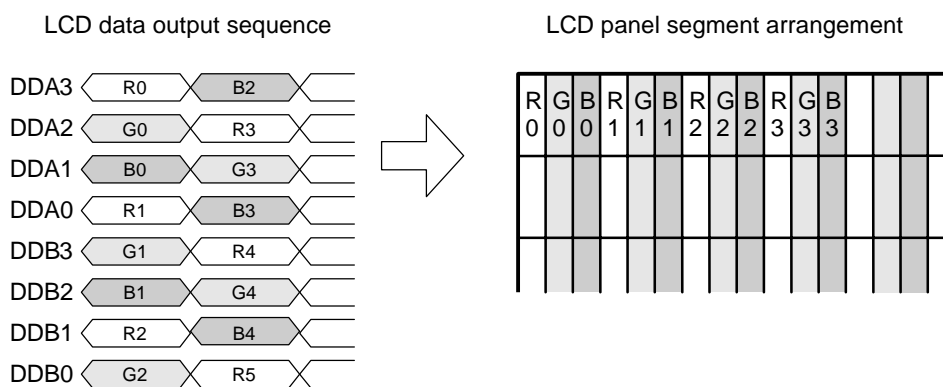


Fig. F3.2.2 Color STN, 8-bit mode

3.2.3 Color STN, 4-bit 2-phase mode

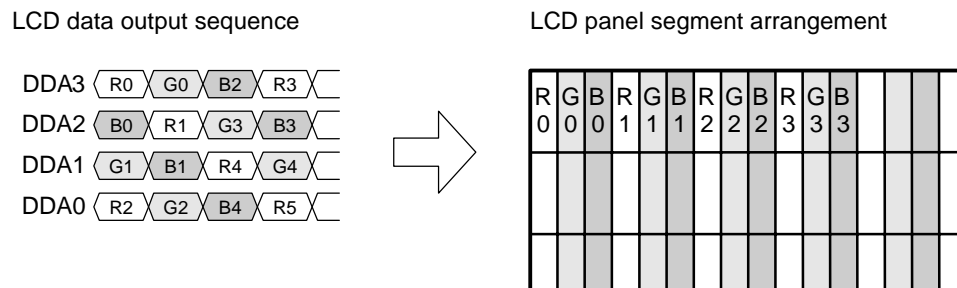


Fig. F3.2.3 Color STN, 4-bit, 2-phase mode

3.2.4 Monochrome STN, 4-bit mode

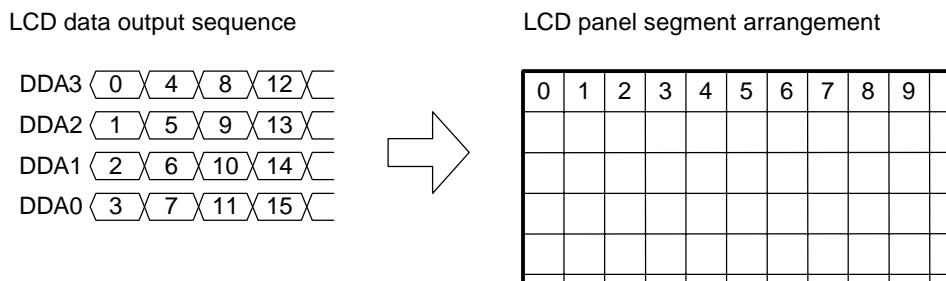


Fig. F3.2.4 Monochrome STN, 4-bit mode

3.2.5 Monochrome STN, 8-bit mode

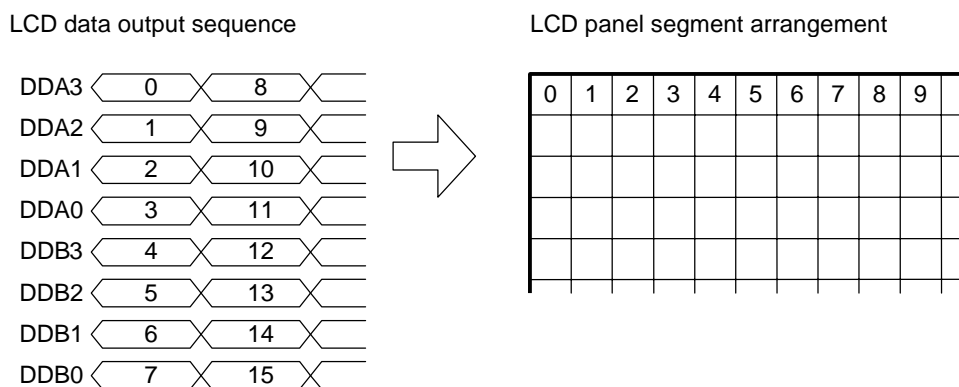
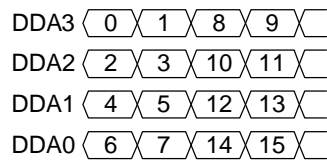


Fig. F3.2.5 Monochrome STN, 8-bit mode

3.2.6 Monochrome STN, 4-bit 2-phase mode

LCD data output sequence



LCD panel segment arrangement

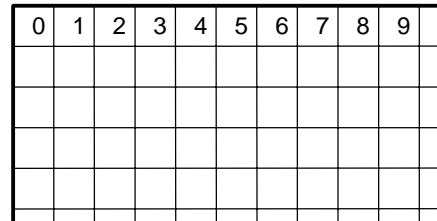


Fig. F3.2.6 Monochrome STN, 4-bit, 2-phase mode

3.2.7 Color TFT, 12-bit mode

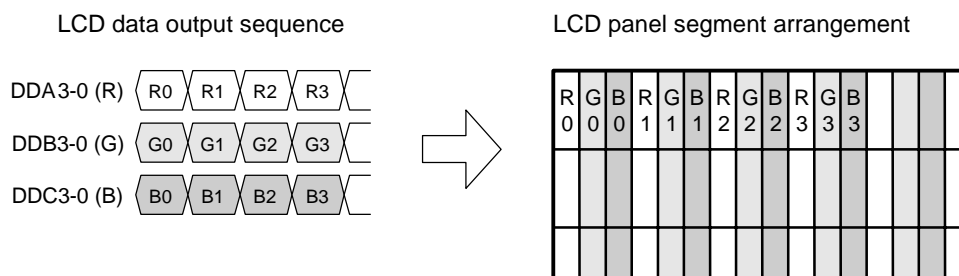


Fig. F3.2.7 Color TFT, 12-bit mode

3.2.8 Color TFT, 16-bit mode

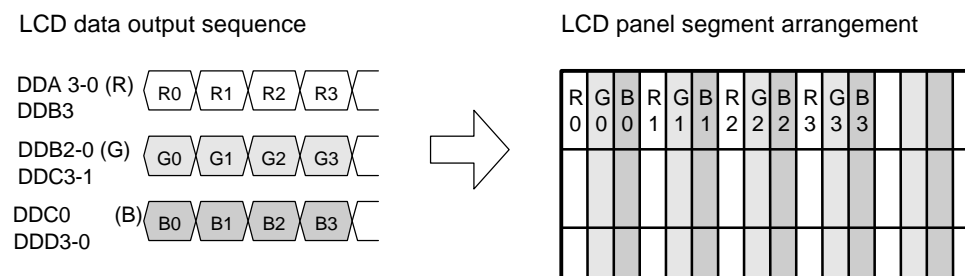


Fig. F3.2.8 Color TFT, 16-bit mode

4. General Purpose I/O Port

The ML87V3104 has two general purpose ports (PORT1, PORT0). It is possible to specify the input/output directions independently for these ports. The output level of the output port can be set by writing data in the data register. Further, the input level of the input port can be read out from the data register. When set as an input port, writing to the data register will not be valid.

- Control registers:

PTDDIR [#0Eh; bit1-0]: General purpose port input/output mode ('0': output, '1': input)

PTDREG [#0Fh; bit1-0]: General purpose port data register ('0': L level, '1': H level)

Bit 1 corresponds to PORT1 and bit 0 corresponds to PORT0.

PTDDIR[n]	PORTn	
0	Output	PTDREG[n] → PORTn
1	Input	PTDREG[n] ← PORTn

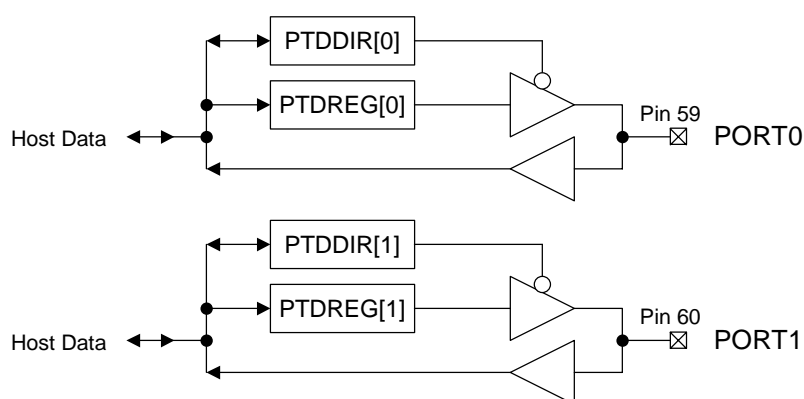


Fig. F4.1 General purpose ports

5. Host Interface

5.1 Host interface bus mode selection

The host interface bus can be selected to suit the external bus modes of different types of CPUs by setting the pins HMOD3 to HMOD0.

Table F5.1 Host interface bus mode

HMOD [3:0]	Bus type	Address/data bus	Bus control	Applicable CPUs*1
0000	A0	Separate A[18:00] D[07:00]	CSN, WEN, REN, Busy	Hitachi SH-1,2, H8S, Fujitsu F ² MC-16F, FR30 Toshiba TLCS-900/H2
0001	A1		AS, WEN, REN, Busy	Hitachi SH-4
0010	A2		BSN, WEN, REN, ACK	Hitachi SH-3, Motorola MCF5204 Toshiba TX39
0011	—		(Reserved)	—
0100	A4		BSN, RWN, DSN, ACK	Toshiba TX19, Motorola MCF5206, MPC801/850, M68K
0101	A5		BSN, RWN, DSN, Busy	Mitsubishi M32R, NEC V830, Intel SA-110
011X	—		(Reserved)	—
1000	B0	Multiplexed A[18:16] AD[15:00]	ASN, WEN, REN, Busy	Hitachi SH-1,2, NEC V850, 78K/IV Mitsubishi M16C Oki MSM66K, 80C51
1001	B1		AS, WEN, REN, Busy	Fujitsu F ² MC-16L, Toshiba TLCS-900
101X	—		(Reserved)	—
11XX	—		(Reserved)	—

*1: The types of CPUs listed here are only for reference. Please examine well about the specifications of the host interface signals and the timings of the MCU being used, and then select the host mode.

5.1.1 Bus control signals

The assignment of the bus control signals to the input/output pins is determined by the host interface bus mode.

