Version 0.2

S-MOS

SYSTEMS

A Seiko Epson Affiliate

Graphics LCD Controller (GLC)

SED1351F OA/LB

Technical Manual

S-MOS Systems, Inc.
2460 North First Street
San Jose CA 95131
Tel: (408) 922-0200
Fax: (408) 922-0238

SED1351F0A/LB

Graphics LCD Controller (GLC)

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S-MOS Systems, Inc.
September, 1995
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Data Sheet

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1.0 DATA SHEET

■ DESCRIPTION

The SED1351F is a graphics LCD controller capable of controlling medium to large resolution displays. It transfers data from MPU to external frame buffer RAM and converts this data to display signals for LCD drivers. The SED1351F can display images with 4 gray shades and support display duty cycle as high as 1/1024.

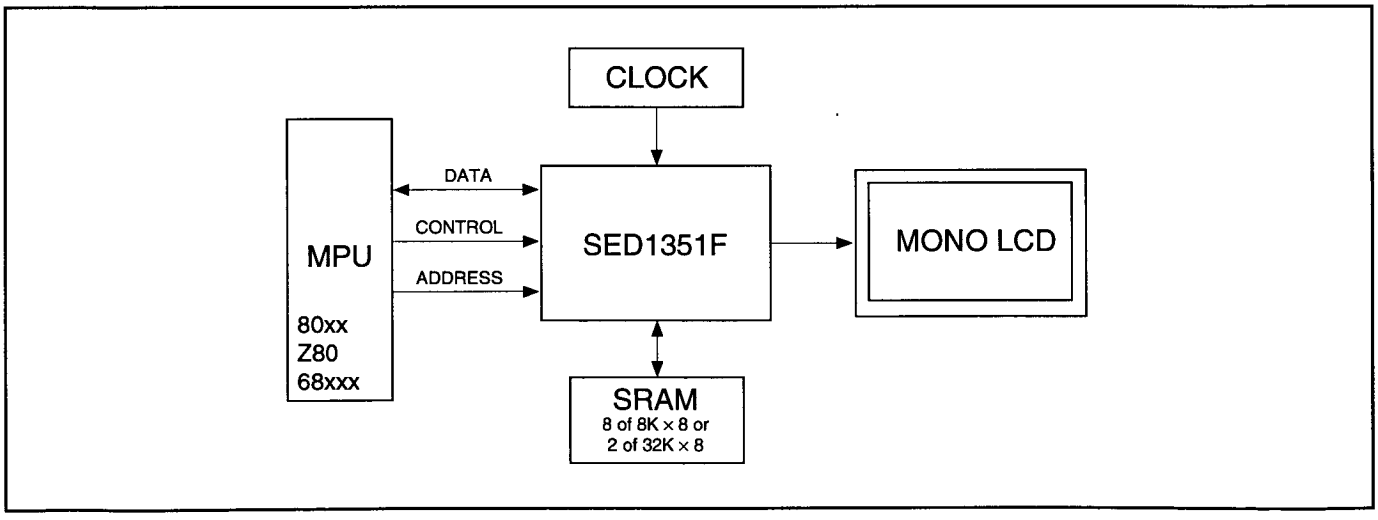
The SED1351F is designed to achieve high efficiency and data throughput to the LCD. It has a cycle steal mode which allows MPU to access frame buffer RAM without interfering with the display operation. The SED1351F can directly interface with up to eight 64K-bit SRAMs or two 256K-bit SRAMs.

The SED1351F can operate with either 5V or 3V power supply. The 5V version chip is the SED1351F0A and the 3V version chip is the SED1351FLB.

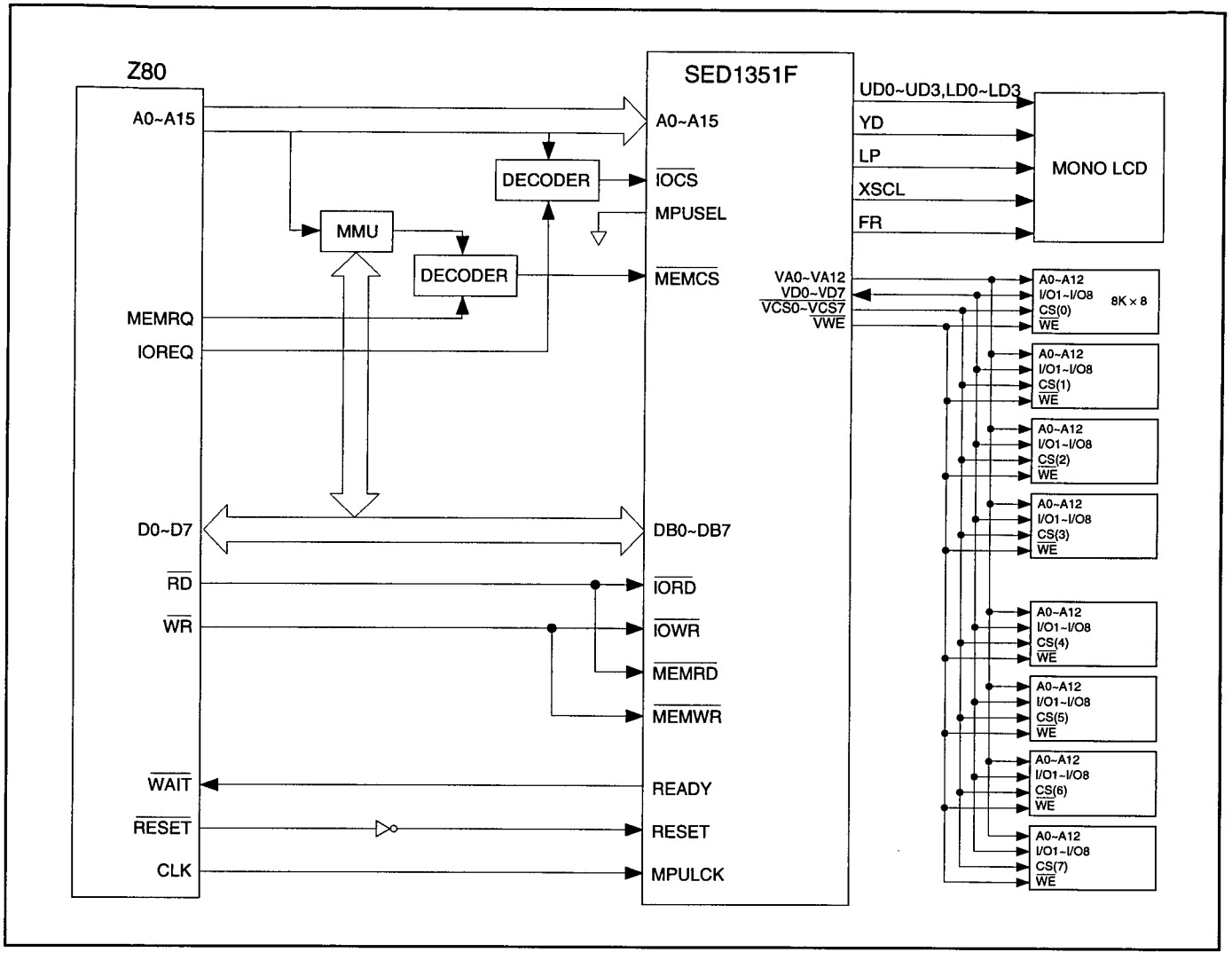
■ FEATURES

- Low-power CMOS technology
- 8-bit or 16-bit MPU data interface
- Direct interface with 80xx, Z80 and 68xxx MPU
- 4- or 8-bit panel data bus for single panel and 4-bit bus for dual panel
- Support logical OR of layers and panel division
- Smooth vertical scrolling
- Virtual screen display up to 1024
- Binary mode (on/off only) generates black & white images
- Gray mode (on/off and two gray steps) generates images with 4 gray shades
- Maximum number of rows
  Binary mode 2048
  Gray mode 1024
- Maximum number of rows:
  Single panel 1024
  Dual panel 2048
- Maximum display sizes when 64K-byte SRAMs are used:
  Binary mode ..... 2048 × 256 / 1024 × 512
  Gray mode ..... 1024 × 256 / 512 × 512
- Available models:
  SED1351F0A ..... 5V, QFP5-100 pin
  SED1351FLB ..... 3V,QFP15-100 pin

■ SYSTEM BLOCK DIAGRAM

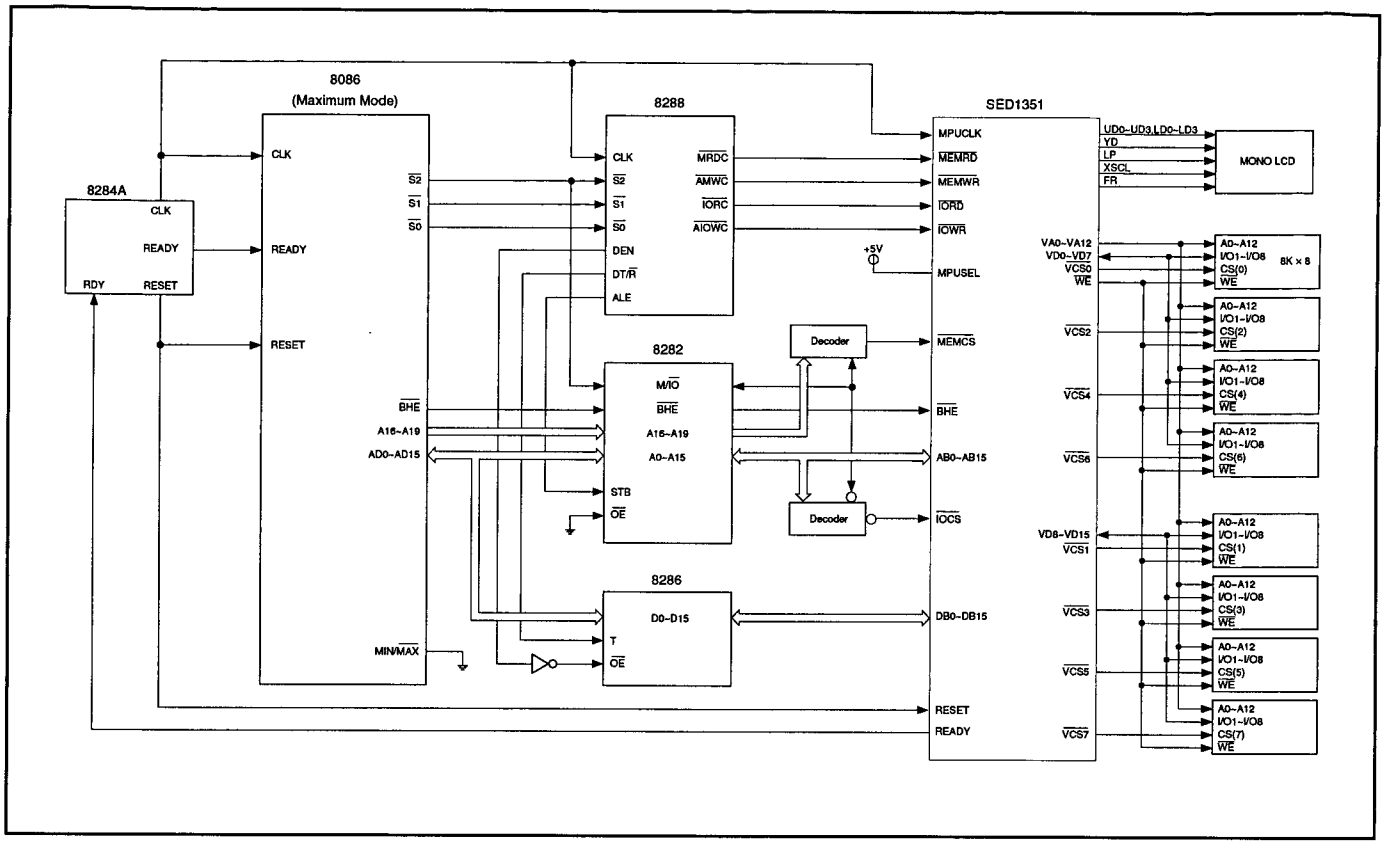


■ INTERFACE WITH 8-BIT MPU (Z-80) AND 64K-BIT SRAM (8 of 8K x 8)



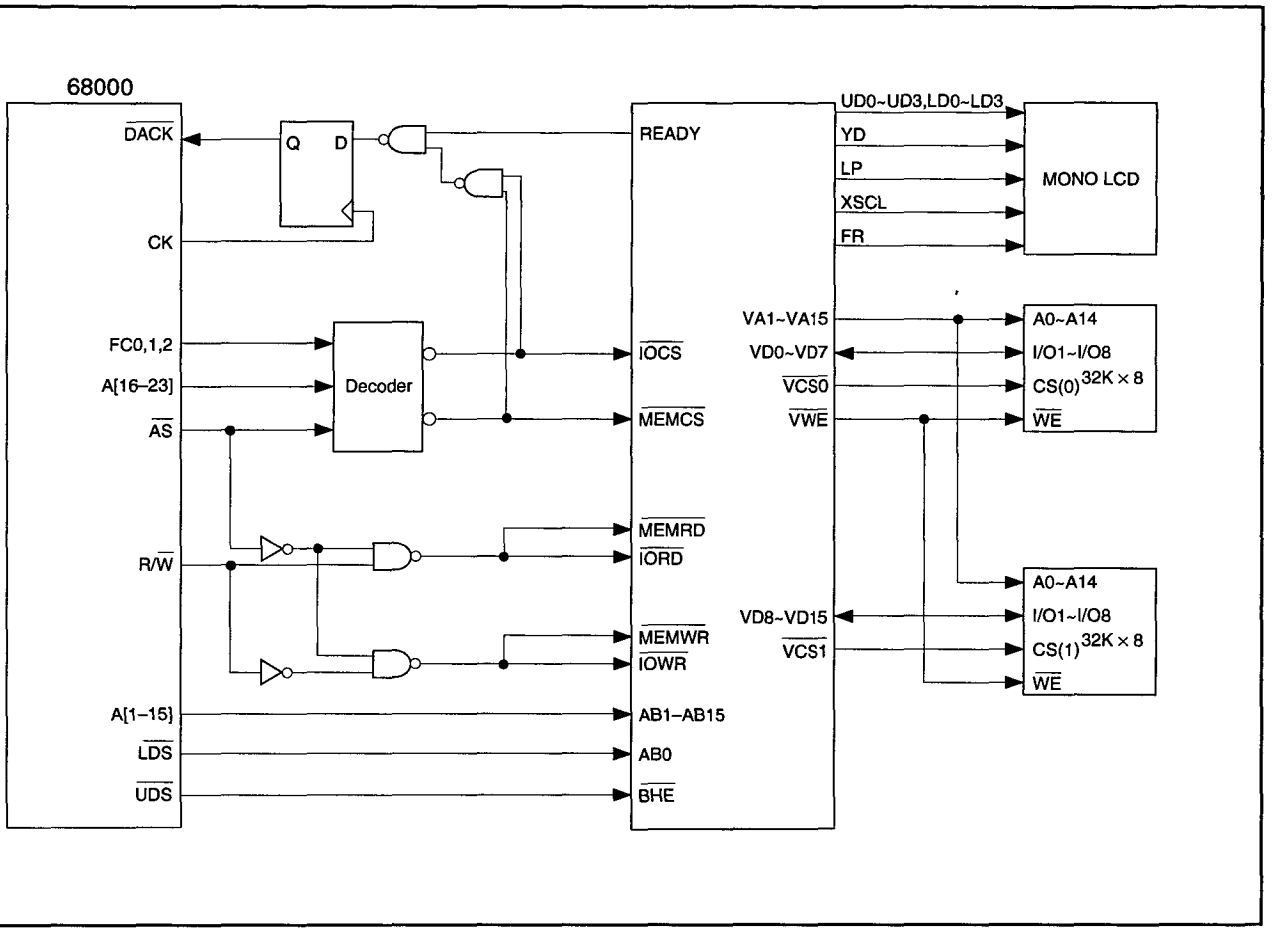
Note: Example implementation, actual may vary.

■ INTERFACE WITH 16-BIT MPU (8086) AND 64K-BIT SRAM (8 of 8K x 8)



Note: Example implementation, actual may vary.

■ INTERFACE WITH 16-BIT MPU (68000) AND 256K-BIT SRAM (2 of 32K x 8)

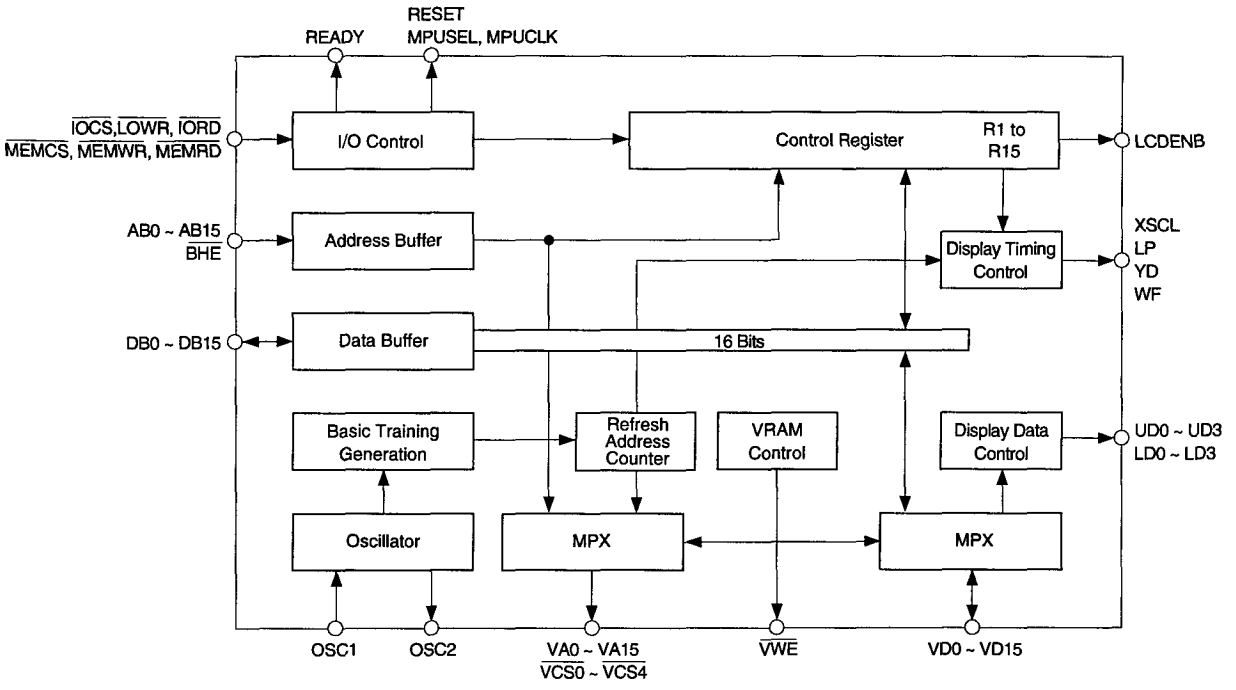


Note: Example implementation, actual may vary.

■ SUPPORTED RESOLUTIONS

Display RAM	Maximum Display Size				SRAM Type	CPU Interface	SRAM Interface
	Monochrome		4 Grayscale				
	X	Y	X	Y			
8K	256	256	256	128	1 of 8K × 8	8 bit	8 bit
16K	512	256	256	256	2 of 8K × 8	8 bit	8 bit
						16 bit	16 bit
24K	512	384	384	256	3 of 8K × 8	8 bit	8 bit
32K	512	512	512	256	4 of 8K × 8	8 bit	8 bit
						16 bit	16 bit
					1 of 32K × 8	8 bit	8 bit
48K	768	512	512	384	6 of 8K × 8	8 bit	8 bit
						16 bit	16 bit
56K	896	512	512	448	7 of 8K × 8	8 bit	8 bit
64K	1024	512	512	512	8 of 8K × 8	8 bit	8 bit
						16 bit	16 bit
					2 of 32K × 8	8 bit	8 bit
						16 bit	16 bit

■ BLOCK DIAGRAM



■ ELECTRICAL CHARACTERISTICS

● SED1351F0A

○ Absolute Maximum Ratings (F0A)

(V_{SS} = 0V)

Parameter	Symbol	Ratings	Unit
Supply voltage	V_{DD}	Vss – 0.3 to 7.0	V
Input voltage	V_I	Vss – 0.3 to V_{DD} + 0.3	V
Output voltage	V_O	Vss – 0.3 to V_{DD} + 0.3	V
Output current/pin	I_O	±10	mA
Power dissipation	P_D	200	mW
Supply current	I_{DD}/Iss	±40	mA
Storage temperature	T_{stg}	–65 to 150	°C
Soldering temperature and time	T_{sol}	260°C, 10s (at lead)	—

● Recommended Operating Conditions (F0A)

(V_{SS} = 0V)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	V_{DD}		4.5	5.0	5.5	V
Input voltage	V_I		Vss	—	V_{DD}	V
Operating temperature	Topr		–20	—	75	°C

○ DC Characteristics (F0A)

(T_a = –20 to 75°C)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Static current	I_{DDS}	$V_{IN} = V_{DD}$, V_{DD} = Max, V_{SS}, $I_{OH} = I_{OL} = 0$	—	—	100	µA
Input leakage current (Type 1)	I_{LI}	V_{DD} = 5.5V, $V_{IH} = V_{DD}$, $V_{IL} = V_{SS}$	–10	—	10	µA
High level input voltage 1 (OSC1)	V_{IH1}	V_{DD} = 5.5V	3.5	—	—	V
Low level input voltage 1 (OSC1)	V_{IL1}	V_{DD} = 4.5V	—	—	1.0	V
High level input voltage 2 (Type 2)	V_{IH2}	V_{DD} = 5.5V	2.0	—	—	V
Low level input voltage 2 (Type 2)	V_{IL2}	V_{DD} = 4.5V	—	—	0.8	V
High level input voltage 3 (Type 3)	V_{T+}	V_{DD} = 5.5V	4.0	—	—	V
Low level input voltage 3 (Type 3)	V_{T-}	V_{DD} = 4.5V	—	—	0.8	V
Hysteresis voltage (Type 3)	V_H	V_{DD} = 5V	0.3	—	—	V
High level output voltage 1 (Type 4)	V_{OH1}	V_{DD} = 4.5V, I_{OH} = –2mA, I_{OL} = 6mA	V_{DD} – 0.4	—	—	V
Low level output voltage 1 (Type 4)	V_{OL1}		—	—	V_{SS} + 0.4	V
High level output voltage 2 (OSC2)	V_{OH2}	V_{DD} = 4.5V, I_{OH} = –50µA, I_{OL} = 50µA	V_{DD} – 0.4	—	—	V
Low level output voltage 2 (OSC2)	V_{OL2}		—	—	V_{SS} + 0.4	V

Note:

Type 1. $\overline{MEMCS}$, $\overline{MEMWR}$, $\overline{MEMRD}$, $\overline{IOCS}$, $\overline{IOWR}$, $\overline{IORD}$, MPUCLK, AB0 ~ AB15, $\overline{BHE}$, MPUSEL, RESET, OSC

Type 2. $\overline{MEMCS}$, $\overline{MEMWR}$, $\overline{MEMRD}$, $\overline{IOCS}$, $\overline{IOWR}$, $\overline{IORD}$, MPUCLK, AB0 ~ AB15, $\overline{BHE}$, DB0 ~ DB15, VD0 ~ VD15

Type 3. MPUSEL, RESET

Type 4. DB0 ~ DB15, READY, VA0 ~ VA15, $\overline{VCS0}$ ~ $\overline{VCS4}$, VD0 ~ VD15, $\overline{VWE}$, XSCL, LP, WF, YD, UD0 ~ UD3, LD0 ~ LD3, LCDENB

■ ELECTRICAL CHARACTERISTICS

● SED1351FLB

○ Absolute Maximum Ratings (FLB)

(Vss = 0V)

Parameter	Symbol	Ratings	Unit
Supply voltage	V_{DD}	Vss – 0.3 to 7.0	V
Input voltage	V_{IN}	Vss – 0.3 to V_{DD} + 0.5	V
Output voltage	V_{OUT}	Vss – 0.3 to V_{DD} + 0.5	V
Output current/pin	I_{OUT}	±24	mA
Power dissipation	P_D	200	mW
Supply current	I_{DD}/Iss	±40	mA
Storage temperature	T_{stg}	–65 to 150	°C

● Recommended Operating Conditions (FLB)

(Vss = 0V)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	V_{DD}		2.7	—	3.6	V
Input voltage	V_{IN}		Vss	—	V_{DD}	V
Operating temperature	Topr		–20	—	75	°C

○ DC Characteristics (FLB)

(T_a = –20 to 75°C)

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Static current	I_{DDS}	$V_{IN} = V_{DD}$ or V_{SS} V_{DD} = MAX $I_{OH} = I_{OL} = 0$	—	—	30	µA
Input leakage current (Type 1)	I_L	V_{DD} = MAX $V_{IH} = V_{DD}$ $V_{IL} = V_{SS}$	–1	—	1	µA
"H" level input voltage (OSC1) "L" level input voltage (OSC1)	V_{IH1} V_{IL1}	V_{DD} = MAX V_{DD} = MIN	0.7 V_{DD} —	— —	— 0.2 V_{DD}	V V
"H" level input voltage (Type 2) "L" level input voltage (Type 2)	V_{IH2} V_{IL2}	V_{DD} = MAX V_{DD} = MIN	0.7 V_{DD} —	— —	— 0.2V_{DD}	V V
"H" level input voltage (Type 3) "L" level input voltage (Type 3) Hysteresis voltage (Type 3)	V_{T+} V_{T-} V_H	V_{DD} = MAX V_{DD} = MIN V_{DD} = TYP	0.8 V_{DD} — 0.3	— — —	— 0.2 V_{DD} —	V V V
"H" level output voltage (Type 4)	V_{OH1}	V_{DD} = MIN I_{OH} = –1.5mA I_{OL} = 3mA	V_{DD} – 0.3	—	—	V
"L" level output voltage (Type 4)	V_{OL1}		—	—	V_{SS} + 0.3	V
"H" level output voltage (OSC2)	V_{OH2}	V_{DD} = MIN I_{OH} = –50µA I_{OL} = 50µA	V_{DD} – 0.4	—	—	V
"L" level output voltage (OSC2)	V_{OL2}		—	—	V_{SS} + 0.4	V

Note:

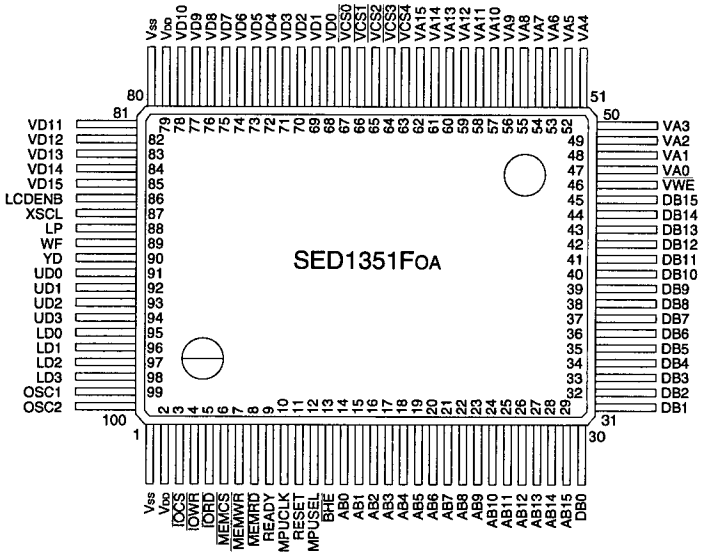
Type 1. $\overline{\text{MEMCS}}$, $\overline{\text{MEMWR}}$, $\overline{\text{MEMRD}}$, $\overline{\text{IOCS}}$, $\overline{\text{IOWR}}$, $\overline{\text{IORD}}$, MPUCLK, AB0 ~ AB15, $\overline{\text{BHE}}$, MPUSEL, RESET, OSC

Type 2. $\overline{\text{MEMCS}}$, $\overline{\text{MEMWR}}$, $\overline{\text{MEMRD}}$, $\overline{\text{IOCS}}$, $\overline{\text{IOWR}}$, $\overline{\text{IORD}}$, MPUCLK, AB0 ~ AB15, $\overline{\text{BHE}}$, DB0 ~ DB15, VD0 ~ VD15

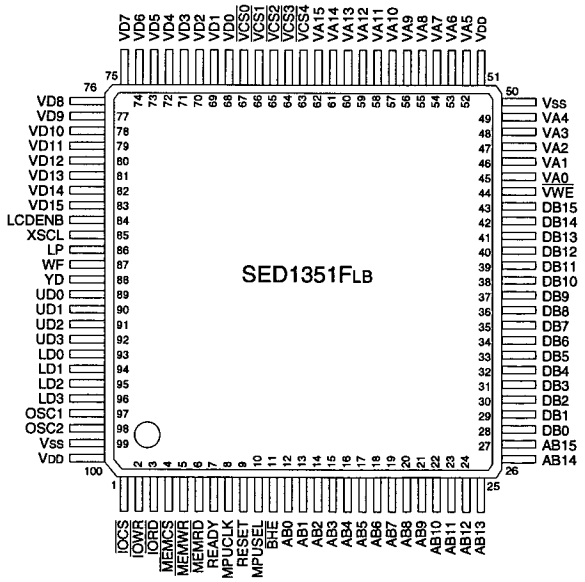
Type 3. MPUSEL, RESET

Type 4. DB0 ~ DB15, READY, VA0 ~ VA15, $\overline{\text{VCS0}}$ ~ $\overline{\text{VCS4}}$, VD0 ~ VD15, $\overline{\text{VWE}}$, XSCL, LP, WF, YD, UD0 ~ UD3, LD0 ~ LD3, LCDENB

■ PIN CONFIGURATION (F0A)



■ PIN CONFIGURATION (FLB)



■ PIN DESCRIPTION

1. System Connector Terminals (at MPU)

Pin Name	Type	F0A Pin No.	FLB Pin No.	Drv	Description
DB0 to DB15	I/O	30 to 45	28 to 43		These pins are interfaced with the MPU data bus. When using an 8-bit MPU, connect DB8 to DB15 to VDD.
AB0 to AB15	I	14 to 29	12 to 27		These pins are interfaced with the MPU address bus. If multiplexed address signals are used, connect them via latch circuits. A control register is selected by AB0 to AB3. Correspondence of the MPU address bus to the VRAM address bus is such that ABi = VAi (where i is a pin number).
$\overline{BHE}$	I	13	11		This signal is a bus high enable signal where a 16-bit MPU is used. It goes "L" (low) when an odd address is encountered. When using an 8-bit MPU configuration, connect the BHE pin to VDD.
$\overline{IOCS}$	I	3	1		This pin selects a control register contained in the SED1351. It is "L" active, and must be assigned to MPU I/O space.
$\overline{IOWR}$	I	4	2		This signal is used for writing data into a control register contained in the SED1351. It is "L" active, and must go "L" when it encounters an OUT instruction from the MPU.
$\overline{IORD}$	I	5	3		This signal is used for reading data from a control register contained in the SED1351. It is "L" active, and must go "L" when it encounters an IN instruction from the MPU.
$\overline{MEMCS}$	I	6	4		This signal is used for selecting VRAM. It is "L" active, and must be assigned to MPU memory space.
$\overline{MEMWR}$	I	7	5		This signal is used for writing data to the VRAM. It is "L" active, and must go "L" when it encounters a memory write instruction from the MPU.
$\overline{MEMRD}$	I	8	6		This signal is used for reading data from the VRAM. It is "L" active, and must go "L" when it encounters a memory read instruction from the MPU.

