

EPSON®



S1D13A05 LCD/USB Companion Chip

S1D13A05 TECHNICAL MANUAL

Document Number: X40A-Q-001-01

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S1D13A05 LCD/USB Companion Chip

August 2001

The S1D13A05 is an LCD/USB solution designed for seamless connection to a wide variety of microprocessors. The S1D13A05 integrates a USB slave controller and an LCD graphics controller with an embedded 256K byte SRAM display buffer. The LCD controller supports all standard panel types and multiple TFT types eliminating the need for an external timing control IC. The S1D13A05 includes a Hardware Acceleration Engine to greatly improve screen drawing functions and the built-in USB controller provides revision 1.1 compliance for applications requiring a USB client. This high level of integration provides a low cost, low power, single chip solution to meet the demands of embedded markets requiring USB client support, such as Mobile Communications devices and Palm-size PCs.

The S1D13A05 utilizes a guaranteed low-latency CPU architecture that provides support for microprocessors without READY/WAIT# handshaking signals. The 32-bit internal data path, write buffer and the Hardware Acceleration Engine provide high performance bandwidth into display memory allowing for fast display updates.

Additionally, products requiring a rotated display can take advantage of the SwivelView™ feature which provides hardware rotation of the display memory transparent to the software application. The S1D13A05 also provides support for “Picture-in-Picture Plus” (a variable size Overlay window).

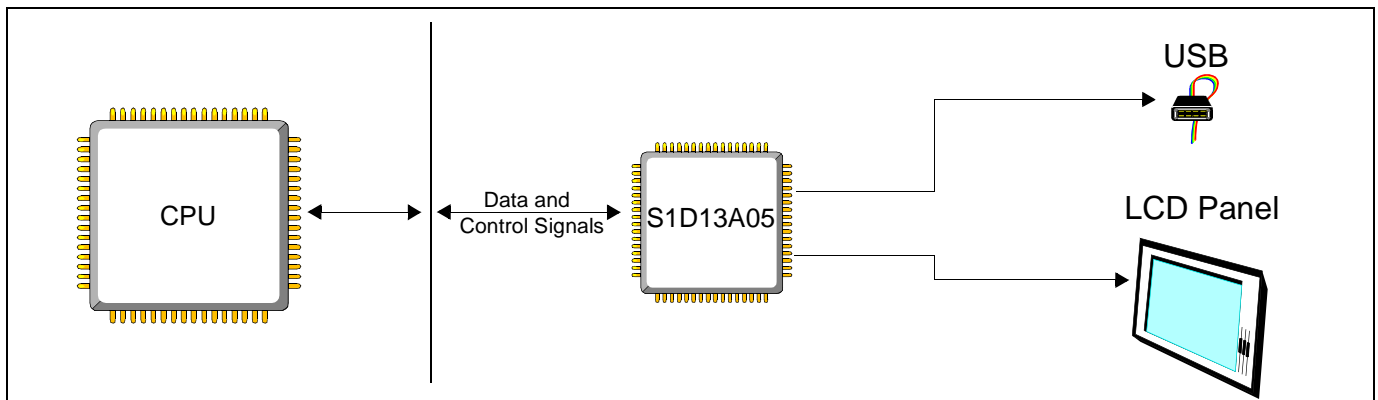
The S1D13A05, with its integrated USB client, provides impressive support for Palm OS® handhelds. However, its impartiality to CPU type or operating system makes it an ideal display solution for a wide variety of applications.

■ **FEATURES**

- Embedded 256KB Display Buffer.
- Low Operating Voltage.
- Low-latency CPU interface.
- Direct support for multiple CPU types.
- Programmable resolutions and color depths.
- Passive LCD support.
- Active Matrix LCD support.
- Extended TFT interfaces (Type 2, 3, 4).
- ‘Direct’ Sharp HR-TFT support (including Mode 2).
- ‘Direct’ Casio TFT support.
- USB Client, Revision 1.1 compliant.
- SwivelView™ (90°, 180°, 270° hardware rotation of displayed image).
 - (Patent # 5,734,875 - Patent # 5,956,049 - Patent #6,262,751)
- “Picture-in-Picture Plus”.
- Pixel Doubling.
- Hardware Acceleration Engine.
- Software Initiated Power Save Mode.
- 48MHz crystal for USBCLK.
- Software Video Invert.
- 121-pin PFBGA package.



■ **SYSTEM BLOCK DIAGRAM**



S1D13A05

DESCRIPTION

Memory Interface

- Embedded 256K byte SRAM display buffer.

CPU Interface

- 'Fixed' low-latency CPU access times.
- Direct support for:
 - Hitachi SH-4 / SH-3.
 - Motorola M68xxx (REDCAP2, DragonBall, ColdFire).
 - Motorola Dragonball SZ support (66MHz)
 - MPU bus interface with programmable READY.

Integrated USB Features

- USB Client, Revision 1.1 Compliant.

Power Down Modes

- Software Initiated Power Save Mode.

Operating Voltage

- $CORE_{VDD}$ 2.0 ± 10% volts or 2.5 ± 10% volts.
- IO_{VDD} 3.3 ± 10% volts.

Clock Source

- Three independent clock inputs including dedicated USB clock (single clock possible if USB not required).
- 48MHz crystal oscillator for USBCLK.

Package

- 121-pin PFBGA

Integrated LCD Controller Features

- 1/2/4/8/16 bit-per-pixel (bpp) support.
- Up to 64 gray shades on monochrome passive panels.
- Up to 64K colors on passive/active matrix panels.
- Single-panel, single-drive passive displays.
 - 4/8-bit monochrome and 4/8/16-bit color interfaces.
- 9/12/18-bit Active matrix TFT interface.
- 'Direct support for multiple TFT interfaces (Epson, Sharp, Type 2, 3, 4, external timing IC not required).
- SwivelView: hardware rotation by 90°, 180°, 270°.
- "Picture-in-Picture Plus": displays a variable size window overlaid over background image.
- Pixel Doubling: horizontal and vertical resolutions can be doubled without any additional memory.
- Software video invert.
- Typical resolutions supported:
 - 320x320 @ 16bpp
 - 160x160 @ 16bpp (2 pages)
 - 160x240 @ 16bpp
- 2D BitBLT Engine.

| | |
|-------------------------------|-----------------------|
| Write BLT | Transparent Write BLT |
| Move BLT | Transparent Move BLT |
| Solid Fill BLT | Read BLT |
| Pattern Fill | Color Expansion BLT |
| Move BLT with Color Expansion | |

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S1D13A05 LCD/USB Companion Chip

Hardware Functional Specification

Document Number: X40A-A-001-04

Status: Revision 4.0

Issue Date: 2003/05/01

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1 Introduction

1.1 Scope

This is the Hardware Functional Specification for the S1D13A05 LCD/USB Companion Chip. Included in this document are timing diagrams, AC and DC characteristics, register descriptions, and power management descriptions. This document is intended for two audiences: Video Subsystem Designers and Software Developers.

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1.2 Overview Description

The S1D13A05 is an LCD/USB solution designed for seamless connection to a wide variety of microprocessors. The S1D13A05 integrates a USB slave controller and an LCD graphics controller with an embedded 256K byte SRAM display buffer. The LCD controller supports all standard panel types and multiple TFT types eliminating the need for an external timing control IC. The S1D13A05 includes a Hardware Acceleration Engine to greatly improve screen drawing functions and the built-in USB controller provides revision 1.1 compliance for applications requiring a USB client. This high level of integration provides a low cost, low power, single chip solution to meet the demands of embedded markets requiring USB client support, such as Mobile Communications devices and Palm-size PCs.

The S1D13A05 utilizes a guaranteed low-latency CPU architecture that provides support for microprocessors without READY/WAIT# handshaking signals. The 32-bit internal data path, write buffer and the Hardware Acceleration Engine provide high performance bandwidth into display memory allowing for fast display updates.

Additionally, products requiring a rotated display can take advantage of the SwivelView™ feature which provides hardware rotation of the display memory transparent to the software application. The S1D13A05 also provides support for “Picture-in-Picture Plus” (a variable size Overlay window).

The S1D13A05, with its integrated USB client, provides impressive support for Palm OS® handhelds. However, its impartiality to CPU type or operating system makes it an ideal display solution for a wide variety of applications.

2 Features

2.1 Integrated Frame Buffer

- Embedded 256K byte SRAM display buffer.

2.2 CPU Interface

- Direct support of the following interfaces:
 - Hitachi SH-4 / SH-3.
 - Motorola M68xxx (REDCAP2, DragonBall, ColdFire).
 - Motorola DragonBall SZ Support (66MHz).
 - Motorola “REDCAP2” - no WAIT# signal.
 - Generic MPU bus interface with programmable ready (WAIT#).
- “Fixed” low-latency CPU access times.
- Registers are memory-mapped - M/R# input selects between memory and register address space.
- The complete 256K byte display buffer is directly and contiguously available through the 18-bit address bus.

2.3 Display Support

- Single-panel, single drive passive displays.
 - 4/8-bit monochrome LCD interface.
 - 4/8/16-bit color LCD interface.
- Active Matrix TFT interface.
 - 9/12/18-bit interface.
 - Extended TFT interfaces (Type 2, 3, 4)
- ‘Direct’ support for 18-bit Sharp HR-TFT LCD (or compatible interfaces).
- ‘Direct’ support for the Casio TFT LCD (or compatible interfaces).

2.4 Display Modes

- 1/2/4/8/16 bit-per-pixel (bpp) color depths.
- Up to 64 gray shades on monochrome passive LCD panels.
- Up to 64K colors on passive panels.
- Up to 64K colors on active matrix LCD panels.
- Example resolutions:
 - 320x320 at a color depth of 16 bpp
 - 160x160 at a color depth of 16 bpp (2 pages)
 - 160x240 at a color depth of 16 bpp

2.5 Display Features

- SwivelView™: 90°, 180°, 270° counter-clockwise hardware rotation of display image.
- Picture-in-Picture Plus (PIP⁺): displays a variable size window overlaid over background image.
- Pixel Doubling: independent control of both horizontal and vertical pixel doubling.
 - example usage: 160x160 8 bpp can be expanded to 320x320 8 bpp without any additional memory.
 - supports all color depths.
- Double Buffering/Multi-pages: provides smooth animation and instantaneous screen updates.

2.6 Clock Source

- Three independent clock inputs: CLKI, CLKI2 and USBCLK.
- Flexible clock source selection:
 - internal Bus Clock (BCLK) selected from CLKI, CLKI/2, or CLKI2
 - internal Memory Clock (MCLK) selected from BCLK or BCLK divide ratio (REG[04h])
 - internal Pixel Clock (PCLK) selected from CLKI, CLKI2, MCLK, or BCLK. PCLK can also be divided down from source
- Single clock input possible if USB support not required.

2.7 USB Device

- USB Client, revision 1.1 compliant.
- Dedicated clock input: USBCLK.
- 48MHz crystal oscillator for USBCLK.

2.8 2D Acceleration

- 2D BitBLT engine including:
 - Write BitBLT
 - Move BitBLT
 - Solid Fill BitBLT
 - Pattern Fill BitBLT
 - Move BitBLT with Color Expansion
 - Transparent Write BitBLT
 - Transparent Move BitBLT
 - Read BitBLT
 - Color Expansion BitBLT

2.9 Miscellaneous

- Software initiated Video Invert.
- Software initiated Power Save mode.
- General Purpose Input/Output pins are available.
- IO Operates at 3.3 volts \pm 10%.
- Core operates at 2.0 volts \pm 10% or 2.5 volts \pm 10%.
- 121-pin PFBGA package.

3 Typical System Implementation Diagrams

3.1 Typical System Diagrams.

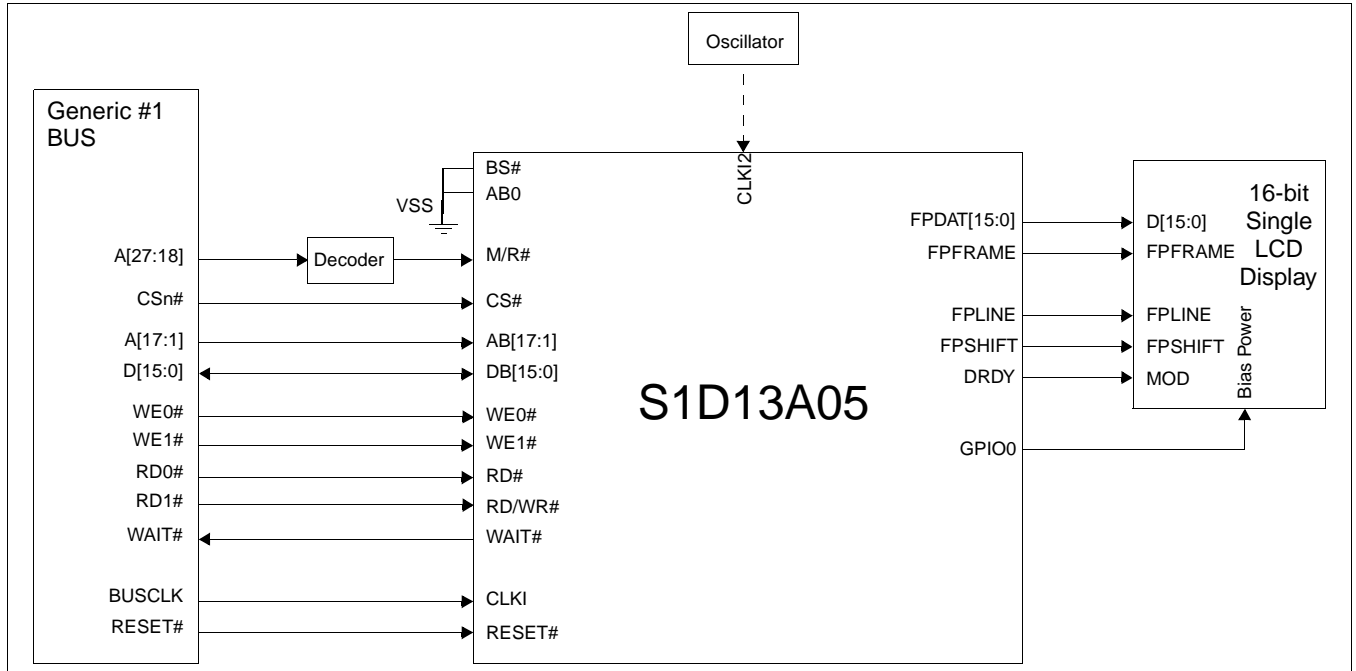


Figure 3-1: Typical System Diagram (Generic #1 Bus)

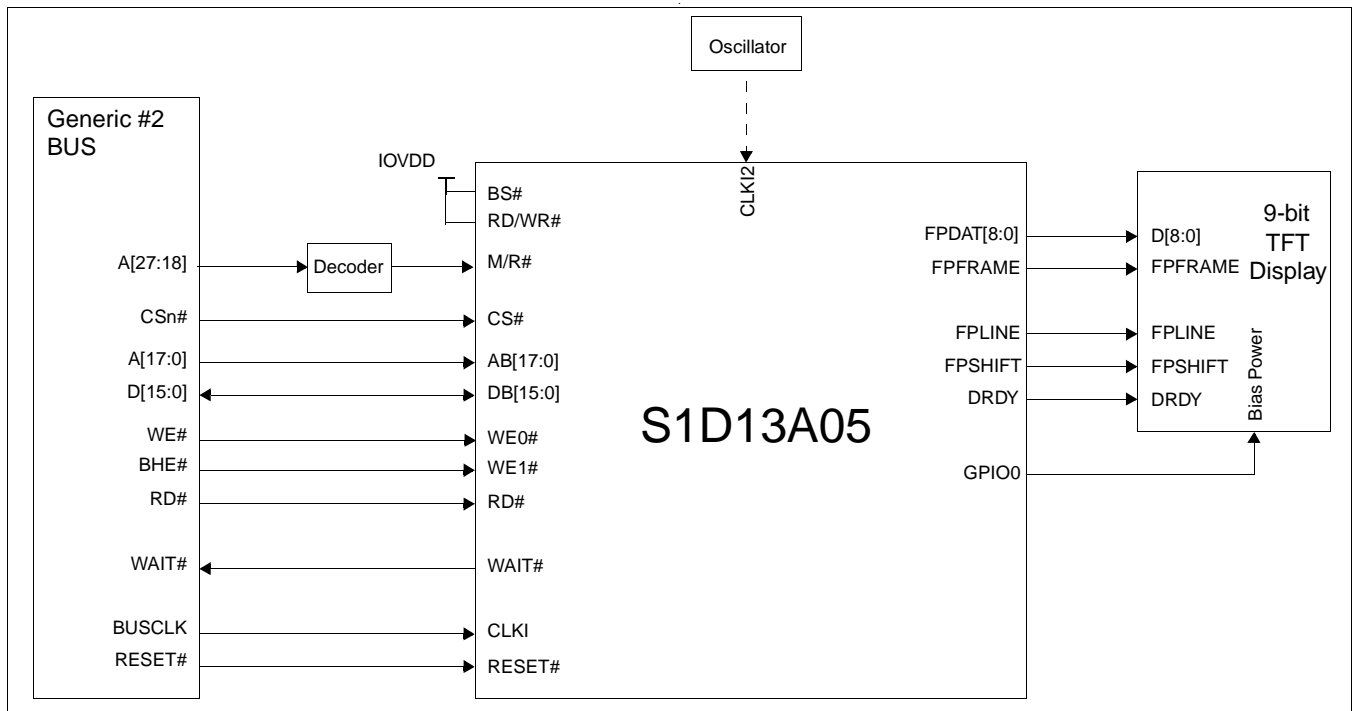


Figure 3-2: Typical System Diagram (Generic #2 Bus)

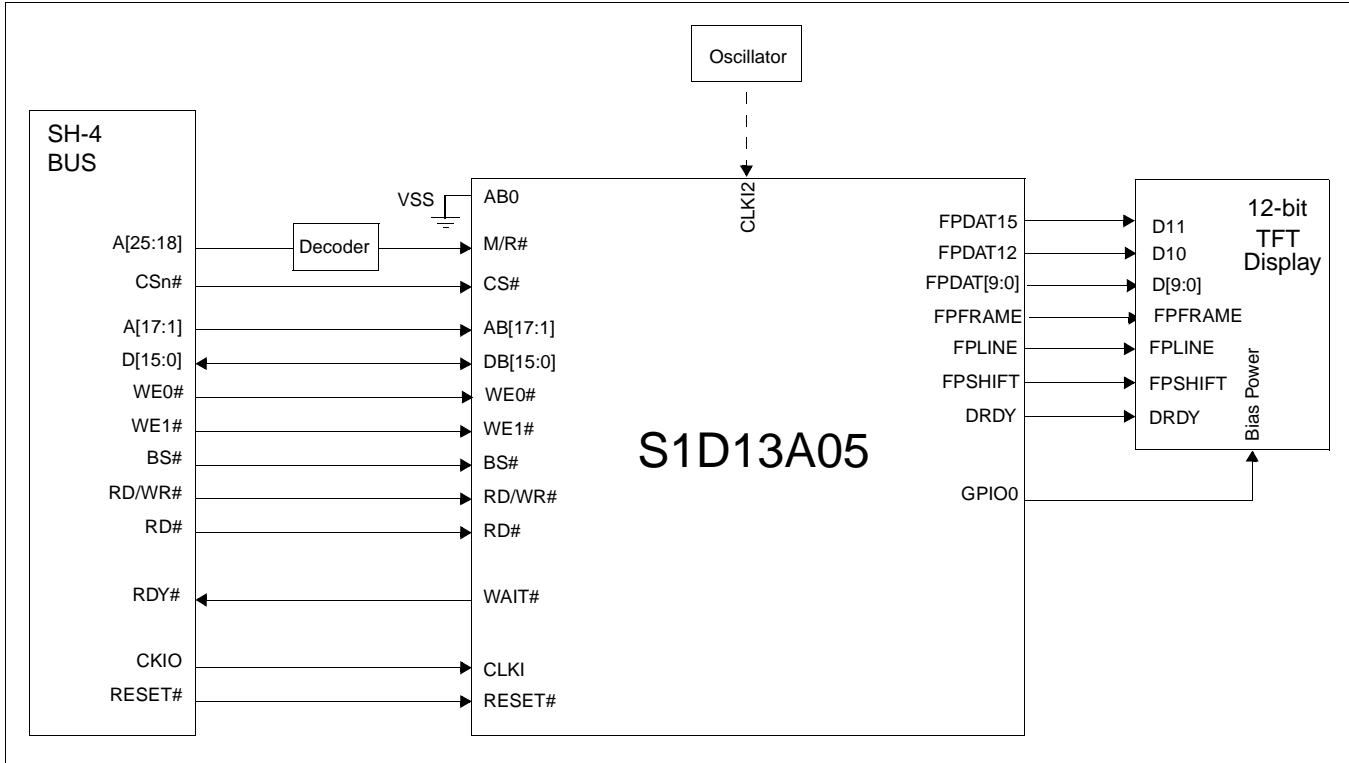


Figure 3-3: Typical System Diagram (Hitachi SH-4 Bus)

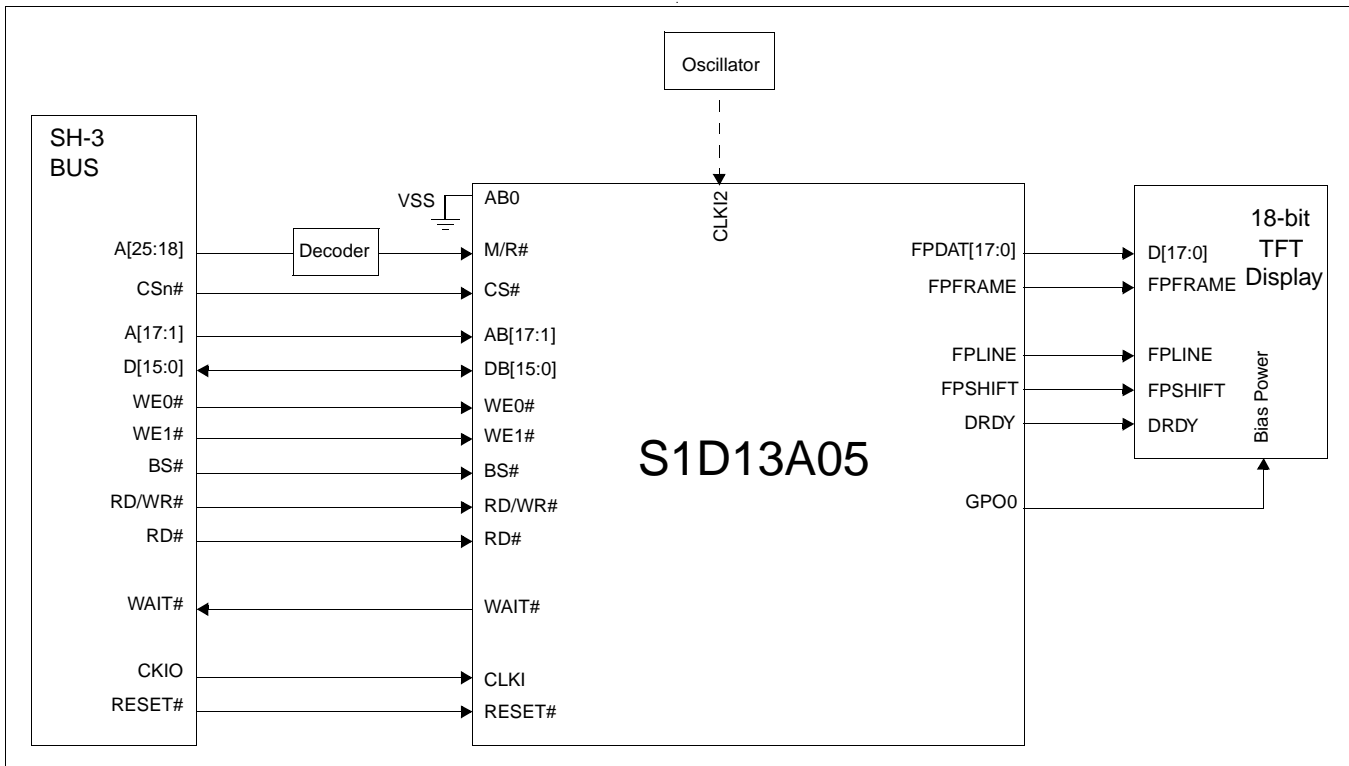


Figure 3-4: Typical System Diagram (Hitachi SH-3 Bus)

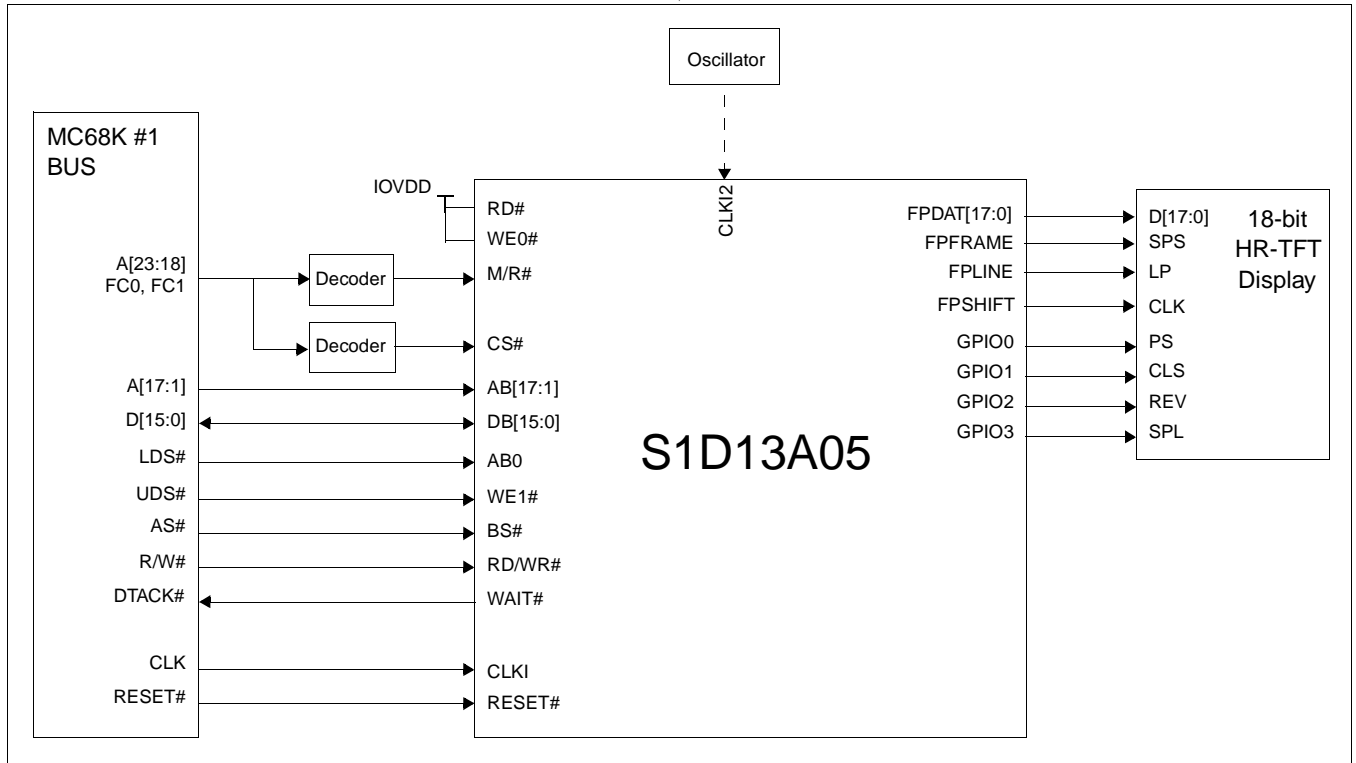


Figure 3-5: Typical System Diagram (MC68K #1, Motorola 16-Bit 68000)

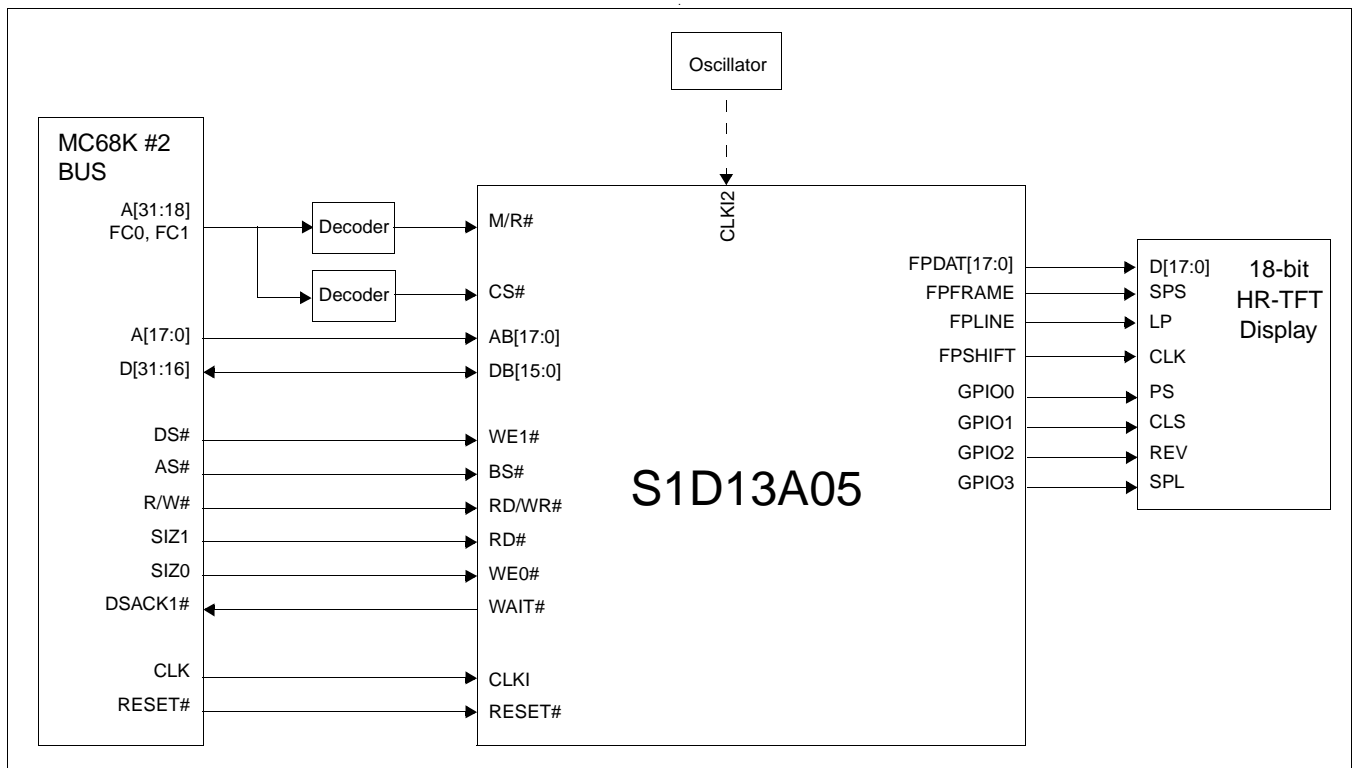


Figure 3-6: Typical System Diagram (MC68K #2, Motorola 32-Bit 68030)

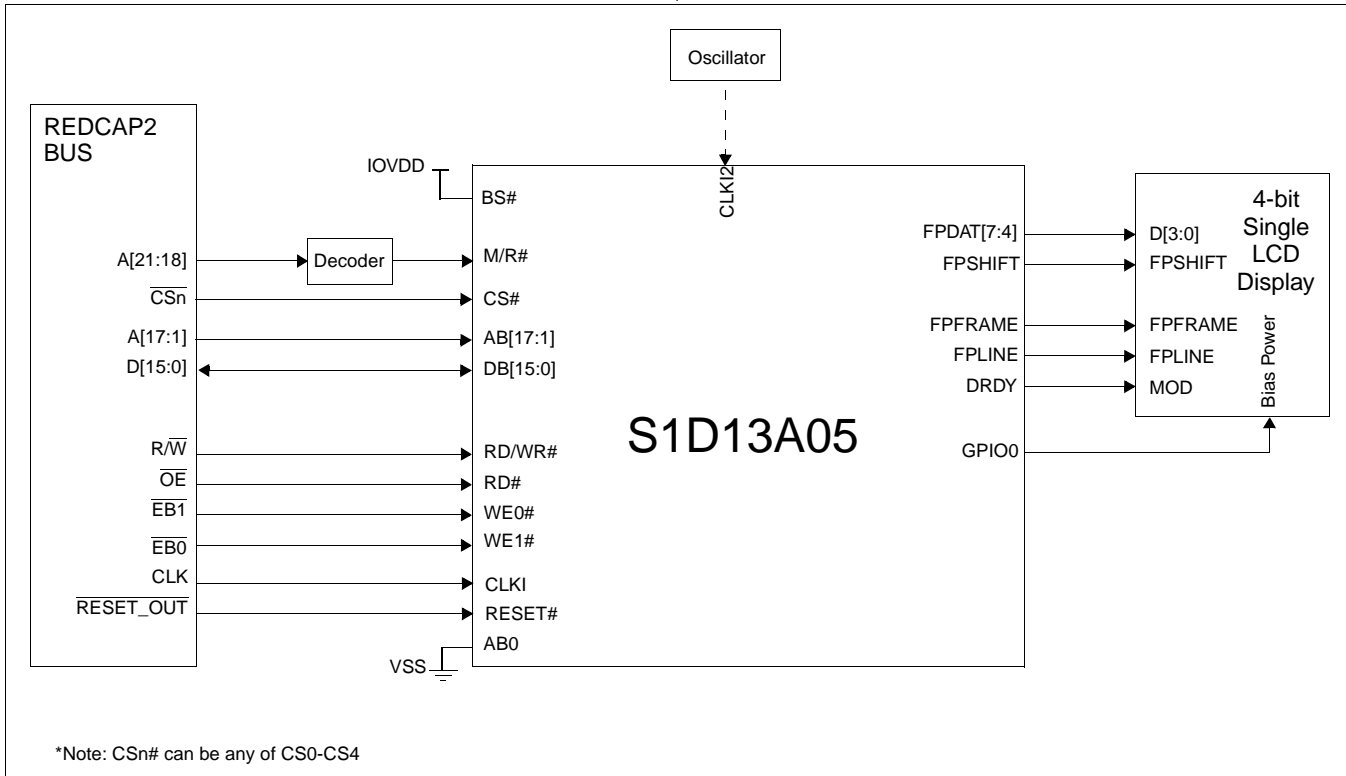


Figure 3-7: Typical System Diagram (Motorola REDCAP2 Bus)

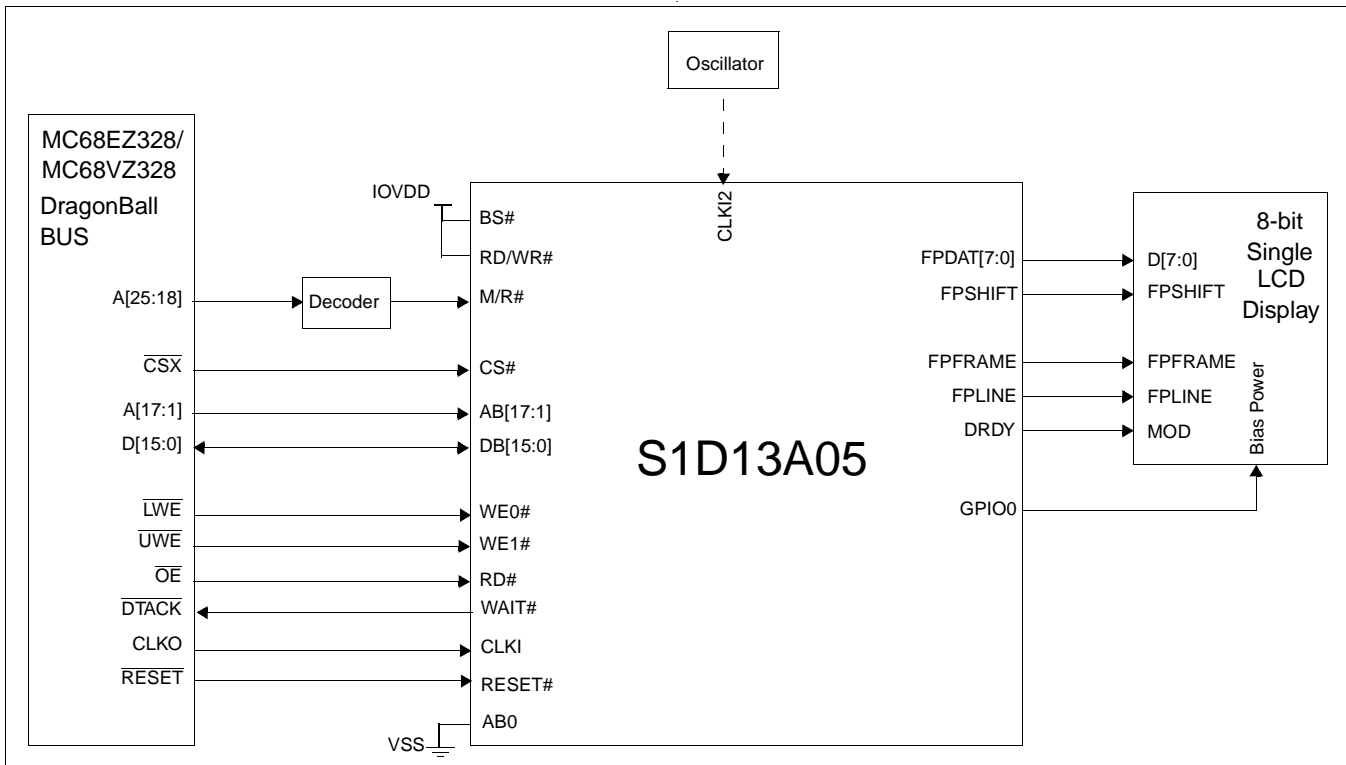


Figure 3-8: Typical System Diagram (Motorola MC68EZ328/MC68VZ328 "DragonBall" Bus)

3.2 USB Interface

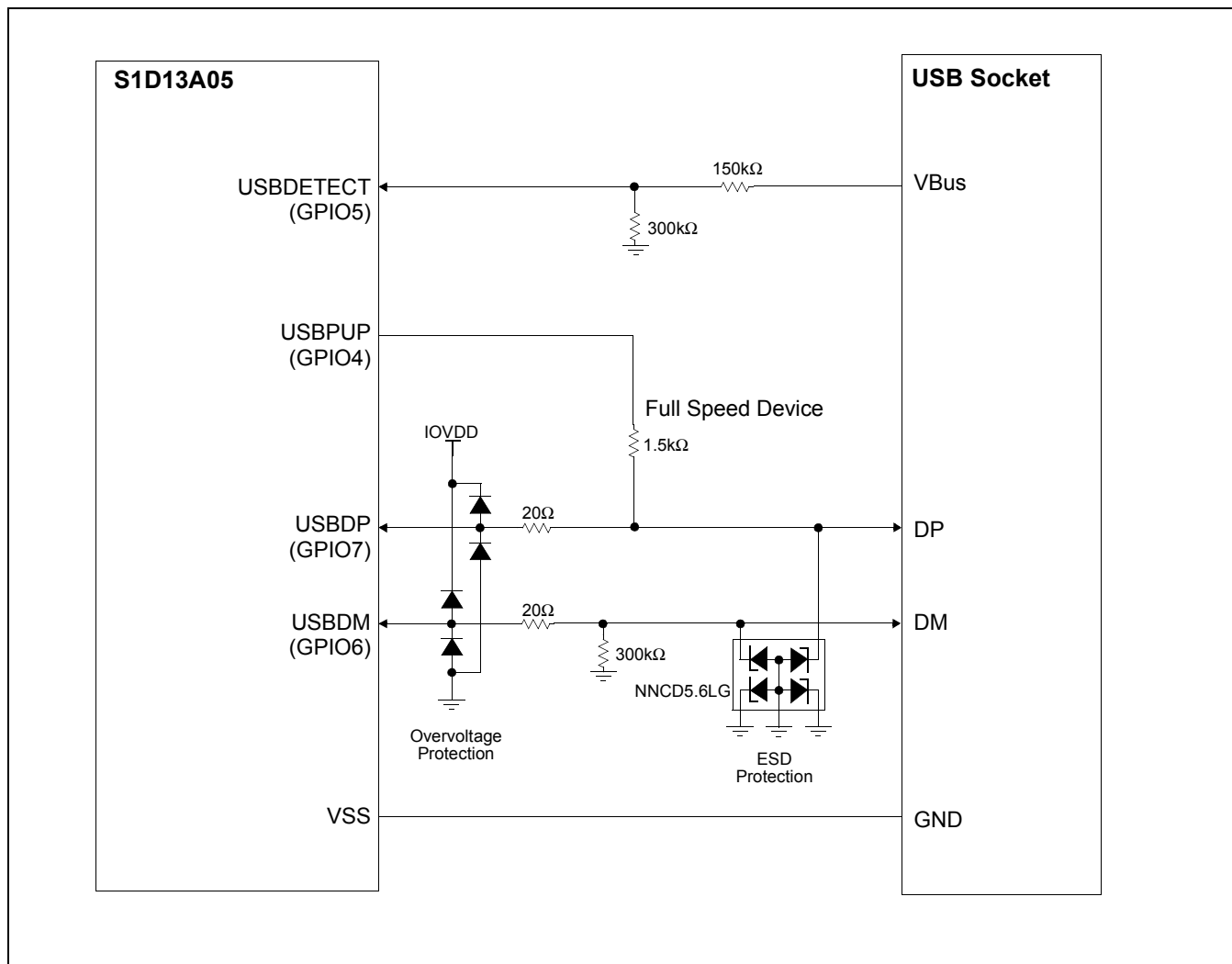


Figure 3-9: USB Typical Implementation

4 Pins

4.1 Pinout Diagram - PFBGA - 121pin

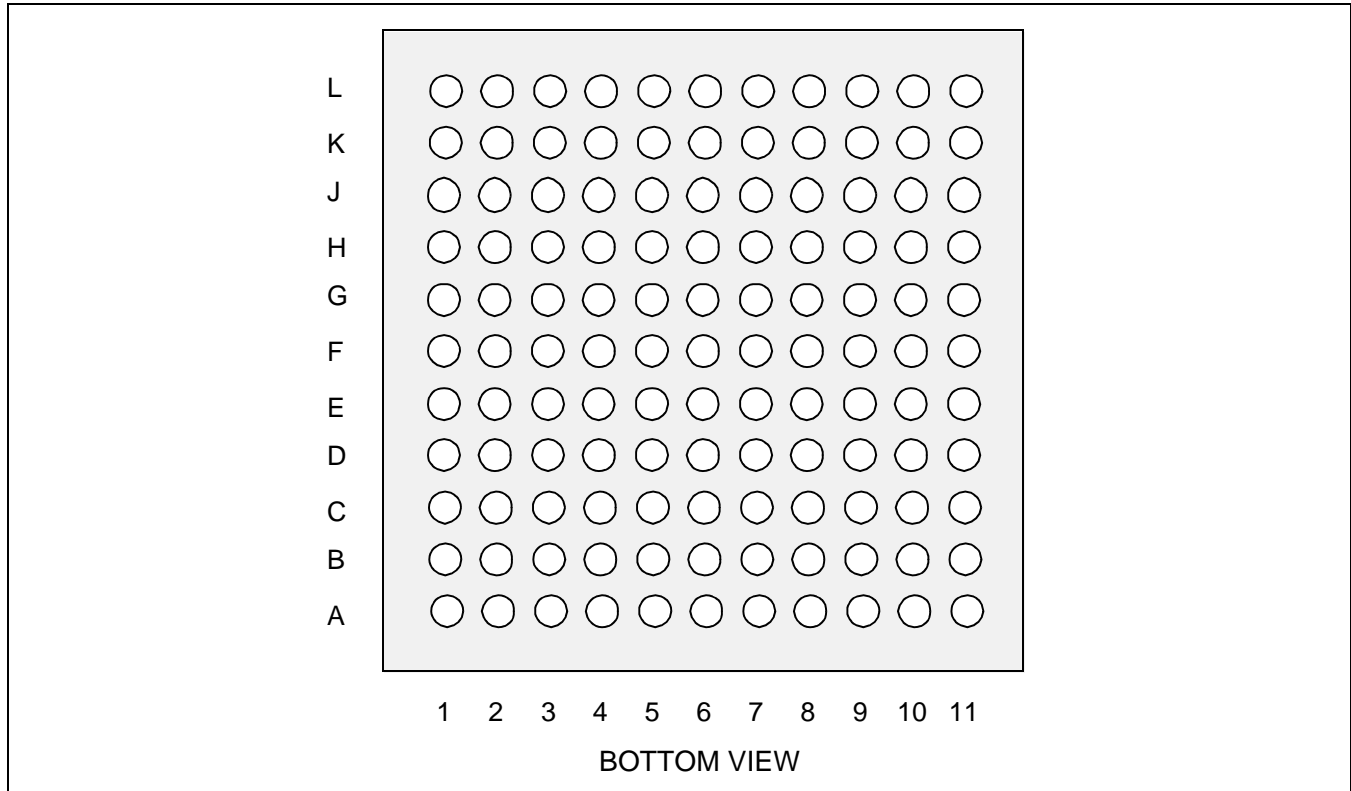


Figure 4-1: Pinout Diagram - PFBGA 121-pin

Table 4-1: PFBGA 121-pin Mapping

| | | | | | | | | | | | |
|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|-----------|-----------|
| L | NC | IOVDD | DB7 | DB3 | DB0 | GPIO7 | GPIO3 | GPIO0 | IOVDD | COREVDD | NC |
| K | GPO0 | VSS | DB8 | DB4 | DB1 | GPIO6 | GPIO2 | IRQ | DRDY | VSS | GPO6 |
| J | GPO1 | DB9 | DB6 | DB5 | DB2 | GPO3 | GPIO1 | USBCLK | FPFRAME | COREVDD | GPO7 |
| H | DB12 | DB11 | DB10 | DB13 | GPO2 | IOVDD | GPIO4 | GPO5 | FPLINE | FPSHIFT | FPDAT0 |
| G | WAIT# | DB15 | DB14 | IOVDD | VSS | GPIO5 | FPDAT5 | FPDAT1 | FPDAT2 | FPDAT3 | FPDAT4 |
| F | RESET# | VSS | RD/WR# | WE1# | CLKI | GPO4 | FPDAT8 | FPDAT6 | VSS | FPDAT7 | IOVDD |
| E | RD# | BS# | M/R# | CS# | WE0# | AB13 | TESTEN | FPDAT9 | FPDAT12 | FPDAT11 | FPDAT10 |
| D | AB0 | AB1 | AB2 | AB8 | AB12 | AB17 | CNF3 | FPDAT13 | FPDAT16 | FPDAT15 | FPDAT14 |
| C | USBOSCO | COREVDD | AB3 | AB6 | AB9 | AB16 | CNF2 | CNF5 | CNF6 | FPDAT17 | GPO8 |
| B | USBOSCI | VSS | AB5 | GPO10 | AB10 | AB14 | CNF1 | CNF4 | CLKI2 | VSS | GPO9 |
| A | NC | COREVDD | AB4 | AB7 | AB11 | AB15 | CNF0 | NC | PWMOUT | IOVDD | NC |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |

4.2 Pin Descriptions

Key:

| | | |
|------|---|---|
| I | = | Input |
| O | = | Output |
| IO | = | Bi-Directional (Input/Output) |
| P | = | Power pin |
| CI | = | CMOS input |
| LI | = | LVTTTL ^a input |
| LB2A | = | LVTTTL IO buffer (6mA/-6mA@3.3V) |
| LB3P | = | Low noise LVTTTL IO buffer (6mA/-6mA@3.3V) |
| LO3 | = | Low noise LVTTTL Output buffer (3mA/-3mA@3.3V) |
| LB3M | = | Low noise LVTTTL IO buffer with input mask (3mA/-3mA@3.3V) |
| T1 | = | Test mode control input with pull-down resistor (typical value of 50KΩ at 3.3V) |
| Hi-Z | = | High Impedance |
| CUS | = | Custom Cell Type |

^a LVTTTL is Low Voltage TTL.

4.2.1 Host Interface

Table 4-2: Host Interface Pin Descriptions

| Pin Name | PFBGA Pin # | I/O type (see key above) | RESET# State | Description |
|----------|--|--------------------------|--------------|--|
| AB0 | D1 | LI | — | This input pin has multiple functions. <ul style="list-style-type: none"> For Generic #1, this pin is not used and should be connected to VSS. For Generic #2, this pin inputs system address bit 0 (A0). For SH-3/SH-4, this pin is not used and should be connected to VSS. For MC68K #1, this pin inputs the lower data strobe (LDS#). For MC68K #2, this pin inputs system address bit 0 (A0). For REDCAP2, this pin is not used and should be connected to VSS. For DragonBall, this pin is not used and should be connected to VSS. |
| AB[17:1] | D6,C6,A6, B6,E6,D5, A5,B5,C5, D4,A4,C4, B3,A3,C3, D3,D2 | CI | — | System address bus bits 17-1. |
| DB[15:0] | L5,K5,J5, L4,K4,J4, J3,L3,K3, J2,H3,H2, H1,H4,G3, G2 | LB2A | Hi-Z | Input data from the system data bus. <ul style="list-style-type: none"> For Generic #1, these pins are connected to D[15:0]. For Generic #2, these pins are connected to D[15:0]. For SH-3/SH-4, these pins are connected to D[15:0]. For MC68K #1, these pins are connected to D[15:0]. For MC68K #2, these pins are connected to D[31:16] for a 32-bit device (e.g. MC68030) or D[15:0] for a 16-bit device (e.g. MC68340). For REDCAP2, these pins are connected to D[15:0]. For DragonBall, these pins are connected to D[15:0]. |

Table 4-2: Host Interface Pin Descriptions

| Pin Name | PFBGA Pin # | I/O type (see key above) | RESET# State | Description |
|----------|-------------|--------------------------|--------------|--|
| WE0# | E5 | LI | — | <p>This input pin has multiple functions.</p> <ul style="list-style-type: none"> For Generic #1, this pin inputs the write enable signal for the lower data byte (WE0#). For Generic #2, this pin inputs the write enable signal (WE#) For SH-3/SH-4, this pin inputs the write enable signal for data byte 0 (WE0#). For MC68K #1, this pin must be tied to IO V_{DD} For MC68K #2, this pin inputs the bus size bit 0 (SIZ0). For REDCAP2, this pin inputs the byte enable signal for the D[7:0] data byte ($\overline{EB1}$). For DragonBall, this pin inputs the byte enable signal for the D[7:0] data byte (LWE). |
| WE1# | F4 | LI | — | <p>This input pin has multiple functions.</p> <ul style="list-style-type: none"> For Generic #1, this pin inputs the write enable signal for the upper data byte (WE1#). For Generic #2, this pin inputs the byte enable signal for the high data byte (BHE#). For SH-3/SH-4, this pin inputs the write enable signal for data byte 1 (WE1#). For MC68K #1, this pin inputs the upper data strobe (UDS#). For MC68K #2, this pin inputs the data strobe (DS#). For REDCAP2, this pin inputs the byte enable signal for the D[15:8] data byte ($\overline{EB0}$). For DragonBall, this pin inputs the byte enable signal for the D[15:8] data byte (\overline{UWE}). |
| CS# | E4 | CI | — | Chip select input. |
| M/R# | E3 | LI | — | This input pin is used to select between the display buffer and register address spaces of the S1D13A05. M/R# is set high to access the display buffer and low to access the registers. |
| BS# | E2 | LI | — | <p>This input pin has multiple functions.</p> <ul style="list-style-type: none"> For Generic #1, this pin must be tied to V_{SS}. For Generic #2, this pin must be tied to IO V_{DD}. For SH-3/SH-4, this pin inputs the bus start signal (BS#). For MC68K #1, this pin inputs the address strobe (AS#). For MC68K #2, this pin inputs the address strobe (AS#). For REDCAP2, this pin must be tied to IO V_{DD}. For DragonBall, this pin must be tied to IO V_{DD}. |

Table 4-2: Host Interface Pin Descriptions

| Pin Name | PFBGA Pin # | I/O type (see key above) | RESET# State | Description |
|----------|-------------|--------------------------|--------------|--|
| RD/WR# | F3 | LI | — | <p>This input pin has multiple functions.</p> <ul style="list-style-type: none"> • For Generic #1, this pin inputs the read command for the upper data byte (RD1#). • For Generic #2, this pin must be tied to IO V_{DD}. • For SH-3/SH-4, this pin inputs the RD/WR# signal. The S1D13A05 needs this signal for early decode of the bus cycle. • For MC68K #1, this pin inputs the R/W# signal. • For MC68K #2, this pin inputs the R/W# signal. • For REDCAP2, this pin inputs the R/W# signal. • For DragonBall, this pin must be tied to IO V_{DD}. |
| RD# | E1 | LI | — | <p>This input pin has multiple functions.</p> <ul style="list-style-type: none"> • For Generic #1, this pin inputs the read command for the lower data byte (RD0#). • For Generic #2, this pin inputs the read command (RD#). • For SH-3/SH-4, this pin inputs the read signal (RD#). • For MC68K #1, this pin must be tied to IO V_{DD}. • For MC68K #2, this pin inputs the bus size bit 1 (SIZ1). • For REDCAP2, this pin inputs the output enable (\overline{OE}). • For DragonBall, this pin inputs the output enable (\overline{OE}). |
| WAIT# | G1 | LB2A | Hi-Z | <p>During a data transfer, this output pin is driven active to force the system to insert wait states. It is driven inactive to indicate the completion of a data transfer. WAIT# is released to the high impedance state after the data transfer is complete. Its active polarity is configurable.</p> <ul style="list-style-type: none"> • For Generic #1, this pin outputs the wait signal (WAIT#). • For Generic #2, this pin outputs the wait signal (WAIT#). • For SH-3 mode, this pin outputs the wait request signal (WAIT#). • For SH-4 mode, this pin outputs the device ready signal (RDY#). • For MC68K #1, this pin outputs the data transfer acknowledge signal (DTACK#). • For MC68K #2, this pin outputs the data transfer and size acknowledge bit 1 (DSACK1#). • For REDCAP2, this pin is unused (Hi-Z). • For DragonBall, this pin outputs the data transfer acknowledge signal (DTACK). <p>Note: This pin should be tied to the inactive voltage level as selected by CNF5, using a pull-up or pull-down resistor. If CNF5 = 1, the WAIT# pin should be tied low using a pull-down resistor. If CNF5 = 0, the WAIT# pin should be tied high using a pull-up resistor. If WAIT# is not used, this pin should be tied either high or low using a pull-up or pull-down resistor.</p> |
| RESET# | F1 | LI | — | <p>Active low input to set all internal registers to the default state and to force all signals to their inactive states.</p> |

4.2.2 LCD Interface

Table 4-3: LCD Interface Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|-------------|--|--------------------------------|-----------------|---|
| FPDAT[17:0] | C10,D9,D10, D11,D8,E9, E10,E11, E8,F7,F10, F8,G7,G11, G10,G9,G8, H11 | LB3P | 0 | Panel Data bits 17-0. |
| FPFRAME | J9 | LB3P | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> • Frame Pulse • SPS for HR-TFT • GSRT for Casio • STV for TFT Type 2 • STV for TFT Type 3 |
| FPLINE | H9 | LB3P | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> • Line Pulse • LP for HR-TFT • GPCK for Casio • STB for TFT Type 2 • LP for TFT Type 3 |
| FPSHIFT | H10 | LB3P | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> • Shift Clock • DCLK for HR-TFT • CLK for Casio • CLK for TFT Type 2 • CPH for TFT Type 3 |
| DRDY | K9 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> • LCD backplane bias signal (MOD) for all other LCD panels • 2nd shift clock (FPSHIFT2) for passive LCD with Format 1 interface • Display enable (DRDY) for TFT panels • MOD for HR-TFT • INV for TFT Type 2/3 • DRDY for TFT Type 4 • General Purpose Output |
| GPO0 | K1 | LO3 | 0 | This is a general purpose output |
| GPO1 | J1 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> • When in TFT Type 3 mode, operates as VCOM • General purpose output bit otherwise |
| GPO2 | H5 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> • When in TFT Type 3 mode, operates as XOEV • General purpose output bit otherwise |

Table 4-3: LCD Interface Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|----------|------------|--------------------------------|-----------------|---|
| GPO3 | J6 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as CMD General purpose output bit otherwise |
| GPO4 | F6 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as PCLK1 General purpose output bit otherwise |
| GPO5 | H8 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as PCLK2 General purpose output bit otherwise |
| GPO6 | K11 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as XRESH General purpose output bit otherwise |
| GPO7 | J11 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as XRESV General purpose output bit otherwise |
| GPO8 | C11 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as XOHV General purpose output bit otherwise |
| GPO9 | B11 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as XSTBY General purpose output bit otherwise |
| GPO10 | B4 | LO3 | 0 | This output pin has multiple functions. <ul style="list-style-type: none"> When in TFT Type 3 mode, operates as PMDE General purpose output bit otherwise |
| GPI00 | L8 | LB3M | — | This pin has multiple functions. <ul style="list-style-type: none"> PS for HR-TFT POL for Casio VCLK for TFT Type 2 CPV for TFT Type 3 General purpose IO pin 0 (GPI00) <p>When this pin is used for the above display modes, it must be configured as an output using REG[64h] after every RESET. Otherwise, it defaults to a Hi-Z state after every RESET and must either be configured as an output or be pulled high or low externally to avoid unnecessary current drain.</p> |

Table 4-3: LCD Interface Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|----------|------------|--------------------------------|-----------------|--|
| GPIO1 | J7 | LB3M | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • CLS for HR-TFT • GRES for Casio • AP for TFT Type 2 • OE for TFT Type 3 • General purpose IO pin 1 (GPIO1) <p>When this pin is used for the above display modes, it must be configured as an output using REG[64h] after every RESET. Otherwise, it defaults to a Hi-Z state after every RESET and must either be configured as an output or be pulled high or low externally to avoid unnecessary current drain.</p> |
| GPIO2 | K7 | LB3M | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • REV for HR-TFT • FRP for Casio • POL for TFT Type 2/3 • General purpose IO pin 2 (GPIO2) <p>When this pin is used for the above display modes, it must be configured as an output using REG[64h] after every RESET. Otherwise, it defaults to a Hi-Z state after every RESET and must either be configured as an output or be pulled high or low externally to avoid unnecessary current drain.</p> |
| GPIO3 | L7 | LB3M | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • SPL for HR-TFT • STH for Casio • STH for TFT Type 2 • EIO for TFT Type 3 • General purpose IO pin 3 (GPIO3) <p>When this pin is used for the above display modes, it must be configured as an output using REG[64h] after every RESET. Otherwise, it defaults to a Hi-Z state after every RESET and must either be configured as an output or be pulled high or low externally to avoid unnecessary current drain.</p> |
| GPIO4 | H7 | LB3M | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • USBPUP • General purpose IO pin 4 (GPIO4) <p>This pin is Hi-Z after every RESET and must either be configured as an output using REG[64h] or be pulled high or low externally to avoid unnecessary current drain.</p> |
| GPIO5 | G6 | LB3M | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • USBDETECT • General purpose IO pin 5 (GPIO5) <p>This pin always defaults as an input. When not used as a USBDETECT pin, it must either be configured as an output using REG[64h] or be pulled high or low externally to avoid unnecessary current drain.</p> |

Table 4-3: LCD Interface Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|----------|------------|--------------------------------|-----------------|---|
| GPIO6 | K6 | CUS | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • USBDM • General purpose IO pin 6 (GPIO6) <p>When not used as a USB connection, this pin defaults to a Hi-Z state after every RESET and must either be configured as an output using REG[64h] or be pulled high or low externally to avoid unnecessary current drain.</p> |
| GPIO7 | L6 | CUS | — | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • USBDP • General purpose IO pin 7 <p>When not used as a USB connection, this pin defaults to a Hi-Z state after every RESET and must either be configured as an output using REG[64h] or be pulled high or low externally to avoid unnecessary current drain.</p> |
| IRQ | K8 | LO3 | 0 | <p>This output pin is the IRQ pin for USB. When IRQ is activated, an active high pulse is generated and stays high until the IRQ is serviced by software at REG[404Ah] or REG[404Ch].</p> |
| PWMOUT | A9 | LO3 | 0 | <p>This pin has multiple functions.</p> <ul style="list-style-type: none"> • PWM Clock output • General purpose output |

4.2.3 Clock Input

Table 4-4: Clock Input Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|----------|------------|--------------------------|--------------|---|
| CLKI | F5 | CI | — | Typically used as input clock source for bus clock and memory clock |
| CLKI2 | B9 | CI | — | Optionally used as input clock source for pixel clock |
| USBCLK | J8 | CI | — | Used as input clock source for USB. Note: If this pin is not connected to an input clock source, this pin must be connected to VSS. |
| USBOSCI | B1 | I | — | USB Crystal Oscillator feedback input from crystal. For an example implementation circuit using a crystal oscillator, see Section 16.1, "USB Oscillator Circuit" on page 184. Note: If this pin is not connected to a USB Crystal Oscillator, this pin must be connected to VSS. |
| USBOSCO | C1 | O | — | USB Crystal Oscillator output to crystal. For an example implementation circuit using a crystal oscillator, see Section 16.1, "USB Oscillator Circuit" on page 184. |

4.2.4 Miscellaneous

Table 4-5: Miscellaneous Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|----------|------------------------------|--------------------------|--------------|--|
| CNF[6:0] | C9,C8,B8, D7,C7,B7, A7 | CI | — | These inputs are used to configure the S1D13A05 - see Table 4-7: "Summary of Power-On/Reset Options," on page 32. Note: These pins are used for configuration of the S1D13A05 and must be connected directly to IO V_{DD} or V_{SS}. |
| TESTEN | E7 | T1 | — | Test Enable input used for production test only (has type 1 pull-down resistor with a typical value of 50KΩ at 3.3V). Note: This pin must be left un-connected. |

4.2.5 Power And Ground

Table 4-6: Power And Ground Pin Descriptions

| Pin Name | PFBGA Pin# | I/O type (see key above) | RESET# State | Description |
|----------|--------------------------------|--------------------------|--------------|--------------------------------|
| IOVDD | L2,G4,H6, L9,A10,F11 | P | — | 6 IO V _{DD} pins. |
| COREVDD | A2,C2,L10, J10 | P | — | 4 Core V _{DD} . pins. |
| VSS | B2,F2,K2, G5,F9,B10, K10 | P | — | 7 V _{SS} pins. |

4.3 Summary of Configuration Options

These pins are used for configuration of the S1D13A05 and must be connected directly to IOV_{DD} or V_{SS}. The state of CNF[6:0] are latched on the rising edge of RESET#. Changing state at any other time has no effect.

Table 4-7: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | |
|------------------------------------|---------------------------------------|-----------------------------------|-------------------------------|--|------------------------------------|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | |
| CNF4,CNF[2:0] | Select host bus interface as follows: | | | | |
| | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus |
| | 1 | 0 | 0 | 0 | SH-4/SH-3 interface, Big Endian |
| | 0 | 0 | 0 | 0 | SH-4/SH-3 interface, Little Endian |
| | 1 | 0 | 0 | 1 | MC68K #1, Big Endian |
| | 0 | 0 | 0 | 1 | Reserved |
| | 1 | 0 | 1 | 0 | MC68K #2, Big Endian |
| | 0 | 0 | 1 | 0 | Reserved |
| | 1 | 0 | 1 | 1 | Generic #1, Big Endian |
| | 0 | 0 | 1 | 1 | Generic #1, Little Endian |
| | 1 | 1 | 0 | 0 | Reserved |
| | 0 | 1 | 0 | 0 | Generic #2, Little Endian |
| | 1 | 1 | 0 | 1 | REDCAP2, Big Endian |
| | 0 | 1 | 0 | 1 | Reserved |
| 1 | 1 | 1 | 0 | DragonBall (MC68EZ328/VZ328/SZ328), Big Endian | |
| 0 | 1 | 1 | 0 | Reserved | |
| X | 1 | 1 | 1 | Reserved | |
| CNF3 | Reserved. Must be set to 1. | | | | |
| CNF5 (see note) | WAIT# is active high | | WAIT# is active low | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | | CLKI to BCLK divide ratio 1:1 | | |

Note

If CNF5 = 1, the WAIT# pin should be tied low using a pull-down resistor. If CNF5 = 0, the WAIT# pin should be tied high using a pull-up resistor. If WAIT# is not used, this pin should be tied either high or low using a pull-up or pull-down resistor.

4.4 Host Bus Interface Pin Mapping

Table 4-8: Host Bus Interface Pin Mapping

| S1D13A05 Pin Name | Generic #1 | Generic #2 | Hitachi SH-3 /SH-4 | Motorola MC68K #1 | Motorola MC68K #2 | Motorola REDCAP2 | Motorola MC68EZ328/ MC68VZ328 DragonBall |
|----------------------|--------------------------------|-----------------------------------|-----------------------|-----------------------------------|----------------------|--------------------------------|---|
| AB[17:1] | A[17:1] | A[17:1] | A[17:1] | A[17:1] | A[17:1] | A[17:1] | A[17:1] |
| AB0 | A0 ¹ | A0 | A0 ¹ | LDS# | A0 | A0 ¹ | A0 ¹ |
| DB[15:0] | D[15:0] | D[15:0] | D[15:0] | D[15:0] | D[15:0] ² | D[15:0] | D[15:0] |
| CS# | External Decode | | CSn# | External Decode | | \overline{CSn} | \overline{CSX} |
| M/R# | External Decode | | | | | | |
| CLKI | BUSCLK | BUSCLK | CKIO | CLK | CLK | CLK | CLKO |
| BS# | Connected to IOV _{DD} | | BS# | AS# | AS# | Connected to IOV _{DD} | |
| RD/WR# | RD1# | Connected to IOV _{DD} | RD/WR# | R/W# | R/W# | R \overline{W} | Connected to IOV _{DD} |
| RD# | RD0# | RD# | RD# | Connected to IOV _{DD} | SIZ1 | \overline{OE} | \overline{OE} |
| WE0# | WE0# | WE# | WE0# | Connected to IOV _{DD} | SIZ0 | $\overline{EB1}$ | \overline{LWE} |
| WE1# | WE1# | BHE# | WE1# | UDS# | DS# | $\overline{EB0}$ | \overline{UWE} |
| WAIT# | WAIT# | WAIT# | WAIT#/ RDY# | DTACK# | DSACK1# | N/A | \overline{DTACK} |
| RESET# | RESET# | RESET# | RESET# | RESET# | RESET# | $\overline{RESET_OUT}$ | \overline{RESET} |

Note

¹ A0 for these busses is not used internally by the S1D13A05 and should be connected to V_{SS}.

² If the target MC68K bus is 32-bit, then these signals should be connected to D[31:16].