Table F5.5.1 Bus control signals

Pin name	Bus type						
	A0	A1	A2	A4	A5	B0	B1
A18-16	A18-16	A18-16	A18-16	A18-16	A18-16	A18-16	A18-16
AD15-00	A15-00	A15-00	A15-00	A15-00	A15-00	AD15-00	AD15-00
D07-00	D07-00	D07-00	D07-00	D07-00	D07-00	—	—
REGS	REGS	REGS	REGS	REGS	REGS	REGS	REGS
CSN	CSN	CSN	CSN	CSN	CSN	CSN	CSN
REN	REN	REN	REN	RWN	RWN	REN	REN
WEN	WEN	WEN	WEN	—	—	WELN	WELN
BSN	—	BS	BSN	BSN	BSN	ASN	AS
DSN	—	—	—	—	—	WEHN	WEHN
BSYN	BSYN	BSYN	ACK	ACK	BSYN	BSYN	BSYN
BCLK	BCLK	BCLK	BCLK	BCLK	BCLK	BCLK	BCLK

REGS: Memory/register address space selection; 'L': memory, 'H': register

CSN: Chip select (Active 'L')

REN: Read enable (Active 'L')

WEN: Write enable (Active 'L')

WEHN: Higher byte write enable (Active 'L')

WELN: Lower byte write enable (Active 'L')

RWN: Read/write selection; 'L': write, 'H': read

BSN: Bus start (Active 'L')

ASN: Address strobe (Active 'L')

DSN: Data strobe (Active 'L')

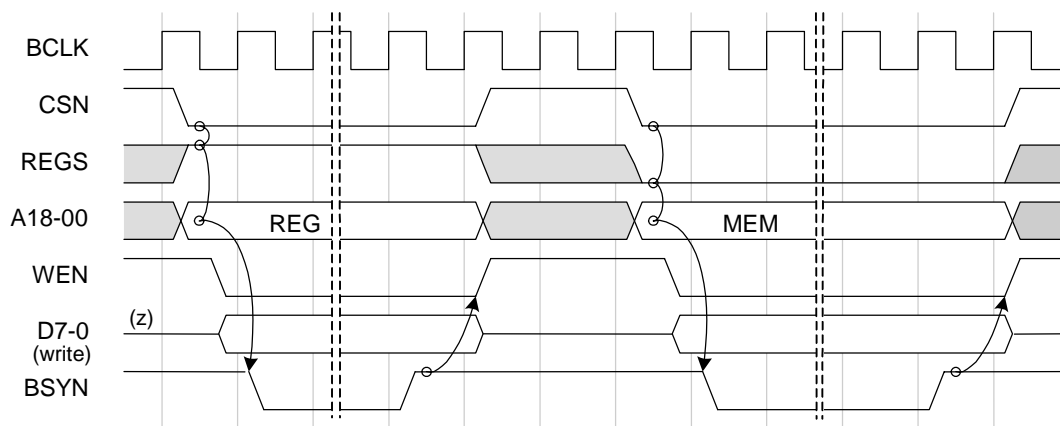
BSYN: Bus busy or wait (Active 'L')

ACK: Data acknowledge (Active 'L')

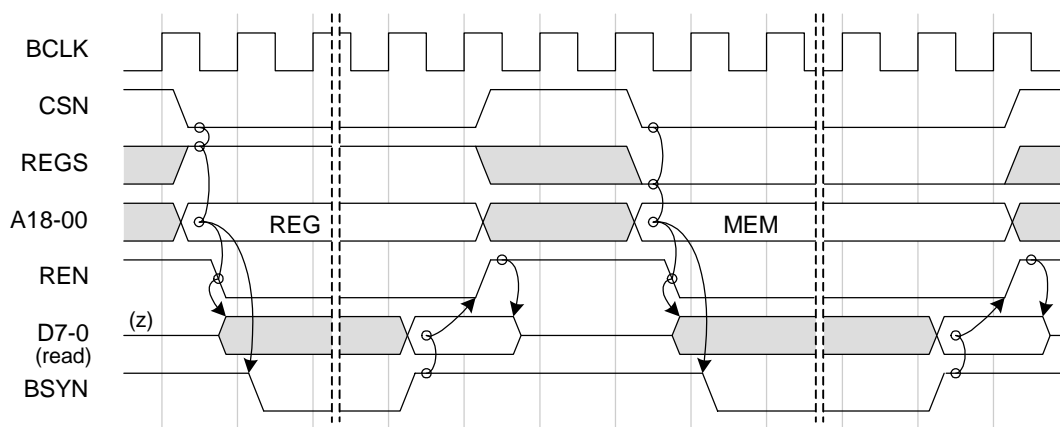
BCLK: Bus clock

5.1.2 Bus interface timings

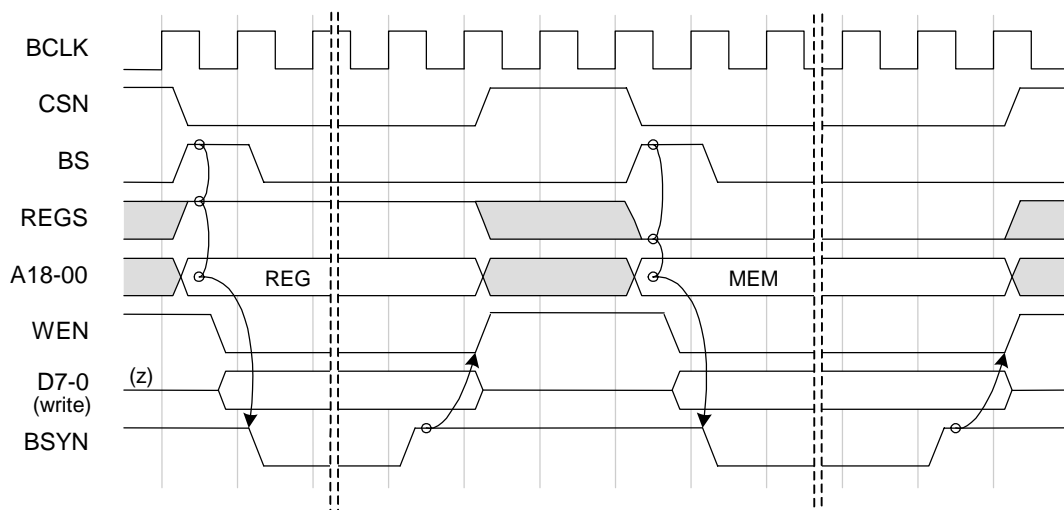
[Type A0 Write]



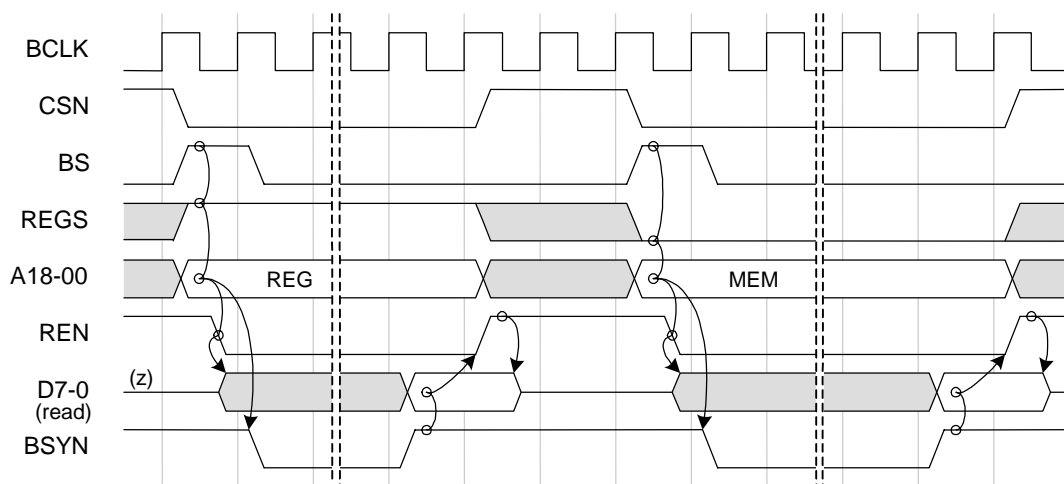
[Type A0 Read]



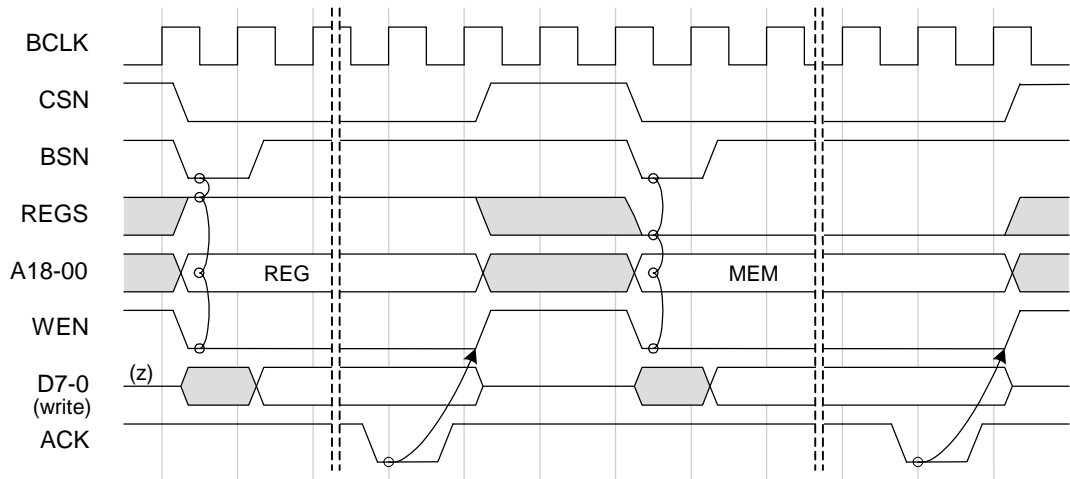
[Type A1 Write]



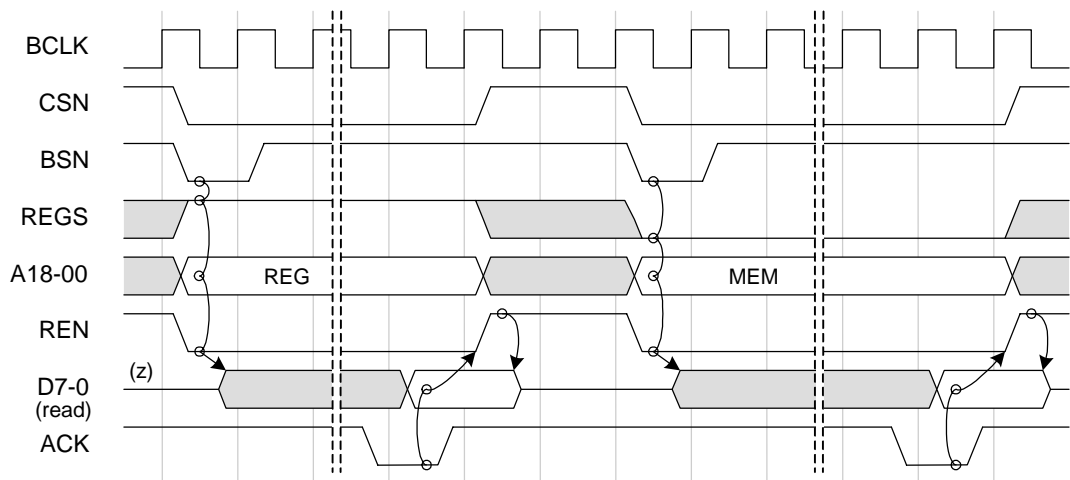
[Type A1 Read]