1. System Connector Terminals (at MPU) (continued)

Pin Name	Type	F0A Pin No.	FLB Pin No.	Drv	Description
READY	O	9	7		This signal requests the MPU to wait. It goes "L" by the falling edge of IOCS or MEMCS. It goes "H" by the rising edge of MPUCLK after completion of the SED1351 internal processing. Since READY is not a tri-state pin, it needed not be pulled up and must be connected directly to the READY (WAIT) terminal of the MPU.
MPUCLK	I	10	8		This pin accepts an MPU clock. The MPU wait state is cleared by the rising edge of MPUCLK.
MPUSEL	I	12	10		This signal is connected to either VDD or VSS for selection of an MPU. MPUSEL = VSS ..... 8-bit MPU (e.g., Z80, V20, i8088) MPUSEL = VDD ..... 16-bit MPU (e.g., V30, i8086)
RESET	I	11	9		The MPU reset signal comes to this pin. It is "H" active, and initializes a control register.

Combinations of Control Pins

$\overline{IOCS}$	$\overline{IOWR}$	$\overline{IORD}$	$\overline{MEMCS}$	$\overline{MEMWR}$	$\overline{MEMRD}$	Operation
1	*	*	1	*	*	Invalid
0	0	1	1	1	1	Write to control register
0	1	0	1	1	1	Read from control register
1	1	1	0	0	1	Write to VRAM
1	1	1	0	1	0	Read from VRAM

Note: Any combination other than those listed above will cause a system error.

1 = "H" (high)
0 = "L" (low)
* = Don't care

2. VRAM Connector Terminals

Pin Name	Type	F0A Pin No.	FLB Pin No.	Drv	Description
VD0 to VD15	I/O	68 to 78, 81 to 85	68 to 83		These pins are interfaced with the VRAM data bus. For a 16-bit MPU configuration, VD0 to VD7 must be connected to even addresses, and VD8 to VD15 to odd addresses. For an 8-bit configuration, VD8 to VD15 must be connected to VDD.
VA0 to VA12	O	47 to 59	45 to 49, 52 to 59		These pins are interfaced with the VRAM address bus and chip select pins.
VA13/$\overline{VCS7}$ to VA15/$\overline{VCS5}$	O	60 to 62	60 to 62		The SED1351 has chip select pins that can directly control eight 64K SRAMs (8K bytes each) or two 256K SRAMs (32K bytes) in the 64K VRAM space. See Technical Manual for details.
$\overline{VCS0}$ to $\overline{VCS4}$	O	67 to 63	67 to 63		
$\overline{VWE}$	O	46	44		This signal is used for writing data to the VRAM. It is "L" active, and must be connected to the WE pin of the VRAM.

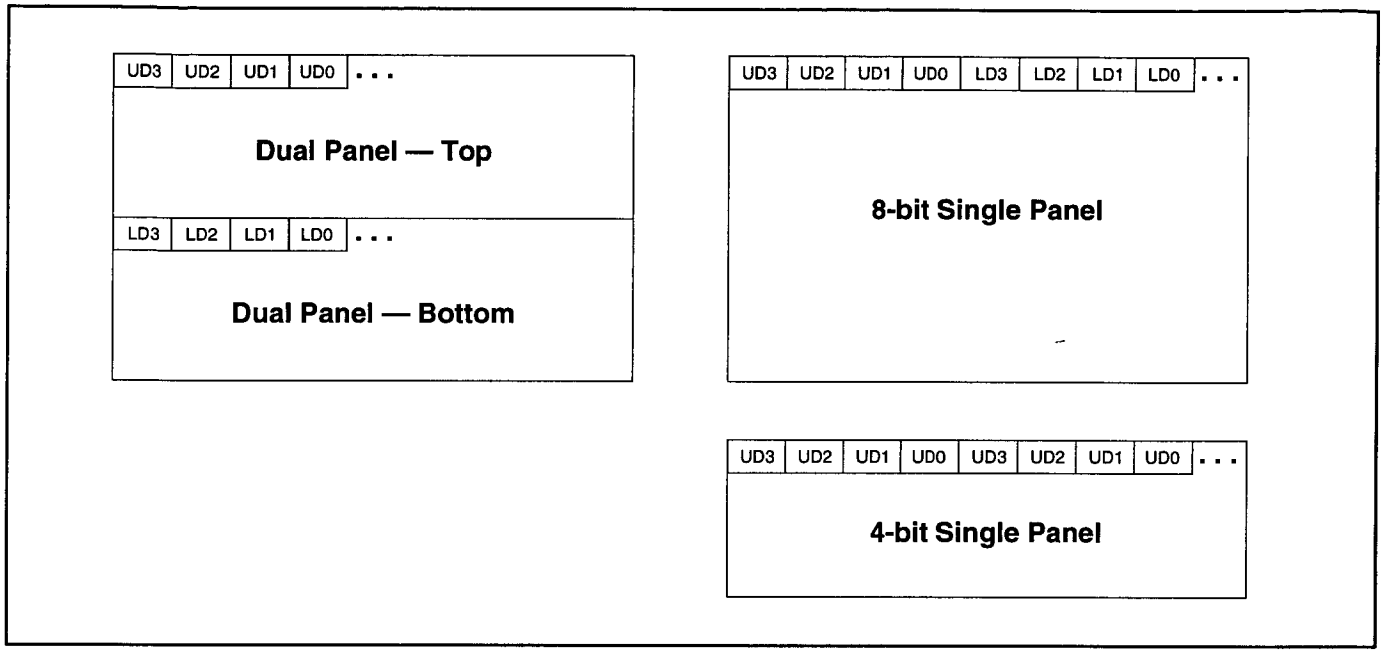
3. Oscillator Terminals

Pin Name	Type	F0A Pin No.	FLB Pin No.	Drv	Description
OSC1	I	99	97		The OSC1 (input) and OSC2 (output) pins generate clocks for internal operation. They allow crystal oscillation and external clock input.
OSC2	O	100	98		

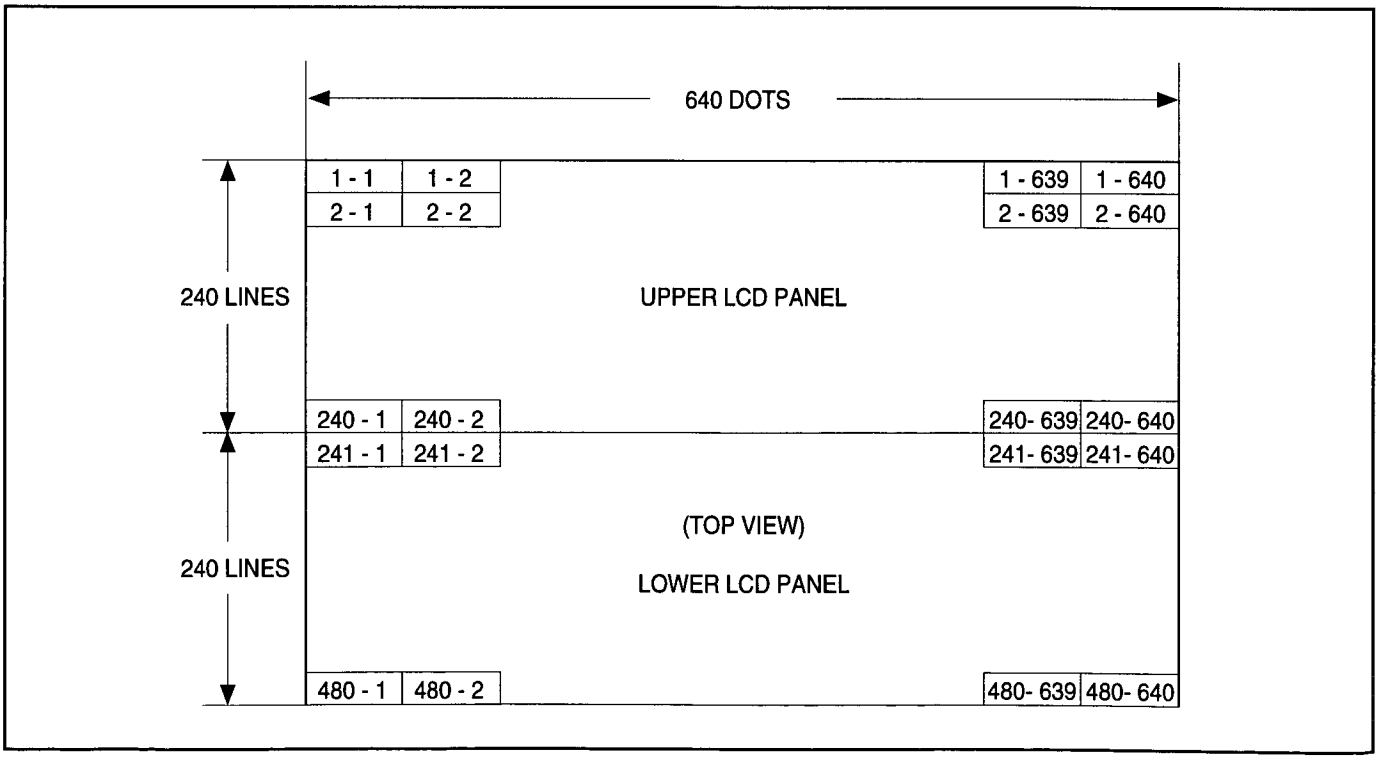
4. Power Terminals

Pin Name	Type	F0A Pin No.	FLB Pin No.	Drv	Description
V_{DD}	—	2, 79	51, 100		The power supply pins include two V_{DD}s and two Vsss. Apply +5V or +3V to V_{DD} and 0V to V_{SS}. A capacitor (4.7 µF or more) must be connected near each pair of V_{DD}/V_{SS} pins.
V_{SS}	—	1, 80	50, 99		

Illustrated below are the display data which are output from the UD0 to UD3, LD0/UD4 to LD3/UD7 and the display on the panel:



■ LCD PANEL PIXELS

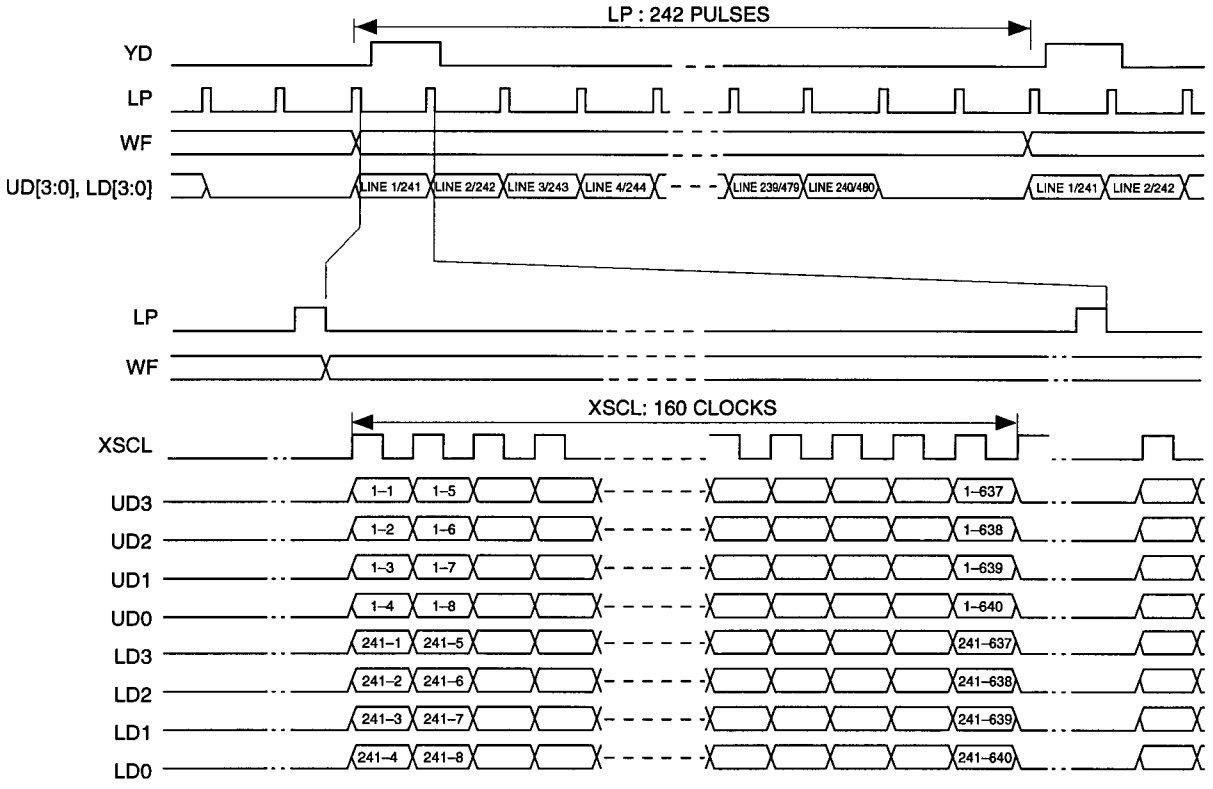


5. LCD Connector Terminals

Pin Name	Type	F0A Pin No.	FLB Pin No.	Drv	Description
UD0 to UD3	I/O	91 to 94	89 to 92		LCD display data. UD0 to UD3 are the upper panel display data in the signal panel or double panel drive panel mode. LD0/UD4 to LD3/UD7 are the lower panel display data in the double panel drive mode. UD0 to UD3, and LD0/UD4 to LD3/UD7 are used for 8-bit data transfer in the single panel drive mode.
LD0/UD4 to LD3/UD7	O	95 to 98	93 to 96		
XSCL	O	87	85		This single is a shift clock for display data transfer. Take the UD0 to UD3, LD0/UD4 to LD3/UD7 display data into LCDs by the falling edge of XSCL.
LP	O	88	86		This pin provides both a display data latch pulse and a scan signal transfer clock. Upon completion of transferring the LCD data on one line, display data can be latched or a scan signal transferred by the falling edge of LP.
WF	O	89	87		This pin provides a frame signal used for LCD AC driving.
YD	O	90	88		This pin provides a scanning line start pulse. The signal is "H" active. Allow the scanning line drive IC to take in YD by the falling edge of LP. The SED1351 has two lines of retracing; if two scanning line drive ICs are cascade-connected for the upper and lower panels in the double panel drive mode, two lines must be provided between the upper and lower scanning line drive outputs.
LCDENB	O	86	84		This pin provides the data which is set in bit 1 (D1) of the mode register (R1). LCDENB goes "L" when the system is reset; it can be effectively used for LCD power control.

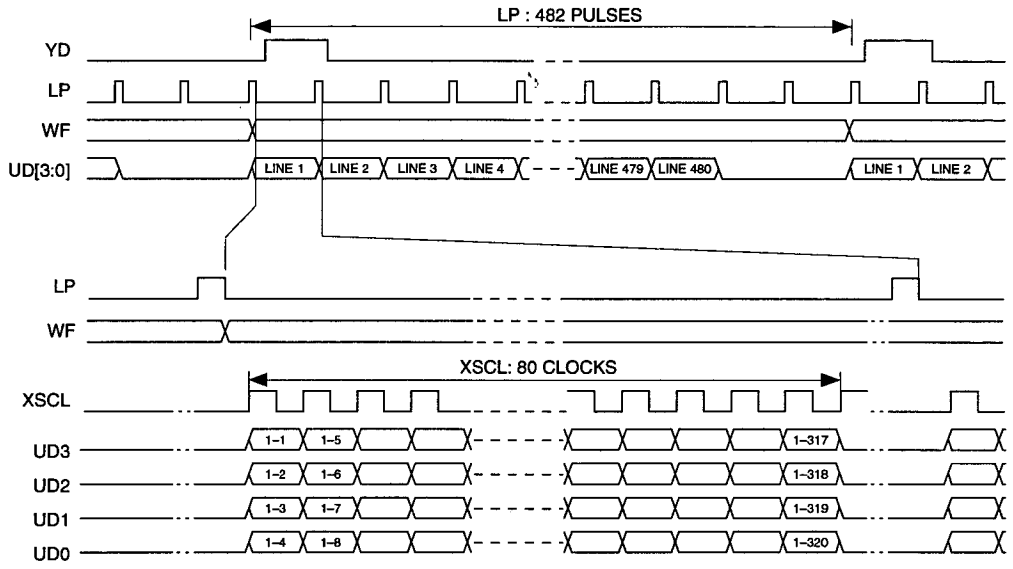
■ MONOCHROME LCD PANEL INTERFACE

8-Bit Dual Monochrome Panel (i.e. 640 × 480)

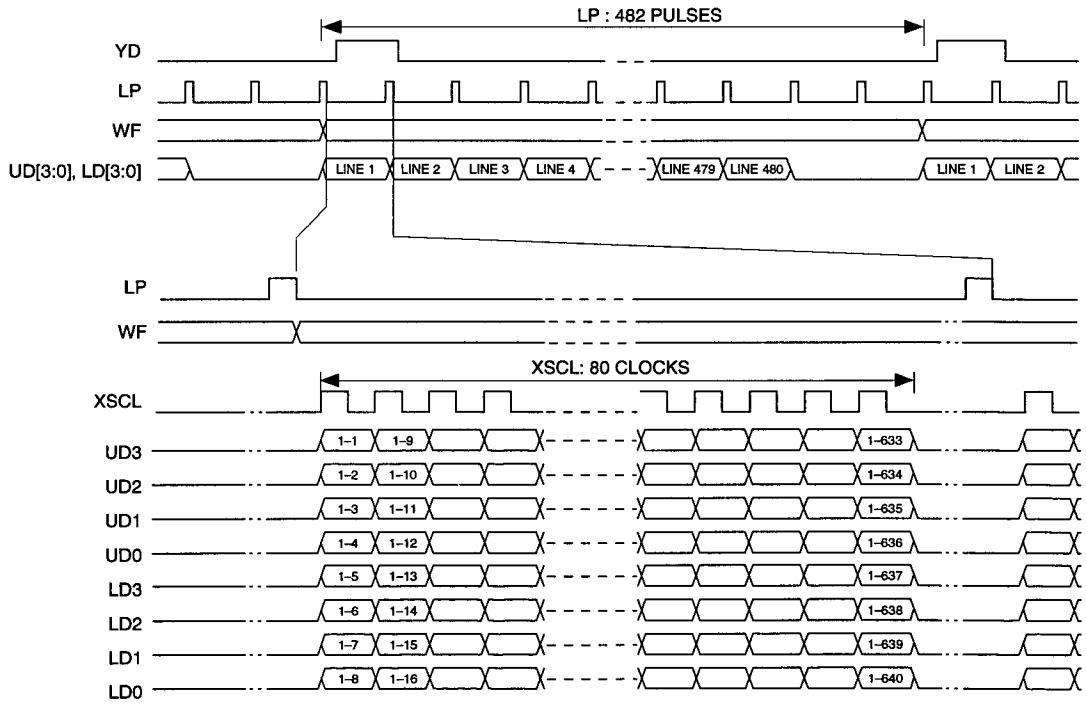


■ MONOCHROME LCD PANEL INTERFACE

4-Bit Single Monochrome Panel (i.e. 320 × 480)



8-Bit Single Monochrome Panel (i.e. 640 × 480)

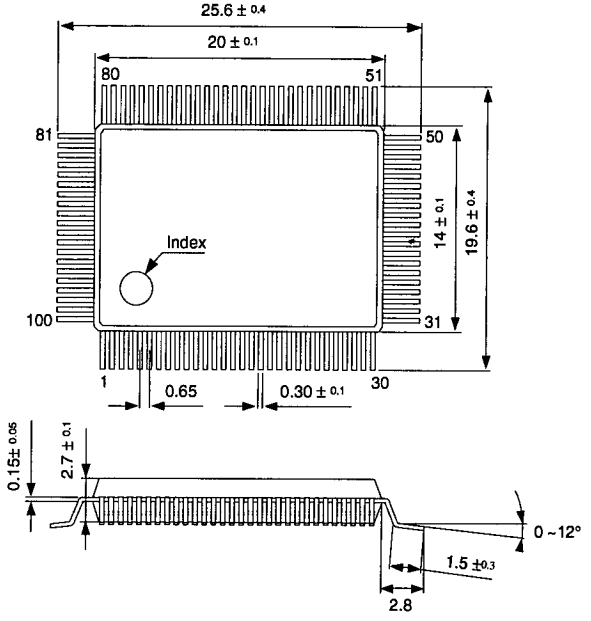


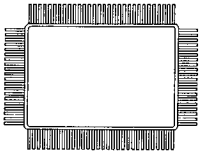
■ PACKAGE DIMENSIONS

● SED1351F0A

QFP5-100pin

Unit: mm



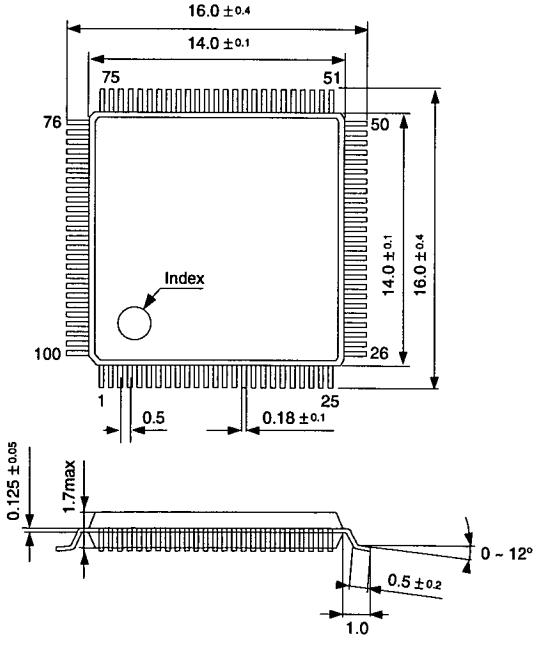


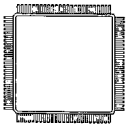
Actual Size

● SED1351FLB

QFP15-100pin

Unit: mm





Actual Size

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2.0
Pin Description

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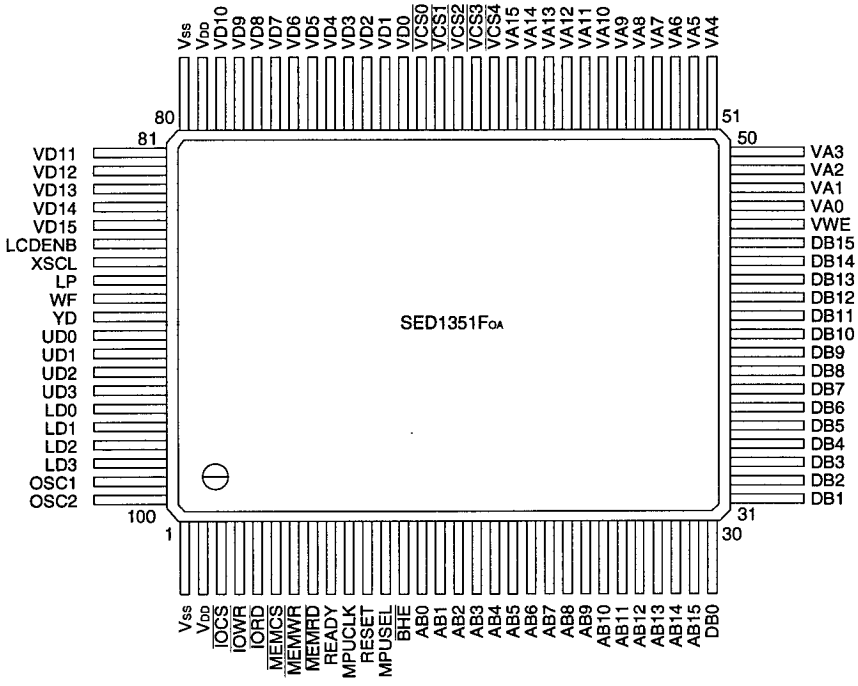
2.0 PIN DESCRIPTION

2.1 SED1351F$_{OA}$

2.1.1 Pinout Diagram



2.1.2 SED1351F0A Pin Description Table

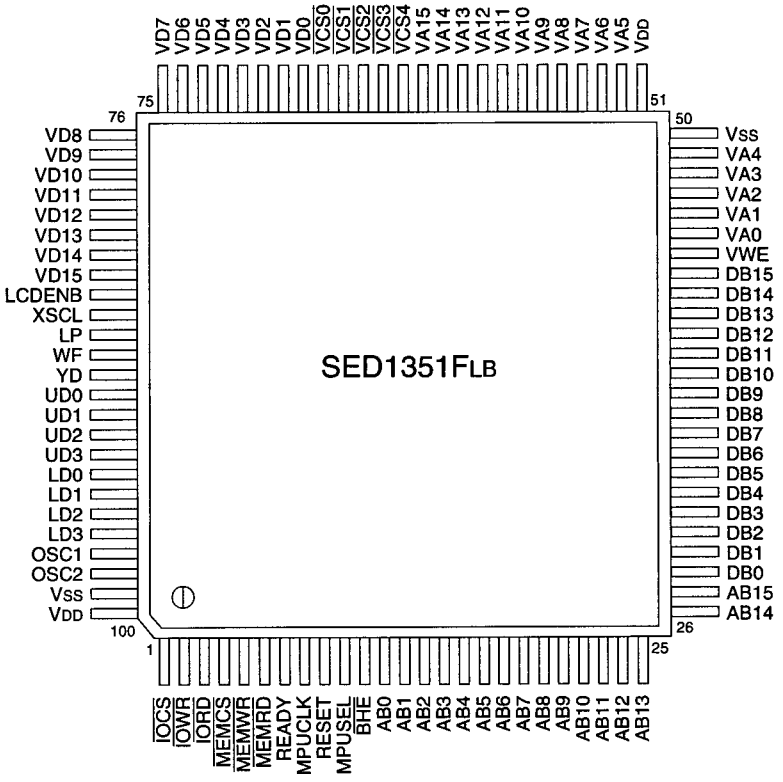
Pin	Pin Name	I/O
1	V_{SS} (GND)	—
2	V_{DD}	—
3	$\overline{IOCS}$	I
4	$\overline{IOWR}$	I
5	$\overline{IORD}$	I
6	$\overline{MEMCS}$	I
7	$\overline{MEMWR}$	I
8	$\overline{MEMRD}$	I
9	READY	O
10	MPUCLK	I
11	RESET	I
12	MPUSEL	I
13	$\overline{BHE}$	I
14	AB0	I
15	AB1	I
16	AB2	I
17	AB3	I
18	AB4	I
19	AB5	I
20	AB6	I
21	AB7	I
22	AB8	I
23	AB9	I
24	AB10	I
25	AB11	I
26	AB12	I
27	AB13	I
28	AB14	I
29	AB15	I
30	DB0	I/O
31	DB1	I/O
32	DB2	I/O
33	DB3	I/O
34	DB4	I/O

Pin	Pin Name	I/O
35	DB5	I/O
36	DB6	I/O
37	DB7	I/O
38	DB8	I/O
39	DB9	I/O
40	DB10	I/O
41	DB11	I/O
42	DB12	I/O
43	DB13	I/O
44	DB14	I/O
45	DB15	I/O
46	$\overline{VWE}$	O
47	VA0	O
48	VA1	O
49	VA2	O
50	VA3	O
51	VA4	O
52	VA5	O
53	VA6	O
54	VA7	O
55	VA8	O
56	VA9	O
57	VA10	O
58	VA11	O
59	VA12	O
60	VA13	O
61	VA14	O
62	VA15	O
63	$\overline{VCS4}$	O
64	$\overline{VCS3}$	O
65	$\overline{VCS2}$	O
66	$\overline{VCS1}$	O
67	$\overline{VCS0}$	O
68	VD0	I/O

Pin	Pin Name	I/O
69	VD1	I/O
70	VD2	I/O
71	VD3	I/O
72	VD4	I/O
73	VD5	I/O
74	VD6	I/O
75	VD7	I/O
76	VD8	I/O
77	VD9	I/O
78	VD10	I/O
79	V_{DD}	—
80	V_{SS} (GND)	—
81	VD11	I/O
82	VD12	I/O
83	VD13	I/O
84	VD14	I/O
85	VD15	I/O
86	LCDENB	O
87	XSCL	O
88	LP	O
89	WF	O
90	YD	O
91	UD0	O
92	UD1	O
93	UD2	O
94	UD3	O
95	LD0	O
96	LD1	O
97	LD2	O
98	LD3	O
99	OSC1	I
100	OSC2	O

2.2 SED1351F$_{LB}$

2.2.1 Package Layout



2.2.2 SED1351F$_{LB}$ Pin Description Table

Pin	Pin Name	I/O
1	$\overline{IOCS}$	I
2	$\overline{IOWR}$	I
3	$\overline{IORD}$	I
4	$\overline{MEMCS}$	I
5	$\overline{MEMWR}$	I
6	$\overline{MEMRD}$	I
7	READY	O
8	MPUCLK	I
9	RESET	I
10	MPUSEL	I
11	$\overline{BHE}$	I
12	AB0	I
13	AB1	I
14	AB2	I
15	AB3	I
16	AB4	I
17	AB5	I
18	AB6	I
19	AB7	I
20	AB8	I
21	AB9	I
22	AB10	I
23	AB11	I
24	AB12	I
25	AB13	I
26	AB14	I
27	AB15	I
28	DB0	I/O
29	DB1	I/O
30	DB2	I/O
31	DB3	I/O
32	DB4	I/O
33	DB5	I/O
34	DB6	I/O

Pin	Pin Name	I/O
35	DB7	I/O
36	DB8	I/O
37	DB9	I/O
38	DB10	I/O
39	DB11	I/O
40	DB12	I/O
41	DB13	I/O
42	DB14	I/O
43	DB15	I/O
44	$\overline{VWE}$	O
45	VA0	O
46	VA1	O
47	VA2	O
48	VA3	O
49	VA4	O
50	V_{SS} (GND)	—
51	V_{DD}	—
52	VA5	O
53	VA6	O
54	VA7	O
55	VA8	O
56	VA9	O
57	VA10	O
58	VA11	O
59	VA12	O
60	VA13	O
61	VA14	O
62	VA15	O
63	$\overline{VCS4}$	O
64	$\overline{VCS3}$	O
65	$\overline{VCS2}$	O
66	$\overline{VCS1}$	O
67	$\overline{VCS0}$	O
68	VD0	I/O

Pin	Pin Name	I/O
69	VD1	I/O
70	VD2	I/O
71	VD3	I/O
72	VD4	I/O
73	VD5	I/O
74	VD6	I/O
75	VD7	I/O
76	VD8	I/O
77	VD9	I/O
78	VD10	I/O
79	VD11	I/O
80	VD12	I/O
81	VD13	I/O
82	VD14	I/O
83	VD15	I/O
84	LCDENB	O
85	XSCL	O
86	LP	O
87	WF	O
88	YD	O
89	UD0	O
90	UD1	O
91	UD2	O
92	UD3	O
93	LD0	O
94	LD1	O
95	LD2	O
96	LD3	O
97	OSC1	I
98	OSC2	O
99	V_{SS} (GND)	—
100	V_{DD}	—

2.3 SYSTEM INTERFACE

Table 1. MPU Interface Control Signal Functions

$\overline{IOCS}$	$\overline{IOWR}$	$\overline{IORD}$	$\overline{MEMCS}$	$\overline{MEMWR}$	$\overline{MEMRD}$	Operation
1	*	*	1	*	*	Invalid
0	0	1	1	1	1	Write to control register
0	1	0	1	1	1	Read from control register
1	1	1	0	0	1	Write to VRAM
1	1	1	0	1	0	Read from VRAM

- **READY**

  MPU "wait" request output. It goes "L" on the falling edge of $\overline{IOCS}$ or $\overline{MEMCS}$. It goes "H" the on the rising edge of the first MPUCLK after completion of SED1351F internal processing. READY is connected directly to the READY (or $\overline{WAIT}$) terminal of the MPU.