4.5 LCD Interface Pin Mapping

Table 4-9: LCD Interface Pin Mapping

| Pin Name | Monochrome Passive Panel | | | Color Passive Panel | | | | | | Color TFT Panel | | | | | | USB | | |
|----------|-------------------------------|----------|----------------------|----------------------|----------------------|-----------------------|----------|----------|--------|--------------------------|----------|------------|---------------------------|------------------------|-------------------------|-----------|-------------------------|------------|
| | Single | | | Single | | | | | | Generic TFT (TFT Type 1) | | | Sharp HR-TFT ¹ | Casio TFT ¹ | TFT Type 2 ¹ | | TFT Type 3 ¹ | TFT Type 4 |
| | 4-bit | 8-bit | | 4-bit | Format 1 8-bit | Format 2 8-bit | 16-Bit | 9-bit | 12-bit | 18-bit | 18-bit | 18-bit | 18-bit | 18-bit | 18-bit | | 18-bit ³ | |
| FPFRAME | FPFRAME | | | FPFRAME | | | | | | SPS | | | GSRT | GSRT | STV | STV | FPFRAME | --- |
| FPLINE | FPLINE | | | FPLINE | | | | | | LP | | | GPCK | GPCK | STB | LP | FPLINE | --- |
| FPSHIFT | FPSHIFT | | | FPSHIFT | | | | | | DCLK | | | CLK | CLK | CLK | CPH | FPSHIFT | --- |
| DRDY | MOD | | | FPSHIFT ₂ | MOD | | | DRDY | | | driven 0 | no connect | INV | INV | DRDY | --- | | |
| FPDAT0 | driven 0 | D0 | driven 0 | D0 (B5) ² | D0 (G3) ² | D0 (R6) ² | R2 | R3 | R5 | R5 | R5 | R5 | R5 | R5 | R5 | --- | | |
| FPDAT1 | driven 0 | D1 | driven 0 | D1 (R5) ² | D1 (R3) ² | D1 (G5) ² | R1 | R2 | R4 | R4 | R4 | R4 | R4 | R4 | R4 | --- | | |
| FPDAT2 | driven 0 | D2 | driven 0 | D2 (G4) ² | D2 (B2) ² | D2 (B4) ² | R0 | R1 | R3 | R3 | R3 | R3 | R3 | R3 | R3 | --- | | |
| FPDAT3 | driven 0 | D3 | driven 0 | D3 (B3) ² | D3 (G2) ² | D3 (R4) ² | G2 | G3 | G5 | G5 | G5 | G5 | G5 | G5 | G5 | --- | | |
| FPDAT4 | D0 | D4 | D0 (R2) ² | D4 (R3) ² | D4 (R2) ² | D8 (B5) ² | G1 | G2 | G4 | G4 | G4 | G4 | G4 | G4 | G4 | --- | | |
| FPDAT5 | D1 | D5 | D1 (B1) ² | D5 (G2) ² | D5 (B1) ² | D9 (R5) ² | G0 | G1 | G3 | G3 | G3 | G3 | G3 | G3 | G3 | --- | | |
| FPDAT6 | D2 | D6 | D2 (G1) ² | D6 (B1) ² | D6 (G1) ² | D10 (G4) ² | B2 | B3 | B5 | B5 | B5 | B5 | B5 | B5 | B5 | --- | | |
| FPDAT7 | D3 | D7 | D3 (R1) ² | D7 (R1) ² | D7 (R1) ² | D11 (B3) ² | B1 | B2 | B4 | B4 | B4 | B4 | B4 | B4 | B4 | --- | | |
| FPDAT8 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D4 (G3) ² | B0 | B1 | B3 | B3 | B3 | B3 | B3 | B3 | B3 | --- | | |
| FPDAT9 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D5 (B2) ² | driven 0 | R0 | R2 | R2 | R2 | R2 | R2 | R2 | R2 | --- | | |
| FPDAT10 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D6 (R2) ² | driven 0 | driven 0 | R1 | R1 | R1 | R1 | R1 | R1 | R1 | --- | | |
| FPDAT11 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D7 (G1) ² | driven 0 | driven 0 | R0 | R0 | R0 | R0 | R0 | R0 | R0 | --- | | |
| FPDAT12 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D12 (R3) ² | driven 0 | G0 | G2 | G2 | G2 | G2 | G2 | G2 | G2 | --- | | |
| FPDAT13 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D13 (G2) ² | driven 0 | driven 0 | G1 | G1 | G1 | G1 | G1 | G1 | G1 | --- | | |
| FPDAT14 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D14 (B1) ² | driven 0 | driven 0 | G0 | G0 | G0 | G0 | G0 | G0 | G0 | --- | | |
| FPDAT15 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | D15 (R1) ² | driven 0 | B0 | B2 | B2 | B2 | B2 | B2 | B2 | B2 | --- | | |
| FPDAT16 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | B1 | B1 | B1 | B1 | B1 | B1 | B1 | --- | | |
| FPDAT17 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | driven 0 | B0 | B0 | B0 | B0 | B0 | B0 | B0 | --- | | |
| GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | GPIO0 | PS | POL | VCLK | CPV | GPIO0 | --- | | |
| GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | GPIO1 | CLS | GRES | AP | OE | GPIO1 | --- | | |
| GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | GPIO2 | REV | FRP | POL | POL | GPIO2 | --- | | |
| GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | GPIO3 | SPL | STH | STH | EIO | GPIO3 | --- | | |
| GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | GPIO4 | USBPUP | | |
| GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | GPIO5 | USBDETECT | | |
| GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | GPIO6 | USBDM | | |
| GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | GPIO7 | USBDBP | | |
| GPO0 | GPO0 (General Purpose Output) | | | | | | | | | | | | | | | --- | | |
| GPO1 | | | | | | | | | | | | | VCOM | GPO1 | --- | | | |
| GPO2 | | | | | | | | | | | | | XOEV | GPO2 | --- | | | |
| GPO3 | | | | | | | | | | | | | CMD | GPO3 | --- | | | |
| GPO4 | | | | | | | | | | | | | PCLK1 | GPO4 | --- | | | |
| GPO5 | | | | | | | | | | | | | PCLK2 | GPO5 | --- | | | |
| GPO6 | | | | | | | | | | | | | XRESH | GPO6 | --- | | | |
| GPO7 | | | | | | | | | | | | | XRESV | GPO7 | --- | | | |
| GPO8 | | | | | | | | | | | | | XOHV | GPO8 | --- | | | |
| GPO9 | | | | | | | | | | | | | XSTBY | GPO9 | --- | | | |
| GPO10 | | | | | | | | | | | | | PMDE | GPO10 | --- | | | |
| PWMOUT | PWMOUT | | | | | | | | | | | | | | | --- | | |

Note

- ¹ GPIO pins which are used by the HR-TFT, Casio, TFT Type 2, and TFT Type 3 interfaces, must be configured as outputs using REG[64h] bits 23-16 after every RESET or power-up.
- ² These pin mappings use signal names commonly used for each panel type, however signal names may differ between panel manufacturers. The values shown in brackets represent the color components as mapped to the corresponding FPDATxx signals at the first valid edge of FPSHIFT. For further FPDATxx to LCD interface mapping, see Section 6.4, “Display Interface” on page 60.
- ³ The S1D13A05 also supports the 9-bit and 12-bit variations of the Type 4 TFT panel.

5 D.C. Characteristics

Note

When applying Supply Voltages to the S1D13A05, Core V_{DD} must be applied to the chip before, or simultaneously with IO V_{DD} , or damage to the chip may result.

Table 5-1: Absolute Maximum Ratings

| Symbol | Parameter | Rating | Units |
|---------------|-------------------------|-------------------------------------|-------|
| Core V_{DD} | Supply Voltage | $V_{SS} - 0.3$ to 3.0 | V |
| IO V_{DD} | Supply Voltage | $V_{SS} - 0.3$ to 4.0 | V |
| V_{IN} | Input Voltage | $V_{SS} - 0.3$ to IO $V_{DD} + 0.5$ | V |
| V_{OUT} | Output Voltage | $V_{SS} - 0.3$ to IO $V_{DD} + 0.5$ | V |
| T_{STG} | Storage Temperature | -65 to 150 | °C |
| T_{SOL} | Solder Temperature/Time | 260 for 10 sec. max at lead | °C |

Table 5-2: Recommended Operating Conditions

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|---------------|-----------------------|----------------|--------------|--------------|---------------|-------|
| Core V_{DD} | Supply Voltage | $V_{SS} = 0$ V | 1.8 (note 1) | 2.0 (note 1) | 2.2 (note 1) | V |
| | | $V_{SS} = 0$ V | 2.25 | 2.5 | 2.75 | V |
| IO V_{DD} | Supply Voltage | $V_{SS} = 0$ V | 3.0 | 3.3 | 3.6 | V |
| V_{IN} | Input Voltage | | V_{SS} | | IO V_{DD} | V |
| | | | V_{SS} | | CORE V_{DD} | |
| T_{OPR} | Operating Temperature | | -40 | 25 | 85 | °C |

- When Core V_{DD} is $2.0V \pm 10\%$, the MCLK must be less than or equal to 30MHz ($MCLK \leq 30MHz$)

Table 5-3: Electrical Characteristics for $V_{DD} = 3.3V$ typical

| Symbol | Parameter | Condition | Min | Typ | Max | Units |
|-----------|--------------------------------|--|----------------|-----|-----|-----------|
| I_{DDs} | Quiescent Current | Quiescent Conditions | | | 170 | μA |
| I_{IZ} | Input Leakage Current | | -1 | | 1 | μA |
| I_{OZ} | Output Leakage Current | | -1 | | 1 | μA |
| V_{OH} | High Level Output Voltage | $V_{DD} = \min$ $I_{OH} = -3mA$ (Type 1) $-6mA$ (Type 2) | $V_{DD} - 0.4$ | | | V |
| V_{OL} | Low Level Output Voltage | $V_{DD} = \min$ $I_{OL} = 3mA$ (Type 1) $6mA$ (Type 2) | | | 0.4 | V |
| V_{IH} | High Level Input Voltage | LVTTL Level, $V_{DD} = \max$ | 2.0 | | | V |
| V_{IL} | Low Level Input Voltage | LVTTL Level, $V_{DD} = \min$ | | | 0.8 | V |
| R_{PD} | Pull Down Resistance | $V_{IN} = V_{DD}$ | 20 | 50 | 120 | $k\Omega$ |
| C_I | Input Pin Capacitance | | | | 10 | pF |
| C_O | Output Pin Capacitance | | | | 10 | pF |
| C_{IO} | Bi-Directional Pin Capacitance | | | | 10 | pF |

6 A.C. Characteristics

Conditions: IO $V_{DD} = 3.3V \pm 10\%$

$T_A = -40^\circ C$ to $85^\circ C$

T_{rise} and T_{fall} for all inputs must be ≤ 5 nsec (10% ~ 90%)

$C_L = 50pF$ (Bus/MPU Interface)

$C_L = 0pF$ (LCD Panel Interface)

6.1 Clock Timing

6.1.1 Input Clocks

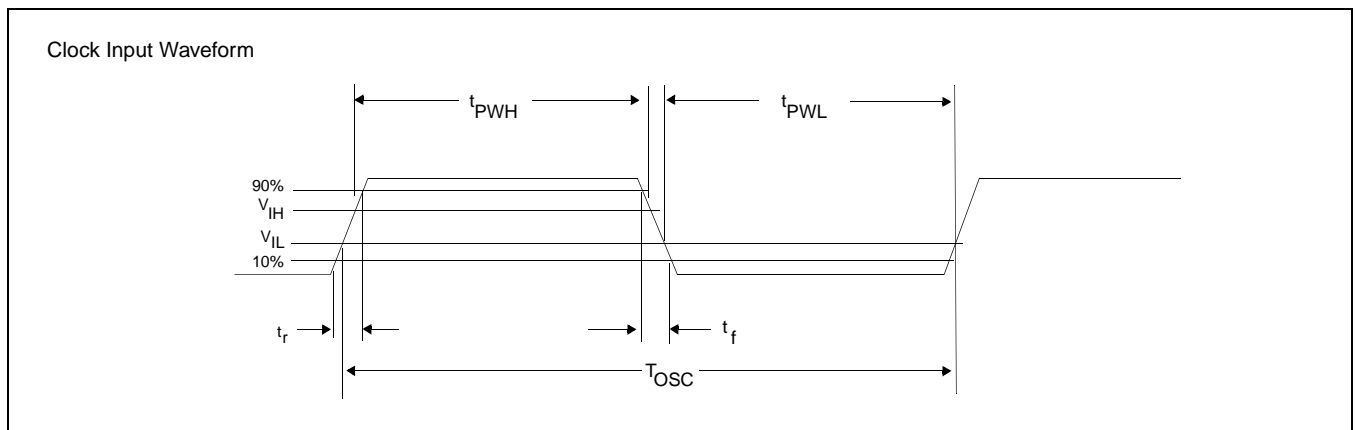


Figure 6-1: Clock Input Requirements

Table 6-1: Clock Input Requirements for CLKI when CLKI to BCLK divide > 1

| Symbol | Parameter | Min | Max | Units |
|-----------|-------------------------------------|-------------|-----|-------|
| f_{OSC} | Input Clock Frequency (CLKI) | | 100 | MHz |
| T_{OSC} | Input Clock period (CLKI) | $1/f_{OSC}$ | | ns |
| t_{PWH} | Input Clock Pulse Width High (CLKI) | 4.5 | | ns |
| t_{PWL} | Input Clock Pulse Width Low (CLKI) | 4.5 | | ns |
| t_f | Input Clock Fall Time (10% - 90%) | | 5 | ns |
| t_r | Input Clock Rise Time (10% - 90%) | | 5 | ns |

Note

Maximum internal requirements for clocks derived from CLKI must be considered when determining the frequency of CLKI. See Section 6.1.2, “Internal Clocks” on page 39 for internal clock requirements.

Table 6-2: Clock Input Requirements for CLKI when CLKI to BCLK divide = 1

| Symbol | Parameter | Min | Max | Units |
|-----------|-------------------------------------|-------------|-----|-------|
| f_{OSC} | Input Clock Frequency (CLKI) | | 66 | MHz |
| T_{OSC} | Input Clock period (CLKI) | $1/f_{OSC}$ | | ns |
| t_{PWH} | Input Clock Pulse Width High (CLKI) | 3 | | ns |
| t_{PWL} | Input Clock Pulse Width Low (CLKI) | 3 | | ns |
| t_f | Input Clock Fall Time (10% - 90%) | | 5 | ns |
| t_r | Input Clock Rise Time (10% - 90%) | | 5 | ns |

Note

Maximum internal requirements for clocks derived from CLKI must be considered when determining the frequency of CLKI. See Section 6.1.2, “Internal Clocks” on page 39 for internal clock requirements.

Table 6-3: Clock Input Requirements for CLKI2

| Symbol | Parameter | Min | Max | Units |
|-----------|--------------------------------------|-------------|-----|-------|
| f_{OSC} | Input Clock Frequency (CLKI2) | | 66 | MHz |
| T_{OSC} | Input Clock period (CLKI2) | $1/f_{OSC}$ | | ns |
| t_{PWH} | Input Clock Pulse Width High (CLKI2) | 3 | | ns |
| t_{PWL} | Input Clock Pulse Width Low (CLKI2) | 3 | | ns |
| t_f | Input Clock Fall Time (10% - 90%) | | 5 | ns |
| t_r | Input Clock Rise Time (10% - 90%) | | 5 | ns |

Note

Maximum internal requirements for clocks derived from CLKI2 must be considered when determining the frequency of CLKI2. See Section 6.1.2, “Internal Clocks” on page 39 for internal clock requirements.

6.1.2 Internal Clocks

Table 6-4: Internal Clock Requirements

| Symbol | Parameter | Min | Max | Units |
|--------------|-------------------------------------|----------------|-----|-------|
| f_{BCLK} | Bus Clock frequency | | 66 | MHz |
| f_{MCLK} | Memory Clock frequency (see note 1) | COREVDD = 2.0V | 30 | MHz |
| | | COREVDD = 2.5V | 50 | MHz |
| f_{PCLK} | Pixel Clock frequency | | 50 | MHz |
| f_{PWMCLK} | PWM Clock frequency | | 66 | MHz |

1. MCLK is derived from BCLK, therefore when BCLK is greater than 50MHz, MCLK must be divided using REG[04h] bits 5-4.

Note

For further information on internal clocks, refer to Section 7, “Clocks” on page 94.

6.2 CPU Interface Timing

6.2.1 Generic #1 Interface Timing

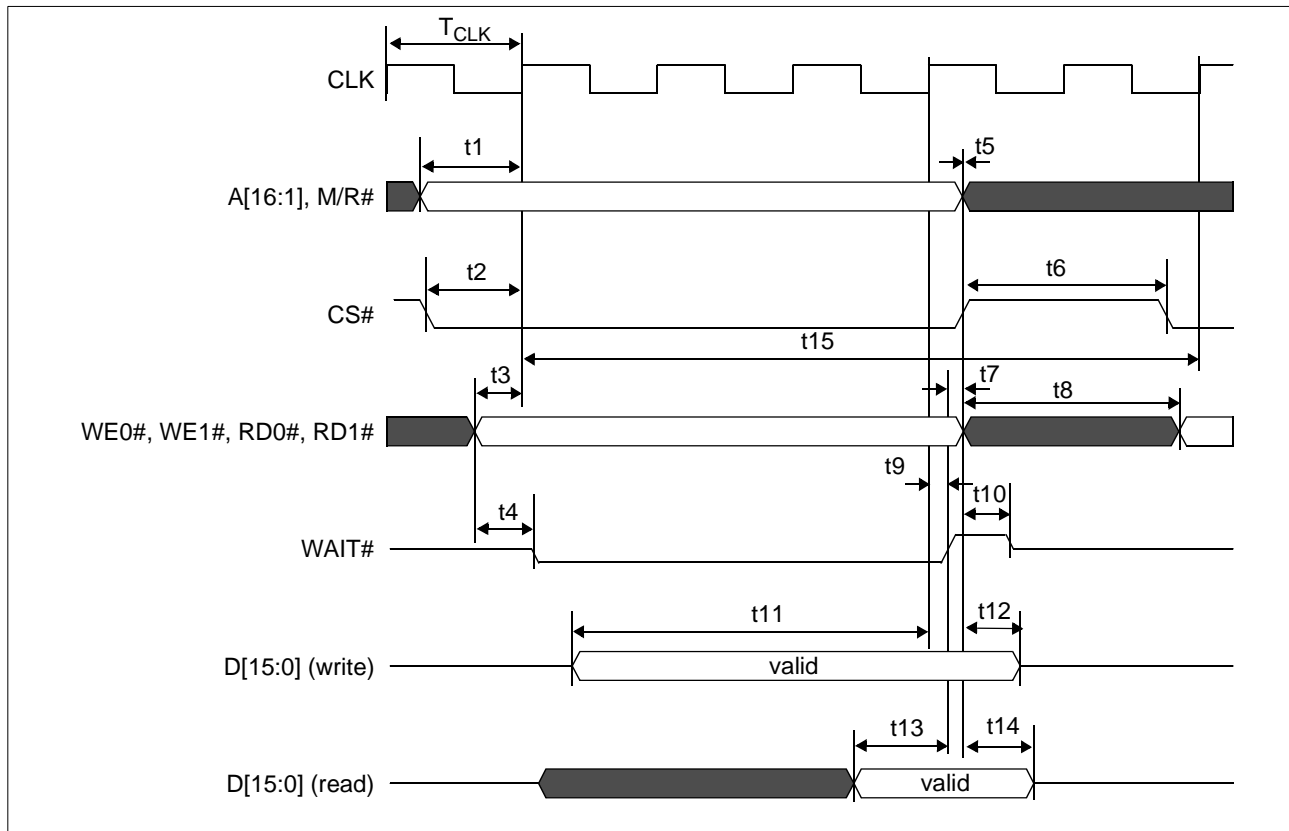


Figure 6-2: Generic #1 Interface Timing

Table 6-5: Generic #1 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|-----------|--|-------------|-----|-----------|
| f_{CLK} | Bus clock frequency | | 50 | MHz |
| T_{CLK} | Bus clock period | $1/f_{CLK}$ | | ns |
| t_1 | A[16:1], M/R# setup to first CLK rising edge where CS# = 0 and either RD0#, RD1# = 0 or WE0#, WE1# = 0 | 0 | | ns |
| t_2 | CS# setup to CLK rising edge | 0 | | ns |
| t_3 | RD0#, RD1#, WE0#, WE1# setup to CLK rising edge | 0 | | ns |
| t_4 | RD0#, RD1# or WE0#, WE1# state change to WAIT# driven low | 3 | 8 | ns |
| t_5 | A[16:1], M/R# and CS# hold from RD0#, RD1#, WE0#, WE1# rising edge | 0 | | ns |
| t_6 | CS# deasserted to reasserted | 0 | | ns |
| t_7 | WAIT# rising edge to RD0#, RD1#, WE0#, WE1# rising edge | 0 | | ns |
| t_8 | WE0#, WE1#, RD0#, RD1# deasserted to reasserted | 1 | | T_{CLK} |
| t_9 | CLK rising edge to WAIT# rising edge | 5 | 14 | ns |

Table 6-5: Generic #1 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|--------|--|-----|-----|------------------|
| t10 | Rising edge of either RD0#, RD1# or WE0#, WE1# to WAIT# high impedance | | 5 | ns |
| t11 | D[15:0] setup to 4th rising CLK edge after CS#=0 and WE0#, WE1#=0 | 1 | | T _{CLK} |
| t12 | D[15:0] hold from WE0#, WE1# rising edge (write cycle) | 0 | | ns |
| t13 | D[15:0] valid to WAIT# rising edge (read cycle) | 0.5 | | T _{CLK} |
| t14 | D[15:0] hold from RD0#, RD1# rising edge (read cycle) | 2 | | ns |
| t15 | Cycle Length | 6 | | T _{CLK} |

Table 6-6: Generic #1 Interface Truth Table for Little Endian

| WE0# | WE1# | RD0# | RD1# | D[15:8] | D[7:0] | Comments |
|------|------|------|------|---------|--------|---|
| 0 | 0 | 1 | 1 | valid | valid | 16-bit write |
| 0 | 1 | 1 | 1 | - | valid | 8-bit write; data on low byte (even byte address ¹) |
| 1 | 0 | 1 | 1 | valid | - | 8-bit write; data on high byte (odd byte address ¹) |
| 1 | 1 | 0 | 0 | valid | valid | 16-bit read |
| 1 | 1 | 0 | 1 | - | valid | 8-bit read; data on low byte (even byte address ¹) |
| 1 | 1 | 1 | 0 | valid | - | 8-bit read; data on high byte (odd byte address ¹) |

Table 6-7: Generic #1 Interface Truth Table for Big Endian

| WE0# | WE1# | RD0# | RD1# | D[15:8] | D[7:0] | Comments |
|------|------|------|------|---------|--------|--|
| 0 | 0 | 1 | 1 | valid | valid | 16-bit write |
| 0 | 1 | 1 | 1 | - | valid | 8-bit write; data on low byte (odd byte address ¹) |
| 1 | 0 | 1 | 1 | valid | - | 8-bit write; data on high byte (even byte address ¹) |
| 1 | 1 | 0 | 0 | valid | valid | 16-bit read |
| 1 | 1 | 0 | 1 | - | valid | 8-bit read; data on low byte (odd byte address ¹) |
| 1 | 1 | 1 | 0 | valid | - | 8-bit read; data on high byte (even byte address ¹) |

1. Because A0 is not used internally, all addresses are seen by the S1D13A05 as even addresses (16-bit word address aligned on even byte addresses).

6.2.2 Generic #2 Interface Timing

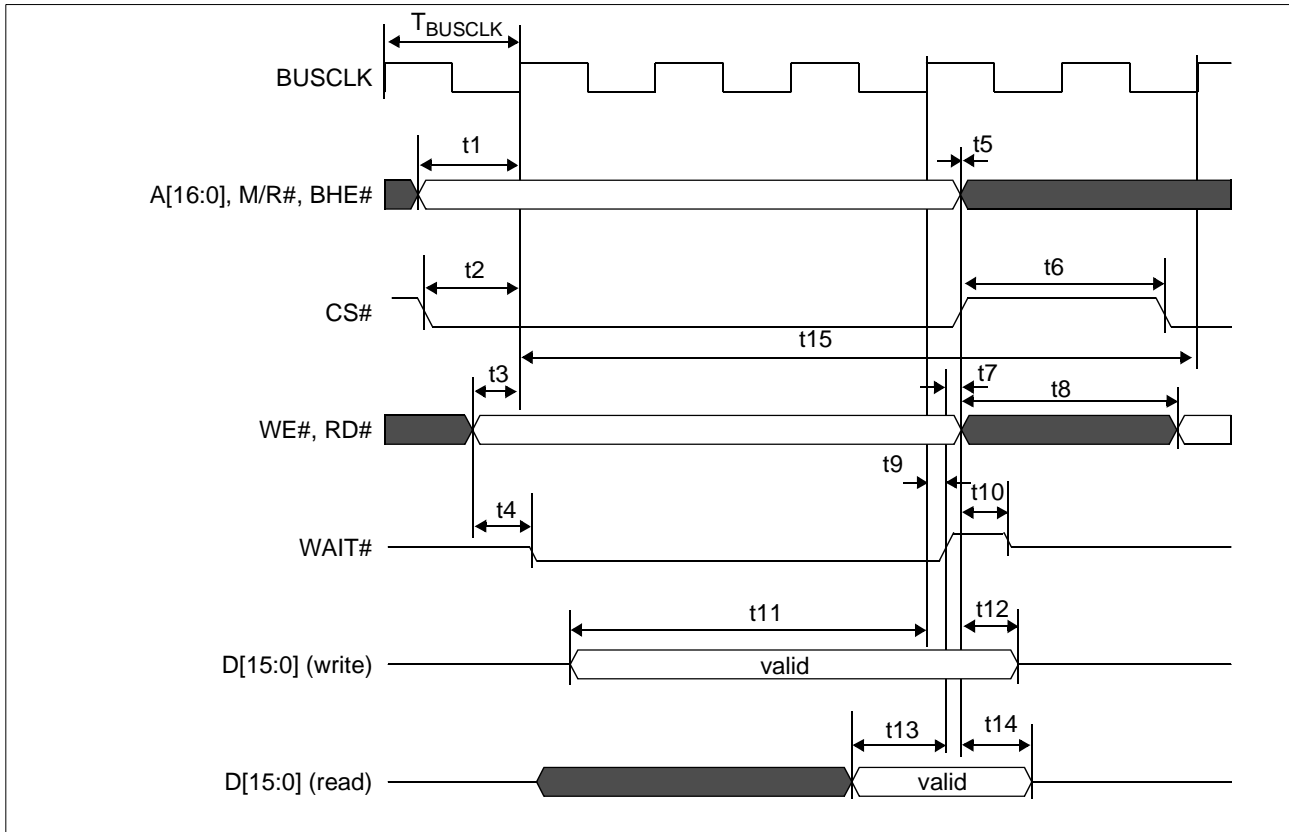


Figure 6-3: Generic #2 Interface Timing

Table 6-8: Generic #2 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|---------------------|---|-----------------------|-----|---------------------|
| f_{BUSCLK} | Bus clock frequency | | 50 | MHz |
| T_{BUSCLK} | Bus clock period | $1/f_{\text{BUSCLK}}$ | | ns |
| t1 | A[16:0], M/R#, BHE# setup to first BUSCLK rising edge where CS# = 0 and either RD# = 0 or WE# = 0 | 0 | | ns |
| t2 | CS# setup to BUSCLK rising edge | 0 | | ns |
| t3 | RD#, WE# setup to BUSCLK rising edge | 0 | | ns |
| t4 | RD# or WE# state change to WAIT# driven low | 3 | 9 | ns |
| t5 | A[16:0], M/R#, BHE# and CS# hold from RD#, WE# rising edge | 0 | | ns |
| t6 | CS# deasserted to reasserted | 0 | | ns |
| t7 | WAIT# rising edge to RD#, WE# rising edge | 0 | | ns |
| t8 | WE#, RD# deasserted to reasserted | 1 | | T_{BUSCLK} |
| t9 | WAIT# rising edge after BUSCLK rising edge | 5 | 14 | ns |
| t10 | Rising edge of either RD# or WE# to WAIT# high impedance | | 7 | ns |
| t11 | D[15:0] setup to 4th rising BUSCLK edge after CS#=0 and WE#=0 | 1 | | T_{BUSCLK} |
| t12 | D[15:0] hold from WE# rising edge (write cycle) | 0 | | ns |
| t13 | D[15:0] valid to WAIT# rising edge setup (read cycle) | 0.5 | | T_{BUSCLK} |
| t14 | D[15:0] hold from RD# rising edge (read cycle) | 2 | | ns |
| t15 | Cycle Length | 6 | | T_{BUSCLK} |

Table 6-9: Generic #2 Interface Truth Table for Little Endian

| WE# | RD# | BHE# | A0 | D[15:8] | D[7:0] | Comments |
|-----|-----|------|----|---------|--------|-----------------------------|
| 0 | 1 | 0 | 0 | valid | valid | 16-bit write |
| 0 | 1 | 1 | 0 | - | valid | 8-bit write at even address |
| 0 | 1 | 0 | 1 | valid | - | 8-bit write at odd address |
| 1 | 0 | 0 | 0 | valid | valid | 16-bit read |
| 1 | 0 | 1 | 0 | - | valid | 8-bit read at even address |
| 1 | 0 | 0 | 1 | valid | - | 8-bit read at odd address |

6.2.3 Hitachi SH-3 Interface Timing

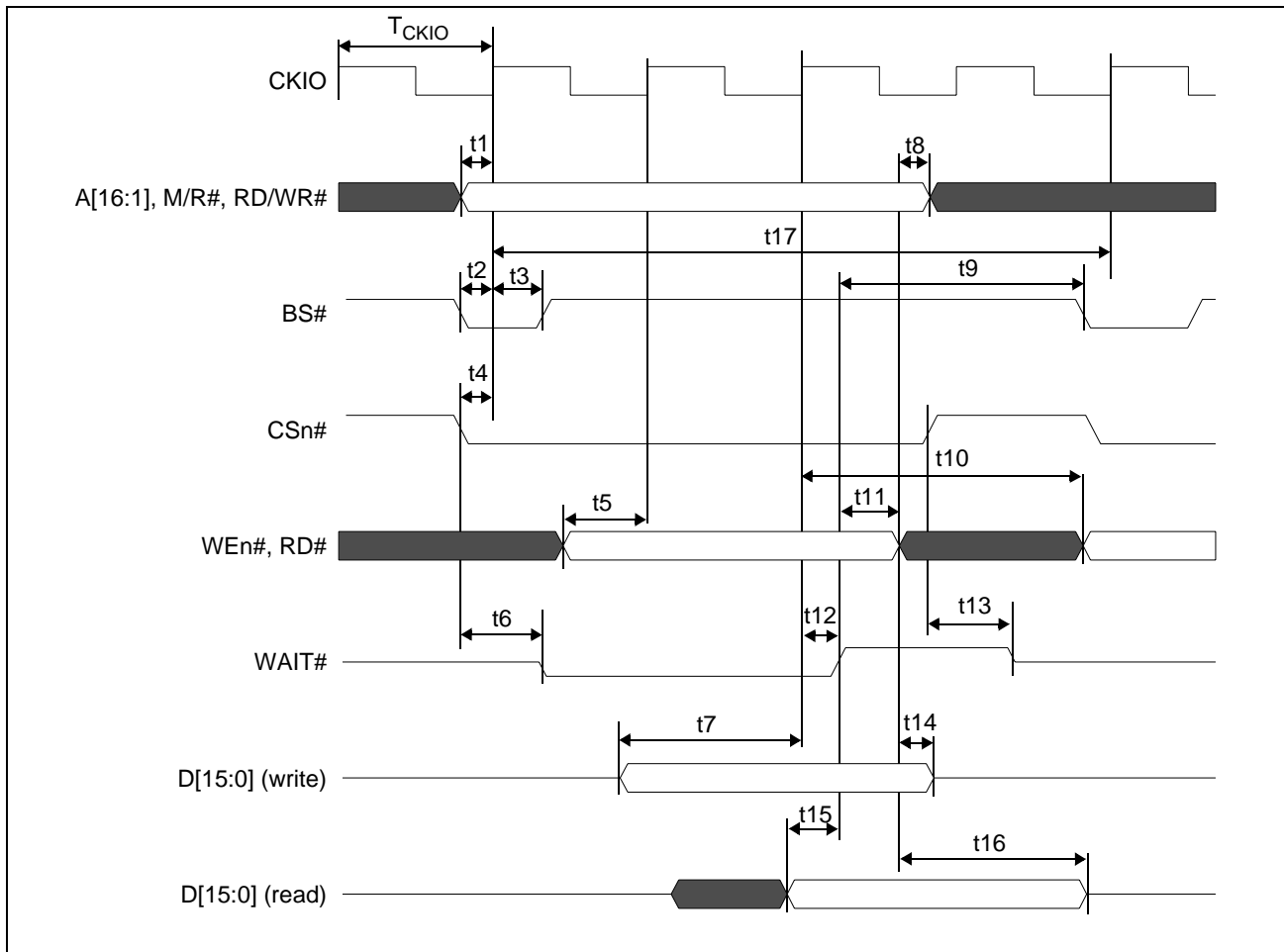


Figure 6-4: Hitachi SH-3 Interface Timing

Note

A minimum of one software wait state is required.

Table 6-10: Hitachi SH-3 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|------------|---|-----------------|-----|------------|
| f_{CKIO} | Bus clock frequency | | 66 | MHz |
| T_{CKIO} | Bus clock period | $1/f_{CKIO}$ | | ns |
| t1 | A[16:1], RD/WR# setup to CKIO | 0 | | ns |
| t2 | BS# setup | 0 | | ns |
| t3 | BS# hold | 9 | | ns |
| t4 | CSn# setup | 0 | | ns |
| t5 | WEn#, RD# setup to next CKIO after BS# low | 0 | | ns |
| t6 | Falling edge CSn# to WAIT# driven low | 4 | 9 | ns |
| t7 | D[15:0] setup to 3rd CKIO rising edge after BS# deasserted (write cycle) | 1 | | ns |
| t8 | WE#, RD# deasserted to A[16:1], M/R#, RD/WR# deasserted | 0 | | ns |
| t9 | Rising edge of WAIT# to BS# falling | $T_{CKIO} + 16$ | | ns |
| t10 | CKIO rising edge before WAIT# deasserted to WEn#, RD# asserted for next cycle | 2 | | T_{CKIO} |
| t11 | Rising edge of WAIT# to WE#, RD# deasserted | 0 | | ns |
| t12 | WAIT# rising edge after CKIO rising edge | 5 | 14 | ns |
| t13 | Rising edge of CSn# to WAIT# high impedance | | 6 | ns |
| t14 | D[15:0] hold from WEn# deasserted (write cycle) | 0 | | ns |
| t15 | D[15:0] setup to WAIT# rising edge (read cycle) | 0.5 | | T_{CKIO} |
| t16 | Rising edge of RD# to D[15:0] high impedance (read cycle) | 3 | 7 | ns |
| t17 | Cycle Length | 5 | | T_{CKIO} |

1. The S1D13A05 requires 2ns of write data hold time.

6.2.4 Hitachi SH-4 Interface Timing

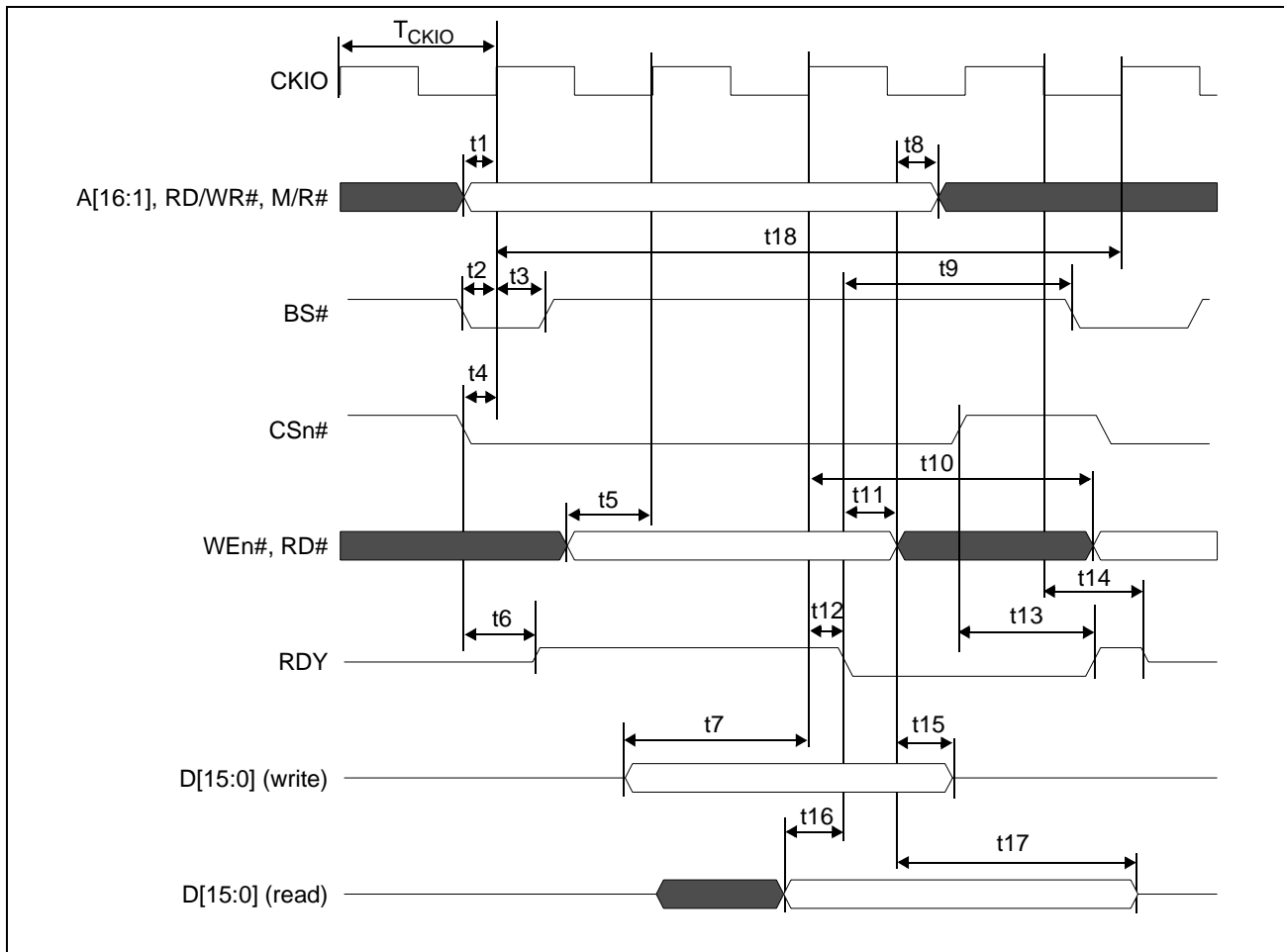


Figure 6-5: Hitachi SH-4 Interface Timing

Note

A minimum of one software wait state is required.

Table 6-11: Hitachi SH-4 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|------------|---|-----------------|-----|------------|
| f_{CKIO} | Bus clock frequency | | 66 | MHz |
| T_{CKIO} | Bus clock period | $1/f_{CKIO}$ | | ns |
| t1 | A[16:1], M/R#, RD/WR# setup to CKIO | 0 | | ns |
| t2 | BS# setup | 0 | | ns |
| t3 | BS# hold | 9 | | ns |
| t4 | CSn# setup | 0 | | ns |
| t5 | WEn#, RD# setup to 1st CKIO rising edge after BS# low | 0 | | ns |
| t6 | Falling edge CSn# to RDY driven high | 3 | 7 | ns |
| t7 | D[15:0] setup to 3rd CKIO rising edge after BS# deasserted (write cycle) | 1 | | ns |
| t8 | WE#,RD# deasserted to A[16:1],M/R#,RD/WR# deasserted | 0 | | ns |
| t9 | RDY falling edge to BS# falling | $T_{CKIO} + 11$ | | ns |
| t10 | CKIO rising edge before RDY deasserted to WEn#, RD# asserted for next cycle | 2 | | T_{CKIO} |
| t11 | RDY falling edge to WE#,RD# deasserted | 0 | | ns |
| t12 | RDY falling edge after CKIO rising edge | 5 | 14 | ns |
| t13 | Rising edge CSn# to RDY rising edge | 4 | 10 | ns |
| t14 | CKIO falling edge to RDY tristate | 4 | 12 | ns |
| t15 | D[15:0] hold from WEn# deasserted (write cycle) | 0 | | ns |
| t16 | D[15:0] valid setup to RDY falling edge (read cycle) | 0.5 | | T_{CKIO} |
| t17 | Rising edge of RD# to D[15:0] high impedance (read cycle) | 2 | 7 | ns |
| t18 | Cycle Length | 4 | | T_{CKIO} |

6.2.5 Motorola MC68K #1 Interface Timing

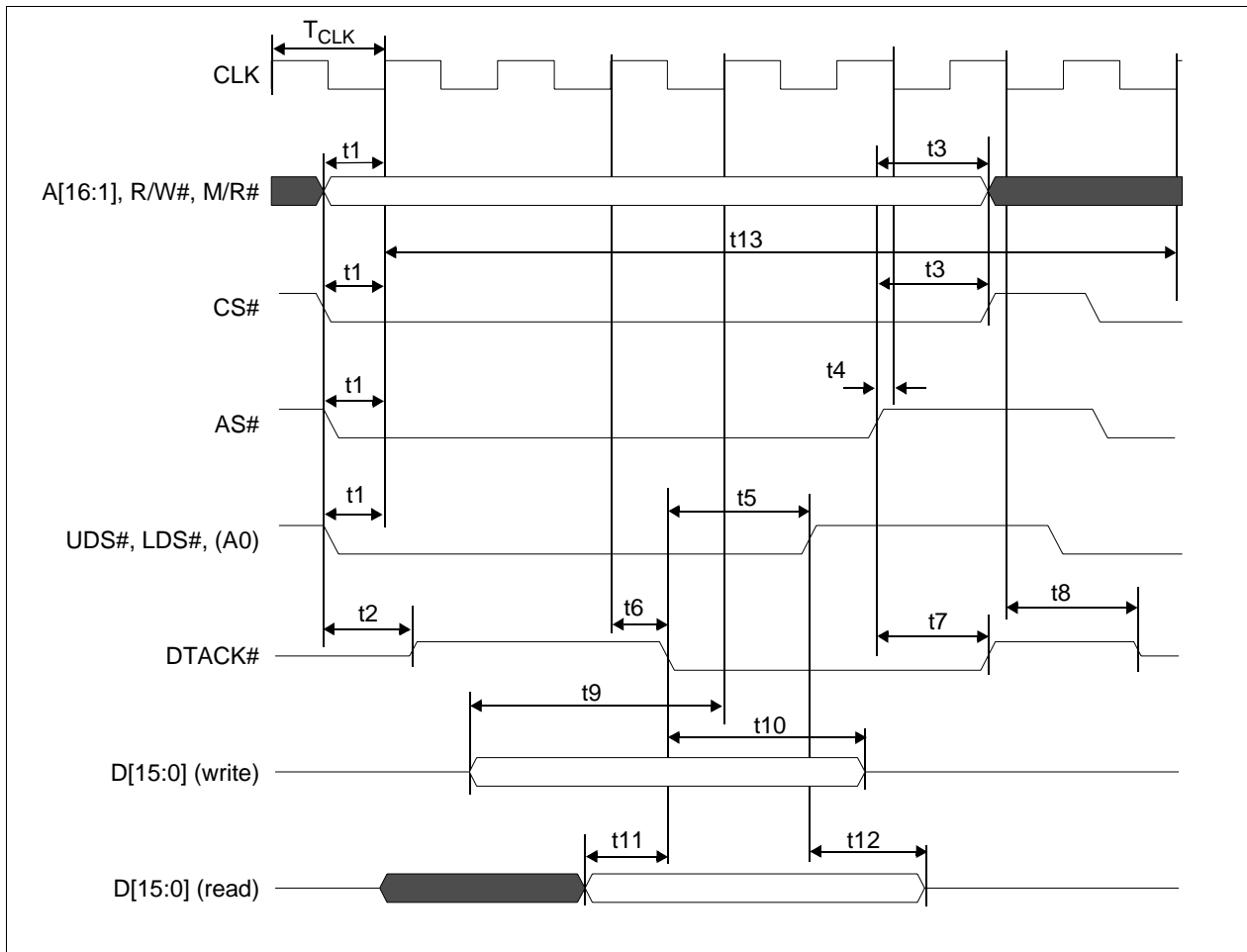


Figure 6-6: Motorola MC68K #1 Interface Timing

Table 6-12: Motorola MC68K#1 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|-----------|---|-------------|--------------------|-----------|
| f_{CLK} | Bus clock frequency | | 50 | MHz |
| T_{CLK} | Bus clock period | $1/f_{CLK}$ | | ns |
| t1 | A[16:1], M/R#, R/W# and CS# and AS# and UDS#, LDS# setup to first CLK rising edge | 1 | | ns |
| t2 | CS# and AS# asserted to DTACK# driven | 2 | 7 | ns |
| t3 | A[16:1], M/R#, R/W# and CS# hold from AS# rising edge | 0 | | ns |
| t4 | AS# rising edge to CLK falling edge | 1 | | ns |
| t5 | DTACK# falling edge to UDS#, LDS# rising edge | 0 | | ns |
| t6 | CLK rising edge to DTACK# falling edge | 5 | 14 | ns |
| t7 | AS# rising edge to DTACK# rising edge | 3 | 9 | ns |
| t8 | 1st CLK falling edge after AS# deasserted to DTACK# high impedance | | $0.5 T_{CLK} + 12$ | ns |
| t9 | D[15:0] valid to 4th CLK rising edge where CS# = 0, AS# = 0 and either UDS# = 0 or LDS# = 0 (write cycle) | 1 | | T_{CLK} |
| t10 | D[15:0] hold from DTACK# falling edge (write cycle) | 0 | | ns |
| t11 | D[15:0] valid setup time to DTACK# goes low (read cycle) | 0.5 | | T_{CLK} |
| t12 | UDS#, LDS# rising edge to D[15:0] high impedance (read cycle) | 2 | | ns |
| t13 | Cycle Length | 7 | | T_{CLK} |

6.2.6 Motorola MC68K #2 Interface Timing

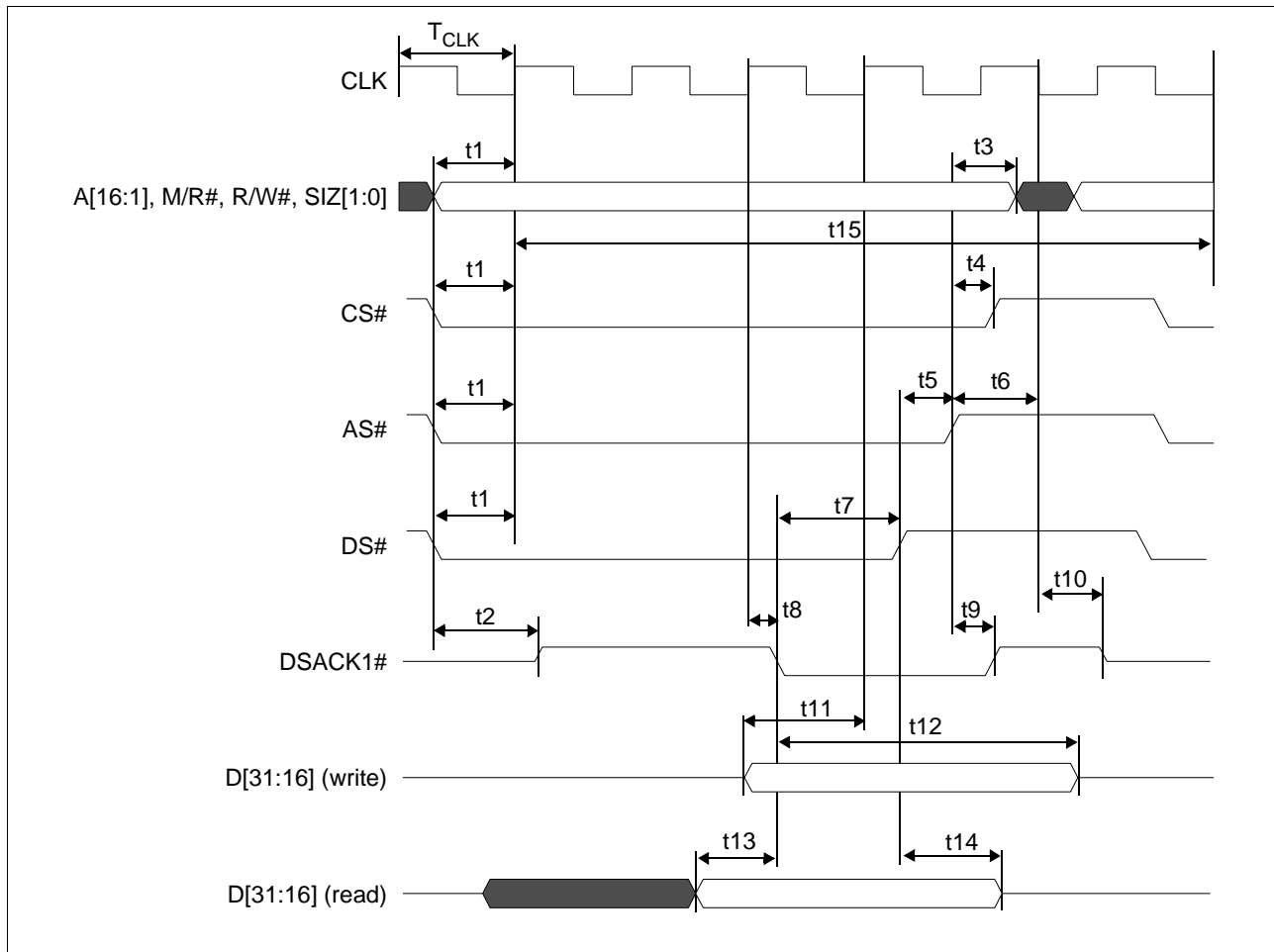


Figure 6-7: Motorola MC68K #2 Interface Timing

Table 6-13: Motorola MC68K#2 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|-----------|--|-------------|---------------|-----------|
| f_{CLK} | Bus clock frequency | | 50 | MHz |
| T_{CLK} | Bus clock period | $1/f_{CLK}$ | | ns |
| t1 | A[16:0], M/R#, R/W#, SIZ[1:0] and CS# and AS# and DS# setup to first CLK rising edge | 0 | | ns |
| t2 | CS# and AS# asserted low to DSACK1# driven | 2 | 7 | ns |
| t3 | A[16:1], M/R#, R/W#, SIZ[1:0] hold from AS# rising edge | 0 | | ns |
| t4 | CS# hold from AS# rising edge | 0 | | ns |
| t5 | DS# rising edge to AS# rising edge | 0 | | ns |
| t6 | AS# setup to CLK falling edge | 1 | | ns |
| t7 | DSACK1# falling edge to DS# rising edge | 0 | | ns |
| t8 | CLK rising edge to DSACK1# falling edge | 5 | 14 | ns |
| t9 | AS# rising edge to DSACK1# rising edge | 3 | 9 | ns |
| t10 | 1st CLK falling edge after AS# deasserted to DSACK1# high impedance | | $T_{CLK} + 3$ | ns |
| t11 | D[15:0] setup to 4th CLK rising edge after CS#=0, AS#=0, DS#=0, and DSACK1#=0 | 1 | | T_{CLK} |
| t12 | D[15:0] hold from DSACK1# falling edge | 0 | | ns |
| t13 | D[15:0] valid setup to DSACK1# falling edge (read cycle) | 0.5 | | T_{CLK} |
| t14 | DS# rising edge to D[15:0] high impedance (read cycle) | 2 | 9 | ns |
| t15 | Cycle Length | 7 | | T_{CLK} |

6.2.7 Motorola REDCAP2 Interface Timing

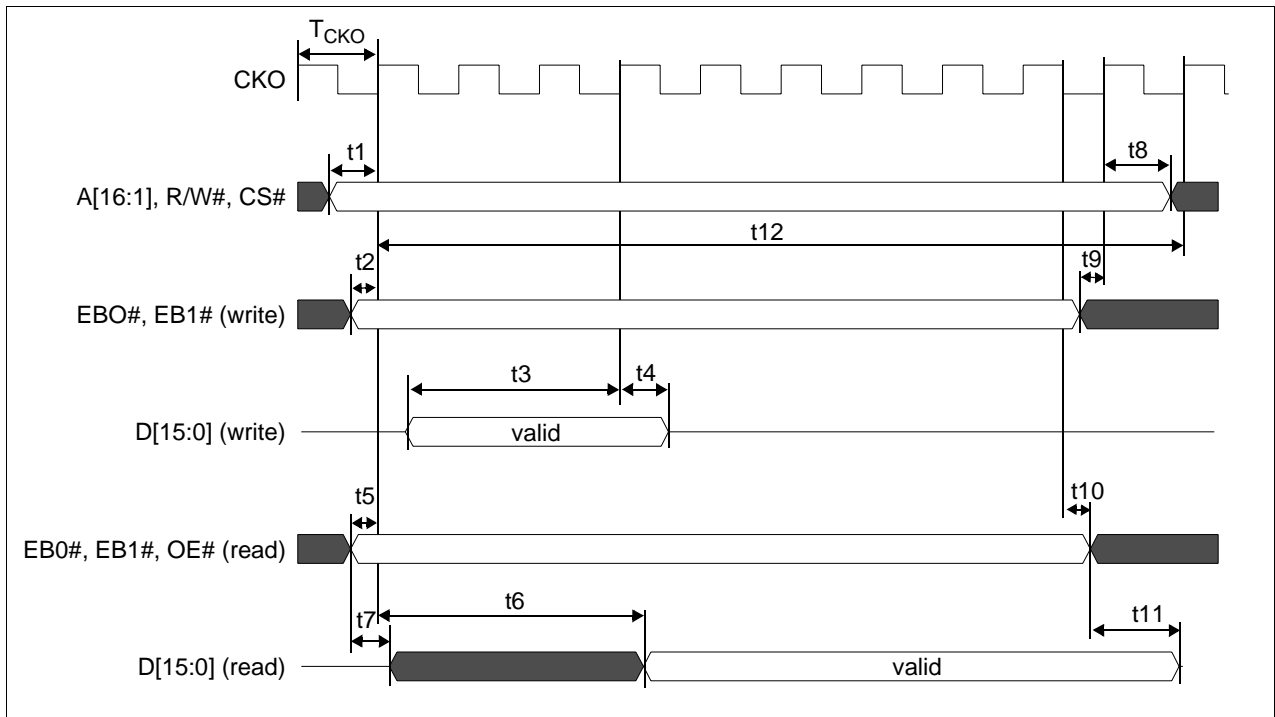


Figure 6-8: Motorola Redcap2 Interface Timing

Table 6-14: Motorola Redcap2 Interface Timing

| Symbol | Parameter | Min | Max | Unit |
|-----------|--|-------------|----------------|-----------|
| f_{CKO} | Bus clock frequency | | 17 | MHz |
| T_{CKO} | Bus clock period | $1/f_{CKO}$ | | ns |
| t1 | A[16:1], R/W, CSn# setup to CKO rising edge | 0 | | ns |
| t2 | $\overline{EB0}, \overline{EB1}$ setup to CKO rising edge (write) | 0 | | ns |
| t3 | D[15:0] input setup to 4th CKO rising edge after CSn# and $\overline{EB0}$ or $\overline{EB1}$ asserted low (write cycle) | 1 | | T_{CKO} |
| t4 | D[15:0] input hold from 4th CKO rising edge after CSn# and $\overline{EB0}$ or $\overline{EB1}$ asserted low (write cycle) | 7 | | ns |
| t5 | $\overline{EB0}, \overline{EB1}, \overline{OE}$ setup to CKO rising edge (read cycle) | 0 | | ns |
| t6a | 1st CKO rising edge after CSn#, EB0 or EB1, OE asserted low to D[15:0] valid for MCLK = BCLK (read cycle) | | $6T_{CKO}+17$ | ns |
| t6b | 1st CKO rising edge after CSn#, EB0 or EB1, OE asserted low to D[15:0] valid for MCLK = BCLK ÷ 2 (read cycle) | | $9T_{CKO}+17$ | ns |
| t6c | 1st CKO rising edge after CSn#, EB0 or EB1, OE asserted low to D[15:0] valid for MCLK = BCLK ÷ 3 (read cycle) | | $12T_{CKO}+17$ | ns |
| t6d | 1st CKO rising edge after CSn#, EB0 or EB1, OE asserted low to D[15:0] valid for MCLK = BCLK ÷ 4 (read cycle) | | $15T_{CKO}+17$ | ns |
| t7 | $\overline{EB0}, \overline{EB1}, \overline{OE}$ falling edge to D[15:0] driven (read cycle) | 2 | 9 | ns |
| t8 | A[16:1], R/W, CSn hold from CKO rising edge | 0 | | ns |
| t9 | EB0, EB1 setup to CKO rising edge (write cycle) | 1 | | ns |
| t10 | CKO falling edge to EB0, EB1, OE deasserted (read) | 0 | | ns |
| t11 | OE, EB0, EB1 deasserted to D[15:0] output high impedance (read) | 2 | 8 | ns |
| t12 | Cycle Length (note 1) | | | T_{CKO} |

1. The cycle length for the REDCAP interface is fixed at $10 T_{CKO}$.
2. The Read and Write 2D BitBLT functions are not available when using the REDCAP interface.

6.2.8 Motorola Dragonball Interface Timing with \overline{DTACK}

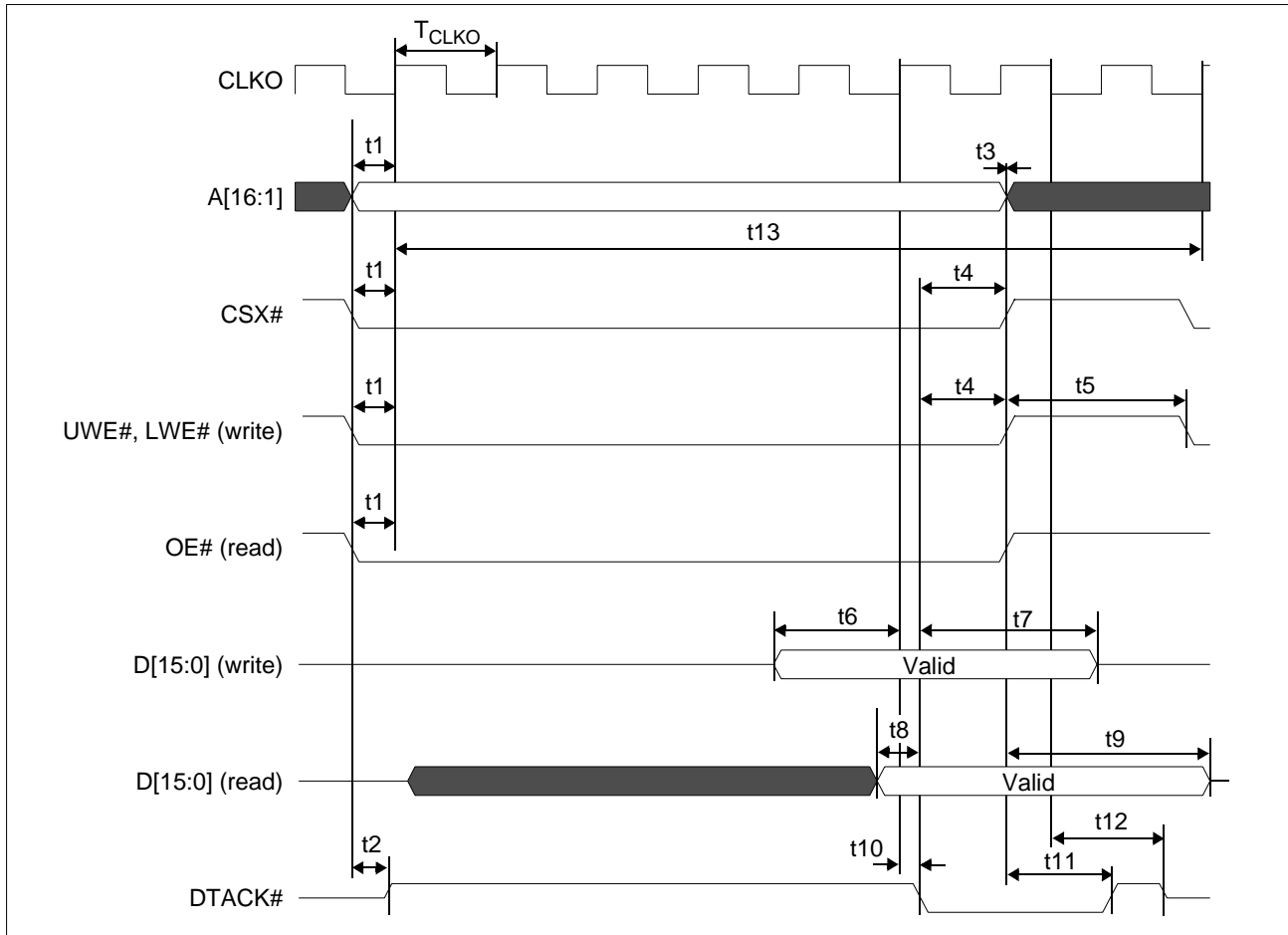


Figure 6-9: Motorola Dragonball Interface Timing with \overline{DTACK}

Table 6-15: Motorola Dragonball Interface Timing with \overline{DTACK}

| Symbol | Parameter | Min | Max | Unit |
|------------|--|-------------------|-------------------|------------|
| f_{CLKO} | Clock frequency | | 66 (note 1) | MHz |
| T_{CLKO} | Clock period | $1/f_{CLKO}$ | | ns |
| t1 | A[16:1], \overline{CSX} , \overline{UWE} , \overline{LWE} , \overline{OE} setup to CLKO rising edge | 1 | | ns |
| t2 | \overline{CSX} asserted low to \overline{DTACK} driven | 2 | 7 | ns |
| t3 | A[16:1] hold from \overline{CSX} rising edge | 0 | | ns |
| t4 | \overline{DTACK} falling edge to \overline{UWE} , \overline{LWE} and \overline{CSX} rising edge | 0 | | ns |
| t5 | \overline{UWE} , \overline{LWE} deasserted to reasserted | 1 | | T_{CLKO} |
| t6 | D[15:0] valid to fourth CLKO rising edge where $\overline{CSX} = 0$ and $\overline{UWE} = 0$ or $\overline{LWE} = 0$ (write cycle) | 1 | | T_{CLKO} |
| t7 | D[15:0] hold from \overline{DTACK} falling edge (write cycle) | 0 | | ns |
| t8 | D[15:0] valid setup to \overline{DTACK} falling edge (read cycle) | 0.5 | | T_{CLKO} |
| t9 | \overline{CSX} rising edge to D[15:0] high impedance (read cycle) | 2 | 6 | ns |
| t10 | CLKO rising edge to $\overline{DTACK\#}$ falling edge | 5 | 14 | ns |
| t11 | \overline{CSX} rising edge to \overline{DTACK} rising edge | 3 | 9 | ns |
| t12 | First CLKO falling edge after deassertion of $\overline{CSX\#}$ to $\overline{DTACK\#}$ high impedance | $0.5T_{CLKO} + 4$ | $0.5T_{CLKO} + 8$ | ns |
| t13 | Cycle Length | 8 | | T_{CLKO} |

1. The MC68SZ328 with a maximum clock frequency of 66MHz is supported.
The MC68VZ328 with a maximum clock frequency of 33MHz is supported.
The MC68EZ328 with a maximum clock frequency of 16MHz is supported.

6.2.9 Motorola Dragonball Interface Timing w/o \overline{DTACK}

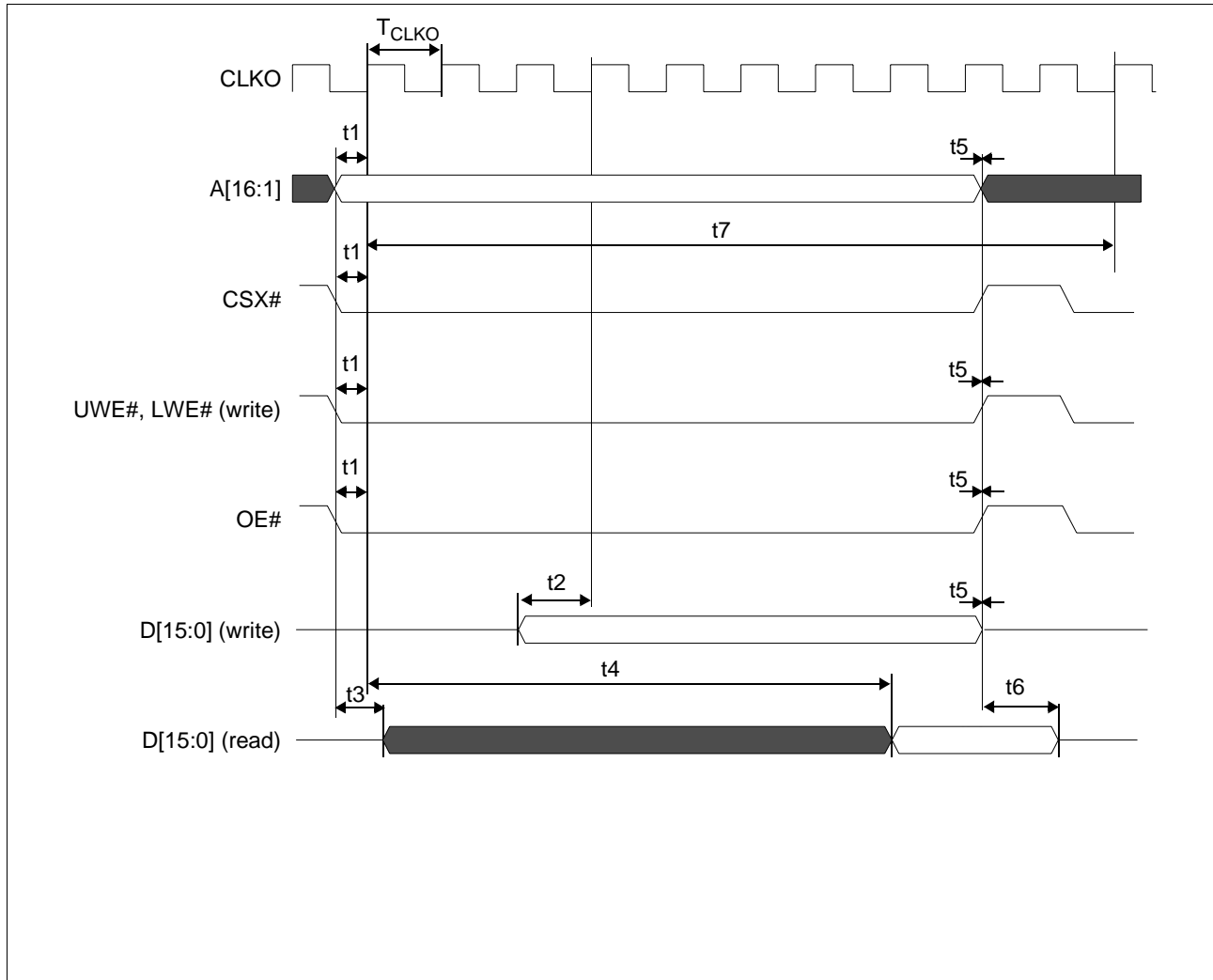


Figure 6-10: Motorola Dragonball Interface Timing w/o \overline{DTACK}

Table 6-16: Motorola Dragonball Interface Timing w/o \overline{DTACK}

| Symbol | Parameter | Min | Max | Unit |
|------------|---|--------------|-------------|------------|
| f_{CLKO} | Bus clock frequency | | 33 (note 1) | MHz |
| T_{CLKO} | Bus clock period | $1/f_{CLKO}$ | | ns |
| t1 | A[16:1] and CSX# and UWE#, LWE# and OE# setup to CLKO rising edge | 1 | | ns |
| t2 | D[15:0] valid to 4th CLK rising edge where CSX# = 0 and UWE# = 0 or LWE# = 0 (write cycle) | 1 | | T_{CLKO} |
| t3 | CSX# and OE# asserted low to D[15:0] driven (read cycle) | 2 | 8 | ns |
| t4a | 1st CLKO rising edge after CSX# and OE# asserted to D[15:0] valid for MCLK=BCLK (read cycle) | | 7 | T_{CLKO} |
| t4b | 1st CLKO rising edge after CSX# and OE# asserted to D[15:0] valid for MCLK=BCLK ÷ 2 (read cycle) | | 10 | T_{CLKO} |
| t4c | 1st CLKO rising edge after CSX# and OE# asserted to D[15:0] valid for MCLK=BCLK ÷ 3 (read cycle) (see note 2) | | 13 | T_{CLKO} |
| t5 | A[16:1] and UWE#, LWE# and OE# and D[15:0] (write) hold from CSX# rising edge | 0 | | ns |
| t6 | CSX# rising edge to D[15:0] high impedance | 2 | 8 | ns |
| t7 | Cycle Length (see note 3) | | | T_{CLKO} |

1. The MC68VZ328 with a maximum clock frequency of 33MHz is supported.
The MC68EZ328 with a maximum clock frequency of 16MHz is supported.
2. The MC68EZ328 does not support the MCLK = BCLK ÷ 3 and MCLK = BCLK ÷ 4 options.
The MC68VZ328 does not support the MCLK = BCLK ÷ 4 option.
3. The cycle length for the Dragonball w/o \overline{DTACK} interface is fixed at $10 T_{CLKO}$.
4. The Read and Write 2D BitBLT functions are not available when using the Dragonball w/o \overline{DTACK} interface.

6.3 LCD Power Sequencing

6.3.1 Passive/TFT Power-On Sequence

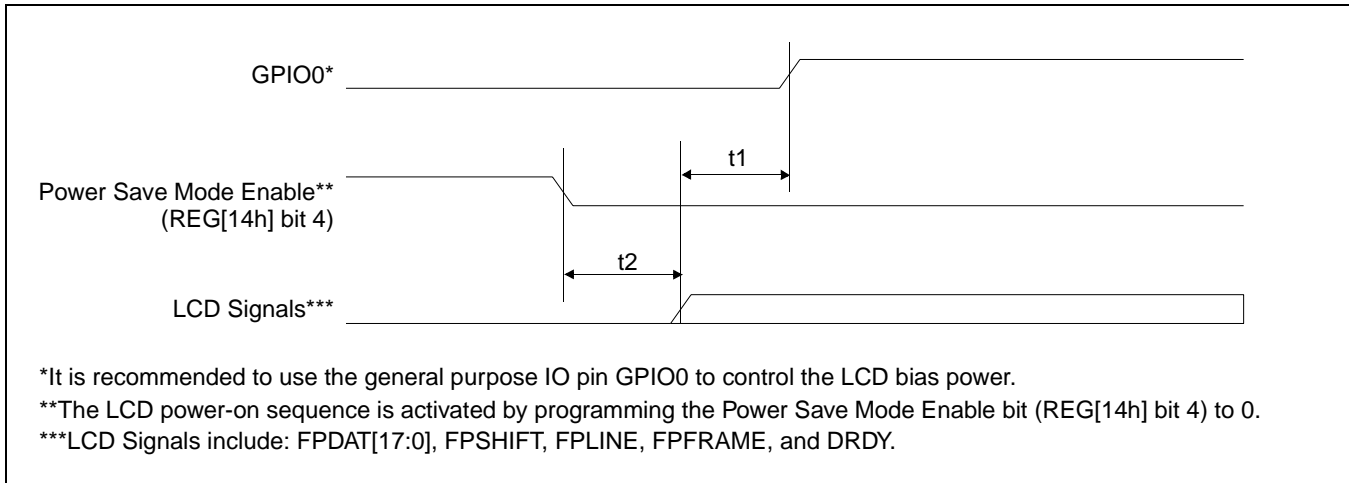


Figure 6-11: Passive/TFT Power-On Sequence Timing

Table 6-17: Passive/TFT Power-On Sequence Timing

| Symbol | Parameter | Min | Max | Units |
|--------|--|--------|--------|-------|
| t1 | LCD signals active to LCD bias active | Note 1 | Note 1 | |
| t2 | Power Save Mode disabled to LCD signals active | 0 | 1 | BCLK |

- t1 is controlled by software and must be determined from the bias power supply delay requirements of the panel connected.