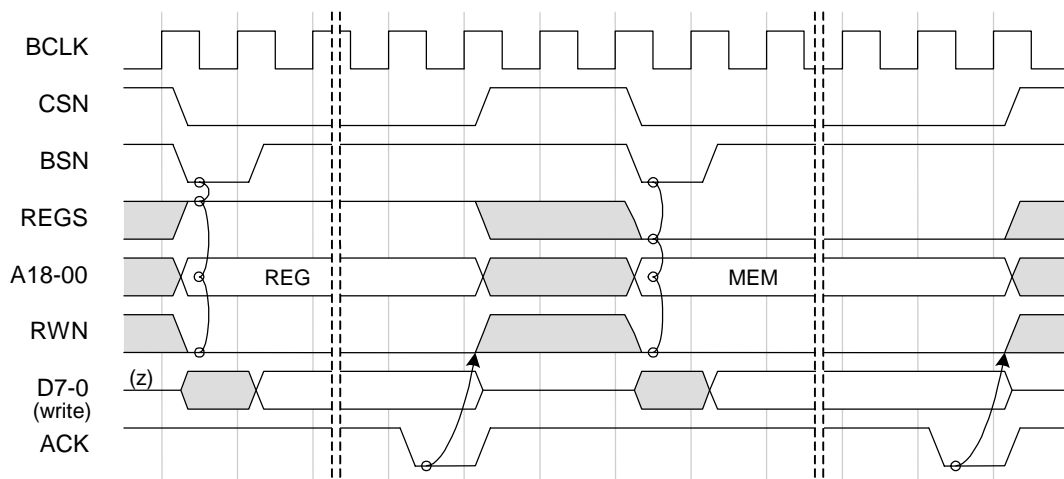
[Type A2 Write]



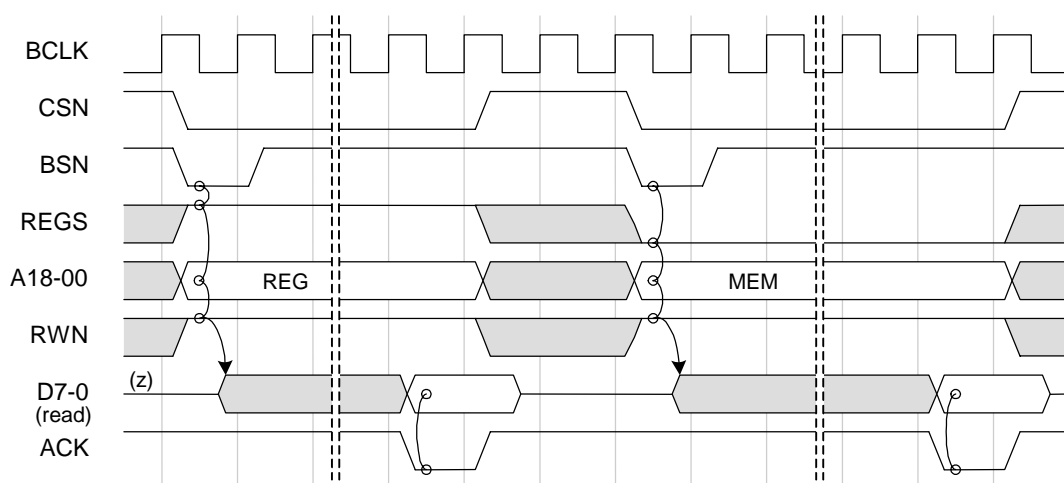
[Type A2 Read]



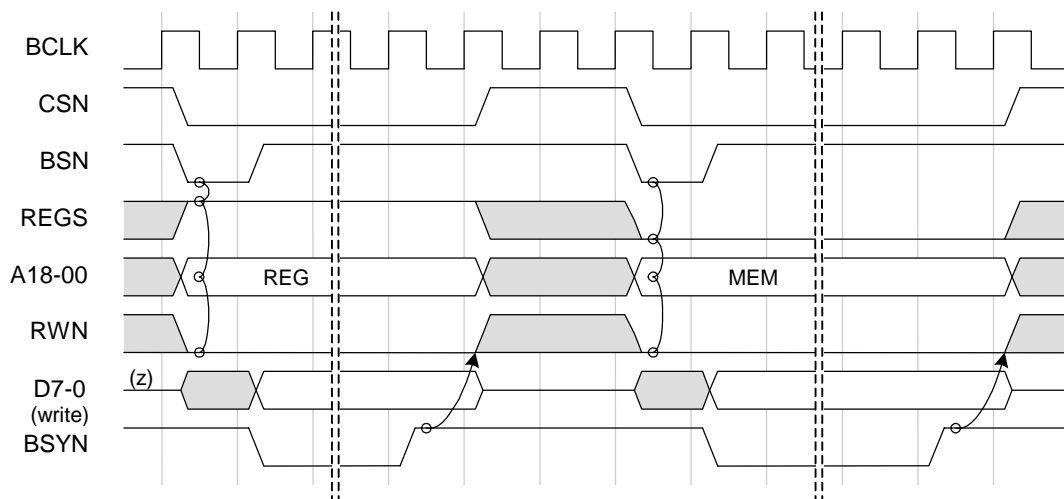
[Type A4 Write]



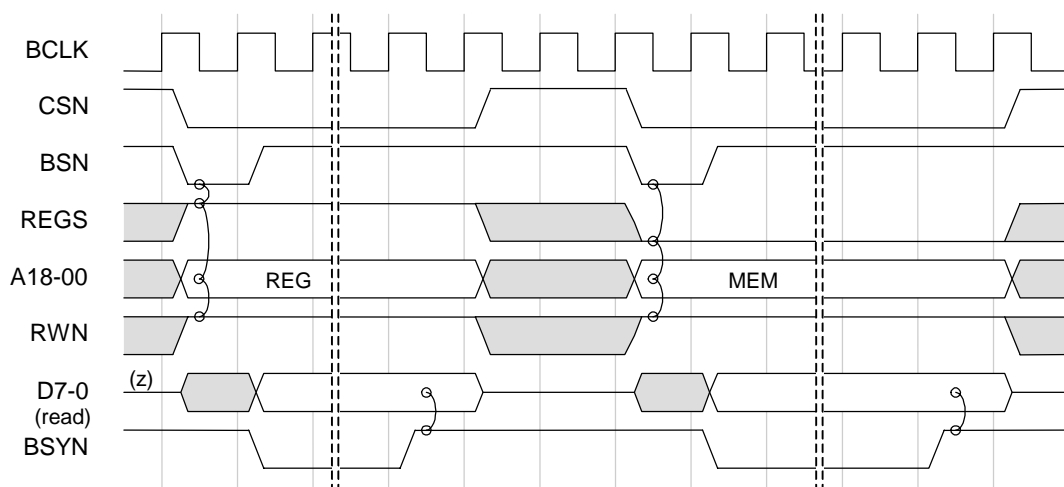
[Type A4 Read]



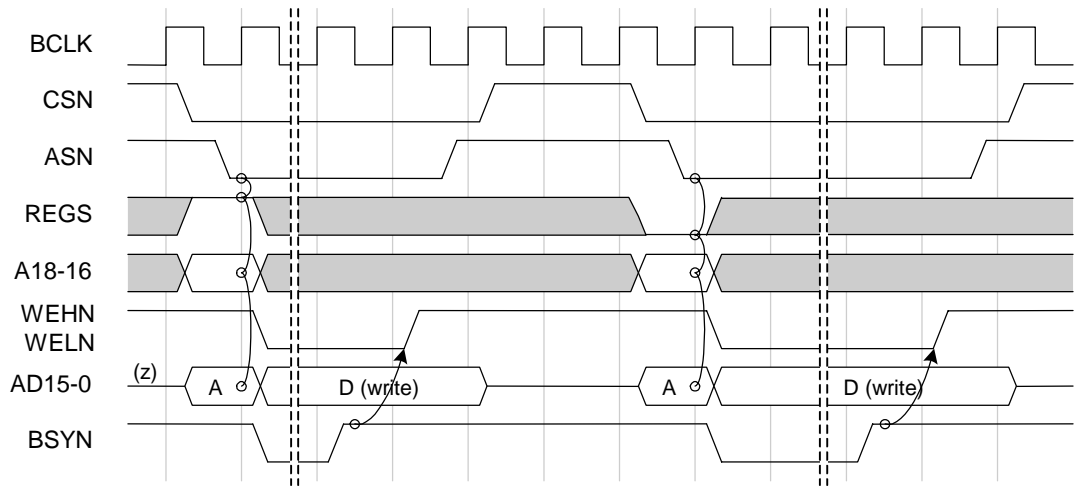
[Type A5 Write]



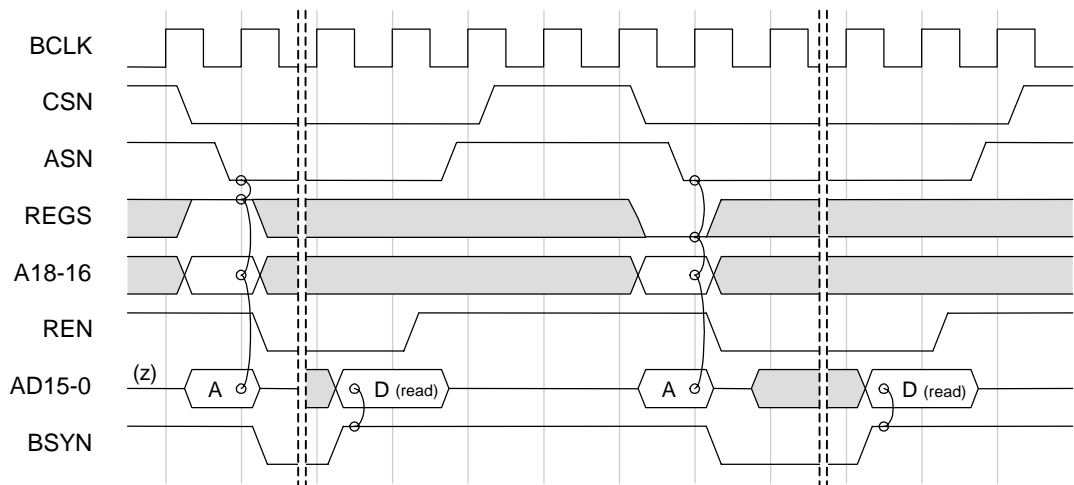
[Type A5 Read]