- **MPUCLK**

  MPU clock input

- **MPUSEL**

  This input selects an 8- or 16-bit MPU interface.
  - MPUSEL=0: 8-bit MPU interface (Z80, V20,i8088)
  - MPUSEL=1: 16-bit MPU interface (V30,i8086)

- **RESET**

  MPU reset imput. This active high signal initializes R1, the system Mode Register.

2.4 VRAM INTERFACE

- **VD0-VD15**

  These pins are connected to the VRAM data bus. For 16-bit MPUs VD0-VD7 are connected to the data bus of even byte addresses and VD8-VD15 to the data bus of odd byte addresses. For 8-bit MPUs, VD8-VD15 must be tied to VDD.

- **VA0-VA12,VA13/$\overline{VCS7}$-VA15/$\overline{VCS5}$,$\overline{VCS0}$-$\overline{VCS4}$**

  These pins are connected to the VRAM address bus and chip select lines.

  The SED1351F provides select signals that can directly control eight 64 Kbit SRAMs (8 Kbytes each) or two 256 Kbit SRAMs (32 Kbytes) in the 64 Kbytes VRAM space.

- **$\overline{VWE}$**

  This output is used for writing data to the VRAM. It is active low and is connected to the $\overline{WE}$ input of the SRAMS.

2.5 LCD INTERFACE

- **UD0-UD3,LD0/UD4-LD3/UD7**

  LCD display data output lines. UD0-UD3 provide the upper panel display data in single- or dual-panel LCD modes. LD0/UD4-LD3/UD7 provide the lower panel display data in dual-panel, dual-drive LCD mode. UD0-UD3, LD0/UD4-LD3/UD7 are used for 8-bit data transfer in single-panel, single-drive LCD mode.

- **XSCL**

  Display data shift clock output. Data is shifted into the LCD X-drivers on the falling edge of this signal.

- **LP**

  Display data latch clock output. One line of data is latched into the LCD X-drivers on the falling edge of this signal. LP can also be used to shift the Y-drive active line down by one.

- **WF**

  LCD AC-drive signal output.

- **YD**

  Active high start-of-frame pulse output. If this signal is shifted through the Y-drivers by LP, it provides the Y-drive active line signal.

- **LCDENB**

  LCD enable signal output controlled by R1:D1.

2.6 OSCILLATOR

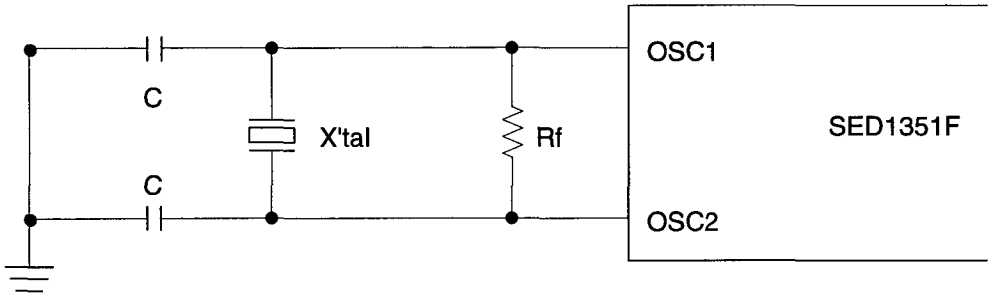
- **OSC1**

  External clock input or internal oscillator external feed back resistor (Rf) connection.

- **OSC2**

  If the internal oscillator is used, connect the external feed back resistor, Rf, to this pin. If an external clock is used, leave open.

(a) Crystal Oscillator



C ≃ 30pF Rf = 1MΩ

Note: Connect C, Rf and X'tal near pins.

(b) External Clock Input

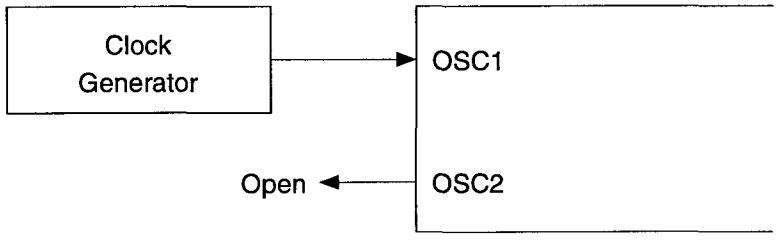


Figure 2. External and Internal Oscillators.

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3.0
Electrical Characteristics

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3.0 ELECTRICAL CHARACTERISTICS

3.1 SED1351F0A

3.1.1 SED1351F0A Absolute Maximum Ratings

V_{SS} = 0V

Parameter	Symbol	Rating	Unit
Supply voltage	V_{DD}	V_{SS} – 0.3 to 7.0	V
Input voltage	V_{IN}	V_{SS} – 0.3 to V_{DD} + 0.3	V
Output voltage	V_{OUT}	V_{SS} – 0.3 to V_{DD} + 0.3	V
Output current/pin	I_{OUT}	±10	mA
Power dissipation	PD	200	mW
Supply current	I_{DD}/I_{SS}	±40	mA
Storage temperature	T_{stg}	–65 to 150	°C

Note: Supply current is equivalent to maximum current into or out of a particular power pin.

3.1.2 Recommended Operating Conditions

V_{SS} = 0V

Parameter	Symbol	Min	Typ	Max	Unit
Supply voltage	V_{DD}	4.5	5.0	5.5	V
Input voltage	V_{IN}	Vss	—	V_{DD}	V
Operating temperature	T_{opr}	–20	—	75	°C

3.1.3 SED1351F0A DC Characteristics

(Ta = –20 to 75°C)

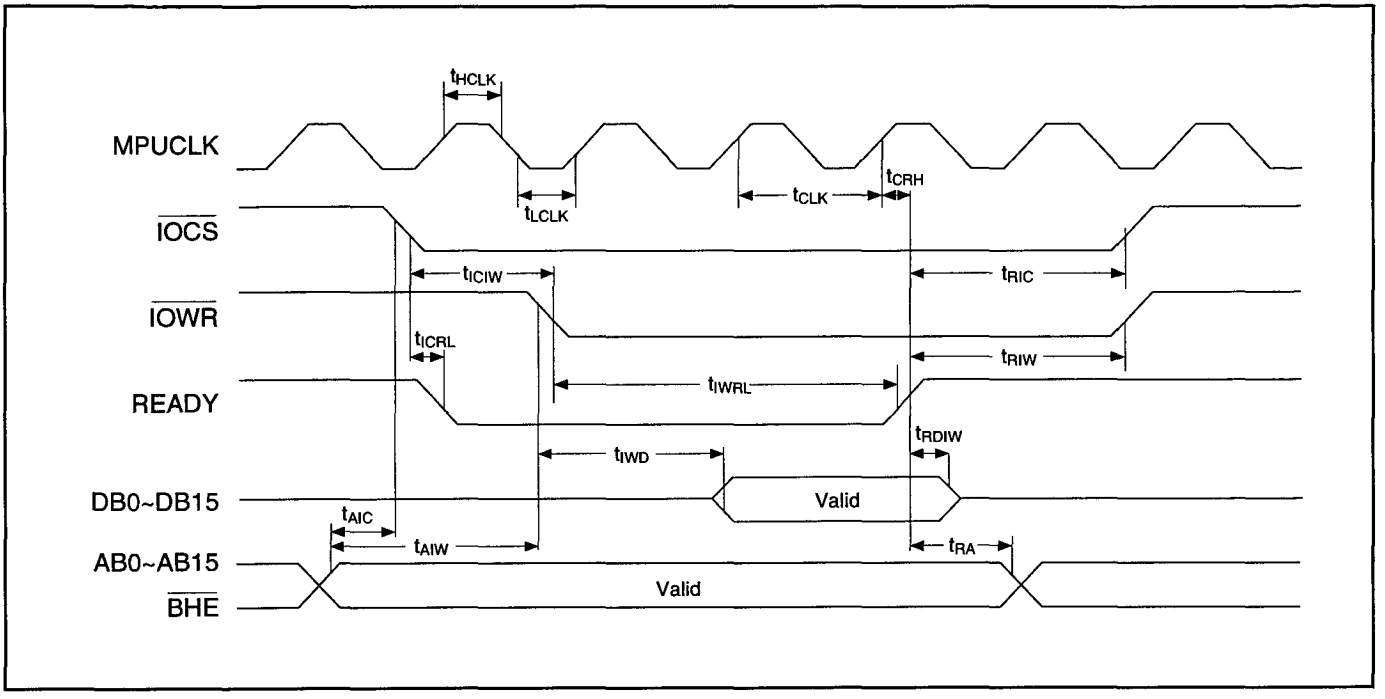
Parameter	Symbol	Condition	Min	Typ	Max	Unit	Pin
Static current	I_{DDS}	$V_{IN} = V_{DD}, V_{SS}$ V_{DD} = MAX $I_{OH} = I_{OL} = 0$	—	—	100	µA	
Input leakage current	I_L	V_{DD} = MAX $V_{IH} = V_{DD}$ $V_{IL} = V_{SS}$	–10	—	10	µA	Note 1
"H" level input voltage (1)	V_{IH1}	V_{DD} = MAX	3.5	—	—	V	OSC1
"L" level input voltage (1)	V_{IL1}	V_{DD} = MIN	—	—	1.0	V	
"H" level input voltage (2)	V_{IH2}	V_{DD} = MAX	2.0	—	—	V	
"L" level input voltage (2)	V_{IL2}	V_{DD} = MIN	—	—	0.8	V	Note 2
"H" level input voltage (3)	V_{T+}	V_{DD} = MAX	4.0	—	—	V	
"L" level input voltage (3)	V_{T-}	V_{DD} = MIN	—	—	0.8	V	Note 3
Hysteresis voltage	V_H	V_{DD} = TYP	0.3	—	—	V	
"H" level output voltage (1)	V_{OH1}	V_{DD} = MIN I_{OH} = 1.5mA I_{OL} = 3mA	V_{DD} – 0.4	—	—	V	Note 4
"L" level output voltage (1)	V_{OL1}		—	—	V_{SS} + 0.4	V	
"H" level output voltage (2)	V_{OH2}	V_{DD} = MIN I_{OH} = –50µA I_{OL} = 50µA	V_{DD} – 0.4	—	—	V	OSC2
"L" level output voltage (2)	V_{OL2}		—	—	V_{SS} + 0.4	V	

Notes:

1. $\overline{\text{MEMCS}}$, $\overline{\text{MEMWR}}$, $\overline{\text{MEMRD}}$, $\overline{\text{IOCS}}$, $\overline{\text{IOWR}}$, $\overline{\text{IORD}}$, MPUCLK, AB0-AB15, $\overline{\text{BHE}}$, MPUSEL, RESET, OSC1
2. $\overline{\text{MEMCS}}$, $\overline{\text{MEMWR}}$, $\overline{\text{MEMRD}}$, $\overline{\text{IOCS}}$, $\overline{\text{IOWR}}$, $\overline{\text{IORD}}$, MPUCLK, AB0-AB15, $\overline{\text{BHE}}$, DB0-DB15, VD0-VD15
3. MPUSEL, RESET
4. DB0-DB15, READY, VA0-VA15, $\overline{\text{VCS0}}$, $\overline{\text{VCS4}}$, VD0-VD15, $\overline{\text{VWE}}$, XSCL, LP, WF, YD, UD0-UD3, LD0-LD3, LCDENB

3.1.4 SED1351F0A AC Characteristics

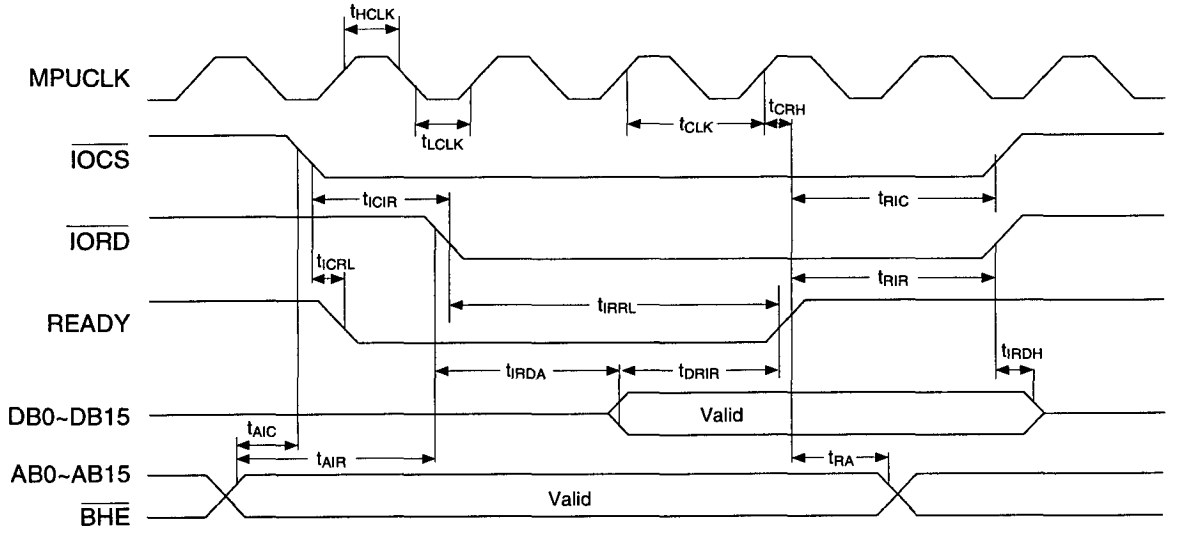
3.1.4.1 IOWR Timing (MPU Write Data to Control Register)



(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK	t_{CLK}	80	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{IOCS}$ address setup time	t_{AIC}	0	—	—	ns
$\overline{IOWR}$ address setup time	t_{AIW}	0	—	—	ns
$\overline{IOCS}\downarrow \rightarrow \overline{IOWR}\downarrow$	t_{ICIW}	0	—	—	ns
$\overline{IOWR}\downarrow \rightarrow$ data valid	t_{IWD}	—	—	1.5 × tosc	ns
$\overline{IOCS}\downarrow \rightarrow$ READY$\downarrow$	t_{ICRL}	—	—	30	ns
$\overline{IOWR}\downarrow \rightarrow$ READY$\uparrow$	t_{IWRL}	2 × tosc	—	4 × tosc + t_{CLK}	ns
MPUCLK$\uparrow \rightarrow$ READY$\uparrow$	t_{CRH}	—	—	20	ns
READY$\uparrow \rightarrow \overline{IOCS}\uparrow$ hold time	t_{RIC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{IOWR}\uparrow$ hold time	t_{RIW}	0	—	—	ns
Write data hold time	t_{RDIW}	0	—	—	ns
Address hold time	t_{RA}	0	—	—	ns

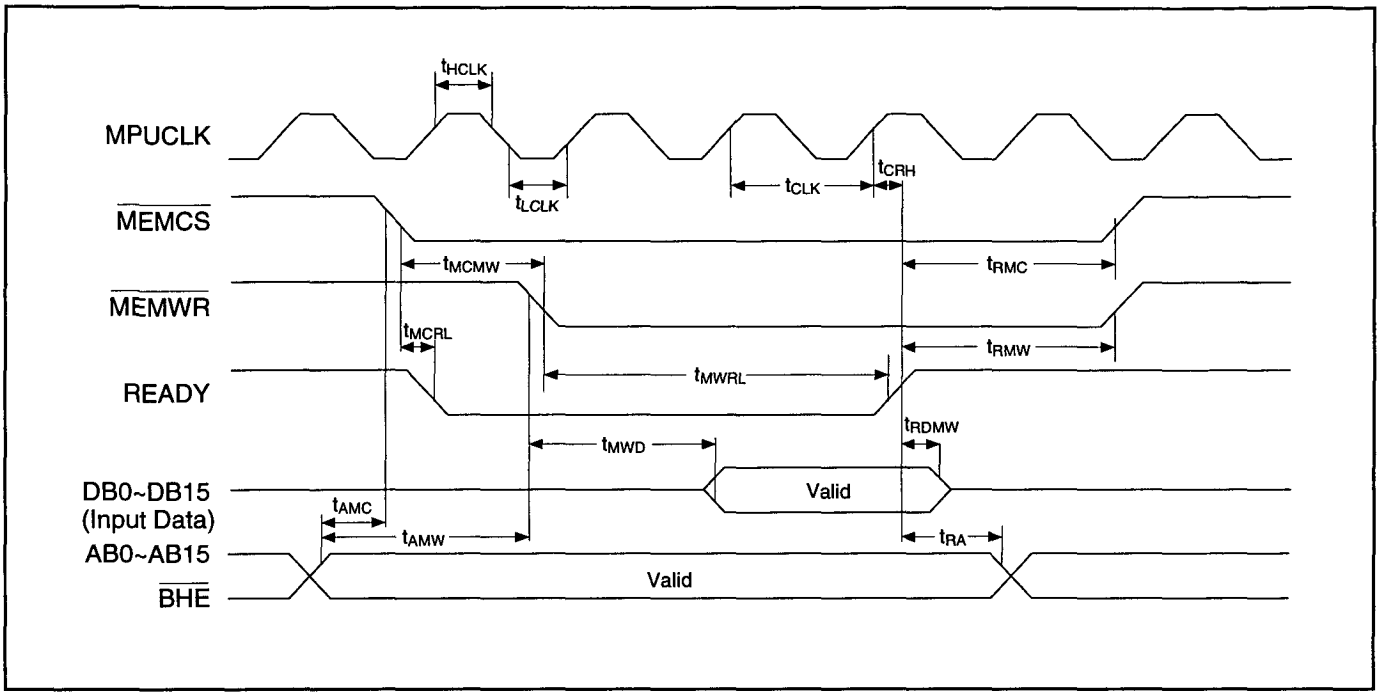
3.1.4.2 IORD Timing (MPU Read Data from Control Register)



(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK	t_{CLK}	80	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{IOCS}$ address setup time	t_{AIC}	0	—	—	ns
$\overline{IORD}$ address setup time	t_{AIR}	0	—	—	ns
$\overline{IOCS}\downarrow \rightarrow \overline{IORD}\downarrow$	t_{ICIR}	0	—	—	ns
$\overline{IOCS}\downarrow \rightarrow$ READY$\downarrow$	t_{ICRL}	—	—	30	ns
$\overline{IORD}\downarrow \rightarrow$ READY$\uparrow$	t_{IRRL}	2 × tosc	—	4 × tosc + t_{CLK}	ns
MPUCLK$\downarrow \rightarrow$ READY$\uparrow$	t_{CRH}	—	—	20	ns
$\overline{IORD}\downarrow \rightarrow$ data valid	t_{IRDA}	2 × tosc	—	4 × tosc	ns
data valid $\rightarrow$ READY$\uparrow$	t_{DRIR}	0	—	—	ns
Read data hold time	t_{IRDH}	0	—	—	ns
READY$\uparrow \rightarrow \overline{IOCS}\uparrow$ hold time	t_{RIC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{IORD}\uparrow$ hold time	t_{RIR}	0	—	—	ns
Address hold time	t_{RA}	0	—	—	ns

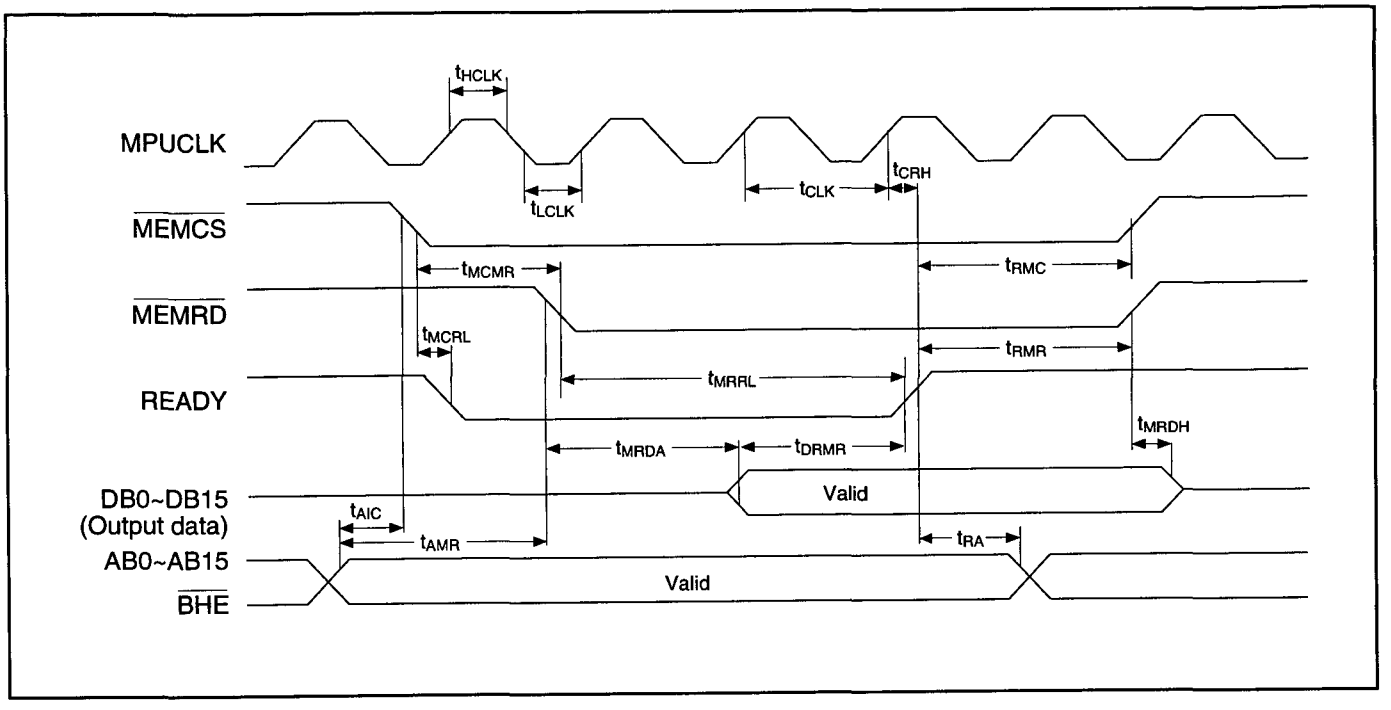
3.1.4.3 MEMWR Timing (MPU Write Data to Video Memory)



(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK	t_{CLK}	80	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{MEMCS}$ address setup time	t_{AMC}	0	—	—	ns
$\overline{MEMWR}$ address setup time	t_{AMW}	0	—	—	ns
$\overline{MEMCS}\downarrow \rightarrow \overline{MEMWR}\downarrow$	t_{MCMW}	0	—	—	ns
$\overline{MEMWR}\downarrow \rightarrow$ data valid	t_{MWD}	—	—	1.5 × tosc	ns
$\overline{IOCS}\downarrow \rightarrow$ READY$\downarrow$	t_{MCRL}	—	—	30	ns
$\overline{MEMWR}\uparrow \rightarrow$ READY$\uparrow$	t_{MWRL}	2 × tosc	—	4 × tosc + t_{CLK}	ns
MPUCLK$\uparrow \rightarrow$ READY$\uparrow$	t_{CRH}	—	—	20	ns
READY$\uparrow \rightarrow \overline{MEMCS}\uparrow$ hold time	t_{RMC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{MEMWR}\uparrow$ hold time	t_{RMW}	0	—	—	ns
Write data hold time	t_{WRMW}	0	—	—	ns
Address hold time	t_{RA}	0	—	—	ns

3.1.4.4 MEMRD Timing (MPU Read Data from Video Memory)

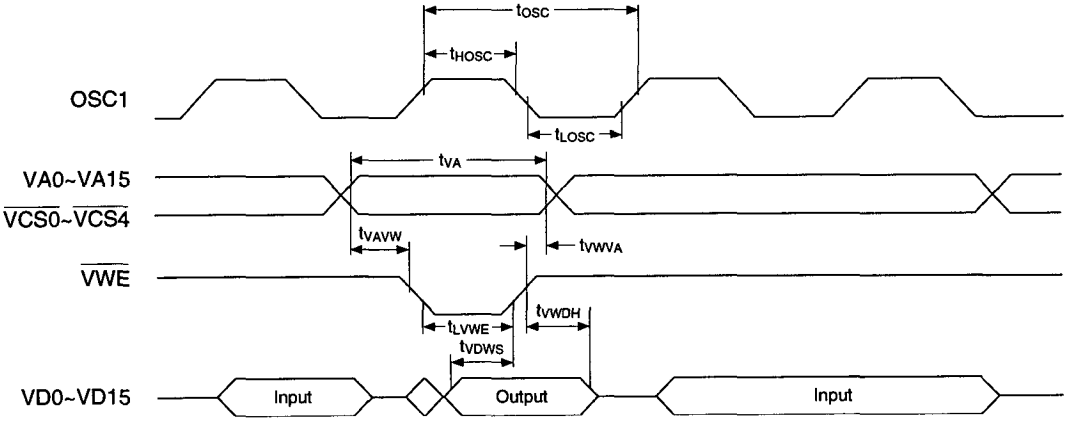


(Ta = –20 to 75°C)