6.3.2 Passive/TFT Power-Off Sequence

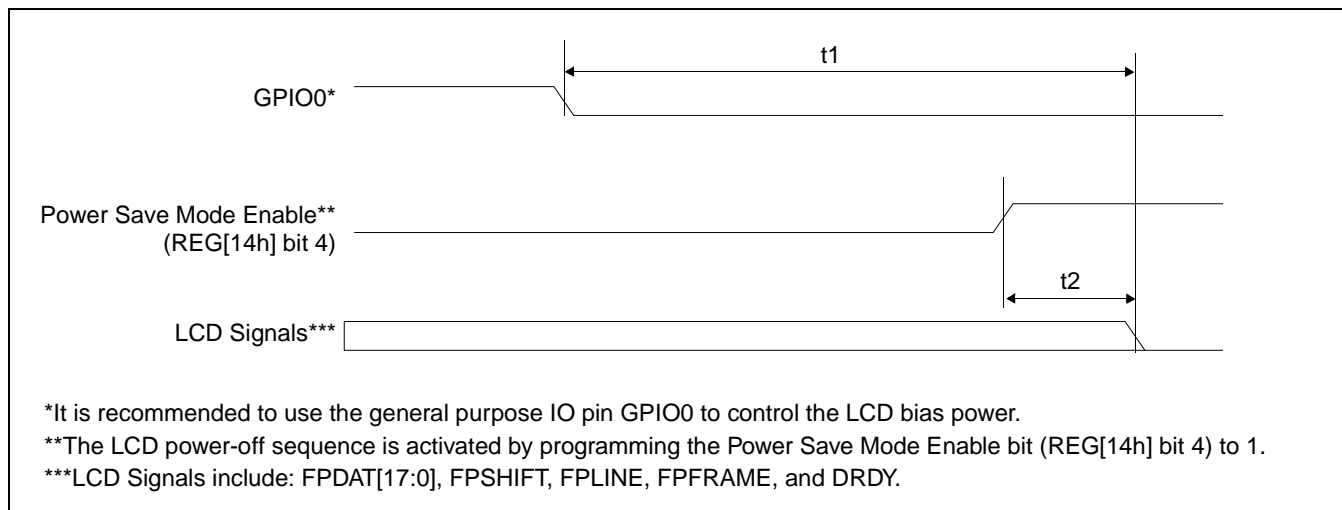


Figure 6-12: Passive/TFT Power-Off Sequence Timing

Table 6-18: Passive/TFT Power-Off Sequence Timing

| Symbol | Parameter | Min | Max | Units |
|--------|--|--------|--------|-------|
| t1 | LCD bias deactivated to LCD signals inactive | Note 1 | Note 1 | |
| t2 | Power Save Mode enabled to LCD signals low | 0 | 1 | BCLK |

- t1 is controlled by software and must be determined from the bias power supply delay requirements of the panel connected.

6.4 Display Interface

The timing parameters required to drive a flat panel display are shown below. Timing details for each supported panel type are provided in the remainder of this section.

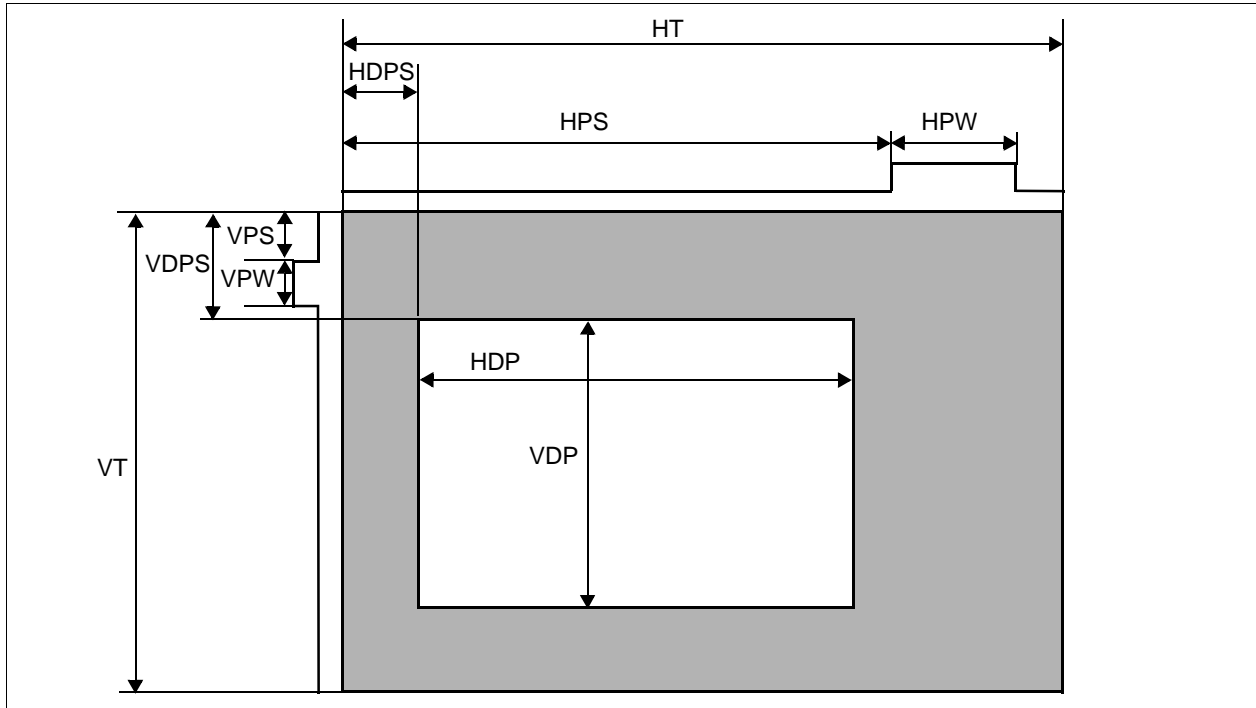


Figure 6-13: Panel Timing Parameters

Table 6-19: Panel Timing Parameter Definition and Register Summary

| Symbol | Description | Derived From | Units |
|------------------|--|---|------------|
| HT | Horizontal Total | $((\text{REG}[20\text{h}] \text{ bits } 6-0) + 1) \times 8$ | Ts |
| HDP ¹ | Horizontal Display Period ¹ | $((\text{REG}[24\text{h}] \text{ bits } 6-0) + 1) \times 8$ | |
| HDPS | Horizontal Display Period Start Position | For STN panels: $((\text{REG}[28\text{h}] \text{ bits } 9-0) + 22)$ For TFT panels: $((\text{REG}[28\text{h}] \text{ bits } 9-0) + 5)$ | |
| HPS | FPLINE Pulse Start Position | $(\text{REG}[2\text{Ch}] \text{ bits } 9-0) + 1$ | |
| HPW | FPLINE Pulse Width | $(\text{REG}[2\text{Ch}] \text{ bits } 22-16) + 1$ | |
| VT | Vertical Total | $(\text{REG}[30\text{h}] \text{ bits } 9-0) + 1$ | Lines (HT) |
| VDP | Vertical Display Period | $(\text{REG}[34\text{h}] \text{ bits } 9-0) + 1$ | |
| VDPS | Vertical Display Period Start Position | $\text{REG}[38\text{h}] \text{ bits } 9-0$ | |
| VPS | FPFRAME Pulse Start Position | $\text{REG}[2\text{Ch}] \text{ bits } 9-0$ | |
| VPW | FPFRAME Pulse Width | $(\text{REG}[3\text{Ch}] \text{ bits } 18-16) + 1$ | |

- For passive panels, the HDP must be a minimum of 32 pixels and must be increased by multiples of 16.
For TFT panels, the HDP must be a minimum of 8 pixels and must be increased by multiples of 8.
- The following formulas must be valid for all panel timings:
 - $\text{HDPS} + \text{HDP} < \text{HT}$
 - $\text{VDPS} + \text{VDP} < \text{VT}$

6.4.1 Generic STN Panel Timing

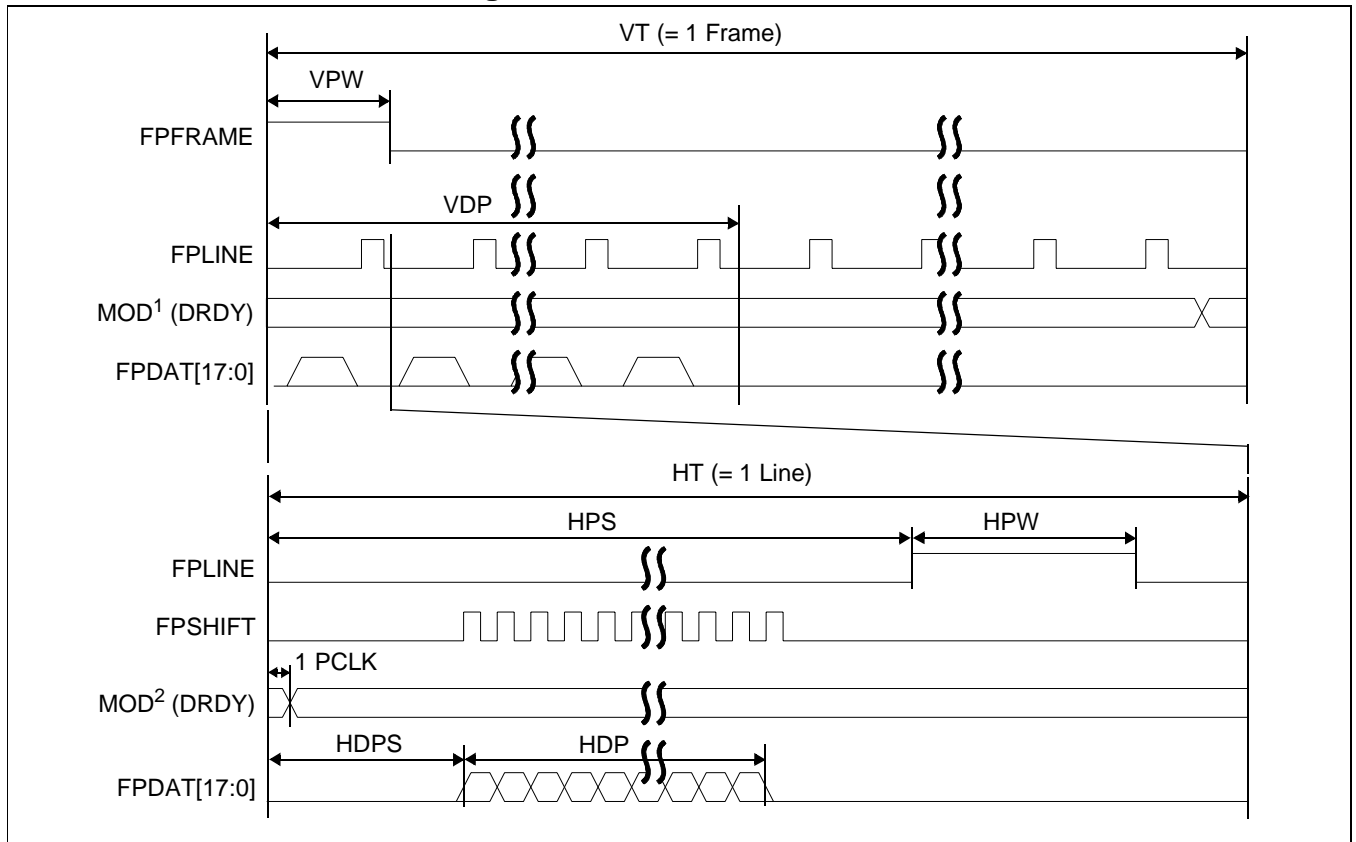


Figure 6-14: Generic STN Panel Timing

| | | |
|------|--|--|
| VT | = Vertical Total | = [(REG[30h] bits 9-0) + 1] lines |
| VPS | = FPFAME Pulse Start Position | = 0 lines, because REG[2Ch] bits 9-0 = 0 |
| VPW | = FPFAME Pulse Width | = [(REG[3Ch] bits 18-16) + 1] lines |
| VDPS | = Vertical Display Period Start Position | = 0 lines, because REG[38h] bits 9-0 = 0 |
| VDP | = Vertical Display Period | = [(REG[34h] bits 9-0) + 1] lines |
| HT | = Horizontal Total | = [((REG[20h] bits 6-0) + 1) x 8] pixels |
| HPS | = FPLINE Pulse Start Position | = [(REG[2Ch] bits 9-0) + 1] pixels |
| HPW | = FPLINE Pulse Width | = [(REG[2Ch] bits 22-16) + 1] pixels |
| HDPs | = Horizontal Display Period Start Position | = 22 pixels, because REG[28h] bits 9-0 = 0 |
| HDP | = Horizontal Display Period | = [((REG[24h] bits 6-0) + 1) x 8] pixels |

*For passive panels, the HDP must be a minimum of 32 pixels and must be increased by multiples of 16.

*HPS should comply with the following formula:

$$\begin{aligned} \text{HPS} &> \text{HDP} + 22 \\ \text{HPS} + \text{HPW} &< \text{HT} \end{aligned}$$

*Panel Type Bits (REG[0Ch] bits 1-0) = 00b (STN)

*FPFRAME Pulse Polarity Bit (REG[3Ch] bit 23) = 1 (active high)

*FPLINE Polarity Bit (REG[2Ch] bit 23) = 1 (active high)

*MOD¹ is the MOD signal when REG[0Ch] bits 21-16 = 0 (MOD toggles every FPFAME)

*MOD² is the MOD signal when REG[0Ch] bits 21-16 = n (MOD toggles every n FPLINE)

6.4.2 Single Monochrome 4-Bit Panel Timing

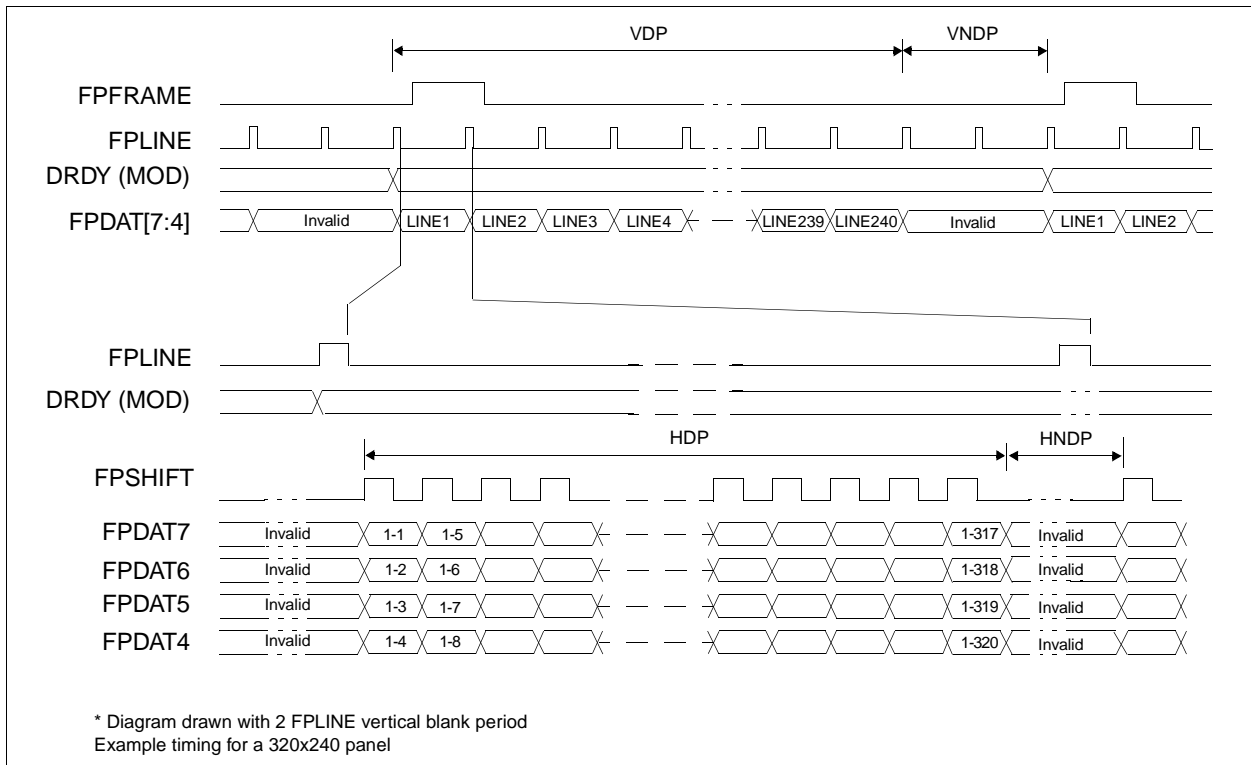


Figure 6-15: Single Monochrome 4-Bit Panel Timing

- VDP = Vertical Display Period
= (REG[34h] bits 9:0) + 1 Lines
- VNDP = Vertical Non-Display Period
= VT - VDP
= (REG[30h] bits 9:0) - (REG[34h] bits 9:0) Lines
- HDP = Horizontal Display Period
= ((REG[24h] bits 6:0) + 1) x 8Ts
- HNDP = Horizontal Non-Display Period
= HT - HDP
= (((REG[20h] bits 6:0) + 1) x 8Ts) - (((REG[24h] bits 6:0) + 1) x 8Ts)

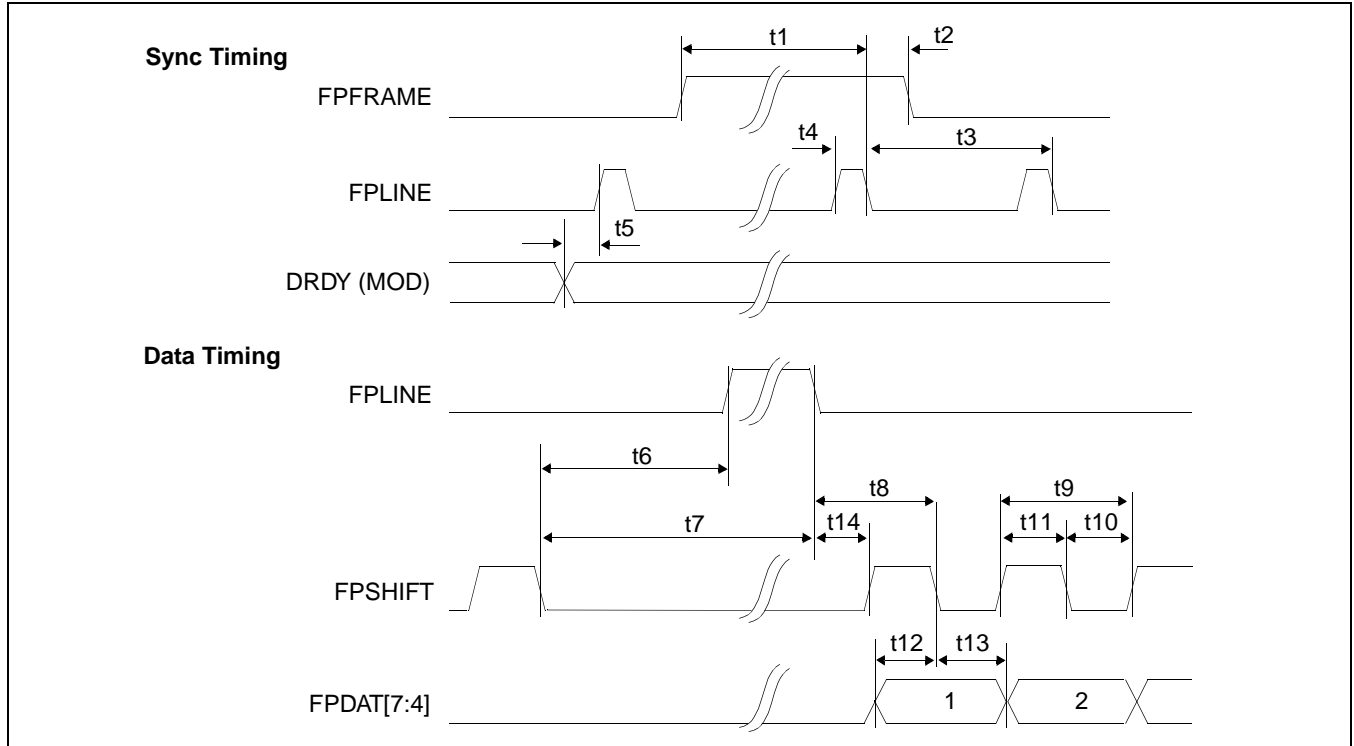


Figure 6-16: Single Monochrome 4-Bit Panel A.C. Timing

Table 6-20: Single Monochrome 4-Bit Panel A.C. Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|---------|-----|-----|-------------|
| t1 | FFRAME setup to FPLINE falling edge | note 2 | | | Ts (note 1) |
| t2 | FFRAME hold from FPLINE falling edge | note 3 | | | Ts |
| t3 | FPLINE period | note 4 | | | Ts |
| t4 | FPLINE pulse width | note 5 | | | Ts |
| t5 | MOD transition to FPLINE rising edge | note 6 | | | Ts |
| t6 | FPSHIFT falling edge to FPLINE rising edge | note 7 | | | Ts |
| t7 | FPSHIFT falling edge to FPLINE falling edge | t6 + t4 | | | Ts |
| t8 | FPLINE falling edge to FPSHIFT falling edge | t14 + 2 | | | Ts |
| t9 | FPSHIFT period | 4 | | | Ts |
| t10 | FPSHIFT pulse width low | 2 | | | Ts |
| t11 | FPSHIFT pulse width high | 2 | | | Ts |
| t12 | FPDAT[7:4] setup to FPSHIFT falling edge | 1 | | | Ts |
| t13 | FPDAT[7:4] hold to FPSHIFT falling edge | 2 | | | Ts |
| t14 | FPLINE falling edge to FPSHIFT rising edge | note 8 | | | Ts |

1. Ts = pixel clock period
2. $t1_{min} = HPS + t4_{min}$
3. $t2_{min} = t3_{min} - (HPS + t4_{min})$
4. $t3_{min} = HT$
5. $t4_{min} = HPW$
6. $t5_{min} = HPS - 1$
7. $t6_{min} = HPS - (HDP + HDPS) + 2$, if negative add $t3_{min}$
8. $t14_{min} = HDPS - (HPS + t4_{min})$, if negative add $t3_{min}$

6.4.3 Single Monochrome 8-Bit Panel Timing

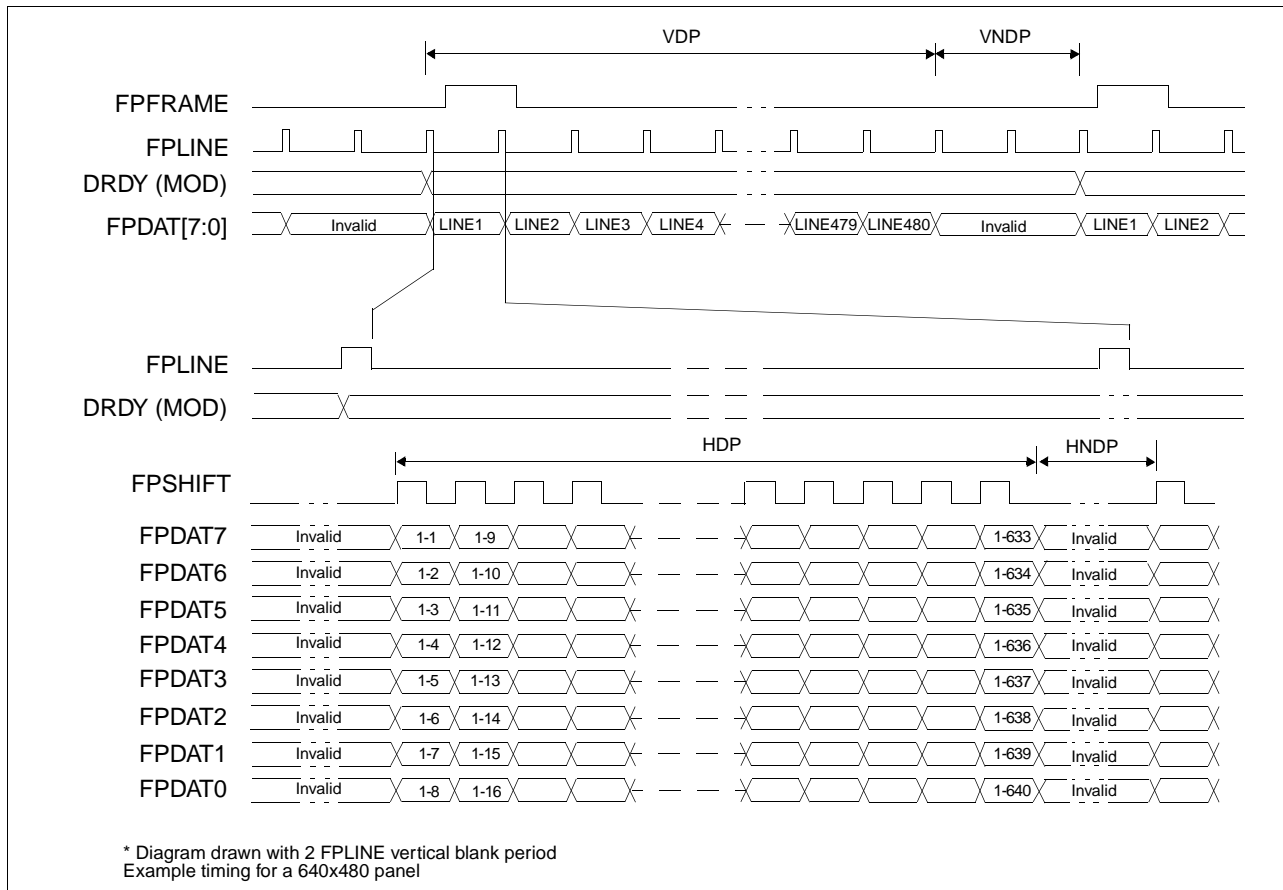


Figure 6-17: Single Monochrome 8-Bit Panel Timing

- VDP = Vertical Display Period
= (REG[34h] bits 9:0) + 1 Lines
- VNDP = Vertical Non-Display Period
= VT - VDP
= (REG[30h] bits 9:0) - (REG[34h] bits 9:0) Lines
- HDP = Horizontal Display Period
= ((REG[24h] bits 6:0) + 1) x 8Ts
- HNDP = Horizontal Non-Display Period
= HT - HDP
= (((REG[20h] bits 6:0) + 1) x 8Ts) - (((REG[24h] bits 6:0) + 1) x 8Ts)

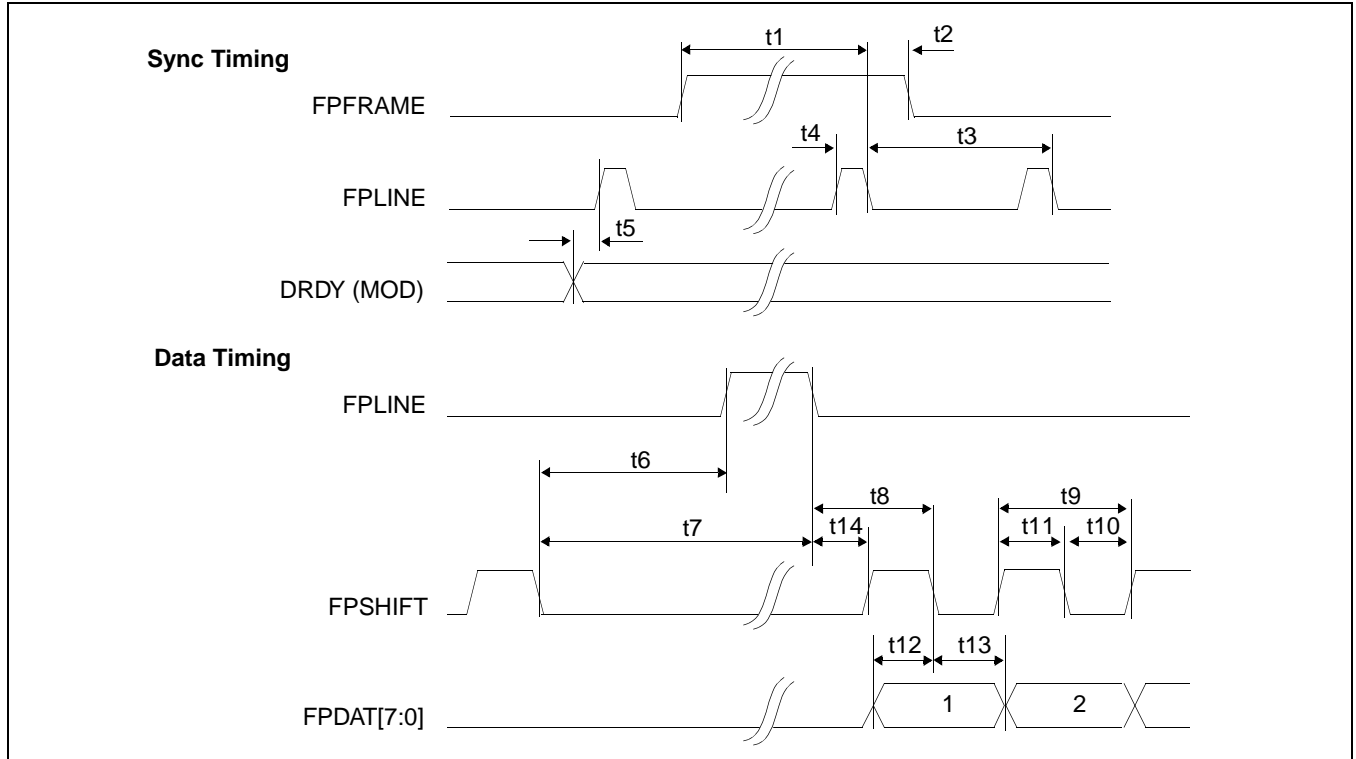


Figure 6-18: Single Monochrome 8-Bit Panel A.C. Timing

Table 6-21: Single Monochrome 8-Bit Panel A.C. Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|---------|-----|-----|-------------|
| t1 | FPFRAME setup to FPLINE falling edge | note 2 | | | Ts (note 1) |
| t2 | FPFRAME hold from FPLINE falling edge | note 3 | | | Ts |
| t3 | FPLINE period | note 4 | | | Ts |
| t4 | FPLINE pulse width | note 5 | | | Ts |
| t5 | MOD transition to FPLINE rising edge | note 6 | | | Ts |
| t6 | FPSHIFT falling edge to FPLINE rising edge | note 7 | | | Ts |
| t7 | FPSHIFT falling edge to FPLINE falling edge | t6 + t4 | | | Ts |
| t8 | FPLINE falling edge to FPSHIFT falling edge | t14 + 4 | | | Ts |
| t9 | FPSHIFT period | 8 | | | Ts |
| t10 | FPSHIFT pulse width low | 4 | | | Ts |
| t11 | FPSHIFT pulse width high | 4 | | | Ts |
| t12 | FPDAT[7:0] setup to FPSHIFT falling edge | 4 | | | Ts |
| t13 | FPDAT[7:0] hold to FPSHIFT falling edge | 4 | | | Ts |
| t14 | FPLINE falling edge to FPSHIFT rising edge | note 8 | | | Ts |

1. Ts = pixel clock period
2. $t1_{min} = HPS + t4_{min}$
3. $t2_{min} = t3_{min} - (HPS + t4_{min})$
4. $t3_{min} = HT$
5. $t4_{min} = HPW$
6. $t5_{min} = HPS - 1$
7. $t6_{min} = HPS - (HDP + HDPS) + 4$, if negative add $t3_{min}$
8. $t14_{min} = HDPS - (HPS + t4_{min})$, if negative add $t3_{min}$

6.4.4 Single Color 4-Bit Panel Timing

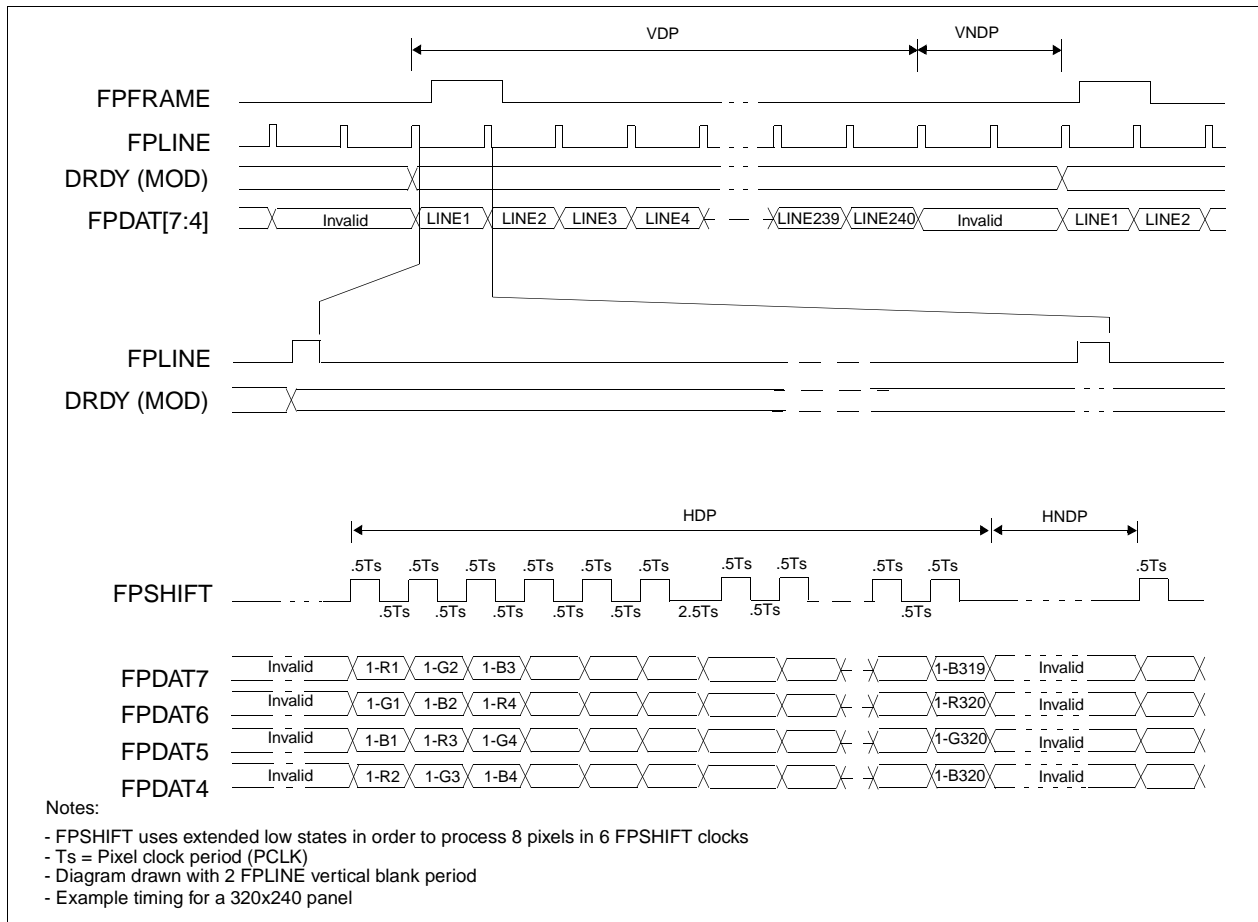


Figure 6-19: Single Color 4-Bit Panel Timing

- VDP = Vertical Display Period
= (REG[34h] bits 9:0) + 1 Lines
- VNDP = Vertical Non-Display Period
= VT - VDP
= (REG[30h] bits 9:0) - (REG[34h] bits 9:0) Lines
- HDP = Horizontal Display Period
= ((REG[24h] bits 6:0) + 1) x 8Ts
- HNDP = Horizontal Non-Display Period
= HT - HDP
= (((REG[20h] bits 6:0) + 1) x 8Ts) - (((REG[24h] bits 6:0) + 1) x 8Ts)

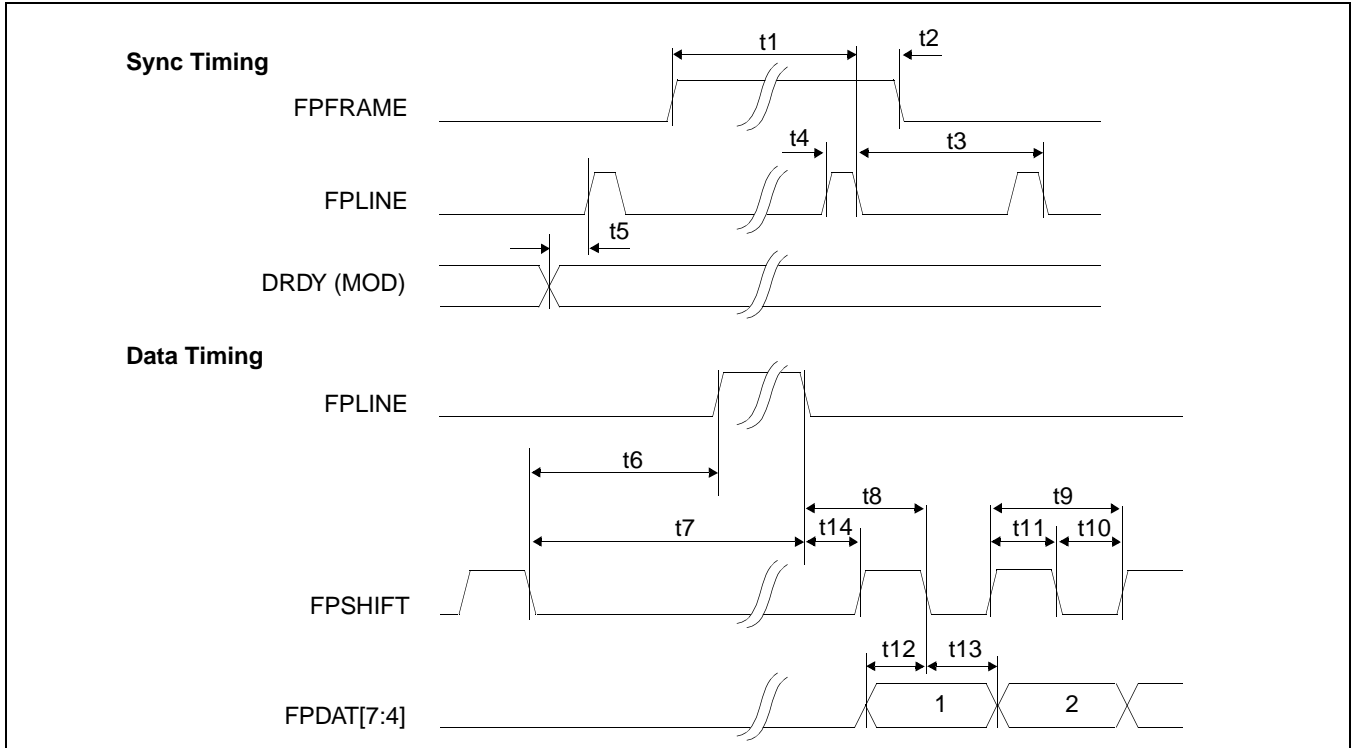


Figure 6-20: Single Color 4-Bit Panel A.C. Timing

Table 6-22: Single Color 4-Bit Panel A.C. Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|-----------|-----|-----|-------------|
| t1 | FPFRAME setup to FPLINE falling edge | note 2 | | | Ts (note 1) |
| t2 | FPFRAME hold from FPLINE falling edge | note 3 | | | Ts |
| t3 | FPLINE period | note 4 | | | Ts |
| t4 | FPLINE pulse width | note 5 | | | Ts |
| t5 | MOD transition to FPLINE rising edge | note 6 | | | Ts |
| t6 | FPSHIFT falling edge to FPLINE rising edge | note 7 | | | Ts |
| t7 | FPSHIFT falling edge to FPLINE falling edge | t6 + t4 | | | Ts |
| t8 | FPLINE falling edge to FPSHIFT falling edge | t14 + 0.5 | | | Ts |
| t9 | FPSHIFT period | 1 | | | Ts |
| t10 | FPSHIFT pulse width low | 0.5 | | | Ts |
| t11 | FPSHIFT pulse width high | 0.5 | | | Ts |
| t12 | FPDAT[7:4] setup to FPSHIFT falling edge | 0.5 | | | Ts |
| t13 | FPDAT[7:4] hold to FPSHIFT falling edge | 0.5 | | | Ts |
| t14 | FPLINE falling edge to FPSHIFT rising edge | note 8 | | | Ts |

1. Ts = pixel clock period
2. t1_{min} = HPS + t4_{min}
3. t2_{min} = t3_{min} - (HPS + t4_{min})
4. t3_{min} = HT
5. t4_{min} = HPW
6. t5_{min} = HPS - 1
7. t6_{min} = HPS - (HDP + HDPS) + 1.5, if negative add t3_{min}
8. t14_{min} = HDPS - (HPS + t4_{min}) + 1, if negative add t3_{min}

6.4.5 Single Color 8-Bit Panel Timing (Format 1)

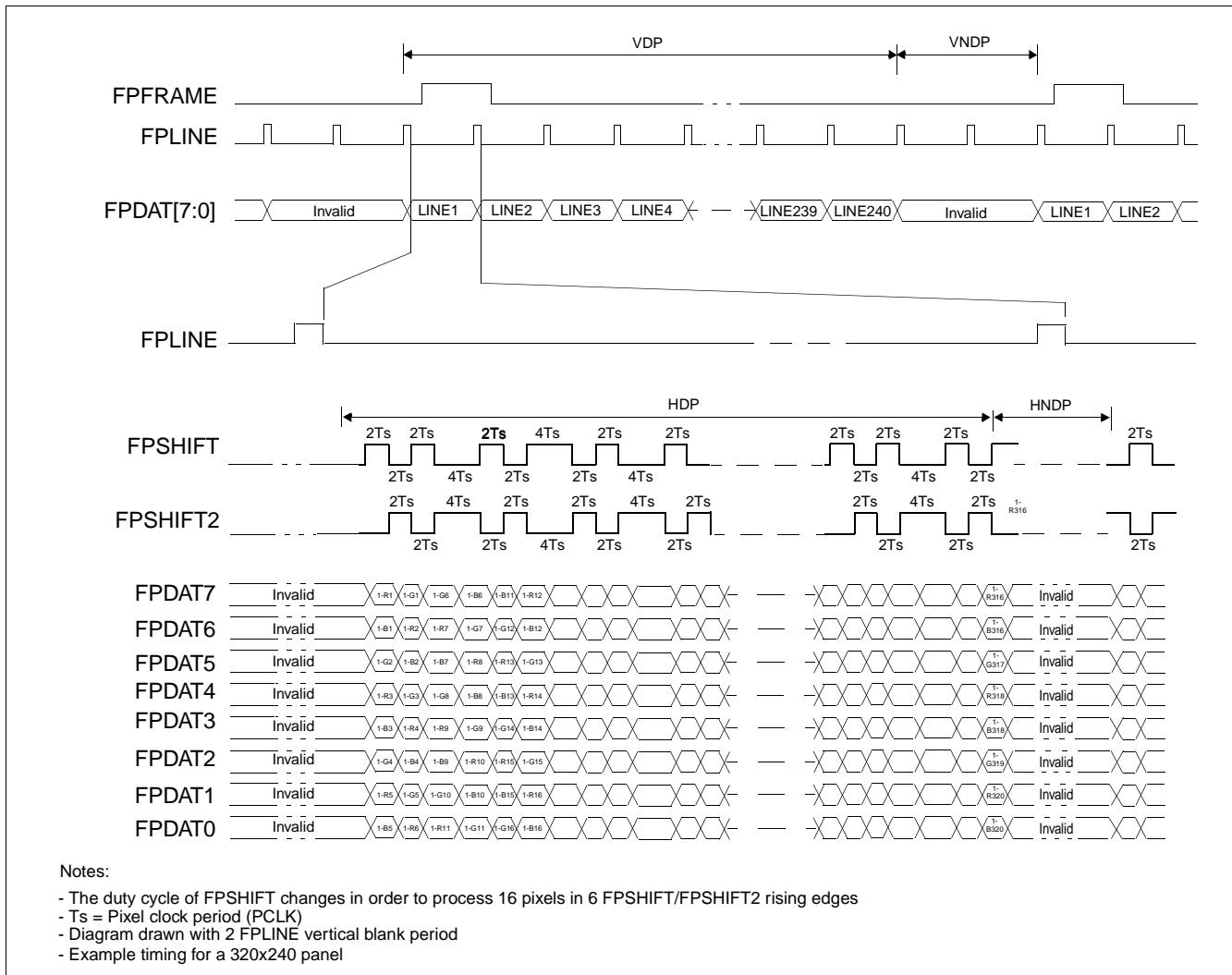


Figure 6-21: Single Color 8-Bit Panel Timing (Format 1)

- VDP = Vertical Display Period
= (REG[34h] bits 9:0) + 1 Lines
- VNDP = Vertical Non-Display Period
= VT - VDP
= (REG[30h] bits 9:0) - (REG[34h] bits 9:0) Lines
- HDP = Horizontal Display Period
= ((REG[24h] bits 6:0) + 1) x 8Ts
- HNDP = Horizontal Non-Display Period
= HT - HDP
= (((REG[20h] bits 6:0) + 1) x 8Ts) - (((REG[24h] bits 6:0) + 1) x 8Ts)

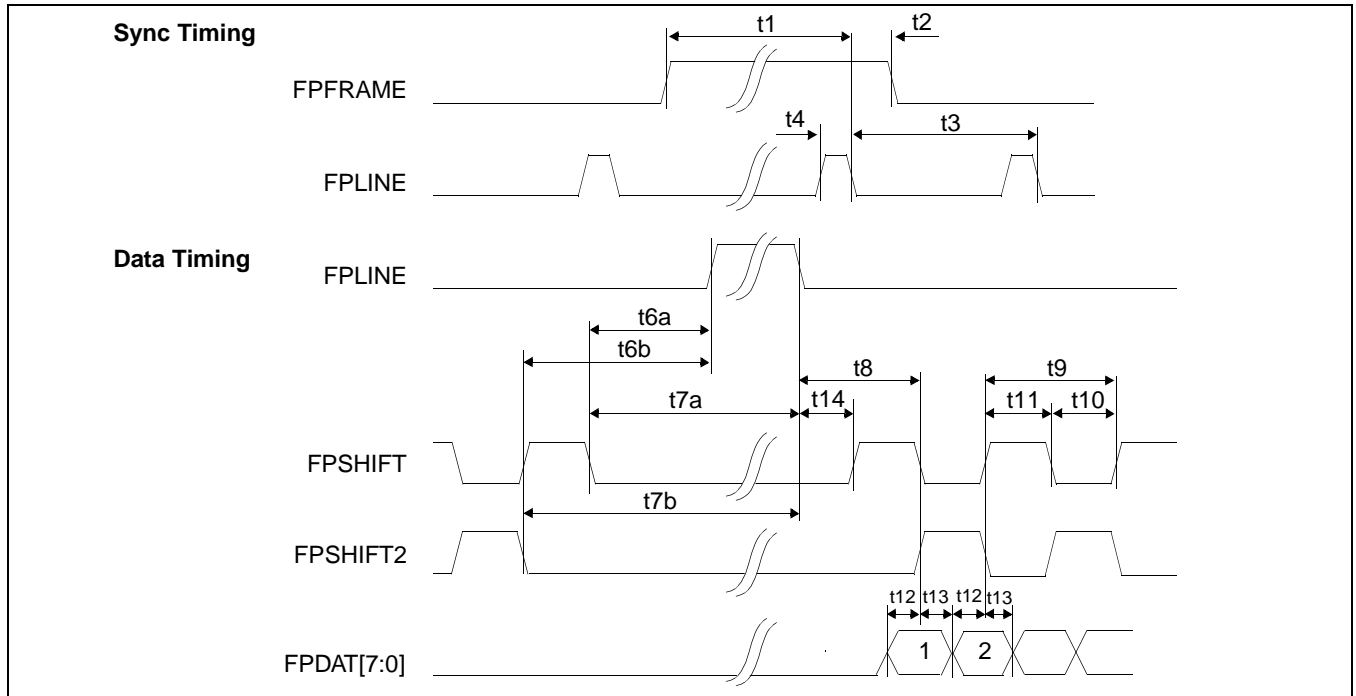


Figure 6-22: Single Color 8-Bit Panel A.C. Timing (Format 1)

Table 6-23: Single Color 8-Bit Panel A.C. Timing (Format 1)

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|----------|-----|-----|-------------|
| t1 | FPFRAME setup to FPLINE falling edge | note 2 | | | Ts (note 1) |
| t2 | FPFRAME hold from FPLINE falling edge | note 3 | | | Ts |
| t3 | FPLINE period | note 4 | | | Ts |
| t4 | FPLINE pulse width | note 5 | | | Ts |
| t6a | FPSHIFT falling edge to FPLINE rising edge | note 6 | | | Ts |
| t6b | FPSHIFT2 falling edge to FPLINE rising edge | note 7 | | | Ts |
| t7a | FPSHIFT falling edge to FPLINE falling edge | t6a + t4 | | | Ts |
| t7b | FPSHIFT2 falling edge to FPLINE falling edge | t6b + t4 | | | Ts |
| t8 | FPLINE falling edge to FPSHIFT rising, FPSHIFT2 falling edge | t14 + 2 | | | Ts |
| t9 | FPSHIFT2, FPSHIFT period | 4 | | 6 | Ts |
| t10 | FPSHIFT2, FPSHIFT pulse width low | 2 | | | Ts |
| t11 | FPSHIFT2, FPSHIFT pulse width high | 2 | | | Ts |
| t12 | FPDAT[7:0] setup to FPSHIFT2, FPSHIFT falling edge | 1 | | | Ts |
| t13 | FPDAT[7:0] hold from FPSHIFT2, FPSHIFT falling edge | 1 | | | Ts |
| t14 | FPLINE falling edge to FPSHIFT rising edge | note 8 | | | Ts |

1. Ts = pixel clock period
2. $t1_{min} = HPS + t4_{min}$
3. $t2_{min} = t3_{min} - (HPS + t4_{min})$
4. $t3_{min} = HT$
5. $t4_{min} = HPW$
6. $t6a_{min} = HPS - (HDP + HDPS)$, if negative add $t3_{min}$
7. $t6b_{min} = HPS - (HDP + HDPS) + 2$, if negative add $t3_{min}$
8. $t14_{min} = HDPS - (HPS + t4_{min})$, if negative add $t3_{min}$

6.4.6 Single Color 8-Bit Panel Timing (Format 2)

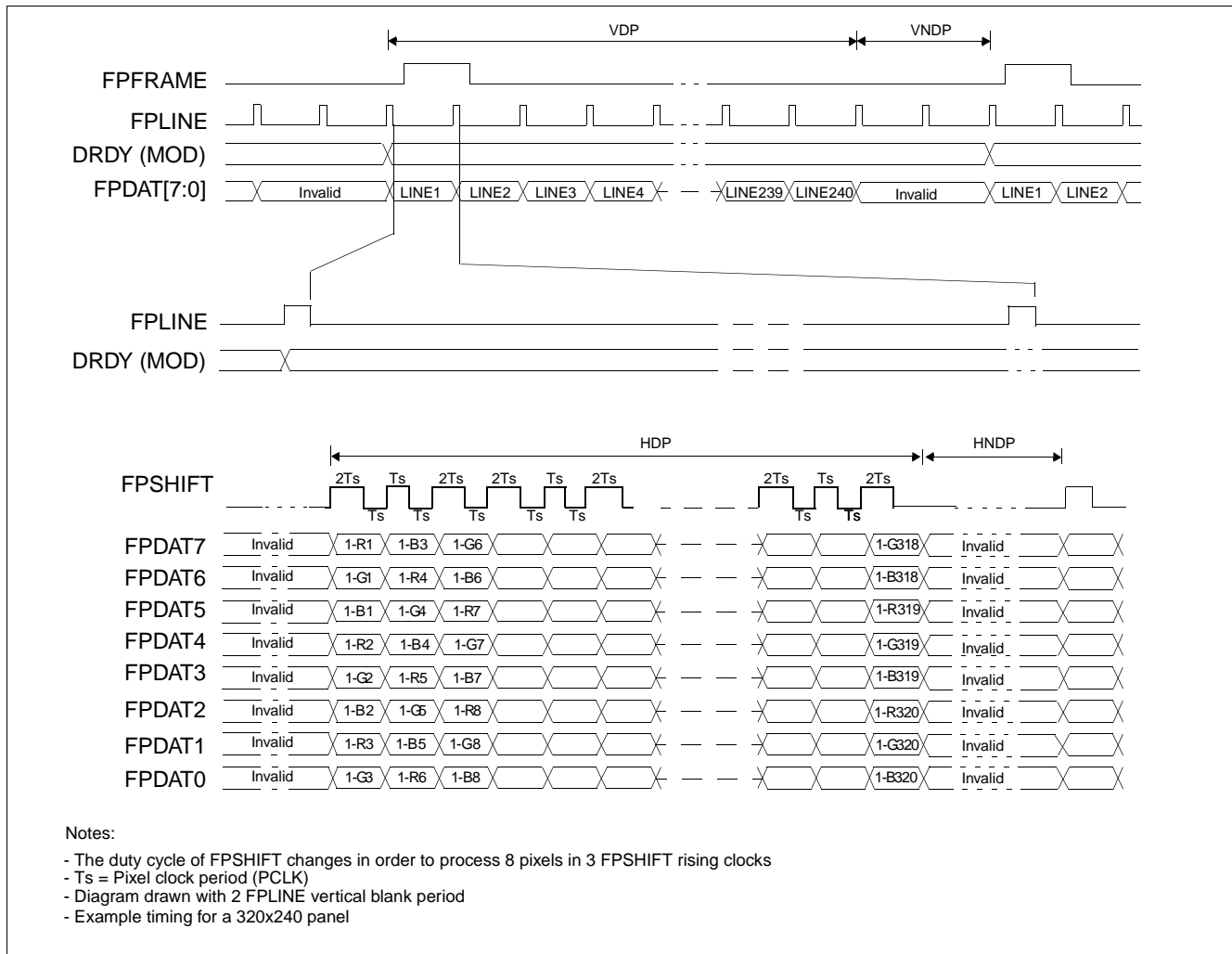


Figure 6-23: Single Color 8-Bit Panel Timing (Format 2)

VDP = Vertical Display Period
 = (REG[34h] bits 9:0) + 1 Lines
VNDP = Vertical Non-Display Period
 = VT - VDP
 = (REG[30h] bits 9:0) - (REG[34h] bits 9:0) Lines
HDP = Horizontal Display Period
 = ((REG[24h] bits 6:0) + 1) x 8Ts
HNDP = Horizontal Non-Display Period
 = HT - HDP
 = (((REG[20h] bits 6:0) + 1) x 8Ts) - (((REG[24h] bits 6:0) + 1) x 8Ts)

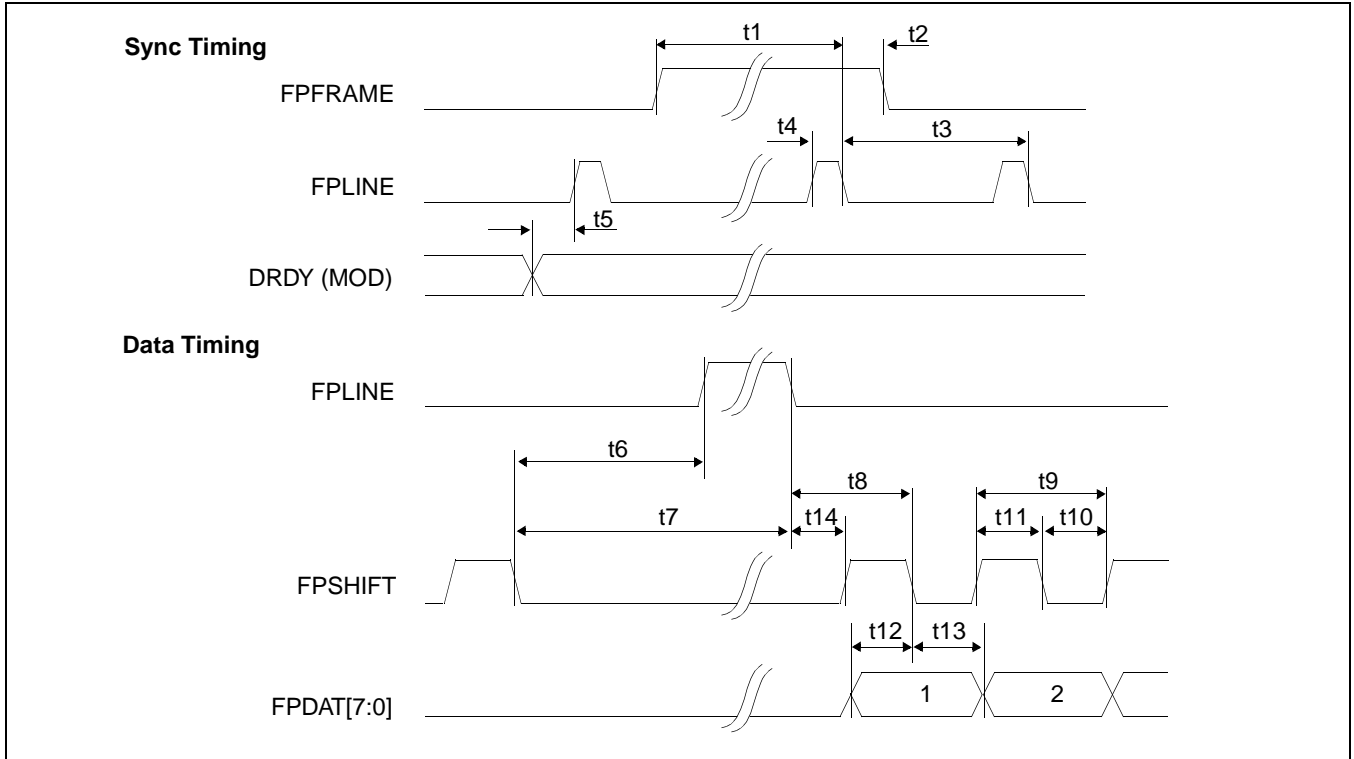


Figure 6-24: Single Color 8-Bit Panel A.C. Timing (Format 2)

Table 6-24: Single Color 8-Bit Panel A.C. Timing (Format 2)

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|---------|-----|-----|-------------|
| t1 | FPFRAME setup to FPLINE falling edge | note 2 | | | Ts (note 1) |
| t2 | FPFRAME hold from FPLINE falling edge | note 3 | | | Ts |
| t3 | FPLINE period | note 4 | | | Ts |
| t4 | FPLINE pulse width | note 5 | | | Ts |
| t5 | MOD transition to FPLINE rising edge | note 6 | | | Ts |
| t6 | FPSHIFT falling edge to FPLINE rising edge | note 7 | | | Ts |
| t7 | FPSHIFT falling edge to FPLINE falling edge | t6 + t4 | | | Ts |
| t8 | FPLINE falling edge to FPSHIFT falling edge | t14 + 2 | | | Ts |
| t9 | FPSHIFT period | 2 | | | Ts |
| t10 | FPSHIFT pulse width low | 1 | | | Ts |
| t11 | FPSHIFT pulse width high | 1 | | | Ts |
| t12 | FPDAT[7:0] setup to FPSHIFT falling edge | 1 | | | Ts |
| t13 | FPDAT[7:0] hold to FPSHIFT falling edge | 1 | | | Ts |
| t14 | FPLINE falling edge to FPSHIFT rising edge | note 8 | | | Ts |

1. Ts = pixel clock period
2. t1_{min} = HPS + t4_{min}
3. t2_{min} = t3_{min} - (HPS + t4_{min})
4. t3_{min} = HT
5. t4_{min} = HPW
6. t5_{min} = HPS - 1
7. t6_{min} = HPS - (HDP + HDPS) + 1, if negative add t3_{min}
8. t14_{min} = HDPS - (HPS + t4_{min}), if negative add t3_{min}

6.4.7 Single Color 16-Bit Panel Timing

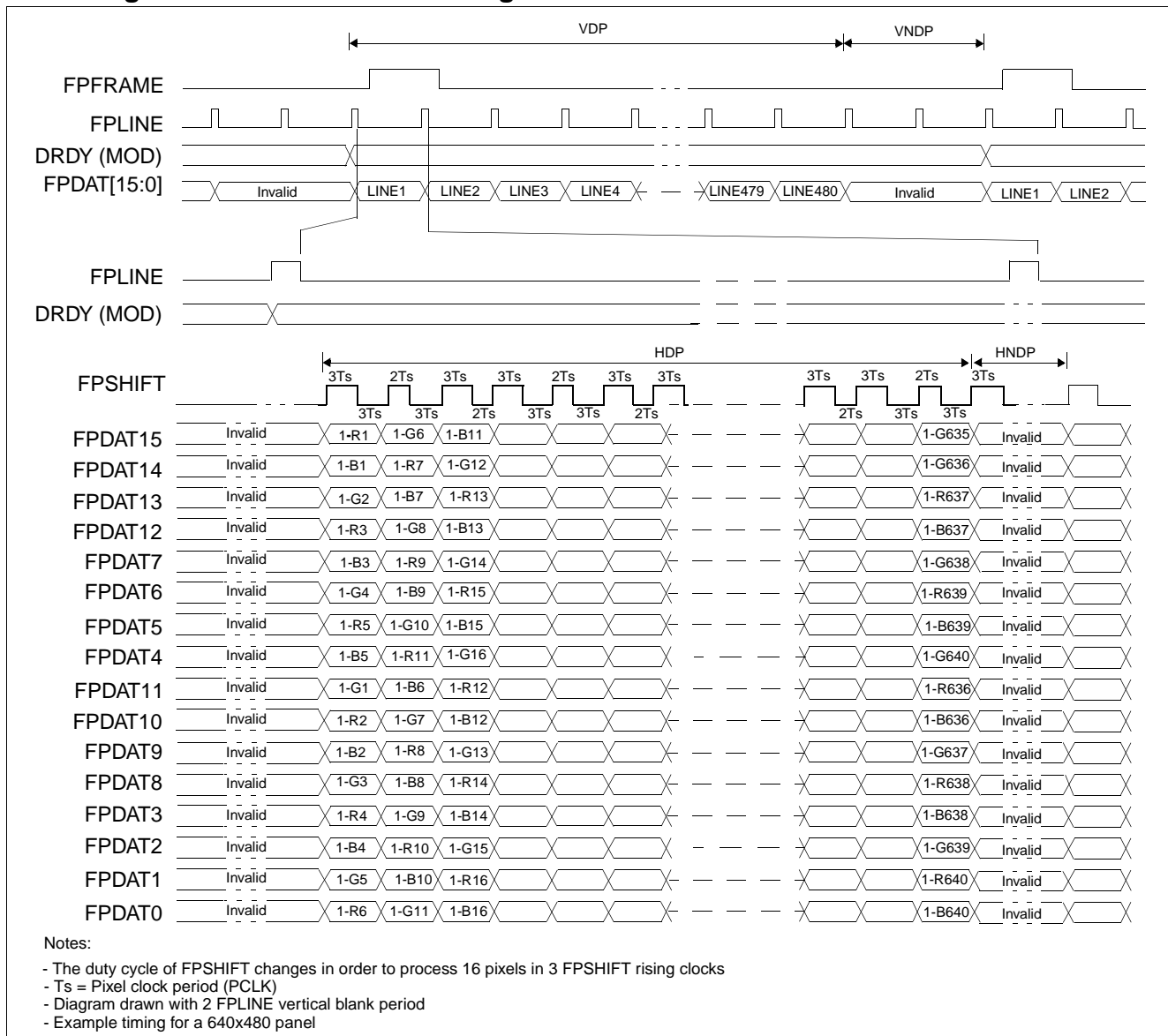


Figure 6-25: Single Color 16-Bit Panel Timing

- VDP = Vertical Display Period
= (REG[34h] bits 9:0) + 1 Lines
- VNDP = Vertical Non-Display Period
= VT - VDP
= (REG[30h] bits 9:0) - (REG[34h] bits 9:0) Lines
- HDP = Horizontal Display Period
= ((REG[24h] bits 6:0) + 1) x 8Ts
- HNDP = Horizontal Non-Display Period
= HT - HDP
= (((REG[20h] bits 6:0) + 1) x 8Ts) - (((REG[24h] bits 6:0) + 1) x 8Ts)

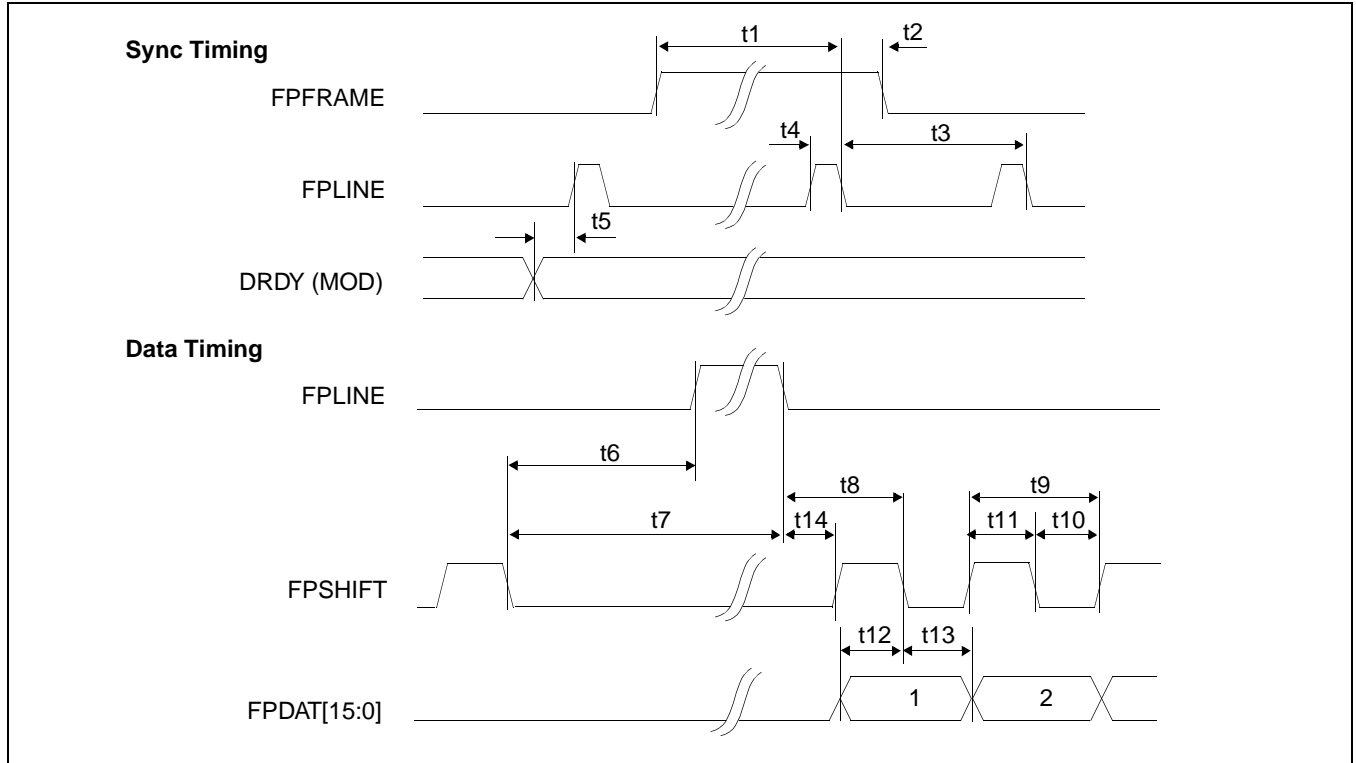


Figure 6-26: Single Color 16-Bit Panel A.C. Timing

Table 6-25: Single Color 16-Bit Panel A.C. Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|---------|-----|-----|-------------|
| t1 | FPFRAME setup to FPLINE falling edge | note 2 | | | Ts (note 1) |
| t2 | FPFRAME hold from FPLINE falling edge | note 3 | | | Ts |
| t3 | FPLINE period | note 4 | | | Ts |
| t4 | FPLINE pulse width | note 5 | | | Ts |
| t5 | MOD transition to FPLINE rising edge | note 6 | | | Ts |
| t6 | FPSHIFT falling edge to FPLINE rising edge | note 7 | | | Ts |
| t7 | FPSHIFT falling edge to FPLINE falling edge | t6 + t4 | | | Ts |
| t8 | FPLINE falling edge to FPSHIFT falling edge | t14 + 3 | | | Ts |
| t9 | FPSHIFT period | 5 | | | Ts |
| t10 | FPSHIFT pulse width low | 2 | | | Ts |
| t11 | FPSHIFT pulse width high | 2 | | | Ts |
| t12 | FPDAT[15:0] setup to FPSHIFT rising edge | 2 | | | Ts |
| t13 | FPDAT[15:0] hold to FPSHIFT rising edge | 2 | | | Ts |
| t14 | FPLINE falling edge to FPSHIFT rising edge | note 8 | | | Ts |

1. Ts = pixel clock period
2. $t1_{min} = HPS + t4_{min}$
3. $t2_{min} = t3_{min} - (HPS + t4_{min})$
4. $t3_{min} = HT$
5. $t4_{min} = HPW$
6. $t5_{min} = HPS - 1$
7. $t6_{min} = HPS - (HDP + HDPS) + 2$, if negative add $t3_{min}$
8. $t14_{min} = HDPS - (HPS + t4_{min})$, if negative add $t3_{min}$

6.4.8 Generic TFT Panel Timing

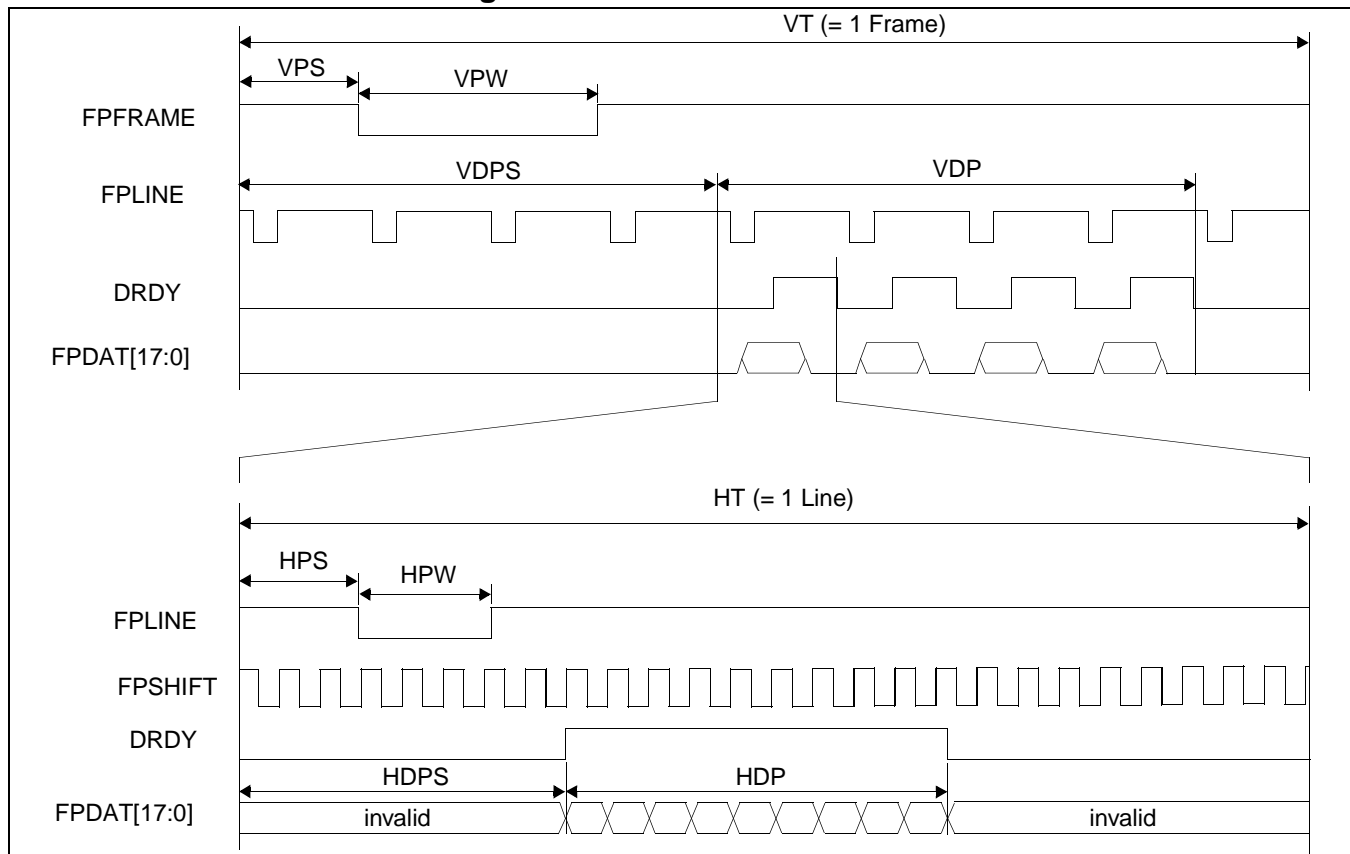


Figure 6-27: Generic TFT Panel Timing

| | | |
|------|--|--|
| VT | = Vertical Total | = [(REG[30h] bits 9-0) + 1] lines |
| VPS | = FPPFRAME Pulse Start Position | = (REG[3Ch] bits 9-0) lines |
| VPW | = FPPFRAME Pulse Width | = [(REG[3Ch] bits 18-16) + 1] lines |
| VDPS | = Vertical Display Period Start Position | = (REG[38h] bits 9-0) lines |
| VDP | = Vertical Display Period | = [(REG[34h] bits 9-0) + 1] lines |
| HT | = Horizontal Total | = [((REG[20h] bits 6-0) + 1) x 8] pixels |
| HPS | = FPLINE Pulse Start Position | = [(REG[2Ch] bits 9-0) + 1] pixels |
| HPW | = FPLINE Pulse Width | = [(REG[2Ch] bits 22-16) + 1] pixels |
| HDPS | = Horizontal Display Period Start Position | = [(REG[28h] bits 9-0) + 5] pixels |
| HDP | = Horizontal Display Period | = [((REG[24h] bits 6-0) + 1) x 8] pixels |

*For TFT panels, the HDP must be a minimum of 8 pixels and must be increased by multiples of 8.