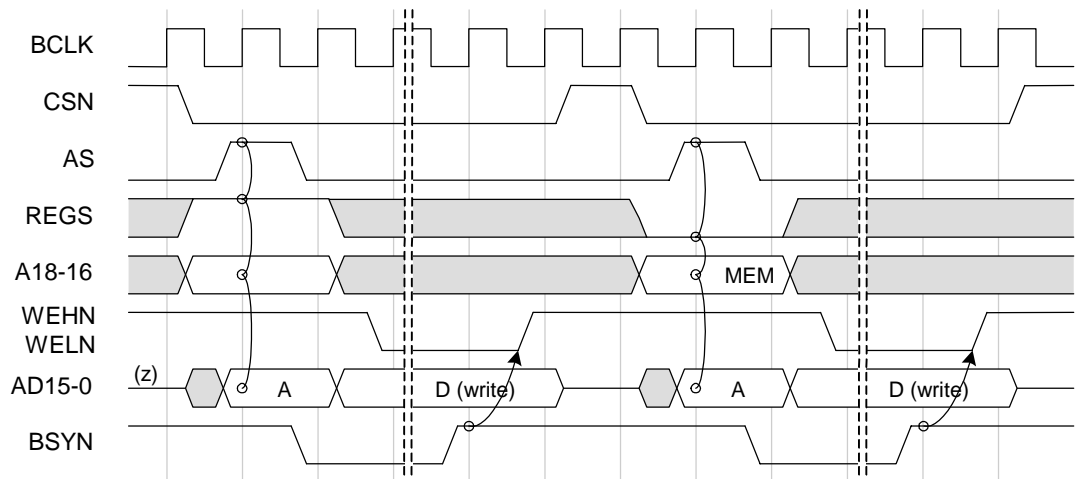
[Type B0 Write]



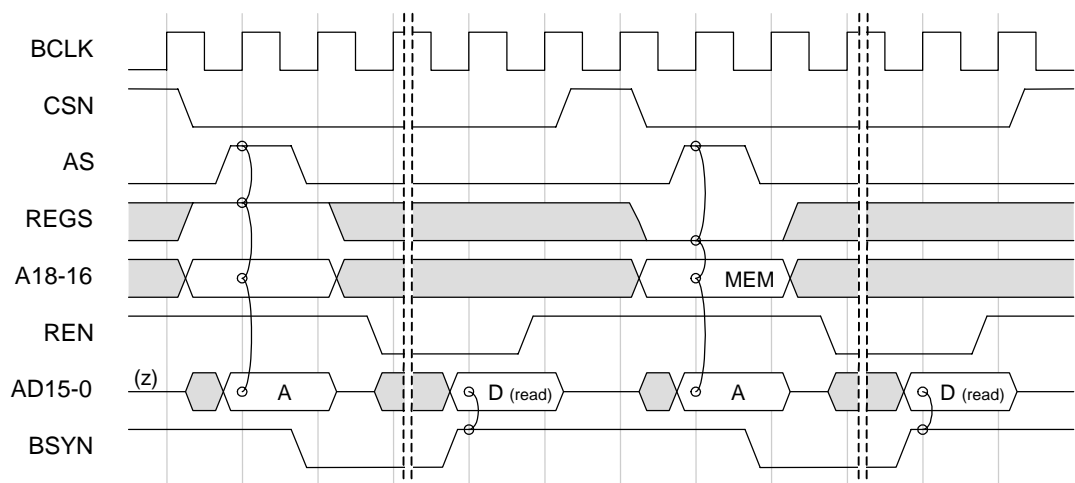
[Type B0 Read]



[Type B1 Write]



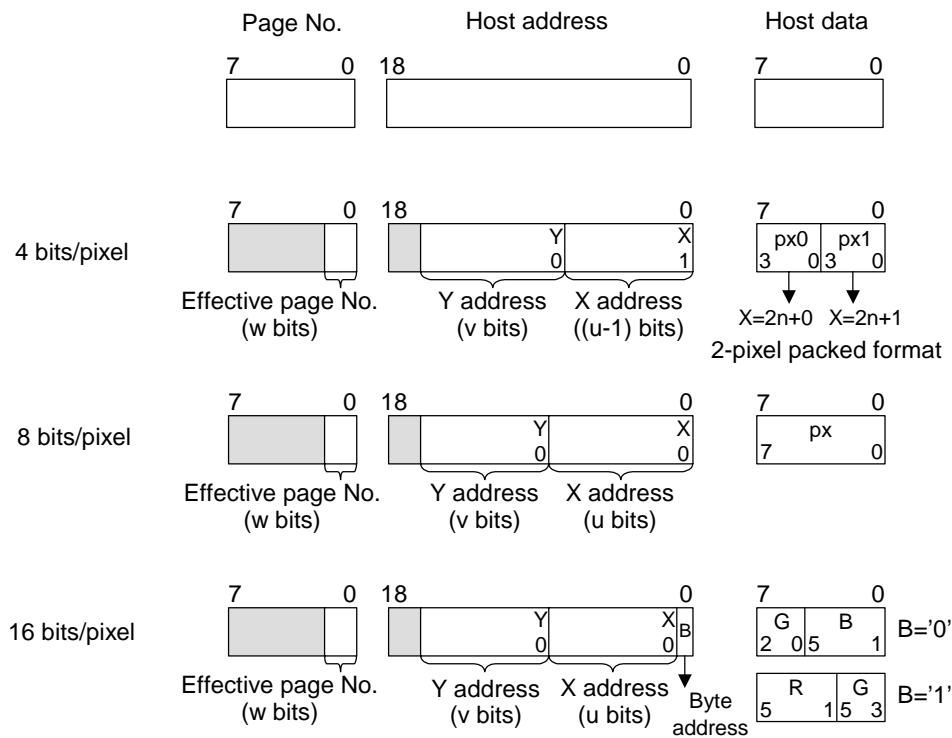
[Type B1 Read]



5.2 Address mapping

The ML87V3104 supports a 19-bit byte address for access from the host CPU. The 4M bit display memory and the 32-byte control registers are mapped to this address.

When accessing the display memory, the bit assignment of the address is determined by the setting of the memory size. (Fig. F5.2) See the next section for details of the control registers.



The number of total address bits = (w bits) + (v bits) + (u bits) = 19 bits (512K Byte)

Fig. F5.2 Display memory address mapping

5.3 Control registers

5.3.1 Outline of control registers

The initial setting and the operation of the ML87V3104 are controlled by writing data from the host CPU in the control registers.

There are 64 single-byte control registers, and in addition, a register space is provided by indirect addressing for the color palette table (256×3 bytes), the FRC table (16×2 bytes), and the cursor pattern register (64 bytes). (See Table F5.1)

The control registers can be accessed by the host CPU by taking the REGS signal input to the 'H' level.

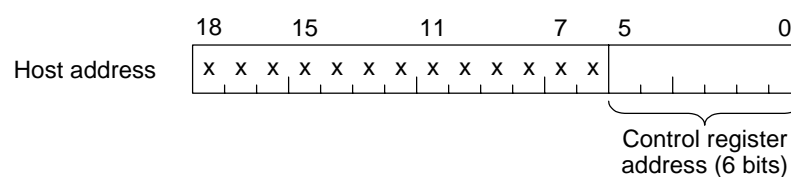


Fig. F5.3 The control register address

Table F5.1 List of control registers (part 1/2)

Register address	Register name ^{*1}								Function
	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	
00	LCDMOD				(Res)	LCDDAT			LCD driving mode
01	CP BLK	COLORD			DPDMOD		DPMENB		Display operation mode
02	REF ENB1	SCRMOD			REF ENB0	IMDBPP			Memory operation mode
03	IMASZY				IMASZX				Display memory size
04	LCPCYC[7:0]								LCP (line) period and polarity
05	LCP POL	(Reserved)			LCPCYC[10:8]				
06	LCPSTA[7:0]								LCP start position, pulse width
07	LCPWID				(Res)	LCPSTA[10:8]			
08	FRPCYC[7:0]								FRP (frame) period and polarity
09	FRP POL	(Reserved)			FRPCYC[10:8]				
0A	FRPSTA[7:0]								FRP start position, pulse width
0B	FRPWID				(Res)	FRPSTA[10:8]			
0C	DFLALT[7:0]								DF (AC driving signal) toggle period (1 frame or n lines)
0D	DFF ALT	(Reserved)			DFLALT[10:8]				
0E	(Reserved)					PTDDIR			General purpose port I/O mode
0F	(Reserved)					PTDREG			General purpose port data register
10	COLPTA[7:0]								Color palette table address
11	COLPDR[3:0]				(Reserved)				Color palette table data R
12	COLPDG[3:0]				(Reserved)				Color palette table data G
13	COLPDB[3:0]				(Reserved)				Color palette table data B
14	(Reserved)								(Reserved)
15	(Reserved)				FRCTBA[3:0]				FRC table address
16	FRCTBD[7:0]								FRC table data
17	FRCTBD[15:8]								
18	(Res)	CSPTAY[3:0]				CSPTAX[3:2]			Cursor pattern register address
19	CSPTD0	CSPTD1	CSPTD2	CSPTD3					Cursor pattern register data
1A	(Reserved)								(Reserved)
1B	(Reserved)								(Reserved)
1C	(Reserved)								(Reserved)
1D	CSCOL1[7:0]								Cursor color register 1
1E	CSCOL2[7:0]								Cursor color register 2
1F	CSCOL3[7:0]								Cursor color register 3

*1: The entries "(Reserved)" or "(Res)" indicate reserved bits. Writing data to these bits is not valid and the data read out from these bits will be indeterminate.

Table F5.1 List of control registers (part 2/2)

Register address	Register name ^{*1}								Function
	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0	
20	MSCSZH[7:0]								Main screen horizontal size
21	(Reserved)						[9:8]		
22	MSCSZV[7:0]								Main screen vertical size
23	(Reserved)						[9:8]		
24	SSCSZH[7:0]								Sub-screen horizontal size
25	(Reserved)						[9:8]		
26	SSCSZV[7:0]								Sub-screen vertical size
27	(Reserved)						[9:8]		
28	SDPOSH[7:0]								Sub-screen display horizontal position
29	(Reserved)						[9:8]		
2A	SDPOSV[7:0]								Sub-screen display vertical position Sub-screen display enable
2B	SSD ENB	(Reserved)						[9:8]	
2C	CSPOSH[7:0]								Cursor display horizontal position
2D	(Reserved)						[9:8]		
2E	CSPOSV[7:0]								Cursor display vertical position Cursor display enable
2F	CSD ENB	(Reserved)						[9:8]	
30	MDPSTX[7:0]								Display memory horizontal position for main screen
31	(Reserved)				MDPSTX[11:8]				
32	MDPSTY[7:0]								Display memory vertical position for main screen
33	(Reserved)				MDPSTY[11:8]				
34	SDPSTX[7:0]								Display memory horizontal position for sub-screen
35	(Reserved)				SDPSTX[11:8]				
36	SDPSTY[7:0]								Display memory vertical position for sub-screen
37	(Reserved)				SDPSTY[11:8]				
38	MDPPGA[7:0]								Display memory page number for main screen
39	SDPPGA[7:0]								Display memory page number for sub-screen
3A	(Reserved)								(Reserved)
3B	HSTPGA[7:0]								Display memory page number for host access
3C	(Reserved)								(For testing, cannot be written into)
3D	(Reserved)								
3E	(Reserved)								
3F	(Reserved)								

*1: The entries "(Reserved)" or "(Res)" indicate reserved bits. Writing data to these bits is not valid and the data read out from these bits will be indeterminate.

5.3.2 Register details

In the following descriptions of the different registers, the underlined part indicates the initial value after a reset.