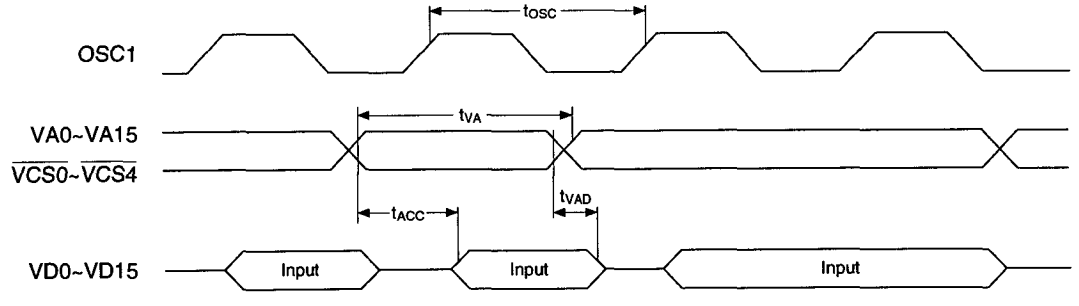
Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK	t_{CLK}	80	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{MEMCS}$ address setup time	t_{AMC}	0	—	—	ns
$\overline{MEMRD}$ address setup time	t_{AMR}	0	—	—	ns
$\overline{MEMCS}\downarrow \rightarrow \overline{MEMRD}\downarrow$	t_{MCMR}	0	—	—	ns
$\overline{MEMCS}\downarrow \rightarrow$ READY$\downarrow$	t_{MCRL}	—	—	30	ns
$\overline{MEMRD}\downarrow \rightarrow$ READY$\uparrow$	t_{MRRL}	2 × tosc	—	4 × tosc + t_{CLK}	ns
MPUCLK$\uparrow \rightarrow$ READY$\uparrow$	t_{CRH}	—	—	20	ns
$\overline{MEMCS}\downarrow \rightarrow$ data valid	t_{MRDA}	2 × tosc	—	4 × tosc	ns
Data valid $\rightarrow$ READY$\uparrow$	t_{DRMR}	0	—	—	ns
Read data hold time	t_{MRDH}	0	—	—	ns
READY$\uparrow \rightarrow \overline{MEMCS}\uparrow$ hold time	t_{RMC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{MEMRD}\uparrow$ hold time	t_{RMR}	0	—	—	ns
Address hold time	t_{RA}	0	—	—	ns

3.1.4.5 VRAM Interface Timing

3.1.4.5.1 Write Data to VRAM



3.1.4.5.2 Read Data From VRAM



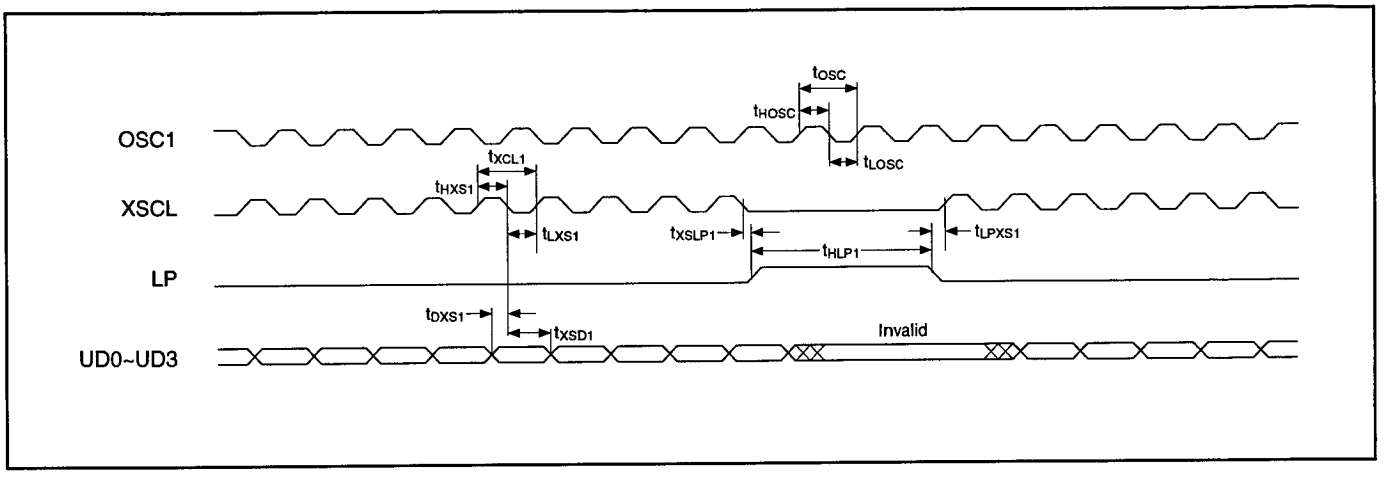
3.1.4.5.3 Timing

(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
OSC1	t_{OSC}	80	—	500	ns
OSC1 "H" pulse width	t_{HOSC}	—	1/2 × tosc	—	ns
OSC1 "L" pulse width	t_{LOSC}	—	1/2 × tosc	—	ns
$\overline{VWE}$ address setup time	t_{VAVW}	1/2 × tosc – 20	1/2 × tosc	—	ns
$\overline{VWE}$ address setup time	t_{VWVA}	0	—	—	ns
$\overline{VWE}$ "L" pulse width	t_{LVWE}	1/2 × tosc – 10	1/2 × tosc	—	ns
$\overline{VWE}$ data setup time	t_{VDWS}	1/2 × tosc – 25	1/2 × tosc	—	ns
$\overline{VWE}$ data hold time	t_{VWDH}	0	—	20	ns
VRAM address cycle time	t_{VA}	tosc	—	—	ns
VRAM address access time	t_{ACC}	—	—	tosc – 20	ns
VRAM read data hold time	t_{VAD}	0	—	—	ns

3.1.4.6 LCD Interface Timing

3.1.4.6.1 Mode 1 (4-Bit transfer)

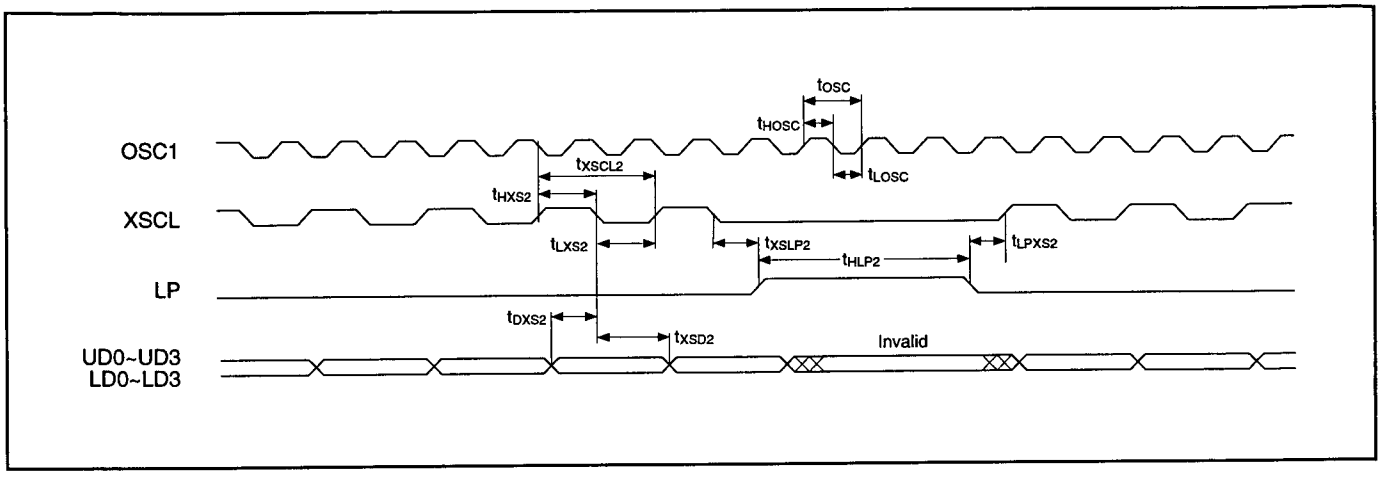


(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
OSC1	t_{OSC}	80	—	500	ns
OSC1 "H" pulse width	t_{HOSC}	1/2 × tosc – 10	—	—	ns
OSC1 "L" pulse width	t_{LOSC}	1/2 × tosc – 10	—	—	ns
XSCL	t_{XSCL1}	—	—	—	ns
XSCL "H" pulse width	t_{HXS1}	1/2 × tosc – 10	—	—	ns
XSCL "L" pulse width	t_{LXS1}	1/2 × tosc – 10	—	—	ns
XSCL↓ → LP↑	t_{XSLP1}	–10			
LP↓ → XSCL↑	t_{LPXS1}	tosc – 10			
Data setup time	t_{DXS1}	1/2 × tosc – 10	—	—	ns
Data hold time	t_{XSD1}	1/2 × tosc – 20	—	—	ns
LP "H" pulse width (Note 1)	t_{HLP1}	(2n – 1/2) × tosc – 20	—	—	ns

Note 1: "n" is the value of LWP

3.1.4.6.2 Mode 1 (8-bit transfer), Mode 2, Mode 3 (4-bit transfer), Mode 5



(Ta = –20 to 75°C)

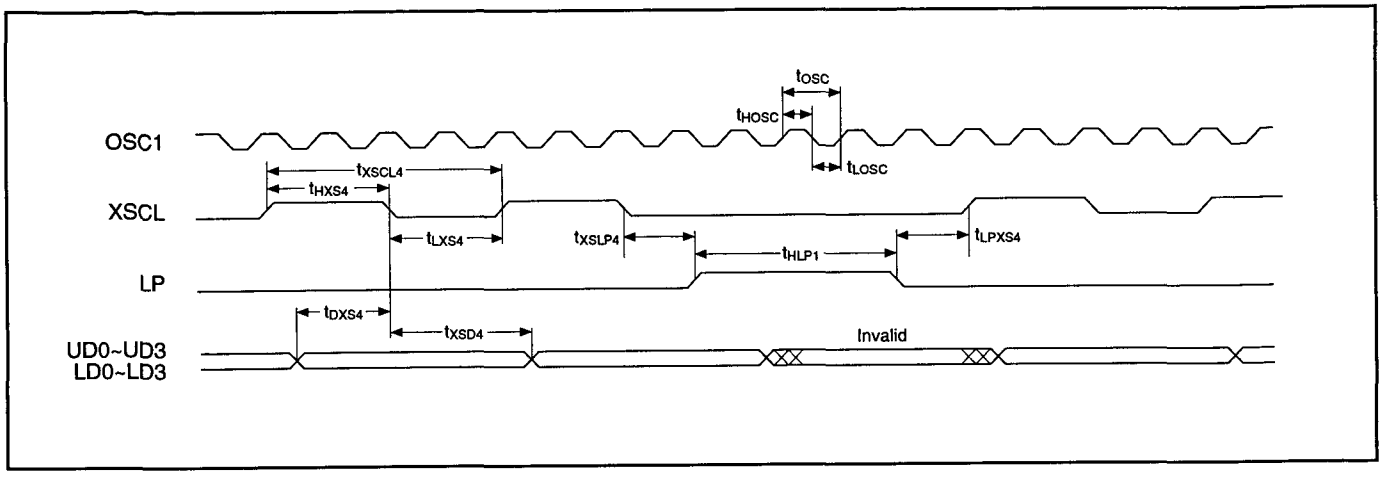
Parameter	Symbol	Min	Typ	Max	Unit
OSC1	tosc	80	—	500	ns
OSC1 "H" pulse width	tHOSC	1/2 × tosc – 10	—	—	ns
OSC1 "L" pulse width	tLOSC	1/2 × tosc – 10	—	—	ns
XSCL	tXSCL1	2 × tosc – 20	—	—	ns
XSCL "H" pulse width	tHXS2	tosc – 10	—	—	ns
XSCL "L" pulse width	tLXS2	tosc – 10	—	—	ns
XSCL↓ → LP↑	tXSLP2	1/2 × tosc – 10	—	—	ns
LP↓ → XSCL↑	tLPXS2	tosc – 10	—	—	ns
Data setup time	tDXS2	tosc – 10	—	—	ns
Data hold time	tXSD2	tosc – 20	—	—	ns
LP "H" pulse width (Note 1)	tHLP2	(2n – 1/2 × tosc – 20	—	—	ns
LP "H" pulse width (Note 2)		(4n – 1/2) × tosc – 20	—	—	ns

- "n" is the value of LWP

Note 1. Mode 1 (8-bit transfer) and Mode 2

Note 2. Mode 3 (4-bit transfer) and Mode 5

3.1.4.6.3 Mode 3 (8-bit transfer, Mode 4, Mode 6

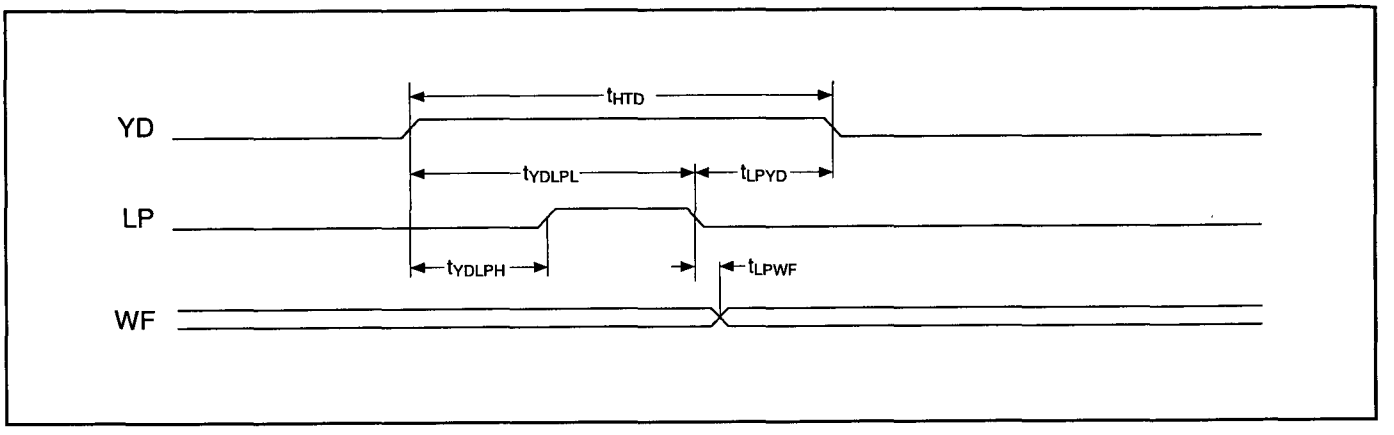


(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
OSC1	tosc	80	—	500	ns
OSC1 "H" pulse width	tHOSC	1/2 × tosc – 10	—	—	ns
OSC1 "L" pulse width	tLOSC	1/2 × tosc – 10	—	—	ns
XSCL	txSCL4	4 × tosc – 20	—	—	ns
XSCL "H" pulse width	tHXS4	2 × tosc – 20	—	—	ns
XSCL "L" pulse width	tLXS4	2 × tosc – 20	—	—	ns
XSCL↓ → LP↑	txSLP4	1.5 × tosc – 10	—	—	ns
LP↓ → XSCL↑	tLPXS4	tosc – 10	—	—	ns
Data setup time	tDXS4	2 × tosc – 20	—	—	ns
Data hold time	txSD4	2 × tosc – 20	—	—	ns
LP "H" pulse width (Note 1)	tHLP4	(4n – 1/2) × tosc – 20	—	—	ns

Note 1. "n" is the value of LWP.

3.1.4.6.4 Sync Timing



(Ta = –20 to 75°C)

Parameter		Symbol	Min	Typ	Max	Unit
YD "H" pulse width	(Note 1)	t_{HYD}	(m + n) 2 × tosc – 20	—	—	ms
	(Note 2)		(m + n) 4 × tosc – 20	—	—	ms
YD↑ → LP↑	(Note 1)	t_{YDLPH}	4.5 × tosc – 20	—	—	ms
	(Note 2)		5.5 × tosc – 20	—	—	ms
YD↑ → LP↓	(Note 1)	t_{YDLPL}	(n + 2) 2 × tosc – 20	—	—	ms
	(Note 2)		(n + 5/4) 4 × tosc – 20	—	—	ms
LP↓ → YD↓	(Note 1)	t_{LPYD}	(m – 2) 2 × tosc – 20	—	—	ms
	(Note 2)		(m – 5/4) 4 tosc – 20	—	—	ms
LP↓ WF↑↓		t_{LPWRF}	–100	—	—	ms

- "m" is the value of C/R
- "n" is the value of LPW
  1. Mode 1, Mode 2
  2. Mode 3, Mode 4, Mode 5, Mode 6.

3.2 SED1351F$_{LB}$

3.2.1 SED1351F$_{LB}$ Absolute Maximum Ratings

V_{SS} = 0V

Parameter	Symbol	Rating	Unit
Power voltage	V_{DD}	V_{SS} – 0.3 to 7.0	V
Input voltage	V_{IN}	V_{SS} – 0.3 to V_{DD} + 0.5	V
Output voltage	V_{OUT}	V_{SS} – 0.3 to V_{DD} + 0.5	V
Output current/pin	I_{OUT}	±24	mA
Allowable loss	P_D	200	mW
Power current	I_{DD}/I_{SS}	±40	mA
Storage temperature	T_{STG}	–65 to 150	°C

Note: Power current: Allowable current input to or output from power terminal V_{DD} or V_{SS}.

3.2.2 Recommended Operating Conditions

V_{SS} = 0V

Parameter	Symbol	Min	Typ	Max	Unit
Power voltage	V_{DD}	2.7	—	3.6	V
Input voltage	V_{IN}	Vss	—	V_{DD}	V
Operating temperature	T_{OPR}	–20	—	75	°C

3.2.3 SED1351F$_{LB}$ DC Characteristics

(Ta = –20 to 75°C)

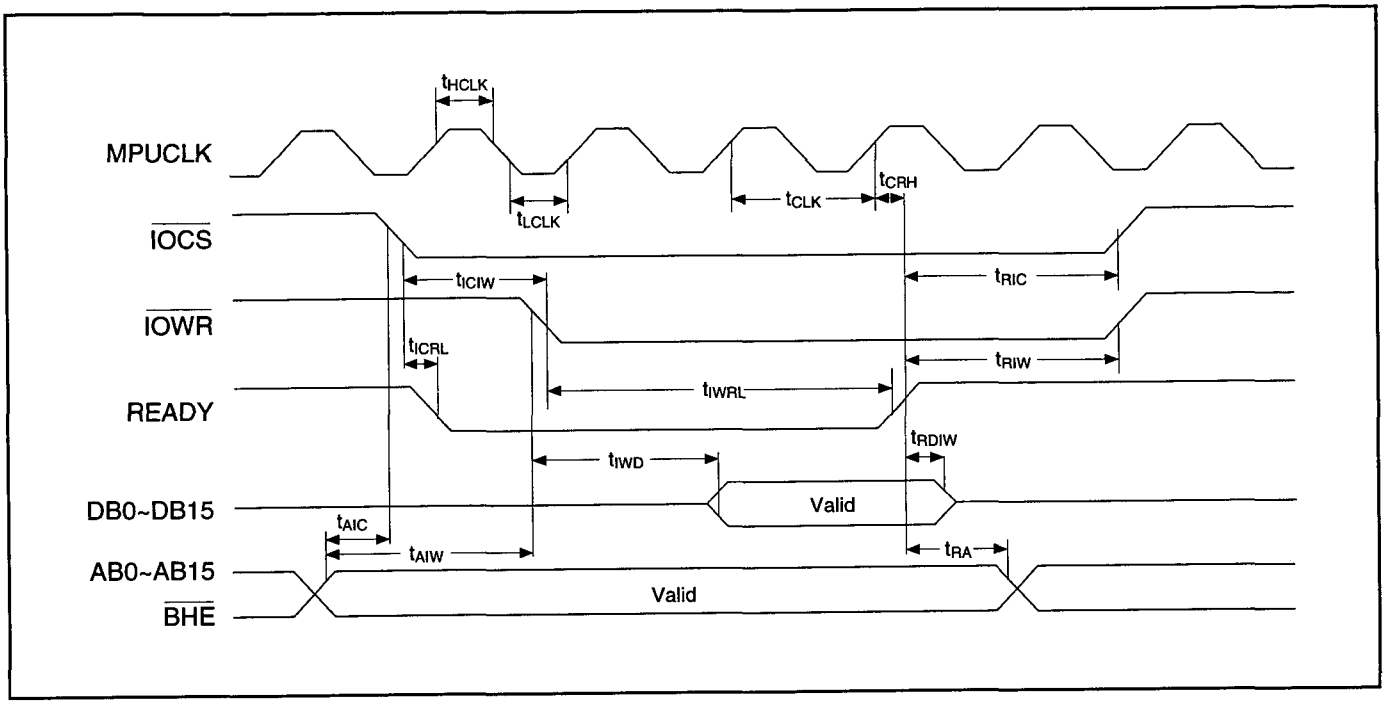
Parameter	Symbol	Condition	Min	Typ	Max	Unit	Pin
Static current	I_{DDS}	$V_{IN} = V_{DD}, V_{SS}$ V_{DD} = MAX $I_{OH} = I_{OL} = 0$	—	—	30	µA	
Input leakage current	I_L	V_{DD} = MAX $V_{IH} = V_{DD}$ $V_{IL} = V_{SS}$	–1	—	1	µA	Note 1
"H" level input voltage (1)	V_{IH1}	V_{DD} = MAX	0.7 V_{DD}	—	—	V	OSC1
"L" level input voltage (1)	V_{IL1}	V_{DD} = MIN	—	—	0.2 V_{DD}	V	
"H" level input voltage (2)	V_{IH2}	V_{DD} = MAX	0.7 V_{DD}	—	—	V	Note 2
"L" level input voltage (2)	V_{IL2}	V_{DD} = MIN	—	—	0.2 V_{DD}	V	
"H" level input voltage (3)	V_{T+}	V_{DD} = MAX	0.8 V_{DD}	—	—	V	
"L" level input voltage (3)	V_{T-}	V_{DD} = MIN	—	—	0.2 V_{DD}	V	Note 3
Hysteresis voltage	V_H	V_{DD} = TYP	0.3	—	—	V	
"H" level output voltage (1)	V_{OH1}	V_{DD} = MIN I_{OH} = –1.5mA I_{OL} = 3mA	V_{DD} – 0.3	—	—	V	Note 4
"L" level output voltage (1)	V_{OL1}		—	—	V_{SS} + 0.3	V	
"H" level output voltage (2)	V_{OH2}	V_{DD} = MIN I_{OH} = –50µA I_{OL} = 50µA	V_{DD} – 0.4	—	—	V	OSC2
"L" level output voltage (2)	V_{OL2}		—	—	V_{SS} + 0.4	V	

Notes:

1. $\overline{MEMCS}$, $\overline{MEMWR}$, $\overline{MEMRD}$, $\overline{IOCS}$, $\overline{IOWR}$, $\overline{IORD}$, MPUCLK, ABO-AB15, $\overline{BHE}$, MPUSEL, RESET, OSC1
2. $\overline{MEMCS}$, $\overline{MEMWR}$, $\overline{MEMRD}$, $\overline{IOCS}$, $\overline{IOWR}$, $\overline{IORD}$, MPUCLK, ABO-AB15, $\overline{BHE}$, DBO-DB15, VD0-VD15
3. MPUSEL, RESET
4. DB0-DB15, READY, VA0-VA15, $\overline{VCS0}$~$\overline{VCS4}$, VD0~VD15, $\overline{VWE}$, XSCL, LP, WF, YD, UD0~UD3, LD0~LD3, LCDENB

3.2.4 SED1351F$_{LB}$ AC Characteristics

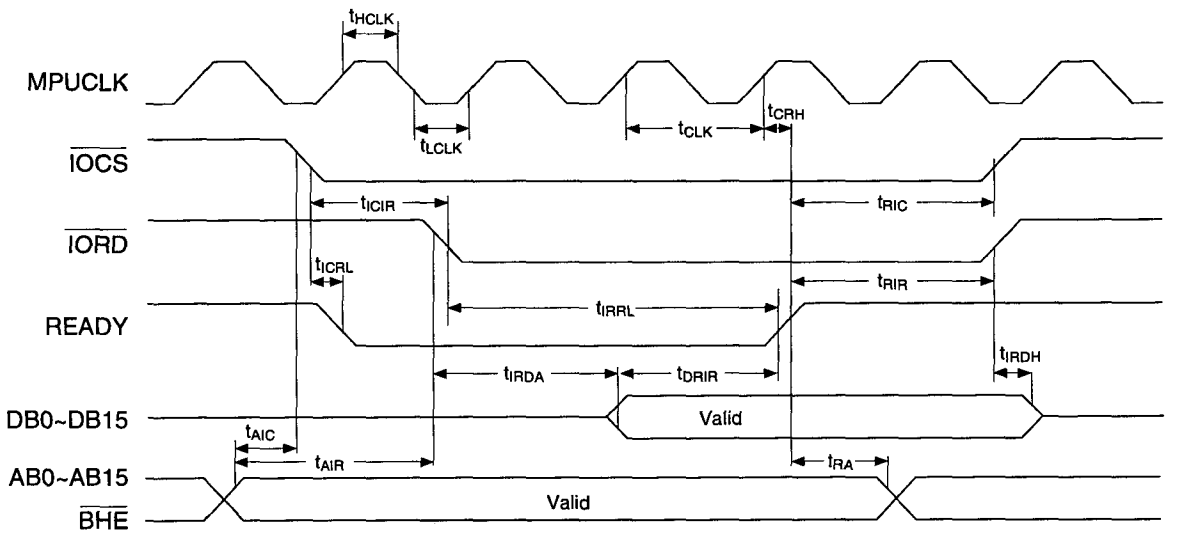
3.2.4.1 IOWR Timing (Write to the Control Register)



(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK cycle	t_{CLK}	100	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{IOCS}$ address setup time	t_{AIC}	0	—	—	ns
$\overline{IOWR}$ address setup time	t_{AIW}	0	—	—	ns
$\overline{IOCS}\downarrow \rightarrow \overline{IOWR}\downarrow$	t_{ICIW}	0	—	—	ns
$\overline{IOWR}\downarrow$ → written data determination	t_{IWD}	—	—	1.5 × tosc	ns
$\overline{IOCS}\downarrow$ → Not Ready	t_{ICRL}	8	—	39	ns
$\overline{IORD}\downarrow$ → Not Ready period	t_{IWRL}	2 × tosc + 17	—	4 × tosc + 85 + t_{CLK}	ns
MPUCLK$\uparrow$ → READY	t_{CRH}	7	—	20	ns
READY$\uparrow \rightarrow \overline{IOCS}$ hold time	t_{RIC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{IOWR}$ hold time	t_{RIW}	0	—	—	ns
READY$\uparrow$ → Written data hold time	t_{RDIW}	0	—	—	ns
READY$\uparrow$ → Address hold time	t_{RA}	0	—	—	ns

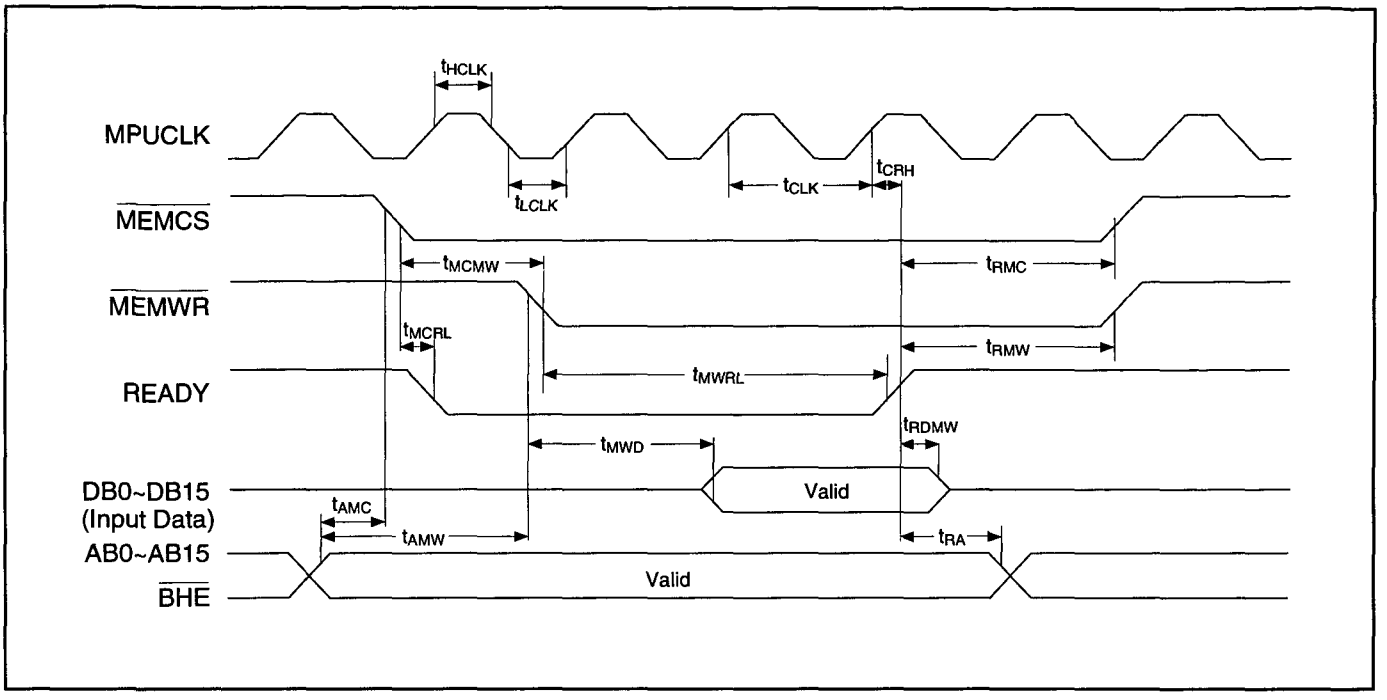
3.2.4.2 IORD Timing (Read from Control Register)



(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK cycle	t_{CLK}	100	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{IOCS}$ address setup time	t_{AIC}	0	—	—	ns
$\overline{IORD}$ address setup time	t_{AIR}	0	—	—	ns
$\overline{IOCS}\downarrow \rightarrow \overline{IORD}\downarrow$	t_{ICIR}	0	—	—	ns
$\overline{IOCS}\downarrow \rightarrow$ Not Ready	t_{ICRL}	8	—	39	ns
$\overline{IORD}\downarrow \rightarrow$ Not Ready period	t_{IRRL}	2 × t_{OSC} + 17	—	4 × t_{OSC} + 85 + t_{CLK}	ns
MPUCLK$\uparrow \rightarrow$ Ready	t_{CRH}	7	—	36	ns
$\overline{IORD}\downarrow \rightarrow$ Read data determination	t_{IRDA}	2 × t_{OSC}	—	4 × t_{OSC} + 50	ns
Read data determination $\rightarrow$ READY$\uparrow$	t_{DRIR}	0	—	—	ns
$\overline{IORD}\downarrow \rightarrow$ Read data hold time	t_{IRDH}	0	—	—	ns
READY$\uparrow \rightarrow \overline{IOCS}$ hold time	t_{RIC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{IORD}$ hold time	t_{RIR}	0	—	—	ns
READY$\uparrow \rightarrow$ Address hold time	t_{RA}	0	—	—	ns