*Panel Type Bits (REG[0Ch] bits 1-0) = 01 (TFT)

*FPLINE Pulse Polarity Bit (REG[2Ch] bit 23) = 0 (active low)

*FPPFRAME Polarity Bit (REG[3Ch] bit 23) = 0 (active low)

6.4.9 9/12/18-Bit TFT Panel Timing

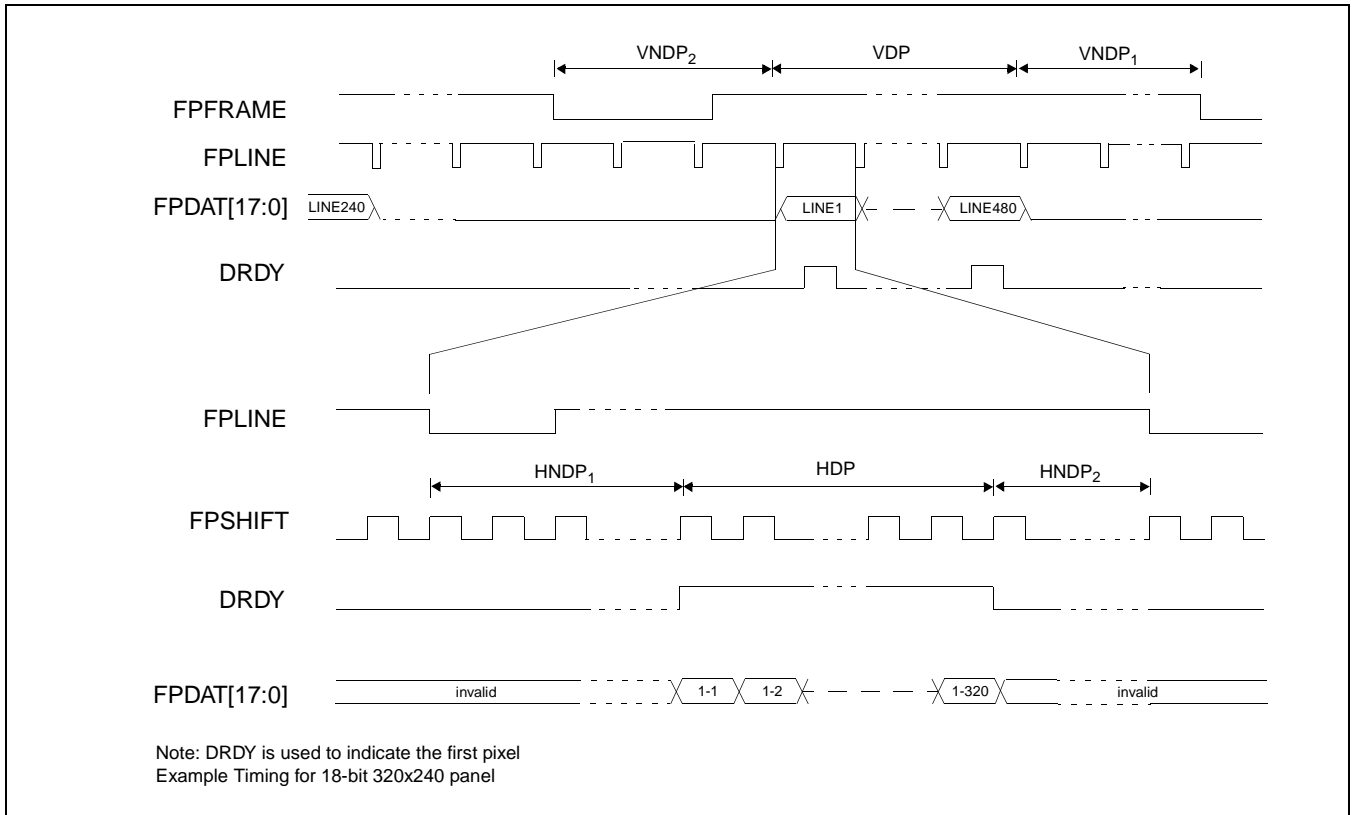


Figure 6-28: 18-Bit TFT Panel Timing

- VDP = Vertical Display Period
= VDP Lines
- VNDP = Vertical Non-Display Period
= VNDP1 + VNDP2
= VT - VDP Lines
- VNDP1 = Vertical Non-Display Period 1
= VNDP - VNDP2 Lines
- VNDP2 = Vertical Non-Display Period 2
= VDPS - VPS Lines if negative add VT
- HDP = Horizontal Display Period
= HDP Ts
- HNDP = Horizontal Non-Display Period
= HNDP1 + HNDP2
= HT - HDP Ts
- HNDP1 = Horizontal Non-Display Period 1
= HDPS - HPS Ts if negative add HT
- HNDP2 = Horizontal Non-Display Period 2
= HPS - (HDP + HDPS) Ts if negative add HT

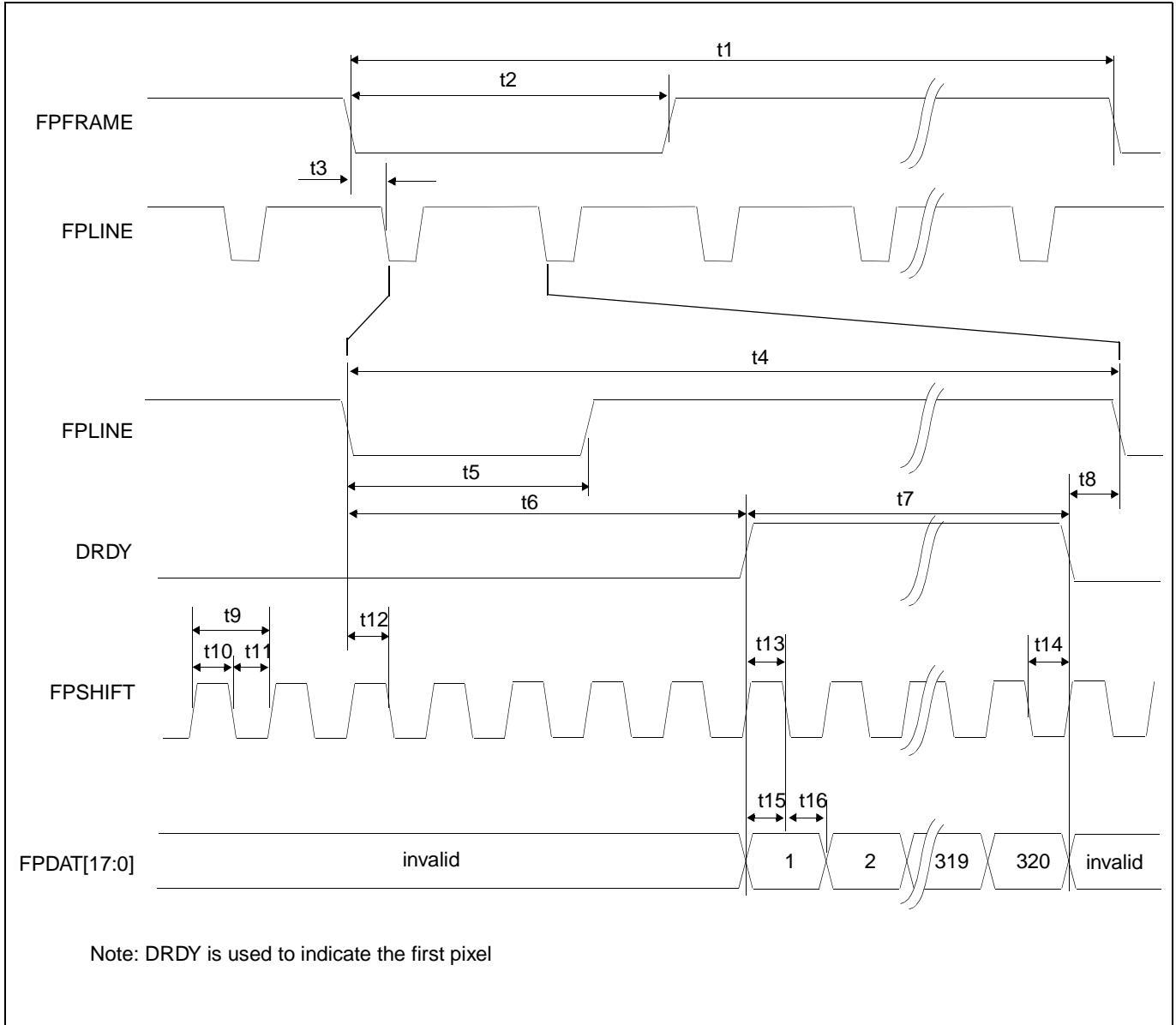


Figure 6-29: TFT A.C. Timing

Table 6-26: TFT A.C. Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|--------|-----|-----|-------------|
| t1 | FPFRAME cycle time | VT | | | Lines |
| t2 | FPFRAME pulse width low | VPW | | | Lines |
| t3 | FPFRAME falling edge to FPLINE falling edge phase difference | HPS | | | Ts (note 1) |
| t4 | FPLINE cycle time | HT | | | Ts |
| t5 | FPLINE pulse width low | HPW | | | Ts |
| t6 | FPLINE Falling edge to DRDY active | note 2 | | 250 | Ts |
| t7 | DRDY pulse width | HDP | | | Ts |
| t8 | DRDY falling edge to FPLINE falling edge | note 3 | | | Ts |
| t9 | FPSHIFT period | 1 | | | Ts |
| t10 | FPSHIFT pulse width high | 0.5 | | | Ts |
| t11 | FPSHIFT pulse width low | 0.5 | | | Ts |
| t12 | FPLINE setup to FPSHIFT falling edge | 0.5 | | | Ts |
| t13 | DRDY to FPSHIFT falling edge setup time | 0.5 | | | Ts |
| t14 | DRDY hold from FPSHIFT falling edge | 0.5 | | | Ts |
| t15 | Data setup to FPSHIFT falling edge | 0.5 | | | Ts |
| t16 | Data hold from FPSHIFT falling edge | 0.5 | | | Ts |

1. Ts = pixel clock period
2. t6min = HDPS - HPS if negative add HT
3. t8min = HPS - (HDP + HDPS) if negative add HT

6.4.10 Sharp HR-TFT Panel Timing

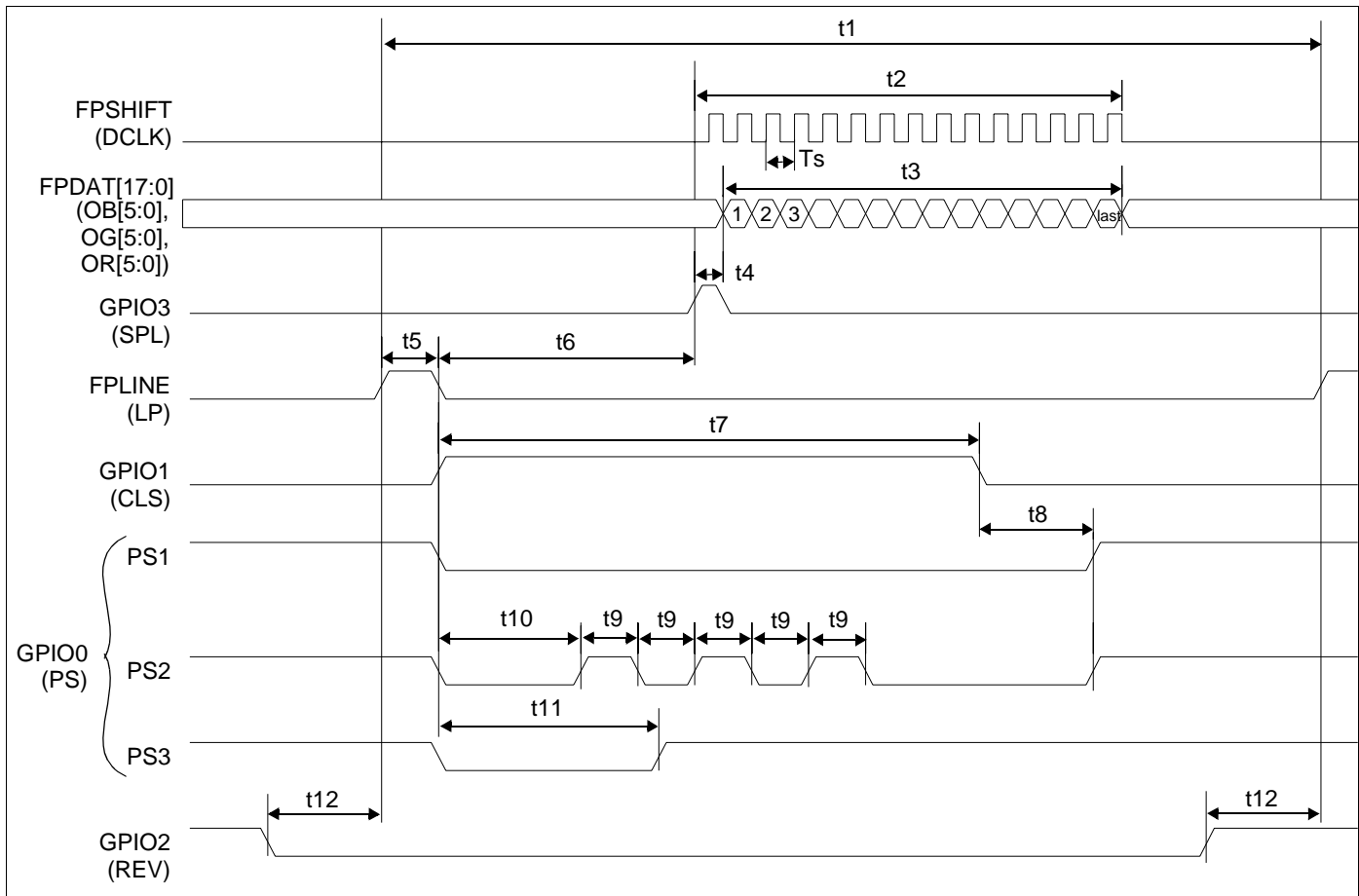


Figure 6-30: Sharp HR-TFT Panel Horizontal Timing

Table 6-27: Sharp HR-TFT Panel Horizontal Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|-----|---------|------|-------------|
| t1 | Horizontal total period | 8 | note 2 | 1024 | Ts (note 1) |
| t2 | FPSHIFT (DCLK) active | 9 | note 3 | 1025 | Ts |
| t3 | Horizontal display period | 8 | note 4 | 1024 | Ts |
| t4 | GPIO3 (SPL) pulse width | | 1 | | Ts |
| t5 | FPLINE (LP) pulse width | 1 | note 5 | 256 | Ts |
| t6 | FPLINE (LP) falling edge to GPIO3 (SPL) rising edge | 2 | note 6 | - | Ts |
| t7 | GPIO1 (CLS) pulse width | 0 | note 7 | 511 | Ts |
| t8 | GPIO1 (CLS) falling edge to GPIO0 (PS1) rising edge | 0 | note 8 | 63 | Ts |
| t9 | GPIO0 (PS2) toggle width | 0 | note 9 | 127 | Ts |
| t10 | GPIO0 (PS2) first falling edge to GPIO0 (PS2) first rising edge | 0 | note 10 | 255 | Ts |
| t11 | GPIO0 (PS3) pulse width | 0 | note 11 | 127 | Ts |
| t12 | GPIO2 (REV) toggle position to FPLINE (LP) rising edge | 0 | note 12 | 31 | Ts |

1. Ts = pixel clock period
2. t1typ = $[(\text{REG}[20\text{h}] \text{ bits } 6-0) + 1] * 8$
3. t2typ = $[\{(\text{REG}[24\text{h}] \text{ bits } 6-0) + 1\} * 8] + 1$
4. t3typ = $[(\text{REG}[24\text{h}] \text{ bits } 6-0) + 1] * 8$
5. t5typ = $(\text{REG}[2\text{Ch}] \text{ bits } 22-16) + 1$

- 6. $t6typ = (REG[28h] \text{ bits } 9-0) - (REG[2Ch] \text{ bits } 22-16) + 2$
- 7. $t7typ = (REG[A0h] \text{ bits } 8-0)$
- 8. $t8typ = (REG[A4h] \text{ bits } 5-0)$
- 9. $t9typ = (REG[ACh] \text{ bits } 6-0)$
- 10. $t10typ = (REG[A8h] \text{ bits } 7-0)$
- 11. $t11typ = (REG[B0h] \text{ bits } 6-0)$
- 12. $t12typ = (REG[B4h] \text{ bits } 4-0)$

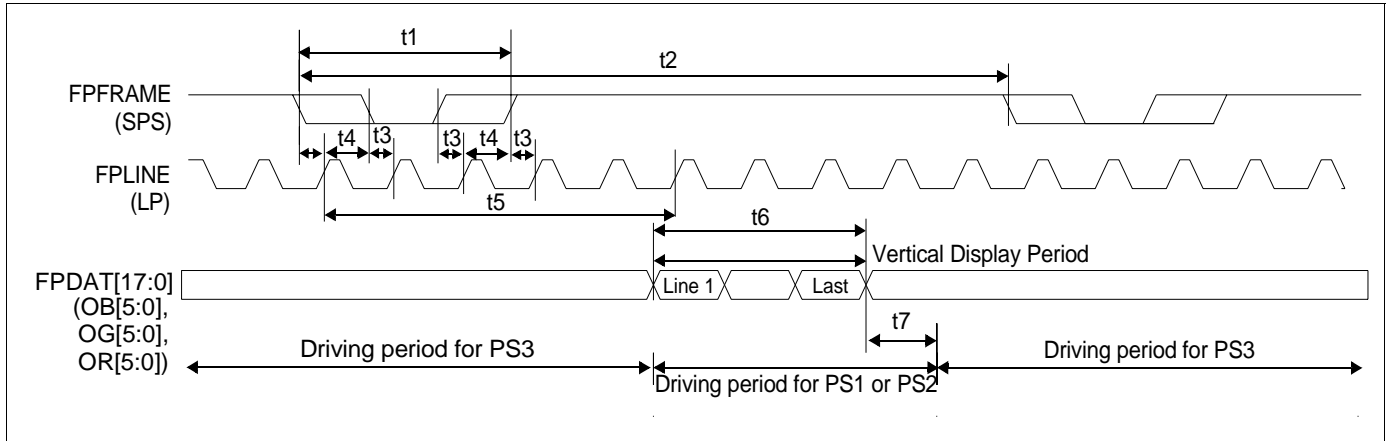


Figure 6-31: Sharp HR-TFT Panel Vertical Timing

Table 6-28: Sharp HR-TFT Panel Vertical Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|-----|------------|------|----------------|
| t1 | FPFRAME (SPS) pulse width | 1 | note 3 | 8 | Lines (note 1) |
| t2 | Vertical total period | 1 | note 4 | 1024 | Lines |
| t3 | FPFRAME (SPS) rising/falling edge to FPLINE (LP) rising edge | | 1 (note 5) | | Ts (note 2) |
| t4 | FPLINE (LP) rising edge to FPFRAME (SPS) rising/falling edge | 0 | note 5 | 1023 | Ts |
| t5 | Vertical display start position | 0 | note 6 | 1023 | Lines |
| t6 | Vertical display period | 1 | note 7 | 1024 | Lines |
| t7 | Extra driving period for GPIO0 (PS1/2) | 0 | note 8 | 7 | Lines |

- 1. Lines = 1 Horizontal Line
- 2. Ts = pixel clock period
- 3. $t1typ = (REG[3Ch] \text{ bits } 18-16) + 1$
- 4. $t2typ = (REG[30h] \text{ bits } 9-0) + 1$
- 5. t3typ The FPFRAME (SPS) rising/falling edge can occur before or after FPLINE (LP) rising edge depending on the value stored in the FPLINE Pulse Start Position bits (REG[2Ch] bits 9-0). To obtain the case indicated by t3, set the FPLINE Pulse Start Position bits to 0 and the FPFRAME (SPS) rising/falling edge will occur 1 Ts before the FPLINE (LP) rising edge. To obtain the case indicated by t4, set the FPLINE Pulse Start Position bits to a value between 1 and the Horizontal Total - 1. Then $t4 = (\text{Horizontal Total Period} - 1) - (REG[2Ch] \text{ bits } 9-0)$
- 6. $t5typ = (REG[38h] \text{ bits } 9-0)$
- 7. $t6typ = (REG[34h] \text{ bits } 9-0) + 1$
- 8. $t7typ = (REG[B8h] \text{ bits } 2-0)$

6.4.11 Casio TFT Panel Timing

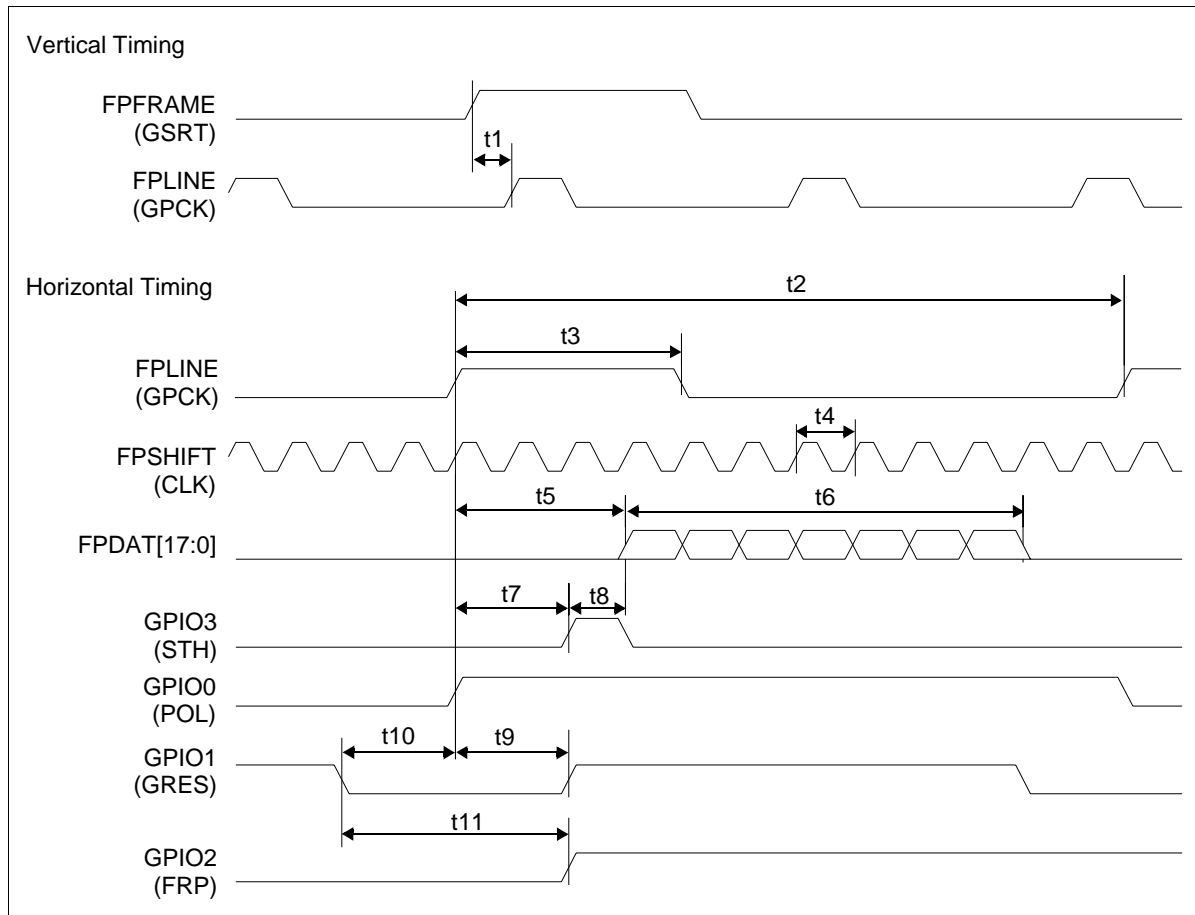


Figure 6-32: Casio TFT Horizontal Timing

Table 6-29: Casio TFT Horizontal Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|-----|---------|------|-------------|
| t1 | Horizontal pulse start position | 1 | note 2 | 1024 | Ts (note 1) |
| t2 | Horizontal total | 8 | note 3 | 1024 | Ts |
| t3 | Horizontal pulse width | 1 | note 4 | 128 | Ts |
| t4 | Pixel clock period | | note 5 | | Ts |
| t5 | Horizontal display period start position | 4 | note 6 | 1027 | Ts |
| t6 | Horizontal display period | 8 | note 7 | 1024 | Ts |
| t7 | FPLINE (GPCK) rising edge to GPIO3 (STH) rising edge | 0 | note 8 | 63 | Ts |
| t8 | GPIO3 (STH) pulse width | | 1 | | Ts |
| t9 | FPLINE (GPCK) rising edge to GPIO1 (GRES) falling edge | 0 | note 9 | 63 | Ts |
| t10 | GPIO1 (GRES) falling edge to FPLINE (GPCK) rising edge | 1 | note 10 | 64 | Ts |
| t11 | FPLINE (GPCK) rising edge to GPIO2 (FRP) toggle point | 0 | note 11 | 127 | Ts |

1. Ts = pixel clock period
2. t1typ = [(REG[2Ch] bits 9-0) + 1]
3. t2typ = [(REG[20h] bits 6-0) + 1] * 8
4. t3typ = [(REG[2Ch] bits 22-16) + 1]
5. t4typ = depends on the pixel clock (PCLK)

6. $t5_{typ} = (REG[28h] \text{ bits } 9-0) + 4$
7. $t6_{typ} = [(REG[24h] \text{ bits } 6-0) + 1] * 8$
8. $t7_{typ} = (REG[C0h] \text{ bits } 29-24)$
9. $t9_{typ} = (REG[C0h] \text{ bits } 5-0)$
10. $t10_{typ} = (REG[C0h] \text{ bits } 13-8) + 1$
11. $t11_{typ} = (REG[C0h] \text{ bits } 22-16)$

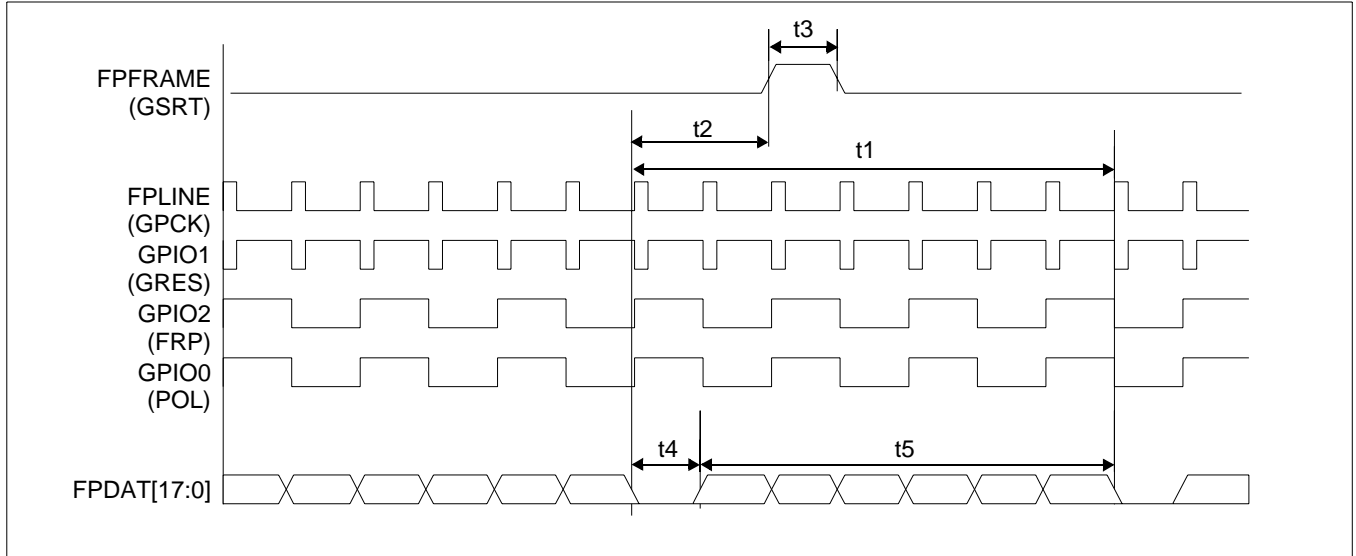


Figure 6-33: Casio TFT Vertical Timing

Table 6-30: Casio TFT Vertical Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|-----|--------|------|----------------|
| t1 | Vertical total | 1 | note 2 | 1024 | lines (note 1) |
| t2 | Vertical pulse start | 0 | note 3 | 1023 | lines |
| t3 | Vertical pulse width | 1 | note 4 | 8 | lines |
| t4 | Vertical display period start position | 1 | note 5 | 1024 | lines |
| t5 | Vertical display period | 1 | note 6 | 1024 | lines |

1. Lines = 1 Horizontal Line
2. $t1_{typ} = (REG[30h] \text{ bits } 9-0) + 1$
3. $t2_{typ} = (REG[3Ch] \text{ bits } 9-0)$
4. $t3_{typ} = (REG[3Ch] \text{ bits } 18-16) + 1$
5. $t4_{typ} = (REG[38h] \text{ bits } 9-0) + 1$
6. $t5_{typ} = (REG[34h] \text{ bits } 9-0) + 1$

6.4.12 TFT Type 2 Panel Timing

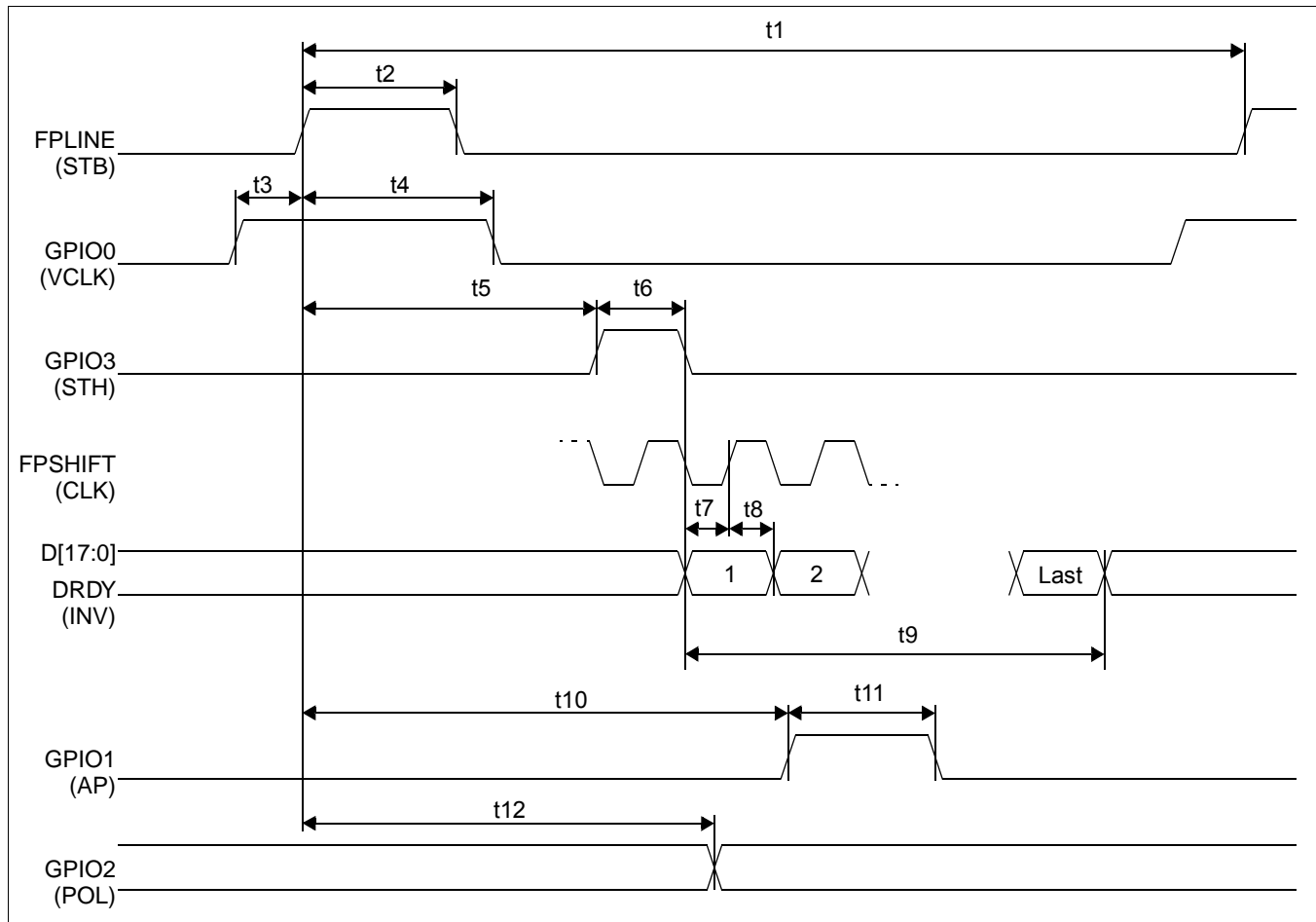


Figure 6-34: TFT Type 2 Horizontal Timing

Table 6-31: TFT Type 2 Horizontal Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|---|-----|--------|------|-------------|
| t1 | Horizontal total period | 1 | note 2 | 1024 | Ts (note 1) |
| t2 | FPLINE (STB) pulse width | | 5 | | Ts |
| t3 | GPIO0 (VCLK) rising edge to FPLINE (STB) rising edge | 7 | note 3 | 16 | Ts |
| t4 | FPLINE (STB) rising edge to GPIO0 (VCLK) falling edge | 7 | note 4 | 16 | Ts |
| t5 | FPLINE (STB) rising edge to GPIO3 (STH) rising edge | | note 5 | | Ts |
| t6 | GPIO3 (STH) pulse width | | 1 | | Ts |
| t7 | Data setup time | 0.5 | | | Ts |
| t8 | Data hold time | 0.5 | | | Ts |
| t9 | Horizontal display period | 8 | note 6 | 1024 | Ts |
| t10 | FPLINE (STB) rising edge to GPIO1 (AP) rising edge | 40 | note 7 | 90 | Ts |
| t11 | GPIO1 (AP) pulse width | 20 | note 8 | 270 | Ts |
| t12 | FPLINE (STB) rising edge to GPIO2 (POL) toggle position | | 10 | | Ts |

1. T_s = pixel clock period
2. t_{1typ} = $[(REG[20h] \text{ bits } 6-0) + 1] * 8$
3. t_{3typ} = (REG[BCh] bits 1-0)
Selected from 7, 9, 12 or 16 T_s
4. t_{4typ} = (REG[BCh] bits 4-3)
Selected from 7, 9, 12 or 16 T_s
5. t_{5typ} = (REG[28h] bits 9-0) + 3 T_s
6. t_{9typ} = $[(REG[24h] \text{ bits } 6-0) + 1] * 8$
7. t_{10typ} = (REG[BCh] bits 9-8)
Selected from 40, 52, 68 or 90 T_s
8. t_{11typ} = (REG[BCh] bits 13-11)
Selected from 20, 40, 80, 120, 150, 190, 240 or 270 T_s

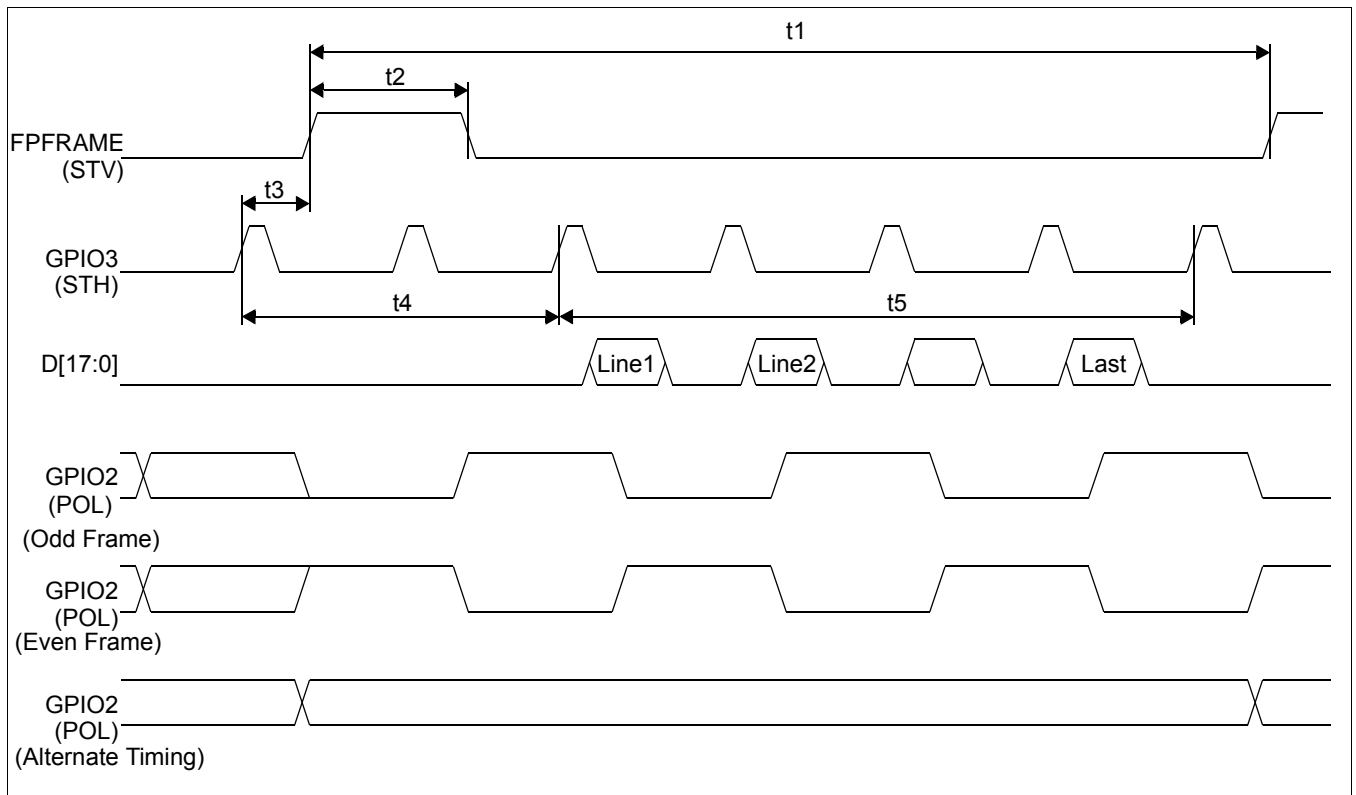


Figure 6-35: TFT Type 2 Vertical Timing

Table 6-32: TFT Type 2 Vertical Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|-----|--------|------|----------------|
| t_1 | Vertical total period | 8 | | 1024 | Lines |
| t_2 | FPFRAME (STV) pulse width | | 1 | | Lines |
| t_3 | GPIO3 (STH) rising edge to FPFRAME (STV) rising edge | | 0 | | T_s (note 1) |
| t_4 | Vertical display start position | 0 | note 3 | 1024 | Lines (note 2) |
| t_5 | Vertical display period | 1 | note 4 | 1024 | T_s |

1. T_s = pixel clock period
2. Lines = 1 Horizontal Line
2. t_{4typ} = (REG[38h] bits 9-0)
3. t_{5typ} = (REG[34h] bits 9-0)

6.4.13 TFT Type 3 Panel Timing

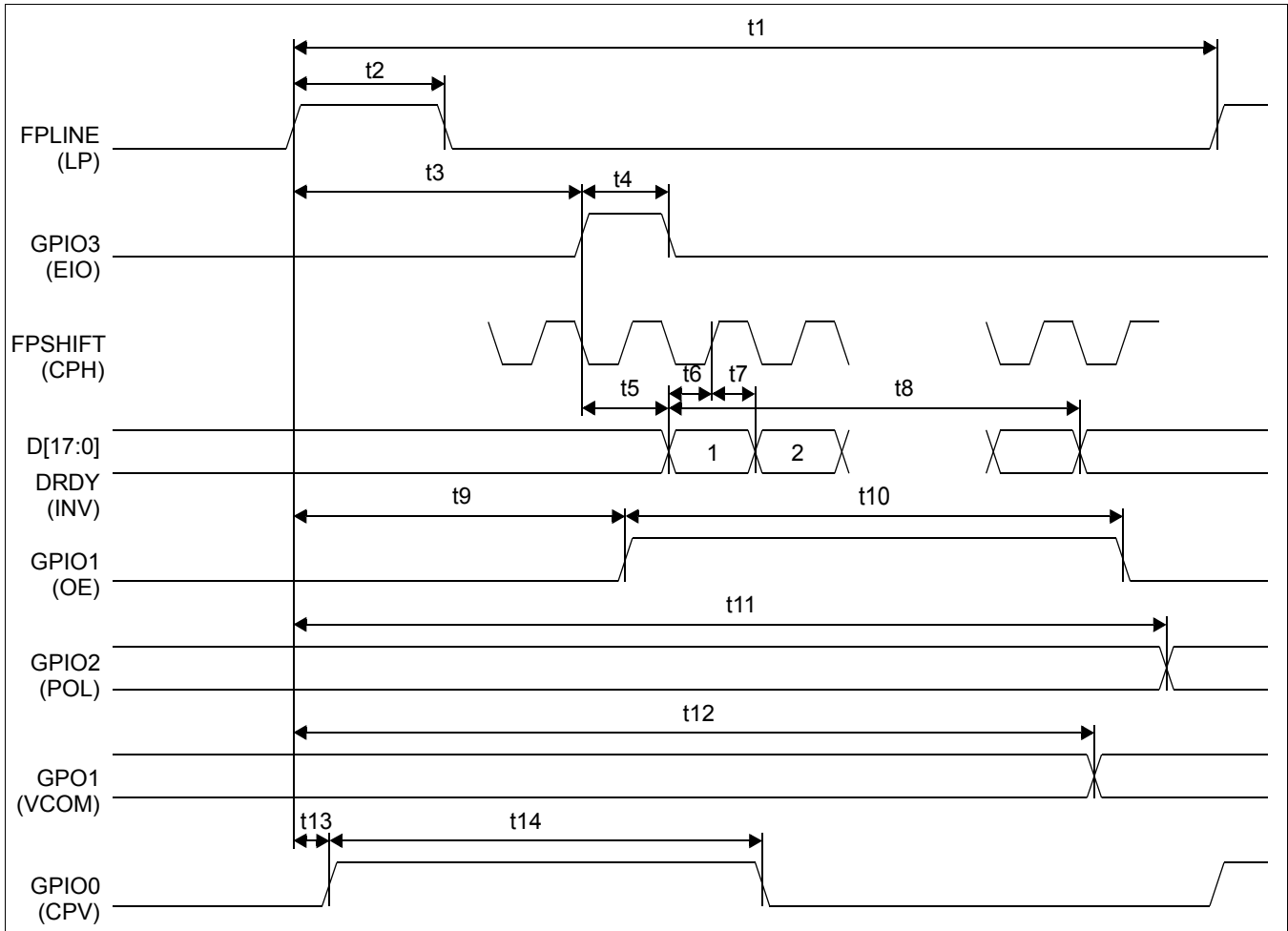


Figure 6-36: TFT Type 3 Horizontal Timing

Table 6-33: TFT Type 3 Horizontal Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|-----|-----|------|-------------|
| t1 | Horizontal total period | 8 | | 1024 | Ts (note 1) |
| t2 | FPLINE (LP) pulse width | 1 | | 256 | Ts |
| t3 | FPLINE (LP) rising edge to GPIO3 (EIO) rising edge | | | | Ts |
| t4 | GPIO3 (EIO) pulse width | | 1 | | Ts |
| t5 | GPIO3 (EIO) rising edge to 1st data | | 1 | | Ts |
| t6 | Data setup time | 0.5 | | | Ts |
| t7 | Data hold time | 0.5 | | | Ts |
| t8 | Horizontal display period | 8 | | 1024 | Ts |
| t9 | FPLINE (LP) rising edge to GPIO1 (OE) rising edge | 0 | | 512 | Ts |
| t10 | GPIO1 (OE) pulse width | 0 | | 512 | Ts |
| t11 | FPLINE (LP) rising edge to GPIO2 (POL) toggle position | 0 | | 512 | Ts |
| t12 | FPLINE (LP) rising edge to GPO1 (VCOM) toggle position | 0 | | 512 | Ts |
| t13 | FPLINE (LP) rising edge to GPIO0 (CPV) rising edge | | 0 | | Ts |
| t14 | GPIO0 (CPV) pulse width | 0 | | 512 | Ts |

1. Ts = pixel clock period
2. t1typ = [(REG[20h] bits 6-0) + 1] * 8
3. t2typ = (REG[2Ch] bits 22-16) + 1
3. t3typ = (REG[28h] bits 9-0) + 4 Ts
4. t4typ = Selected from 0, 1, 2 Ts
6. t8typ = [(REG[24h] bits 6-0) + 1] * 8
7. t9typ = (REG[D8h] bits 15-8) * 2
8. t10typ = (REG[D8h] bits 23-16) * 2
9. t11typ = (REG[D8h] bits 31-24) * 2
10. t12typ = (REG[DCh] bits 7-0) * 2
7. t14typ = (REG[DCh] bits 15-8) * 2

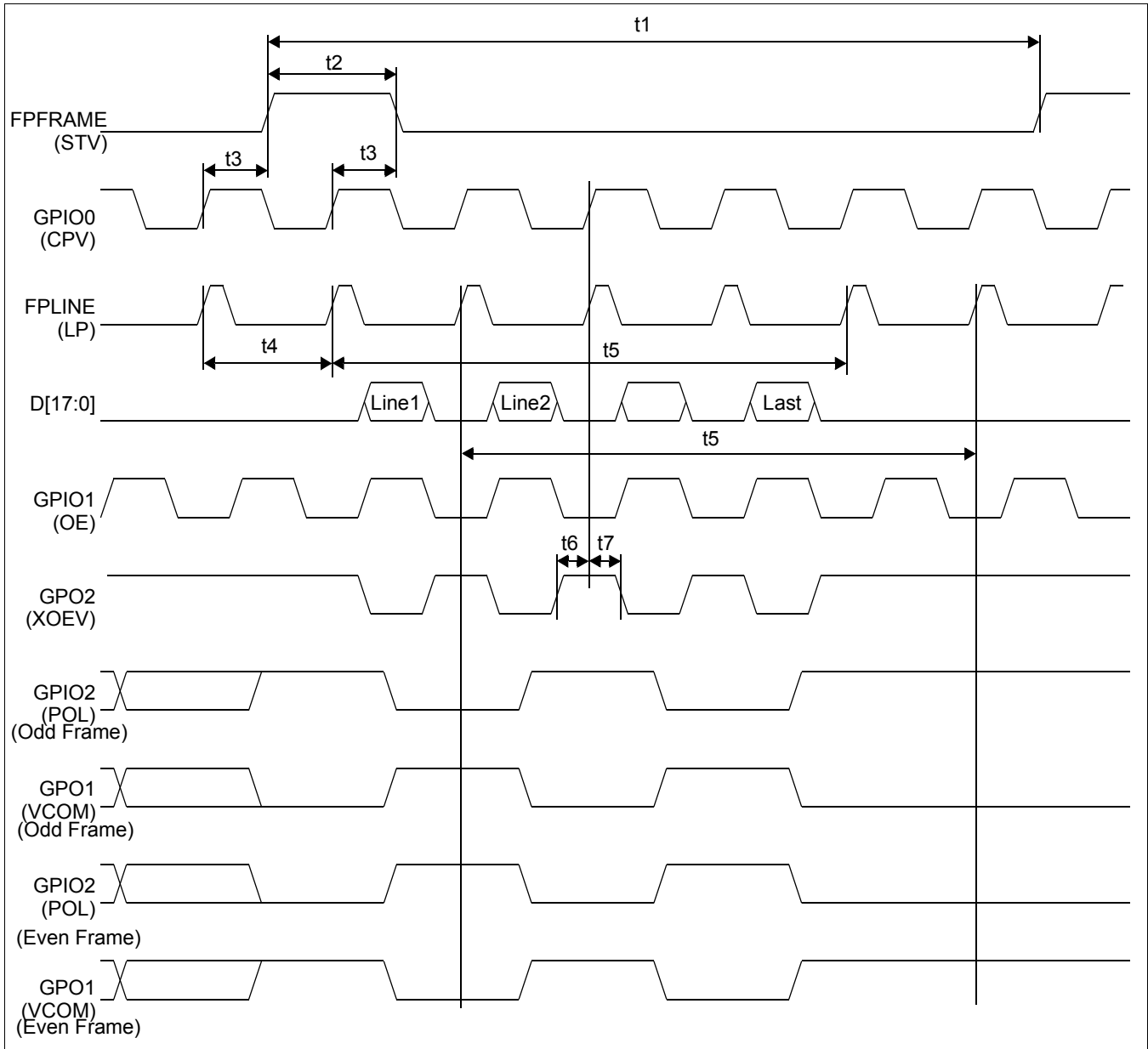


Figure 6-37: TFT Type 3 Vertical Timing

Table 6-34: TFT Type 3 Vertical Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|-----|-----|------|-------|
| t1 | Vertical total period | 1 | | 1024 | Lines |
| t2 | FPFRAME (STV) pulse width | | 1 | | Lines |
| t3 | GPIO0 (CPV) rising edge to FPFRAME (STV) rising (falling) edge | | 0.5 | | Lines |
| t4 | Vertical display start position | 1 | | | Lines |
| t5 | Vertical display period | 1 | | 1024 | Lines |
| t6 | GPO2 (XOEV) rising edge to GPIO0 (CPV) rising edge | 0 | | 512 | Ts |
| t7 | GPIO0 (CPV) rising edge to GPO2 (XOEV) falling edge | 0 | | 512 | Ts |

1. Ts = pixel clock period
2. t4typ = (REG[38h] bits 9-0)
2. t5typ = (REG[34h] bits 9-0) + 1
3. t6typ = (REG[DCh] bits 23-16) * 2
4. t7typ = (REG[DCh] bits 31-24) * 2

6.4.14 TFT Type 4 Panel Timing

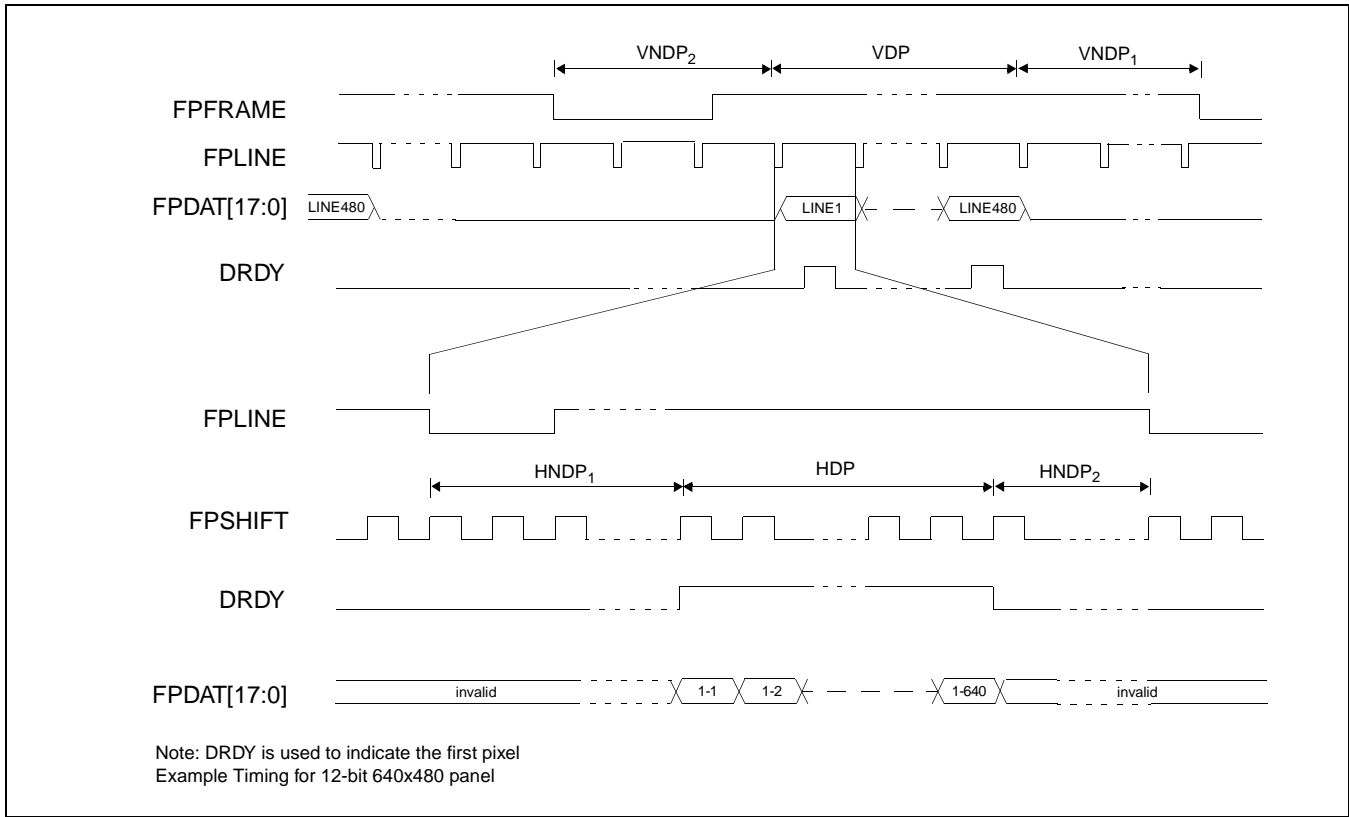


Figure 6-38: TFT Type 4 Panel Timing

VDP = Vertical Display Period
= VDP Lines

VNDP = Vertical Non-Display Period
= VNDP1 + VNDP2
= VT - VDP Lines

VNDP1 = Vertical Non-Display Period 1
= VNDP - VNDP2 Lines

VNDP2 = Vertical Non-Display Period 2
= VDPS - VPS Lines if negative add VT

HDP = Horizontal Display Period
= HDP Ts

HNDP = Horizontal Non-Display Period
= HNDP1 + HNDP2
= HT - HDP Ts

HNDP1 = Horizontal Non-Display Period 1
= HDPS - (HPS + 1) + 5 Ts if negative add HT

HNDP2 = Horizontal Non-Display Period 2
= (HPS + 1) - (HDP + HDPS + 5) Ts if negative add HT

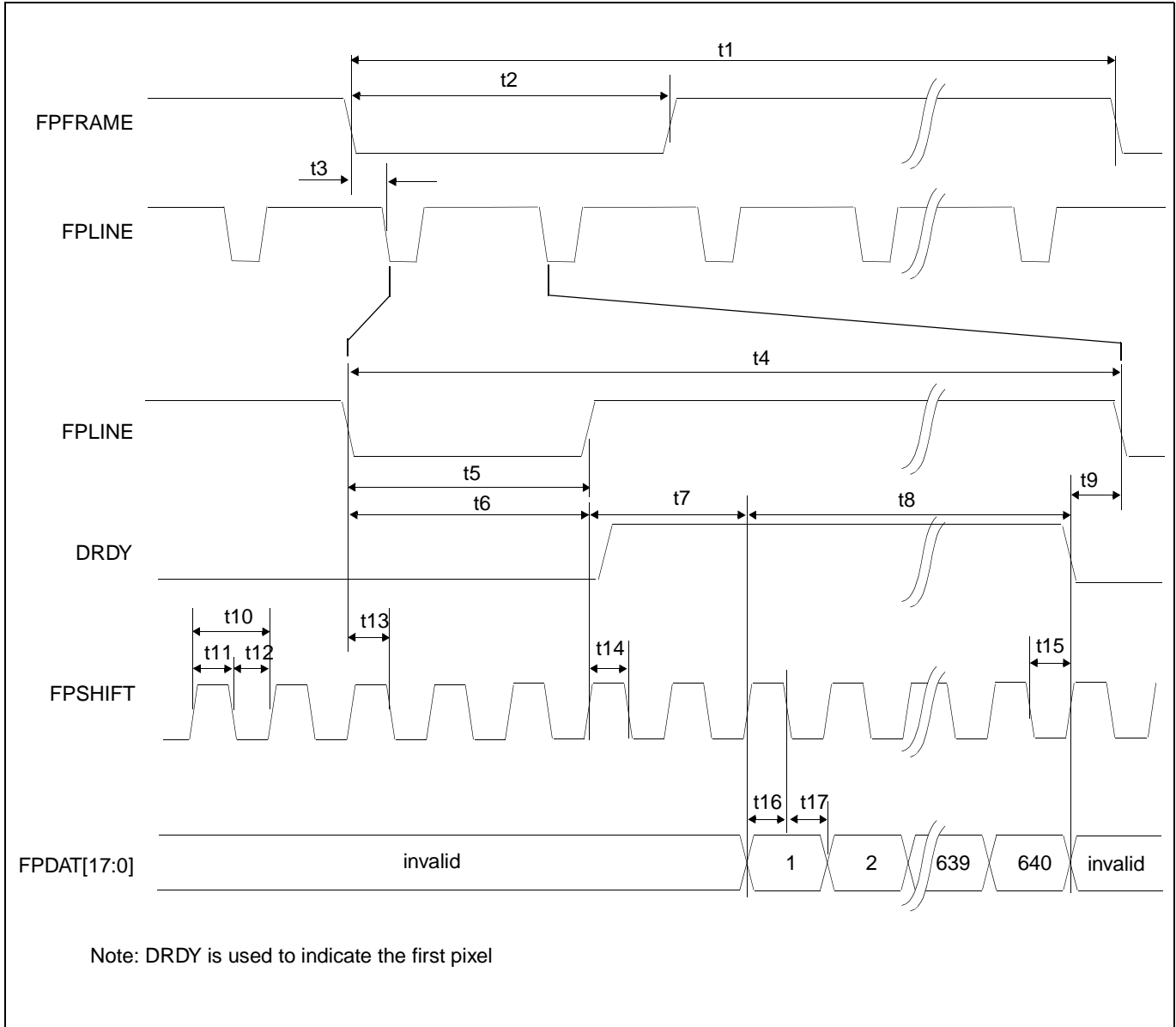


Figure 6-39: TFT Type 4 A.C. Timing

Table 6-35: TFT Type 4 A.C. Timing

| Symbol | Parameter | Min | Typ | Max | Units |
|--------|--|---------|-----|-----|-------------|
| t1 | FPFRAME cycle time | VT | | | Lines |
| t2 | FPFRAME pulse width low | VPW | | | Lines |
| t3 | FPFRAME falling edge to FPLINE falling edge phase difference | HPS + 1 | | | Ts (note 1) |
| t4 | FPLINE cycle time | HT | | | Ts |
| t5 | FPLINE pulse width low | HPW | | | Ts |
| t6 | FPLINE Falling edge to DRDY active | note 2 | | 250 | Ts |
| t7 | DRDY active to data setup | | 8 | | Ts |
| t8 | DRDY pulse width | HDP | | | Ts |
| t9 | DRDY falling edge to FPLINE falling edge | note 3 | | | Ts |
| t10 | FPSHIFT period | 1 | | | Ts |
| t11 | FPSHIFT pulse width high | 0.5 | | | Ts |
| t12 | FPSHIFT pulse width low | 0.5 | | | Ts |
| t13 | FPLINE setup to FPSHIFT falling edge | 0.5 | | | Ts |
| t14 | DRDY to FPSHIFT falling edge setup time | 0.5 | | | Ts |
| t15 | DRDY hold from FPSHIFT falling edge | 0.5 | | | Ts |
| t16 | Data setup to FPSHIFT falling edge | 0.5 | | | Ts |
| t17 | Data hold from FPSHIFT falling edge | 0.5 | | | Ts |

1. Ts = pixel clock period
2. t6min = HDPS - (HPS + 1) + 5 if negative add HT
3. t8min = (HPS + 1) - (HDP + HDPS + 5) if negative add HT

6.5 USB Timing

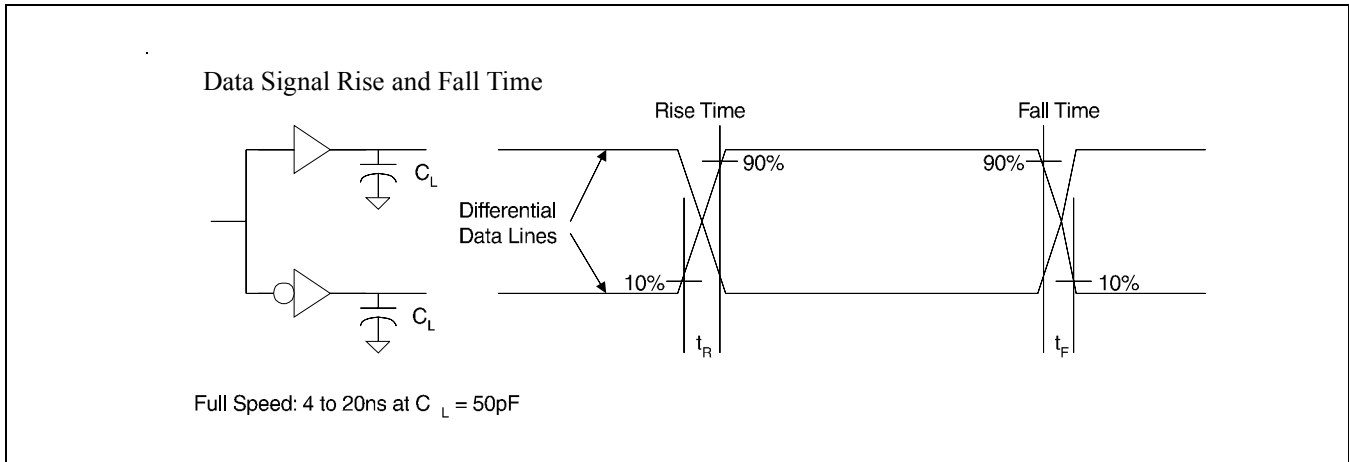


Figure 6-40 Data Signal Rise and Fall Time

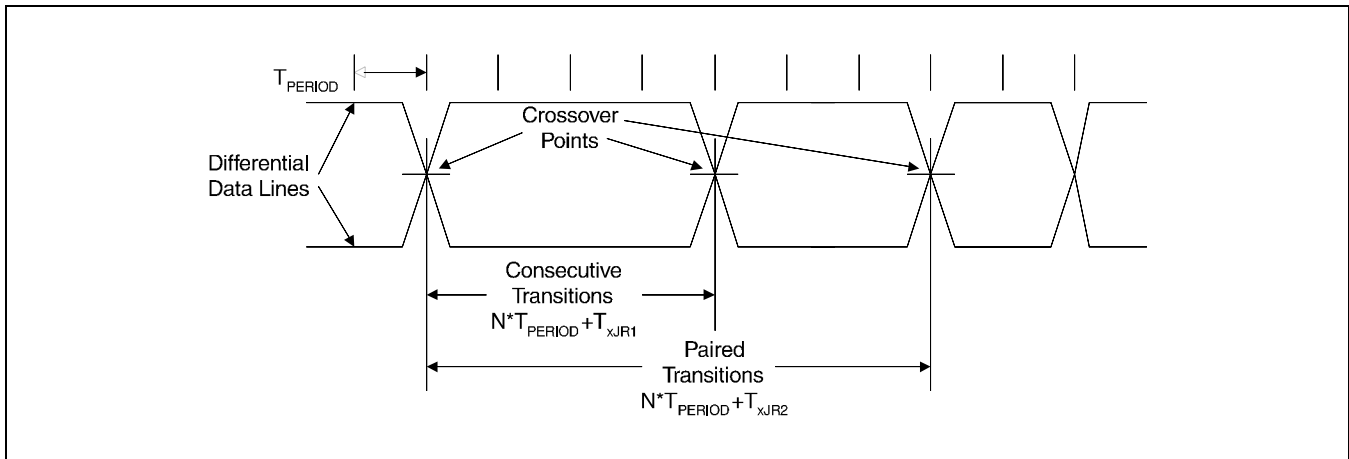


Figure 6-41 Differential Data Jitter

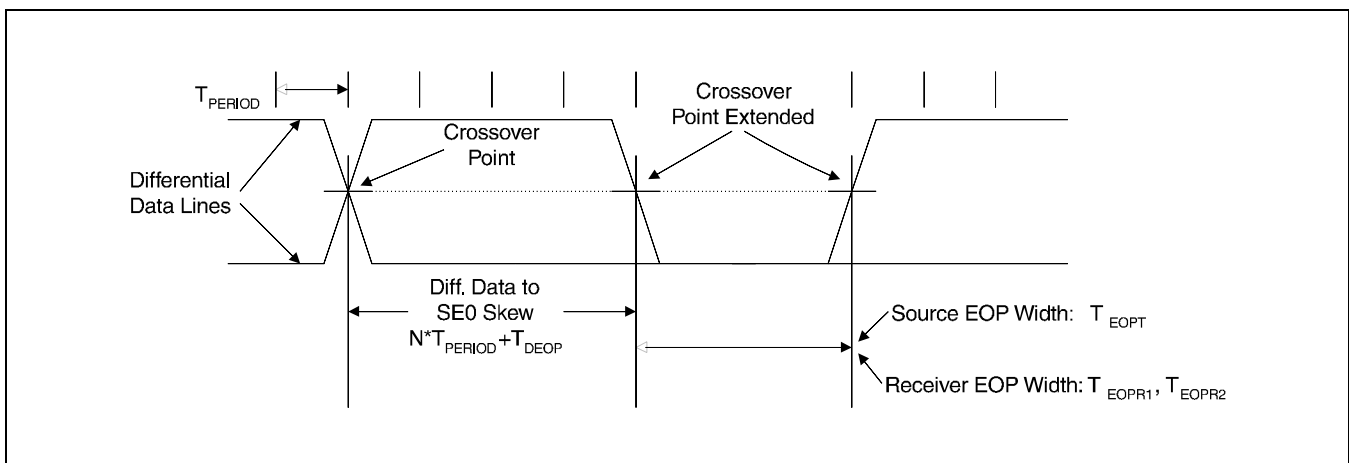


Figure 6-42 Differential to EOP Transition Skew and EOP Width

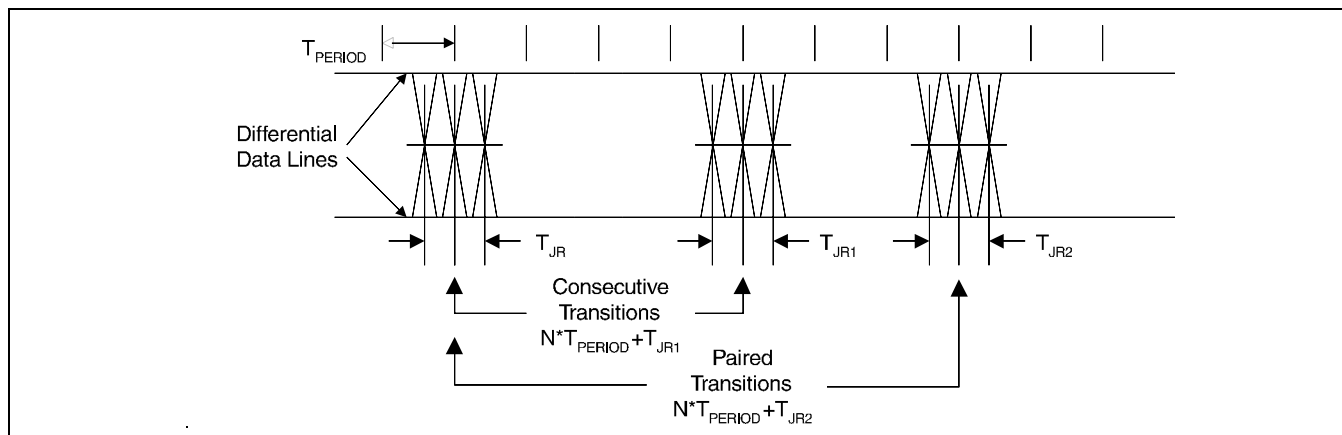


Figure 6-43 Receiver Jitter Tolerance

Table 6-36 USB Interface Timing

| Symbol | Parameter | Conditions | Waveform | Min | Typ | Max | Unit |
|---------------------|--|-------------------------------------|-------------|----------------------|--------------------------------------|-------|------|
| USB _{FREQ} | USB Clock Frequency | | | | 48 | | MHz |
| T _{PERIOD} | USB Clock Period | | Figure 6-40 | | $\frac{1}{\text{USB}_{\text{FREQ}}}$ | | |
| T _R | Rise & Fall Times | C _L = 50 pF Notes 1,2 | Figure 6-40 | 4 | | 20 | ns |
| T _F | | | | 4 | | 20 | |
| T _{RFM} | Rise/Fall time matching | (T _R / T _F) | Figure 6-40 | 90 | | 110 | % |
| V _{CRS} | Output Signal Crossover Voltage | | | 1.3 | | 2.0 | V |
| Z _{DRV} | Driver Output Resistance | Steady State Drive | | 28 ^{Note 5} | | 44 | Ω |
| T _{DRATE} | Data Rate | | | 11.97 | 12 | 12.03 | Mbs |
| T _{DDJ1} | Source Differential Driver Jitter to Next Transition | Notes 3,4. | Figure 6-41 | -3.5 | 0 | 3.5 | ns |
| T _{DDJ2} | Source Differential Driver Jitter for Paired Transitions | Notes 3,4 | Figure 6-41 | -4.0 | 0 | 4.0 | ns |
| T _{DEOP} | Differential to EOP Transition Skew | Note 4 | Figure 6-42 | -2 | 0 | 5 | ns |
| T _{EOP1} | Source EOP Width | Note 4 | Figure 6-42 | 160 | 167 | 175 | ns |
| T _{JR1} | Receiver Data Jitter Tolerance to Next Transition | Note 4 | Figure 6-43 | -18.5 | 0 | 18.5 | ns |
| T _{JR2} | Receiver Data Jitter Tolerance for Paired Transitions | Note 4 | Figure 6-43 | -9 | 0 | 9 | ns |
| T _{EOPR1} | EOP Width at Receiver; Must reject as EOP | Note 4 | Figure 6-42 | 40 | | | ns |
| T _{EOPR2} | EOP Width at Receiver; Must accept as EOP | Note 4 | Figure 6-42 | 80 | | | ns |

- 1 Measured from 10% to 90% of the data signal.
- 2 The rising and falling edges should be smoothly transitioning (monotonic).
- 3 Timing difference between the differential data signals.
- 4 Measured at crossover point of differential data signals.
- 5 20 Ω is placed in series to meet this USB specification. The actual driver output impedance is 15 Ω.