[#00h] LCD driving mode

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	LCDMOD				(Reserved)	LCDDAT		
	3	2	1	0		2	1	0
W/R	W/R				—	W/R		

- LCDMOD[3:0]: LCD panel operation mode selection
- LCDDAT[2:0]: LCD panel interface data width selection

LCDMOD	LCDDAT	LCD Driving mode	
<u>0000</u>	<u>000</u>	Color STN	4-bit mode
	010		8-bit mode
	100		4-bit 2-phase mode
0010	XXX	(Reserved)	—
0100	000	Monochrome STN	4-bit mode
	010		8-bit mode
	100		4-bit 2-phase mode
0110	XXX	(Reserved)	—
1000	000	Color TFT	12-bit mode (pseudo-color)
1001	001		16-bit mode (direct color)
11XX	XXX	(Reserved)	—

'X': Don't care

[#01h] Display operation mode

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CP BLK	COLORD			DPDMOD		DPMENB	
		2	1	0	1	0	1	0
W/R	W/R	W/R			W/R		W/R	

- CPBLK: Control of CP clock output during blanking

CPBLK	CP Output during blanking
0	Active
1	Fixed at CP = 'L', CPS = 'H'

- COLORD[2:0]: Color arrangement sequence of color LCD panel

COLORD[2:0]	Color arrangement sequence
000	R, G, B, R, G, B, •••
001	G, B, R, G, B, R, •••
010	B, R, G, B, R, G, •••
011	(Reserved)
100	(Reserved)
101	R, B, G, R, B, G, •••
110	G, R, B, G, R, B, •••
111	B, G, R, B, G, R, •••

- DPDMOD[1:0]: LCD data display mode

DPDMOD[1:0]	LCD data display mode
00	Normal
01	Inverted
10	All '0'
11	All '1'

- DPMENB[1:0]: Display memory readout control, DISP signal output specification

DPMENB[1:0]	Display memory readout	DISP signal
00	Memory readout stopped	DISP = 'L'
01	LCD drive stopped	DISP = 'H'
10	Memory readout operating	DISP = 'L'
11	LCD drive operating	DISP = 'H'

[#02h] Memory operation mode

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	REF ENB1	SCRMOD			REF ENB0	IMDBPP		
		2	1	0		2	1	0
W/R	W/R	W/R			W/R	W/R		

- REFENB[1:0]: Embedded DRAM refreshing operation enable

REFENB		DRAM refreshing
1	0	
0	×	(Reserved)
1	0	Operation only during blanking
	1	Always operating

- SCRMOD[2:0]: Screen mode

SCRMOD[2:0]	Screen mode	
<u>000</u>	Landscape	Normal
001		Left/right flip
010		Top/bottom flip
011		Left/right and top/bottom flips
100	Portrait	Normal
101		Left/right flip
110		Top/bottom flip
111		Left/right and top/bottom flips

- IMDBPP[1:0]: Display memory data mode (number of bits per pixel)

IMDBPP[2:0]	Bits/pixel	Number of displayable colors
00X	(Reserved)	—
010	4	16 colors
<u>011</u>	8	256 colors
100	16	65,536 colors
101	Reserved	—
110		
111		

Note: The pseudo-color mode using the color palette for 4 or 8 bits/pixel, and direct color mode for 16 bits/pixel.

[#03h] Display memory size

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	IMASZY				IMASZX			
	3	2	1	0	3	2	1	0
W/R	W/R				W/R			

- IMASZY[3:0]: Display memory vertical size (2^n)
- IMASZX[3:0]: Display memory horizontal size (2^n)

IMASZY	Vertical size (lines)
<u>0000</u>	64
0001	128
0010	256
0011	512
0100	1024
0101	2048
0110	4096
0111	(Reserved)
1XXX	(Reserved)

IMASZX	Horizontal size (pixels)
<u>0000</u>	64
0001	128
0010	256
0011	512
0100	1024
0101	2048
0110	4096
0111	(Reserved)
1XXX	(Reserved)

[#04h] LCP (line clock) period (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	LCPCYC							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#05h] LCP (line clock) period (MSB) and pulse polarity

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	LCP POL	(Reserved)				LCPCYC		
		10	9	8				
W/R	W/R	—				W/R		

- LCPCYC[10:0]: (LCP signal period - 1)
 In units of a CP clock in the STN color 4-bit mode
 In units of 2 CP clocks in the STN color 8-bit mode or 4-bit 2-phase mode
 In units of 4 CP clocks in the STN monochrome 4-bit mode
 In units of 8 CP clocks in the STN monochrome 8-bit mode or 4-bit 2-phase mode
 In units of a CP clock in the TFT color mode
- LCPPOL: LCP Pulse output polarity

LCPPOL	LCP Output polarity
0	Positive pulse
1	Negative pulse

[#06h] LCP (line clock) start position (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	LCPSTA							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#07h] LCP (line clock) start position (MSB) and pulse width

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	LCPWID				(Reserved)	LCPSTA		
	3	2	1	0		10	9	8
W/R	W/R				—	W/R		

- LCPSTA[10:0]: LCP start timing, in units of a CP clock
- LCPWID[3:0]: (LCP pulse width/4 - 1), in units of a CP clock

[#08h] FRP (frame pulse) period (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRPCYC							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#09h] FRP (frame pulse) period (MSB) and pulse polarity

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRP POL	(Reserved)			FRPCYC			
					10	9	8	
W/R	W/R	—			W/R			

- FRPCYC[10:0]: FRP signal period, in units of a line
- FRPPOL: FRP pulse output polarity

LCPOL	FRP pulse output polarity
0	Positive pulse
1	Negative pulse

[#0Ah] FRP (frame pulse) start position (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRPSTA							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#0Bh] FRP (frame pulse) start position (MSB) and pulse width

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRPWID				(Reserved)	FRPSTA		
	3	2	1	0		10	9	8
W/R	W/R				—	W/R		

- FRPSTA[10:0]: FRP start position
- FRPWID[3:0]: (FRP pulse width – 1)

[#0Ch] DF (AC driving signal) toggle period (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	DFLALT							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#0Dh] DF (AC driving signal) toggle period (MSB) and toggle mode

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRP POL	(Reserved)			DFLALT			
					10	9	8	
W/R	W/R	—			W/R			

- DFLALT[10:0]: (DF signal toggle period – 1), in units of a line Valid when DFFALT = '1'.
- DFFALT: DF signal toggle mode

DFFALT	DF toggle mode
0	Reversal at one frame periods
1	Reversal at periods of (DFLALT+1) lines

[#0Eh] General purpose port I/O mode

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						PTDDIR	
							1	0
W/R	—						W/R	

[#0Fh] General purpose port data register

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						PTDREG	
							1	0
W/R	—						W/R	

- PTDDIR[1:0]: General purpose port (PORT1, PORT0) I/O direction setting
- PTDREG[1:0]: General purpose port (PORT1, PORT0) data register

PTDDIR[n]	PORTn	
0	Output	PTDREGn → PORTn
1	Input	PTDREGn ← PORTn

[#10h] Color palette table address

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	COLPTA							
	7	6	5	4	3	2	1	0
W/R	W/R							

- COLPTA[7:0]: Color palette table address
Table address when writing table data
The table address is equivalent to the color palette entry number
Incremented automatically every time the table data B is written.

[#11h] Color palette table data R

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	COLPDR				(Reserved)			
	3	2	1	0				
W/R	W only				—			

[#12h] Color palette table data G

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	COLPDG				(Reserved)			
	3	2	1	0				
W/R	W only				—			

[#13h] Color palette table data B, table address incrementing

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	COLPDB				(Reserved)			
	3	2	1	0				
W/R	W only				—			

- COLPDR[3:0]: Color palette table data R (red)
- COLPDG[3:0]: Color palette table data G (green)
- COLPDB[3:0]: Color palette table data B (blue)
Contents of the entry specified by the color palette table address.
The table address is incremented automatically when data is written in COLPDB.

[#15h] FRC table address

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)				FRCTBA			
					3	2	1	0
W/R	—				W only			

- COLPTA[7:0]: FRC table address
The address of the table containing the setting of the FRC dot blinking pattern.
Incremented automatically when the table data (MSB) is written.

[#16h] FRC table data (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRCTBD							
	7	6	5	4	3	2	1	0
W/R	W only							

[#17h] FRC table data (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	FRCTBD							
	15	14	13	12	11	10	9	8
W/R	W only							

- FRCTBD[3:0]: FRC table data
The data of the table containing the setting of the FRC dot blinking pattern.
The table address denotes the gray level for each color of the color palette output, and the table data specifies the dot blinking pattern for that gradation value.
(Blinking in sequence from FRCTBD[15] to FRCTBD[0].)

[#18h] Cursor pattern register address

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)		CSPTAY				CSPTAX	
			3	2	1	0	3	2
W/R	—		W only					

- CSPTAY[3:0]: Cursor pattern register Y address
- CSPTAX[3:2]: Cursor pattern register X address
The address of the register for setting the dot pattern of the cursor.
The X address is incremented automatically when the register data is written, and the Y address is incremented when there is an overflow in the X address.

[#19h] Cursor pattern register data

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSPTD0		CSPTD1		CSPTD2		CSPTD3	
	1	0	1	0	1	0	1	0
W/R	W only							

- CSPTD0-3[1:0]: Cursor pattern register data
The data of the register for setting the dot pattern of the cursor.
This is the 2 bits/pixel data in the 4-pixel packed format.

CSPTDn	Cursor display data
0 0	Transparent (display memory contents)
0 1	Color register 1 (CSCOL1)
1 0	Color register 2 (CSCOL2)
1 1	Color register 3 (CSCOL3)

[#1Dh] Cursor color register 1

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSCOL1							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#1Eh] Cursor color register 2

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSCOL2							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#1Fh] Cursor color register 3

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSCOL3							
	7	6	5	4	3	2	1	0
W/R	W/R							

- CSCOL0-3[1:0]: Cursor color register 0 to 3
Color data of the cursor. Corresponds to the entry of the color palette.

[#20h] Main screen horizontal size (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	MSCSZH							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#21h] Main screen horizontal size (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						MSCSZH	
							9	8
W/R	—						W/R	

- MSCSZH[9:0]: (Main screen horizontal size – 1), in units of 16 pixels.

[#22h] Main screen vertical size (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	MSCSZV							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#23h] Main screen vertical size (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						MSCSZV	
							9	8
W/R	—						W/R	

- MSCSZV[9:0]: (Main screen vertical size – 1), in units of the number of lines.

[#24h] Sub-screen horizontal size (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SSCSZH							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#25h] Sub-screen horizontal size (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						SSCSZH	
							9	8
W/R	—						W/R	

- SSCSZH[9:0]: (Sub-screen horizontal size – 1), in units of a pixel.

[#26h] Sub-screen vertical size (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SSCSZV							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#27h] Sub-screen vertical size (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						SSCSZV	
							9	8
W/R	—						W/R	

- SSCSZV[9:0]: (Sub-screen vertical size – 1), in units of the number of lines.

[#28h] Sub-screen display horizontal position (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SDPOSH							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#29h] Sub-screen display horizontal position (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						SDPOSH	
							9	8
W/R	—						W/R	

- SDPOSH[9:0]: Sub-screen display horizontal position in units of 16 pixels.
The position of displaying the origin of the sub-screen is specified in terms of the display address within the main screen.