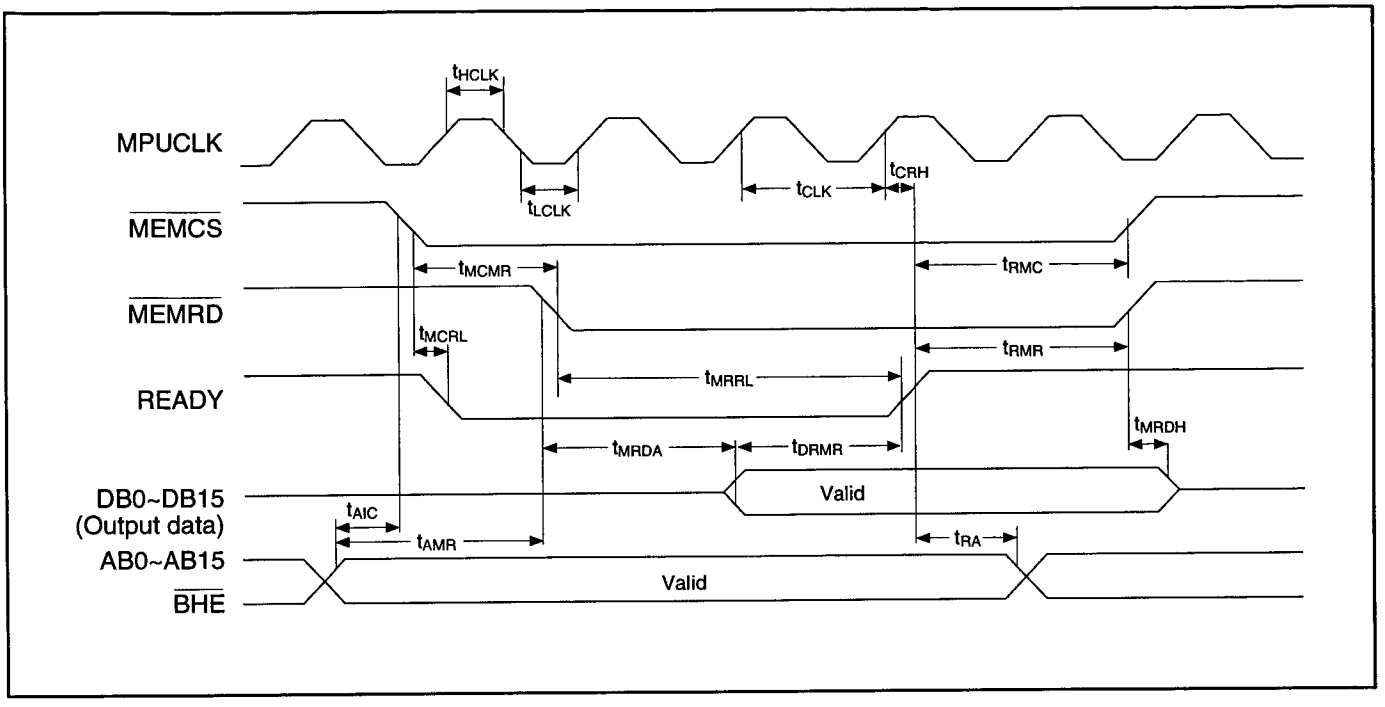
3.2.4.3 MEMWR Timing (Write to the VRAM)



(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK cycle	t_{CLK}	100	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{MEMCS}$ address setup time	t_{AMC}	0	—	—	ns
$\overline{MEMWR}$ address setup time	t_{AMW}	0	—	—	ns
$\overline{MEMCS}\downarrow \rightarrow \overline{MEMWR}\downarrow$	t_{MCMW}	0	—	—	ns
$\overline{MEMWR}\downarrow \rightarrow$ Written data determination	t_{MWD}	—	—	1.5 × t_{OSC}	ns
$\overline{MEMCS}\downarrow \rightarrow$ Not Ready	t_{MCRL}	8	—	39	ns
$\overline{MEMWR}\downarrow \rightarrow$ Not Ready period	t_{MWRL}	2 × t_{OSC} +17	—	4 × t_{OSC} + 85 + t_{CLK}	ns
MPUCLK$\uparrow \rightarrow$ READY	t_{CRH}	7	—	36	ns
READY$\uparrow \rightarrow \overline{MEMCS}$ hold time	t_{RMC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{MEMWR}$ hold time	t_{RMW}	0	—	—	ns
READY$\uparrow \rightarrow$ Written data hold time	t_{RDMW}	0	—	—	ns
READY$\uparrow \rightarrow$ Address hold time	t_{RA}	0	—	—	ns

3.2.4.4 MEMRD Timing (Read from the VRAM)

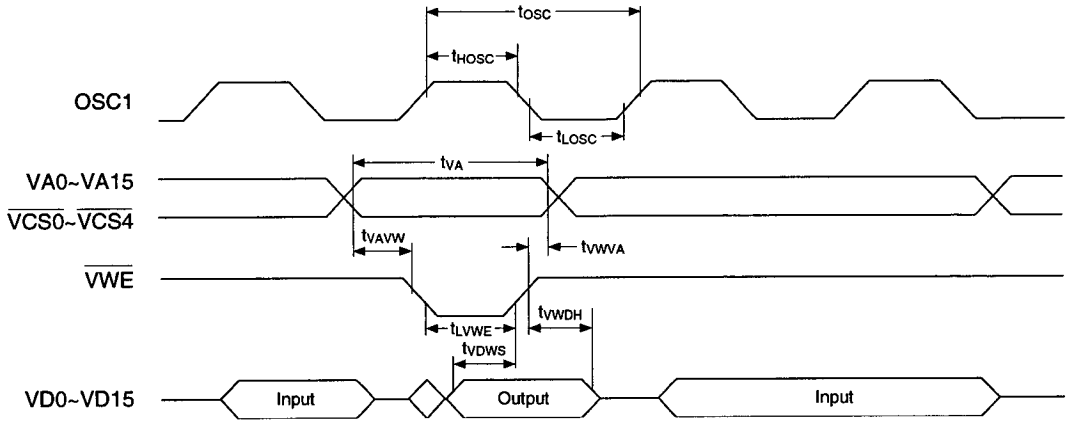


(Ta = –20 to 75°C)

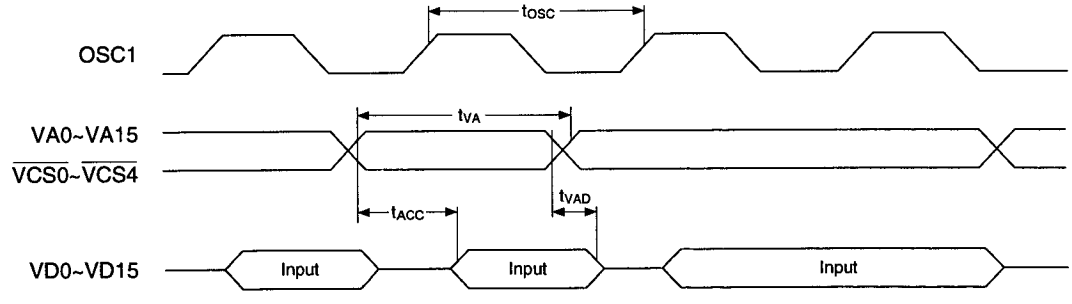
Parameter	Symbol	Min	Typ	Max	Unit
MPUCLK cycle	t_{CLK}	100	—	1000	ns
MPUCLK "H" pulse width	t_{HCLK}	20	1/2 × t_{CLK}	—	ns
MPUCLK "L" pulse width	t_{LCLK}	20	1/2 × t_{CLK}	—	ns
$\overline{MEMCS}$ address setup time	t_{AMC}	0	—	—	ns
$\overline{MEMRD}$ address setup time	t_{AMR}	0	—	—	ns
$\overline{MEMCS}\downarrow \rightarrow \overline{MEMRD}\downarrow$	t_{MCMR}	0	—	—	ns
$\overline{MEMCS}\downarrow \rightarrow$ Not Ready	t_{MCRL}	8	—	39	ns
$\overline{MEMRD}\downarrow \rightarrow$ Not Ready period	t_{MRRL}	2 × tosc + 17	—	4 × tosc + 85 + t_{CLK}	ns
MPUCLK$\uparrow \rightarrow$ Ready	t_{CRH}	7	—	36	ns
$\overline{MEMRD}\downarrow \rightarrow$ Read data determination	t_{MRDA}	2 × tosc	—	4 × tosc + 76	ns
Read data determination $\rightarrow$ READY$\uparrow$	t_{DRMR}	0	—	—	ns
$\overline{MEMRD}\uparrow \rightarrow$ Read data hold time	t_{MRDH}	0	—	—	ns
READY$\uparrow \rightarrow \overline{MEMCS}$ hold time	t_{RMC}	0	—	—	ns
READY$\uparrow \rightarrow \overline{MEMRD}$ hold time	t_{RMR}	0	—	—	ns
READY$\uparrow \rightarrow$ Address hold time	t_{RA}	0	—	—	ns

3.2.4.5 Timing of Interface with VRAM

3.2.4.5.1 Write to the VRAM



3.2.4.5.2 Read from the VRAM



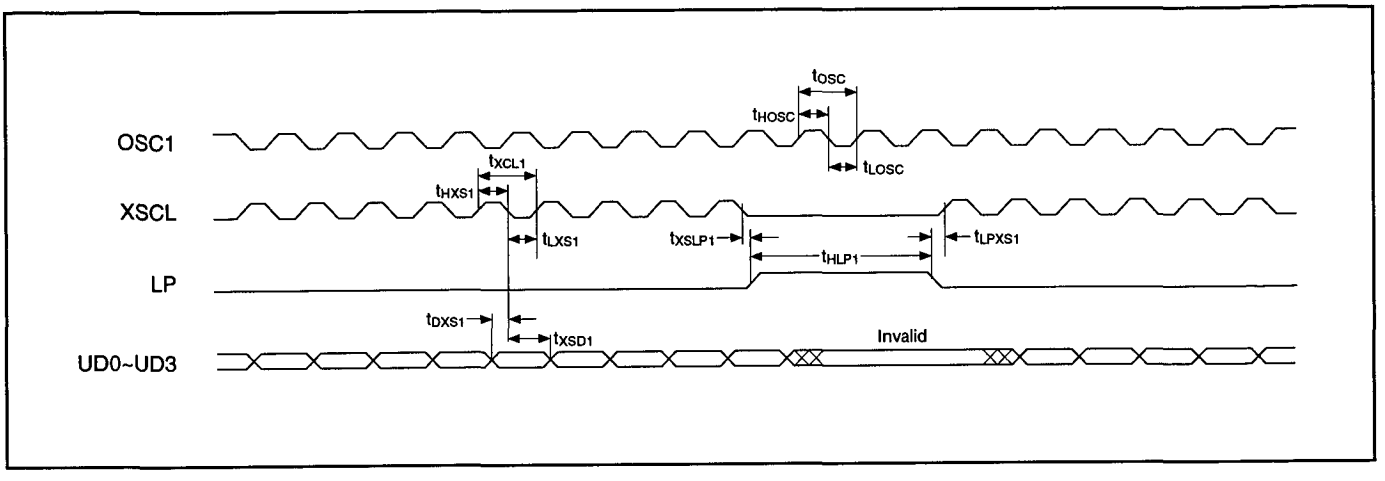
3.2.4.5.3 Timing

(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
OSC1 cycle	t_{OSC}	100	—	500	ns
OSC1 "H" pulse width	t_{HOSC}	—	1/2 × tosc	—	ns
OSC1 "L" pulse width	t_{LOSC}	—	1/2 × tosc	—	ns
$\overline{VWE}$ address setup time	t_{VAVW}	1/2 × tosc – 20	1/2 × tosc	—	ns
$\overline{VWE}$ address hold time	t_{VWVA}	0	—	—	ns
$\overline{VWE}$ "L" pulse width	t_{LVWE}	1/2 × tosc – 10	1/2 × tosc	—	ns
$\overline{VWE}$ data setup time	t_{VDWS}	1/2 × tosc – 25	1/2 × tosc	—	ns
$\overline{VWE}$ data hold time	t_{VWDH}	0	—	20	ns
VRAM address cycle time	t_{VA}	tosc	—	—	ns
VRAM address access time	t_{ACC}	—	—	tosc – 20	ns
VRAM read data hold time	t_{VAD}	0	—	—	ns

3.2.4.6 LCD Interface Timing

3.2.4.6.1 Mode 1 (4-Bit transfer)

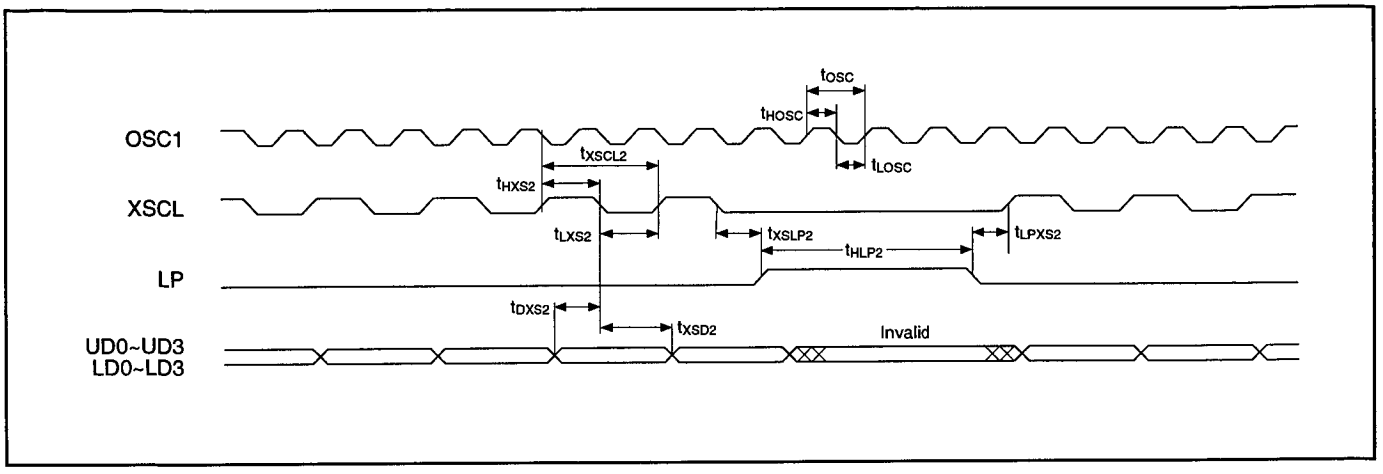


(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
OSC1 clock cycle	tosc	1000	—	500	ns
OSC1 "H" pulse width	tHOSC	1/2 × tosc – 10	—	—	ns
OSC1 "L" pulse width	tLOSC	1/2 × tosc – 10	—	—	ns
XSCL cycle	tXSCL1	—	—	—	ns
XSCL "H" pulse width	tHXS1	1/2 × tosc – 10	—	—	ns
XSCL "L" pulse width	tLXS1	1/2 × tosc – 10	—	—	ns
XSCL↓ → LP↑	tXSLP1	–10			
LP↓ → XSCL↑	tLPXS1	tosc – 10			
Data determination → XSCL↓	tDXS1	1/2 × tosc – 10	—	—	ns
XSCL↓ → Data hold time	tXSD1	1/2 × tosc – 20	—	—	ns
LP "H" pulse width (Note 1)	tHLP1	(2n – 1/2) × tosc – 20	—	—	ns

Note 1: "n" indicates the LPW value (unit: number of characters)

3.2.4.6.2 Mode 1 (8-bit transfer), Mode 2, Mode 3 (4-bit transfer), Mode 5



(Ta = –20 to 75°C)

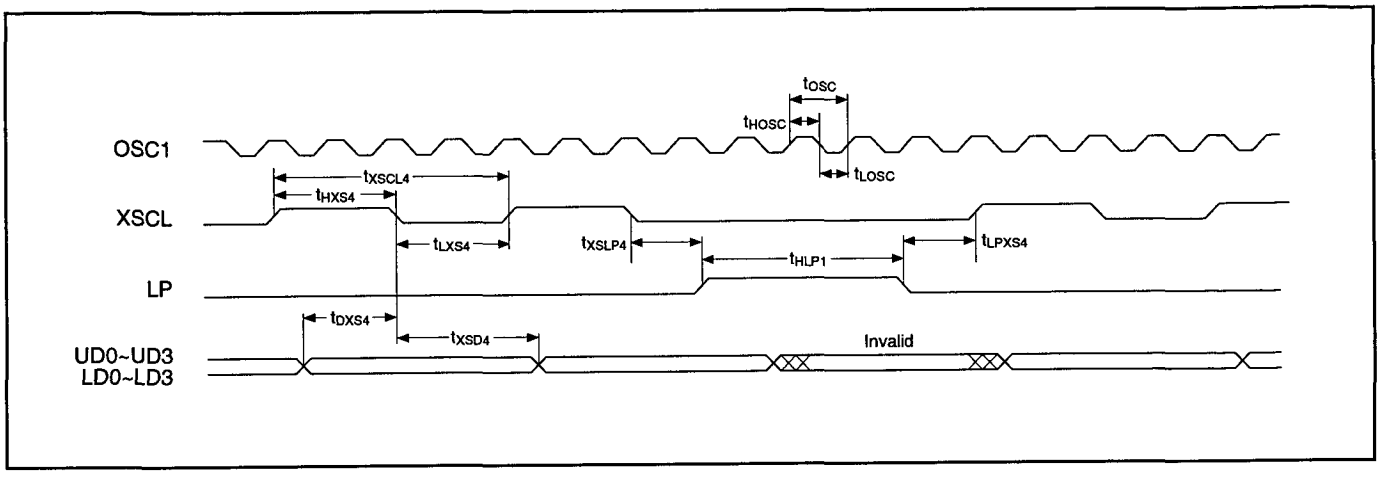
Parameter	Symbol	Min	Typ	Max	Unit
OSC1 clock cycle	t_{OSC}	100	—	500	ns
OSC1 "H" pulse width	t_{HOSC}	1/2 × tosc – 10	—	—	ns
OSC1 "L" pulse width	t_{LOSC}	1/2 × tosc – 10	—	—	ns
XSCL cycle	t_{XSCL2}	2 × tosc – 20	—	—	ns
XSCL "H" pulse width	t_{HXS2}	tosc – 10	—	—	ns
XSCL "L" pulse width	t_{LXS2}	tosc – 10	—	—	ns
XSCL↓ → LP↑	t_{XSLP2}	1/2 × tosc – 10	—	—	ns
LP↓ → XSCL↑	t_{LPXS2}	tosc – 10	—	—	ns
Data determination → XSCL↓	t_{DXS2}	tosc – 10	—	—	ns
XSCL↓ → data hold time	t_{XSD2}	tosc – 20	—	—	ns
LP "H" pulse width (Note 1)	t_{HLP2}	(2n – 1/2 × tosc – 20	—	—	ns
LP "H" pulse width (Note 2)		(4n – 1/2) × tosc – 20	—	—	ns

Notes 1 and 2: "n" is the LPW value (unit: number of characters).

Note 1: Applies to display mode Nos. 1 (8-bit transfer) and 2.

Note 2: Applies to display mode Nos. 3 (4-bit transfer) and 5.

3.2.4.6.3 Mode 3 (6-bit transfer), Mode 4, Mode 6

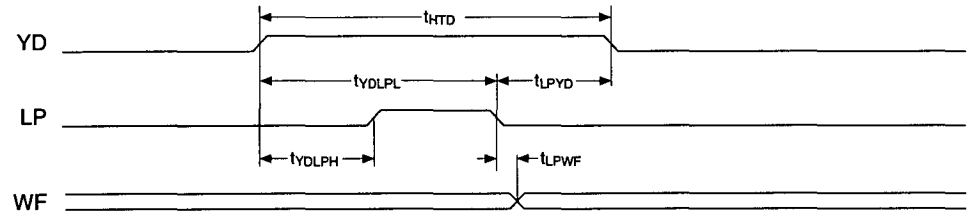


(Ta = –20 to 75°C)

Parameter	Symbol	Min	Typ	Max	Unit
OSC1 clock cycle	t_{OSC}	100	—	500	ns
OSC1 "H" pulse width	t_{HOSC}	1/2 × tosc – 10	—	—	ns
OSC1 "L" pulse width	t_{LOSC}	1/2 × tosc – 10	—	—	ns
XSCL cycle	t_{XSCL4}	4 × tosc – 20	—	—	ns
XSCL "H" pulse width	t_{HXS4}	2 × tosc – 20	—	—	ns
XSCL "L" pulse width	t_{LXS4}	2 × tosc – 20	—	—	ns
XSCL↓ → LP↑	t_{XSLP4}	1.5 × tosc – 10	—	—	ns
LP↓ → XSCL↑	t_{LPXS4}	tosc – 10	—	—	ns
Data determination → XSCL↓	t_{DXS4}	2 × tosc – 20	—	—	ns
XSCL↓ → data hold time	t_{XSD4}	2 × tosc – 20	—	—	ns
LP "H" pulse width (Note 1)	t_{HLP4}	(4n – 1/2) × tosc – 20	—	—	ns

Note 1. "n" indicates the LPW value (unit: number of characters).

3.2.4.6.4 Sync Timing



(Ta = –20 to 75°C)

Parameter		Symbol	Min	Typ	Max	Unit
YD "H" pulse width	(Note 1)	t_{HYD}	(m + n) 2 × tosc – 20	—	—	ns
	(Note 2)		(m + n) 4 × tosc – 20	—	—	ns
YD↑ → LP↑	(Note 1)	t_{YDLPH}	4.5 × tosc – 20	—	—	ns
	(Note 2)		5.5 × tosc – 20	—	—	ns
YD↑ → LP↓	(Note 1)	t_{YDLPL}	(n + 2) 2 × tosc – 20	—	—	ns
	(Note 2)		(n + 5/4) 4 × tosc – 20	—	—	ns
LP↓ → YD↓	(Note 1)	t_{LPYD}	(m – 2) 2 × tosc – 20	—	—	ns
	(Note 2)		(m – 5/4) 4 tosc – 20	—	—	ns
LP↓ → WF↑↓		t_{LPWF}	–100	—	100	ns

"m" indicates the C/R value (unit: number of characters)

"n" indicates the LPW value (unit: number of characters)

1. Applies to display mode Nos. 1 and 2.
2. Applies to display mode Nos. 3, 4, 5 and 6.

4.0
Internal Registers

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4.0 INTERNAL REGISTERS

The SED1351F is configured and controlled via an internal 14-register set, mapped into the MPU's I/O space. The address of each register is defined by AB0-AB3.

4.1 SUMMARY

Table 3. Control Registers

Type of Register		I/O Address				Data								R/W	Function
No.	Name	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0		
R1	Mode register	0	0	0	1	DISP	REV	PANEL	OR	GRAY	4/8	LCDE	RAMS	W	Sets SED1351 basic operational mode.
R2	Line Byte Count register	0	0	1	0	C/R								W	Sets number of horizontal display characters per line.
R3	Horizontal sync pulse width register	0	0	1	1	LPW								W	Sets width of LP pulse.
R4	Total display line count register	0	1	0	0	SLTL								W	Sets total number of displayed lines (the low-order 8 bits in SLTL and the high-order 2 bits in SLTH).
R5		0	1	0	1	*	*	*	*	*	*	SLTH		W	
R6	Screen 1 display start address register	0	1	1	0	SAD1L								R/W	Sets start address of screen 1 (the low-order 8 bits in SAD1L and the high-order 8 bits in SAD1H).
R7		0	1	1	1	SAD1H								R/W	
R8	Screen 2 display start address register	1	0	0	0	SAD2L								R/W	Sets start address of screen 2 (the low-order 8 bits in SAD2L and the high-order 8 bits in SAD2H).
R9		1	0	0	1	SAD2H								R/W	
R10	Screen 1 display line count register	1	0	1	0	SL1L								W	Sets number of displayed lines in screen 1 (the low-order 8 bits in SL1L and the high-order 4 bits in SL1H).
R11		1	0	1	1	*	*	*	*	*	*	SL1H		W	
R13	Address pitch adjustment register	1	1	0	1	APADJ								W	Set when a virtual screen is configured.
R14	Gray scale registers conversion	1	1	1	0	GS1								W	Sets gray level for gray-scale display. (C1, C0) = (0, 1) → GS1 (C1, C0) = (1, 0) → GS2
R15		1	1	1	1	GS2								W	

4.2 REGISTER DESCRIPTION

4.2.1 R1 Mode Register

This register determines the basic configuration of the SED1351F.

Table 4. R1: Mode Register

I/O Address				Data								R/W
A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
0	0	0	1	DISP	REV	PANEL	OR	GRAY	4/8	LCDE	RAMS	W

- **DISP**
  - DISP = 0: Display OFF
  - DISP = 1: Display ON

  Selects display on/off. DISP goes to 0 on RESET. If inverse video is selected (R1:D6=1) then setting the display OFF causes data 1's to be output to the LCD.

- **REV**
  - REV = 0: Normal display
  - REV = 1: Inverse display

  Selects normal/inverse display. REV goes to 0 on RESET. If back lit LCDs are used in the system REV should be set to 1.

- **PANEL**
  - PANEL = 1: Dual LCD panel drive
  - PANEL = 0: Single LCD panel drive

  Selects the LCD panel configuration. PANEL goes to 0 on RESET.

- **OR**
  - OR = 1: Single display of ORed data
  - OR = 0: Display split into two screens

  Selects one of two display modes in a single LCD system (PANEL = 0).

  (a) The display is split into two screens, with each screen being allocated a block of data in display memory (Set by SAD1 and SAD2. See description of R6, R7, R8 and R9).

  (b) A single screen is generated, made up of a bit-wise OR of the data in block 1 with that in block 2.

  OR goes to 0 on RESET. If PANEL = 1, the contents of OR are ignored.

- **GRAY**
  - GRAY = 1: Gray scale display
  - GRAY = 0: "B&W" display

  Selects between 2-level "B&W" or 4-level gray-scale display. GRAY goes to 0 on RESET.

  When a gray-scale display is selected, two bits of video memory data are used for the display of each pixel, using the conversion specification set by the contents of R14 and R15.

- **$\overline{4}$/8**
  - $\overline{4}$/8 = 1:8 bit data transfer
  - $\overline{4}$/8 = 0:4 bit data transfer

  Selects between 4- and 8-bit display data widths for the LCD, in "B&W", single LCD mode. Gray-scale or dual LCD modes force 4-bit data width, irrespective of the contents of $\overline{4}$/8. $\overline{4}$/8 goes to 0 on RESET.

- **LCDE**
  - LCDE = 0: LCDENB = V_{SS}, and the LCD power is off.
  - LCDE = 1: LCDENB = V_{DD}, and the LCD power is on.

  This bit sets the output of the LCD control line, LCDENB. LCDE goes to 0 on RESET.

  This control bit, and its associated line, are intended for use in systems that implement LCD DC voltage protection, but LCDE can ben used for other purposes if required.

- **RAMS**
  - RAMS = 0: Addressing for 8K × 8 SRAM's
  - RAMS = 1: Addressing for 32K × 8 SRAM's

  Configure the video memory address lines. RAMS goes to 0 on RESET.

4.2.2 R2 Line Byte Count Register

This register sets the number of bytes per display line.

Table 5. Line Byte Count Register

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R2	0	0	1	0	C/R								W

The contents of R2 are given by C/R = (No. of bytes) – 1

Since the maximum value of C/R is FFH, the maximum number of pixels in one display line is

- 256 × 8 = 2048 in "B&W" mode
- or 256 × 4 = 1024 in gray-scale mode

4.2.3 R3 Horizontal Sync Pulse Width Register

This register sets LPW, the width of the horizontal sync pulse (LP), which is output at the end of every line. LPW has units of "time per byte", t_B, and the contents of R3 are given by LPW = (Pulsewidth) – 1. "time per byte" is $2/f_{OSC}$ for single LCD, single screen configurations, and $4/f_{OSC}$ for all other configurations.

Note that LPW partially determines the period of one line, and hence affects the frame period.

Table 6. Horizontal Sync Pulse Width Register

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R3	0	0	1	0	LPW								W

4.2.4 R4, R5 Total Display Line Count Registers

This register sets the number of display lines on an LCD panel. The data is 10 bits long. The low order 8 bits are contained in R4, the high order 2 bits in R5.

Table 7. Total Display Line Count Register

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R4	0	1	0	0	SLTL								W
R5	0	1	0	1	*	*	*	*	*	*	SLTH		W

The contents of R4 and R5 are given by SLT = (No. of lines) – 1. Since SLT sets the number of display lines on one LCD, in dual panel mode the actual number of display lines is twice the value of (SLT). Note that SLT partially determines the frame period, and hence affects the display duty cycle. The display duty cycle is 1 / (SLT + VR) where VR, the vertical retrace period, is equal to 2. It is during the vertical retrace period that the polarity of the LCD drive waveforms are inverted.

4.2.5 R6, R7 Screen 1 Display Start Address Registers

These registers set SAD1, the start address in video memory, of screen 1. The data width is 16 bits. The low-order byte is contained in R6, the high-order byte in R7.

Table 8. Screen 1 Display Start Address Registers

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R6	0	1	1	0	SAD1L								R/W
R7	0	1	1	1	SAD1H								R/W

Screen 1 is the upper screen in 2-screen and dual-panel, dual-drive LCD mode, or the top layer in ORed mode.