7 Clocks

7.1 Clock Descriptions

7.1.1 BCLK

BCLK is an internal clock derived from CLKI or CLKI2 (see REG[04h] bit 0). If CLKI is selected as the source, BCLK can be a divided version ($\div 1$, $\div 2$) of CLKI. CLKI is typically derived from the host CPU bus clock.

The source clock options for BCLK may be selected as in the following table.

Table 7-1: BCLK Clock Selection

| Source Clock Options | BCLK Selection |
|----------------------|----------------|
| CLKI | CNF6 = 0 |
| CLKI $\div 2$ | CNF6 = 1 |

Note

For synchronous bus interfaces, it is recommended that BCLK be set the same as the CPU bus clock (not a divided version of CLKI) e.g. SH-3, SH-4.

7.1.2 MCLK

MCLK provides the internal clock required to access the embedded SRAM. The S1D13A05 is designed with efficient power saving control for clocks (clocks are turned off when not used); reducing the frequency of MCLK does not necessarily save more power. Furthermore, reducing the MCLK frequency relative to the BCLK frequency increases the CPU cycle latency and so reduces screen update performance. For a balance of power saving and performance, the MCLK should be configured to have a high enough frequency setting to provide sufficient screen refresh as well as acceptable CPU cycle latency.

Note

The maximum frequency of MCLK is 50MHz (30MHz if running CORE V_{DD} at $2.0V \pm 10\%$). As MCLK is derived from BCLK, when BCLK is greater than 50MHz, MCLK must be divided using REG[04h] bits 5-4.

The source clock options for MCLK may be selected as in the following table.

Table 7-2: MCLK Clock Selection

| Source Clock Options | MCLK Selection |
|----------------------|------------------------|
| BCLK | REG[04h] bits 5-4 = 00 |
| BCLK $\div 2$ | REG[04h] bits 5-4 = 01 |
| BCLK $\div 3$ | REG[04h] bits 5-4 = 10 |
| BCLK $\div 4$ | REG[04h] bits 5-4 = 11 |

7.1.3 PCLK

PCLK is the internal clock used to control the panel. It should be chosen to match the optimum frame rate of the panel. See Section 10, “Frame Rate Calculation” on page 167 for details on the relationship between PCLK and frame rate.

Some flexibility is possible in the selection of PCLK. Firstly, panels typically have a range of permissible frame rates. Secondly, it may be possible to choose a higher PCLK frequency and tailor the horizontal non-display period to bring down the frame-rate to its optimal value.

The source clock options for PCLK may be selected as in the following table.

Table 7-3: PCLK Clock Selection

| Source Clock Options | PCLK Selection |
|----------------------|--------------------------|
| MCLK | REG[08h] bits 7-0 = 00h |
| MCLK ÷2 | REG[08h] bits 7-0 = 10h |
| MCLK ÷3 | REG[08h] bits 7-0 = 20h |
| MCLK ÷4 | REG[08h] bits 7-0 = 30h |
| MCLK ÷8 | REG[08h] bits 7-0 = 40h |
| BCLK | REG[08h] bits 7-0 = 01h |
| BCLK ÷2 | REG[08h] bits 7-0 = 11h |
| BCLK ÷3 | REG[08h] bits 7-0 = 21h |
| BCLK ÷4 | REG[08h] bits 7-0 = 31h |
| BCLK ÷8 | REG[08h] bits 7-0 = 41h |
| CLKI | REG[08h] bits 7-0 = 02h |
| CLKI ÷2 | REG[08h] bits 7-0 = 12h |
| CLKI ÷3 | REG[08h] bits 7-0 = 22h |
| CLKI ÷4 | REG[08h] bits 7-0 = 32h |
| CLKI ÷8 | REG[08h] bits 7-0 = 42h |
| CLKI2 | REG[08h] bits 7-0 = 03h |
| CLKI2 ÷2 | REG[08h] bits 7-0 = 13h |
| CLKI2 ÷3 | REG[08h] bits 7-0 = 23h |
| CLKI2 ÷4 | RREG[08h] bits 7-0 = 33h |
| CLKI2 ÷8 | REG[08h] bits 7-0 = 43h |

There is a relationship between the frequency of MCLK and PCLK that must be maintained.

Table 7-4: Relationship between MCLK and PCLK

| SwivelView Orientation | Color Depth (bpp) | MCLK to PCLK Relationship |
|-------------------------|-------------------|----------------------------------|
| SwivelView 0° and 180° | 16 | $f_{MCLK} \geq f_{PCLK}$ |
| | 8 | $f_{MCLK} \geq f_{PCLK} \div 2$ |
| | 4 | $f_{MCLK} \geq f_{PCLK} \div 4$ |
| | 2 | $f_{MCLK} \geq f_{PCLK} \div 8$ |
| | 1 | $f_{MCLK} \geq f_{PCLK} \div 16$ |
| SwivelView 90° and 270° | 16/8/4/2/1 | $f_{MCLK} \geq 1.25f_{PCLK}$ |

7.1.4 PWMCLK

PWMCLK is the internal clock used by the Pulse Width Modulator for output to the panel.

The source clock options for PWMCLK may be selected as in the following table.

Table 7-5: PWMCLK Clock Selection

| Source Clock Options | PWMCLK Selection |
|----------------------|------------------------|
| CLKI | REG[70h] bits 2-1 = 00 |
| CLKI2 | REG[70h] bits 2-1 = 01 |
| MCLK | REG[70h] bits 2-1 = 10 |
| PCLK | REG[70h] bits 2-1 = 11 |

For further information on controlling PWMCLK, see “PWM Clock Configuration Register” on page 127..

7.2 Clock Selection

The following diagram provides a logical representation of the S1D13A05 internal clocks used for the LCD controller.

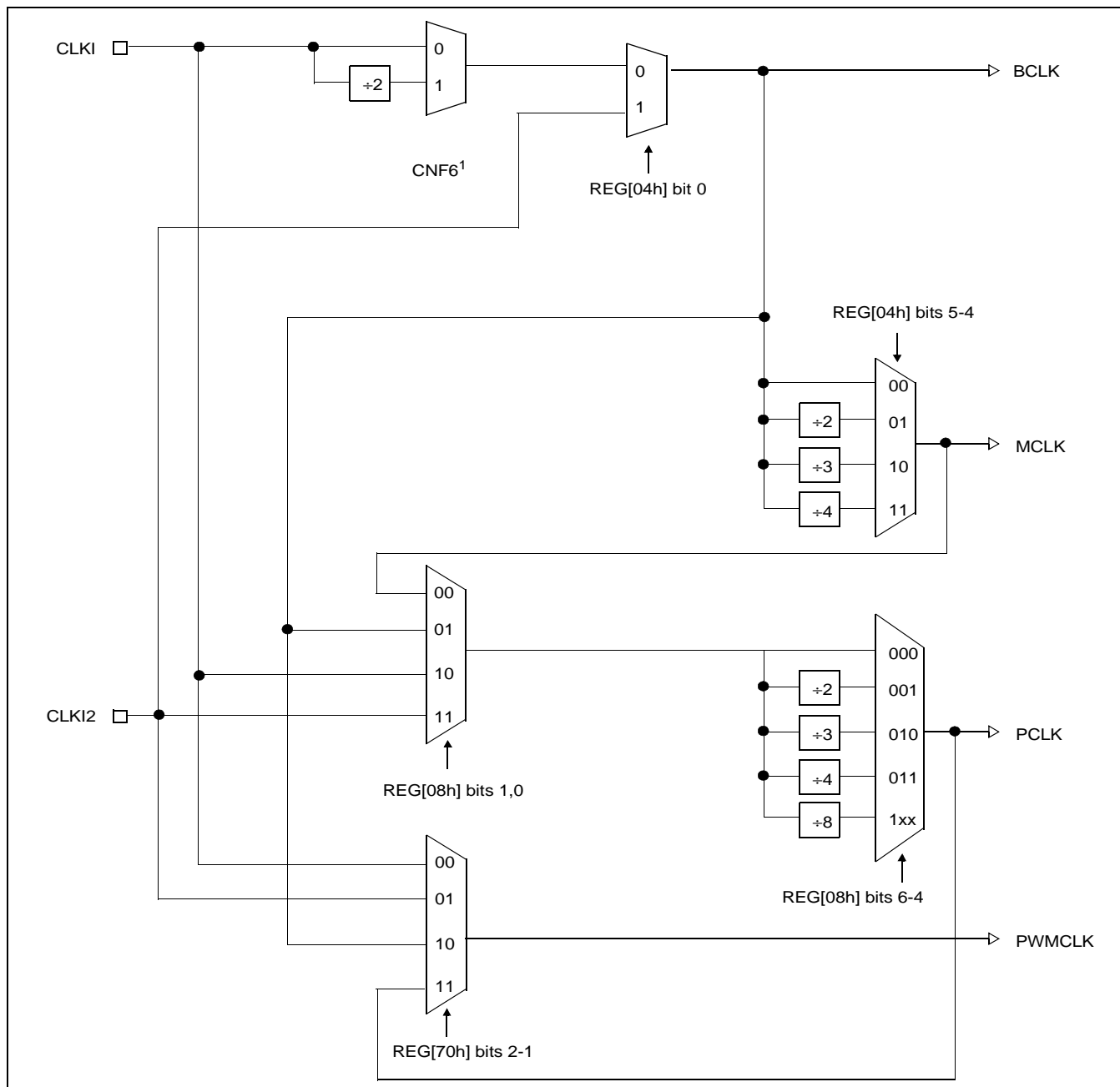


Figure 7-1: Clock Selection

Note
¹ CNF6 must be set at RESET#.

7.3 Clocks versus Functions

Table 7-6: “S1D13A05 Internal Clock Requirements”, lists the internal clocks required for the following S1D13A05 functions.

Table 7-6: S1D13A05 Internal Clock Requirements

| Function | Bus Clock (BCLK) | Memory Clock (MCLK) | Pixel Clock (PCLK) | PWM Clock (PWMCLK) | USB Clock (USBCLK) |
|-----------------------------------|------------------|---------------------|--------------------|---------------------------|--------------------|
| Register Read/Write | Required | Not Required | Not Required | Not Required ¹ | Not Required |
| Memory Read/Write | Required | Required | Not Required | Not Required ¹ | Not Required |
| Look-Up Table Register Read/Write | Required | Required | Not Required | Not Required ¹ | Not Required |
| Software Power Save | Required | Not Required | Not Required | Not Required ¹ | Not Required |
| LCD Output | Required | Required | Required | Not Required ¹ | Not Required |
| USB Register Read/Write | Required | Not Required | Not Required | Not Required | Required |

Note

¹PWMCLK is an optional clock (see Section 7.1.4, “PWMCLK” on page 96).

8 Registers

This section discusses how and where to access the S1D13A05 registers. It also provides detailed information about the layout and usage of each register.

8.1 Register Mapping

The S1D13A05 registers are memory-mapped. When the system decodes the input pins as CS# = 0 and M/R# = 0, the registers may be accessed. The register space is decoded by AB[17:0] and is mapped as follows.

Table 8-1: S1D13A05 Register Mapping

| M/R# | Address | Size | Function |
|------|------------------|-------------------------|---------------------------|
| 1 | 00000h to 40000h | 256K bytes | SRAM memory |
| 0 | 0000h to 00E3h | 227 bytes | Configuration registers |
| 0 | 4000h to 4054h | 84 bytes | USB registers |
| 0 | 8000h to 8019h | 25 bytes | 2D Acceleration Registers |
| 0 | 10000h to 1FFFEh | 65536 bytes (64K bytes) | 2D Accelerator Data Port |

8.2 Register Set

The S1D13A05 register set is as follows.

Table 8-2: S1D13A05 Register Set

| Register | Pg | Register | Pg |
|--|-----|---|-----|
| LCD Register Descriptions (Offset = 0h) | | | |
| Read-Only Configuration Registers | | | |
| REG[00h] Product Information Register | 101 | | |
| Clock Configuration Registers | | | |
| REG[04h] Memory Clock Configuration Register | 102 | REG[08h] Pixel Clock Configuration Register | 103 |
| Panel Configuration Registers | | | |
| REG[0Ch] Panel Type & MOD Rate Register | 103 | REG[10h] Display Settings Register | 105 |
| REG[14h] Power Save Configuration Register | 107 | | |
| Look-Up Table Registers | | | |
| REG[18h] Look-Up Table Write Register | 108 | REG[1Ch] Look-Up Table Read Register | 109 |
| Display Mode Registers | | | |
| REG[20h] Horizontal Total Register | 110 | REG[24h] Horizontal Display Period Register | 110 |
| REG[28h] Horizontal Display Period Start Position Register | 111 | REG[2Ch] FPLINE Register | 111 |
| REG[30h] Vertical Total Register | 112 | REG[34h] Vertical Display Period Register | 113 |
| REG[38h] Vertical Display Period Start Position Register | 113 | REG[3Ch] FPFRAME Register | 114 |
| REG[40h] Main Window Display Start Address Register | 115 | REG[44h] Main Window Line Address Offset Register | 115 |
| REG[48h] Extended Panel Type Register | 115 | | |

Table 8-2: SID13A05 Register Set

| Register | Pg | Register | Pg |
|---|-----|---|-----|
| Picture-in-Picture Plus (PIP⁺) Registers | | | |
| REG[50h] PIP ⁺ Window Display Start Address Register | 117 | REG[54h] PIP ⁺ Window Line Address Offset Register | 117 |
| REG[58h] PIP ⁺ Window X Positions Register | 118 | REG[5Ch] PIP ⁺ Window Y Positions Register | 120 |
| Miscellaneous Registers | | | |
| REG[60h] Reserved | 122 | REG[64h] GPIO Status and Control Register | 122 |
| REG[68h] GPO Status and Control Register | 125 | REG[70h] PWM Clock Configuration Register | 127 |
| REG[74h] PWMOUT Duty Cycle Register | 129 | REG[80h] Scratch Pad A Register | 130 |
| REG[84h] Scratch Pad B Register | 130 | REG[88h] Scratch Pad C Register | 130 |
| Extended Panel Registers | | | |
| REG[A0h] HR-TFT CLS Width Register | 131 | REG[A4h] HR-TFT PS1 Rising Edge Register | 131 |
| REG[A8h] HR-TFT PS2 Rising Edge Register | 131 | REG[ACh] HR-TFT PS2 Toggle Width Register | 132 |
| REG[B0h] HR-TFT PS3 Signal Width Register | 132 | REG[B4h] HR-TFT REV Toggle Point Register | 132 |
| REG[B8h] HR-TFT PS1/2 End Register | 133 | REG[BCh] Type 2 TFT Configuration Register | 133 |
| REG[C0h] Casio TFT Timing Register | 136 | REG[D8h] Type 3 TFT Configuration 0 Register | 135 |
| REG[DCh] Type 3 TFT Configuration 1 Register | 136 | REG[E0h] Type 3 TFT PCLK Divide Register | 137 |
| REG[E4h] Type 3 TFT Partial Mode Display Control Register | 138 | REG[E8h] Type 3 TFT Partial Area 0 Positions Register | 139 |
| REG[ECh] Type 3 TFT Partial Area 1 Positions Register | 139 | REG[F0h] Type 3 TFT Partial Area 2 Positions Register | 140 |
| REG[F4h] Type 3 TFT Command Store Register | 140 | REG[F8h] Type 3 TFT Miscellaneous Register | 141 |
| USB Register Descriptions (Offset = 4000h) | | | |
| REG[4000h] Control Register | 142 | REG[4002h] Interrupt Enable Register 0 | 143 |
| REG[4004h] Interrupt Status Register 0 | 144 | REG[4006h] Interrupt Enable Register 1 | 145 |
| REG[4008h] Interrupt Status Register 1 | 145 | REG[4010h] Endpoint 1 Index Register | 146 |
| REG[4012h] Endpoint 1 Receive Mailbox Data Register | 146 | REG[4018h] Endpoint 2 Index Register | 146 |
| REG[401Ah] Endpoint 2 Transmit Mailbox Data Register | 147 | REG[401Ch] Endpoint 2 Interrupt Polling Interval Register | 147 |
| REG[4020h] Endpoint 3 Receive FIFO Data Register | 147 | REG[4022h] Endpoint 3 Receive FIFO Count Register | 147 |
| REG[4024h] Endpoint 3 Receive FIFO Status Register | 148 | REG[4026h] Endpoint 3 Maximum Packet Size Register | 148 |
| REG[4028h] Endpoint 4 Transmit FIFO Data Register | 148 | REG[402Ah] Endpoint 4 Transmit FIFO Count Register | 149 |
| REG[402Ch] Endpoint 4 Transmit FIFO Status Register | 149 | REG[402Eh] Endpoint 4 Maximum Packet Size Register | 149 |
| REG[4030h] Endpoint 4 Maximum Packet Size Register | 149 | REG[4032h] USB Status Register | 150 |
| REG[4034h] Frame Counter MSB Register | 151 | REG[4036h] Frame Counter LSB Register | 151 |
| REG[4038h] Extended Register Index | 151 | REG[403Ah] Extended Register Data | 151 |
| REG[403Ah], Index[00h] Vendor ID MSB | 151 | REG[403Ah], Index[01h] Vendor ID LSB | 151 |
| REG[403Ah], Index[02h] Product ID MSB | 152 | REG[403Ah], Index[03h] Product ID LSB | 152 |
| REG[403Ah], Index[04h] Release Number MSB | 152 | REG[403Ah], Index[05h] Release Number LSB | 152 |
| REG[403Ah], Index[06h] Receive FIFO Almost Full Threshold | 152 | REG[403Ah], Index[07h] Transmit FIFO Almost Empty Threshold | 152 |
| REG[403Ah], Index[08h] USB Control | 153 | REG[403Ah], Index[09h] Maximum Power Consumption | 153 |
| REG[403Ah], Index[0Ah] Packet Control | 153 | REG[403Ah], Index[0Bh] Reserved | 154 |
| REG[403Ah], Index[0Ch] FIFO Control | 154 | REG[4040h] USBFC Input Control Register | 155 |
| REG[4042h] Reserved | 155 | REG[4044h] Pin Input Status / Pin Output Data Register | 156 |
| REG[4046h] Interrupt Control Enable Register 0 | 156 | REG[4048h] Interrupt Control Enable Register 1 | 156 |
| REG[404Ah] Interrupt Control Status/Clear Register 0 | 157 | REG[404Ch] Interrupt Control Status/Clear Register 1 | 158 |
| REG[404Eh] Interrupt Control Masked Status Register 0 | 159 | REG[4050h] Interrupt Control Masked Status Register 1 | 159 |
| REG[4052h] USB Software Reset Register | 159 | REG[4054h] USB Wait State Register | 159 |

Table 8-2: S1D13A05 Register Set

| Register | Pg | Register | Pg |
|--|-----|--|-----|
| 2D Acceleration (BitBLT) Register Descriptions (Offset = 8000h) | | | |
| REG[8000h] BitBLT Control Register | 160 | REG[8004h] BitBLT Status Register | 161 |
| REG[8008h] BitBLT Command Register | 162 | REG[800Ch] BitBLT Source Start Address Register | 163 |
| REG[8010h] BitBLT Destination Start Address Register | 164 | REG[8014h] BitBLT Memory Address Offset Register | 164 |
| REG[8018h] BitBLT Width Register | 164 | REG[801Ch] BitBLT Height Register | 164 |
| REG[8020h] BitBLT Background Color Register | 165 | REG[8024h] BitBLT Foreground Color Register | 165 |
| 2D Acceleration (BitBLT) Data Register Descriptions (Offset = 10000h) | | | |
| AB16-AB0 = 10000h-1FFFEh, 2D Accelerator (BitBLT) Data Memory Mapped Region Register | | | 165 |

8.3 LCD Register Descriptions (Offset = 0h)

Unless specified otherwise, all register bits are set to 0 during power-on.

8.3.1 Read-Only Configuration Registers

| Product Information Register | | | | | | | | | | | | | | Read Only | | |
|------------------------------|----|----|----|----|----|------------------------|----|-----------------------|-----------------|----|----|----|----|------------------------|----|--|
| REG[00h] Default = 2Dxx402Dh | | | | | | | | | | | | | | | | |
| Product Code bits 5-0 | | | | | | Revision Code bits 1-0 | | n/a | CNF[6:0] Status | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| Display Buffer Size bits 7-0 | | | | | | | | Product Code bits 5-0 | | | | | | Revision Code bits 1-0 | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bits 31-26 Product Code
These read-only bits indicate the product code. The product code is 001011 (0Bh).
- bits 25-24 Revision Code
These are read-only bits that indicates the revision code. The revision code is 01.
- bits 22-16 CNF[6:0] Status
These read-only status bits return the status of the configuration pins CNF[6:0]. CNF[6:0] are latched at the rising edge of RESET#.

Note

For a functional description of each configuration bit (CNF[6:0]), see Section 4.3, “Summary of Configuration Options” on page 32.

- bits 15-8 Display Buffer Size Bits [7:0]
This is a read-only register that indicates the size of the SRAM display buffer measured in 4K byte increments. The S1D13A05 display buffer is 256K bytes and therefore this register returns a value of 64 (40h).

Value of this register = display buffer size ÷ 4K bytes
= 256K bytes ÷ 4K bytes
= 64 (40h)

- bits 7-2 Product Code
These read-only bits indicate the product code. The product code is 001011 (0Bh).
- bits 1-0 Revision Code
These are read-only bits that indicates the revision code. The revision code is 01.

8.3.2 Clock Configuration Registers

| Memory Clock Configuration Register | | | | | | | | | | | | | | Read/Write | | |
|-------------------------------------|----|----|----|----|----|----|----|----|----|--------------------------------|----|-----|----|---------------------|--------------------------|--|
| REG[04h] | | | | | | | | | | | | | | Default = 00000000h | | |
| n/a | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | | | MCLK Divide Select bits 1-0 | | n/a | | | BCLK Source Select | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bits 5-4 MCLK Divide Select Bits [1:0]
These bits determine the divide used to generate the Memory Clock (MCLK) from the Bus Clock (BCLK).

Table 8-3: MCLK Divide Selection

| MCLK Divide Select Bits | BCLK to MCLK Frequency Ratio |
|-------------------------|------------------------------|
| 00 | 1:1 |
| 01 | 2:1 |
| 10 | 3:1 |
| 11 | 4:1 |

- bit 0 BCLK Source Select
When this bit = 0, the source of the Bus Clock (BCLK) is input pin CLKI or a divided down version of CLKI. CLKI may be divided down using the CLKI to BCLK divide select configuration pins CNF[7:6].
When this bit = 1, the source of the Bus Clock (BCLK) is input pin CLKI2.

Note

Changing this bit allows the BCLK source to be switched in a glitch-free manner.

| Pixel Clock Configuration Register | | | | | | | | | | | | | | Read/Write | |
|------------------------------------|----|----|----|----|----|----|----|----|-----------------------------|----|----|-----|----|-----------------------------|----|
| REG[08h] | | | | | | | | | | | | | | Default = 00000000h | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | PCLK Divide Select bits 2-0 | | | n/a | | PCLK Source Select bits 1-0 | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 6-4

PCLK Divide Select Bits [1:0]

These bits determine the divide used to generate the Pixel Clock (PCLK) from the Pixel Clock Source.

Table 8-4: PCLK Divide Selection

| PCLK Divide Select Bits | PCLK Source to PCLK Frequency Ratio |
|-------------------------|-------------------------------------|
| 000 | 1:1 |
| 001 | 2:1 |
| 010 | 3:1 |
| 011 | 4:1 |
| 1XX | 8:1 |

bits 1-0

PCLK Source Select Bits [1:0]

These bits determine the source of the Pixel Clock (PCLK).

Table 8-5: PCLK Source Selection

| PCLK Source Select Bits | PCLK Source |
|-------------------------|-------------|
| 00 | MCLK |
| 01 | BCLK |
| 10 | CLKI |
| 11 | CLKI2 |

8.3.3 Panel Configuration Registers

| Panel Type & MOD Rate Register | | | | | | | | | | Read/Write | | | | | |
|--------------------------------|----|----|----|----|----|----|----------------|--------------------------|-------------------------|---------------------------|----|-----------|-----|---------------------|----|
| REG[0Ch] | | | | | | | | | | Default = 00000000h | | | | | |
| n/a | | | | | | | FPSHIFT Invert | n/a | | MOD Rate bits 5-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | HR-TFT PS Mode | Panel Data Format Select | Color/Mono Panel Select | Panel Data Width bits 1-0 | | Reserv ed | n/a | Panel Type bits 1-0 | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 24

FPSHIFT Invert

This bit inverts the FPSHIFT signal used by active panels. For passive panels, this bit has no effect.

When this bit is 0, FPSHIFT is unchanged.

When this bit is 1, FPSHIFT is inverted.

- bits 21-16 MOD Rate Bits [5:0]
These bits are for passive LCD panels only.
 When these bits are all 0, the MOD output signal (DRDY) toggles every FPFFRAME.
 For a non-zero value n , the MOD output signal (DRDY) toggles every n FPLINE.
- bit 8 HR-TFT PS Mode
This bit is for HR-TFT panels only.
 This bit selects the timing used for the PS signal. The alternate PS timings (PS1, PS2, PS3) result in additional power savings on the HR-TFT Panel.
 When this bit = 0, the PS signal uses PS1 timing.
 When this bit = 1, the PS signal uses PS2 timing.
- bit 7 Panel Data Format Select
 When this bit = 0, 8-bit single color passive LCD panel data format 1 is selected. For AC timing see Section 6.4.5, “Single Color 8-Bit Panel Timing (Format 1)” on page 68.
 When this bit = 1, 8-bit single color passive LCD panel data format 2 is selected. For AC timing see Section 6.4.6, “Single Color 8-Bit Panel Timing (Format 2)” on page 70.
- bit 6 Color/Mono Panel Select
 When this bit = 0, a monochrome LCD panel is selected.
 When this bit = 1, a color LCD panel is selected.
- bits 5-4 Panel Data Width Bits [1:0]
 These bits select the data width size of the LCD panel.

Table 8-6: Panel Data Width Selection

| Panel Data Width Bits [1:0] | Passive Panel Data Width Size | Active Panel Data Width Size |
|-----------------------------|-------------------------------|------------------------------|
| 00 | 4-bit | 9-bit |
| 01 | 8-bit | 12-bit |
| 10 | 16-bit | 18-bit |
| 11 | Reserved | Reserved |

- bit 3 Reserved.
 This bit must be set to 0.
- bits 1-0 Panel Type Bits[1:0]
 These bits select the panel type.

Table 8-7: LCD Panel Type Selection

| Panel Type Bits [1:0] | Panel Type |
|-----------------------|------------|
| 00 | STN |
| 01 | TFT |
| 10 | Reserved |
| 11 | HR-TFT |

| Display Settings Register | | | | | | | | | | | | | | Read/Write | |
|---------------------------|----|----|----|----|----|--|-----------------------|---------------|-------------------|------------------------|-----------------|--------------------|-----|------------------------|----|
| REG[10h] | | | | | | | | | | | | | | Default = 00000000h | |
| n/a | | | | | | Pixel Doubling Vertical | Pixel Doubling Horiz. | Display Blank | Dithering Disable | Display Blank Polarity | SW Video Invert | PIP+ Window Enable | n/a | SwivelView Mode Select | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Bits-per-pixel Select (actual value: 1, 2, 4, 8 or 16 bpp) | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 25 Pixel Doubling Vertical Enable
 This bit controls the pixel doubling feature for the vertical dimension or height of the panel (i.e. 160 pixel high data doubled to 320 pixel high panel).
 When this bit = 1, pixel doubling in the vertical dimension (height) is enabled.
 When this bit = 0, there is no hardware effect.

Note
 Pixel Doubling is not supported in SwivelView 90° or SwivelView 270° modes.

bit 24 Pixel Doubling Horizontal Enable
 This bit controls the pixel doubling feature for the horizontal dimension or width of the panel (i.e. 160 pixel wide data doubled to 320 pixel wide panel).
 When this bit = 1, pixel doubling in the horizontal dimension (width) is enabled.
 When this bit = 0, there is no hardware effect.

Note
 Pixel Doubling is not supported in SwivelView 90° or SwivelView 270° modes.

bit 23 Display Blank
 When this bit = 0, the LCD display pipeline is enabled.
 When this bit = 1, all applicable LCD data outputs (see Table 4-9: “LCD Interface Pin Mapping,” on page 34) are forced to zero or one. The following table summarizes the changes to the signals on FPDAT[17:0] for each combination of bits.

Table 8-8: Display Control Summary

| Display Blank (REG[10h] bit 23) | Display Blank Polarity (REG[10h] bit 21) | Software Video Invert (REG[10h] bit 20) | Output Data Lines (FPDAT[17:0]) |
|---------------------------------|--|---|---------------------------------|
| 0 | X | 0 | Normal |
| | | 1 | Inverted |
| 1 | 0 | 0 | All 0 |
| | | 1 | All 1 |
| | 1 | 0 | All 1 |
| | | 1 | All 0 |

- bit 22 Dithering Disable
When this bit = 0, dithering on the passive LCD panel is enabled, allowing a maximum of 64K colors (2^{18}) or 64 gray shades in 1/2/4/8 bpp mode. In 16bpp mode, only 64K colors (2^{16}) can also be achieved.
When this bit = 1, dithering on the passive LCD panel is disabled, allowing a maximum of 4096 colors (2^{12}) or 16 gray shades.
The dithering algorithm provides more shades of each primary color.

Note

For a summary of the results of dithering for each color depth, see Table 8-10: “LCD Bit-per-pixel Selection,” on page 107.

- bit 21 Display Blank Polarity
When this bit = 0, the display blank function operates normally.
When this bit = 1, the display blank function switches polarity.

This bit works in conjunction with bit 23 and bit 20. Table 8-8: “Display Control Summary” summarizes the changes to the signals on FPDAT[17:0] for each combination of bits.

- bit 20 Software Video Invert
When this bit = 0, video data is normal.
When this bit = 1, video data is inverted.

This bit works in conjunction with bit 23 and bit 21. Table 8-8: “Display Control Summary” summarizes the changes to the signals on FPDAT[17:0] for each combination of bits.

Note

Video data is inverted after the Look-Up Table

- bit 19 PIP+ Window Enable
This bit enables a PIP+ window within the main window. The location of the PIP+ window within the landscape window is determined by the PIP+ X Position register (REG[58h]) and PIP+ Y Position register (REG[5Ch]). The PIP+ window has its own Display Start Address register (REG[50h]) and Memory Address Offset register (REG[54h]). The PIP+ window shares the same color depth and SwivelView™ orientation as the main window.

- bit 17-16 SwivelView Mode Select Bits [1:0]
These bits select different SwivelView™ orientations:

Table 8-9: SwivelView™ Mode Select Options

| SwivelView Mode Select Bits | SwivelView Orientation |
|-----------------------------|------------------------|
| 00 | 0° (Normal) |
| 01 | 90° |
| 10 | 180° |
| 11 | 270° |

bits 4-0

Bit-per-pixel Select Bits [4:0]

These bits select the color depth (bit-per-pixel) for the displayed data for both the main window and the PIP⁺ window (if active).

1, 2, 4 and 8 bpp modes use the 18-bit LUT, allowing maximum 64K colors. 16 bpp mode bypasses the LUT, allowing only 64K colors.

Table 8-10: LCD Bit-per-pixel Selection

| Bit-per-pixel Select Bits [4:0] | Color Depth (bpp) | Maximum Number of Colors/Shades | | Max. No. Of Simultaneously Displayed Colors/Shades |
|---------------------------------|-------------------|---------------------------------|---------------|--|
| | | Passive Panels (Dithering On) | Active Panels | |
| 00000 | Reserved | | | |
| 00001 | 1 bpp | 64K/64 | 64K/64 | 2/2 |
| 00010 | 2 bpp | 64K/64 | 64K/64 | 4/4 |
| 00011 | Reserved | | | |
| 00100 | 4 bpp | 64K/64 | 64K/64 | 16/16 |
| 00101 - 00111 | Reserved | | | |
| 01000 | 8 bpp | 64K/64 | 64K/64 | 256/64 |
| 10000 | 16 bpp | 64K/64 | 64K/64 | 64K/64 |
| 10001 - 11111 | Reserved | | | |

| Power Save Configuration Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|------------------|-------------------------------|-----|-------------------|-----|----|----|----------|
| REG[14h] Default = 00000010h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | VNDP Status (RO) | Memory Power Save Status (RO) | n/a | Power Save Enable | n/a | | | Reserved |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 7

Vertical Non-Display Period Status (Read-only)

This is a read-only status bit.

When this bit = 0, the LCD panel output is in a Vertical Display Period.

When this bit = 1, the LCD panel output is in a Vertical Non-Display Period.

bit 6

Memory Controller Power Save Status (Read-only)

This read-only status bit indicates the power save state of the memory controller.

When this bit = 0, the memory controller is powered up.

When this bit = 1, the memory controller is powered down and the MCLK source can be turned off.

Note

Memory reads/writes are possible during power save mode because the S1D13A05 dynamically enables the memory controller for display buffer accesses.

bit 4 Power Save Mode Enable
When this bit = 1, the software initiated power save mode is enabled.
When this bit = 0, the software initiated power save mode is disabled.
At reset, this bit is set to 1. For a summary of Power Save Mode, see Section 15, “Power Save Mode” on page 183.

Note

Memory reads/writes are possible during power save mode because the S1D13A05 dynamically enables the memory controller for display buffer accesses.

bit 0 Reserved
This bit must be set to 0.

8.3.4 Look-Up Table Registers

| Look-Up Table Write Register | | | | | | | | | | | | | | Write Only | |
|------------------------------|----|----|----|----|----|-----|----|---------------------|----|----|----|----|----|---------------------|----|
| REG[18h] | | | | | | | | | | | | | | Default = 00000000h | |
| LUT Write Address | | | | | | | | LUT Red Write Data | | | | | | n/a | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| LUT Green Write Data | | | | | | n/a | | LUT Blue Write Data | | | | | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Note

The S1D13A05 has three 256-position, 6-bit wide LUTs, one for each of red, green, and blue (see Section 12, “Look-Up Table Architecture” on page 169).

Note

This is a write-only register and returns 00h if read.

bits 31-24 LUT Write Address Bits [7:0]
These bits form a pointer into the Look-Up Table (LUT) which is used to write the LUT Red, Green, and Blue data. **When the S1D13A05 is set to a host bus interface using little endian (CNF4 = 0), the RGB data is updated to the LUT with the completion of a write to these bits.**

Note

When a value is written to the LUT Write Address Bits, the same value is automatically placed in the LUT Read Address Bits (REG[1Ch] bits 31-24).

bits 23-18 LUT Red Write Data Bits [5:0]
These bits contains the data to be written to the red component of the Look-Up Table. The LUT position is controlled by the LUT Write Address bits (bits 31-24).

bits 15-10 LUT Green Write Data Bits [5:0]
These bits contains the data to be written to the green component of the Look-Up Table. The LUT position is controlled by the LUT Write Address bits (bits 31-24).

bits 7-2 LUT Blue Write Data Bits [5:0]
These bits contains the data to be written to the blue component of the Look-Up Table. The LUT position is controlled by the LUT Write Address bits (bits 31-24). **When the S1D13A05 is set to a host bus interface using big endian (CNF4 = 1), the RGB data is updated to the LUT with the completion of a write to these bits.**

| Look-Up Table Read Register | | | | | | | | | | | | | | | |
|-------------------------------|----|----|----|----|----|-----|----|-----------------------------------|----|----|----|----|----|-----|----|
| REG[1Ch] Default = 00000000h | | | | | | | | Write Only (bits 31-24)/Read Only | | | | | | | |
| LUT Read Address (write only) | | | | | | | | LUT Red Read Data | | | | | | n/a | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| LUT Green Read Data | | | | | | n/a | | LUT Blue Read Data | | | | | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Note

The S1D13A05 has three 256-position, 6-bit wide LUTs, one for each of red, green, and blue (see Section 12, “Look-Up Table Architecture” on page 169).

bits 31-24 LUT Read Address Bits [7:0] (**Write Only**)
This register forms a pointer into the Look-Up Table (LUT) which is used to read LUT data. Red data is read from bits 23-18, green data from bits 15-10, and blue data from bits 7-2.

Note

If a write to the LUT Write Address Bits (REG[18h] bits 31-24) is made, the LUT Read Address bits are automatically updated with the same value.

bits 23-18 LUT Red Read Data Bits [5:0] (**Read Only**)
These bits point to the data from the red component of the Look-Up Table. The LUT position is controlled by the LUT Read Address bits (bits 31-24). This is a read-only register.

bits 15-10 LUT Green Read Data Bits [5:0] (**Read Only**)
These bits point to the data from the green component of the Look-Up Table. The LUT position is controlled by the LUT Read Address bits (bits 31-24). This is a read-only register.

bits 7-2 LUT Blue Read Data Bits [5:0] (**Read Only**)
These bits point to the data from the blue component of the Look-Up Table. The LUT position is controlled by the LUT Read Address bits (bits 31-24). This is a read-only register.

8.3.5 Display Mode Registers

| Horizontal Total Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| REG[20h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | | | | | |
| Horizontal Total bits 6-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 6-0

Horizontal Total Bits [6:0]

These bits specify the LCD panel Horizontal Total period, in 8 pixel resolution. The Horizontal Total is the sum of the Horizontal Display period and the Horizontal Non-Display period. Since the maximum Horizontal Total is 1024 pixels, the maximum panel resolution supported is 800x600.

REG[20h] bits 6:0 = (Horizontal Total in number of pixels ÷ 8) - 1

Note

- ¹ For all panels this register must be programmed such that:
 $HDPS + HDP < HT$
 $HT - HDP \geq 8MCLK$
- ² For passive panels, this register must be programmed such that:
 $HPS + HPW < HT$
- ³ See Section 6.4, "Display Interface" on page 60.

| Horizontal Display Period Register | | | | | | | | | | | | | | | |
|------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| REG[24h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | | | | | |
| Horizontal Display Period bits 6-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 6-0

Horizontal Display Period Bits [6:0]

These bits specify the LCD panel Horizontal Display period, in 8 pixel resolution. The Horizontal Display period should be less than the Horizontal Total to allow for a sufficient Horizontal Non-Display period.

REG[24h] bits 6:0 = (Horizontal Display Period in number of pixels ÷ 8) - 1

Note

For passive panels, HDP must be a minimum of 32 pixels and must be increased by multiples of 16.

For TFT panels, HDP must be a minimum of 8 pixels and must be increased by multiples of 8.

Note

See Section 6.4, "Display Interface" on page 60.

| Horizontal Display Period Start Position Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|---|----|----|----|----|----|----|----|----|----|
| REG[28h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Horizontal Display Period Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0 Horizontal Display Period Start Position Bits [9:0]
 These bits specify a value used in the calculation of the Horizontal Display Period Start Position (in 1 pixel resolution) for TFT and HR-TFT panels.

For passive LCD panels these bits must be set to 00h which will result in HDPS = 22.
 $HDPS = (REG[28h] \text{ bits } 9-0) + 22$

For TFT panels, HDPS is calculated using the following formula.
 $HDPS = (REG[28h] \text{ bits } 9-0) + 5$

Note

This register must be programmed such that the following formula is valid.
 $HDPS + HDP < HT$

| FPLINE Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|--------------------------------------|----|----|----|----|----|----|----|----|----|
| REG[2Ch] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | FPLINE Pulse Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 23 FPLINE Pulse Polarity
 This bit selects the polarity of the horizontal sync signal. For passive panels, this bit must be set to 1. For active panels, this bit is set according to the horizontal sync signal of the panel (typically FPLINE or LP). This bit has no effect for TFT Type 2 and TFT Type 3 panels.
 When this bit = 0, the horizontal sync signal is active low.
 When this bit = 1, the horizontal sync signal is active high.

bits 22-16 FPLINE Pulse Width Bits [6:0]
 These bits specify the width of the panel horizontal sync signal, in 1 pixel resolution. The horizontal sync signal is typically FPLINE or LP, depending on the panel type.
 $REG[2Ch] \text{ bits } 22:16 = \text{FPLINE Pulse Width in number of pixels} - 1$

Note

For passive panels, these bits must be programmed such that the following formula is valid.
 $HPW + HPS < HT$

Note

See Section 6.4, “Display Interface” on page 60.

bits 9-0

FPLINE Pulse Start Position Bits [9:0]

These bits specify the start position of the horizontal sync signal, in 1 pixel resolution.

FPLINE Pulse Start Position in pixels = (REG[2Ch] bits 9-0) + 1

Note

For passive panels, these bits must be programmed such that the following formula is valid.

$$HPW + HPS < HT$$

Note

See Section 6.4, “Display Interface” on page 60.

| Vertical Total Register | | | | | | | | | | | | | | | |
|------------------------------|----|----|----|----|----|-------------------------|----|----|----|----|----|----|----|----|----|
| REG[30h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Vertical Total bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

Vertical Total Bits [9:0]

These bits specify the LCD panel Vertical Total period, in 1 line resolution. The Vertical Total is the sum of the Vertical Display Period and the Vertical Non-Display Period. The maximum Vertical Total is 1024 lines.

REG[30h] bits 9:0 = Vertical Total in number of lines - 1

Note¹ This register must be programmed such that the following formula is valid.

$$VT > VDPS + VDP$$

² If an HR-TFT panel is selected, the following formula must also apply.

$$VT > (\text{REG}[B8h] \text{ bits } 2-0) + VDP + VPS + 1$$

³ See Section 6.4, “Display Interface” on page 60.

| Vertical Display Period Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----------------------------------|----|----|----|----|----|----|----|----|----|
| REG[34h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Vertical Display Period bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

Vertical Display Period Bits [9:0]

These bits specify the LCD panel Vertical Display period, in 1 line resolution. The Vertical Display period should be less than the Vertical Total to allow for a sufficient Vertical Non-Display period.

REG[34h] bits 9:0 = Vertical Display Period in number of lines - 1

Note

¹ This register must be programmed such that the following formula is valid.

$$VT > VDPS + VDP$$

² If an HR-TFT panel is selected, the following formula must also apply.

$$VT > (REG[B8h] \text{ bits 2-0}) + VDP + VPS + 1$$

³ See Section 6.4, “Display Interface” on page 60.

| Vertical Display Period Start Position Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|---|----|----|----|----|----|----|----|----|----|
| REG[38h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Vertical Display Period Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

Vertical Display Period Start Position Bits [9:0]

These bits specify the Vertical Display Period Start Position for TFT and HR-TFT panels in 1 line resolution. For passive LCD panels these bits must be set to 00h.

For passive LCD panels these bits must be set to 00h.

For TFT panels, VDPS is calculated using the following formula.

$$VDPS = REG[38h] \text{ bits 9-0}$$

Note

¹ This register must be programmed such that the following formula is valid.

$$VT > VDPS + VDP$$

² If an HR-TFT panel is selected, the following formula must also apply.

$$VT > (REG[B8h] \text{ bits 2-0}) + VDP + VPS + 1$$

³ See Section 6.4, “Display Interface” on page 60.

| FPFRAME Register | | | | | | | | | | | | | | Read/Write | | | |
|------------------------------|----|----|----|----|----|---------------------------------------|----|----|----|---------------------|-----|----|----|------------|---------------------------------|--|--|
| REG[3Ch] Default = 00000000h | | | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | FPFRAME Polarity | n/a | | | | FPFRAME Pulse Width bits 2-0 | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | FPFRAME Pulse Start Position bits 9-0 | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bit 23

FPFRAME Pulse Polarity

This bit selects the polarity of the vertical sync signal. For passive panels, this bit must be set to 1. For TFT panels, this bit is set according to the horizontal sync signal of the panel (typically FPFRAME, SPS). This bit has no effect for TFT Type 2 panels.

When this bit = 0, the vertical sync signal is active low.

When this bit = 1, the vertical sync signal is active high.

bits 18-16

FPFRAME Pulse Width Bits [2:0]

These bits specify the width of the panel vertical sync signal, in 1 line resolution. The vertical sync signal is typically FPFRAME, or SPS, depending on the panel type.

REG[3Ch] bits 2:0 = FPFRAME Pulse Width in number of lines - 1

Note

See Section 6.4, "Display Interface" on page 60.

bits 9-0

FPFRAME Pulse Start Position Bits [9:0]

These bits specify the start position of the vertical sync signal, in 1 line resolution.

For passive panels, these bits must be set to 00h.

For TFT panels, VDPS is calculated using the following formula.

$$VPS = \text{REG}[3\text{Ch}] \text{ bits } 9-0$$

Note

See Section 6.4, "Display Interface" on page 60.

| Main Window Display Start Address Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|--------|----|
| REG[40h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | bit 16 | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| Main Window Display Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 16-0

Main Window Display Start Address Bits [16:0]

This register specifies the starting address, in DWORDS, for the LCD image in the display buffer for the main window.

Note that this is a double-word (32-bit) address. An entry of 00000h into these registers represents the first double-word of display memory, an entry of 00001h represents the second double-word of the display memory, and so on. Calculate the Display Start Address as follows:

$$\text{REG}[40\text{h}] \text{ bits } 16:0 = \text{image address} \div 4 \text{ (valid only for SwivelView } 0^\circ\text{)}$$

Note

For information on setting this register for other SwivelView orientations, see Section 13, “SwivelView™” on page 175.

| Main Window Line Address Offset Register | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[44h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | 17 | 16 |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Main Window Line Address Offset bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

Main Window Line Address Offset Bits [9:0]

This register specifies the offset, in DWORDS, from the beginning of one display line to the beginning of the next display line in the main window. **Note that this is a 32-bit address increment.** Calculate the Line Address Offset as follows:

$$\text{REG}[44\text{h}] \text{ bits } 9:0 = \text{display width in pixels} \div (32 \div \text{bpp})$$

Note

A virtual display can be created by programming this register with a value greater than the formula requires. When a virtual display is created the image width is larger than the display width and the displayed image becomes a window into the larger virtual image.

| Extended Panel Type Register | | | | | | | | | | | | | | Read/Write | |
|------------------------------|----|----|----|----|----|----|-------------------------------------|-----|----|----|----|------------------------------|----|---------------------|----|
| REG[48h] | | | | | | | | | | | | | | Default = 00000000h | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | Data Compare Invert Enable | n/a | | | | Extended Panel Type bits 3-0 | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 8

Data Compare Invert Enable

This bit can be used to lower power consumption for TFT Type 2 and TFT Type 3 Interfaces. The Data Compare and Invert function reduces the amount of data toggled by counting the number of bits that are changed (1 to 0 or 0 to 1) from the previous pixel data. If more than half of the bits are changed the data is inverted and the lesser amount of bits are toggled. For all other panel interfaces it has no effect.

When this bit = 0, the Data Compare and Invert functions are disabled.

When this bit = 1, the Data Compare and Invert functions are enabled.

bits 3-0

Extended Panel Type Bits [3:0]

These bits override the setting in REG[0Ch] bits 1-0 and allow selection of the alternate TFT panel types.

Table 8-11: Extended Panel Type Selection

| REG[48h] Bits [3:0] | Panel Type |
|---------------------|----------------------------------|
| 0000 | no effect from REG[0Ch] bits 1-0 |
| 0001 | TFT Type 2 |
| 0010 | TFT Type 3 |
| 0011 | TFT Type 4 |
| 0100 | Casio TFT |
| 0101 - 1111 | Reserved |

8.3.6 Picture-in-Picture Plus (PIP⁺) Registers

| PIP ⁺ Display Start Address Register | | | | | | | | | | | | | | | Read/Write |
|--|----|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------------|
| REG[50h] | | | | | | | | | | | | | | | Default = 00000000h |
| n/a | | | | | | | | | | | | | | | bit 16 |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| PIP ⁺ Display Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 16-0

PIP⁺ Display Start Address Bits [16:0]

These bits form the 17-bit address for the starting double-word of the PIP⁺ window.

Note that this is a double-word (32-bit) address. An entry of 00000h into these registers represents the first double-word of display memory, an entry of 00001h represents the second double-word of the display memory, and so on.

Note

These bits have no effect unless the PIP⁺ Window Enable bit is set to 1 (REG[10h] bit 19).

| PIP ⁺ Line Address Offset Register | | | | | | | | | | | | | | | Read/Write |
|---|----|----|----|----|----|---|----|----|----|----|----|----|----|----|---------------------|
| REG[54h] | | | | | | | | | | | | | | | Default = 00000000h |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | PIP ⁺ Line Address Offset bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

PIP⁺ Window Line Address Offset Bits [9:0]

These bits are the LCD display's 10-bit address offset from the starting double-word of line "n" to the starting double-word of line "n + 1" for the PIP⁺ window. **Note that this is a 32-bit address increment.**

Note

These bits have no effect unless the PIP⁺ Window Enable bit is set to 1 (REG[10h] bit 19).

| PIP ⁺ X Positions Register | | | | | | | | | | | | | | | |
|---------------------------------------|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[58h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | PIP ⁺ X End Position bits 9-0 | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | PIP ⁺ X Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Note

The effect of REG[58h] through REG[5Ch] takes place only after REG[5Ch] is written and at the next vertical non-display period.

bits 25-16

PIP⁺ Window X End Position Bits [9:0]

These bits determine the X end position of the PIP⁺ window in relation to the origin of the panel. Due to the S1D13A05 SwivelView feature, the X end position may not be a horizontal position value (only true in 0° and 180° SwivelView). For further information on defining the value of the X End Position register, see Section 14, “Picture-in-Picture Plus (PIP+)” on page 180.

The register is also incremented differently based on the SwivelView orientation. For 0° and 180° SwivelView the X end position is incremented by x pixels where x is relative to the current color depth.

Table 8-12: 32-bit Address Increments for Color Depth

| Color Depth | Pixel Increment (x) |
|-------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

For 90° and 270° SwivelView the X end position is incremented in 1 line increments.

Depending on the color depth, some of the higher bits in this register are unused because the maximum horizontal display width is 1024 pixels.

Note

These bits have no effect unless the PIP⁺ Window Enable bit is set to 1 (REG[10h] bit 19).

bits 9-0

PIP⁺ Window X Start Position Bits [9:0]

These bits determine the X start position of the PIP⁺ window in relation to the origin of the panel. Due to the S1D13A05 SwivelView feature, the X start position may not be a horizontal position value (only true in 0° and 180° SwivelView). For further information on defining the value of the X Start Position register, see Section 14, “Picture-in-Picture Plus (PIP+)” on page 180.

The register is also incremented differently based on the SwivelView orientation. For 0° and 180° SwivelView the X start position is incremented by x pixels where x is relative to the current color depth.

Table 8-13: 32-bit Address Increments for Color Depth

| Color Depth | Pixel Increment (x) |
|-------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

For 90° and 270° SwivelView the X start position is incremented in 1 line increments.

Depending on the color depth, some of the higher bits in this register are unused because the maximum horizontal display width is 1024 pixels.

Note

These bits have no effect unless the PIP⁺ Window Enable bit is set to 1 (REG[10h] bit 19).

| PIP ⁺ Y Positions Register | | | | | | | | | | | | | | | |
|---------------------------------------|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[5Ch] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | PIP ⁺ Y End Position bits 9-0 | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | PIP ⁺ Y Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Note

- ¹ The effect of REG[58h] through REG[5Ch] takes place only after REG[5Ch] is written and at the next vertical non-display period.
- ² For host bus interfaces using little endian (CNF4 = 0), a write to bits 31-24 causes the PIP⁺ Window Y End Position to take effect.
For host bus interfaces using big endian (CNF4 = 1), a write to bits 7-0 causes the PIP⁺ Window Y End Position to take effect.

bits 25-16

PIP⁺ Window Y End Position Bits [9:0]

These bits determine the Y end position of the PIP⁺ window in relation to the origin of the panel. Due to the S1D13A05 SwivelView feature, the Y end position may not be a vertical position value (only true in 0° and 180° SwivelView). For further information on defining the value of the Y End Position register, see Section 14, “Picture-in-Picture Plus (PIP+)” on page 180.

The register is also incremented differently based on the SwivelView orientation. For 0° and 180° SwivelView the Y end position is incremented in 1 line increments. For 90° and 270° SwivelView the Y end position is incremented by *y* pixels where *y* is relative to the current color depth.

Table 8-14: 32-bit Address Increments for Color Depth

| Color Depth | Pixel Increment (y) |
|-------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

Depending on the color depth, some of the higher bits in this register are unused because the maximum vertical display height is 1024 pixels.

Note

These bits have no effect unless the PIP⁺ Window Enable bit is set to 1 (REG[10h] bit 19).

bits 9-0

PIP⁺ Window Y Start Position Bits [9:0]

These bits determine the Y start position of the PIP⁺ window in relation to the origin of the panel. Due to the S1D13A05 SwivelView feature, the Y start position may not be a vertical position value (only true in 0° and 180° SwivelView). For further information on defining the value of the Y Start Position register, see Section 14, “Picture-in-Picture Plus (PIP+)” on page 180.

The register is also incremented differently based on the SwivelView orientation. For 0° and 180° SwivelView the Y start position is incremented in 1 line increments. For 90° and 270° SwivelView the Y start position is incremented by *y* pixels where *y* is relative to the current color depth.

Table 8-15: 32-bit Address Increments for Color Depth

| Color Depth | Pixel Increment (y) |
|-------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

Depending on the color depth, some of the higher bits in this register are unused because the maximum vertical display height is 1024 pixels.

Note

These bits have no effect unless the PIP⁺ Window Enable bit is set to 1 (REG[10h] bit 19).

8.3.7 Miscellaneous Registers

| Reserved | | | | | | | | | | | | | | | | | |
|------------------------------|----|----|----|----|----|----|----|----------|----|----|----|-----|----|----------|----|-----|--|
| REG[60h] Default = 00000000h | | | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | | | |
| n/a | | | | | | | | Reserved | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | | | Reserved | | | | n/a | | Reserved | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

| GPIO Status and Control Register | | | | | | | | | | | | | | | |
|----------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|
| REG[64h] Default = 20000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| GPIO7 Input Enable | GPIO6 Input Enable | GPIO5 Input Enable | GPIO4 Input Enable | GPIO3 Input Enable | GPIO2 Input Enable | GPIO1 Input Enable | GPIO0 Input Enable | GPIO7 Config | GPIO6 Config | GPIO5 Config | GPIO4 Config | GPIO3 Config | GPIO2 Config | GPIO1 Config | GPIO0 Config |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | GPIO7 Control/ Status | GPIO6 Control/ Status | GPIO5 Control/ Status | GPIO4 Control/ Status | GPIO3 Control/ Status | GPIO2 Control/ Status | GPIO1 Control/ Status | GPIO0 Control/ Status |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

The S1D13A05 GPIO pins default to inputs, however they can be individually configured to outputs or inputs using the GPIO[7:0] Config bits (bits 23-16). If a GPIO pin is configured as an input, the input functionality must be enabled using the corresponding GPIO[7:0] Input Enable pin (see bits 31-24). Once the GPIO pin has been configured, it can be controlled/read using the GPIO[7:0] Control/Status bits (bits 7-0). See the individual bit descriptions for further details.

Some GPIOs must be configured as outputs after every RESET for use with some extended panel types (i.e. Sharp HR-TFT, Casio TFT, etc.). See Table 4-9: “LCD Interface Pin Mapping,” on page 34 and the individual bit descriptions for bits 7-0 for specific information on each GPIO pin.

bits 31-24

GPIO[7:0] Input Enable bits

These bits individually enable the input function for each GPIO pin (GPIO[7:0]). After power-on/reset, each bit must be set to a 1 to enable the input function of each GPIO pin (default is 0 except for GPIO5 which is 1). If the GPIO pin is configured as an output the GPIO[7:0] Input Enable bit has no effect.

Note

At power-on/reset, the GPIO5 Input Enable bit (bit 29) defaults to 1.

bits 23-16

GPIO[7:0] IO Configuration

At power-on/reset, the GPIO[7:0] pins default to inputs. These bits individually configure each GPIO pin as either an output or input.

When these bits = 0, the associated GPIO pin is configured as an input.

When these bits = 1, the associated GPIO pin is configured as an output.

This may be required for some extended panel types (i.e. Sharp HR-TFT, Casio TFT, etc.) or USB. See Table 4-9: “LCD Interface Pin Mapping,” on page 34 and the individual bit descriptions for bits 7-0 for specific information on each GPIO pin.

Note

If a GPIO pin is configured as an input, the input function of the GPIO pin must be enabled using the corresponding GPIOx Input Enable bit (bits 31-24) before the input configuration takes effect.

bit 7 GPIO7 IO Control/Status
The following table shows the multiple uses of GPIO7.

Table 8-16: GPIO7 Usage

| Pin Usage | Function | | |
|--------------|-------------------------------|-------------------------------|-------------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO7 | GPIO7 driven low | GPIO7 driven high | GPIO7 status returned |
| USB | not available (used by USBDP) | not available (used by USBDP) | not available (used by USBDP) |

bit 6 GPIO6 IO Control/Status
The following table shows the multiple uses of GPIO6.

Table 8-17: GPIO6 Usage

| Pin Usage | Function | | |
|--------------|-------------------------------|-------------------------------|-------------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO6 | GPIO6 driven low | GPIO6 driven high | GPIO6 status returned |
| USB | not available (used by USBDM) | not available (used by USBDM) | not available (used by USBDM) |

bit 5 GPIO5 IO Control/Status
The following table shows the multiple uses of GPIO5.

Table 8-18: GPIO5 Usage

| Pin Usage | Function | | |
|--------------|-----------------------------------|-----------------------------------|-----------------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO5 | GPIO5 driven low | GPIO5 driven high | GPIO5 status returned |
| USB | not available (used by USBDETECT) | not available (used by USBDETECT) | not available (used by USBDETECT) |

bit 4 GPIO4 IO Control/Status
The following table shows the multiple uses of GPIO4.

Table 8-19: GPIO4 Usage

| Pin Usage | Function | | |
|--------------|--------------------------------|--------------------------------|--------------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO4 | GPIO4 driven low | GPIO4 driven high | GPIO4 status returned |
| USB | not available (used by USBPUP) | not available (used by USBPUP) | not available (used by USBPUP) |

bit 3

GPIO3 IO Control/Status

The following table shows the multiple uses of GPIO3.

Table 8-20: GPIO3 Usage

| Pin Usage | Function | | |
|---------------------|-----------------------------|-----------------------------|-----------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO3 | GPIO3 driven low | GPIO3 driven high | GPIO3 status returned |
| Sharp HR-TFT | not available (used by SPL) | not available (used by SPL) | not available (used by SPL) |
| Casio TFT | not available (used by STH) | not available (used by STH) | not available (used by STH) |
| TFT Type 2 | not available (used by STH) | not available (used by STH) | not available (used by STH) |
| TFT Type 3 | not available (used by EIO) | not available (used by EIO) | not available (used by EIO) |

bit 2

GPIO2 IO Control/Status

The following table shows the multiple uses of GPIO2.

Table 8-21: GPIO2 Usage

| Pin Usage | Function | | |
|---------------------|-----------------------------|-----------------------------|-----------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO2 | GPIO2 driven low | GPIO2 driven high | GPIO2 status returned |
| Sharp HR-TFT | not available (used by REV) | not available (used by REV) | not available (used by REV) |
| Casio TFT | not available (used by FRP) | not available (used by FRP) | not available (used by FRP) |
| TFT Type 2 | not available (used by POL) | not available (used by POL) | not available (used by POL) |
| TFT Type 3 | not available (used by POL) | not available (used by POL) | not available (used by POL) |

bit 1

GPIO1 IO Control/Status

The following table shows the multiple uses of GPIO1.

Table 8-22: GPIO1 Usage

| Pin Usage | Function | | |
|---------------------|-----------------------------|-----------------------------|-----------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO1 | GPIO1 driven low | GPIO1 driven high | GPIO1 status returned |
| Sharp HR-TFT | not available (used by CLS) | not available (used by CLS) | not available (used by CLS) |
| Casio TFT | GRES forced low | GRES enabled | GRES status returned |
| TFT Type 2 | not available (used by AP) | not available (used by AP) | not available (used by AP) |
| TFT Type 3 | OE forced low | OE enabled | OE status returned |

bit 0 GPIO0 IO Control/Status
The following table shows the multiple uses of GPIO0.

Table 8-23: GPIO0 Usage

| Pin Usage | Function | | |
|---------------------|------------------------------|------------------------------|------------------------------|
| | Output | | Input |
| | Write 0 | Write 1 | Read |
| GPIO0 | GPIO0 driven low | GPIO0 driven high | GPIO0 status returned |
| Sharp HR-TFT | not available (used by PS) | not available (used by PS) | not available (used by PS) |
| Casio TFT | not available (used by POL) | not available (used by POL) | not available (used by POL) |
| TFT Type 2 | not available (used by VCLK) | not available (used by VCLK) | not available (used by VCLK) |
| TFT Type 3 | not available (used by CPV) | not available (used by CPV) | not available (used by CPV) |

| GPO Control Register | | | | | | | | | | | | | | | |
|------------------------------|----|----|----|----|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| REG[68h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | GPO10 Control | GPO9 Control | GPO8 Control | GPO7 Control | GPO6 Control | GPO5 Control | GPO4 Control | GPO3 Control | GPO2 Control | GPO1 Control | GPO0 Control |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 10 **GPO10 Control**
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO10 high and writing a 0 to this bit drives GPO10 low. A read from this bit returns the status of GPO10.

When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit sets PDME = 1 and writing a 0 sets PDME = 0.

bit 9 **GPO9 Control**
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO9 high and writing a 0 to this bit drives GPO9 low. A read from this bit returns the status of GPO9.

When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit sets XSTBY = 1 and writing a 0 sets XSTBY = 0.

bit 8 **GPO8 Control**
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO8 high and writing a 0 to this bit drives GPO8 low. A read from this bit returns the status of GPO8.

When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit sets XOHV = 1 and writing a 0 sets XOHV = 0.

- bit 7 GPO7 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO7 high and writing a 0 to this bit drives GPO7 low. A read from this bit returns the status of GPO7.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit sets XRESV = 1 and writing a 0 sets XRESV = 0.
- bit 6 GPO6 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO6 high and writing a 0 to this bit drives GPO6 low. A read from this bit returns the status of GPO6.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit sets XRESH = 1 and writing a 0 sets XRESH = 0.
- bit 5 GPO5 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO5 high and writing a 0 to this bit drives GPO5 low. A read from this bit returns the status of GPO5.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit enables PCLK2 and writing a 0 forces PCLK2 low.
- bit 4 GPO4 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO4 high and writing a 0 to this bit drives GPO4 low. A read from this bit returns the status of GPO4.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit enables PCLK1 and writing a 0 forces PCLK1 low.
- bit 3 GPO3 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO3 high and writing a 0 to this bit drives GPO3 low. A read from this bit returns the status of GPO3.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), GPO3 is not available.
- bit 2 GPO2 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), **writing a 1 to this bit drives GPO2 low and writing a 0 to this bit drives GPO2 high**. A read from this bit returns the status of GPO2.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), **writing a 1 to this bit enables XOEV and writing a 0 sets XOEV = 0**.