[#2Ah] Sub-screen display vertical position (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SDPOSV							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#2Bh] Sub-screen display vertical position (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SSD ENB	(Reserved)					SDPOSV	
							9	8
W/R	W/R	—					W/R	

- SDPOSV[9:0]: Sub-screen display vertical position in units of a line.
The position of displaying the origin of the sub-screen is specified in terms of the display address within the main screen.
- SSDENB: Sub-screen display enable

SSDENB	Sub-screen
0	Not displayed
1	Displayed

[#2Ch] Cursor display horizontal position (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSPOSH							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#2Dh] Cursor display horizontal position (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)						CSPOSH	
							9	8
W/R	—						W/R	

- CSPOSH[9:0]: Cursor display horizontal position in units of the number of pixels.
The position of displaying the origin of the cursor is specified in terms of the display address within the main screen.

[#2Eh] Cursor display vertical position (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSPOSV							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#2Fh] Cursor display vertical position (MSB), Cursor display enable

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	CSD ENB	(Reserved)					CSPOSV	
							9	8
W/R	W/R	—					W/R	

- CSPOSV[9:0]: Cursor display vertical position in units of the number of lines.
The position of displaying the origin of the cursor is specified in terms of the display address within the main screen.
- CSDENB: Cursor display enable

CSDENB	Cursor display
0	Disable (Not displayed)
1	Enable (Displayed)

[#30h] Display memory horizontal position for main screen (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	MDPSTX							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#31h] Display memory horizontal position for main screen (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)				MDPSTX			
					11	10	9	8
W/R	—				W/R			

- MDPSTX[11:0]: Main screen display memory horizontal position in units of 16 pixels.
The start address of the display memory for displaying in the main screen is specified here.

[#32h] Display memory vertical position for main screen (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	MDPSTY							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#33h] Display memory vertical position for main screen (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)				MDPSTY			
					11	10	9	8
W/R	—				W/R			

- MDPSTY[11:0]: Main screen display memory vertical position in units of a line.
The start address of the display memory for displaying in the main screen is specified here.

[#34h] Display memory horizontal position for sub-screen (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SDPSTX							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#35h] Display memory horizontal position for sub-screen (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)				SDPSTX			
					11	10	9	8
W/R	—				W/R			

- SDPSTX[11:0]: Sub-screen display memory horizontal position in units of 16 pixels.
The start address of the display memory for displaying in the sub-screen is specified here.

[#36h] Display memory vertical position for sub-screen (LSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SDPSTY							
	7	6	5	4	3	2	1	0
W/R	W/R							

[#37h] Display memory vertical position for sub-screen (MSB)

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	(Reserved)				SDPSTY			
					11	10	9	8
W/R	—				W/R			

- SDPSTY[11:0]: Sub-screen display memory vertical position in units of a line.
The start address of the display memory for displaying in the sub-screen is specified here.

[#38h] Display memory page number for main screen

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	MDPPGA							
	7	6	5	4	3	2	1	0
W/R	W/R							

- MDPPGA[7:0]: Main screen display memory page number
This is the page number of the display memory that is to be displayed in the main screen.

[#39h] Display memory page number for sub-screen

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	SDPPGA							
	7	6	5	4	3	2	1	0
W/R	W/R							

- SDPPGA[7:0]: Sub-screen display memory page number
This is the page number of the display memory that is to be displayed in the sub-screen.

[#3Bh] Display memory page for host access

Data bit	bit 7	bit 6	bit 5	bit 4	bit 3	bit 2	bit 1	bit 0
Register	HSTPGA							
	7	6	5	4	3	2	1	0
W/R	W/R							

- HSTPGA[7:0]: Host access display memory page number
This is the page number of the display memory to be accessed by the host CPU.

[#3Ch–3Fh] Writing and reading of these registers are prohibited

ABSOLUTE MAXIMUM RATINGS

(VSS = 0 V)

Parameter	Symbol	Condition	Rating	Unit
Power supply voltage (for the internal core)	VDDI	—	-0.5 to +4.6	V
Power supply voltage (for the LCD driving signals)	VDDO	—	-0.5 to +4.6	V
Output voltage	Vout	—	V _{SS} - 0.5 to V _{DD} + 0.5	V
Input voltage	Vin	—	V _{SS} - 0.5 to V _{DD} + 0.5	V
Output short-circuit current	Ios	—	50	mA
Power dissipation	Pd	Ta = 25°C	1	W
Storage temperature range	Tstg	—	-55 to +150	°C

RECOMMENDED OPERATING CONDITIONS

(VSS = 0 V)

Parameter		Symbol	Condition	Min.	Typ.	Max.	Unit
Power supply voltage	Internal core	VDDI		3.0	3.3	3.6	V
	LCD driving signals	VDDO		3.0	3.3	3.6	V
Operating temperature range		Ta		-40	25	85	°C

Note: VDDI and VDDO must be powered up at the same time.

ELECTRICAL CHARACTERISTICS

1. DC Characteristics

(Ta = -40 to 85°C, VDD = VDDO = VDDI = 3.3 ± 0.3 V, VSS = 0 V)

Parameter		Symbol	Condition	Min.	Typ.	Max.	Unit
H level input voltage	XOSCI	VIH1	—	2.4	—	VDDI+0.3	V
L level input voltage		VIL1	—	VSS -0.3	—	0.4	V
H level input voltage	Others	VIH	—	2.0	—	5.5	V
L level input voltage		VIL	—	VSS -0.3	—	0.8	V
H level output voltage	BSYN, PORT0,1	VOH1	IOH = 8 mA	0.8VDD	—	—	V
L level output voltage		VOL1	IOL = 8 mA	—	—	0.2VDD	V
H level output voltage	Others	VOH2	IOH = 4 mA	0.8VDD	—	—	V
L level output voltage		VOL2	IOL = 4 mA	—	—	0.2VDD	V
Input leakage current		ILI	—	-10	—	+10	μA
Output leakage current		ILO	—	-10	—	+10	μA
Supply current (internal core)	During operation	IDDI1	fope = 15MHz	—	—	55	mA
	Display Off	IDDI2		—	—	45	mA
	Clock Stopping	IDDI3		—	—	5	mA
Clock input feedback resistance		RF	—	0.4	1.0	2.0	MΩ

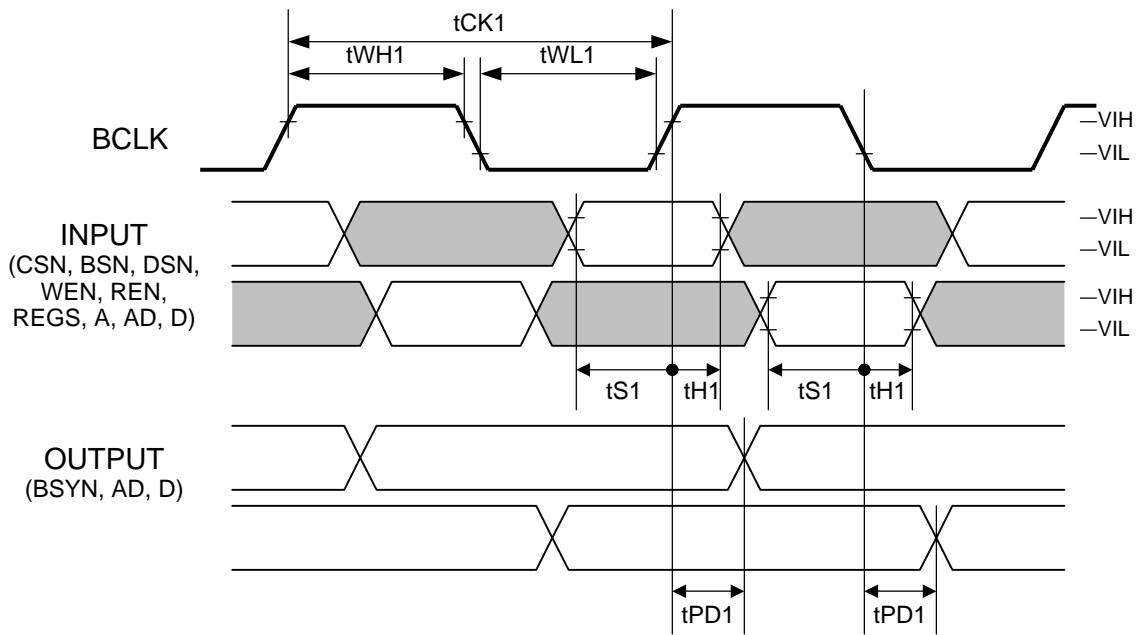
2. AC Characteristics

(Ta = -40 to 85°C, VDDO = VDDI = 3.3 ± 0.3 V, VSS = 0 V)

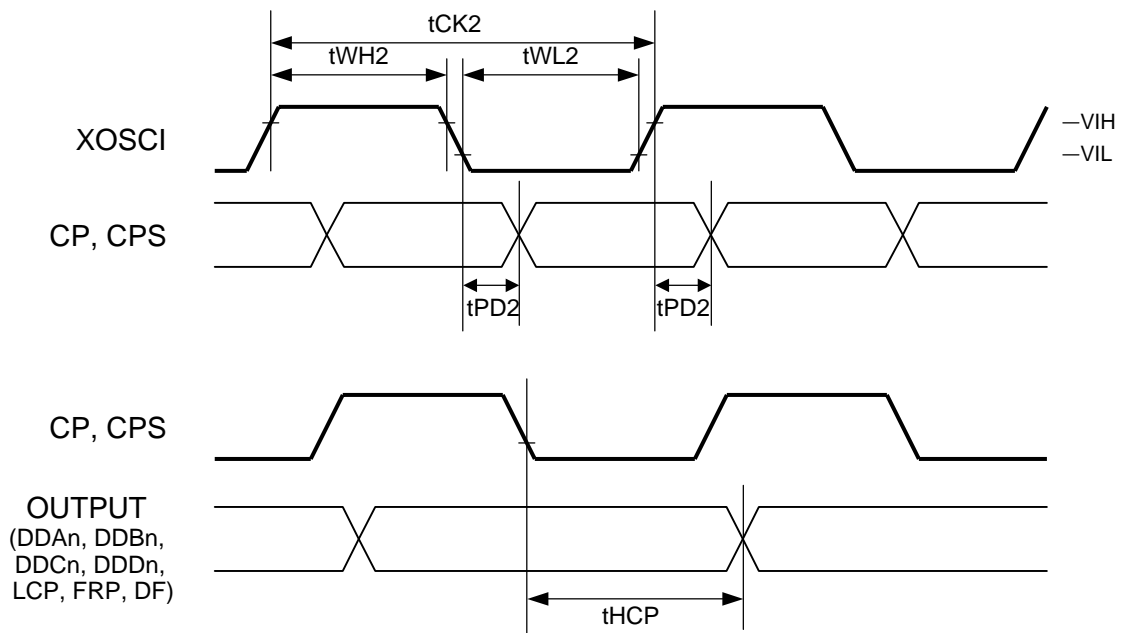
Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
Operating frequency	fope	—	—	—	15.0	MHz
Output rise time (10% to 90%)	tRO	CL = 15 pF	2	—	15	ns
Output fall time (90% to 10%)	tFO	CL = 15 pF	2	—	15	ns
BCLK clock period	tCK1	—	66	—	—	ns
BCLK H level pulse width	tWH1	—	30	—	—	ns
BCLK L level pulse width	tWL1	—	30	—	—	ns
Input setup time (to BCLK)	tS1	—	10	—	—	ns
Input hold time (to BCLK)	tH1	—	8	—	—	ns
Output delay time (from BCLK)*1	tPD1	CL = 15 pF	5	—	20	ns
XOSCI clock period	tCK2	—	66	—	—	ns
XOSCI H level pulse width	tWH2	—	30	—	—	ns
XOSCI L level pulse width	tWL2	—	30	—	—	ns
Output delay time (XOSCI to CP, CPS)*1	tPD2	CL = 15 pF	2	—	25	ns
Output hold time (from CP, CPS)*2	tHCP	CL = 15 pF	25	—	50	ns

*1: The output timing characteristics are measured at the signal levels of VDD/2.