4.2.6 R8, R9 Screen 2 Display Start Address Registers

These registers set SAD2 the start address, in video memory, of screen 2. The data width is 16 bits. The low-order word is contained in R8, the high-order word in R9.

Table 9. Screen 2 Display Start Address Registers

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R8	1	0	0	0	SAD2L								R/W
R8	0	1	1	1	SAD2H								R/W

Screen 2 is the lower screen in split screen and dual LCD-panel modes, or the bottom layer in ORed mode.

4.2.7 R10, R11 Screen 1 Display Line Count Registers

These registers set the number of display lines on screen 1. The data width is 10 bits. The lower 8 bits are contained in R10, the upper 2 bits in R11.

Table 10. Screen 1 Display Line Count Register

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R10	1	0	1	0	SL1L								W
R11	1	0	1	1	*	*	*	*	*	*	SL1H		W

The contents of R10 and R11 are given by SL1= (No. of lines)-1. The contents of these registers are only meaningful in single-panel, single-drive LCD mode and when R1:OR=0, beieng otherwise ignored. Note that single screen mode can be forced by setting SL1=SLT in single LCD-panel mode, as well as by setting R1:OR=1.

4.2.8 R13 Address Pitch Adjustment Register

The contents of this register set the numerical difference between the last address of a display line, and the first address in the following display line.

Table 11. Address Pitch Adjustment Register

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R13	1	1	0	0	APADJ								W

If APADJ is not equal to zero, then a virtual screen with a line length of (C/R+APADJ) bytes is created, with the display reflecting the contents of a window (C/R+1) bytes wide. The position of the window on the virtual screen is determined by SAD1 and SAD2.

4.2.9 R14, R15 Gray-Scale Conversion Registers

The contents of these registers determine the two intermediate gray levels, GS1 and GS2, associated with the bit patterns (0,1) and (1,0) respectively, when the display is in 4-level gray-scale mode.

Table 12. Gray-Scale Conversion Register

R No.	I/O Address				Data								R/W
	A3	A2	A1	A0	D7	D6	D5	D4	D3	D2	D1	D0	
R14	1	1	1	0	GS1								W
R15	1	1	1	1	GS2								W

Table 13. Gray Scale Display

C1	C0	Contents of Display
0	0	Display off
0	1	Gray display based on GS1 conversion code
1	0	Gray display based on GS2 conversion code
1	1	Display on

Note that intensity differences are produced by turning off a particular pixel during selected frames in an 8 frame cycle. Each bit in GS1 and GS2 corresponds to 1 frame in this 8 frame cycle, and if the bit is zero, the pixel will be off for that frame.

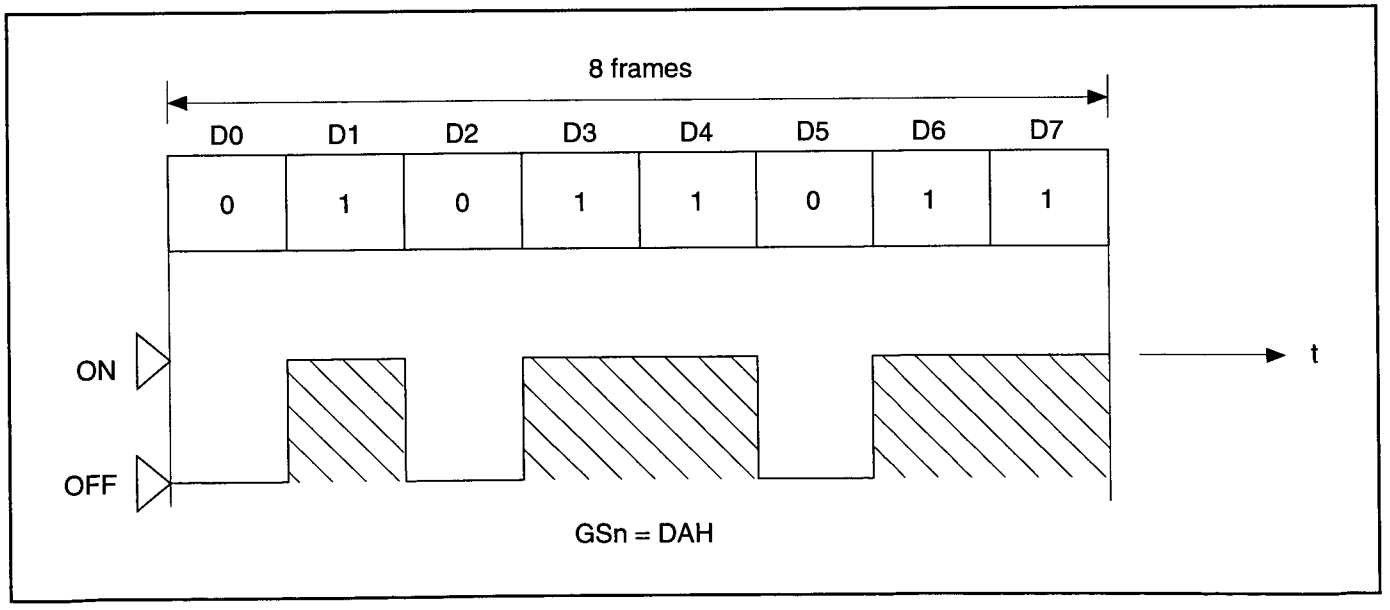

Figure 3. Gray Scale Display Implementation

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5.0
Display Modes

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5.0 DISPLAY MODES

The SED1351F has six basic oprational modes, Mode 1 to 6, which are configured by the contents of R1, the Mode Register.

Table 14. Display Modes

Mode No.	Mode Register (R1)								Configuration			
	D7	D6	D5	D4	D3	D2	D1	D0	N = LCD's	Screen	Video	Output Data Width
1	*	*	0	0	0	0	*	*	1	Split	B&W	4 bit
	*	*	0	0	0	1	*	*				8 bit
2	*	*	0	0	1	X	*	*			Gray	4 bit
3	*	*	0	1	0	0	*	*		OR	B&W	4 bit
	*	*	0	1	0	1	*	*				8 bit
4	*	*	0	1	1	X	*	*			Gray	4 bit
5	*	*	1	X	0	X	*	*	2	1 per LCD	B&W	4 bit
6	*	*	1	X	1	X	*	*			Gray	

* : Don't care

X : Ignored

5.1 MODE 1

- Single-panel, single-drive LCD
- Split display
- B&W display

Table 15. Display Mode 1

Mode register (R1)							
D7	D6	D5	D4	D3	D2	D1	D0
DISP	REV	PANEL	OR	GRAY	$\overline{4}$/8	LCDE	RAMS
*	*	0	0	0	*	*	*

An example setting for a 640 pixel × 200 line LCD panel is:

- C/R = 4FH
- LPW = 75H
- SLT = 00C7H
- SAD1 = 0000H
- SAD2 = 3E80H
- SL1 = 0063H
- APADJ = 00H

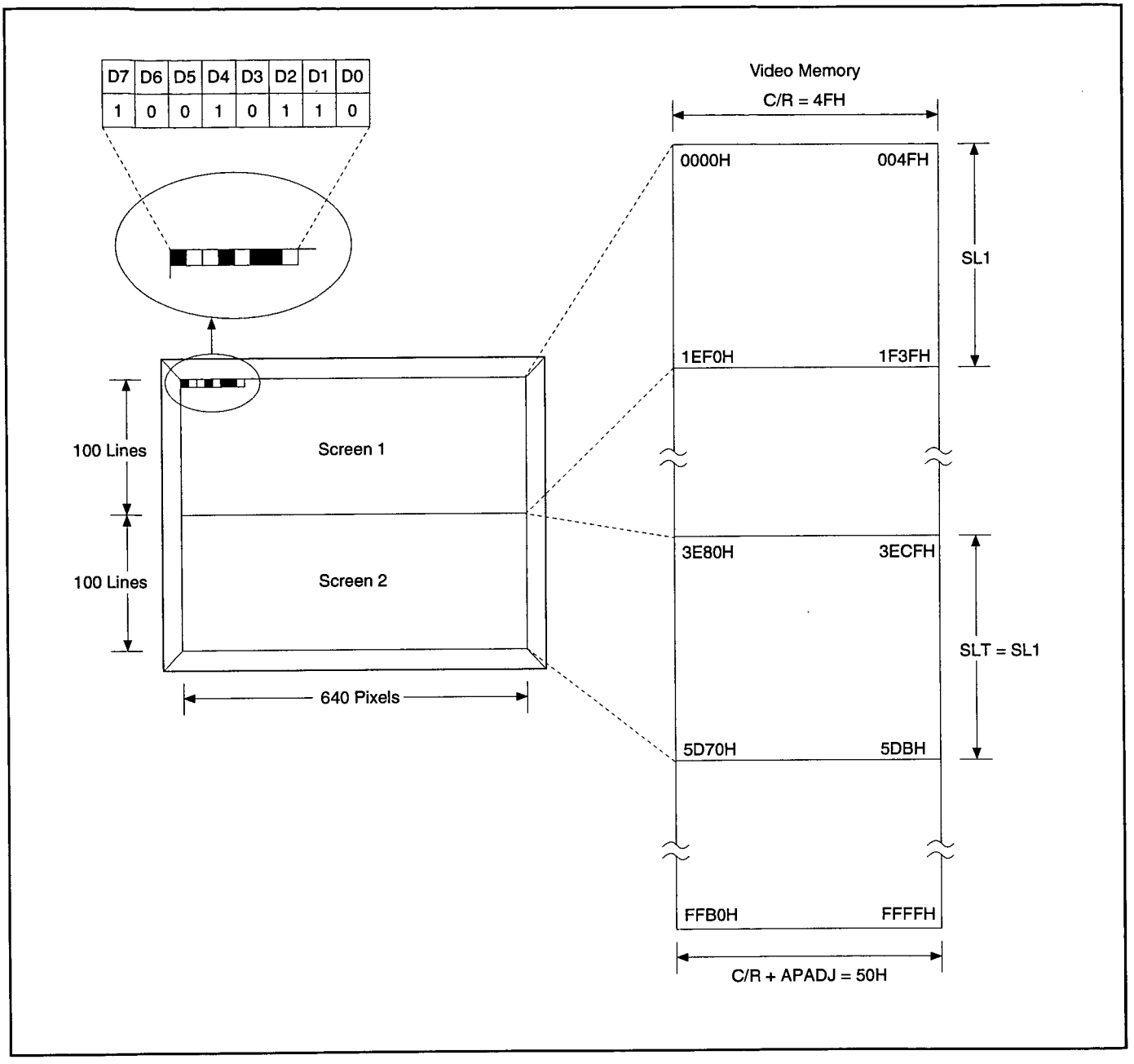


Figure 4. Display vs. VRAM: Mode 1

Mode 1 basic timing:

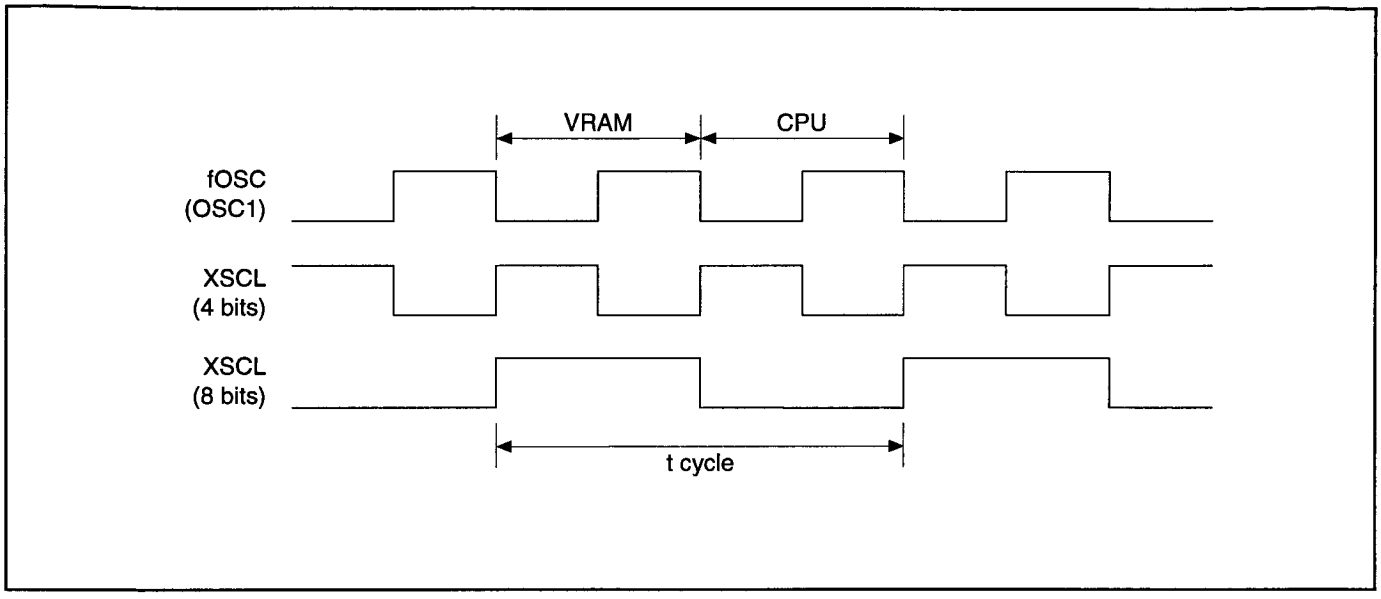


Figure 5. Basic Timing: Mode 1

A basic cycle consists of two cycles of f_{OSC}; during the first cycle data is read from video memory by the controller, during the second cycle data is prepared for CPU access to VRAM.

The period of 1 horizontal line is given by $t_H = 2 / f_{OSC} \times (C/R + LPW)$ and the period of 1 frame is given by $t_{FR} = t_H \times (SLT + 2)$.

For example:

- t_{FR} = 16 msec (f_{FR} = 62.5 Hz)
- f_{OSC} = 5 Hz

then

$$16 \times 10^{-3} = t_H \times (200 + 2)$$

$$\therefore t_H = 7.92 \times 10^{-5}s$$

$$7.92 \times 10^{-5} = \frac{2}{5 \times 10^6} \times (80 + LPW)$$

$$\therefore LPW \approx 118 \text{ characters (75H)}$$

Note that it is possible to fix LPW and then calculate f_{OSC}. If this is done the relationship below, between f_{OSC} and the VRAM access time, must hold.

$$t_{ACC} \leq \frac{1}{f_{OSC}\ (MHz)} - 20ns$$

5.2 MODE 2

- Single-panel, single-drive LCD
- Split display
- Gray-scale display

Table 16. Display Mode 2

Mode register (R1)							
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
DISP	REV	PANEL	OR	GRAY	$\overline{4}$/8	LCDE	RAMS
*	*	0	0	1	*	*	*

An example setting for a 640 pixel by 200 line LCD panel is:

- C/R = 9FH
- LPW = 19H
- SLT = 00C7
- SAD1 = 1350H
- SAD2 = XXXX
- SL1 = 00C7H
- APADJ = 60H
- GS1 = 29H
- GS2 = DAH

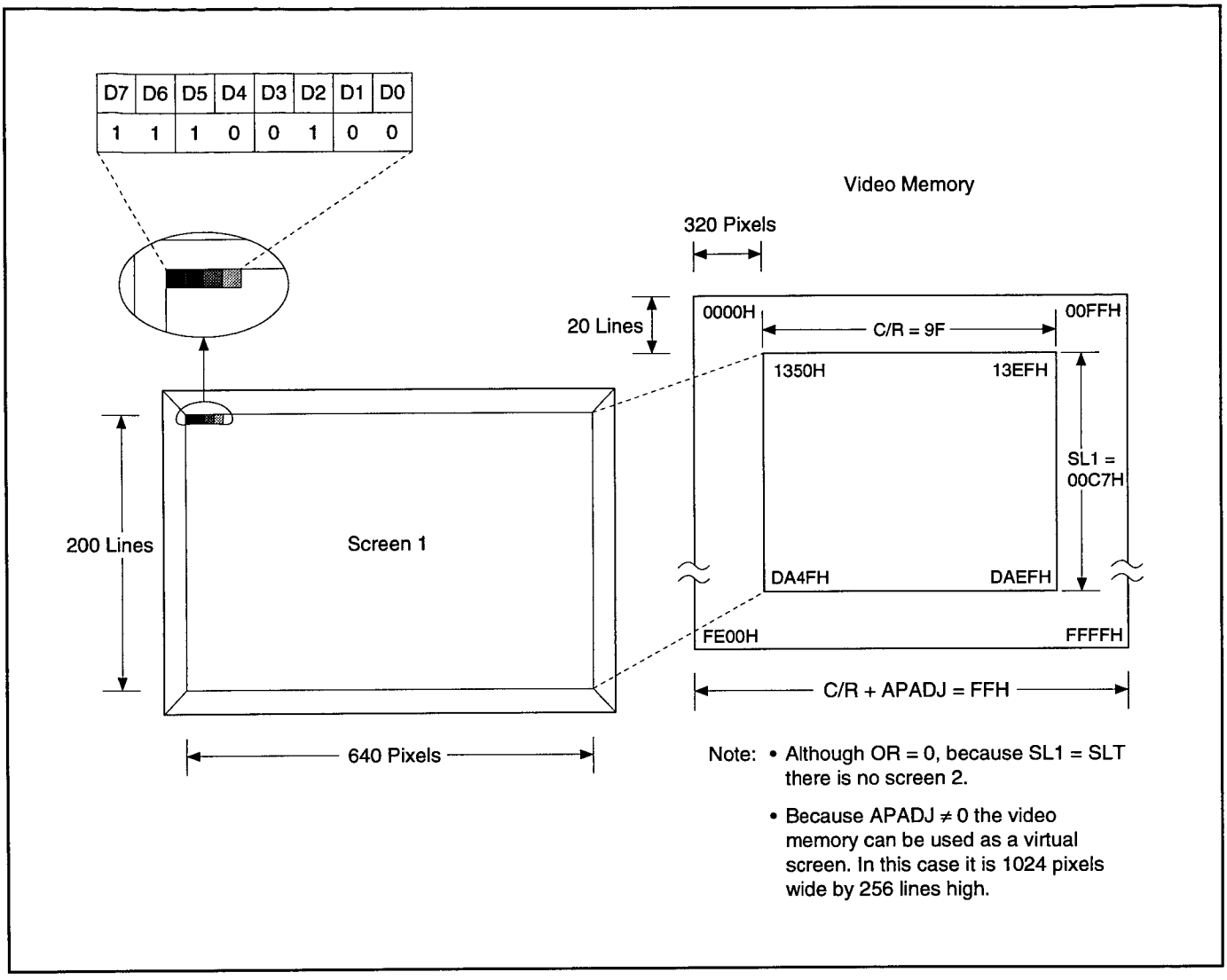


Figure 6. Display vs. VRAM: Mode 2

Mode 2 basic timing: See mode 1

For example:

- t_{FR} = 12.5 msec (f_{FR} = 80 Hz)
- f_{OSC} = 6 MHz

$$12.5\times10^{-3} = t_H \times (200+2)$$

$$\therefore t_H = 6.19\times10^{-5}\text{s}$$

$$6.19\times10^{-5} = \frac{2}{6\times10^{6}} \times (160+\text{LPW})$$

$$\therefore \text{LPW} \approx 26 \text{ characters (19H)}$$

5.3 MODE 3

- Single-panel, single-drive LCD
- ORed layer display
- B&W display

Table 17. Display Mode 3

Mode register (R1)							
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
DISP	REV	PANEL	OR	GRAY	$\overline{4}$/8	LCDE	RAMS
*	*	0	1	0	*	*	*

An example setting for a 640 pixel by 200 line LCD panel is:

- C/R = 4F
- LPW = 12H
- SLT = 00C7
- SAD1 = 0000H
- SAD2 = 3E80H
- APADJ = 00H

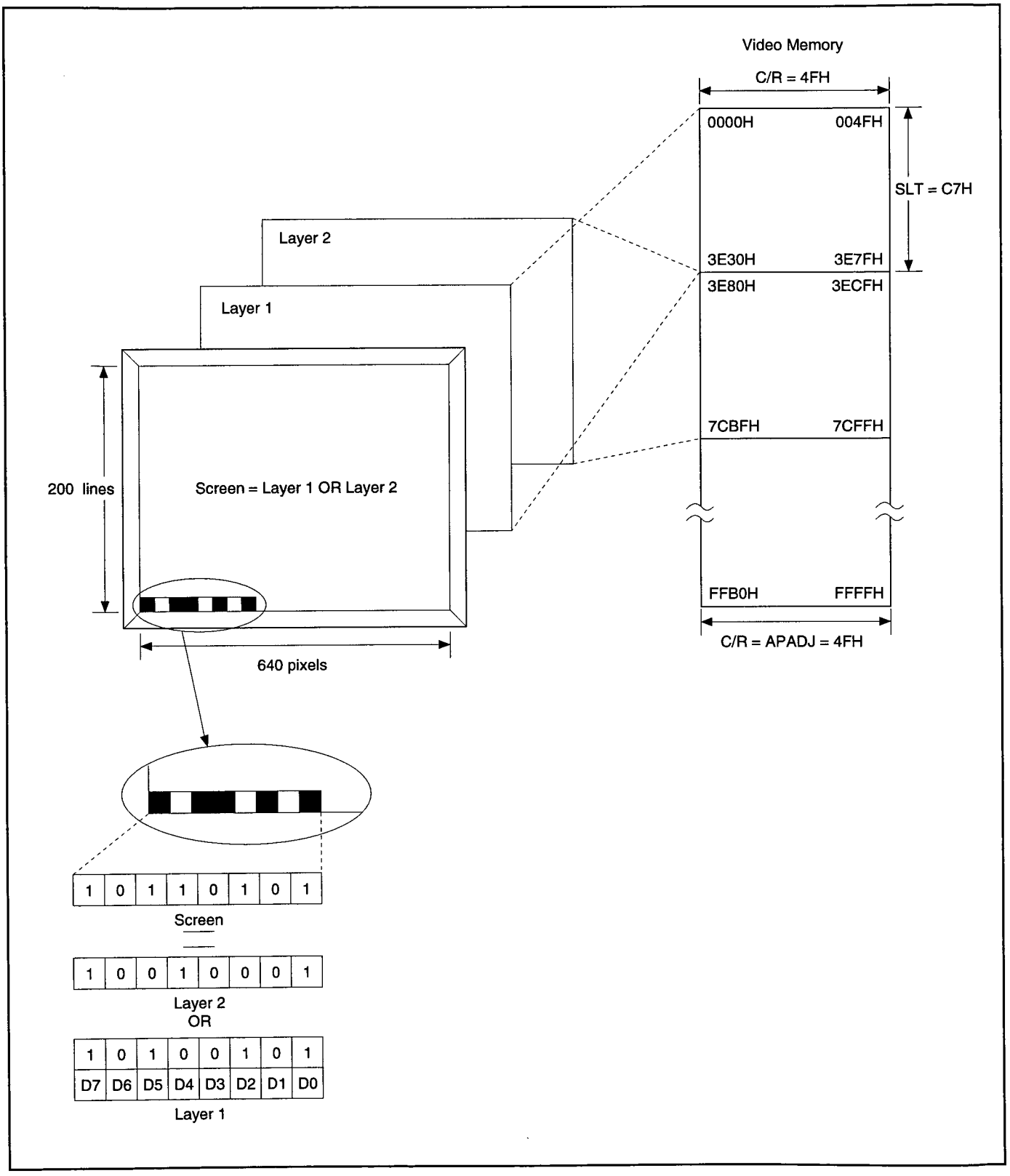


Figure 7. Display vs. VRAM: Mode 3

Mode 3 basic timing:

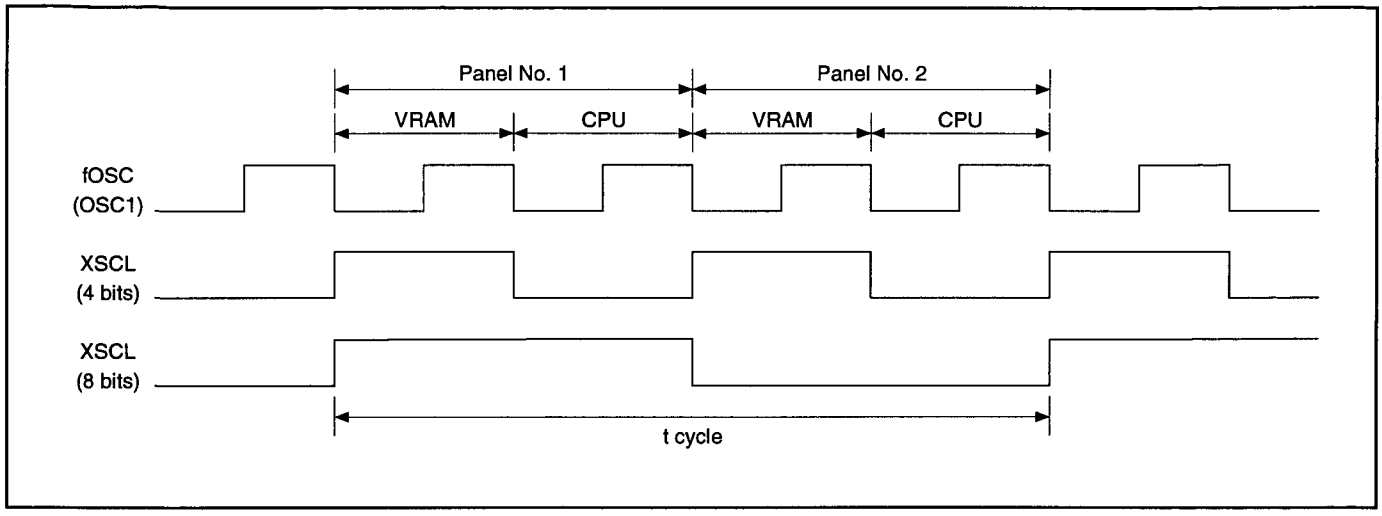


Figure 8. Basic Timing: Mode 3

For an ORed display one gasic cycle is required for each layer, that is 4 cycles of f_{OSC} are required for 1 basic period. The period of 1 horizontal line is given by $t_H = (4 / f_{OSC} \times (C/R + LPW)$ and the period of 1 frame by $t_{FH} = (f_H) \times (SLT + 2)$.