- bit 1 GPO1 Control
When the Type 3 TFT LCD interface is not selected (REG[48h] bits 3:0), writing a 1 to this bit drives GPO1 high and writing a 0 to this bit drives GPO1 low. A read from this bit returns the status of GPO1.
- When the Type 3 TFT LCD interface is selected (REG[48h] bits 3:0 = 0010), writing a 1 to this bit enables VCOM and writing a 0 sets VCOM = 0.
- bit 0 GPO0 Control
Writing a 1 to this bit drives GPO0 high and writing a 0 to this bit drives GPO0 low. A read from this bit returns the status of GPO0.

| PWM Clock Configuration Register | | | | | | | | | | | | | | Read/Write | | | | |
|----------------------------------|----|----|----|----|----|----|----|----------------------------------|----|----|----|----------------------|-------------------------------|---------------------|------------------|--|--|--|
| REG[70h] | | | | | | | | | | | | | | Default = 00000000h | | | | |
| n/a | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| n/a | | | | | | | | PWM Clock Divide Select bits 3-0 | | | | PWM Clock Force High | PWMCLK Source Select bits 1-0 | | PWM Clock Enable | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |

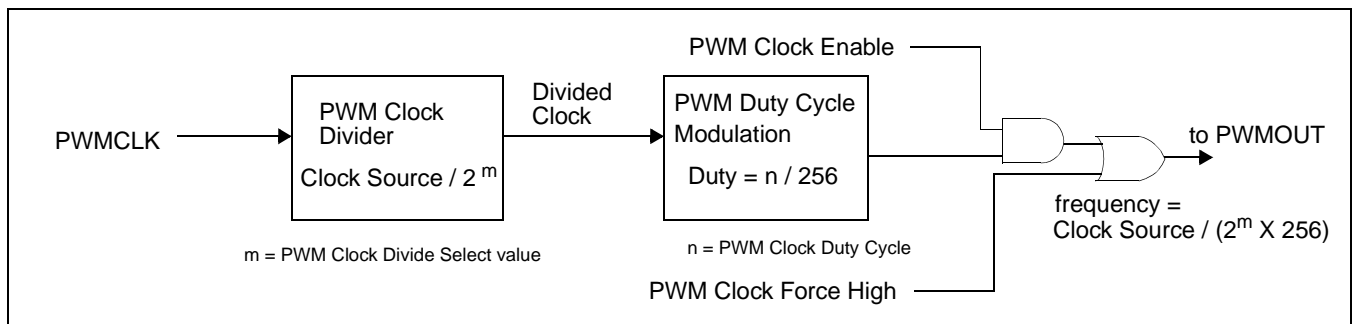


Figure 8-1: PWM Clock Block Diagram

Note

For further information on PWMCLK, see Section 7.1.4, “PWMCLK” on page 96.

bits 7-4

PWM Clock Divide Select Bits [3:0]

The value of these bits represents the power of 2 by which the selected PWM clock source is divided.

Table 8-24: PWM Clock Divide Select Options

| PWM Clock Divide Select Bits [3:0] | PWM Clock Divide Amount |
|---|--------------------------------|
| 0h | 1 |
| 1h | 2 |
| 2h | 4 |
| 3h | 8 |
| 4h | 16 |
| 5h | 32 |
| 6h | 64 |
| 7h | 128 |
| 8h | 256 |
| 9h | 512 |
| Ah | 1024 |
| Bh | 2048 |
| Ch | 4096 |
| Dh | 8192 |
| Eh | 16384 |
| Fh | 32768 |

Note

This divided clock is further divided by 256 before it is output at PWMOUT.

bit 3

PWM Clock Force High

When this bit = 0, the PWMOUT pin function is controlled by the PWM Clock enable bit.
When this bit = 1, the PWMOUT pin is forced to high.

bits 2-1

PWMCLK Source Select Bits [1:0]

These bits determine the source of PWMCLK.

Table 8-25: PWMCLK Source Selection

| REG[70h] bits 2-1 | PWMCLK Source |
|--------------------------|----------------------|
| 00 | CLKI |
| 01 | CLKI2 |
| 10 | BCLK |
| 11 | PCLK |

Note

For further information on the PWMCLK source select, see Section 7.2, “Clock Selection” on page 97.

bit 0 PWM Clock Enable
When this bit = 0, PWMOUT output acts as a general purpose output pin controllable by bit 3 of REG[70h].
When this bit = 1, the PWM Clock circuitry is enabled.

Note

The PWM Clock circuitry is disabled when Power Save Mode is enabled.

| PWMOUT Duty Cycle Register | | | | | | | | | | | | | | | Read/Write | | |
|----------------------------|----|----|----|----|----|----|----|----------------------------|----|----|----|----|----|----|---------------------|--|--|
| REG[74h] | | | | | | | | | | | | | | | Default = 00000000h | | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | | | PWMOUT Duty Cycle bits 7-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 7-0 PWMOUT Duty Cycle Bits [7:0]
This register determines the duty cycle of the PWMOUT output.

Table 8-26: PWMOUT Duty Cycle Select Options

| PWMOUT Duty Cycle [7:0] | PWMOUT Duty Cycle |
|-------------------------|---------------------------------------|
| 00h | Always Low |
| 01h | High for 1 out of 256 clock periods |
| 02h | High for 2 out of 256 clock periods |
| ... | ... |
| FFh | High for 255 out of 256 clock periods |

| Scratch Pad A Register | | | | | | | | | | | | | | | |
|-------------------------------|----|--------------------------|----|----|----|----|----|----|----|----|----|----|----|------------|----|
| REG[80h] | | Default = not applicable | | | | | | | | | | | | Read/Write | |
| Scratch Pad A bits 31-24 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| Scratch Pad A bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 31-0

Scratch Pad A Bits [31:0]

This register contains general purpose read/write bits. These bits have no effect on hardware.

Note

The contents of the Scratch Pad A register defaults to an un-defined state after initial power-up. Any data written to this register remains intact when the S1D13A05 is reset, **as long as the chip is not powered off.**

| Scratch Pad B Register | | | | | | | | | | | | | | | |
|-------------------------------|----|--------------------------|----|----|----|----|----|----|----|----|----|----|----|------------|----|
| REG[84h] | | Default = not applicable | | | | | | | | | | | | Read/Write | |
| Scratch Pad B bits 31-24 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| Scratch Pad B bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 31-0

Scratch Pad B Bits [31:0]

This register contains general purpose read/write bits. These bits have no effect on hardware.

Note

The contents of the Scratch Pad B register defaults to an un-defined state after initial power-up. Any data written to this register remains intact when the S1D13A05 is reset, **as long as the chip is not powered off.**

| Scratch Pad C Register | | | | | | | | | | | | | | | |
|-------------------------------|----|--------------------------|----|----|----|----|----|----|----|----|----|----|----|------------|----|
| REG[88h] | | Default = not applicable | | | | | | | | | | | | Read/Write | |
| Scratch Pad C bits 31-24 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| Scratch Pad C bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 31-0

Scratch Pad C Bits [31:0]

This register contains general purpose read/write bits. These bits have no effect on hardware.

Note

The contents of the Scratch Pad C register defaults to an un-defined state after initial power-up. Any data written to this register remains intact when the S1D13A04 is reset, **as long as the chip is not powered off.**

8.3.8 Extended Panel Registers

| HR-TFT CLS Width Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|--------------------------|----|----|----|----|----|----|----|----|
| REG[A0h] Default = 0000012Ch | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | CLS Pulse Width bits 8-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 8-0

CLS Pulse Width Bits [8:0]

This register determines the width of the CLS signal in PCLKs.

Note

This register must be programmed such that the following formula is valid.

$$(\text{REG}[A0h] \text{ bits } 8-0) > 0$$

| HR-TFT PS1 Rising Edge Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|--------------------------|----|----|----|----|----|----|----|----|
| REG[A4h] Default = 00000032h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | PS1 Rising Edge bits 5-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 5-0

PS1 Rising Edge Bits [5:0]

This register determines the number of PCLKs between the CLS falling edge and the PS1 rising edge.

| HR-TFT PS2 Rising Edge Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|--------------------------|----|----|----|----|----|----|----|----|
| REG[A8h] Default = 00000064h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | PS2 Rising Edge bits 7-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0

PS2 Rising Edge Bits [7:0]

This register determines the number of PCLKs between the LP falling edge and the first PS2 rising edge.

Note

This register must be programmed such that the following formula is valid.

$$(\text{REG}[A8h] \text{ bits } 7-0) > 0$$

| HR-TFT PS2 Toggle Width Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|----|---------------------------|----|----|----|----|----|----|
| REG[ACh] Default = 0000000Ah | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | PS2 Toggle Width bits 6-0 | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 6-0

PS2 Toggle Width Bits [6:0]

This register determines the width of the PS2 signal before toggling (in number of PCLKs).

Note

This register must be programmed such that the following formula is valid.
 $(\text{REG[ACh] bits 6-0}) > 0$

| HR-TFT PS3 Signal Width Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|----|---------------------------|----|----|----|----|----|----|
| REG[B0h] Default = 00000064h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | PS3 Signal Width bits 6-0 | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 6-0

PS3 Signal Width Bits [6:0]

This register determines the width of the PS3 signal in PCLKs.

Note

This register must be programmed such that the following formula is valid.
 $(\text{REG[B0h] bits 6-0}) > 0$

| HR-TFT REV Toggle Point Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|----|----|----|---------------------|----|----|----|----|
| REG[B4h] Default = 0000000Ah | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | REV Toggle bits 4-0 | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 4-0

REV Toggle Bits [4:0]

This register determines the width in PCLKs to toggle the REV signal prior to LP rising edge.

| HR-TFT PS1/2 End Register | | | | | | | | | | | | | | | | | |
|----------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|--------------------|---------------------|----|------------|--|
| REG[B8h] | | | | | | | | | | | | | | Default = 00000007h | | Read/Write | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | | | | | | | | PS1/2 End bits 2-0 | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 2-0 PS1/2 End Bits [2:0]
This register allows the PS signal to continue into the vertical non-display period (in lines).

Note

This register must be programmed such that the following formula is valid.

$$VT > (REG[B8h] \text{ bits } 2-0) + VDP + VPS + 1$$

| Type 2 TFT Configuration Register | | | | | | | | | | | | | | | | | |
|--|-----|-------------------------|----|----|-----|-----------------------------|----|-----|----|----|--------------------|----|-----|---------------------|----|------------|--|
| REG[BCh] | | | | | | | | | | | | | | Default = 00000000h | | Read/Write | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| POL Type | n/a | AP Pulse Width bits 2-0 | | | n/a | AP Rising Position bits 1-0 | | n/a | | | VCLK Hold bits 1-0 | | n/a | VCLK Setup bits 1-0 | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bit 15 POL Type
This bit selects how often the POL signal is toggled. The S1D13A05 GPIO2 pin controls the POL signal used for the TFT Type 2 Interface. For all other panel interfaces this bit has no effect.
When this bit = 0, the POL signal is toggled every line.
When this bit = 1, the POL signal is toggled every frame.

bits 13-11 AP Pulse Width Bits [2:0]
These bits specify the AP Pulse Width used for the TFT Type 2 Interface. The S1D13A05 GPIO1 pin controls the AP signal for the TFT Type 2 Interface. For all other panel interfaces it has no effect.

Table 8-27: AP Pulse Width

| REG[4Ch] bits 13-11 | AP Pulse Width (in PCLKs) |
|---------------------|---------------------------|
| 000 | 20 |
| 001 | 40 |
| 010 | 80 |
| 011 | 120 |
| 100 | 150 |
| 101 | 190 |
| 110 | 240 |
| 111 | 270 |

bits 9-8

AP Rising Position Bits [1:0]

These bits specify the TFT Type 2 AC timing parameter from the rising edge of FPLINE (STB) to the rising edge of GPIO1 (AP). The parameter is selected as follows. For all other panel interfaces it has no effect.

Table 8-28: AP Rising Position

| REG[4Ch] bits 9-8 | AP Rising Position (in PCLKs) |
|--------------------------|--------------------------------------|
| 00 | 40 |
| 01 | 52 |
| 10 | 68 |
| 11 | 90 |

bits 4-3

VCLK Hold Bits [1:0]

These bits specify the TFT Type 2 AC timing parameter from the rising edge of FPLINE (STB) to the falling edge of GPIO0 (VCLK). The parameter is selected as follows. For all other panel interfaces it has no effect.

Table 8-29: VCLK Hold

| REG[4Ch] bits 4-3 | VCLK Hold (in PCLKs) |
|--------------------------|-----------------------------|
| 00 | 7 |
| 01 | 9 |
| 10 | 12 |
| 11 | 16 |

bits 1-0

VCLK Setup Bits [1:0]

These bits specify the TFT Type 2 AC timing parameter from the rising edge of GPIO0 (VCLK) to the rising edge of FPLINE (STB). The parameter is selected as follows. For all other panel interfaces it has no effect.

Table 8-30: VCLK Setup

| REG[4Ch] bits 1-0 | VCLK Setup (in PCLKs) |
|--------------------------|------------------------------|
| 00 | 7 |
| 01 | 9 |
| 10 | 12 |
| 11 | 16 |

| Casio TFT Timing Register | | | | | | | | | | | | | | | |
|---|----|--|----|----|----|----|----|-----|----|--|----|----|----|----|----|
| REG[C0h] Default = 09180E09h Read/Write | | | | | | | | | | | | | | | |
| n/a | | GPCK Rising Edge to STH Pulse bits 5-0 | | | | | | n/a | | GRES Falling Edge to FRP Toggle Point bits 6-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | GRES Falling Edge to GPCK Rising Edge bits 4-0 | | | | | | n/a | | GPCK Rising Edge to GRES Rising Edge bits 5-0 | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

- bits 29-24 **GPCK Rising Edge to STH Pulse Bits[5:0]**
These bits determine the number of PCLKs from GPCK rising edge to STH pulse.
- bits 22-16 **GRES Falling Edge to FRP Toggle Point Bits[6:0]**
These bits determine the number of PCLKs from GRES falling edge to FRP Toggle point.
- bits 13-8 **GRES Falling Edge to GPCK Rising Edge Bits[5:0]**
These bits determine the number of PCLKs from GRES falling edge to GPCK rising edge.
- bits 5-0 **GPCK Rising Edge to GRES Rising Edge Bits[5:0]**
These bits determine the number of PCLKs from GPCK rising edge to GRES rising edge.

| Type 3 TFT Configuration Register 0 | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|-------------------------|----|----|----|----|----|----|----|----|
| REG[D8h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| POL Toggle Position bits 7-0 | | | | | | | OE Pulse Width bits 7-0 | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| OE Rising Edge Position bits 7-0 | | | | | | | n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

- bits 31-24 **POL Toggle Position Bits [7:0]**
These bits specify the toggle position of the POL signal in 2 pixel resolution. The S1D13A05 GPIO2 pin controls the POL signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.
- $\text{POL Toggle Position in pixels} = (\text{REG}[\text{D8h}] \text{ bits } 31\text{-}24) \times 2$
- bits 23-16 **OE Pulse Width Bits [7:0]**
These bits specify the pulse width of the OE signal in 2 pixel resolution. The S1D13A05 GPIO1 pin controls the OE signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.
- $\text{OE Pulse Width in pixels} = (\text{REG}[\text{D8h}] \text{ bits } 23\text{-}16) \times 2$
- bits 15-8 **OE Rising Edge Position Bits [7:0]**
These bits specify the rising edge position of the OE signal in 2 pixel resolution. The S1D13A05 GPIO1 pin controls the OE signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.
- $\text{OE Rising Edge Position in pixels} = (\text{REG}[\text{D8h}] \text{ bits } 15\text{-}8) \times 2$

| Type 3 TFT Configuration Register 1 | | | | | | | | | | | | | | | |
|-------------------------------------|----|----|----|----|----|----|-------------------------------|----|----|----|----|----|----|----|----|
| REG[DCh] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| XOEV End Position bits 7-0 | | | | | | | XOEV Start Position bits 7-0 | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| CPV Pulse Width bits 6-0 | | | | | | | VCOM Toggle Position bits 7-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 31-24 XOEV End Position Bits [7:0]
 These bits specify the falling/rising edge position of the XOEV signal in 2 pixel resolution (depending on the FPFAME Pulse Polarity bit in REG[3Ch] bit 23). The S1D13A05 GPO2 pin controls the XOEV signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.

$$\text{XOEV Falling Edge Position in pixels} = (\text{REG[DCh] bits 31-24}) \times 2$$

Note

If this register is set to 0, no pulse is generated.

bits 23-16 XOEV Start Position Bits [7:0]
 These bits specify the rising/falling edge position of the XOEV signal in 2 pixel resolution (depending on the FPFAME Pulse Polarity bit in REG[3Ch] bit 23). The S1D13A05 GPO2 pin controls the XOEV signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.

$$\text{XOEV Rising Edge Position in pixels} = (\text{REG[DCh] bits 23-16}) \times 2$$

Note

If this register is set to 0, no pulse is generated.

bits 15-8 CPV Pulse Width Bits [7:0]
 These bits specify the pulse width of the CPV signal in 2 pixel resolution. The S1D13A05 GPIO0 pin controls the CPV signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.

$$\text{CPV Pulse Width in pixels} = (\text{REG[DCh] bits 15-8}) \times 2$$

bits 7-0 VCOM Toggle Position Bits [7:0]
 These bits specify the toggle position of the VCOM signal in 2 pixel resolution. The S1D13A05 GPO1 pin controls the VCOM signal used for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.

$$\text{VCOM Toggle Position in pixels} = (\text{REG[DCh] bits 7-0}) \times 2$$

| Type 3 TFT PCLK Divide Register | | | | | | | | | | | | | | Read/Write | | | |
|---------------------------------|----|----|----|----|----|----|----|----|----|----------------------------|----|----------------------------|----|---------------------|----|--|--|
| REG[E0h] | | | | | | | | | | | | | | Default = 00000000h | | | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | | | | | PCLK2 Divide Rate bits 1-0 | | PCLK1 Divide Rate bits 3-0 | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bit 5-4 PCLK2 Divide Rate Bits [1:0]
These bits specify the divide rate for PCLK2. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.

Table 8-31: PCLK2 Divide Rate

| REG[C8h] bits 5-4 | PCLK2 Divide Rate |
|-------------------|-------------------|
| 00 | 64 |
| 01 | 128 |
| 10 | 256 |
| 11 | 512 |

bits 3-0 PCLK1 Divide Rate Bits [3:0]
These bits specify the divide rate for PCLK1. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.

Table 8-32: PCLK1 Divide Rate

| REG[C8h] bits 3-0 | PCLK1 Divide Rate |
|-------------------|-------------------|
| 0000 | 2 |
| 0001 | 4 |
| 0010 | 8 |
| 0011 | 16 |
| 0100 | 32 |
| 0101 | 64 |
| 0110 | 128 |
| 0111 | 256 |
| 1000 | 512 |
| 1001 | 1024 |
| 1010 | 2048 |
| 1011 | 4096 |
| 1100 | 8192 |
| 1101 | 16384 |
| 1110 | 32768 |
| 1111 | 65536 |

| Type 3 TFT Partial Mode Display Area Control Register | | | | | | | | | | | | | | | |
|---|----|---|----|----|----|----|----|-----|----|----|-----------------------------|----------------------------------|-----------------------|-----------------------|-----------------------|
| REG[E4h] | | | | | | | | | | | Default = 00000000h | | | Read/Write | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | Partial Mode Display Refresh Cycle bits 5-0 | | | | | | n/a | | | Partial Mode Display Enable | Partial Mode Display Type Select | Area 2 Display Enable | Area 1 Display Enable | Area 0 Display Enable |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

- bits 13-8 **Partial Mode Display Refresh Cycle Bits [5:0]**
These bits specify the refresh cycle for the Partial Mode Display. The refresh cycle can be a value from 0 to 63. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bit 4 **Partial Mode Display Enable**
This bit enables/disables the Partial Mode Display for the TFT Type 3 and has no effect for all other panel interfaces.
When this bit = 1, Partial Mode Display is enabled.
When this bit = 0, Partial Mode Display is disabled.
- bit 3 **Partial Mode Display Type Select**
This bit selects the type of partial mode display.
When this bit = 0, the Stripe type of partial mode display is selected. If Stripe is enabled only the Y Position registers are used in calculating the partial display.
When this bit = 1, type Block type of partial mode display is selected. If Block is enabled both the X and Y Position registers are used in calculating the partial display.
- bit 2 **Area 2 Display Enable**
This bit enables/disables the Area 2 for Partial Mode Display on the TFT Type 3 and has no effect for all other panel interfaces.
When this bit = 1, Area 2 is enabled.
When this bit = 0, Area 2 is disabled.
- bit 1 **Area 1 Display Enable**
This bit enables/disables the Area 1 for Partial Mode Display on the TFT Type 3 and has no effect for all other panel interfaces.
When this bit = 1, Area 1 is enabled.
When this bit = 0, Area 1 is disabled.
- bit 0 **Area 0 Display Enable**
This bit enables/disables the Area 0 for Partial Mode Display on the TFT Type 3 and has no effect for all other panel interfaces.
When this bit = 1, Area 0 is enabled.
When this bit = 0, Area 0 is disabled.

| Type 3 TFT Partial Area 0 Positions Register | | | | | | | | | | | | | | | | | |
|---|----|--|----|----|----|----|----|-----|----|--|----|----|----|----|----|------------|--|
| REG[E8h] | | | | | | | | | | Default = 00000000h | | | | | | Read/Write | |
| n/a | | Partial Area 0 Y End Position bits 5-0 | | | | | | n/a | | Partial Area 0 X End Position bits 5-0 | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | Partial Area 0 Y Start Position bits 5-0 | | | | | | n/a | | Partial Area 0 X Start Position bits 5-0 | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

- bits 29-24 Partial Area 0 Y End Position Bits [5:0]
These bits specify the Y End Position of Partial Area 0 in 8 line resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 21-16 Partial Area 0 X End Position Bits [5:0]
These bits specify the X End Position of Partial Area 0 in 8 pixel resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 13-8 Partial Area 0 Y Start Position Bits [5:0]
These bits specify the Y Start Position of Partial Area 0 in 8 line resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 5-0 Partial Area 0 X Start Position Bits [5:0]
These bits specify the X Start Position of Partial Area 0 in 8 pixel resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.

| Type 3 TFT Partial Area 1 Positions Register | | | | | | | | | | | | | | | | | |
|---|----|--|----|----|----|----|----|-----|----|--|----|----|----|----|----|------------|--|
| REG[ECh] | | | | | | | | | | Default = 00000000h | | | | | | Read/Write | |
| n/a | | Partial Area 1 Y End Position bits 5-0 | | | | | | n/a | | Partial Area 1 X End Position bits 5-0 | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | Partial Area 1 Y Start Position bits 5-0 | | | | | | n/a | | Partial Area 1 X Start Position bits 5-0 | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

- bits 29-24 Partial Area 1 Y End Position Bits [5:0]
These bits specify the Y End Position of Partial Area 1 in 8 line resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 21-16 Partial Area 1 X End Position Bits [5:0]
These bits specify the X End Position of Partial Area 1 in 8 pixel resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 13-8 Partial Area 1 Y Start Position Bits [5:0]
These bits specify the Y Start Position of Partial Area 1 in 8 line resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 5-0 Partial Area 1 X Start Position Bits [5:0]
These bits specify the X Start Position of Partial Area 1 in 8 pixel resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.

| Type 3 TFT Partial Area 2 Positions Register | | | | | | | | | | | | | | | |
|--|----|--|----|----|----|----|----|-----|----|--|----|----|----|----|----|
| REG[F0h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | Partial Area 2 Y End Position bits 5-0 | | | | | | n/a | | Partial Area 2 X End Position bits 5-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | Partial Area 2 Y Start Position bits 5-0 | | | | | | n/a | | Partial Area 2 X Start Position bits 5-0 | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

- bits 29-24 Partial Area 2 Y End Position Bits [5:0]
These bits specify the Y End Position of Partial Area 2 in 8 line resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 21-16 Partial Area 2 X End Position Bits [5:0]
These bits specify the X End Position of Partial Area 2 in 8 pixel resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 13-8 Partial Area 2 Y Start Position Bits [5:0]
These bits specify the Y Start Position of Partial Area 2 in 8 line resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.
- bits 5-0 Partial Area 2 X Start Position Bits [5:0]
These bits specify the X Start Position of Partial Area 2 in 8 pixel resolution. This register is used for the TFT Type 3 Interface and has no effect for all other panel interfaces.

| Type 3 TFT Command Store Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|---------------------------|----|----|----|----|----|----|----|----|----|----|----|
| REG[F4h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | Command 1 Store bits 11-0 | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | Command 0 Store bits 11-0 | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

- bits 27-16 Command 1 Store Bits [11:0]
These bits store command 1 for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.
- bits 11-0 Command 0 Store Bits [11:0]
These bits store command 0 for the TFT Type 3 Interface. This register has no effect for all other panel interfaces.

| Type 3 TFT Miscellaneous Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|-------------------------------------|----|-----|----|----|----|----|----|----------------------------|----|
| REG[F8h] Default = 00000000h | | | | | | | | | | | | | | Read/Write | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Source Driver IC Number bits 1-0 | | n/a | | | | | | Command Send Request | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-8

Source Driver IC Number Bits [1:0]
 These bits contain the number of Source Driver ICs.

Table 8-33: Number of Source Driver ICs

| REG[E0h] bits 1-0 | Source Driver ICs |
|-------------------|-------------------|
| 00 | 1 |
| 01 | 2 |
| 10 | 3 |
| 11 | 4 |

bit 0

Command Send Request
 After the CPU sets this bit, the S1D13A05 sends the command in the next non-display period and clears this bit automatically. This register has no effect for all other panel interfaces.

8.4 USB Registers (Offset = 4000h)

The S1D13A05 USB device occupies a 48 byte local register space which can be accessed by the CPU on the local host interface.

To access the USB registers:

1. A valid USBCLK must be provided.
2. The USBCLK Enable bit (REG[4000h] bit 7) must be set to 1 and the USB Setup bit (REG[4000h] bit 2) must be set to 1. Both bits should be set together.

If any of the above conditions are not true, the USB registers must not be accessed.

| Control Register REG[4000h] | | | | | | | Default = 00h | | Read/Write |
|--------------------------------|--------------|------------|------------------|------------------|-----------|----------|---------------|--|------------|
| n/a | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | | |
| USBClk Enable | Software EOT | USB Enable | Endpoint 4 Stall | Endpoint 3 Stall | USB Setup | Reserved | Reserved | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bit 7

USBClk Enable.

This bit allows the USBClk to be enabled/disabled allowing the S1D13A05 to save power when the USBClk is not required. The USBClk Enable bit operates independently of the Power Save Mode Enable bit (REG[14h] bit 4). For example, enabling power save mode does not disable the USB section of the S1D13A05. It must be disabled using the USBClk enable bit.

This bit should initially be set with the USB Setup bit. However, it can be disabled/re-enabled individually.

When this bit = 1, the USBClk is enabled.

When this bit = 0, the USBClk is disabled.

Note

The USB Registers must not be accessed when this bit is 0.

bit 6

Software EOT

This bit determines the response to an IN request to Endpoint 4 when the transmit FIFO is empty. If this bit is asserted, the S1D13A05 responds to an IN request to Endpoint 4 with an ACK and a zero length packet if the FIFO is empty. If this bit is not asserted, the S1D13A05 responds to an IN request from Endpoint 4 with a NAK if the FIFO is empty, indicating that it expects to transmit more data. This bit is automatically cleared when the S1D13A05 responds to the host with a zero length packet when the FIFO is empty.

bit 5 USB Enable
Any device or configuration descriptor reads from the host will be acknowledged with a NAK until this bit is set. This allows time for the local CPU to set up the interrupt polling register, maximum packet size registers, and other configuration registers (e.g. Product ID and Vendor ID) before the host reads the descriptors.

Note

As the device and configuration descriptors cannot be read by the host until the USB Enable bit is set, the device enumeration process will not complete and the device will not be recognized on the USB.

bit 4 Endpoint 4 Stall.
If this bit is set, host bulk reads from the transmit FIFO will result in a STALL acknowledge by the S1D13A05. No data will be returned to the USB host.

bit 3 Endpoint 3 Stall.
If this bit is set, host bulk writes to the receive FIFO will result in a STALL acknowledge by the S1D13A05. Receive data will be discarded.

bit 2 USB Setup
This bit is used by software to select between GPIO and USB functions for multifunction GPIO pins (GPIO[7:4]). This bit should be set at the same time as the USBCLK Enable bit. When this bit = 1, the USB function is selected. When this bit = 0, the GPIO function is selected.

Note

The USB Registers must not be accessed when this bit is 0.

bit 1 Reserved.
This bit must be set to 0.

bit 0 Reserved.
This bit must be set to 0.

| Interrupt Enable Register 0 | | | | | | | |
|---|----------------------|----------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------|
| REG[4002h] Default = 00h | | | | | | | Read/Write |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Suspend Request Interrupt Enable | SOF Interrupt Enable | Reserved | Endpoint 4 Interrupt Enable | Endpoint 3 Interrupt Enable | Endpoint 2 Interrupt Enable | Endpoint 1 Interrupt Enable | n/a |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 7 Suspend Request Interrupt Enable.
When set, this bit enables an interrupt to occur when the USB host is requesting the S1D13A05 USB device to enter suspend mode.

bit 6 SOF Interrupt Enable.
When set, this bit enables an interrupt to occur when a start-of-frame packet is received by the S1D13A05.

bit 5 Reserved.
This bit must be set to 0.

- bit 4 Endpoint 4 Interrupt Enable.
When set, this bit enables an interrupt to occur when a USB Endpoint 4 Data Packet has been sent by the S1D13A05.
- bit 3 Endpoint 3 Interrupt Enable.
When set, this bit enables an interrupt to occur when a USB Endpoint 3 Data Packet has been received by the S1D13A05.
- bit 2 Endpoint 2 Interrupt Enable.
When set, this bit enables an interrupt to occur when the USB Endpoint 2 Transmit Mailbox registers have been read by the USB host.
- bit 1 Endpoint 1 Interrupt Enable.
When set, this bit enables an interrupt to occur when the USB Endpoint 1 Receive Mailbox registers have been written to by the USB host.

| Interrupt Status Register 0 | | | | | | | |
|----------------------------------|----------------------|---------------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|------------------------------------|
| REG[4004h] | | Default = 00h | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Suspend Request Interrupt Status | SOF Interrupt Status | Reserved | Endpoint 4 Interrupt Status | Endpoint 3 Interrupt Status | Endpoint 2 Interrupt Status | Endpoint 1 Interrupt Status | Upper Interrupt Active (read only) |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

- bit 7 Suspend Request Interrupt Status.
This bit indicates when a suspend-request has been received by the S1D13A05. Writing a 1 clears this bit.
- bit 6 SOF Interrupt Status.
This bit indicates when a start-of-frame packet has been received by the S1D13A05. Writing a 1 clears this bit.
- bit 5 Reserved.
This bit must be set to 0.
- bit 4 Endpoint 4 Interrupt Status.
This bit indicates when a USB Endpoint 4 Data packet has been sent by the S1D13A05. Writing a 1 clears this bit.
- bit 3 Endpoint 3 Interrupt Status (Receive FIFO Valid).
This bit indicates when a USB Endpoint 3 Data packet has been received by the S1D13A05. No more packets to endpoint 3 will be accepted until this bit is cleared. Writing a 1 clears this bit.
- bit 2 Endpoint 2 Interrupt Status.
This bit indicates when the USB Endpoint 2 Mailbox registers have been read by the USB host. Writing a 1 clears this bit.
- bit 1 Endpoint 1 Interrupt Status (Receive Mailbox Valid).
This bit indicates when the USB Endpoint 1 Mailbox registers have been written to by the USB host. Writing a 1 clears this bit.
- bit 0 Upper Interrupt Active (read only).
At least one interrupt status bit is set in register REG[4008h].

| Interrupt Enable Register 1 | | | | | | | | Read/Write | |
|-----------------------------|----|----|----|----|----|---|---|---|---|
| REG[4006h] | | | | | | | | Default = 00h | |
| n/a | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | | |
| n/a | | | | | | | | Transmit FIFO Almost Empty Interrupt Enable | Receive FIFO Almost Full Interrupt Enable |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bit 1 Transmit FIFO Almost Empty Interrupt Enable.
When set, this bit enables an interrupt to be generated when the Transmit FIFO Almost status bit is set.

Note

The Transmit FIFO Almost Empty threshold must be set greater than zero, as the FIFO count must drop below the threshold to cause an interrupt.

bit 0 Receive FIFO Almost Full Interrupt Enable.
When set, this bit enables an interrupt to be generated when the Receive FIFO Almost Full status bit is set.

Note

The Receive FIFO Almost Full threshold must be set less than 64, as the FIFO count must rise above the threshold to cause an interrupt.

| Interrupt Status Register 1 | | | | | | | | Read/Write | |
|-----------------------------|----|----|----|----|----|---|---|---|---------------------------------------|
| REG[4008h] | | | | | | | | Default = 00h | |
| n/a | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | | |
| n/a | | | | | | | | Transmit FIFO Almost Empty Status | Receive FIFO Almost Full Status |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bit 1 Transmit FIFO Almost Empty Status.
This bit is set when the number of bytes in the Transmit FIFO is equal to the Transmit FIFO Almost Empty Threshold, and another byte is sent to the USB bus from the FIFO. Writing a 1 clears this bit.

bit 0 Receive FIFO Almost Full Status.
This bit is set when the number of bytes in the Receive FIFO is equal to the Receive FIFO Almost Full Threshold, and another byte is received from the USB bus into the FIFO. Writing a 1 clears this bit.

| Endpoint 1 Index Register | | | | | | | |
|----------------------------------|----|---------------|----|--------------------------------|----|------------|---|
| REG[4010h] | | Default = 00h | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | | | | Endpoint 1 Index bits 2-0 (RO) | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 2-0

Endpoint 1 Index Register Bits [2:0].

This register determines which Endpoint 1 Receive Mailbox is accessed when the Endpoint 1 Receive Mailbox Data register is read. This register is automatically incremented after the Endpoint 1 Receive Mailbox Data register is read. This index register wraps around to zero when it reaches the maximum count (7).

| Endpoint 1 Receive Mailbox Data Register | | | | | | | |
|---|----|---------------|----|----|----|-----------|---|
| REG[4012h] | | Default = 00h | | | | Read Only | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Endpoint 1 Receive Mailbox Data bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0

Endpoint 1 Receive Mailbox Data Bits [7:0].

This register is used to read data from one of the receive mailbox registers. Data is returned from the register selected by the Endpoint 1 Index Register. The eight receive mailbox registers are written by a USB bulk transfer to endpoint 1, and can be used to pass messages from the USB host to the local CPU. The format and content of the messages are user defined. If enabled, USB writes to this register can generate an interrupt.

| Endpoint 2 Index Register | | | | | | | |
|----------------------------------|----|---------------|----|---------------------------|----|------------|---|
| REG[4018h] | | Default = 00h | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | | | | Endpoint 2 Index bits 2-0 | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 2-0

Endpoint 2 Index Register Bits [2:0].

This register determines which Endpoint 2 Transmit Mailbox is accessed when the Endpoint 2 Transmit Mailbox Data register is read or written. This register is automatically incremented after the Endpoint 2 Transmit Mailbox Data port is read or written. This index register wraps around to zero when it reaches the maximum count (7).

| Endpoint 2 Transmit Mailbox Data Register | | | | | | | |
|--|----|---------------|----|----|----|------------|---|
| REG[401Ah] | | Default = 00h | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Endpoint 2 Transmit Mailbox Data bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0 Endpoint 2 Transmit Mailbox Data Bits [7:0].
 This register is used to read or write one of the transmit mailbox registers. The register being accessed is selected by the Endpoint 2 Index register. The eight Transmit Mailbox registers are written by the local CPU and are read by a USB transfer from endpoint 2. The format and content of the messages are user defined. If enabled, USB reads from this register can generate an interrupt.

| Endpoint 2 Interrupt Polling Interval Register | | | | | | | |
|---|----|---------------|----|----|----|------------|---|
| REG[401Ch] | | Default = FFh | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Interrupt Polling Interval bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0 Interrupt Polling Interval Bits [7:0].
 This register specifies the Endpoint 2 interrupt polling interval in milliseconds. It can be read by the host through the endpoint 2 descriptor.

| Endpoint 3 Receive FIFO Data Register | | | | | | | |
|--|----|---------------|----|----|----|-----------|---|
| REG[4020h] | | Default = 00h | | | | Read Only | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Endpoint 3 Receive FIFO Data bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits7-0 Endpoint 3 Receive FIFO Data Bits [7:0].
 This register is used by the local CPU to read USB receive FIFO data. The FIFO data is written by the USB host using bulk or isochronous transfers to endpoint 3.

| Endpoint 3 Receive FIFO Count Register | | | | | | | |
|---|----|---------------|----|----|----|-----------|---|
| REG[4022h] | | Default = 00h | | | | Read Only | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Receive FIFO Count bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0 Receive FIFO Count Bits [7:0].
 This register returns the number of receive FIFO entries containing valid entries. Values range from 0 (empty) to 64 (full). This register is automatically decremented after every read of the of the Receive FIFO Data Register (REG[4020h]).

| Endpoint 3 Receive FIFO Status Register | | | | | | | | |
|---|----|---------------|--------------------|-----------------------|------------------------|-------------------------------|--------------------------------|------------|
| REG[4024h] | | Default = 01h | | | | | | Read/Write |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| n/a | | | Receive FIFO Flush | Receive FIFO Overflow | Receive FIFO Underflow | Receive FIFO Full (read only) | Receive FIFO Empty (read only) | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bit 4 Receive FIFO Flush.
Writing to this bit causes the receive FIFO to be flushed. Reading this bit always returns a 0.
- bit 3 Receive FIFO Overflow.
If set, this bit indicates that an attempt was made by the USB host to write to the receive FIFO when the receive FIFO was full. Writing a 1 clears this bit.
- bit 2 Receive FIFO Underflow.
If set, this bit indicates that an attempt was made to read the receive FIFO when the receive FIFO was empty. Writing a 1 clears this bit.
- bit 1 Receive FIFO Full.
If set, this bit indicates that the receive FIFO is full.
- bit 0 Receive FIFO Empty.
If set, this bit indicates that the receive FIFO is empty.

| Endpoint 3 Maximum Packet Size Register | | | | | | | | |
|---|----|---------------|----|----|----|---|---|------------|
| REG[4026h] | | Default = 08h | | | | | | Read/Write |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| Endpoint 3 Max Packet Size bits 7-0 | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bits 7-0 Endpoint 3 Max Packet Size Bits [7:0].
This register specifies the maximum packet size for endpoint 3 in units of 8 bytes (default = 64 bytes). It can be read by the host through the endpoint 3 descriptor.

| Endpoint 4 Transmit FIFO Data Register | | | | | | | | |
|--|----|---------------|----|----|----|---|---|------------|
| REG[4028h] | | Default = 00h | | | | | | Write Only |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| Transmit FIFO Data bits 7-0 | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bits 7-0 Transmit FIFO Data Bits [7:0].
This register is used by the local CPU to write data to the transmit FIFO. The FIFO data is read by the USB host using bulk or isochronous transfers from endpoint 4.

| Endpoint 4 Transmit FIFO Count Register | | | | | | | | |
|--|----|---------------|----|----|----|---|---|-----------|
| REG[402Ah] | | Default = 00h | | | | | | Read Only |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| Transmit FIFO Count bits 7-0 | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

bits 7-0 Transmit FIFO Count Bits [7:0].
This register returns the number of transmit FIFO entries containing valid entries. Values range from 0 (empty) to 64 (full).

| Endpoint 4 Transmit FIFO Status Register | | | | | | | | |
|---|----|---------------------|---------------------|------------------------|----------|--------------------------------|---------------------------------|------------|
| REG[402Ch] | | Default = 01h | | | | | | Read/Write |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| n/a | | Transmit FIFO Valid | Transmit FIFO Flush | Transmit FIFO Overflow | Reserved | Transmit FIFO Full (read only) | Transmit FIFO Empty (read only) | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

bit 5 Transmit FIFO Valid.
If set, this bit allows the data in the Transmit FIFO to be read by the next read from the host. This bit is automatically cleared by a host read. This bit is only used if bit 0 in USB[403Ah] Index [0Ch] is set.

bit 4 Transmit FIFO Flush.
Writing to this bit causes the transmit FIFO to be flushed. Reading this bit always returns a 0.

bit 3 Transmit FIFO Overflow.
If set, this bit indicates that an attempt was made by the local CPU to write to the transmit FIFO when the transmit FIFO was full. Writing a 1 clears this bit.

bit 2 Reserved.

bit 1 Transmit FIFO Full (read only).
If set, this bit indicates that the transmit FIFO is full.

bit 0 Transmit FIFO Empty (read only).
If set, this bit indicates that the transmit FIFO is empty.

| Endpoint 4 Maximum Packet Size Register | | | | | | | | |
|--|----|---------------|----|----|----|---|---|------------|
| REG[402Eh] | | Default = 08h | | | | | | Read/Write |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| Endpoint 4 Max Packet Size bits 7-0 | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

bits 7-0 Endpoint 4 Max Packet Size Bits [7:0].
This register specifies the maximum packet size for endpoint 4 in units of 8 bytes (default = 64 bytes). It can be read by the host through the endpoint 4 descriptor.

| Revision Register | | | | | | | |
|-------------------------------|----|----|----|----|----|---|-----------|
| REG[4030h] Default = 01h | | | | | | | Read Only |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Chip Revision bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0

Chip Revision Bits [7:0].

This register returns current silicon revision number of the USB client.

| USB Status Register | | | | | | | |
|-------------------------------|----------------------|--------------------|--------------------|----------------------|--------------------|--------------------|------------------|
| REG[4032h] Default = 00h | | | | | | | Read/Write |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Suspend Control | USB Endpoint 4 STALL | USB Endpoint 4 NAK | USB Endpoint 4 ACK | USB Endpoint 3 STALL | USB Endpoint 3 NAK | USB Endpoint 3 ACK | Endpoint 2 Valid |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 7

Suspend Control

If set, this bit indicates that there is a pending suspend request. Writing a 1 clears this bit and causes the S1D13A05 USB device to enter suspended mode.

bit 6

USB Endpoint 4 STALL

The last USB IN token could not be serviced because the endpoint was stalled (REG[4000h] bit 4 set), and was acknowledged with a STALL. Writing a 1 clears this bit.

bit 5

USB Endpoint 4 NAK

The last USB packet transmitted (IN packet) encountered a FIFO underrun condition, and was acknowledged with a NAK. Writing a 1 clears this bit.

bit 4

USB Endpoint 4 ACK

The last USB packet transmitted (IN packet) was successfully acknowledged with an ACK from the USB host. Writing a 1 clears this bit.

bit 3

USB Endpoint 3 STALL

The last USB packet received (OUT packet) could not be accepted because the endpoint was stalled (REG[4000h] bit 3 set), and was acknowledged with a STALL. Writing a 1 clears this bit.

bit 2

USB Endpoint 3 NAK

The last USB packet received (OUT packet) could not be accepted, and was acknowledged with a NAK. Writing a 1 clears this bit.

bit 1

USB Endpoint 3 ACK.

The last USB packet received (OUT packet) was successfully acknowledged with an ACK. Writing a 1 clears this bit.

bit 0

Endpoint 2 Valid.

When this bit is set, the 8-byte endpoint 2 mailbox registers have been written by the local CPU, but not yet read by the USB host. The local CPU should not write into these registers while this bit is set.

| Frame Counter MSB Register | | | | | | | |
|-----------------------------------|----|---------------|----|-------------------------|----|-----------|---|
| REG[4034h] | | Default = 00h | | | | Read Only | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | | | | Frame Counter bits 10-8 | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| Frame Counter LSB Register | | | | | | | |
|-----------------------------------|----|---------------|----|----|----|-----------|---|
| REG[4036h] | | Default = 00h | | | | Read Only | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Frame Counter bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 10-0 **Frame Counter Bits [10:0]**
This register contains the frame counter from the most recent start-of-frame packet.

| Extended Register Index | | | | | | | |
|----------------------------------|----|---------------|----|----|----|------------|---|
| REG[4038h] | | Default = 00h | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Extended Register Index bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0 **Extended Register Index Bits [7:0]**
This register selects which extended data register is accessed when the REG[403Ah] is read or written.

| Extended Register Data | | | | | | | |
|-------------------------------|----|---------------|----|----|----|------------|---|
| REG[403Ah] | | Default = 04h | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| Extended Data bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0 **Extended Data Bits [7:0]**
This port provides access to one of the extended data registers. The index of the current register is held in REG[4038h].

| Vendor ID MSB | | | | | | | |
|------------------------|---|---------------|---|---|---|------------|---|
| REG[403Ah], Index[00h] | | Default = 04h | | | | Read/Write | |
| Vendor ID bits 15-8 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| Vendor ID LSB | | | | | | | |
|------------------------|---|---------------|---|---|---|------------|---|
| REG[403Ah], Index[01h] | | Default = B8h | | | | Read/Write | |
| Vendor ID bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 15-0 **Vendor ID Bits [15:0]**
These registers determine the Vendor ID returned in a “Get Device Descriptor” request.

| | | | | | | | |
|------------------------|---|---|---|---------------|---|------------|---|
| Product ID MSB | | | | | | | |
| REG[403Ah], Index[02h] | | | | Default = 88h | | Read/Write | |
| Product ID bits 15-8 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| | | | | | | | |
|------------------------|---|---|---|---------------|---|------------|---|
| Product ID LSB | | | | | | | |
| REG[403Ah], Index[03h] | | | | Default = 21h | | Read/Write | |
| Product ID bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 15-0 Product ID Bits [15:0]
These registers determine the Product ID returned in a “Get Device Descriptor” request.

| | | | | | | | |
|---------------------------|---|---|---|---------------|---|------------|---|
| Release Number MSB | | | | | | | |
| REG[403Ah], Index[04h] | | | | Default = 01h | | Read/Write | |
| Release Number bits 15-8 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| | | | | | | | |
|---------------------------|---|---|---|---------------|---|------------|---|
| Release Number LSB | | | | | | | |
| REG[403Ah], Index[05h] | | | | Default = 00h | | Read/Write | |
| Release Number bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 15-0 Release Number Bits [15:0]
These registers determine the device release number returned in a “Get Device Descriptor” request.

| | | | | | | | |
|---|-----|---|---|---------------|---|------------|--|
| Receive FIFO Almost Full Threshold | | | | | | | |
| REG[403Ah], Index[06h] | | | | Default = 3Ch | | Read/Write | |
| 7 | n/a | 6 | Receive FIFO Almost Full Threshold bits 5-0 | | | | |
| 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 5-0 Receive FIFO Almost Full Threshold Bits [5:0]
This register determines the threshold at which the receive FIFO almost full status bit is set.

Note

The Receive FIFO Almost Full threshold must be set less than 64, as the FIFO count must rise above the threshold to cause an interrupt.

| | | | | | | | |
|---|-----|---|---|---------------|---|------------|--|
| Transmit FIFO Almost Empty Threshold | | | | | | | |
| REG[403Ah], Index[07h] | | | | Default = 04h | | Read/Write | |
| 7 | n/a | 6 | Transmit FIFO Almost Empty Threshold bits 5-0 | | | | |
| 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 5-0 Transmit FIFO Almost Empty Threshold Bits [5:0].
This register determines the threshold at which the transmit FIFO almost empty status bit is set.

Note

The Transmit FIFO Almost Empty threshold must be set greater than zero, as the FIFO count must drop below the threshold to cause an interrupt.

| USB Control | | | | | | | Read/Write |
|------------------------|---|---|---|---|---|---|-------------------|
| REG[403Ah], Index[08h] | | | | | | | Default = 01h |
| n/a | | | | | | | USB String Enable |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bit 0 USB String Enable.
When set, this bit allows the default Vendor and Product ID String Descriptors to be returned to the host. When this bit is cleared, the string index values in the Device Descriptor are set to zero.

| Maximum Power Consumption | | | | | | | | Read/Write |
|---------------------------|---|---|---|---|---|---|---|---------------|
| REG[403Ah], Index[09h] | | | | | | | | Default = FAh |
| Maximum Current bits 7-0 | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

bits 7-0 Maximum Current Bits [7:0].
The amount of current drawn by the peripheral from the USB port in increments of 2 mA. The S1D13A05 reports this value to the host controller in the configuration descriptor. The default and maximum value is 500 mA (FAh * 2 mA).

In order to comply with the USB specification the following formula must apply:
 $REG[403Ah] \text{ index}[09h] \leq FAh$.

| Packet Control | | | | | | | | Read/Write |
|------------------------|-----------------|-----------------|-----------------|----------|----------|-----|----------|---------------|
| REG[403Ah], Index[0Ah] | | | | | | | | Default = 00h |
| EP4 Data Toggle | EP3 Data Toggle | EP2 Data Toggle | EP1 Data Toggle | Reserved | Reserved | n/a | Reserved | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

bit 7 EP4 Data Toggle Bit.
Contains the value of the Data Toggle bit to be sent in response to the next IN token to endpoint 4 from the USB host.

Note

When a write is made to this bit, the value cannot be read back before a minimum of 12 USBCLK.

bit 6 EP3 Data Toggle Bit.
Contains the value of the Data Toggle bit expected in the next DATA packet to endpoint 3 from the USB host.

Note

When a write is made to this bit, the value cannot be read back before a minimum of 12 USBCLK.

bit 5 EP2 Data Toggle Bit.
Contains the value of the Data Toggle bit to be sent in response to the next IN token to endpoint 2 from the USB host.

Note

When a write is made to this bit, the value cannot be read back before a minimum of 12 USBCLK.

bit 4

EPI Data Toggle Bit.

Contains the value of the Data Toggle bit expected in the next DATA packet to endpoint 1 from the USB host.

Note

When a write is made to this bit, the value cannot be read back before a minimum of 12 USBCLK.

bit 3

Reserved.

This bit must be set to 0.

bit 2

Reserved.

This bit must be set to 0.

bit 0

Reserved.

This bit must be set to 0.

| Reserved | | | | | | | Read/Write |
|------------------------|---|---|---|---|---|---|---------------|
| REG[403Ah], Index[0Bh] | | | | | | | Default = 00h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | Reserved 0 |
| n/a | | | | | | | |

bit 0

Reserved.

This bit must be set to 0.

| FIFO Control | | | | | | | Read/Write |
|------------------------|---|---|---|---|---|---|----------------------------------|
| REG[403Ah], Index[0Ch] | | | | | | | Default = 00h |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | Transmit FIFO Valid Mode 0 |
| n/a | | | | | | | |

bit 0

Transmit FIFO Valid Mode.

When set, this bit causes a NAK response to a host read request from the transmit FIFO (EP4) unless the FIFO Valid bit (in register EP4STAT) is set. When this bit is cleared, any data waiting in the transmit FIFO will be sent in response to a host read request, and the FIFO Valid bit is ignored.

| USBFC Input Control Register | | | | | | | |
|-------------------------------------|---------|---------------|----------|-----|--------|------------|----------|
| REG[4040h] | | Default = 0Dh | | | | Read/Write | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | USCMPEN | Reserved | Reserved | ISO | WAKEUP | Reserved | Reserved |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

These bits control inputs to the USB module.

- bit 6 **USCMPEN**
This bit controls the USB differential input receiver.
0 = differential input receiver disabled
1 = differential input receiver enabled
- bits 5 **Reserved.**
This bit must be set to 0.
- bits 4 **Reserved.**
This bit must be set to 0.
- bit 3 **ISO**
This bits selects between isochronous and bulk transfer modes for the FIFOs (Endpoint 3 and Endpoint 4).
0 = Isochronous transfer mode
1 = Bulk transfer mode
- bit 2 **WAKEUP**
This active low bit initiates a USB remote wake-up.
0 = initiate USB remote wake-up
1 = no action
- bit 1 **Reserved.**
This bit must be set to 0.
- bit 0 **Reserved.**
This bit must be set to 0.

| Reserved | | | | | | | |
|-----------------|----|----|----|----|----|---|---|
| REG[4042h] | | | | | | | |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| Pin Input Status / Pin Output Data Register | | | | | | | | |
|---|----|--|----|----|----|--|-----------------------------|--|
| REG[4044h] | | Default = depends on USB input pin state | | | | | Read/Write | |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| n/a | | | | | | USBDETECT Input Pin Status (read only) | USBPUP Output Pin Status | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

These bits can generate interrupts.

bit 1 USBDETECT Input Pin Status
This read-only bit indicates the status of the USBDETECT input pin after a steady-state period of 0.5 seconds.

bit 0 USBPUP Output Pin Status
This bit controls the state of the USBPUP output pin.

This bit must be set to 1 to enable the USB interface and USB registers. See the *S1D13A05 Programming Notes and Examples*, document number X40-A-G-003-xx for further information on this bit.

| Interrupt Control Enable Register 0 | | | | | | | | |
|-------------------------------------|-----------------------|---------------|----------|----------|----------|----------|------------|--|
| REG[4046h] | | Default = 00h | | | | | Read/Write | |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| n/a | USB Host Connected | Reserved | Reserved | Reserved | Reserved | USBRESET | Reserved | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

These bits enable interrupts from the corresponding bit of the Interrupt Control Status/Clear Register 0.

0 = corresponding interrupt bit disabled (masked).

1 = corresponding interrupt bit enabled.

| Interrupt Control Enable Register 1 | | | | | | | | |
|-------------------------------------|------------------------|---------------|----------------------|----------|----------|----------|------------|--|
| REG[4048h] | | Default = 00h | | | | | Read/Write | |
| n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | |
| n/a | USB Host Disconnect | Reserved | Device Configured | Reserved | Reserved | Reserved | INT | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

These bits enable interrupts from the corresponding bit of the Interrupt Control Status/Clear Register 1.

0 = corresponding interrupt bit disabled (masked).

1 = corresponding interrupt bit enabled.

| Interrupt Control Status/Clear Register 0 | | | | | | | |
|---|--------------------|----------|----------|----------|----------|----------|------------|
| REG[404Ah] Default = 00h | | | | | | | Read/Write |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | USB Host Connected | Reserved | Reserved | Reserved | Reserved | USBRESET | Reserved |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

On reads, these bits represent the interrupt status for interrupts caused by low-to-high transitions on the corresponding signals.

0 (read) = no low-to-high event detected on the corresponding signal.

1 (read) = low-to-high event detected on the corresponding signal.

On writes, these bits clear the corresponding interrupt status bit.

0 (write) = corresponding interrupt status bit unchanged.

1 (write) = corresponding interrupt status bit cleared to zero.

These bits must always be cleared via a write to this register before first use. This will ensure that any changes on input pins during system initialization do not generate erroneous interrupts. The interrupt bits are used as follows.

- bit 6 **USB Host Connected**
Indicates the USB device is connected to a USB host.
- bit 5 Reserved.
Must be set to 0.
- bit 4 Reserved.
Must be set to 0.
- bit 3 Reserved.
Must be set to 0.
- bit 2 Reserved.
Must be set to 0.
- bit 1 **USBRESET**
Indicates the USB device is reset using the RESET# pin or using the USB port reset.
- bit 0 Reserved.
Must be set to 0.

| Interrupt Control Status/Clear Register 1 | | | | | | | |
|---|-----------------------|----------|-------------------|----------|----------|----------|------------|
| REG[404Ch] Default = 00h | | | | | | | Read/Write |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | USB Host Disconnected | Reserved | Device Configured | Reserved | Reserved | Reserved | INT |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

On reads, these bits represent the interrupt status for interrupts caused by high-to-low transitions on the corresponding signals.

0 (read) = no high-to-low event detected on the corresponding signal.

1 (read) = high-to-low event detected on the corresponding signal.

On writes, these bits clear the corresponding interrupt status bit.

0 (write) = corresponding interrupt status bit unchanged.

1 (write) = corresponding interrupt status bit cleared to zero.

These bits must always be cleared via a write to this register before first use. This will ensure that any changes on input pins during system initialization do not generate erroneous interrupts. The interrupt bits are used as follows.

| | |
|-------|---|
| bit 6 | USB Host Disconnected Indicates the USB device is disconnected from a USB host. |
| bit 5 | Reserved. Must be set to 0. |
| bit 4 | Device Configured. Indicates the USB device has been configured by the USB host. |
| bit 3 | Reserved. Must be set to 0. |
| bit 2 | Reserved. Must be set to 0. |
| bit 1 | Reserved. Must be set to 0. |
| bit 0 | INT Indicates an interrupt request originating from within the USB registers (REG[4000h] to REG[403Ah]). |

| Interrupt Control Masked Status Register 0 | | | | | | | |
|---|--------------------|----------|----------|----------|----------|----------|-----------|
| REG[404Eh] Default = 00h | | | | | | | Read Only |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | USB Host Connected | Reserved | Reserved | Reserved | Reserved | USBRESET | Reserved |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

These read-only bits represent the logical AND of the corresponding Interrupt Control Status/Clear Register 0 (REG[404Ah]) and the Interrupt Control Enable Register 0 (REG[4046h]).

| Interrupt Control Masked Status Register 1 | | | | | | | |
|---|-----------------------|----------|-------------------|----------|----------|----------|-----------|
| REG[4050h] Default = 00h | | | | | | | Read Only |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | USB Host Disconnected | Reserved | Device Configured | Reserved | Reserved | Reserved | INT |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

These read-only bits represent the logical AND of the corresponding Interrupt Control Status/Clear Register 1 (REG[404Ch]) and the Interrupt Control Enable Register 1 (REG[4048h]).

| USB Software Reset Register | | | | | | | |
|---|----|----|----|----|----|---|------------|
| REG[4052h] Default = 00h | | | | | | | Write Only |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| USB Software Reset (Code = 10100100) bits 7-0 | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 7-0

USB Software Reset Bits [7:0] (Write Only)

When the specific code of 10100100b is written to these bits the USB module of the S1D13A05 is reset. Use of the above code avoids the possibility of accidentally resetting the USB.

| USB Wait State Register | | | | | | | |
|--------------------------------|----|----|----|----|----|-------------------------|------------|
| REG[4054h] Default = 00h | | | | | | | Read/Write |
| n/a | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 |
| n/a | | | | | | USB Wait State bits 1-0 | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 1-0

USB Wait State Bits [1:0]

This register controls the number of wait states the S1D13A05 uses for its internal USB support. For all bus interfaces supported by the S1D13A05 **these bits must be set to 01.**

8.5 2D Acceleration (BitBLT) Registers (Offset = 8000h)

These registers control the S1D13A05 2D Acceleration engine. For detailed BitBLT programming instructions, see the *S1D13A05 Programming Notes and Examples*, document number X40A-G-003-xx.

| BitBLT Control Register | | | | | | | | | | | | | | Read/Write | | |
|-------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------------------|--------------------------|----------------------------|
| REG[8000h] | | | | | | | | | | | | | | Default = 00000000h | | |
| n/a | | | | | | | | | | | | | | Color Format Select | Dest Linear Select | Source Linear Select |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | | | | | | | | | BitBLT Enable (WO) |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bit 18 BitBLT Color Format Select
This bit selects the color format that the 2D operation is applied to.
When this bit = 0, 8 bpp (256 color) format is selected.
When this bit = 1, 16 bpp (64K color) format is selected.
- bit 17 BitBLT Destination Linear Select
When this bit = 1, the Destination BitBLT is stored as a contiguous linear block of memory.
When this bit = 0, the Destination BitBLT is stored as a rectangular region of memory.
The BitBLT Memory Address Offset register (REG[8014h]) determines the address offset from the start of one line to the next line.
- bit 16 BitBLT Source Linear Select
When this bit = 1, the Source BitBLT is stored as a contiguous linear block of memory.
When this bit = 0, the Source BitBLT is stored as a rectangular region of memory.
The BitBLT Memory Address Offset register (REG[8014h]) determines the address offset from the start of one line to the next line.
- bit 0 BitBLT Enable
This bit is write only.
Setting this bit to 1 begins the 2D BitBLT operation. **This bit must not be set to 0 while a BitBLT operation is in progress.**

Note

To determine the status of a BitBLT operation use the BitBLT Busy Status bit (REG[8004h] bit 0).

| BitBLT Status Register | | | | | | | | | | | | | | | Read Only | |
|------------------------|----|----|-----------------------------|----|----|----|----|----|----------------|----------------|------------------|--|----|----|---------------------|--|
| REG[8004h] | | | | | | | | | | | | | | | Default = 00000000h | |
| n/a | | | Number of Used FIFO Entries | | | | | | n/a | | | Number of Free FIFO Entries (0 means full) | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | | FIFO Not Empty | FIFO Half Full | FIFO Full Status | n/a | | | BitBLT Busy Status | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

- bits 28-24 Number of Used FIFO Entries Bits [4:0]
These bits indicate the minimum number of FIFO entries currently in use (there may be more values in internal pipeline stages).
- bits 20-16 Number of Free FIFO Entries Bits [4:0]
These bits indicate the number of empty FIFO entries available. If these bits return a 0, the FIFO is full.
- bit 6 BitBLT FIFO Not-Empty Status
This is a read-only status bit.
When this bit = 0, the BitBLT FIFO is empty.
When this bit = 1, the BitBLT FIFO has at least one data.
To reduce system memory read latency, software can monitor this bit prior to a BitBLT read burst operation.
- The following table shows the number of words available in BitBLT FIFO under different status conditions.

Table 8-34: BitBLT FIFO Words Available

| BitBLT FIFO Full Status (REG[8004h] Bit 4) | BitBLT FIFO Half Full Status (REG[8004h] Bit 5) | BitBLT FIFO Not Empty Status (REG[8004h] Bit 6) | Number of Words available in BitBLT FIFO |
|---|--|--|--|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 to 6 |
| 0 | 1 | 1 | 7 to 14 |
| 1 | 1 | 1 | 15 to 16 |

- bit 5 BitBLT FIFO Half Full Status
This is a read-only status bit.
When this bit = 1, the BitBLT FIFO is half full or greater than half full.
When this bit = 0, the BitBLT FIFO is less than half full.
- bit 4 BitBLT FIFO Full Status
This is a read-only status bit.
When this bit = 1, the BitBLT FIFO is full.
When this bit = 0, the BitBLT FIFO is not full.

bit 0 BitBLT Busy Status
This bit is a read-only status bit.
When this bit = 1, the BitBLT operation is in progress.
When this bit = 0, the BitBLT operation is complete.

Note

During a BitBLT Read operation, the BitBLT engine does not attempt to keep the FIFO full. If the FIFO becomes full, the BitBLT operation stops temporarily as data is read out of the FIFO. The BitBLT will restart only when less than 14 values remain in the FIFO.

| BitBLT Command Register | | | | | | | | | | | | Read/Write | | | |
|--------------------------------|----|----|----|----|----|----|----|----|----|----|----|---------------------------|----|----|----|
| REG[8008h] Default = 00000000h | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | BitBLT ROP Code bits 3-0 | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | | BitBLT Operation bits 3-0 | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 19-16 BitBLT Raster Operation Code/Color Expansion Bits [3:0]
ROP Code for Write BitBLT and Move BitBLT. Bits 2-0 also specify the start bit position for Color Expansion.

Table 8-35 : BitBLT ROP Code/Color Expansion Function Selection

| BitBLT ROP Code Bits [3:0] | Boolean Function for Write BitBLT and Move BitBLT | Boolean Function for Pattern Fill | Start Bit Position for Color Expansion |
|----------------------------|---|--|--|
| 0000 | 0 (Blackness) | 0 (Blackness) | bit 0 |
| 0001 | $\sim S \cdot \sim D$ or $\sim(S + D)$ | $\sim P \cdot \sim D$ or $\sim(P + D)$ | bit 1 |
| 0010 | $\sim S \cdot D$ | $\sim P \cdot D$ | bit 2 |
| 0011 | $\sim S$ | $\sim P$ | bit 3 |
| 0100 | $S \cdot \sim D$ | $P \cdot \sim D$ | bit 4 |
| 0101 | $\sim D$ | $\sim D$ | bit 5 |
| 0110 | $S \wedge D$ | $P \wedge D$ | bit 6 |
| 0111 | $\sim S + \sim D$ or $\sim(S \cdot D)$ | $\sim P + \sim D$ or $\sim(P \cdot D)$ | bit 7 |
| 1000 | $S \cdot D$ | $P \cdot D$ | bit 0 |
| 1001 | $\sim(S \wedge D)$ | $\sim(P \wedge D)$ | bit 1 |
| 1010 | D | D | bit 2 |
| 1011 | $\sim S + D$ | $\sim P + D$ | bit 3 |
| 1100 | S | P | bit 4 |
| 1101 | $S + \sim D$ | $P + \sim D$ | bit 5 |
| 1110 | $S + D$ | $P + D$ | bit 6 |
| 1111 | 1 (Whiteness) | 1 (Whiteness) | bit 7 |

Note

S = Source, D = Destination, P = Pattern.
 \sim = NOT, \cdot = Logical AND, $+$ = Logical OR, \wedge = Logical XOR

bits 3-0

BitBLT Operation Bits [3:0]

Specifies the 2D Operation to be carried out based on the following table.

Table 8-36 : BitBLT Operation Selection

| BitBLT Operation Bits [3:0] | BitBLT Operation |
|-----------------------------|--|
| 0000 | Write BitBLT with ROP. |
| 0001 | Read BitBLT. |
| 0010 | Move BitBLT in positive direction with ROP. |
| 0011 | Move BitBLT in negative direction with ROP. |
| 0100 | Transparent Write BitBLT. |
| 0101 | Transparent Move BitBLT in positive direction. |
| 0110 | Pattern Fill with ROP. |
| 0111 | Pattern Fill with transparency. |
| 1000 | Color Expansion. |
| 1001 | Color Expansion with transparency. |
| 1010 | Move BitBLT with Color Expansion. |
| 1011 | Move BitBLT with Color Expansion and transparency. |
| 1100 | Solid Fill. |
| Other combinations | Reserved |

| BitBLT Source Start Address Register | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|--|----|----|----|----|------------|--|
| REG[800Ch] | | | | | | | | | | | Default = 00000000h | | | | | Read/Write | |
| n/a | | | | | | | | | | | BitBLT Source Start Address bits 20-16 | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| BitBLT Source Start Address bits 15-0 | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 20-0

BitBLT Source Start Address Bits [20:0]

A 21-bit register that specifies the source start address for the BitBLT operation.

If data is sourced from the CPU, then bit 0 is used for byte alignment within a 16-bit word and the other address bits are ignored. In pattern fill operation, the BitBLT Source Start Address is defined by the following equation.

$$\text{Value programmed to the Source Start Address Register} = \text{Pattern Base Address} + \text{Pattern Line Offset} + \text{Pixel Offset.}$$

The following table shows how Source Start Address Register is defined for 8 and 16 bpp color depths.

Table 8-37 : BitBLT Source Start Address Selection

| Color Format | Pattern Base Address[20:0] | Pattern Line Offset[2:0] | Pixel Offset[3:0] |
|--------------|-----------------------------------|----------------------------------|----------------------------------|
| 8 bpp | BitBLT Source Start Address[20:6] | BitBLT Source Start Address[5:3] | BitBLT Source Start Address[2:0] |
| 16 bpp | BitBLT Source Start Address[20:7] | BitBLT Source Start Address[6:4] | BitBLT Source Start Address[3:0] |

Note

For further information on the BitBLT Source Start Address register, see the *S1D13A05 Programming Notes and Examples*, document number X40A-G-003-xx.

| BitBLT Destination Start Address Register | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|----|----|----|----|----|---|----|----|----|----|
| REG[8010h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | BitBLT Destination Start Address bits 20-16 | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Destination Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 20-0

BitBLT Destination Start Address Bits [20:0]

A 21-bit register that specifies the destination start address for the BitBLT operation.

| BitBLT Memory Address Offset Register | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|--|----|----|----|----|--|----|----|----|----|
| REG[8014h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | BitBLT Memory Address Offset bits 10-0 | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Memory Address Offset bits 10-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 10-0

BitBLT Memory Address Offset Bits [10:0]These bits are the display's 11-bit address offset from the starting word of line n to the starting word of line $n + 1$. They are used only for address calculation when the BitBLT is configured as a rectangular region of memory. They are not used for the displays.

| BitBLT Width Register | | | | | | | | | | | | | | | |
|-------------------------------------|----|----|----|----|----|-----------------------|----|----|----|----|-----------------------|----|----|----|----|
| REG[8018h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | BitBLT Width bits 9-0 | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Width bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

BitBLT Width Bits [9:0]

A 10-bit register that specifies the BitBLT width in pixels - 1.

BitBLT width in pixels = (REG[8018h] bits 9-0) + 1

| BitBLT Height Register | | | | | | | | | | | | | | | |
|-------------------------------------|----|----|----|----|----|------------------------|----|----|----|----|------------------------|----|----|----|----|
| REG[801Ch] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | BitBLT Height bits 9-0 | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Height bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 9-0

BitBLT Height Bits [9:0]

A 10-bit register that specifies the BitBLT height in lines - 1.

BitBLT height in lines = (REG[801Ch] bits 9-0) + 1

| BitBLT Background Color Register | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------------|----|------------|--|
| REG[8020h] | | | | | | | | | | | | | | Default = 00000000h | | Read/Write | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| BitBLT Background Color bits 15-0 | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 15-0 BitBLT Background Color Bits [15:0]
 This register specifies the BitBLT background color for Color Expansion or key color for Transparent BitBLT. For 16 bpp color depths (REG[8000h] bit 18 = 1), bits 15-0 are used. For 8 bpp color depths (REG[8000h] bit 18 = 0), bits 7-0 are used.

| BitBLT Foreground Color Register | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------------|----|------------|--|
| REG[8024h] | | | | | | | | | | | | | | Default = 00000000h | | Read/Write | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| BitBLT Foreground Color bits 15-0 | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

bits 15-0 BitBLT Foreground Color Bits [15:0]
 This register specifies the BitBLT foreground color for Color Expansion or Solid Fill. For 16 bpp color depths (REG[8000h] bit 18 = 1), bits 15-0 are used. For 8 bpp color depths (REG[8000h] bit 18 = 0), bits 7-0 are used.