*2: The output hold time is a relative value, which should be used as a reference value for application design.



(a) Host interface



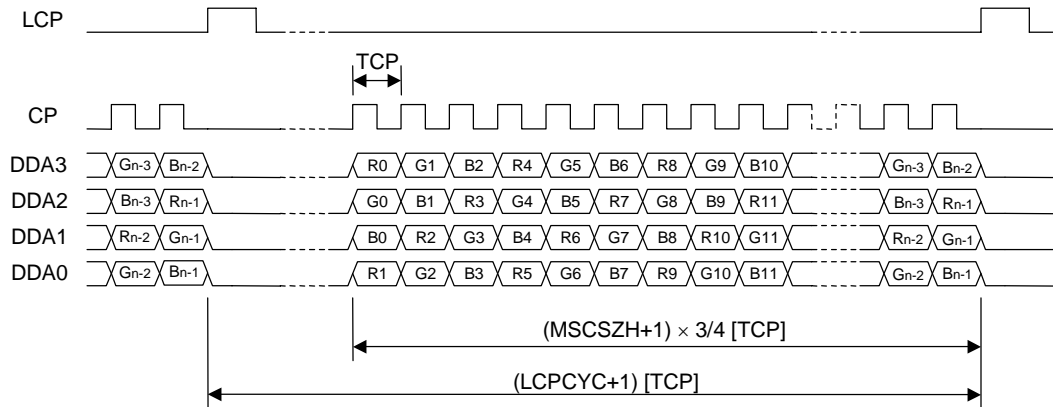
(b) LCD interface

Fig. A1 AC characteristics

TIMING DIAGRAMS

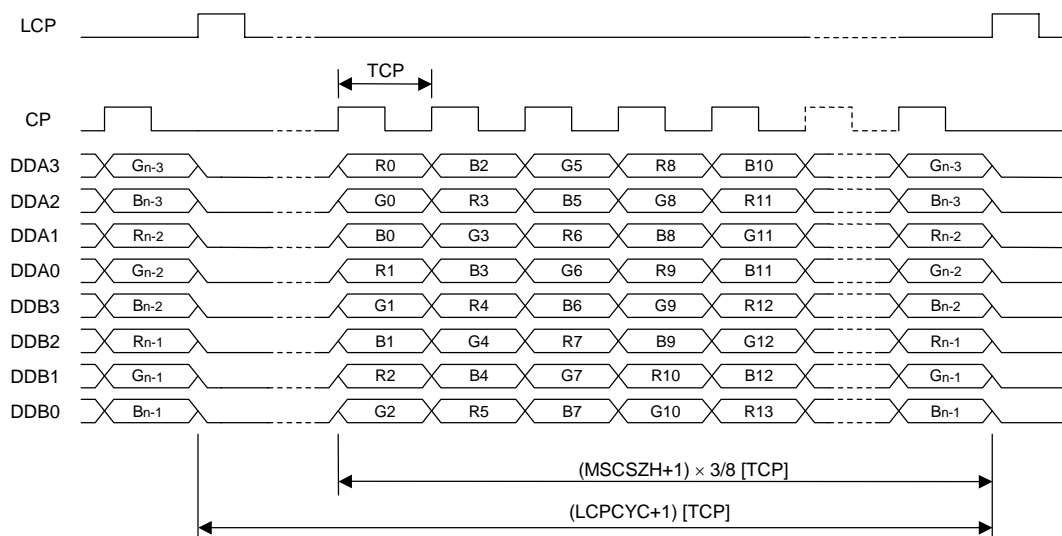
1. LCD Interface

1.1 Color STN, 4-bit mode



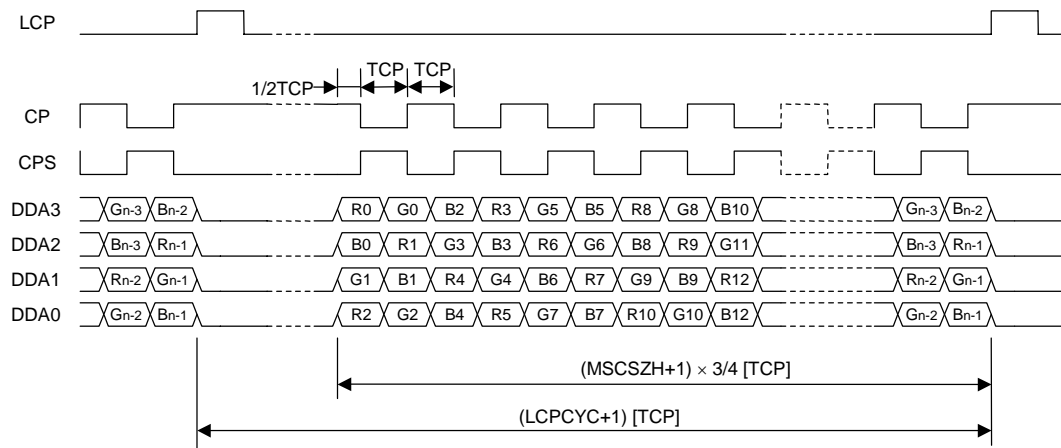
TCP = TX (TX is the XOSCI input clock period)

1.2 Color STN, 8-bit mode



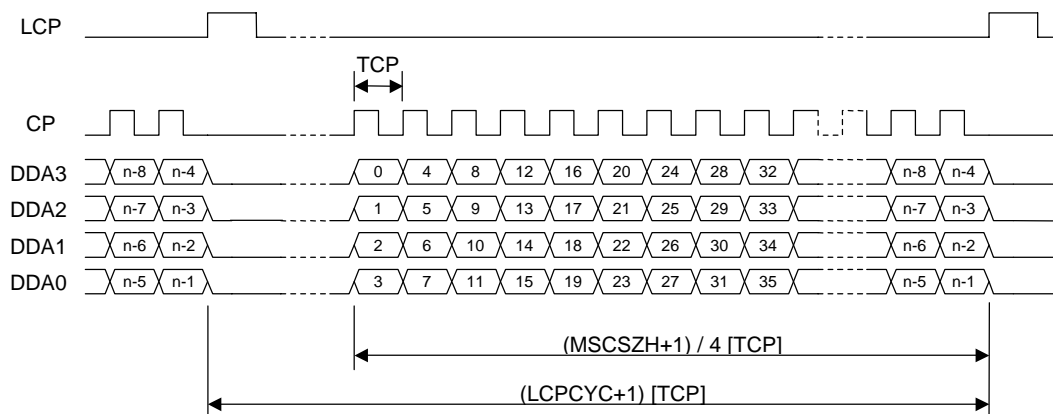
TCP = 2TX (TX is the XOSCI input clock period)

1.3 Color STN, 4-bit 2-phase mode



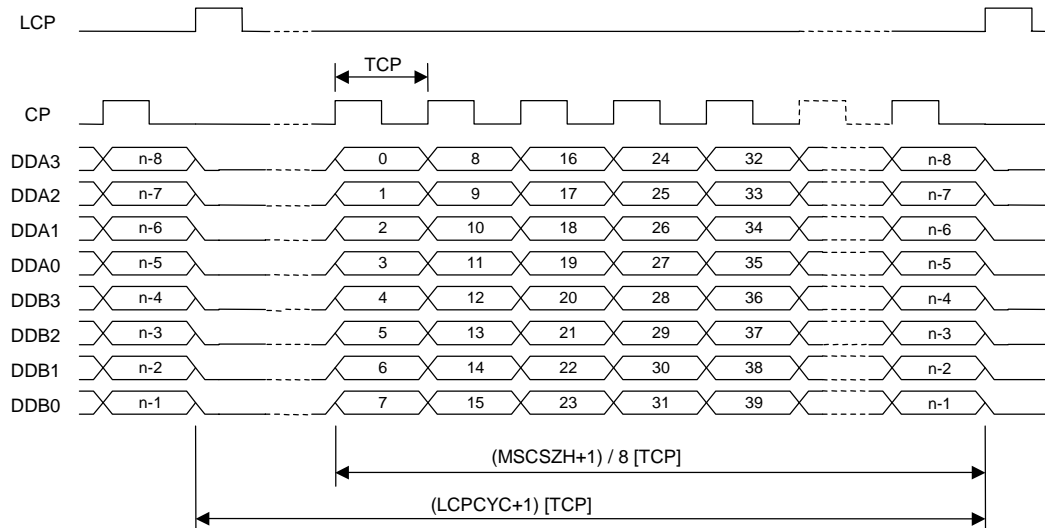
TCP = TX (TX is the XOSCI input clock period)

1.4 Monochrome STN, 4-bit mode



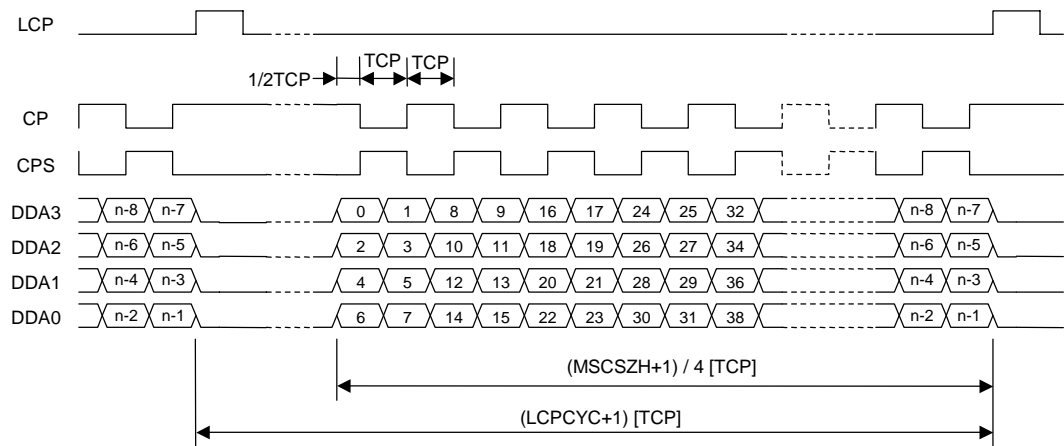
TCP = 4TX (TX is the XOSCI input clock period)