For example:

- t_{FH} = 116 msec (f_{FR} = 62.5 Hz)
- f_{OSC} = 5 MHz

$$16 \times 10^{-3} = t_H \times (200 + 2)$$

$$\therefore t_H = 7.92 \times 10^{-5} s$$

$$7.92 \times 10^{-5} = \frac{4}{5 \times 10^6} \times (80 + LPW)$$

$$\therefore LPW \approx 19 \text{ characters (12H)}$$

5.4 MODE 4

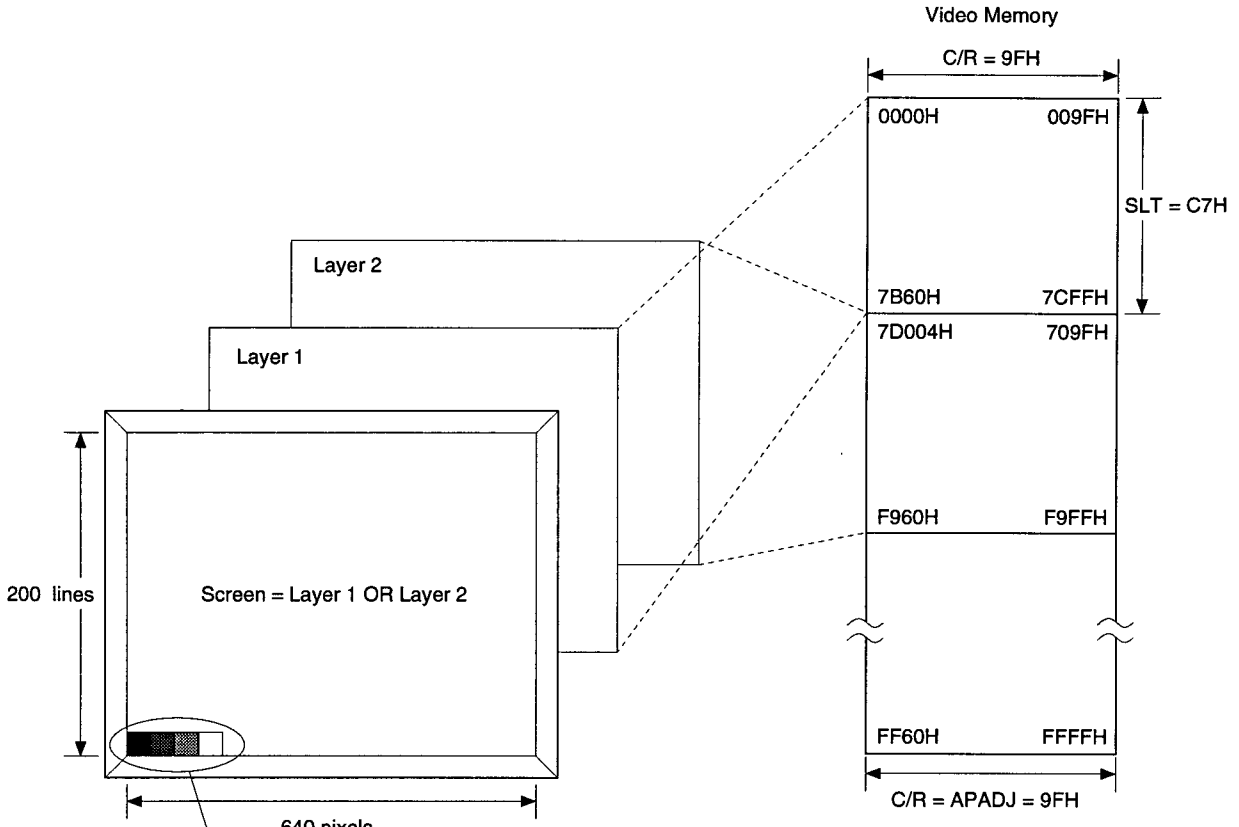
- Single-panel, single-drive LCD
- ORed layer display
- Gray-scale display

Table 18. Display Mode 4

Mode register (R1)							
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
DISP	REV	PANEL	OR	GRAY	$\overline{4}$/8	LCDE	RAMS
*	*	0	1	1	*	*	*

An example setting for a 640 pixel × 200 line LCD panel is:

- C/R = 9FH
- LPW = 18HSLT = 00C7H
- SAD1 = 0000H
- SAD2 = 7D00H
- APADJ = 00H
- GS1 = 29H
- GS2 = D5H



	L1	L2	GRAY LEVEL
D7	1	0	GS1 + GS2
D6	0	1	
D5	1	0	GS2
D4	0	0	
D3	0	0	GS1
D2	0	1	
D1	0	0	0
D0	0	0	

Figure 9. Display vs. VRAM: Mode 4

Mode 4 basic timing: See Mode 3

For example:

- t_{FR} = 14.3 ms (f_{FR} = 70 Hz
- f_{OSC} = 10 MHz

$$14.3 \times 10^{-3} = t_H \times (200 + 2)$$

$$\therefore t_H = 7.08 \times 10^{-5} s$$

$$6.19 \times 10^{-5} = \frac{4}{12 \times 10^6} \times (160 + LPW)$$

$$\therefore LPW \approx 17 \text{ characters (10H)}$$

5.5 MODE 5

- Dual-panel, dual-drive LCD
- B&W display

Table 19. Display Mode 5

Mode register (R1)							
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
DISP	REV	PANEL	OR	GRAY	$\overline{4}$/8	LCDE	RAMS
*	*	1	X	0	X	*	*

An example setting for two 640 pixel × 200 line LCD panels is:

- C/R = 4FH
- LPW = 12H
- SLT = 0047H
- SAD1 = 0000H
- SAD2 = 3E80H
- APADJ = 00H

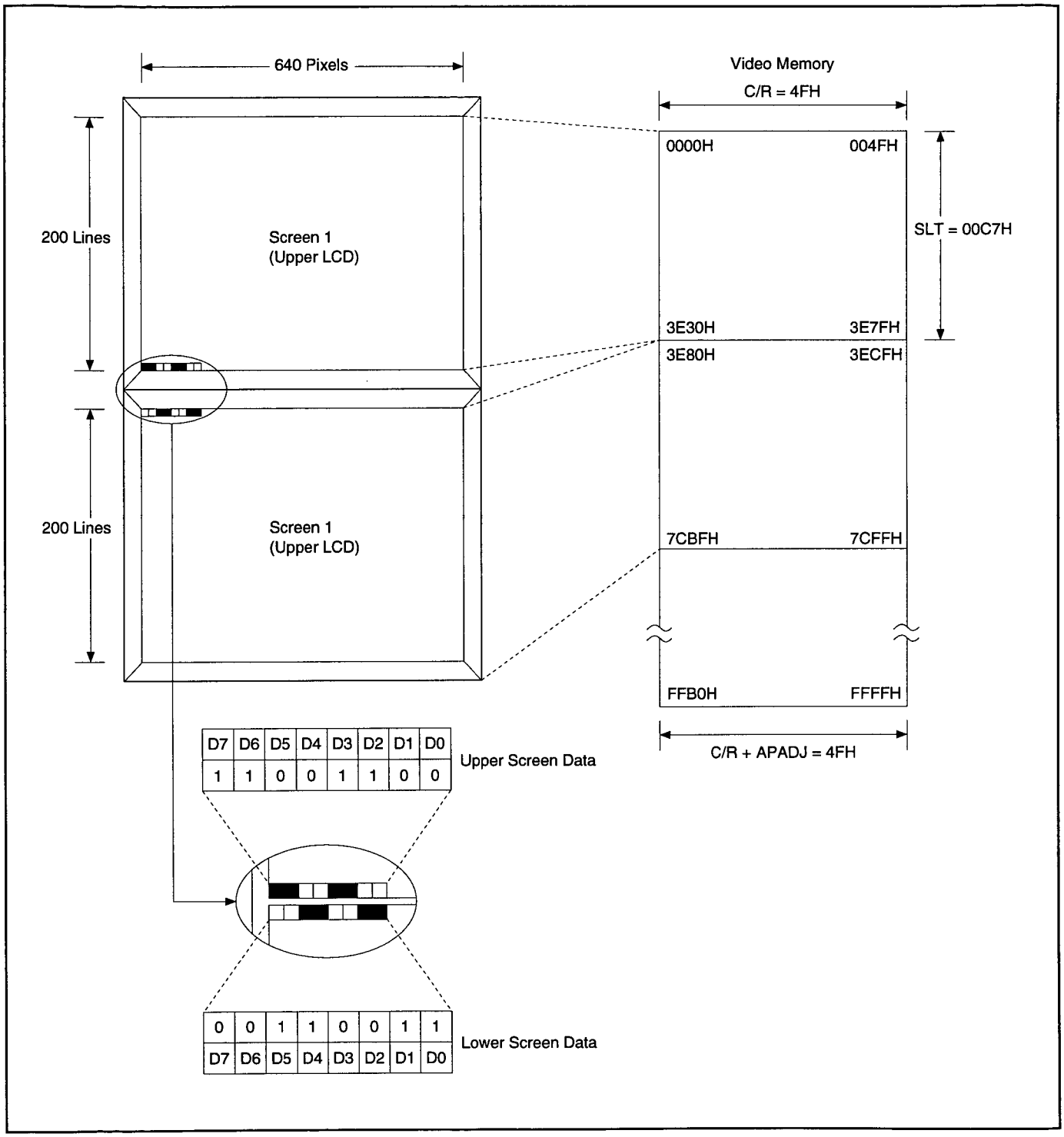


Figure 10. Display vs VRAM: Mode 5

Mode 5 basic timing:

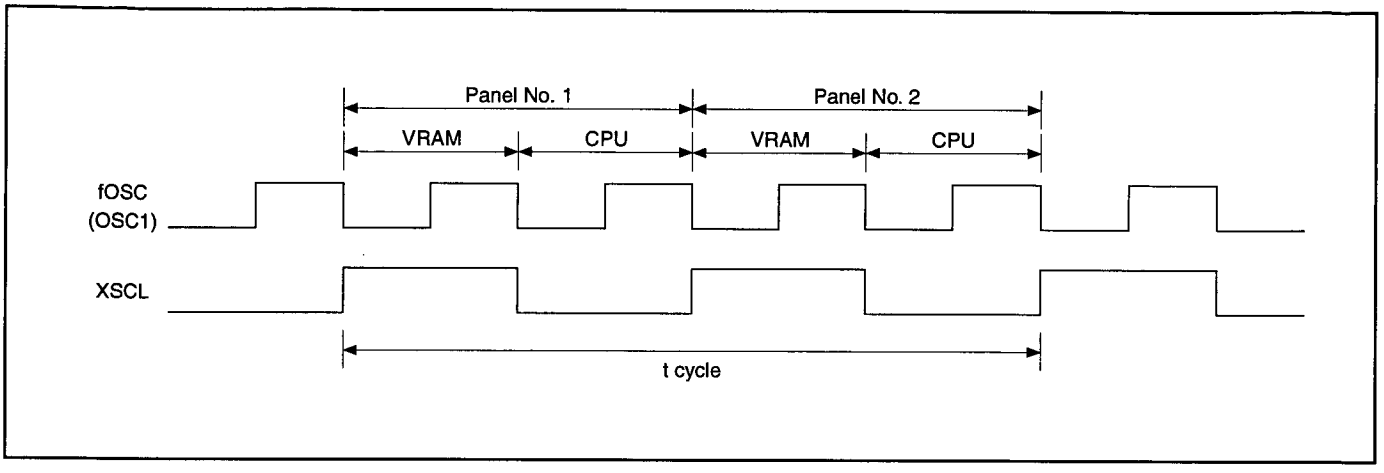


Figure 11. Basic Timing: Mode 5

With a dual LCD-panel display chosen, one basic cycle is required for each of the panels, that is 4 fosc cycles. The line and frame periods are the same as for Mode 3.

For example:

- t_{FR} = 16 msec (f_{FR} = 62.5 Hz)
- fosc = 5 MHz

$$16 \times 10^{-3} = t_H \times (200 + 2)$$

$$\therefore t_H = 7.92 \times 10^{-5} s$$

$$7.92 \times 10^{-5} = \frac{4}{5 \times 10^6} \times (80 + LPW)$$

$$\therefore LPW \approx 19 \text{ characters (12H)}$$

5.6 Mode 6

- Dual-panel, dual-drive LCD
- Gray-scale display

Table 20. Display Mode 6

Mode register (R1)							
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**
DISP	REV	PANEL	OR	GRAY	$\overline{4}$/8	LCDE	RAMS
*	*	1	X	1	X	*	*

An example setting for two 640 pixel × 200 line LCD panels is:

- C/R = 9FH
- LPW = 18H
- SLT = 00C7H
- SAD1 = 0000H
- SAD2 = 7D00H
- APADJ = 00H
- GS1 = 29H
- GS2 = D5H

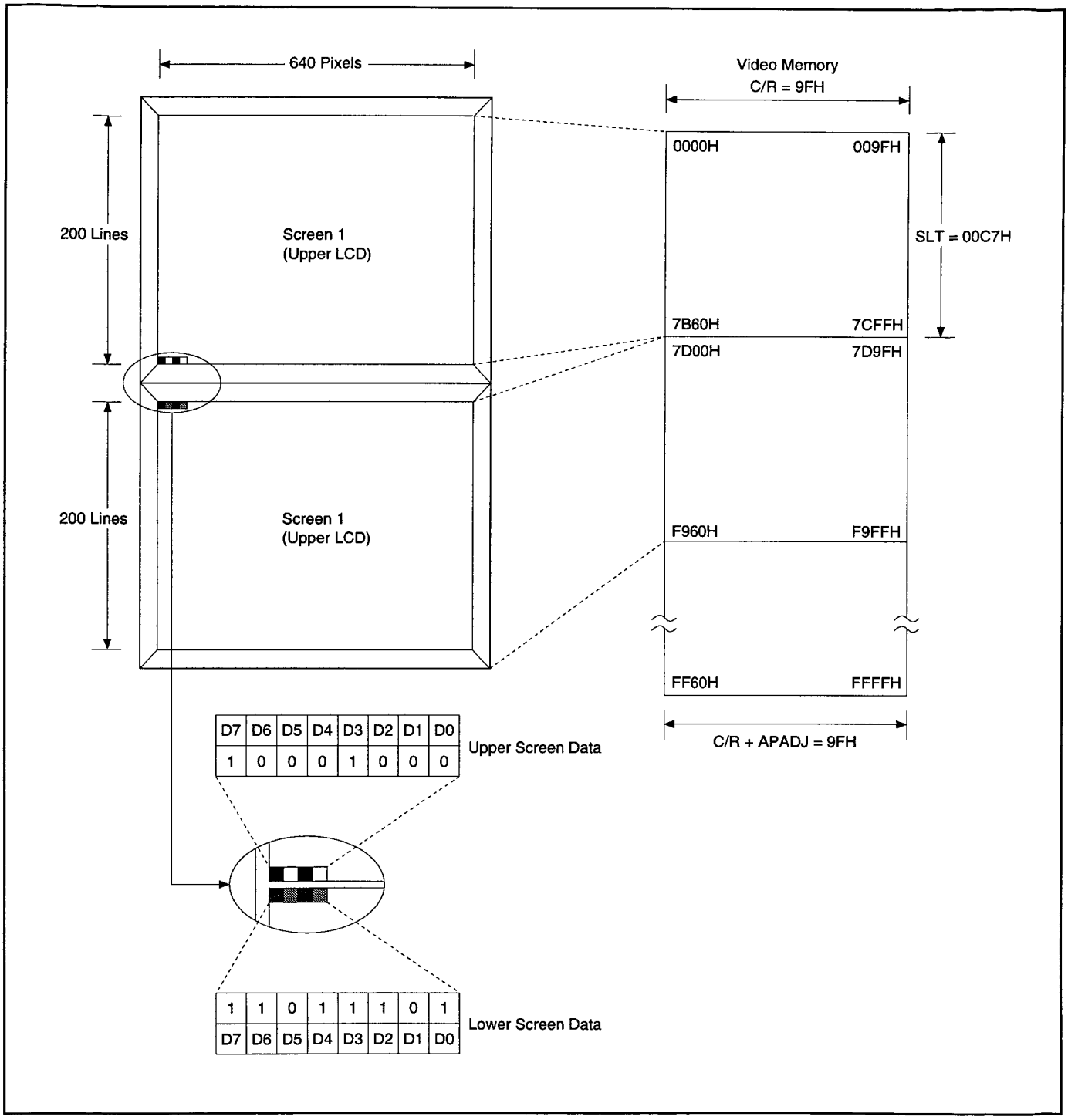


Figure 12. Display vs. VRAM: Mode 6

Mode 6 basic timing: See Mode 5

For example:

- t_{FR} = 14.3 msec (f_{FR} = 70 Hz)
- f_{OSC} = 10 MHz

$$14.3\times10^{-3} = t_H \times (200+2)$$

$$\therefore t_H = 7.08\times10^{-5}\text{s}$$

$$6.19\times10^{-5} = \frac{4}{12\times10^{6}} \times (160+\text{LPW})$$

$$\therefore \text{LPW} \approx 17 \text{ characters (10H)}$$

6.0
MPU Interface

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6.0 MPU INTERFACE

6.1 8-BIT MPU INTERFACE

Example: Z80

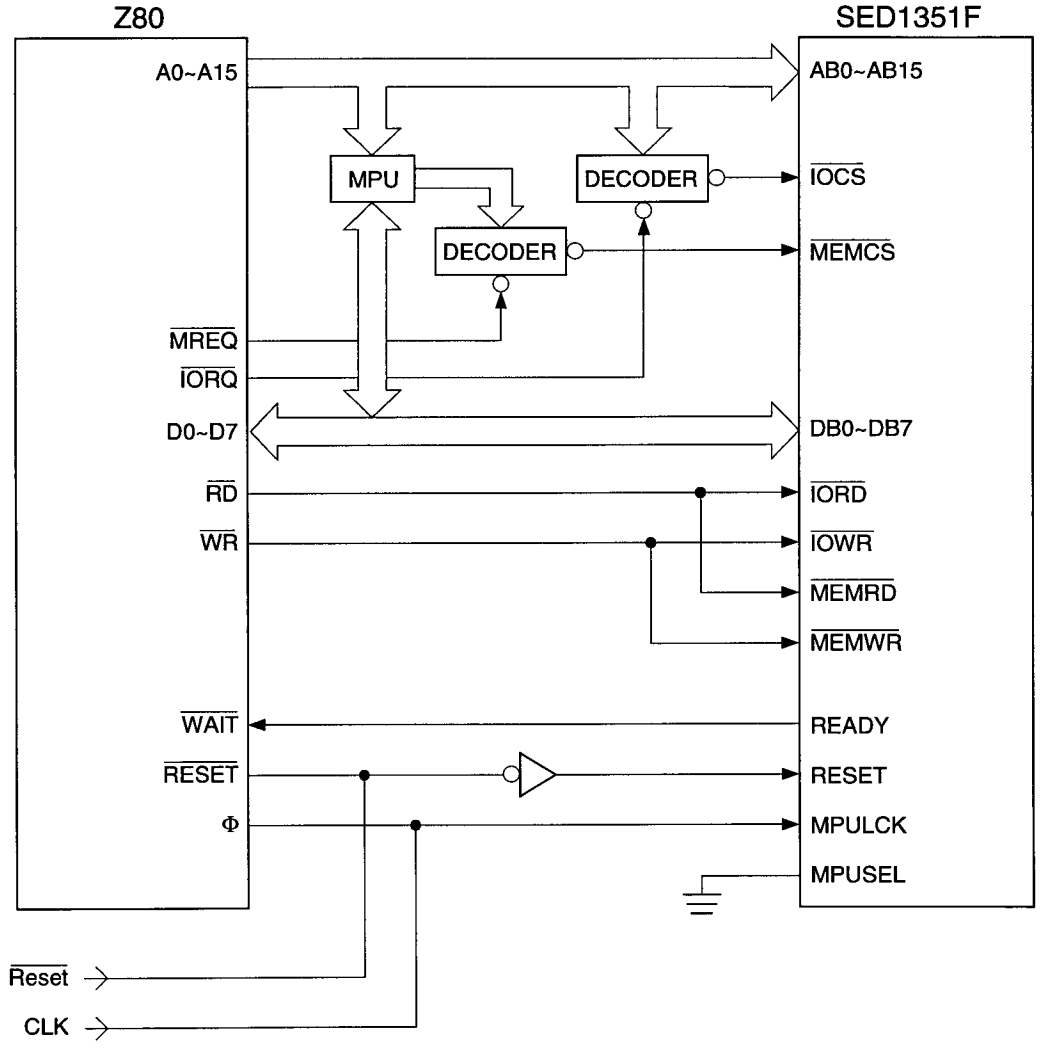

Figure 13. SED1351F/Z80 Interface

6.2 16-BIT MPU INTERFACE

Example: i8086 (Maximum Mode)

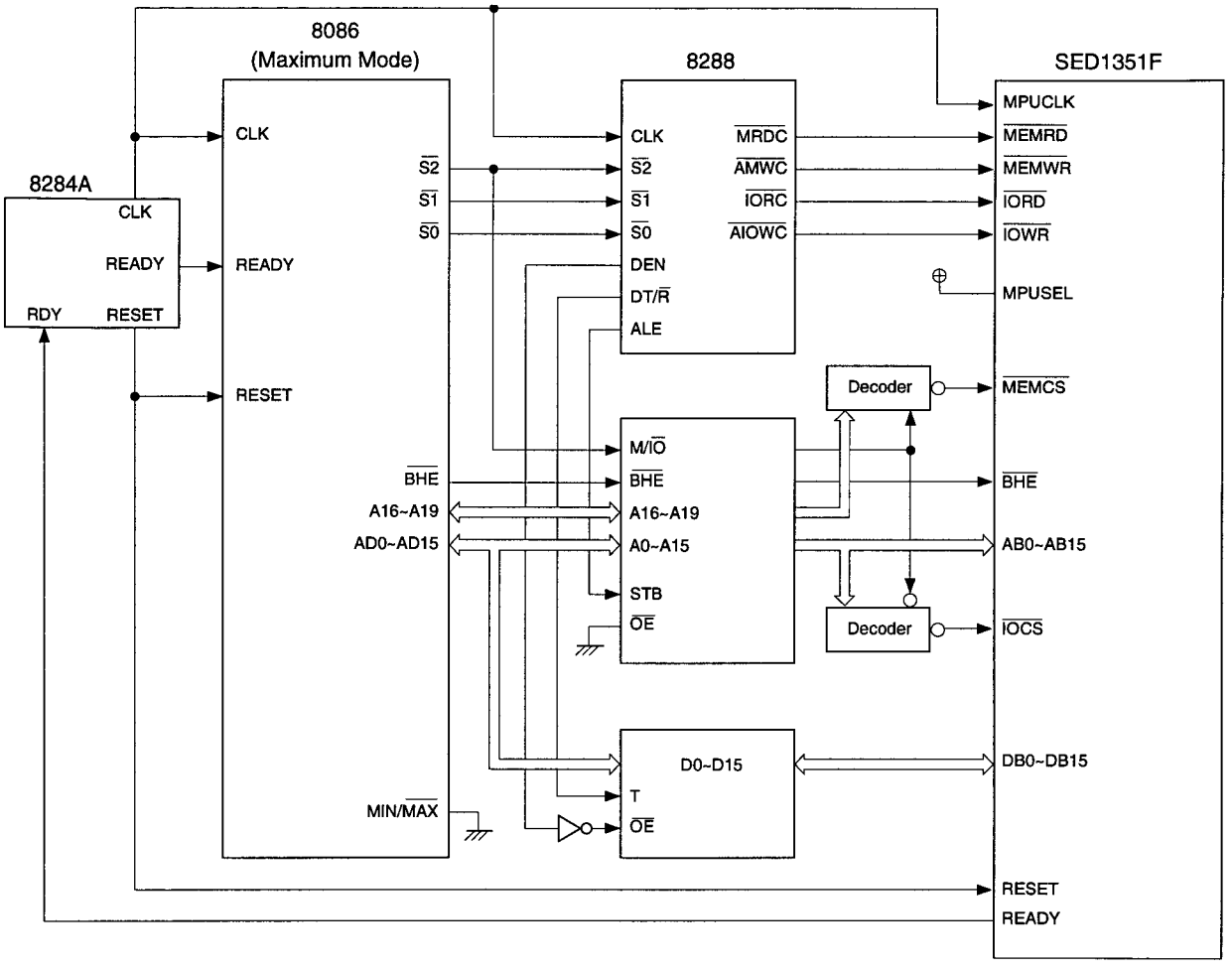

Figure 14. SED1351F/i8086 Interface

7.0
Video Memory Interface

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7.0 VIDEO MEMORY INTERFACE

7.1 64 KBIT SRAM/8-BIT MPU

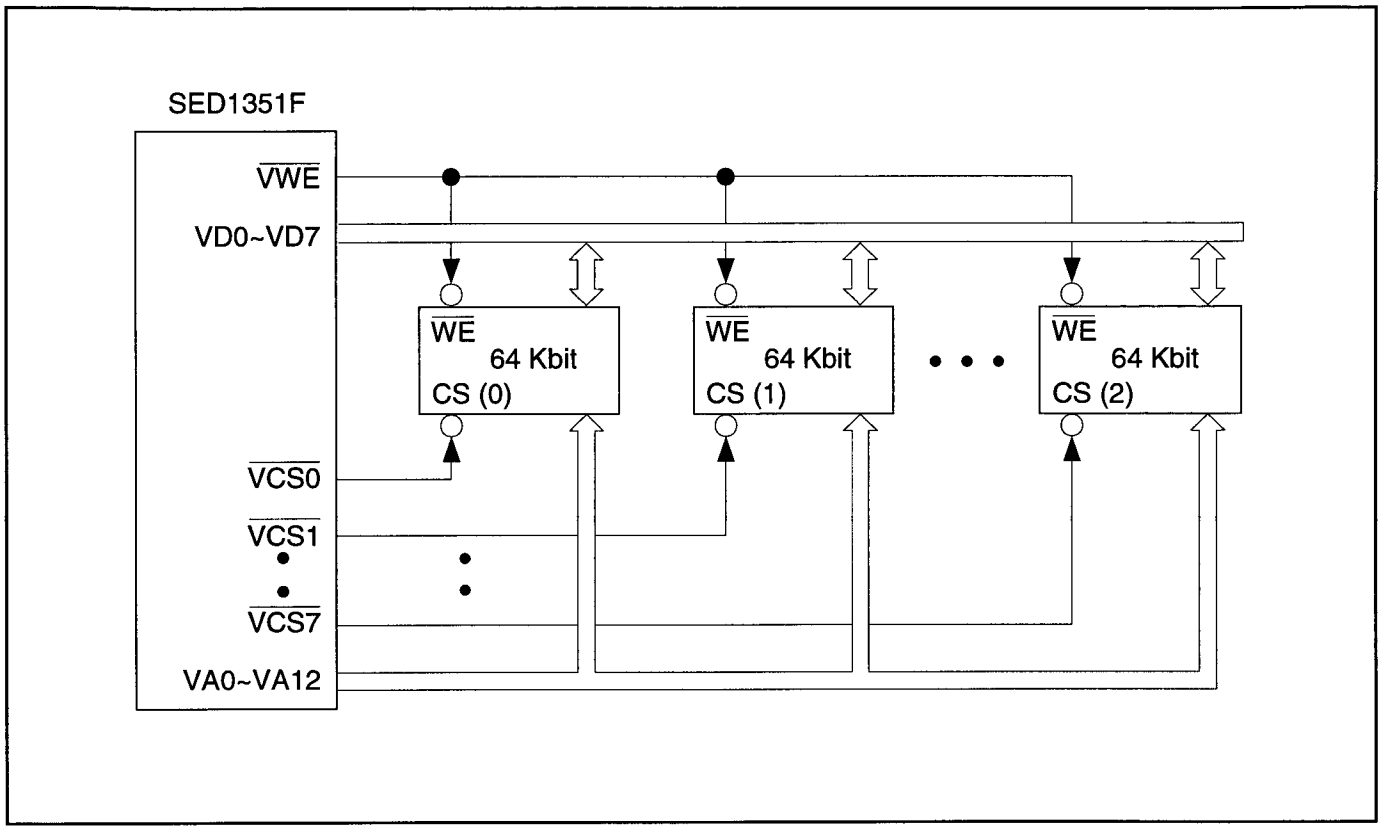

Figure 15. 8-bit MPU/64 Kbit SRAM Interface

Table 21. 8-bit MPU/64 Kbit SRAM Address Assignment

SED1351	VRAM		
	VRAM Terminals		Memory Mapping
	Address Bus	Chip Select	
VA0	A0		
VA1	A1		
VA2	A2		
VA3	A3		
VA4	A4		
VA5	A5		
VA6	A6		
VA7	A7		
VA8	A8		
VA9	A9		
VA10	A10		
VA11	A11		
VA12	A12		
VA13 / $\overline{VCS7}$		$\overline{VCS7}$	E000H to FFFFH
VA14 / $\overline{VCS6}$		$\overline{VCS6}$	C000H to DFFFH
VA15 / $\overline{VCS5}$		$\overline{VCS5}$	A000H to BFFFH
$\overline{VCS4}$		$\overline{VCS4}$	8000H to 9FFFH
$\overline{VCS3}$		$\overline{VCS3}$	6000H to 7FFFH
$\overline{VCS2}$		$\overline{VCS2}$	4000H to 5FFFH
$\overline{VCS1}$		$\overline{VCS1}$	2000H to 3FFFH
$\overline{VCS0}$		$\overline{VCS0}$	0000H to 1FFFH

7.2 256 KBIT SRAM/8-BIT MPU

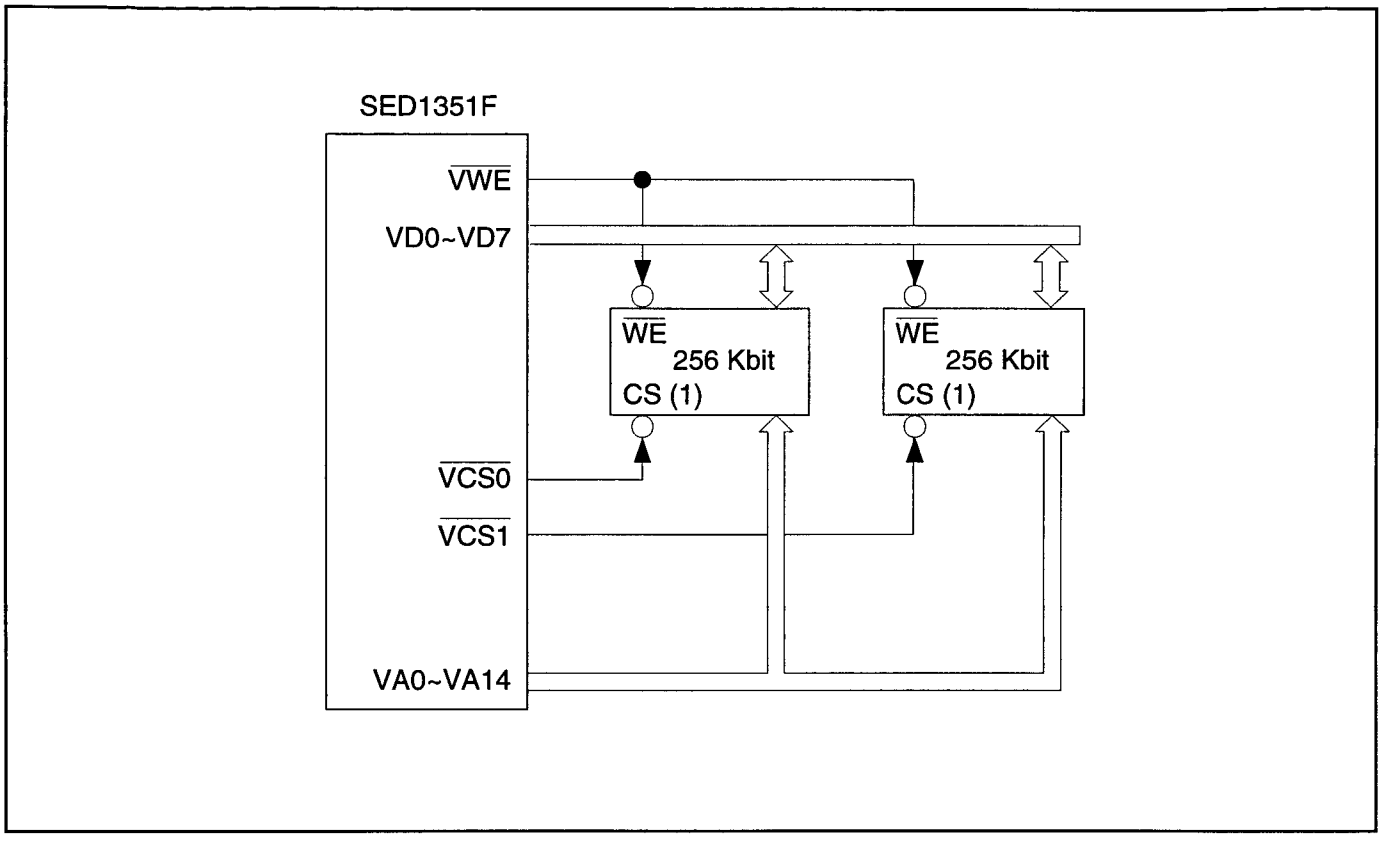

Figure 16. 8-bit MPU/256 Kbit SRAM Interface

Table 22. 8-bit MPU/256 Kbit SRAM Address Assignment

SED1351	VRAM		
	VRAM Terminals		Memory Mapping
	Address Bus	Chip Select	
VA0 VA1 VA2 VA3 VA4 VA5 VA6 VA7 VA8 VA9 VA10 VA11 VA12 VA13 / $\overline{VCS7}$ VA14 / $\overline{VCS6}$	A0 A1 A2 A3 A4 A5 A6 A7 A8 A9 A10 A11 A12 A13 A14		
VA15 / $\overline{VCS5}$ $\overline{VCS4}$ $\overline{VCS3}$ $\overline{VCS2}$	Not used		
$\overline{VCS1}$ $\overline{VCS0}$		$\overline{VCS1}$ $\overline{VCS0}$	8000H to FFFFH 0000H to 7FFFH