8.6 2D Accelerator (BitBLT) Data Register Descriptions

The 2D Accelerator (BitBLT) data registers decode AB15-AB0 and require AB16 = 1. The BitBLT data registers are 32-bit wide. Byte access to the BitBLT data registers is not allowed.

| 2D Accelerator (BitBLT) Data Memory Mapped Region Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|------------|----|
| AB16-AB0 = 10000h-1FFFEh, even addresses | | | | | | | | | | | | | | Read/Write | |
| BitBLT Data bits 31-16 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Data bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

bits 15-0 BitBLT Data Bits [15:0]
 This register specifies the BitBLT data. This register is loosely decoded from 10000h to 1FFFEh.

9 2D Accelerator (BitBLT) Engine

9.1 Overview

The S1D13A05 is designed with a built-in 2D BitBLT engine which increases the performance of Bit Block Transfers (BitBLT). It supports 8 and 16 bit-per-pixel color depths.

The BitBLT engine supports rectangular and linear addressing modes for source and destination in a positive direction for all BitBLT operations except the move BitBLT which also supports in a negative direction.

The BitBLT operations support byte alignment of all types. The BitBLT engine has a dedicated BitBLT IO access space. This allows the BitBLT engine to support simultaneous BitBLT and host side operations.

9.2 BitBLT Operations

The S1D13A05 2D BitBLT engine supports the following BitBLTs. For detailed information on using the individual BitBLT operations, refer to the S1D13A05 Programming Notes and Examples, document number X40A-G-003-xx.

- Write BitBLT.
- Move BitBLT.
- Solid Fill BitBLT.
- Pattern Fill BitBLT.
- Transparent Write BitBLT.
- Transparent Move BitBLT.
- Read BitBLT.
- Color Expansion BitBLT.
- Move BitBLT with Color Expansion.

Note

For details on the BitBLT registers, see Section 8.5, “2D Acceleration (BitBLT) Registers (Offset = 8000h)” on page 160.

10 Frame Rate Calculation

The following formula is used to calculate the display frame rate.

$$\text{FrameRate} = \frac{f_{\text{PCLK}}}{(\text{HT}) \times (\text{VT})}$$

Where:

f_{PCLK} = PCLK frequency (Hz)

HT = Horizontal Total
= ((REG[20h] bits 6-0) + 1) x 8 Pixels

VT = Vertical Total
= ((REG[30h] bits 9-0) + 1) Lines

11 Display Data Formats

The following diagrams show the display mode data formats for a little-endian system.

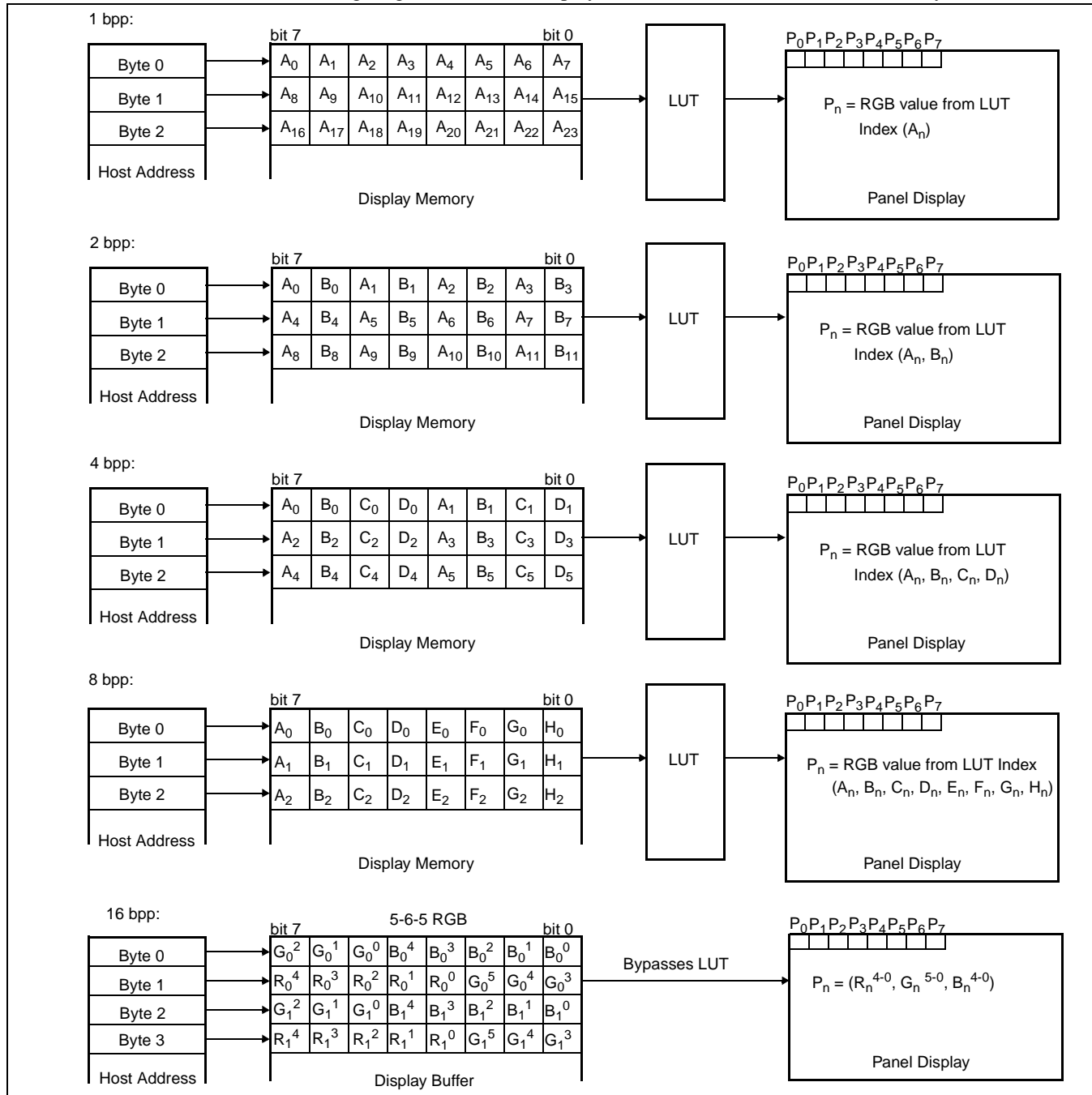


Figure 11-1: 4/8/16 Bit-Per-Pixel Display Data Memory Organization

Note

1. The Host-to-Display mapping shown here is for a little endian system.
2. For 16 bpp format, R_n, G_n, B_n represent the red, green, and blue color components.

12 Look-Up Table Architecture

The following figures are intended to show the display data output path only.

Note

When Video Data Invert is enabled the video data is inverted after the Look-Up Table.

12.1 Monochrome Modes

The green Look-Up Table (LUT) is used for all monochrome modes.

1 Bit-per-pixel Monochrome Mode

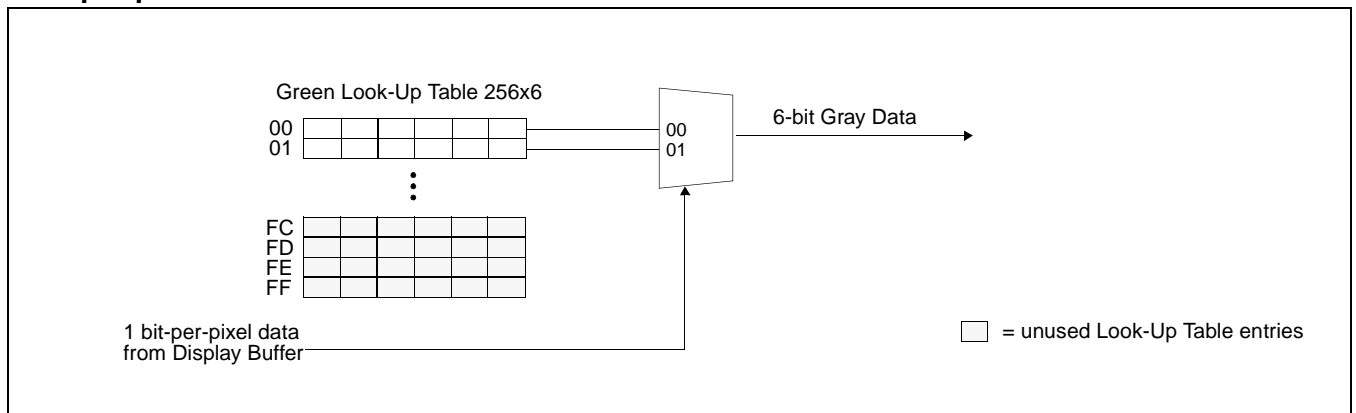


Figure 12-1: 1 Bit-per-pixel Monochrome Mode Data Output Path

2 Bit-per-pixel Monochrome Mode

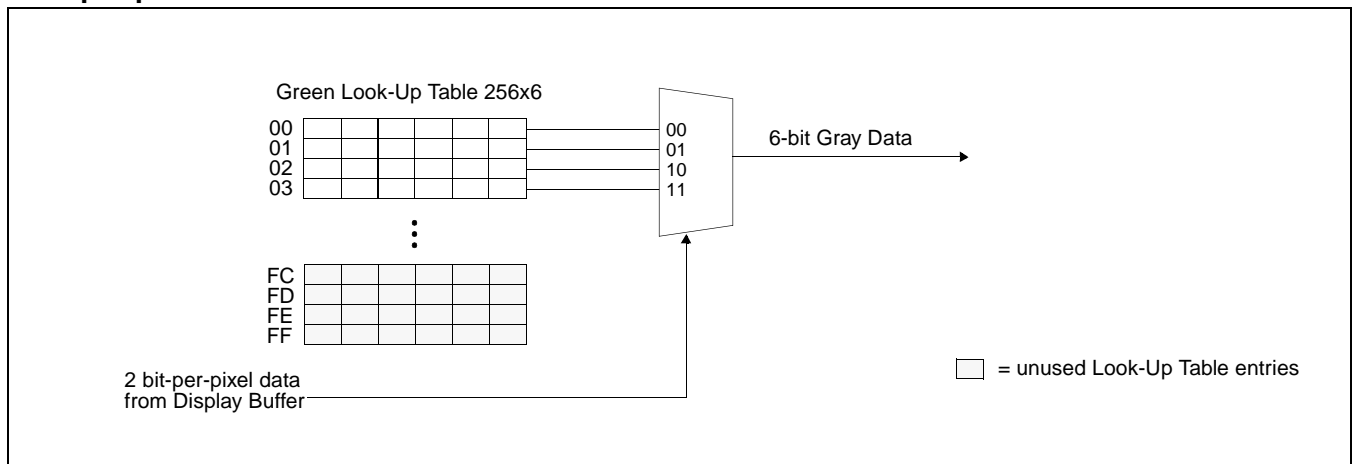


Figure 12-2: 2 Bit-per-pixel Monochrome Mode Data Output Path

4 Bit-per-pixel Monochrome Mode

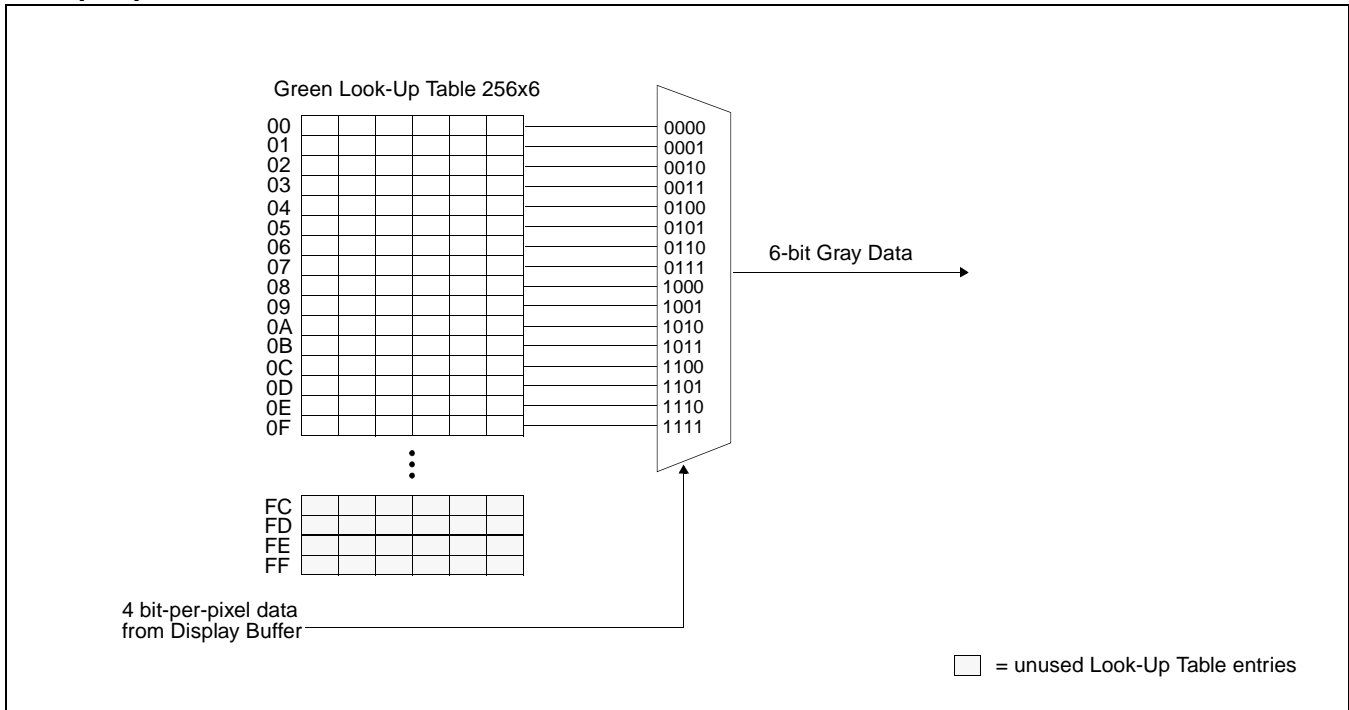


Figure 12-3: 4 Bit-per-pixel Monochrome Mode Data Output Path

8 Bit-per-pixel Monochrome Mode

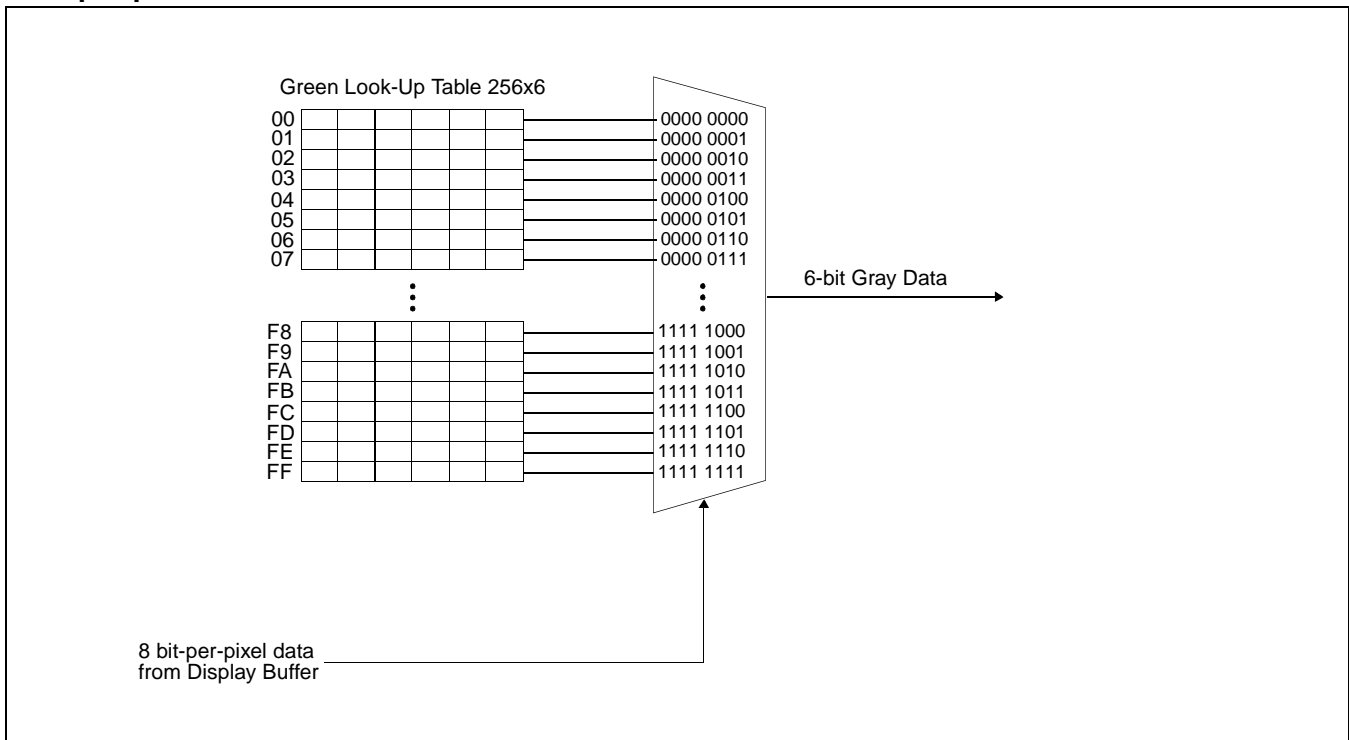


Figure 12-4: 8 Bit-per-pixel Monochrome Mode Data Output Path

16 Bit-Per-Pixel Monochrome Mode

The LUT is bypassed and the green data is directly mapped for this color depth– “Display Data Formats” on page 168..

12.2 Color Modes

1 Bit-Per-Pixel Color

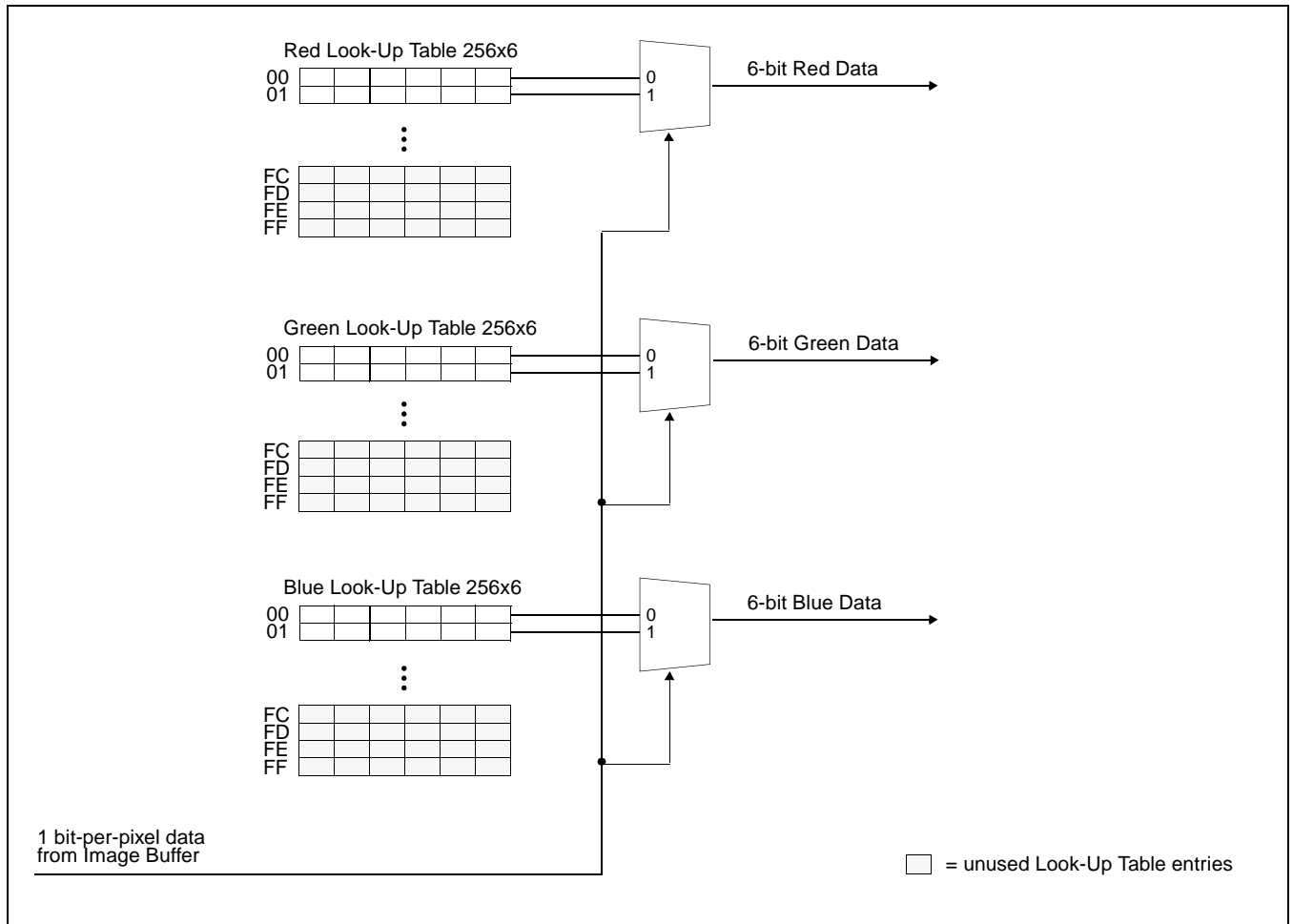


Figure 12-5: 1 Bit-Per-Pixel Color Mode Data Output Path

2 Bit-Per-Pixel Color

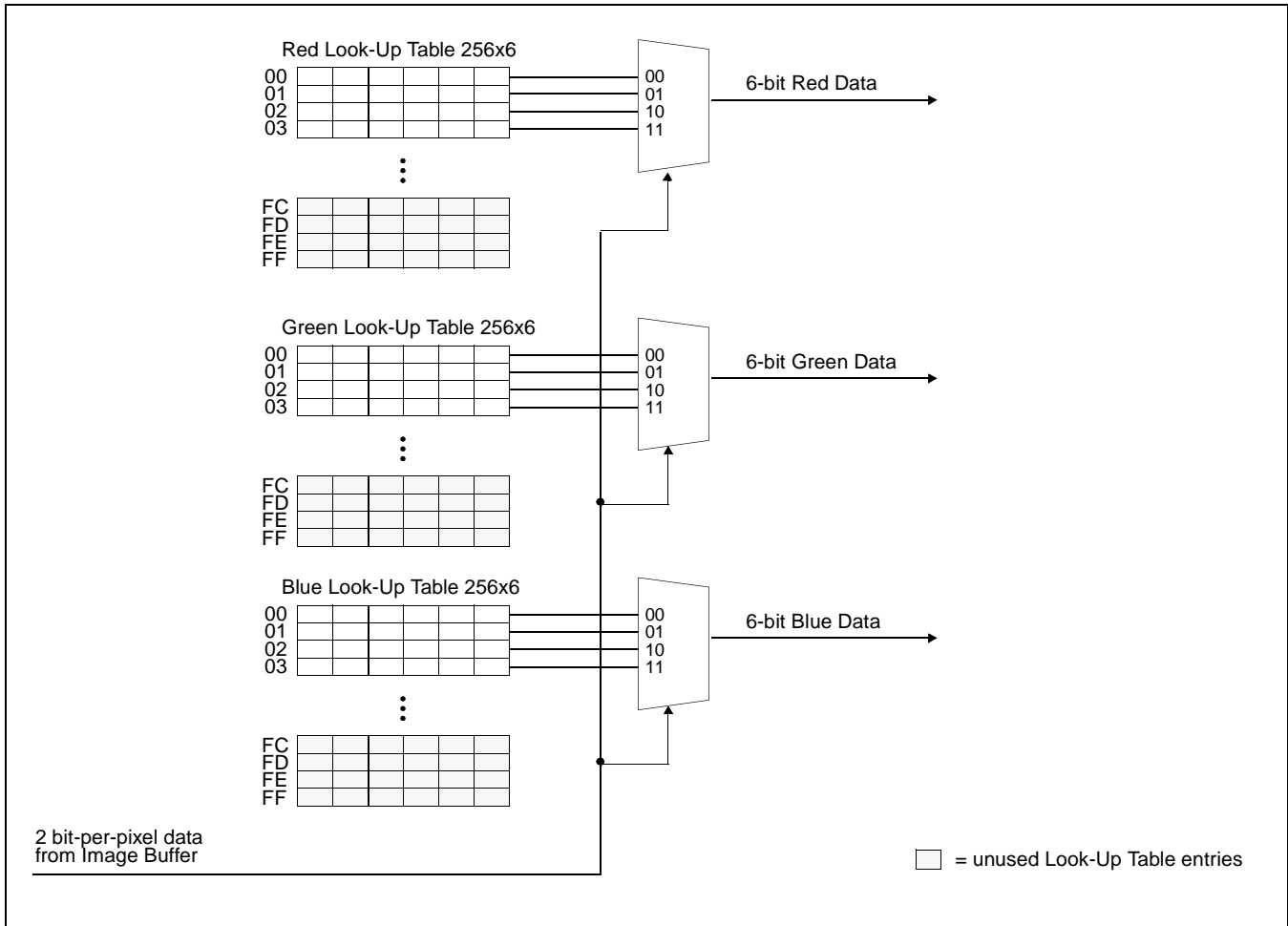


Figure 12-6: 2 Bit-Per-Pixel Color Mode Data Output Path

4 Bit-Per-Pixel Color

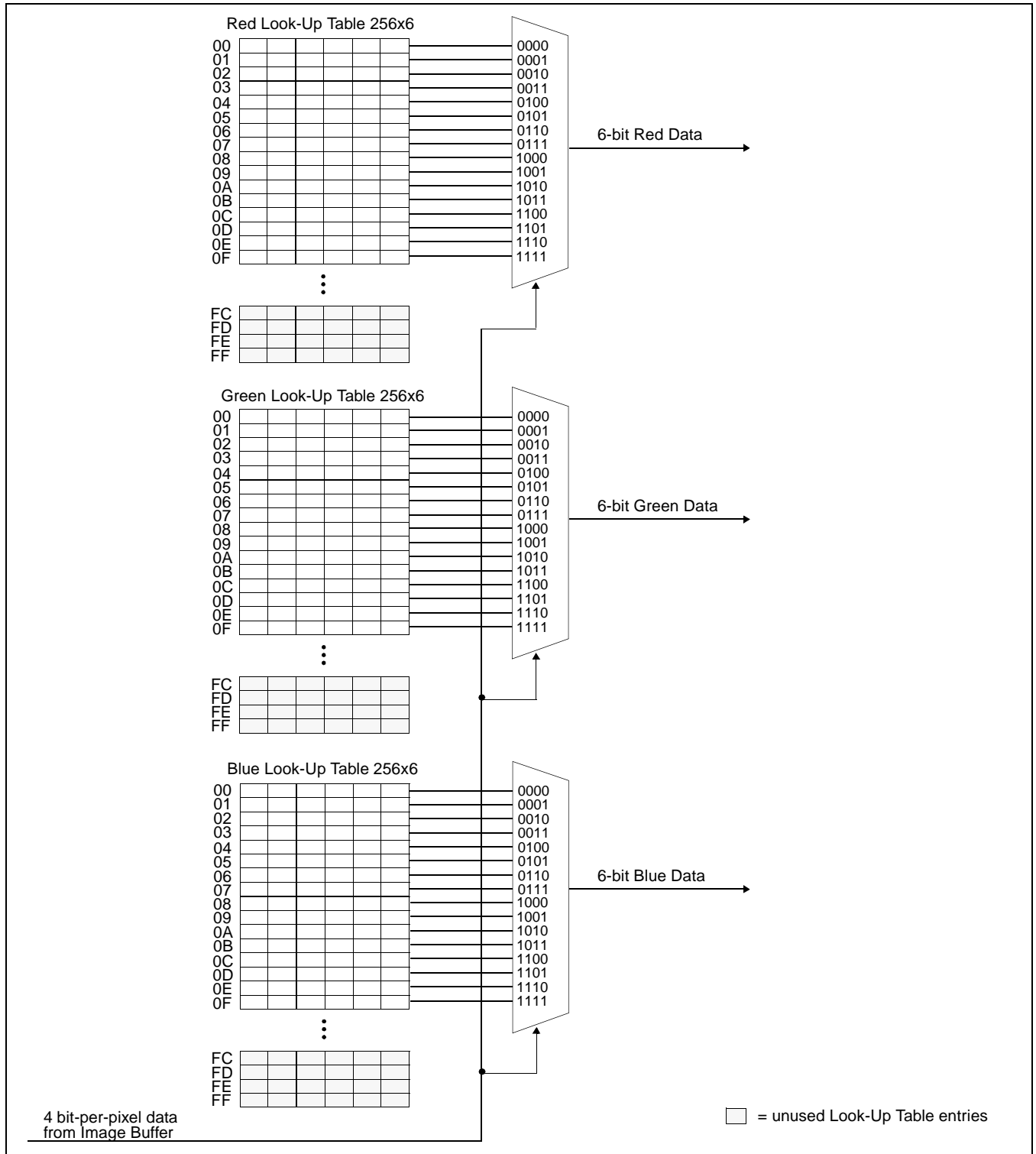


Figure 12-7: 4 Bit-Per-Pixel Color Mode Data Output Path

8 Bit-per-pixel Color Mode

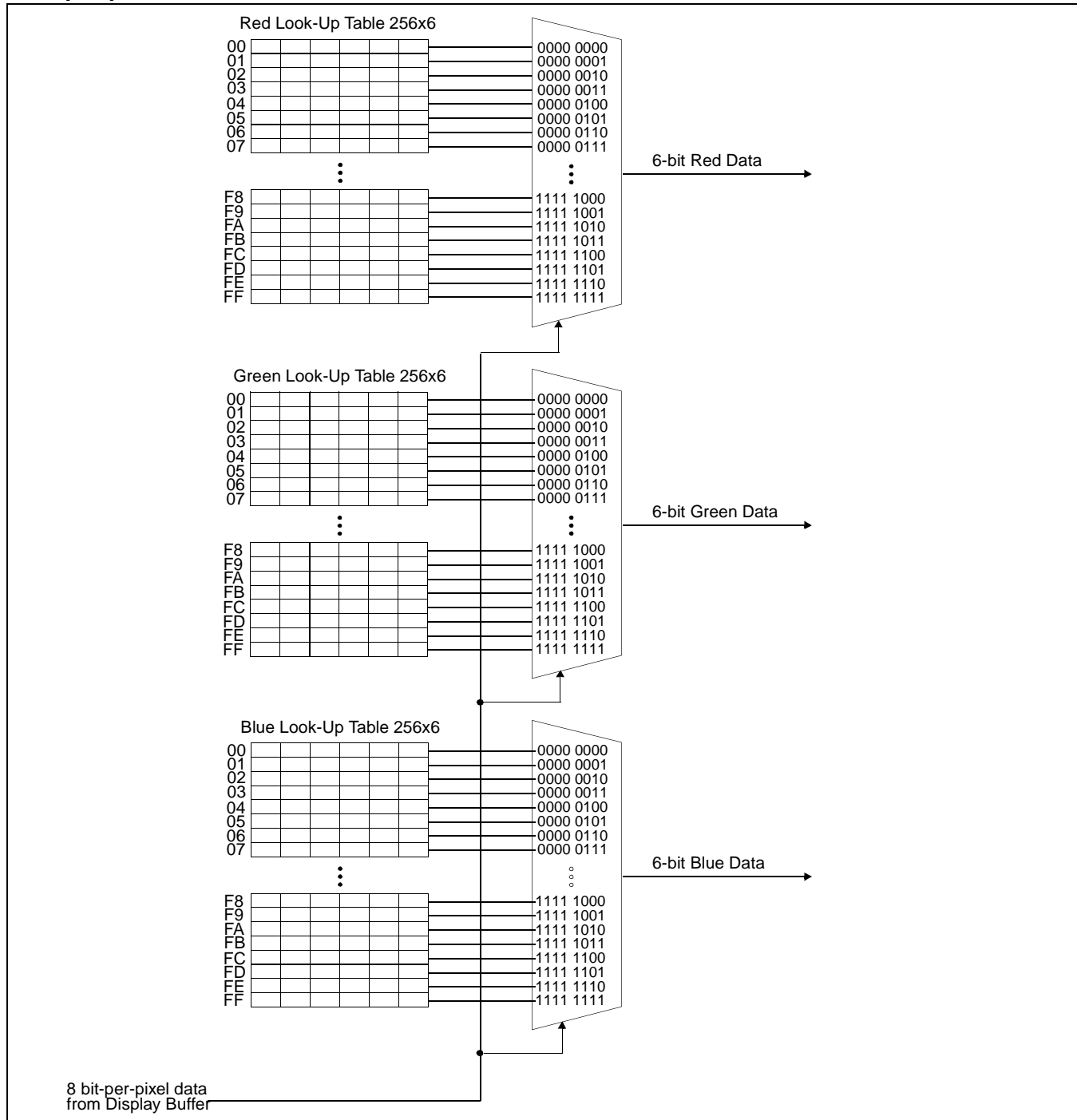


Figure 12-8: 8 Bit-per-pixel Color Mode Data Output Path

16 Bit-Per-Pixel Color Mode

The LUT is bypassed and the color data is directly mapped for this color depth— “Display Data Formats” on page 168.

13 SwivelView™

13.1 Concept

Most computer displays are refreshed in landscape orientation – from left to right and top to bottom. Computer images are stored in the same manner. SwivelView™ is designed to rotate the displayed image on an LCD by 90°, 180°, or 270° in a counter-clockwise direction. The rotation is done in hardware and is transparent to the user for all display buffer reads and writes. By processing the rotation in hardware, SwivelView™ offers a performance advantage over software rotation of the displayed image.

The image is not actually rotated in the display buffer since there is no address translation during CPU read/write. The image is rotated during display refresh.

13.2 90° SwivelView™

90° SwivelView™ requires the Memory Clock (MCLK) to be at least 1.25 times the frequency of the Pixel Clock (PCLK), i.e. $MCLK \geq 1.25PCLK$.

The following figure shows how the programmer sees a 320x480 portrait image and how the image is being displayed. The application image is written to the S1D13A05 in the following sense: A–B–C–D. The display is refreshed by the S1D13A05 in the following sense: B–D–A–C.

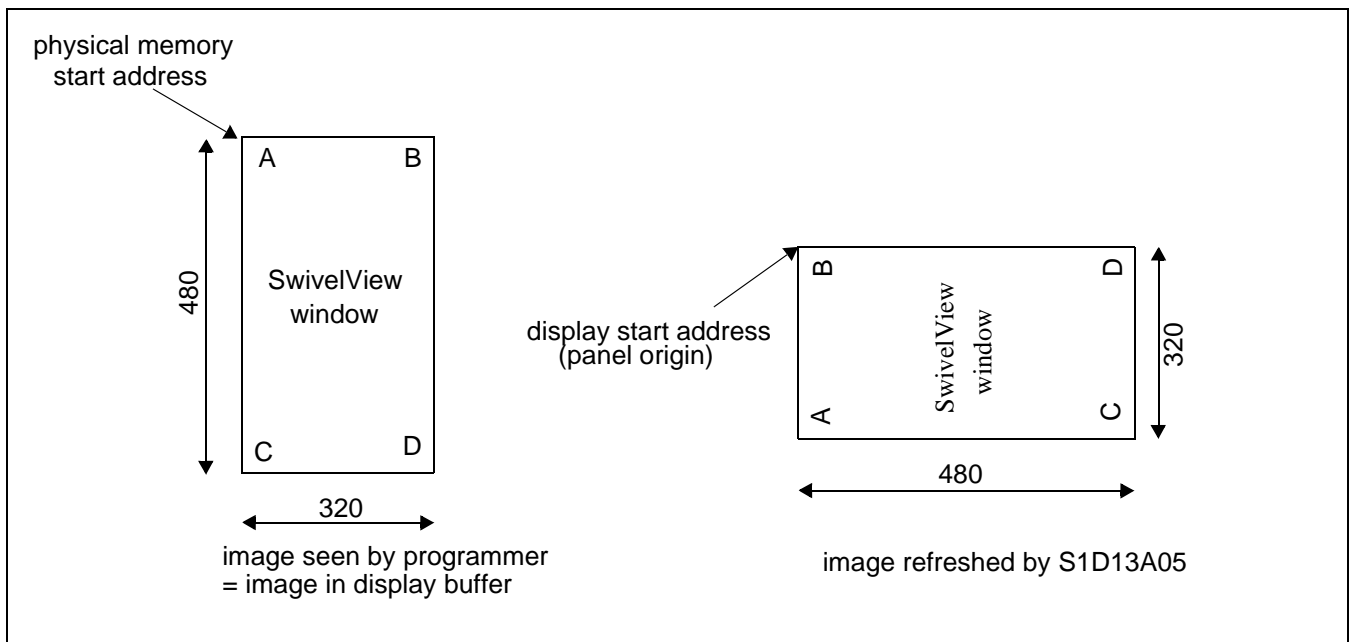


Figure 13-1: Relationship Between The Screen Image and the Image Refreshed in 90° SwivelView.

13.2.1 Register Programming

Enable 90° SwivelView™ Mode

Set SwivelView™ Mode Select bits (REG[10h] bits 17:16) to 01.

Display Start Address

The display refresh circuitry starts at pixel “B”, therefore the Main Window Display Start Address register (REG[40h]) must be programmed with the address of pixel “B”. To calculate the value of the address of pixel “B” use the following formula (assumes 8 bpp color depth).

$$\begin{aligned}\text{REG}[40\text{h}] \text{ bits } 16:0 &= ((\text{image address} + (\text{panel height} \times \text{bpp} \div 8)) \div 4) - 1 \\ &= ((0 + (320 \text{ pixels} \times 8 \text{ bpp} \div 8)) \div 4) - 1 \\ &= 79 (4\text{Fh})\end{aligned}$$

Line Address Offset

The Main Window Line Address Offset register (REG[44h]) is based on the display width and programmed using the following formula.

$$\begin{aligned}\text{REG}[44\text{h}] \text{ bits } 9:0 &= \text{display width in pixels} \div (32 \div \text{bpp}) \\ &= 320 \text{ pixels} \div 32 \div 8 \text{ bpp} \\ &= 80 (50\text{h})\end{aligned}$$

13.3 180° SwivelView™

The following figure shows how the programmer sees a 480x320 landscape image and how the image is being displayed. The application image is written to the S1D13A05 in the following sense: A–B–C–D. The display is refreshed by the S1D13A05 in the following sense: D–C–B–A.

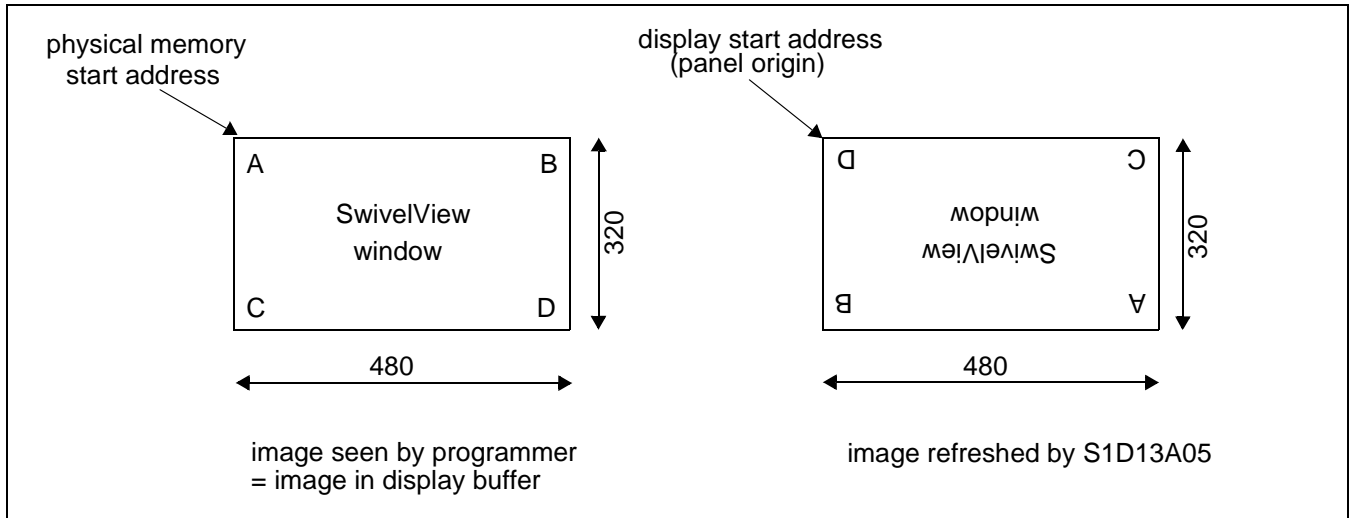


Figure 13-2: Relationship Between The Screen Image and the Image Refreshed in 180° SwivelView.

13.3.1 Register Programming

Enable 180° SwivelView™ Mode

Set SwivelView™ Mode Select bits (REG[10h] bits 17:16) to 10.

Display Start Address

The display refresh circuitry starts at pixel “D”, therefore the Main Window Display Start Address register (REG[40h]) must be programmed with the address of pixel “D”. To calculate the value of the address of pixel “D” use the following formula (assumes 8 bpp color depth).

$$\begin{aligned}
 &\text{REG}[40\text{h}] \text{ bits } 16:0 \\
 &= ((\text{image address} + (\text{offset} \times (\text{panel height} - 1) + \text{panel width}) \times \text{bpp} \div 8) \div 4) - 1 \\
 &= ((0 + (480 \text{ pixels} \times 319 \text{ pixels} + 480 \text{ pixels}) \times 8 \text{ bpp} \div 8) \div 4) - 1 \\
 &= 38399 \text{ (95FFh)}
 \end{aligned}$$

Line Address Offset

The Main Window Line Address Offset register (REG[44h]) is based on the display width and programmed using the following formula.

$$\begin{aligned} \text{REG}[44\text{h}] \text{ bits } 9:0 &= \text{display width in pixels} \div (32 \div \text{bpp}) \\ &= 480 \text{ pixels} \div 32 \div 8 \text{ bpp} \\ &= 120 \text{ (78h)} \end{aligned}$$

13.4 270° SwivelView™

270° SwivelView™ requires the Memory Clock (MCLK) to be at least 1.25 times the frequency of the Pixel Clock (PCLK), i.e. $\text{MCLK} \geq 1.25\text{PCLK}$.

The following figure shows how the programmer sees a 320x480 portrait image and how the image is being displayed. The application image is written to the S1D13A05 in the following sense: A–B–C–D. The display is refreshed by the S1D13A05 in the following sense: C–A–D–B.

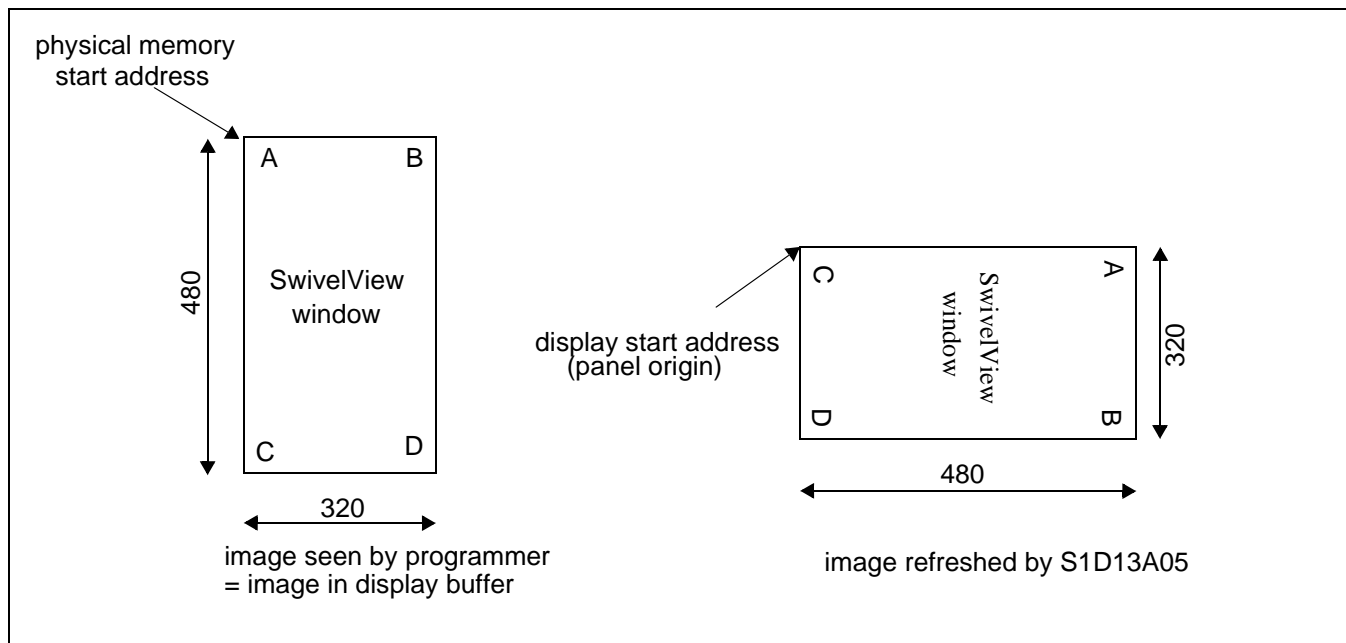


Figure 13-3: Relationship Between The Screen Image and the Image Refreshed in 270° SwivelView.

13.4.1 Register Programming

Enable 270° SwivelView™ Mode

Set SwivelView™ Mode Select bits (REG[10h] bits 17:16) to 11.

Display Start Address

The display refresh circuitry starts at pixel “C”, therefore the Main Window Display Start Address register (REG[40h]) must be programmed with the address of pixel “C”. To calculate the value of the address of pixel “C” use the following formula (assumes 8 bpp color depth).

$$\begin{aligned}\text{REG}[40\text{h}] \text{ bits } 16:0 &= (\text{image address} + ((\text{panel width} - 1) \times \text{offset} \times \text{bpp} \div 8) \div 4) \\ &= (0 + ((480 \text{ pixels} - 1) \times 320 \text{ pixels} \times 8 \text{ bpp} \div 8) \div 4) \\ &= 38320 \text{ (95B0h)}\end{aligned}$$

Line Address Offset

The Main Window Line Address Offset register (REG[44h]) is based on the display width and programmed using the following formula.

$$\begin{aligned}\text{REG}[44\text{h}] \text{ bits } 9:0 &= \text{display width in pixels} \div (32 \div \text{bpp}) \\ &= 320 \text{ pixels} \div 32 \div 8 \text{ bpp} \\ &= 80 \text{ (50h)}\end{aligned}$$

14 Picture-in-Picture Plus (PIP⁺)

14.1 Concept

Picture-in-Picture Plus (PIP⁺) enables a secondary window (or PIP⁺ window) within the main display window. The PIP⁺ window may be positioned anywhere within the virtual display and is controlled through the PIP⁺ Window control registers (REG[50h] through REG[5Ch]). The PIP⁺ window retains the same color depth and SwivelView orientation as the main window.

The following diagram shows an example of a PIP⁺ window within a main window and the registers used to position it.

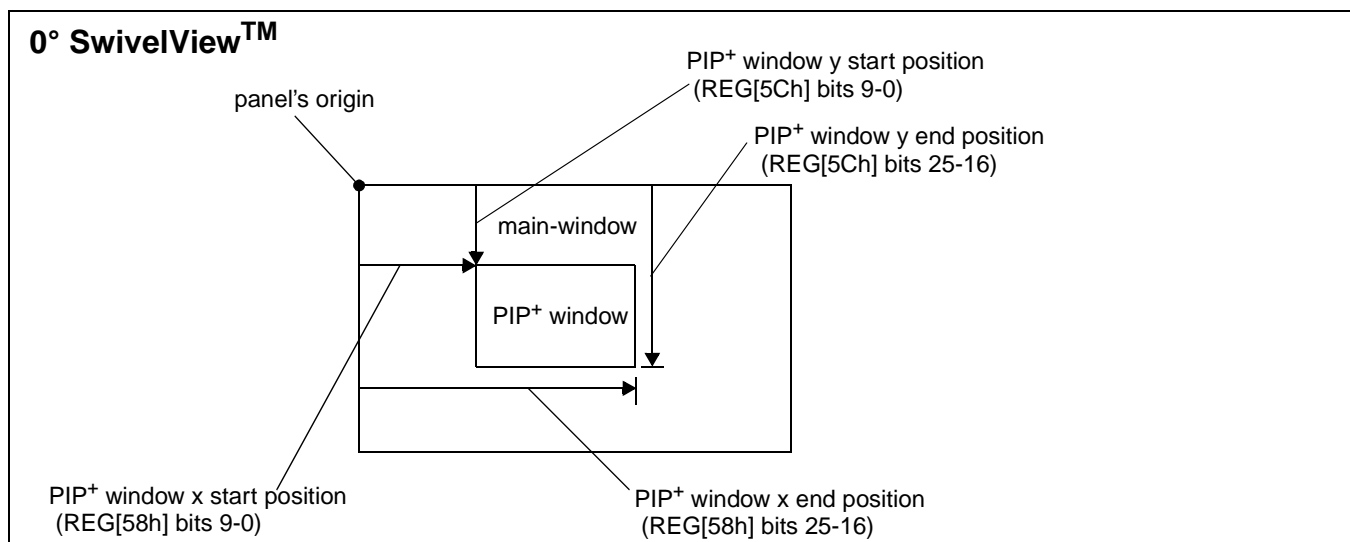


Figure 14-1: Picture-in-Picture Plus with SwivelView disabled

14.2 With SwivelView Enabled

14.2.1 SwivelView 90°

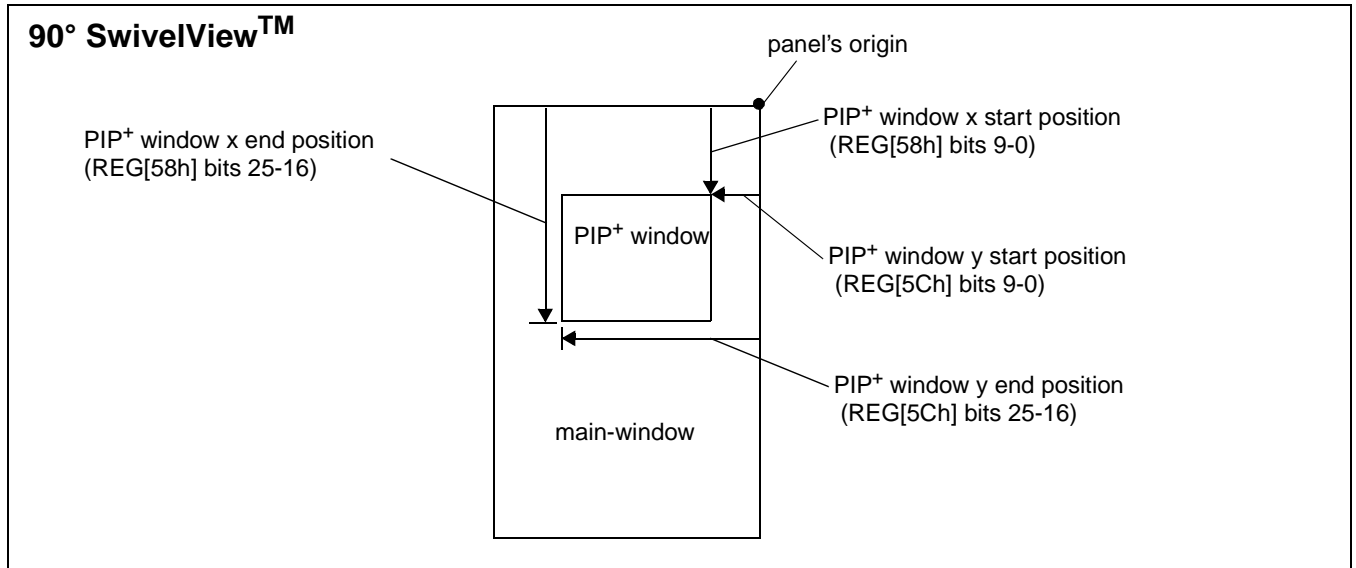


Figure 14-2: Picture-in-Picture Plus with SwivelView 90° enabled

14.2.2 SwivelView 180°

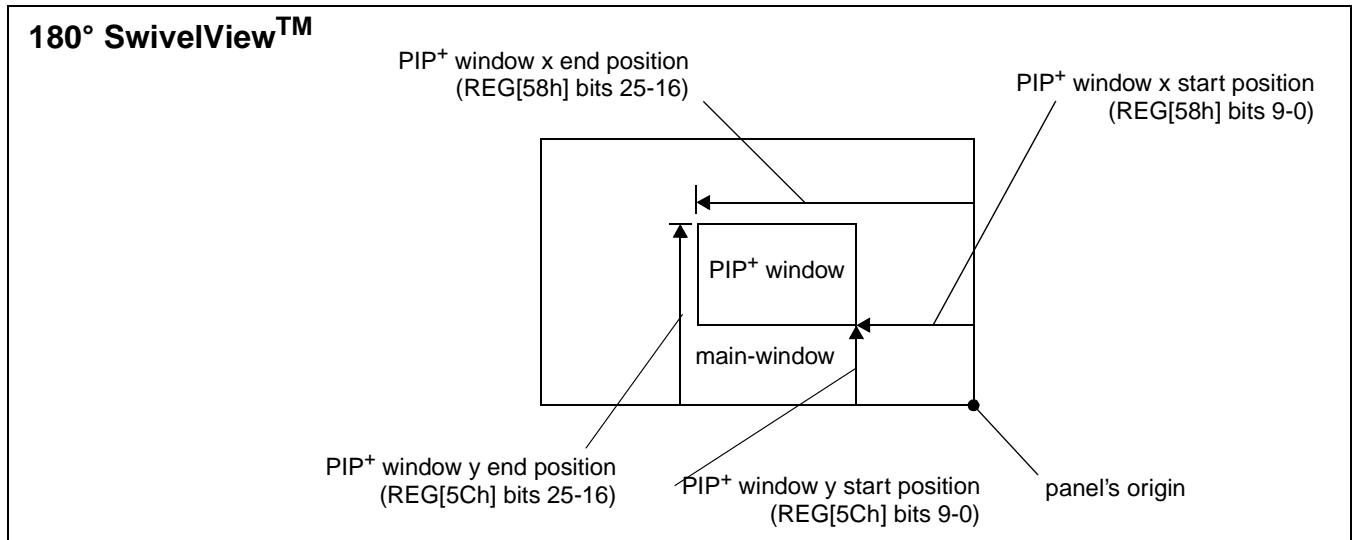


Figure 14-3: Picture-in-Picture Plus with SwivelView 180° enabled

14.2.3 SwivelView 270°

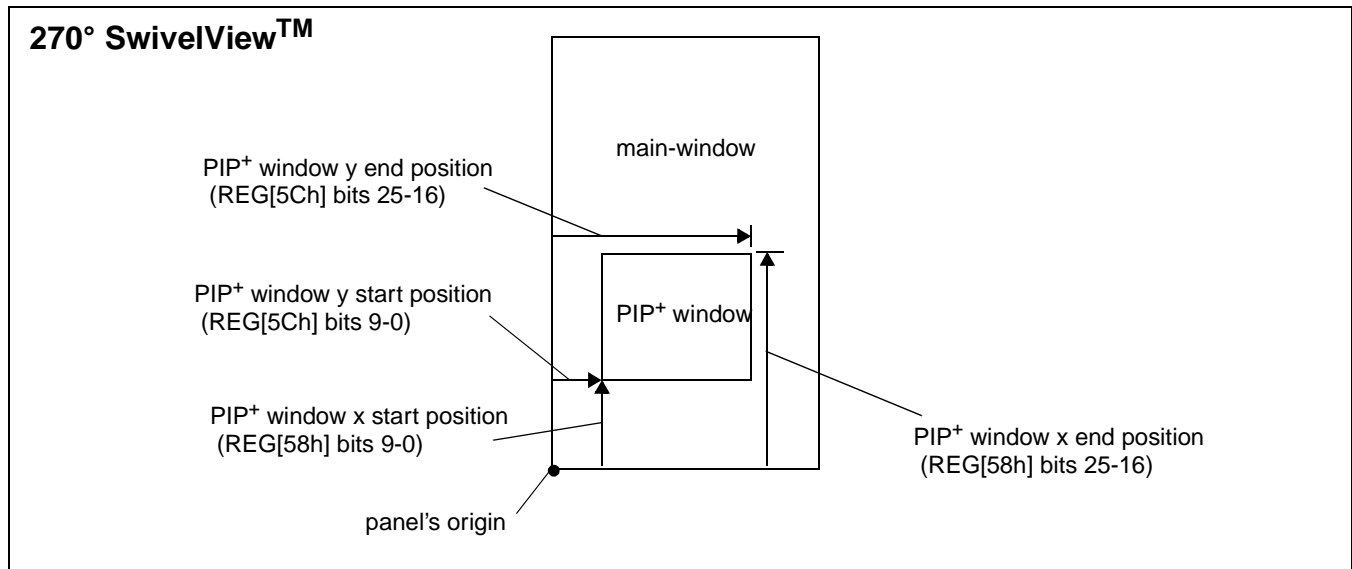


Figure 14-4: Picture-in-Picture Plus with SwivelView 270° enabled

15 Power Save Mode

A software initiated Power Save Mode is incorporated into the S1D13A05 to accommodate the need for power reduction in the hand-held devices market. This mode is enable via the Power Save Mode Enable bit (REG[14h] bit 4).

Software Power Save Mode saves power by powering down the control signals and stopping display refresh accesses to the display buffer. For programming information on disabling the clocks, see the *S1D13A05 Programming Notes and Examples*, document number X40A-G-003-xx.

Table 15-1: Power Save Mode Function Summary

| | Software Power Save | Normal |
|---|---------------------|--------|
| IO Access Possible? | Yes | Yes |
| Memory Access Possible? | Yes ¹ | Yes |
| Look-Up Table Registers Access Possible? | Yes | Yes |
| Display Active? | No | Yes |
| LCD I/F Outputs | Forced Low | Active |
| PWMCLK | Stopped | Active |
| GPIO Pins configured for HR-TFT | Forced Low | Active |
| GPIO Pins configured as GPIOs; Access Possible? | Yes ² | Yes |
| USB Running? | Yes ³ | Yes |

Note

¹ When power save mode is enabled, the memory controller is powered down and the status of the memory controller is indicated by the Memory Controller Power Save Status bit (REG[14h] bit 6). However, memory reads/writes are possible during power save mode because the S1D13A05 dynamically enables the memory controller for display buffer accesses.

² GPIOs can be accessed and if configured as outputs can be changed.

³ The power-down state of the USB section is controlled by the USBCLK Enable bit (REG[4000h] bit 7).

After reset, the S1D13A05 is always in Power Save Mode. Software must initialize the chip (i.e. programs all registers) and then clear the Power Save Mode Enable bit.

16 USB Considerations

16.1 USB Oscillator Circuit

The following circuit provides an example implementation for using an external oscillator to drive USBCLK.

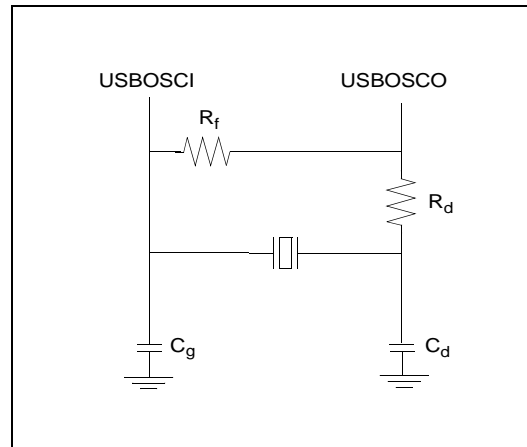


Figure 16-1: USB Oscillator Example Circuit

The following values are recommended for a 48MHz fundamental mode oscillator. If an oscillator of a different value is used, the capacitive and resistive values must be adjusted accordingly.

Table 16-1: Resistance and Capacitance Values for Example Circuit

| Symbol | Value |
|--------|--------------|
| R_f | 1M Ω |
| R_d | 470 Ω |
| C_g | 12pF |
| C_d | 12pF |

17 Mechanical Data

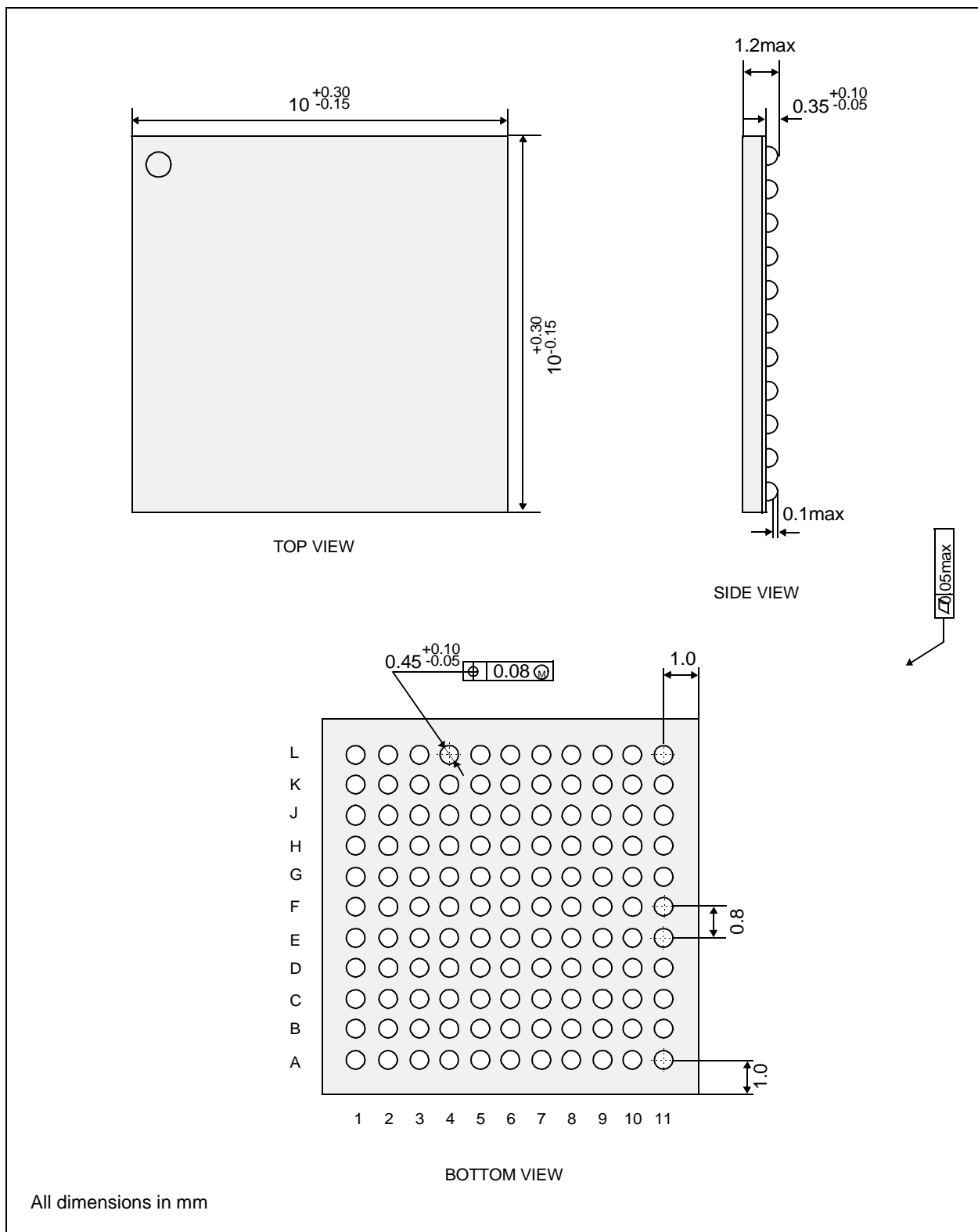


Figure 17-1: Mechanical Data PFBGA 121-pin Package

18 References

The following documents contain additional information related to the S1D13A05. Document numbers are listed in parenthesis after the document name. All documents can be found at the Epson Research and Development Website at www.erd.epson.com.

- S1D13A05 Product Brief (X40A-C-001-xx)
- S1D13A05 Programming Notes And Examples (X40A-G-003-xx)
- S1D13A05 Register Summary (X40A-R-001-xx)
- Interfacing to the Toshiba TMPR3905/3912 Microprocessor (X40A-G-002-xx)
- Interfacing to the PC Card Bus (X40A-G-005-xx)
- S1D13A05 Power Consumption (X40A-G-006-xx)
- Interfacing to the NEC VR4102/VR4111 Microprocessors (X40A-G-007-xx)
- Interfacing to the NEC VR4181 Microprocessor (X40A-G-008-xx)
- Interfacing to the Motorola MPC821 Microprocessor (X40A-G-009-xx)
- Interfacing to the Motorola MCF5307 "Coldfire" Microprocessor (X40A-G-010-xx)
- Interfacing to the Motorola MC68VZ328 Dragonball Microprocessor (X40A-012-xx)
- Interfacing to the Intel StrongARM SA-1110 Microprocessor (X40A-013-xx)
- S1D13A05 Windows CE v3.x Display Drivers (X40A-E-002-xx)
- S1D13A05 Windows CE v3.x USB Driver (X40A-E-006-xx)
- S1D13A05 Linux Console Driver (X40A-E-004-xx)
- S1D13A05 Wind River WindML v2.0 Display Drivers (X40A-E-003-xx)
- S5U13A05B00C Rev. 1.0 Evaluation Board User Manual (X40A-G-004-xx)
- 13A05CFG Configuration Utility Users Manual (X40A-B-001-xx)
- 13A05PLAY Diagnostic Utility Users Manual (X40A-B-002-xx)
- 13A05VIEW Demonstration Utility Users Manual (X40A-B-003-xx)

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Errata No. X00Z-P-001-01

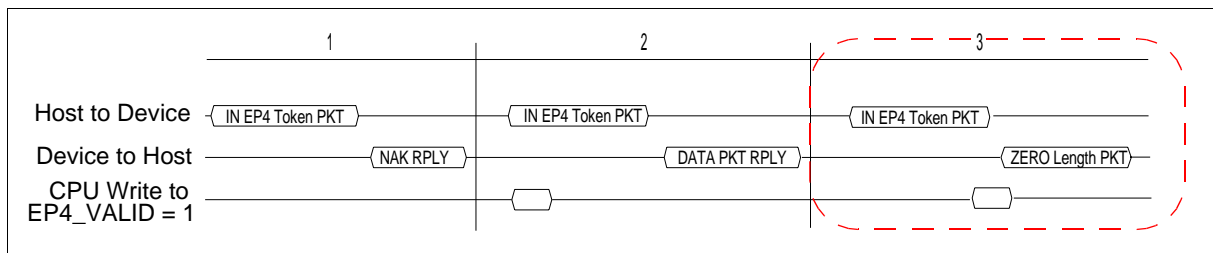
Device: S1D13A03, S1D13A04, S1D13A05.

Description: Setting EP4 FIFO Valid bit while NAKing an IN token.

Bit 5 of REG[402Ch] indicates to the S1D13A0x controller when data in the endpoint 4 FIFO is ready to be transferred to the host computer. Changing the state of this bit at certain times may generate an error.

When the S1D13A0x USB controller receives an endpoint 4 IN request and endpoint 4 is not ready to transmit data (REG[402Ch] bit 5 = 0), the response is a NAK packet. If endpoint 4 is toggled to a ready to transmit state just before a NAK response packet is sent, the controller may erroneously send a zero length packet instead. When this happens, the data toggle state will be incorrectly set for the next endpoint 4 data transmit.

The following timing diagram shows the error occurring in section 3.



This unexpected occurrence of a zero length packet may cause file system handling errors for some operating systems.

Corrective Action:

There are two software solutions for this occurrence.

Disable USB Receiver before setting the EP4 FIFO Valid bit

The first solution involves disabling the USB receiver to avoid responding to an EP4 IN packet. During the time the USB receiver is disabled the EP4 FIFO Valid bit is set.

When the local CPU is ready to send data on endpoint 4 the steps to follow are:

1. Disable the USB differential input receiver (REG[4040h] bit 6 = 0)
2. Wait a minimum of 1 μ s. If needed, delays may be added
3. Enable the EP4 FIFO Valid bit (REG[402Ch] bit 5 = 1)
4. Clear the EP4 Interrupt status bit (REG[4004h] bit 4 = 1)
5. Enable the USB differential input receiver (REG[4040h] bit 6 = 1)

Note

Steps 1 through 5 are time critical and must be performed in less than 6 μ s.

Note

To comply with “EP4 NAK Status not set correctly in USB Status register”, steps 3 and 4 must be completed within 5 μ s of each other. For further information on “EP4 NAK Status not set correctly in USB Status register”, see the S1D13A0x Programming Notes and Examples, document numbers X36A-G-003-xx, X37A-G-003-xx, and X40A-G-003-xx.

EP4 FIFO Valid bit set after NAK and before the next IN token.

The second solution is to wait until immediately after the USB has responded to an IN request with a NAK packet before setting the transmit FIFO valid bit. This solution is recommended only for fast processors.

When the local CPU is ready to send data on endpoint 4, it must first detect that a NAK packet has been sent. This is done by reading the EP4 Interrupt Status bit (REG[4004h] bit 4). If the EP4 FIFO Valid bit was not set, the EP4 Interrupt Status bit is set only if a NAK packet has been sent. When the local CPU detects the NAK it must immediately set the EP4 FIFO Valid bit (before responding to the next IN token).