1.5 Monochrome STN, 8-bit mode



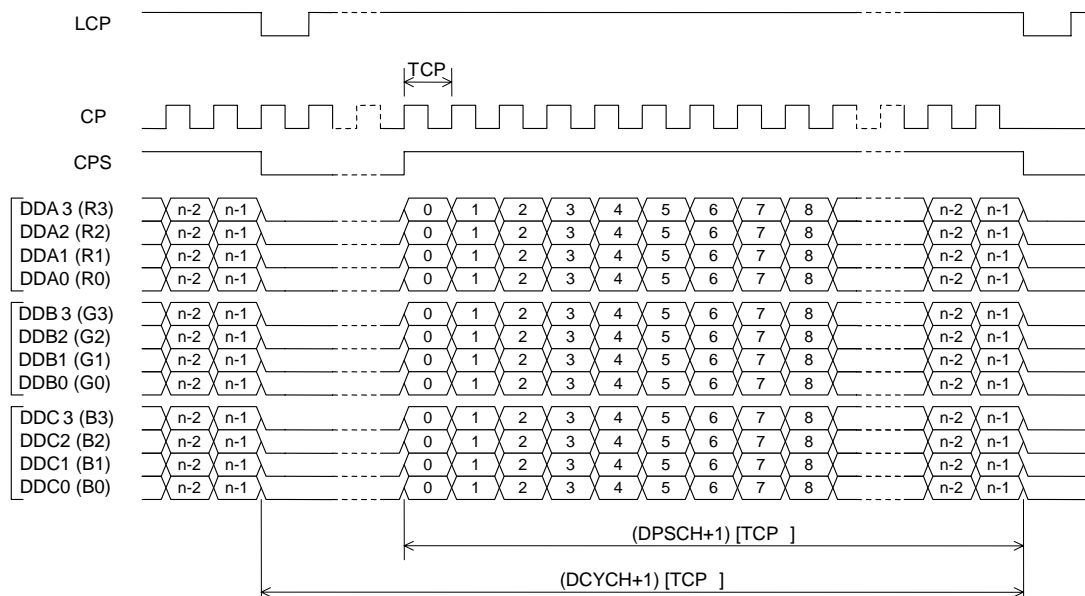
TCP = 8TX (TX is the XOSCI input clock period)

1.6 Monochrome STN, 4-bit 2-phase mode



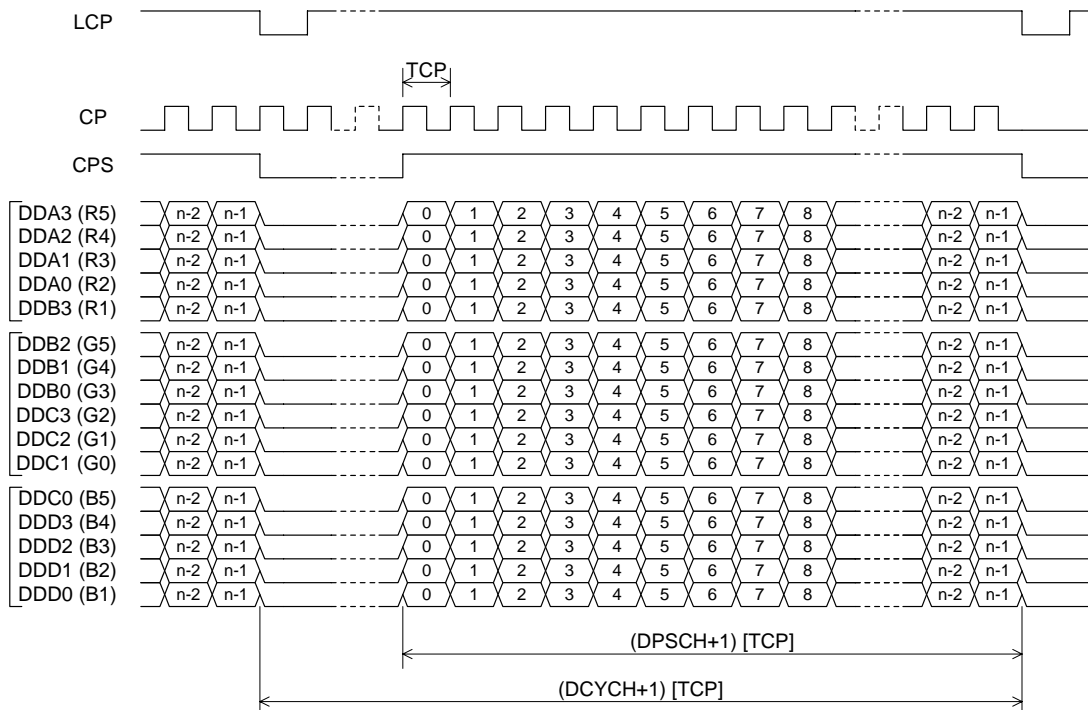
TCP = 4TX (TX is the XOSCI input clock period)

1.7 Color TFT, 12-bit mode



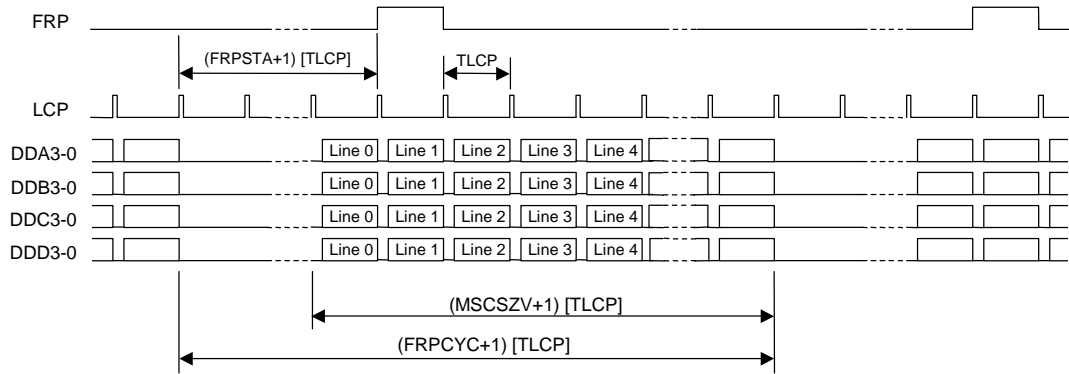
TCP = TX (TX is the XOSCI input clock period)

1.8 Color TFT, 16-bit mode

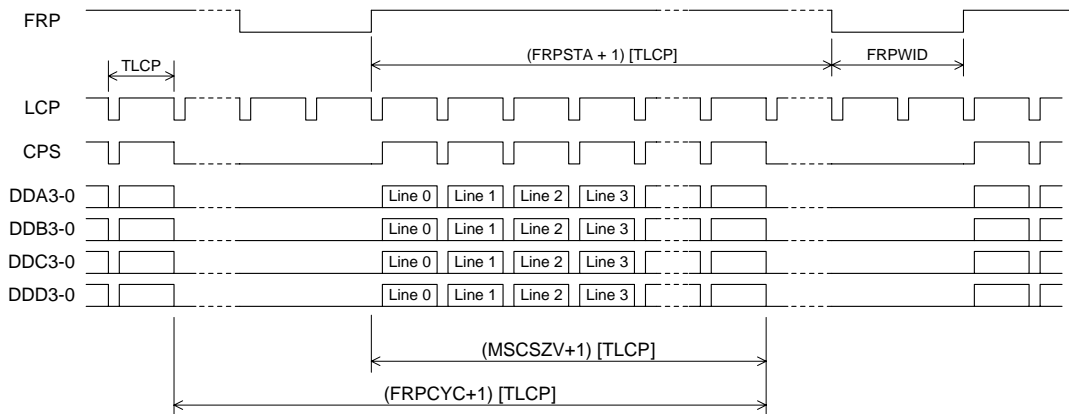


TCP = TX (TX is the XOSCI input clock period)

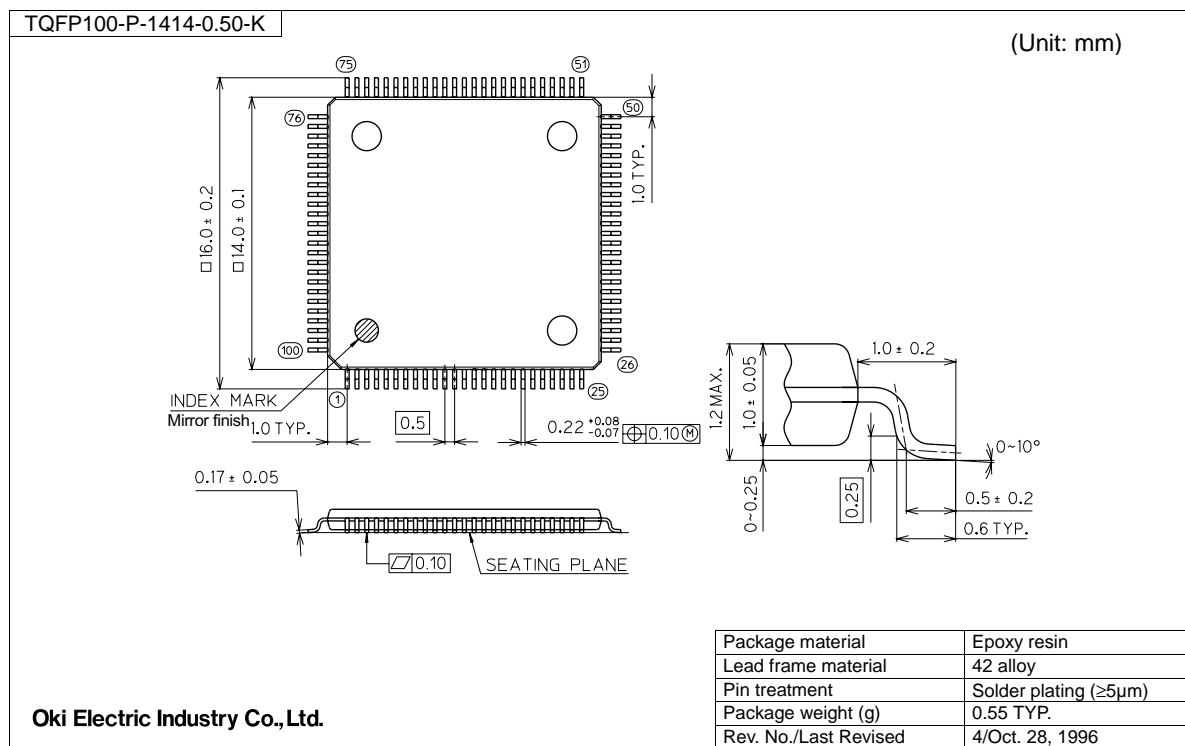
1.9 STN vertical timing



1.10 TFT vertical timing



PACKAGE DIMENSIONS



Notes for Mounting the Surface Mount Type Package

The surface mount type packages are very susceptible to heat in reflow mounting and humidity absorbed in storage. Therefore, before you perform reflow mounting, contact Oki's responsible sales person for the product name, package name, pin number, package code and desired mounting conditions (reflow method, temperature and times).

REVISION HISTORY

Document No.	Date	Page		Description
		Previous Edition	Current Edition	
FEDL87V3104-01	Feb., 2001	–	–	First version released
FEDL87V3104-02	Nov., 2001	67	67	
FEDL87V3104-03	Nov. 28, 2003	1	1	Fixed the memory size descriptions
		4	4	Added the pin types
		5, 17	5, 17	Added the notations
		10	10	Fixed the behavior at the Portrait mode
		19	19	COLORD[1:0] → [2:0]
		20	20	“352” → “360”
		27	27	Added the descriptions
		36	36	Added the descriptions of the bit number
		40	40	LCDDAT[1:0] → [2:0]
		42	42	#02h bit3 “—” → “W/R”
		42	42	IMDBPP[1:0] → [2:0]
		58, 59	58, 59	Temp. ranges 0 to 70°C → -45 to 85°C
–	68, 69	Added “REV. HISTORY” and “NOTICE” pages		

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