7.3 64 KBIT SRAM/16-BIT MPU

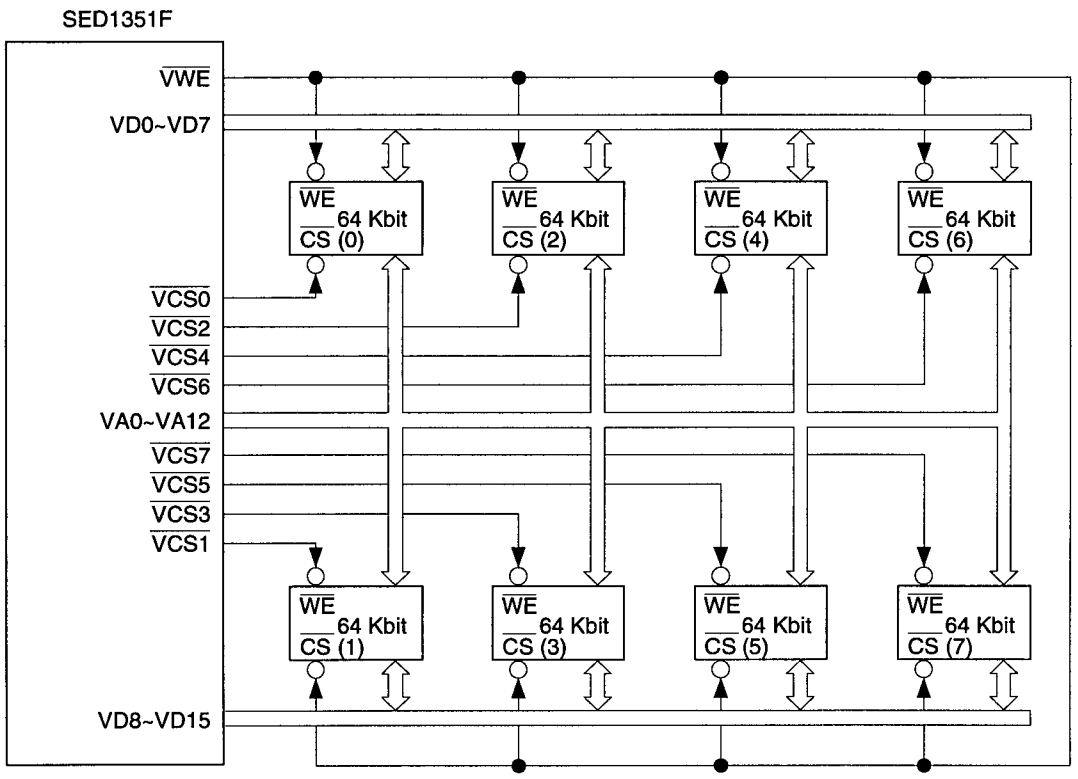

Figure 17. 16-bit MPU/64 Kbit SRAM Interface

Table 23. 16-bit MPU/64 Kbit SRAM Address Assignment

SED1351	VRAM			
	VRAM Terminals		Memory Mapping	
	Address Bus	Chip Select	Address	Odd/Even
VA0	A12			
VA1	A0			
VA2	A1			
VA3	A2			
VA4	A3			
VA5	A4			
VA6	A5			
VA7	A6			
VA8	A7			
VA9	A8			
VA10	A9			
VA11	A10			
VA12	A11			
VA13 / $\overline{VCS7}$		$\overline{VCS7}$	C000H to FFFFH	Odd address
VA14 / $\overline{VCS6}$		$\overline{VCS6}$		Even address
VA15 / $\overline{VCS5}$		$\overline{VCS5}$	8000H to BFFFH	Odd address
VA16 / $\overline{VCS4}$		$\overline{VCS4}$		Even address
$\overline{VCS3}$		$\overline{VCS3}$	4000H to 7FFFH	Odd address
$\overline{VCS2}$		$\overline{VCS2}$		Even address
$\overline{VCS1}$		$\overline{VCS1}$	0000H to 3FFFH	Odd address
$\overline{VCS0}$		$\overline{VCS0}$		Even address

7.4 256 KBIT SRAM/16-BIT MPU

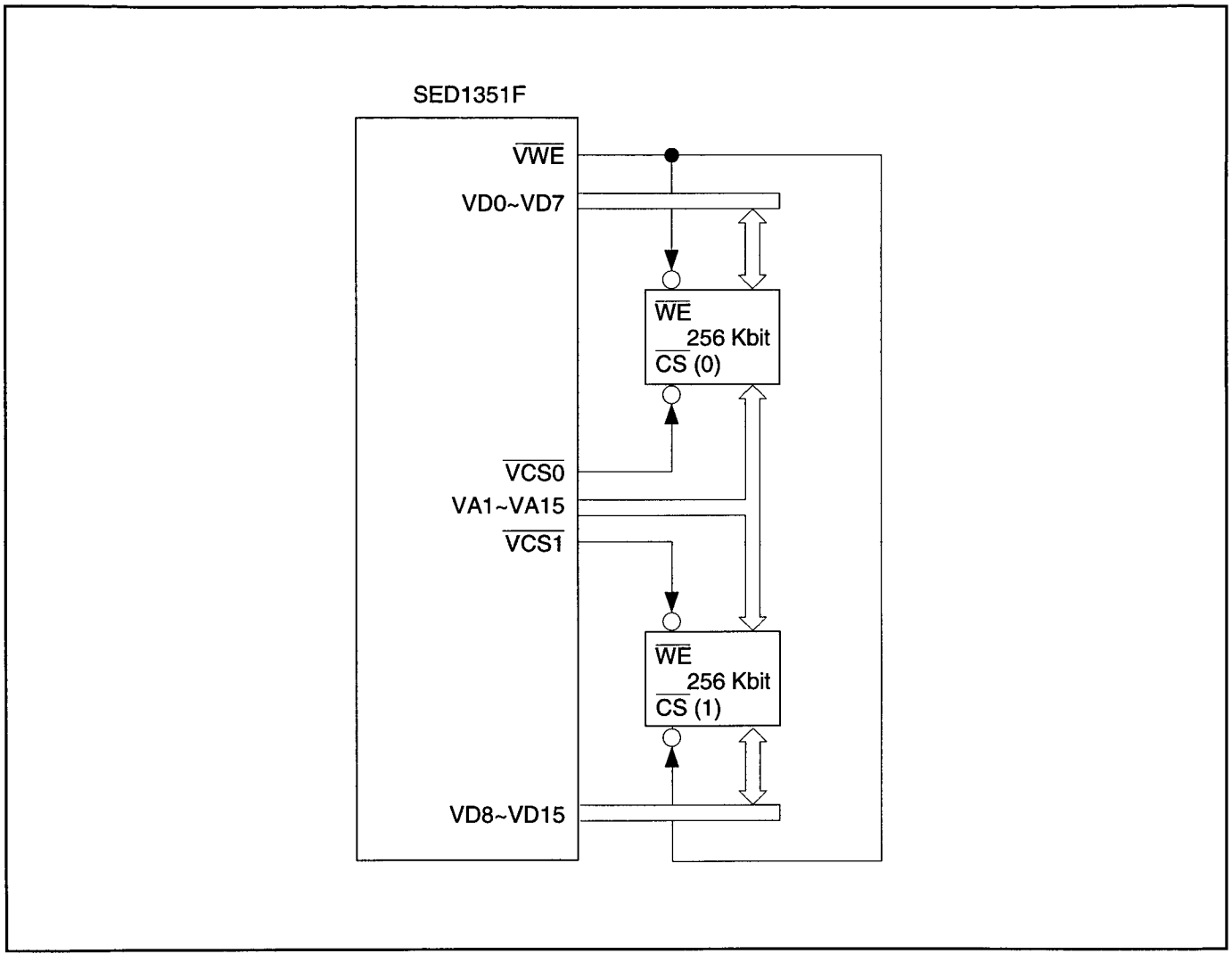

Figure 18. 16-bit MPU/256 Kbit SRAM Interface

Table 24. 16-bit MPU/256 Kbit SRAM Address Assignment

SED1351	VRAM			
	VRAM Terminals		Memory Mapping	
	Address Bus	Chip Select	Address	Odd/Even
VA0	Not used			
VA1	A0			
VA2	A1			
VA3	A2			
VA4	A3			
VA5	A4			
VA6	A5			
VA7	A6			
VA8	A7			
VA9	A8			
VA10	A9			
VA11	A10			
VA12	A11			
VA13 / $\overline{VCS7}$	A12			
VA14 / $\overline{VCS6}$	A13			
VA15 / $\overline{VCS5}$	A14			
/ $\overline{VCS4}$	Not used			
$\overline{VCS3}$				
$\overline{VCS2}$				
$\overline{VCS1}$		$\overline{VCS1}$	0000H to FFFFH	Odd address
$\overline{VCS0}$		$\overline{VCS0}$		Even address

8.0
LCD Interface

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8.0 LCD INTERFACE

8.1 DC PROTECTION

The LCD panels will be damaged if V_{LCD} is applied to the LCD panel before V_{DD} is applied. To prevent this the LCDENB line should be connected to the enable imput of the V_{LCD} control circuitry in the LCD module and the following startup procedure used.

- Set up the control register as required, with LCDE (R1:D1) set to "0".
- Set LCDE to "1" to apply V_{LCD}.

When shutting down the system, set LCDENB to "0" to switch off V_{LCD} before removing V_{DD} from the LCD panel.

8.2 Y-DRIVERS IN DUAL-LCD PANEL MODE

The SED1351F has a two line vertical retrace period, so when cascaded Y drivers are used to drive two LCD panels, two lines should be left disconnected beween the upper and lower panel.

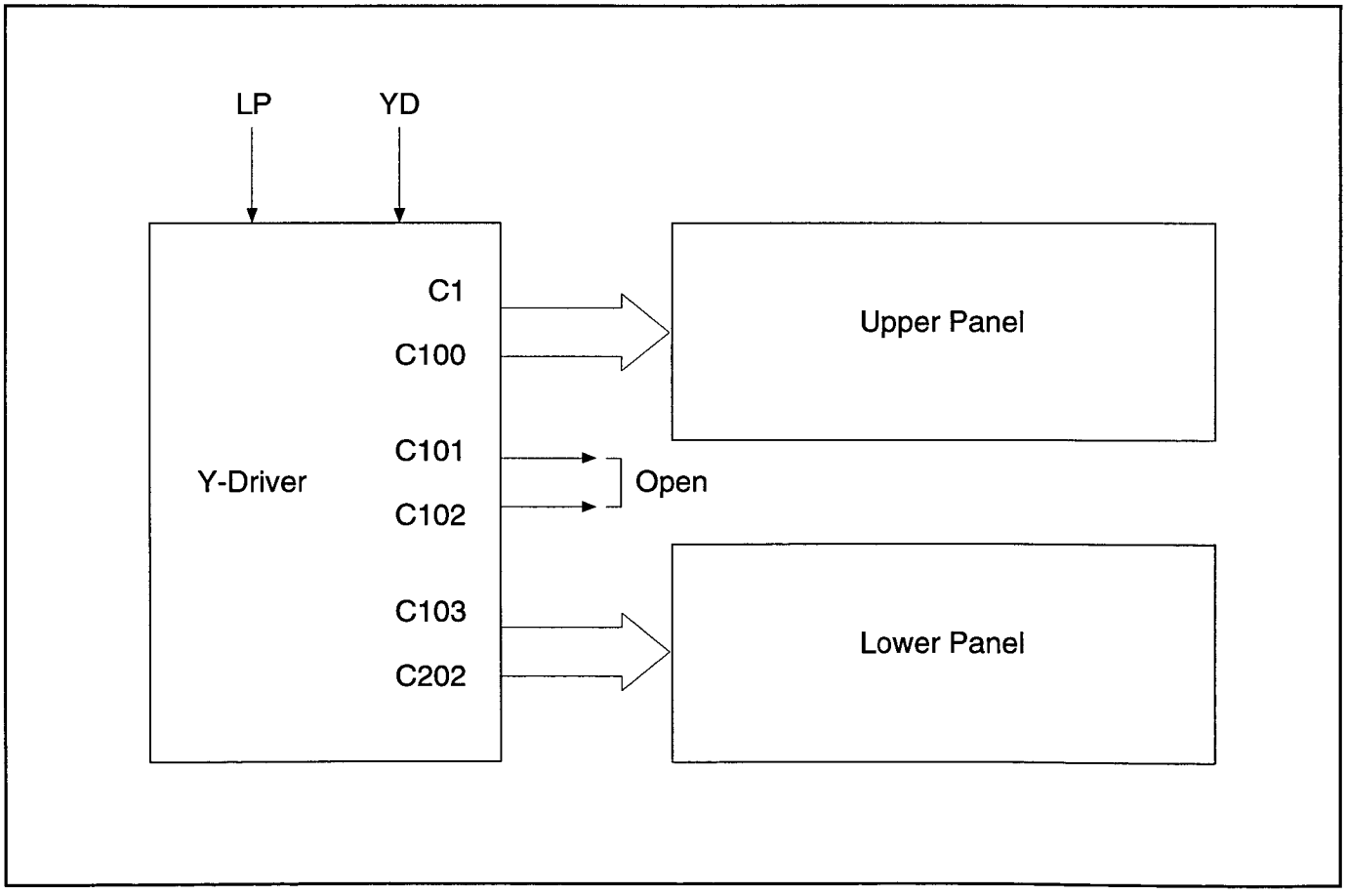
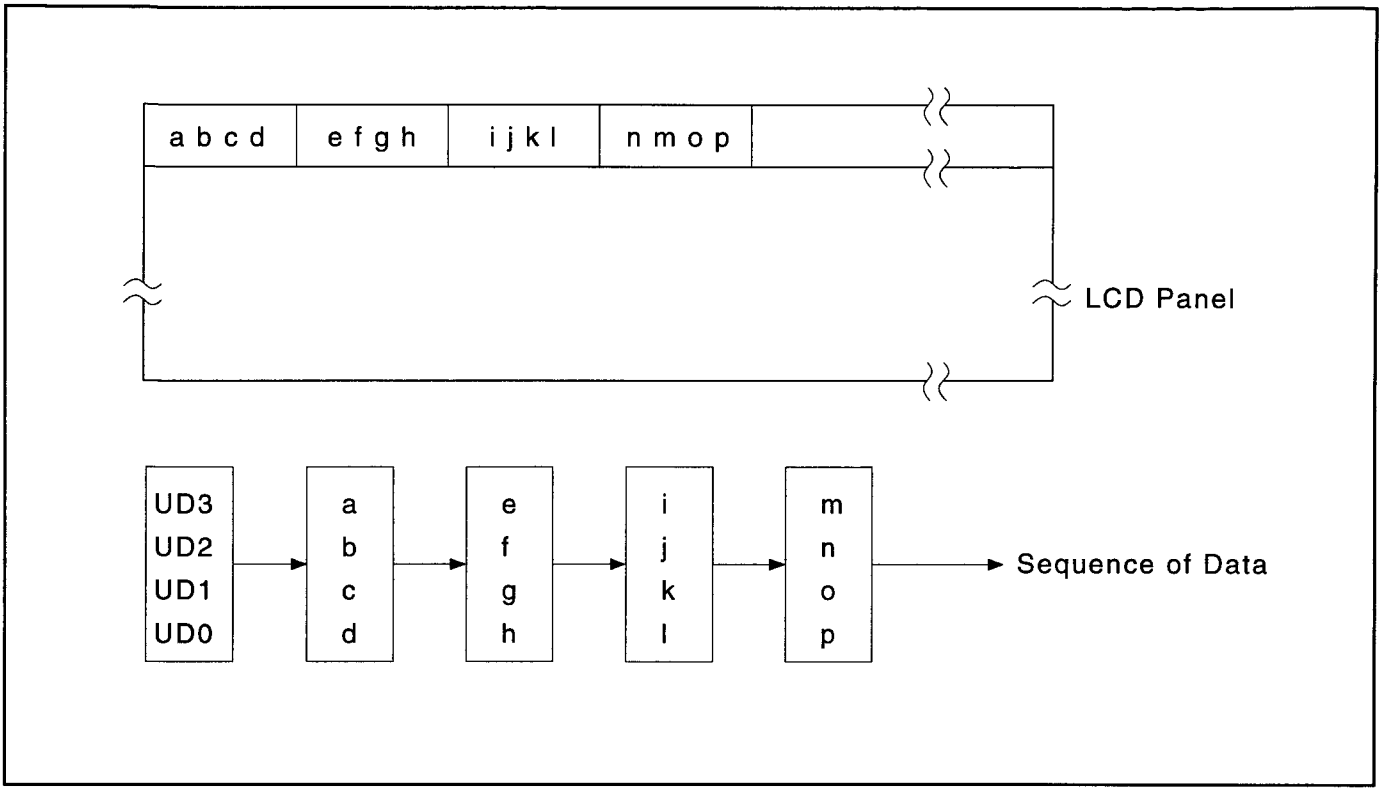


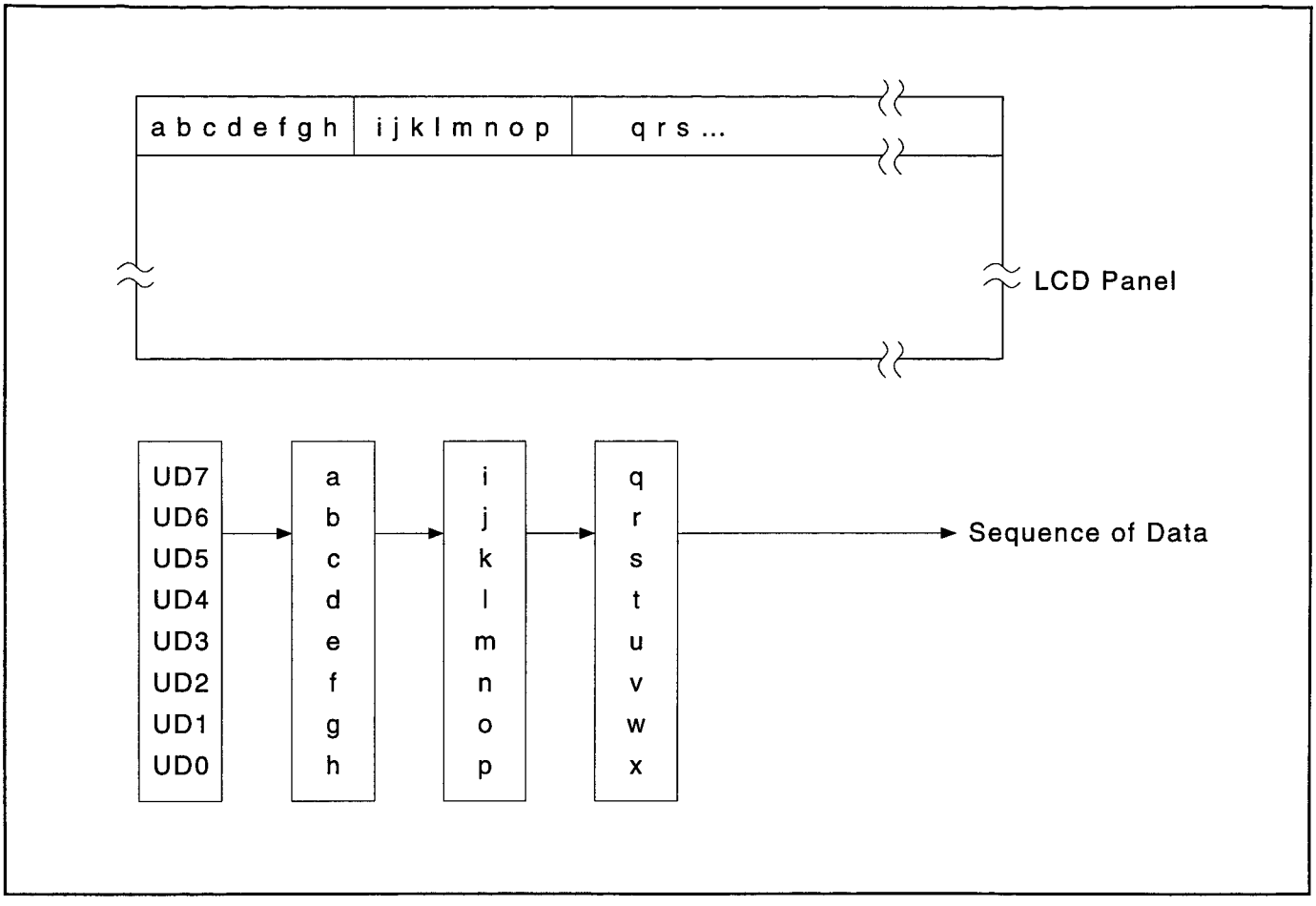
Figure 19. Cascaded Connection of Y-drivers

8.3 OUTPUT DATA FORMAT

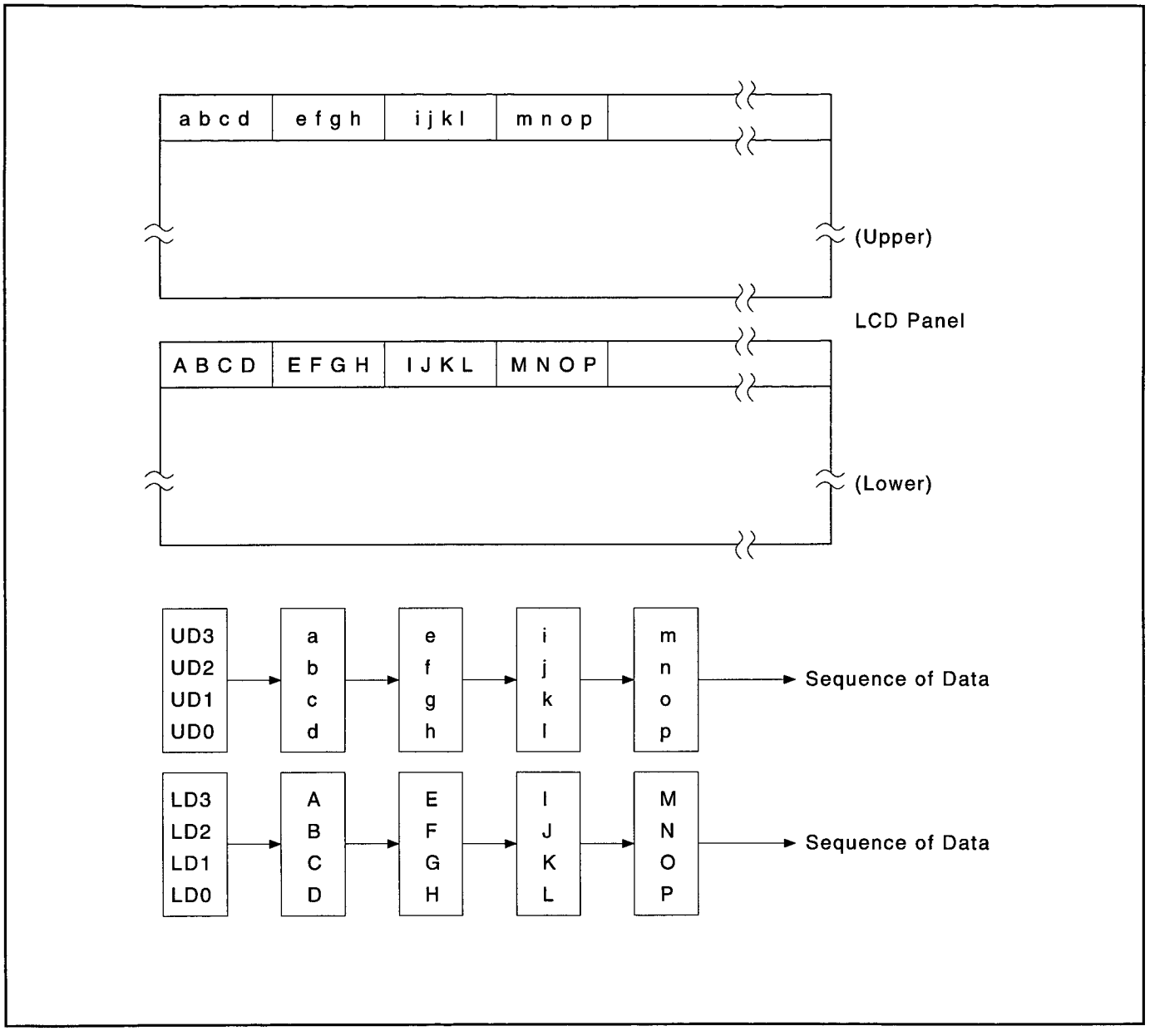
8.3.1 Single LCD/4-bit data



8.3.2 Single LCD/8-bit data



8.3.3 Dual LCD


a b c d
e f g h
i j k l
m n o p
(Upper)
LCD Panel
A B C D
E F G H
I J K L
M N O P
(Lower)
UD3
UD2
UD1
UD0
a b c d
e f g h
i j k l
m n o p
Sequence of Data
LD3
LD2
LD1
LD0
A B C D
E F G H
I J K L
M N O P
Sequence of Data

9.0
Package Dimensions

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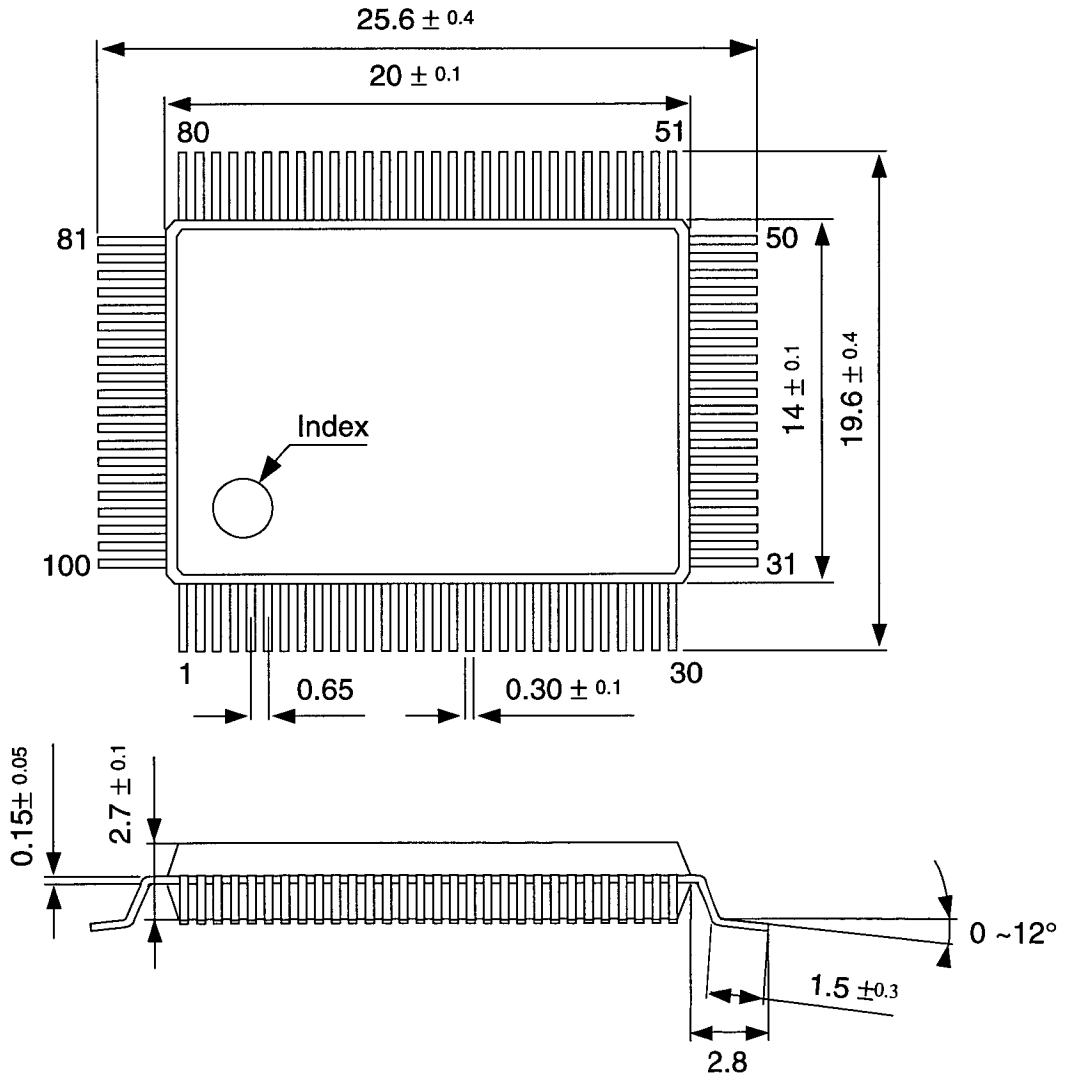
9.0 PACKAGE DIMENSIONS

9.1 SED1351F0A

Plastic QFP5-100 pin Unit: mm



9.2 SED1351F$_{LB}$

Plastic QFP15-100 pin

Unit: mm