After filling the EP4 FIFO the steps to follow before setting the EP4 FIFO Valid bit are:

1. Clear the EP4 Interrupt Status bit (REG[4004h] bit 4)
2. Read the EP4 Interrupt Status bit (REG[4004h] bit 4) until it is set
3. Set the EP4 FIFO Valid bit (REG[402Ch] bit 5 = 1)

Note

The setting of the EP4 FIFO Valid bit is time critical. The EP4 FIFO Valid bit must be set within 3 μ s after the EP4 Interrupt Status has been set internally by the S1D13A0x.

EPSON®



S1D13A05 LCD/USB Companion Chip

Programming Notes and Examples

Document Number: X40A-G-003-04

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1 Introduction

This guide discusses programming issues and provides examples for the main features of the S1D13A05, such as SwivelView, Picture-in-Picture Plus, and the BitBLT engine. The example source code referenced in this guide is available on the web at www.erd.epson.com.

This guide also introduces the Hardware Abstraction Layer (HAL), which is designed to simplify the programming of the S1D13A05. Most S1D13xxx products have HAL support, thus allowing OEMs to do multiple designs with a common code base.

This document is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document and source before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

2 Identifying the S1D13A05

The S1D13A05 can be identified by reading the value contained in the Product Information Register (REG[00h]). To identify the S1D13A05 follow the steps below.

1. Read REG[00h].
2. The production version of the S1D13A05 returns a value of 2Dxx402Dh (where xx depends on the configuration of the CNF[6:0] pins). This value can be broken down into the following.
 1. The product code for the S1D13A05 is 0Bh (001011 binary) and can be found in bits 7-2. The product code is repeated in bits 31-26.
 2. The revision code is 1h (01 binary) and can be found in bits 1-0. The revision code is repeated in bits 25-24.
 3. The display buffer size is encoded as 40h (00101000 binary) and is contained in bits 15-8.

3 Initialization

This section describes how to initialize the S1D13A05. Sample code for performing initialization of the S1D13A05 is provided in the file **init13A05.c** which is available on the internet at www.erd.epson.com.

S1D13A05 initialization can be broken into the following steps.

1. Set all registers to initial values. The values are obtained by using a **s1d13A0x.h** file exported from the 13A05CFG configuration utility. For more information on 13A05CFG, see the *13A05CFG User Manual*, document number X40A-B-001-xx.
2. Program the Look-Up Table (LUT) with color values. For details on programming the LUT, see Section 5, “Look-Up Table (LUT)” on page 17.
3. Clear the display buffer.

Refer to the HAL (Hardware Abstraction Layer) sample code available on the internet at www.erd.epson.com for S5U13A05B00C specific initialization (i.e. programming the Cypress clock chip).

4 Memory Models

The S1D13A05 contains a display buffer of 256K bytes and supports color depths of 1, 2, 4, 8, and 16 bit-per-pixel. For each color depth, the data format is packed pixel.

Packed pixel data may be envisioned as a stream of pixels. In this stream, pixels are packed adjacent to each other. If a pixel requires four bits, then it is located in the four most significant bits of a byte. The pixel to the immediate right on the display occupies the lower four bits of the same byte. The next two pixels to the immediate right are located in the following byte, etc.

4.1 Display Buffer Location

The S1D13A05 display buffer is 256K bytes of embedded SRAM. The display buffer is memory mapped and is accessible directly by software. The memory block location assigned to the S1D13A05 display buffer varies with each individual hardware platform.

For further information on the display buffer, see the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

4.2 Memory Organization for One Bit-per-pixel (2 Colors/Gray Shades)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------|---------|---------|---------|---------|---------|---------|---------|
| Pixel 0 | Pixel 1 | Pixel 2 | Pixel 3 | Pixel 4 | Pixel 5 | Pixel 6 | Pixel 7 |

Figure 4-1: Pixel Storage for 1 Bpp in One Byte of Display Buffer

At a color depth of 1 bpp, each byte of display buffer contains eight adjacent pixels. Setting or resetting any pixel requires reading the entire byte, masking out the unchanged bits and setting the appropriate bits to 1.

One bit pixels provide 2 gray shades/color possibilities. For monochrome panels the gray shades are generated by indexing into the first two elements of the green component of the Look-Up Table (LUT). For color panels the 2 colors are derived by indexing into the first 2 positions of the LUT.

4.3 Memory Organization for Two Bit-per-pixel (4 Colors/Gray Shades)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------------------|-------|---------------------|-------|---------------------|-------|---------------------|-------|
| Pixel 0 bits 1-0 | | Pixel 1 bits 1-0 | | Pixel 2 bits 1-0 | | Pixel 3 bits 1-0 | |

Figure 4-2: Pixel Storage for 2 Bpp in One Byte of Display Buffer

At a color depth of 2 bpp, each byte of display buffer contains four adjacent pixels. Setting or resetting any pixel requires reading the entire byte, masking out the unchanged bits and setting the appropriate bits to 1.

Two bit pixels provide 4 gray shades/color possibilities. For monochrome panels the gray shades are generated by indexing into the first 4 elements of the green component of the Look-Up Table (LUT). For color panels the 4 colors are derived by indexing into the first 4 positions of the LUT.

4.4 Memory Organization for Four Bit-per-pixel (16 Colors/Gray Shades)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------------------|-------|-------|-------|---------------------|-------|-------|-------|
| Pixel 0 bits 3-0 | | | | Pixel 1 bits 3-0 | | | |

Figure 4-3: Pixel Storage for 4 Bpp in One Byte of Display Buffer

At a color depth of 4 bpp, each byte of display buffer contains two adjacent pixels. Setting or resetting any pixel requires reading the entire byte, masking out the upper or lower nibble (4 bits) and setting the appropriate bits to 1.

Four bit pixels provide 16 gray shades/color possibilities. For monochrome panels the gray shades are generated by indexing into the first 16 elements of the green component of the Look-Up Table (LUT). For color panels the 16 colors are derived by indexing into the first 16 positions of the LUT.

4.5 Memory Organization for 8 Bpp (256 Colors/64 Gray Shades)

| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------------------|-------|-------|-------|-------|-------|-------|-------|
| Pixel 0 bits 7-0 | | | | | | | |

Figure 4-4: Pixel Storage for 8 Bpp in One Byte of Display Buffer

At a color depth of 8 bpp, each byte of display buffer represents one pixel on the display. At this color depth the read-modify-write cycles are eliminated making the update of each pixel faster.

Each byte indexes into one of the 256 positions of the LUT. The S1D13A05 LUT supports six bits per primary color. This translates into 256K possible colors when color mode is selected. Therefore the display has 256 colors available out of a possible 256K colors.

When a monochrome panel is selected, the green component of the LUT is used to determine the intensity. The green indices, with six bits, can resolve 64 gray shades. Display memory values > 64 are truncated. Thus a display memory value of 65 (1000 0001) displays the same intensity as a display memory value of 1.

4.6 Memory Organization for 16 Bpp (65536 Colors/64 Gray Shades)

| Bit 15 | Bit 14 | Bit 13 | Bit 12 | Bit 11 | Bit 10 | Bit 9 | Bit 8 |
|-----------------------------|--------|--------|--------|----------------------------|-----------------------------|-------|-------|
| Red Component bits 4-0 | | | | | Green Component bits 5-3 | | |
| Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
| Green Component bits 2-0 | | | | Blue Component bits 4-0 | | | |

Figure 4-5: Pixel Storage for 16 Bpp in Two Bytes of Display Buffer

At a color depth of 16 bpp the S1D13A05 is capable of displaying 64K (65536) colors. The 64K color pixel is divided into three parts: five bits for red, six bits for green, and five bits for blue. In this mode the LUT is bypassed and output goes directly into the Frame Rate Modulator.

Should monochrome mode be chosen at this color depth, the output sends the six bits of the green component to the modulator for a total of 64 possible gray shades.

5 Look-Up Table (LUT)

This section discusses programming the S1D13A05 Look-Up Table (LUT). Included is a summary of the LUT registers, recommendations for color/gray shade LUT values, and additional programming considerations. For a discussion of the LUT architecture, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The S1D13A05 is designed with a LUT consisting of 256 red/green/blue entries. Each LUT entry is six bits wide. The color depth (bpp) determines how many indices are used. For example, 1 bpp uses the first 2 indices, 2 bpp uses the first 4 indices, 4 bpp uses the first 16 indices and 8 bpp uses all 256 indices. 16 bpp bypasses the LUT.

In color modes, the pixel values stored in the display buffer index directly to an RGB value stored in the LUT. In monochrome modes, the pixel value indexes into the green component of the LUT and the amount of green at that index controls the intensity.

5.1 Registers

5.1.1 Look-Up Table Write Register

| Look-Up Table Write Register | | | | | | | | | | | | | | Write Only | |
|------------------------------|----|----|----|----|----|-----|----|---------------------|----|----|----|----|----|---------------------|----|
| REG[18h] | | | | | | | | | | | | | | Default = 00000000h | |
| LUT Write Address | | | | | | | | LUT Red Write Data | | | | | | n/a | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| LUT Green Write Data | | | | | | n/a | | LUT Blue Write Data | | | | | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

This register receives the data to be written to the red (bits 23-18), green (bits 15-10), and blue (bits 7-2) components of the Look-Up Table (LUT). Also contained in this register is the LUT Write Address (bits 31-24) which forms a pointer to the location in the LUT where the RGB components will be written.

This register should be accessed using a 32-bit write cycle to ensure proper operation. If the Look-Up Table Write Register is accessed with 8 or 16-bit write, it is important to understand that the RGB data is latched into the LUT only after the completion of the write to the LUT Write Address bits. On little endian systems, this means a write to bits 31-24. On big endian systems, this means a write to bits 7-2.

This is a write-only register and returns 00000000h if read.

Note

For further information on the S1D13A05 LUT architecture, see the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

5.1.2 Look-Up Table Read Register

| Look-Up Table Read Register | | | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|-------------------|----|--------------------|----|----|----|-----|----|-----|--|
| REG[1Ch] Default = 00000000h | | | | | | | | | | | | | | | | | |
| Write Only (bits 31-24)/Read Only | | | | | | | | | | | | | | | | | |
| LUT Read Address (write only) | | | | | | | | LUT Red Read Data | | | | | | n/a | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| LUT Green Read Data | | | | | | | | n/a | | LUT Blue Read Data | | | | | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

This register contains the data returned from the red (bits 23-18), green (bits 15-10), and blue (bits 7-2) components of the Look-Up Table. This register also contains the LUT Read Address (bits 31-24) which forms a pointer to the offset in the LUT where the RGB components are read from.

Reading the LUT is a two step process. First the desired index must be set by writing the LUT Read Address bits with the desired index. Second, the LUT values are retrieved by reading the Look-Up Table Read Register.

Bits 31-24 are write only and will return 00h when read.

Note

For further information on the S1D13A05 LUT architecture, see the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

5.2 Look-Up Table Organization

- The Look-Up Table treats the value of a pixel as an index into an array. For example, a pixel value of zero would point to the first LUT entry, whereas a pixel value of seven would point to the eighth LUT entry.
- The value contained in each LUT entry represents the intensity of the given color or gray shade. This intensity can range in value from 0 to 3Fh.
- Increasing the LUT data value results in a brighter color or gray shade. For example, a LUT entry of FCh in the red bank results in bright red output while a LUT entry of 1Ch results in dull red.

Table 5-1: Look-Up Table Configurations

| Color Depth | Look-Up Table Indices Used | | | Effective Gray Shades/Colors |
|--------------|----------------------------|-------|------|------------------------------|
| | RED | GREEN | BLUE | |
| 1 bpp gray | | 2 | | 2 gray shades |
| 2 bpp gray | | 4 | | 4 gray shades |
| 4 bpp gray | | 16 | | 16 gray shades |
| 8 bpp gray | | 64 | | 64 gray shades |
| 16 bpp gray | | | | 64 gray shades |
| 1 bpp color | 2 | 2 | 2 | 2 colors |
| 2 bpp color | 4 | 4 | 4 | 4 colors |
| 4 bpp color | 16 | 16 | 16 | 16 colors |
| 8 bpp color | 256 | 256 | 256 | 256 colors |
| 16 bpp color | | | | 65536 colors |

= Indicates the Look-Up Table is not used for that display mode

5.2.1 Gray Shade Modes

Gray shade (monochrome) modes are selected by the Color/Mono Panel Select bit (REG[0Ch] bit 6). When this bit is set to 0, the value output to the panel is derived solely from the green component of the LUT.

For each gray shade depth a table of sample LUT values is provided. These LUT values are a standardized set of intensities used by the Epson S1D13A05 utility programs.

Note

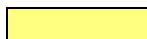
These LUT values show eight bits of significance. The S1D13A05 LUT uses only the six MSB. The 2 LSB are ignored.

1 bpp gray shade

The 1 bpp gray shade mode uses the green component of the first 2 LUT entries. The remaining indices of the LUT are unused.

Table 5-2: Suggested LUT Values for 1 Bpp Gray Shade

| Index | Red | Green | Blue |
|-------|-----|-------|------|
| 00 | 00 | 00 | 00 |
| 01 | 00 | FF | 00 |
| 02 | 00 | 00 | 00 |
| ... | 00 | 00 | 00 |
| FF | 00 | 00 | 00 |



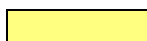
Unused entries

2 bpp gray shade

The 2 bpp gray shade mode uses the green component of the first 4 LUT entries. The remaining indices of the LUT are unused.

Table 5-3: Suggested LUT Values for 4 Bpp Gray Shade

| Index | Red | Green | Blue |
|-------|-----|-------|------|
| 00 | 00 | 00 | 00 |
| 01 | 00 | 55 | 00 |
| 02 | 00 | AA | 00 |
| 03 | 00 | FF | 00 |
| 04 | 00 | 00 | 00 |
| ... | 00 | 00 | 00 |
| FF | 00 | 00 | 00 |



Unused entries

4 bpp gray shade

The 4 bpp gray shade mode uses the green component of the first 16 LUT entries. The remaining indices of the LUT are unused.

Table 5-4: Suggested LUT Values for 4 Bpp Gray Shade

| Index | Red | Green | Blue |
|-------|-----|-------|------|
| 00 | 00 | 00 | 00 |
| 01 | 00 | 10 | 00 |
| 02 | 00 | 20 | 00 |
| 03 | 00 | 34 | 00 |
| 04 | 00 | 44 | 00 |
| 05 | 00 | 54 | 00 |
| 06 | 00 | 68 | 00 |
| 07 | 00 | 78 | 00 |
| 08 | 00 | 88 | 00 |
| 09 | 00 | 9C | 00 |
| 0A | 00 | AC | 00 |
| 0B | 00 | BC | 00 |
| 0C | 00 | CC | 00 |
| 0D | 00 | DC | 00 |
| 0E | 00 | EC | 00 |
| 0F | 00 | FC | 00 |
| 10 | 00 | 00 | 00 |
| ... | 00 | 00 | 00 |
| FF | 00 | 00 | 00 |



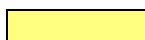
Unused entries

8 bpp gray shade

When configured for 8 bpp gray shade mode, the green component of all 256 LUT entries may be used. The green component of the LUT has six bits of resolution resulting in 64 gray shades. The remaining 192 green color indices can be programmed, but only to one of the existing 64 intensities.

Table 5-5: Suggested LUT Values for 8 Bpp Gray Shade

| Index | Red | Green | Blue | Index | Red | Green | Blue |
|-------|-----|-------|------|-------|-----|-------|------|
| 00 | 00 | 00 | 00 | 20 | 00 | 80 | 00 |
| 01 | 00 | 04 | 00 | 21 | 00 | 84 | 00 |
| 02 | 00 | 08 | 00 | 22 | 00 | 88 | 00 |
| 03 | 00 | 0C | 00 | 23 | 00 | 8C | 00 |
| 04 | 00 | 10 | 00 | 24 | 00 | 90 | 00 |
| 05 | 00 | 14 | 00 | 25 | 00 | 94 | 00 |
| 06 | 00 | 18 | 00 | 26 | 00 | 98 | 00 |
| 07 | 00 | 1C | 00 | 27 | 00 | 9C | 00 |
| 08 | 00 | 20 | 00 | 28 | 00 | A0 | 00 |
| 09 | 00 | 24 | 00 | 29 | 00 | A4 | 00 |
| 0A | 00 | 28 | 00 | 2A | 00 | A8 | 00 |
| 0B | 00 | 2C | 00 | 2B | 00 | AC | 00 |
| 0C | 00 | 30 | 00 | 2C | 00 | B0 | 00 |
| 0D | 00 | 34 | 00 | 2D | 00 | B4 | 00 |
| 0E | 00 | 38 | 00 | 2E | 00 | B8 | 00 |
| 0F | 00 | 3C | 00 | 2F | 00 | BC | 00 |
| 10 | 00 | 40 | 00 | 30 | 00 | C0 | 00 |
| 11 | 00 | 44 | 00 | 31 | 00 | C4 | 00 |
| 12 | 00 | 48 | 00 | 32 | 00 | C8 | 00 |
| 13 | 00 | 4C | 00 | 33 | 00 | CC | 00 |
| 14 | 00 | 50 | 00 | 34 | 00 | D0 | 00 |
| 15 | 00 | 54 | 00 | 35 | 00 | D4 | 00 |
| 16 | 00 | 58 | 00 | 36 | 00 | D8 | 00 |
| 17 | 00 | 5C | 00 | 37 | 00 | DC | 00 |
| 18 | 00 | 60 | 00 | 38 | 00 | E0 | 00 |
| 19 | 00 | 64 | 00 | 39 | 00 | E4 | 00 |
| 1A | 00 | 68 | 00 | 3A | 00 | E8 | 00 |
| 1B | 00 | 6C | 00 | 3B | 00 | EC | 00 |
| 1C | 00 | 70 | 00 | 3C | 00 | F0 | 00 |
| 1D | 00 | 74 | 00 | 3D | 00 | F4 | 00 |
| 1E | 00 | 78 | 00 | 3E | 00 | F8 | 00 |
| 1F | 00 | 7C | 00 | 3F | 00 | FC | 00 |
| | | | | 40 | 00 | 00 | 00 |
| | | | | ... | 00 | 00 | 00 |
| | | | | FF | 00 | 00 | 00 |

 Unused entries

16 bpp gray shade

The Look-Up Table is bypassed at this color depth, therefore programming the LUT is not required.

In this mode, the six bits of green in each pixel are used to set the absolute intensity of the image. This results in 64 gray shades.

5.2.2 Color Modes

In color display modes, the number of LUT entries used is determined by the color depth. For each supported color depth a table of sample LUT values is provided. These LUT values are a standardized set of colors used by the Epson S1D13A05 utility programs.

Note

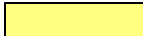
These LUT values show eight bits of significance. The S1D13A05 LUT uses only the six MSB. The 2 LSB are ignored.

1 bpp color

When the S1D13A05 is configured for 1 bpp color mode the first 2 entries in the LUT are used. The remaining indices of the LUT are unused.

Table 5-6: Suggested LUT Values for 1 bpp Color

| Index | Red | Green | Blue |
|-------|-----|-------|------|
| 00 | 00 | 00 | 00 |
| 01 | FF | FF | FF |
| 02 | 00 | 00 | 00 |
| ... | 00 | 00 | 00 |
| FF | 00 | 00 | 00 |

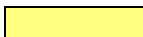
 = Indicates unused entries in the LUT

2 bpp color

When the S1D13A05 is configured for 2 bpp color mode the first 4 entries in the LUT are used. The remaining indices of the LUT are unused.

Table 5-7: Suggested LUT Values for 2 bpp Color

| Index | Red | Green | Blue |
|-------|-----|-------|------|
| 00 | 00 | 00 | 00 |
| 01 | 00 | 00 | FF |
| 02 | FF | 00 | 00 |
| 03 | FF | FF | FF |
| 04 | 00 | 00 | 00 |
| ... | 00 | 00 | 00 |
| FF | 00 | 00 | 00 |

 = Indicates unused entries in the LUT

4 bpp color

When the S1D13A05 is configured for 4 bpp color mode the first 16 entries in the LUT are used. The remaining indices of the LUT are unused.

The following table shows LUT values that simulate those of a VGA operating in 16 color mode.

Table 5-8: Suggested LUT Values for 4 bpp Color

| Index | Red | Green | Blue |
|-------|-----|-------|------|
| 00 | 00 | 00 | 00 |
| 01 | 00 | 00 | AA |
| 02 | 00 | AA | 00 |
| 03 | 00 | AA | AA |
| 04 | AA | 00 | 00 |
| 05 | AA | 00 | AA |
| 06 | AA | AA | 00 |
| 07 | AA | AA | AA |
| 08 | 00 | 00 | 00 |
| 09 | 00 | 00 | FF |
| 0A | 00 | FF | 00 |
| 0B | 00 | FF | FF |
| 0C | FF | 00 | 00 |
| 0D | FF | 00 | FF |
| 0E | FF | FF | 00 |
| 0F | FF | FF | FF |
| 10 | 00 | 00 | 00 |
| ... | 00 | 00 | 00 |
| FF | 00 | 00 | 00 |

= Indicates unused entries in the LUT

8 bpp color

When the S1D13A05 is configured for 8 bpp color mode all 256 entries in the LUT are used.

The S1D13A05 LUT has six bits (64 intensities) of intensity control per primary color which is the same as a standard VGA RAMDAC.

The following table shows LUT values that simulate the VGA default color palette.

Table 5-9: Suggested LUT Values 8 bpp Color

| Index | R | G | B | Index | R | G | B | Index | R | G | B | Index | R | G | B |
|-------|----|----|----|-------|----|----|----|-------|----|----|----|-------|----|----|----|
| 00 | 00 | 00 | 00 | 40 | 00 | 00 | 00 | 80 | FF | FF | 00 | C0 | 00 | 00 | 00 |
| 01 | 00 | 00 | AA | 41 | 00 | 00 | 11 | 81 | FF | EF | 00 | C1 | 00 | 11 | 11 |
| 02 | 00 | AA | 00 | 42 | 00 | 00 | 22 | 82 | FF | DE | 00 | C2 | 00 | 22 | 22 |
| 03 | 00 | AA | AA | 43 | 00 | 00 | 33 | 83 | FF | CD | 00 | C3 | 00 | 33 | 33 |
| 04 | AA | 00 | 00 | 44 | 00 | 00 | 44 | 84 | FF | BC | 00 | C4 | 00 | 44 | 44 |
| 05 | AA | 00 | AA | 45 | 00 | 00 | 55 | 85 | FF | AB | 00 | C5 | 00 | 55 | 55 |
| 06 | AA | AA | 00 | 46 | 00 | 00 | 66 | 86 | FF | 9A | 00 | C6 | 00 | 66 | 66 |
| 07 | AA | AA | AA | 47 | 00 | 00 | 77 | 87 | FF | 89 | 00 | C7 | 00 | 77 | 77 |
| 08 | 55 | 55 | 55 | 48 | 00 | 00 | 89 | 88 | FF | 77 | 00 | C8 | 00 | 89 | 89 |
| 09 | 00 | 00 | FF | 49 | 00 | 00 | 9A | 89 | FF | 66 | 00 | C9 | 00 | 9A | 9A |
| 0A | 00 | FF | 00 | 4A | 00 | 00 | AB | 8A | FF | 55 | 00 | CA | 00 | AB | AB |
| 0B | 00 | FF | FF | 4B | 00 | 00 | BC | 8B | FF | 44 | 00 | CB | 00 | BC | BC |
| 0C | FF | 00 | 00 | 4C | 00 | 00 | CD | 8C | FF | 33 | 00 | CC | 00 | CD | CD |
| 0D | FF | 00 | FF | 4D | 00 | 00 | DE | 8D | FF | 22 | 00 | CD | 00 | DE | DE |
| 0E | FF | FF | 00 | 4E | 00 | 00 | EF | 8E | FF | 11 | 00 | CE | 00 | EF | EF |
| 0F | FF | FF | FF | 4F | 00 | 00 | FF | 8F | FF | 00 | 00 | CF | 00 | FF | FF |
| 10 | 00 | 00 | 00 | 50 | 00 | 00 | FF | 90 | FF | 00 | 00 | D0 | FF | 00 | 00 |
| 11 | 11 | 11 | 11 | 51 | 00 | 11 | FF | 91 | FF | 00 | 11 | D1 | FF | 11 | 11 |
| 12 | 22 | 22 | 22 | 52 | 00 | 22 | FF | 92 | FF | 00 | 22 | D2 | FF | 22 | 22 |
| 13 | 33 | 33 | 33 | 53 | 00 | 33 | FF | 93 | FF | 00 | 33 | D3 | FF | 33 | 33 |
| 14 | 44 | 44 | 44 | 54 | 00 | 44 | FF | 94 | FF | 00 | 44 | D4 | FF | 44 | 44 |
| 15 | 55 | 55 | 55 | 55 | 00 | 55 | FF | 95 | FF | 00 | 55 | D5 | FF | 55 | 55 |
| 16 | 66 | 66 | 66 | 56 | 00 | 66 | FF | 96 | FF | 00 | 66 | D6 | FF | 66 | 66 |
| 17 | 77 | 77 | 77 | 57 | 00 | 77 | FF | 97 | FF | 00 | 77 | D7 | FF | 77 | 77 |
| 18 | 89 | 89 | 89 | 58 | 00 | 89 | FF | 98 | FF | 00 | 89 | D8 | FF | 89 | 89 |
| 19 | 9A | 9A | 9A | 59 | 00 | 9A | FF | 99 | FF | 00 | 9A | D9 | FF | 9A | 9A |
| 1A | AB | AB | AB | 5A | 00 | AB | FF | 9A | FF | 00 | AB | DA | FF | AB | AB |
| 1B | BC | BC | BC | 5B | 00 | BC | FF | 9B | FF | 00 | BC | DB | FF | BC | BC |
| 1C | CD | CD | CD | 5C | 00 | CD | FF | 9C | FF | 00 | CD | DC | FF | CD | CD |
| 1D | DE | DE | DE | 5D | 00 | DE | FF | 9D | FF | 00 | DE | DD | FF | DE | DE |
| 1E | EF | EF | EF | 5E | 00 | EF | FF | 9E | FF | 00 | EF | DE | FF | EF | EF |
| 1F | FF | FF | FF | 5F | 00 | FF | FF | 9F | FF | 00 | FF | DF | FF | FF | FF |
| 20 | 00 | 00 | 00 | 60 | 00 | FF | FF | A0 | FF | 00 | FF | E0 | 00 | FF | 00 |
| 21 | 11 | 00 | 00 | 61 | 00 | FF | EF | A1 | EF | 00 | FF | E1 | 11 | FF | 11 |
| 22 | 22 | 00 | 00 | 62 | 00 | FF | DE | A2 | DE | 00 | FF | E2 | 22 | FF | 22 |
| 23 | 33 | 00 | 00 | 63 | 00 | FF | CD | A3 | CD | 00 | FF | E3 | 33 | FF | 33 |

Table 5-9: Suggested LUT Values 8 bpp Color (Continued)

| Index | R | G | B | Index | R | G | B | Index | R | G | B | Index | R | G | B |
|-------|----|----|----|-------|----|----|----|-------|----|----|----|-------|----|----|----|
| 24 | 44 | 00 | 00 | 64 | 00 | FF | BC | A4 | BC | 00 | FF | E4 | 44 | FF | 44 |
| 25 | 55 | 00 | 00 | 65 | 00 | FF | AB | A5 | AB | 00 | FF | E5 | 55 | FF | 55 |
| 26 | 66 | 00 | 00 | 66 | 00 | FF | 9A | A6 | 9A | 00 | FF | E6 | 66 | FF | 66 |
| 27 | 77 | 00 | 00 | 67 | 00 | FF | 89 | A7 | 89 | 00 | FF | E7 | 77 | FF | 77 |
| 28 | 89 | 00 | 00 | 68 | 00 | FF | 77 | A8 | 77 | 00 | FF | E8 | 89 | FF | 89 |
| 29 | 9A | 00 | 00 | 69 | 00 | FF | 66 | A9 | 66 | 00 | FF | E9 | 9A | FF | 9A |
| 2A | AB | 00 | 00 | 6A | 00 | FF | 55 | AA | 55 | 00 | FF | EA | AB | FF | AB |
| 2B | BC | 00 | 00 | 6B | 00 | FF | 44 | AB | 44 | 00 | FF | EB | BC | FF | BC |
| 2C | CD | 00 | 00 | 6C | 00 | FF | 33 | AC | 33 | 00 | FF | EC | CD | FF | CD |
| 2D | DE | 00 | 00 | 6D | 00 | FF | 22 | AD | 22 | 00 | FF | ED | DE | FF | DE |
| 2E | EF | 00 | 00 | 6E | 00 | FF | 11 | AE | 11 | 00 | FF | EE | EF | FF | EF |
| 2F | FF | 00 | 00 | 6F | 00 | FF | 00 | AF | 00 | 00 | FF | EF | FF | FF | FF |
| 30 | 00 | 00 | 00 | 70 | 00 | FF | 00 | B0 | 00 | 00 | 00 | F0 | 00 | 00 | FF |
| 31 | 00 | 11 | 00 | 71 | 11 | FF | 00 | B1 | 11 | 00 | 11 | F1 | 11 | 11 | FF |
| 32 | 00 | 22 | 00 | 72 | 22 | FF | 00 | B2 | 22 | 00 | 22 | F2 | 22 | 22 | FF |
| 33 | 00 | 33 | 00 | 73 | 33 | FF | 00 | B3 | 33 | 00 | 33 | F3 | 33 | 33 | FF |
| 34 | 00 | 44 | 00 | 74 | 44 | FF | 00 | B4 | 44 | 00 | 44 | F4 | 44 | 44 | FF |
| 35 | 00 | 55 | 00 | 75 | 55 | FF | 00 | B5 | 55 | 00 | 55 | F5 | 55 | 55 | FF |
| 36 | 00 | 66 | 00 | 76 | 66 | FF | 00 | B6 | 66 | 00 | 66 | F6 | 66 | 66 | FF |
| 37 | 00 | 77 | 00 | 77 | 77 | FF | 00 | B7 | 77 | 00 | 77 | F7 | 77 | 77 | FF |
| 38 | 00 | 89 | 00 | 78 | 89 | FF | 00 | B8 | 89 | 00 | 89 | F8 | 89 | 89 | FF |
| 39 | 00 | 9A | 00 | 79 | 9A | FF | 00 | B9 | 9A | 00 | 9A | F9 | 9A | 9A | FF |
| 3A | 00 | AB | 00 | 7A | AB | FF | 00 | BA | AB | 00 | AB | FA | AB | AB | FF |
| 3B | 00 | BC | 00 | 7B | BC | FF | 00 | BB | BC | 00 | BC | FB | BC | BC | FF |
| 3C | 00 | CD | 00 | 7C | CD | FF | 00 | BC | CD | 00 | CD | FC | CD | CD | FF |
| 3D | 00 | DE | 00 | 7D | DE | FF | 00 | BD | DE | 00 | DE | FD | DE | DE | FF |
| 3E | 00 | EF | 00 | 7E | EF | FF | 00 | BE | EF | 00 | EF | FE | EF | EF | FF |
| 3F | 00 | FF | 00 | 7F | FF | FF | 00 | BF | FF | 00 | FF | FF | FF | FF | FF |

16 bpp color

The Look-Up Table is bypassed at this color depth, therefore programming the LUT is not required.

6 Power Save Mode

The S1D13A05 is designed for very low-power applications. During normal operation, the internal clocks are dynamically disabled when not required. The S1D13A05 design also includes a Power Save Mode to further save power. When Power Save Mode is initiated, LCD power sequencing is required to ensure the LCD bias power supply is disabled properly. For further information on LCD power sequencing, see Section 6.3, “LCD Power Sequencing” on page 28.

For Power Save Mode AC Timing, see the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

6.1 Overview

The S1D13A05 includes a software initiated Power Save Mode. Enabling/disabling Power Save Mode is controlled using the Power Save Mode Enable bit (REG[14h] bit 4).

While Power Save Mode is enabled the following conditions apply.

- Most registers are accessible.
 - USB registers are not accessible
- Memory writes are possible¹
- Memory reads are not possible
- LCD display is inactive.
- LCD interface outputs are forced low.

Note

¹ Memory writes are possible during power save mode because the S1D13A05 dynamically enables the memory controller for display buffer writes.

6.2 Registers

6.2.1 Power Save Mode Enable

| Power Save Configuration Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|------------------|-------------------------------|-----|------------------------|-----|----|----|----------|
| REG[14h] Default = 00000010h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | VNDP Status (RO) | Memory Power Save Status (RO) | n/a | Power Save Mode Enable | n/a | | | Reserved |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

The Power Save Mode Enable bit initiates Power Save Mode when set to 1. Setting the bit to 0 disables Power Save Mode and returns the S1D13A05 to normal mode. At reset this bit is set to 1.

Note

Enabling/disabling Power Save Mode requires proper LCD Power Sequencing. See Section 6.3, “LCD Power Sequencing” on page 28.

6.2.2 Memory Controller Power Save Status

| Power Save Configuration Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|----|----|------------------|-------------------------------|-----|------------------------|-----|----|----|----------|
| REG[14h] Default = 00000010h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | VNDP Status (RO) | Memory Power Save Status (RO) | n/a | Power Save Mode Enable | n/a | | | Reserved |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

The Memory Controller Power Save Status bit is a read-only status bit which indicates the power save state of the S1D13A05 SRAM interface. When this bit returns a 1, the SRAM interface is powered down and the memory clock source may be disabled. When this bit returns a 0, the SRAM interface is active. This bit returns a 0 after a chip reset.

Note

Memory writes are possible during power save mode because the S1D13A05 dynamically enables the memory controller for display buffer writes.

6.3 LCD Power Sequencing

The S1D13A05 requires LCD power sequencing (the process of powering-on and powering-off the LCD panel). LCD power sequencing allows the LCD bias voltage to discharge prior to shutting down the LCD signals, preventing long term damage to the panel and avoiding unsightly “lines” at power-on/power-off.

Proper LCD power sequencing for power-off requires a delay from the time the LCD power is disabled to the time the LCD signals are shut down. Power-on requires the LCD signals to be active prior to applying power to the LCD. This time interval depends on the LCD bias power supply design. For example, the LCD bias power supply on the S1D13A05 Evaluation Board requires 0.5 seconds to fully discharge. Other power supply designs may vary.

This section assumes the LCD bias power is controlled through GPIO0. The S1D13A05 GPIO pins are multi-use pins and may not be available in all system designs. For further information on the availability of GPIO pins, see the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

6.4 Enabling Power Save Mode

Enable Power Save Mode using the following steps.

1. Turn off the LCD bias power.

Note

The S1D13A05 evaluation board uses GPIO0 to control the LCD bias power supplies. Your system design may vary.

2. Wait for the LCD bias power supply to discharge. The discharge time is based on the discharge rate of the power supply.
3. Enable Power Save Mode - set REG[14h] bit 4 to 1.

The S1D13A05 is now in Power Save Mode. To further increase power savings PCLK and MCLK can be switched off (see steps 4 and 5).

4. At this time, the LCD pixel clock source may be disabled.
5. After the Memory Controller Power Save Status bit (REG[14h] bit 6) returns a 1, the Memory Clock source may be shut down.

6.5 Disabling Power Save Mode

Bring the S1D13A05 out of Power Save Mode using the following steps.

1. If the Memory Clock source is shut down, it must be started.
2. If the pixel clock is disabled, it must be started.
3. Disable Power Save Mode - set REG[14h] bit 4 to 0.
4. Wait for the LCD bias power supply to charge. The charge time is based on the time required for the LCD power supply to reach operating voltage.
5. Enable the LCD bias power.

Note

The S1D13A05 evaluation board uses GPIO0 to control the LCD bias power supplies. Your system design may vary.

7 SwivelView™

Computer displays usually show an image in only one orientation, which is typically wider than it is high. For example, a display size of 320x240 is 320 pixels wide and 240 lines high.

SwivelView uses hardware to rotate the displayed image counter-clockwise in ninety degree increments. Rotating the image on a 320x240 display by 90° or 270° yields a display that is now 240 pixels wide and 320 lines high.

The S1D13A05 provides hardware support for SwivelView in the following configurations:

- SwivelView 0° (landscape) with or without pixel doubling
- SwivelView 90° without pixel doubling
- SwivelView 180° with or without pixel doubling
- SwivelView 270° without pixel doubling

The SwivelView feature only affects the main display window and the PIP⁺ window.

7.1 SwivelView 90°

When design constraints require physical rotation of a display by 90°, enable SwivelView 90° mode. The following example shows a LCD panel, which is physically rotated clockwise by 90°. The top left corner of the physical panel is marked for reference.

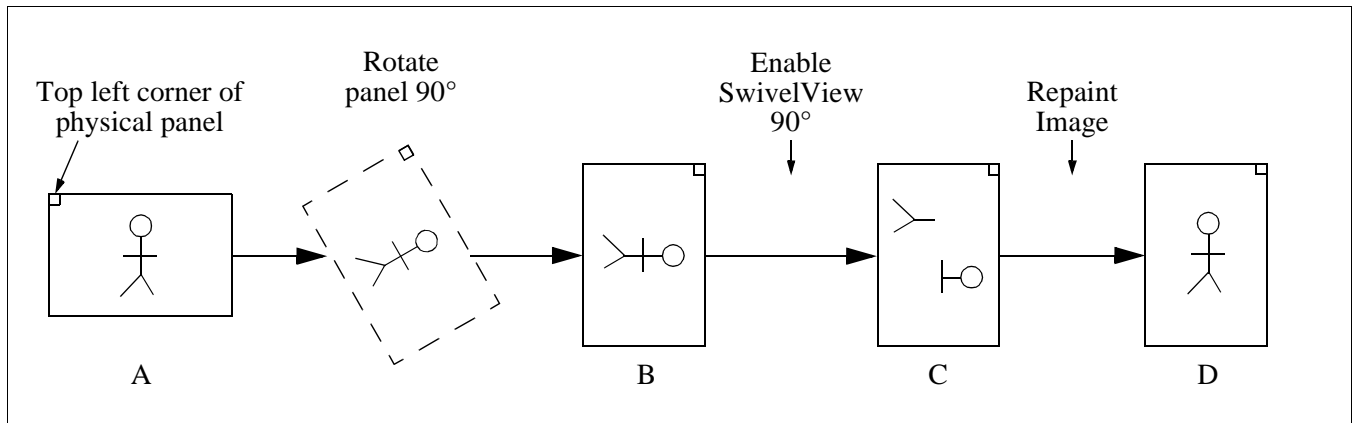


Figure 7-1: SwivelView 90° Rotation

The above illustration shows a series of transitions:

- A to B shows the LCD panel being physically rotated. Note that the physical display is rotated clockwise and the image is rotated counter-clockwise.
- B to C shows the effect of enabling SwivelView 90°. The broken image in C indicates that after the registers are programmed the image in display memory is invalid and must be repainted. The following register values must be updated to select SwivelView 90°:
 - SwivelView Mode Select (REG[010h] bits 17 and 16)
 - Main Window Display Start Address (REG[040h])
 - Main Window Line Address Offset (REG[044h])
 - PIP⁺ Line Address Offset (REG[054h])
 - PIP⁺ X End Position (REG[058h] bits 25-16)
 - PIP⁺ X Start Position (REG[058h] bits 9-0)
 - PIP⁺ Y End Position (REG[05Ch] bits 25-16)
 - PIP⁺ Y Start Position (REG[05Ch] bits 9-0)
- C to D shows the effect of repainting the display in SwivelView 90°. The image must be drawn based on the new display dimensions.

7.2 SwivelView 180°

When design constraints require physical rotation of a display by 180°, enable SwivelView 180° mode. The following example shows a LCD panel which is physically rotated by 180°. The top left corner of the physical panel is marked for reference.

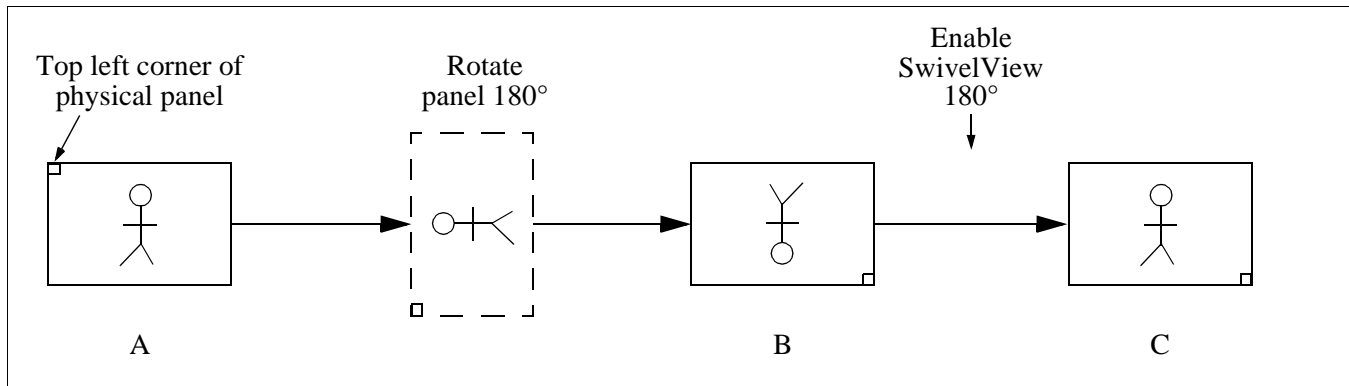


Figure 7-2: SwivelView 90° Rotation

The above illustration shows a series of transitions:

- A to B shows the LCD panel being physically rotated.
- B to C shows the effect of enabling SwivelView 180°. The following register values must be updated to support SwivelView 180°:
 - SwivelView Mode Select (REG[010h] bits 17 and 16)
 - Main Window Display Start Address (REG[040h])
 - Main Window Line Address Offset (REG[044h])
 - PIP⁺ X End Position (REG[058h] bits 25-16)
 - PIP⁺ X Start Position (REG[058h] bits 9-0)
 - PIP⁺ Y End Position (REG[05Ch] bits 25-16)
 - PIP⁺ Y Start Position (REG[05Ch] bits 9-0)
- Notice that the image does not have to be repainted when SwivelView 180° is enabled.

7.3 SwivelView 270°

When design constraints require physical rotation of a display by 270°, enable SwivelView 270° mode. The following example shows a LCD panel which is physically rotated clockwise by 270°. The top left corner of the physical panel is marked for reference.

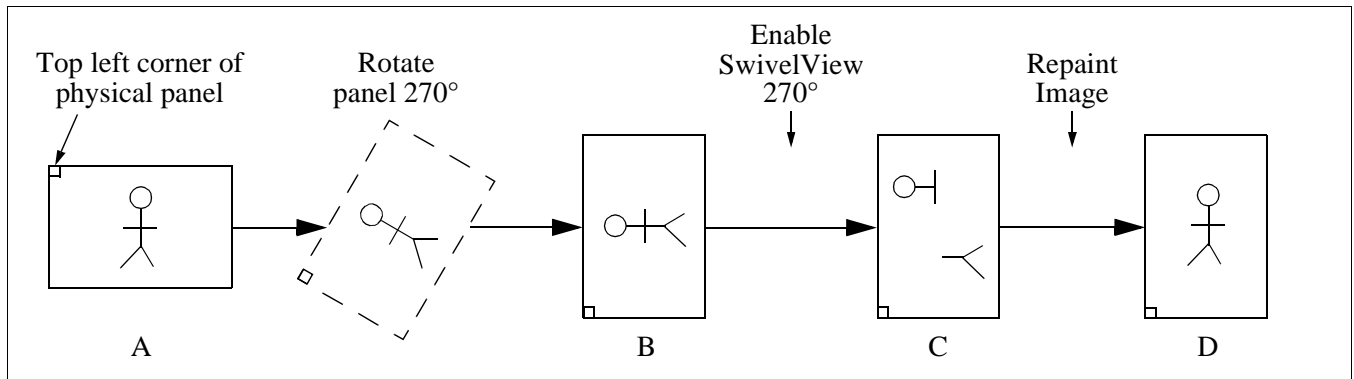


Figure 7-3: SwivelView 270° Rotation

The above illustration shows a series of transitions:

- A to B shows the LCD panel being physically rotated.
- B to C shows the effect of enabling SwivelView 270°. The broken image in Box C indicates that after registers are programmed the image in display memory is invalid and must be repainted. The following register values must be updated to support SwivelView 270°:
 - SwivelView Mode Select (REG[010h] bits 17 and 16)
 - Main Window Display Start Address (REG[040h])
 - Main Window Line Address Offset (REG[044h])
 - PIP⁺ X End Position (REG[058h] bits 25-16)
 - PIP⁺ X Start Position (REG[058h] bits 9-0)
 - PIP⁺ Y End Position (REG[05Ch] bits 25-16)
 - PIP⁺ Y Start Position (REG[05Ch] bits 9-0)
- C to D shows the effect of repainting the display in SwivelView 270°. The image must be drawn based on the new display dimensions.

7.4 SwivelView Registers

These registers control the SwivelView feature.

| Display Settings Register | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|-------------------------------|-----------------------------|------------------|----------------------|-----|---|--------------------------|-----|---------------------------|
| REG[10h] Default = 00000000h | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | |
| n/a | | | | | | Pixel Doubling Vertical | Pixel Doubling Horiz. | Display Blank | Dithering Disable | n/a | SW Video Invert | PIP+ Window Enable | n/a | SwivelView Mode Select |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 16 |
| n/a | | | | | | | | | | | Bits-per-pixel Select (actual value: 1, 2, 4, 8 or 16 bpp) | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 0 |

SwivelView Mode Select

The SwivelView modes are selected using the SwivelView Mode Select Bits[1:0] (bits 17-16). The combinations of these bits provide the following rotations.

Table 7-1: SwivelView Mode Select Bits

| SwivelView Mode Select Bit 1 | SwivelView Mode Select Bit 0 | SwivelView Orientation |
|---------------------------------|---------------------------------|---------------------------|
| 0 | 0 | 0° (normal) |
| 0 | 1 | 90° |
| 1 | 0 | 180° |
| 1 | 1 | 270° |

| Main Window Display Start Address Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|--------|
| REG[40h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | bit 16 |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| Main Window Display Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Main Window Display Start Address

The Main Window Display Start Address Register represents a DWORD address which points to the start of the main window image in the display buffer. An address of 0 is the start of the display buffer. The Main Window Display Start Address is programmed to the address of display memory which is at the upper left corner of the rotated image.

For the following SwivelView mode descriptions, calculations refer to the *Upper Left Coordinate Address* as the address of display memory for the coordinates at the upper left corner of the display whether or not the image is rotated. Normally this coordinate is zero and therefore the address is zero. However, this address is dependent on the number of bits-per-pixel and is programmed into the Main Window Display Start Address register in dwords.

In SwivelView 0°, program the Main Window Display Start Address
= Upper Left Coordinate Address ÷ 4

In SwivelView 90°, program the Main Window Display Start Address

$$= ((\text{Upper Left Coordinate Address} + (\text{unrotated panel height} \times \text{bpp} \div 8) + ((4 - (\text{unrotated panel height} \times \text{bpp} \div 8)) \& 03h)) \div 4) - 1$$

In SwivelView 180°, calculate the value of the Main Window Stride and then program the Main Window Display Start Address

$$= ((\text{Upper Left Coordinate Address} + (\text{Main Window Stride} \times (\text{unrotated panel height} - 1)) + (\text{unrotated panel width} \times \text{bpp} \div 8) + ((4 - (\text{unrotated panel width} \times \text{bpp} \div 8)) \& 03h)) \div 4) - 1$$

In SwivelView 270°, calculate the value of the Main Window Stride and then program the Main Window Display Start Address

$$= (\text{Upper Left Coordinate Address} + ((\text{unrotated panel width} - 1) \times \text{Main Window Stride})) \div 4$$

Note

Truncate all fractional values before writing to the address registers.

SwivelView 0° and 180° require the unrotated panel width to be a multiple of (32 ÷ bits-per-pixel). SwivelView 90° and 270° require the unrotated panel height to be a multiple of (32 ÷ bits-per-pixel). If this is not possible, refer to Section 7.6, “Limitations” on page 44.

| Main Window Line Address Offset Register | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[44h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Main Window Line Address Offset bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

Main Window Line Address Offset

The Main Window Line Address Offset Register indicates the number of dwords per line in the main window image.

For SwivelView 0° and 180°, the image width must be at least the rotated panel width. For SwivelView 90° and 270°, the image width must be at least the rotated panel height. In addition, the image width must be a multiple of (32 ÷ bpp). If the image width is not such a multiple, a slightly larger width must be chosen (see Section 7.6, “Limitations”).

Unrotated panel width and *Unrotated panel height* refer to the physical panel dimensions in pixels. *Stride* is the number of bytes required for one line of the image; the offset register represents the stride in DWORD steps.

Main Window Stride = unrotated panel width × bpp ÷ 8

Note

In SwivelView 0° or 180° the image width must be equal to or greater than the unrotated panel width and in SwivelView 90° or 270° the image width must be equal to or greater than the unrotated panel height.

number of dwords per line = unrotated panel width ÷ (32 ÷ bpp)

7.4.1 SwivelView 0° (Landscape)

This section describes how to program the registers to establish SwivelView 0° in a series of steps. Calculations in each step must be truncated to integers. For the following SwivelView mode descriptions, calculations refer to the *Upper Left Coordinate Address* as the address of display memory for coordinates at the upper left corner of the display.

1. Determine the Stride.

$$\begin{aligned} \textit{Stride} \\ &= \text{unrotated panel width} \times \text{bpp} \div 8 \end{aligned}$$

2. Determine the Upper Left Coordinate Address.

$$\begin{aligned} \textit{Upper Left Coordinate Address} \\ &= (\text{upper coordinate} \times \text{Stride}) + (\text{left coordinate} \div \text{bpp}) \end{aligned}$$

3. Determine and program the Main Window Display Start Address Register.

$$\begin{aligned} \textit{Main Window Display Start Address Register} \\ &= \text{Upper Left Coordinate Address} \div 4 \end{aligned}$$

4. Determine and program the Main Window Line Offset Register.

$$\begin{aligned} \textit{Main Window Line Offset Register} \\ &= \text{display width in pixels} \div (32 \div \text{bpp}) \end{aligned}$$

7.4.2 SwivelView 90°

This section describes how to program the registers to establish SwivelView 90° in a series of steps. Calculations in each step must be truncated to integers. For the following SwivelView mode descriptions, calculations refer to the *Upper Left Coordinate Address* as the address of display memory for the coordinates at the upper left corner of the rotated display.

1. Determine the Stride.

Stride

$$= \text{unrotated panel width} \times \text{bpp} \div 8$$

2. Determine the Upper Left Coordinate Address.

Upper Left Coordinate Address

$$= (\text{upper-coordinate} \times \text{Stride}) + (\text{left-coordinate} \div \text{bpp})$$

3. Determine and program the Main Window Display Start Address Register.

Main Window Display Start Address Register

$$= ((\text{Upper Left Coordinate Address} + \text{unrotated panel height} \times \text{bpp} \div 8)) \\ + ((4 - (\text{unrotated panel height} \times \text{bpp} \div 8))) \& 03\text{h}) \div 4) - 1$$

4. Determine and program the Main Window Line Address Offset Register.

Main Window Line Address Offset Register

$$= \text{unrotated panel height} \div (32 \div \text{bpp})$$

7.4.3 SwivelView 180°

This section describes how to program the registers to establish SwivelView 180° in a series of steps. Calculations in each step must be truncated to integers. For the following SwivelView mode descriptions, calculations refer to the *Upper Left Coordinate Address* as the address of display memory for the coordinates at the upper left corner of the rotated display.

1. Determine the Stride.

$$\begin{aligned} \textit{Stride} \\ &= \text{rotated panel width} \times \text{bpp} \div 8 \end{aligned}$$

2. Determine the Upper Left Coordinate Address.

$$\begin{aligned} \textit{Upper Left Coordinate Address} \\ &= (\text{upper coordinate} \times \text{Stride}) + (\text{left coordinate} \div \text{bpp}) \end{aligned}$$

3. Determine and program the Main Window Display Start Address Register.

$$\begin{aligned} \textit{Main Window Display Start Address Register} \\ &= ((\text{Upper Left Coordinate Address} + (\text{Stride} \times (\text{unrotated panel height} - 1)) \\ &\quad + (\text{unrotated panel width} \times \text{bpp} \div 8)) + ((4 - \text{unrotated panel width} \times \text{bpp} \div 8) \\ &\quad \& 03h) \div 4) - 1 \end{aligned}$$

4. Determine and program the Main Window Line Address Offset Register.

$$\begin{aligned} \textit{Main Window Line Address Offset Register} \\ &= \text{unrotated panel height} \div (32 \div \text{bpp}) \end{aligned}$$

7.4.4 SwivelView 270°

This section describes how to program the registers to establish SwivelView 270° in a series of steps. Calculations in each step must be truncated to integers. For the following SwivelView mode descriptions, calculations refer to the *Upper Left Coordinate Address* as the address of display memory for the coordinates at the upper left corner of the rotated display.

1. Determine the Stride.

$$\begin{aligned} \textit{Stride} \\ &= \text{unrotated panel height} \times \text{bpp} \div 8 \end{aligned}$$

2. Determine the Upper Left Coordinate Address.

$$\begin{aligned} \textit{Upper Left Coordinate Address} \\ &= (\text{upper coordinate} \times \text{Stride}) + (\text{left coordinate} \div \text{bpp}) \end{aligned}$$

3. Determine and program the Main Window Display Start Address Register.

$$\begin{aligned} \textit{Main Window Display Start Address Register} \\ &= ((\text{Upper Left Coordinate Address} + ((\text{unrotated panel width} - 1) \times \text{Stride})) \div 4) \end{aligned}$$

4. Determine and program the Main Window Line Address Offset Register.

$$\begin{aligned} \textit{Main Window Line Address Offset Register} \\ &= \text{unrotated panel height} \div (32 \div \text{bpp}) \end{aligned}$$

7.5 Examples

Example 1: In SwivelView 0° (normal) mode, program the main window registers for a 320x240 panel at a color depth of 4 bpp.

1. Determine the Stride.

$$\begin{aligned} \text{Stride} \\ &= \text{unrotated panel width} \times \text{bpp} \div 8 \end{aligned}$$

2. Determine the Upper Left Coordinate Address.

$$\begin{aligned} \text{Upper Left Coordinate Address} \\ &= (0 \times \text{Stride}) + (0 \div \text{bpp}) \\ &= 0 \end{aligned}$$

3. Determine and program the Main Window Display Start Address. The main window is typically placed at the start of display memory which is at display address 0.

$$\begin{aligned} \text{Main Window Display Start Address Register} \\ &= \text{Upper Left Coordinate Address} \div 4 \\ &= 0 \end{aligned}$$

Program the Main Window Display Start Address register. REG[40h] is set to 00000000h.

4. Determine the Main Window Line Address Offset.

$$\begin{aligned} \text{number of dwords per line} \\ &= \text{unrotated panel width} \div (32 \div \text{bpp}) \\ &= 320 \div (32 \div 4) \\ &= 40 \\ &= 28\text{h} \end{aligned}$$

Program the Main Window Line Address Offset register. REG[44h] is set to 00000028h.

Example 2: In SwivelView 90° mode, program the main window registers for a 320x240 panel at a color depth of 4 bpp.

1. Determine the Stride.

Stride

$$= \text{unrotated panel width} \times \text{bpp} \div 8$$

2. Determine the Upper Left Coordinate Address.

Upper Left Coordinate Address

$$= (0 \times \text{Stride}) + (0 \div \text{bpp})$$

$$= 0$$

3. Determine and program the Main Window Display Start Address. The main window is typically placed at the start of display memory, which is at display address 0.

Main Window Display Start Address Register

$$= ((\text{Upper Left Coordinate Address} + (\text{unrotated panel height} \times \text{bpp} \div 8)$$

$$+ ((4 - (\text{unrotated panel height} \times \text{bpp} \div 8)) \& 03\text{h})) \div 4) - 1$$

$$= ((0 + (240 \times 4 \div 8) + ((4 - (240 \times 4 \div 8)) \& 03\text{h})) \div 4) - 1$$

$$= 29$$

$$= 1\text{Dh}$$

Program the Main Window Display Start Address register. REG[40h] is set to 0000001Dh.

4. Determine and program the Main Window Line Address Offset.

number of dwords per line

$$= \text{unrotated panel height} \div (32 \div \text{bpp})$$

$$= 240 \div (32 \div 4)$$

$$= 30$$

$$= 1\text{Eh}$$

Program the Main Window Line Address Offset register. REG[44h] is set to 0000001Eh.

Example 3: In SwivelView 180° mode, program the main window registers for a 320x240 panel at a color depth of 4 bpp.

1. Determine the Stride.

Stride

$$\begin{aligned}
 &= \text{unrotated panel width} \times \text{bpp} \div 8 \\
 &= 320 \times 4 \div 8 \\
 &= 160 \\
 &= \text{A0h}
 \end{aligned}$$

2. Determine the Upper Left Coordinate Address.

Upper Left Coordinate Address

$$\begin{aligned}
 &= (0 \times \text{Stride}) + (0 \div \text{bpp}) \\
 &= 0
 \end{aligned}$$

3. Determine and program the Main Window Display Start Address. The main window is typically placed at the start of display memory which is at display address 0.

Main Window Display Start Address Register

$$\begin{aligned}
 &= ((\text{Upper Left Coordinate Address} + (\text{Stride} \times (\text{unrotated panel height} - 1)) \\
 &\quad + (\text{unrotated panel width} \times \text{bpp} \div 8) + ((4 - (\text{unrotated panel width} \times \text{bpp} \div 8)) \\
 &\quad \& 03\text{h})) \div 4) - 1 \\
 &= ((0 + (160 \times (240 - 1)) + (320 \times 4 \div 8) + ((4 - (320 \times 4 \div 8)) \& 03\text{h})) \div 4) - 1 \\
 &= 9599 \\
 &= 257\text{Fh}
 \end{aligned}$$

Program the Main Window Display Start Address register. REG[40h] is set to 0000257Fh.

4. Determine and program the Main Window Line Address Offset.

number of dwords per line

$$\begin{aligned}
 &= \text{unrotated panel width} \div (32 \div \text{bpp}) \\
 &= 320 \div (32 \div 4) \\
 &= 40 \\
 &= 28\text{h}
 \end{aligned}$$

Program the Main Window Line Address Offset register. REG[44h] is set to 00000028h.

Example 4: In SwivelView 270° mode, program the main window registers for a 320x240 panel at a color depth of 4 bpp.

1. Determine the Stride.

Stride

$$\begin{aligned} &= \text{unrotated panel height} \times \text{bpp} \div 8 \\ &= 240 \times 4 \div 8 \\ &= 120 \\ &= 78\text{h} \end{aligned}$$

2. Determine the Upper Left Coordinate Address.

Upper Left Coordinate Address

$$\begin{aligned} &= (0 \times \text{Stride}) + (0 \div \text{bpp}) \\ &= 0 \end{aligned}$$

3. Determine and program Main Window Display Start Address. The main window is typically placed at the start of display memory, which is at display address 0.

Main Window Display Start Address Register

$$\begin{aligned} &= (\text{Upper Left Coordinate Address} + ((\text{unrotated panel width} - 1) \times \text{Stride})) \div 4 \\ &= (0 + ((320 - 1) \times 120)) \div 4 \\ &= 9570 \\ &= 2562\text{h} \end{aligned}$$

Program the Main Window Display Start Address register. REG[40h] is set to 00002562h.

4. Determine and program the Main Window Line Address Offset.

number of dwords per line

$$\begin{aligned} &= \text{unrotated panel height} \div (32 \div \text{bpp}) \\ &= 240 \div (32 \div 4) \\ &= 30 \\ &= 1\text{Eh} \end{aligned}$$

Program the Main Window Line Address Offset register. REG[44h] is set to 0000001Eh.

7.6 Limitations

7.6.1 SwivelView 0° and 180°

In SwivelView 0° and 180°, the Main Window Line Address Offset Register (REG[44h]) requires the *panel width* to be a multiple of $(32 \div \text{bits-per-pixel})$. If this is not the case, then the Main Window Line Address Offset Register must be programmed to a longer line which meets this requirement. This longer line creates a virtual image where the width is *Main Window Line Address Offset Register* $\times (32 \div \text{bits-per-pixel})$.

In SwivelView 0°, this virtual image should be drawn in display memory as left justified, and in SwivelView 180°, this virtual image should be drawn in display memory as right justified.

A left-justified image is one drawn in display memory such that each of the image's lines only use the left most portion of the line width defined by the line address offset register (i.e. starting at horizontal position 0).

A right-justified image is one drawn in display memory such that each of the image's lines only use the right most portion of the line width defined by the line address offset register (i.e. starting at a non-zero horizontal position which is the virtual width - image width).

7.6.2 SwivelView 90° and 270°

In SwivelView 90° and 270°, the Main Window Line Address Offset Register (REG[44h]) requires the *panel height* to be a multiple of $(32 \div \text{bits-per-pixel})$. If this is not the case, then the Main Window Line Address Offset Register must be programmed to a longer line which meets this requirement. This longer line creates a virtual image whose width is *Main Window Line Address Offset Register* $\times (32 \div \text{bits-per-pixel})$.

In SwivelView 270°, this virtual image should be drawn in display memory as left justified, and in SwivelView 90°, this virtual image should be drawn in display memory as right justified.

A left-justified image is one drawn in display memory such that each of the image's lines only use the left most portion of the line width defined by the line address offset register (i.e. starting at horizontal position 0).

A right-justified image is one drawn in display memory such that each of the image's lines only use the right most portion of the line width defined by the line address offset register (i.e. starting at a non-zero horizontal position which is the virtual width - image width).

8 Picture-in-Picture Plus (PIP⁺)

Picture-in-Picture Plus (PIP⁺) enables a secondary window (or PIP⁺ window) within the main display window. The PIP⁺ window may be positioned anywhere within the virtual display and is controlled through the PIP⁺ Window control registers (REG[50h] through REG[5Ch]). The PIP⁺ window retains the same color depth and SwivelView orientation as the main window.

A PIP⁺ window can be used to display temporary items such as a dialog box or to “float” the display item so that the system doesn’t have to exclude the area during screen repaints.

The following diagram shows an example of a PIP⁺ window within a main window.

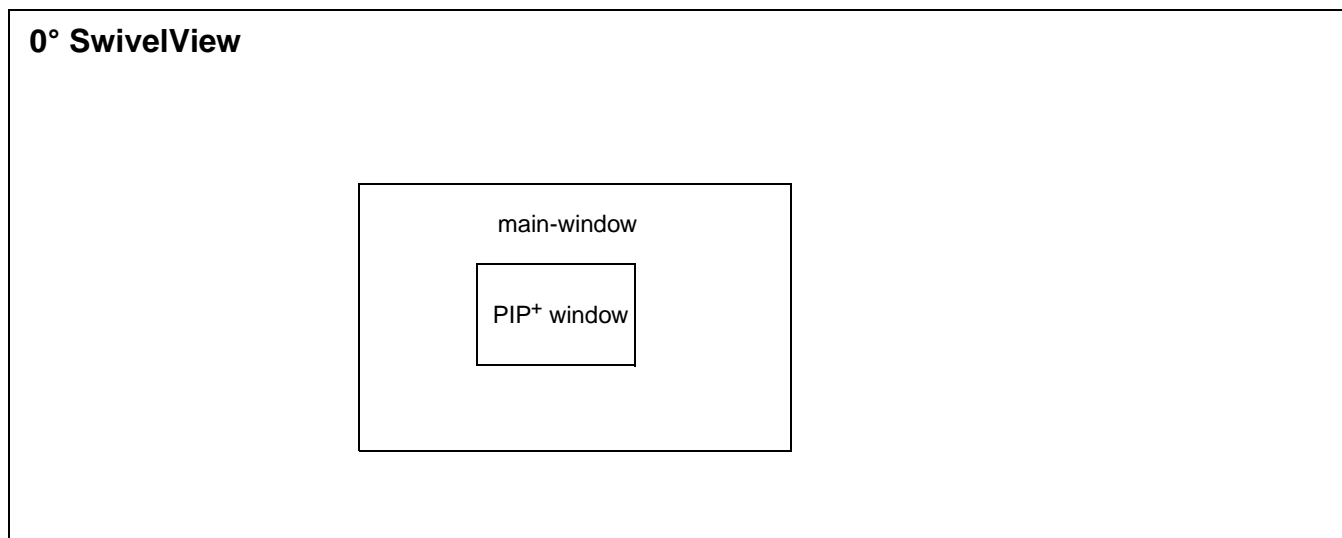


Figure 8-1: Picture-in-Picture Plus with SwivelView Disabled

8.1 Registers

The following registers control the Picture-In-Picture Plus feature.

| Display Settings Register | | | | | | | | | | | | | | | |
|-----------------------------------|----|----|----|----|----|-------------------------------|-----------------------------|------------------|----------------------|-----|---|--------------------------------------|-----|---------------------------|----|
| REG[10h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | Pixel Doubling Vertical | Pixel Doubling Horiz. | Display Blank | Dithering Disable | n/a | SW Video Invert | PIP ⁺ Window Enable | n/a | SwivelView Mode Select | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | Bits-per-pixel Select (actual value: 1, 2, 4, 8 or 16 bpp) | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

PIP⁺ Window Enable

The PIP⁺ Window Enable bit enables a PIP⁺ window within the main window. The location of the PIP⁺ window within the landscape window is determined by the PIP⁺ X Position register (REG[58h]) and PIP⁺ Y Position register (REG[5Ch]). The PIP⁺ window has its own Display Start Address register (REG[50h]) and Line Address Offset register (REG[54h]). The PIP⁺ window shares the same color depth and SwivelView™ orientation as the main window.

| PIP ⁺ Display Start Address Register | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|----|----|----|----|----|----|----|----|--------|----|
| REG[50h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | bit 16 | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| PIP ⁺ Display Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

PIP⁺ Display Start Address

The PIP⁺ Display Start Address register is a DWORD which represents an address that points to the start of the PIP⁺ window image in the display buffer. An address of 0 is the start of the display buffer. For the following PIP⁺ descriptions, the *desired byte address* is the starting display address for the PIP⁺ window image.

In SwivelView 0°, program the start address
= desired byte address ÷ 4

In SwivelView 90°, program the start address
= ((desired byte address + (PIP⁺ width × bpp ÷ 8)
+ ((4 - (PIP⁺ width × bpp ÷ 8)) & 03h) ÷ 4) - 1

In SwivelView 180°, program the start address
= ((desired byte address + (PIP⁺ Stride × (PIP⁺ height - 1))
+ (PIP⁺ width × bpp ÷ 8) + ((4 - (PIP⁺ width × bpp ÷ 8)) & 03h) ÷ 4) - 1

In SwivelView 270°, program the start address
= (desired byte address + ((PIP⁺ height - 1) × PIP⁺ Stride)) ÷ 4

Note

Truncate all fractional values before writing to the address registers.

SwivelView 0° and 180° require the PIP⁺ width to be a multiple of (32 ÷ bits-per-pixel). SwivelView 90° and 270° require the PIP⁺ height to be a multiple of (32 ÷ bits-per-pixel). If this is not possible, refer to Section 8.3, “Limitations” .

| PIP ⁺ Line Address Offset Register | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|---|----|----|----|----|----|----|----|---------------------|----|------------|--|
| REG[54h] | | | | | | | | | | | | | | Default = 00000000h | | Read/Write | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | PIP ⁺ Line Address Offset bits 9-0 | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

PIP⁺ Line Address Offset

The PIP⁺ Line Address Offset register indicates the number of dwords per line in the PIP⁺ window image.

The image width must be a multiple of (32 ÷ bpp). If the image width is not such a multiple, a slightly larger width must be chosen (see Section 8.3, “Limitations”).

PIP⁺ width and *PIP⁺ height* refer to the PIP⁺ dimensions as seen in SwivelView 0° (landscape mode). *Stride* is the number of bytes required for one line of the image; the offset register represents the stride in DWORD steps.

$$\text{PIP}^+ \text{ Stride} = \text{image width} \times \text{bpp} \div 8$$

For SwivelView 0° and 180°, program the line address offset

$$= \text{PIP}^+ \text{ Width}$$

$$= ((\text{REG}[58\text{h}] \text{ bits } 25:16) - (\text{REG}[58\text{h}] \text{ bits } 9:0) + 1) \times (32 \div \text{bpp})$$

For SwivelView 90° and 270°, program the line address offset

$$= \text{PIP}^+ \text{ Width}$$

$$= ((\text{REG}[5\text{Ch}] \text{ bits } 25:16) - (\text{REG}[5\text{Ch}] \text{ bits } 9:0) + 1) \times (32 \div \text{bpp})$$

| PIP ⁺ X Positions Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[58h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | PIP ⁺ X End Position bits 9-0 | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | PIP ⁺ X Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

PIP⁺ X End Position

The PIP⁺ X End Position bits determine the horizontal end of the PIP⁺ window in 0° and 180° SwivelView orientations. These bits determine the vertical end position in 90° and 270° SwivelView. For further information on defining the value of the X End Position, see Section 8.2, “Picture-In-Picture-Plus Examples” on page 53.

This register increments differently based on the SwivelView orientation. For 0° and 180° SwivelView the X End Position is incremented by *X* pixels where *X* is relative to the current color depth. For 90° and 270° SwivelView the X End Position is incremented in 1 line increments.

Table 8-1: 32-bit Address Increments for PIP⁺ X Position in SwivelView 0° and 180°

| Bits-Per-Pixel (Color Depth) | Pixel Increment (X) |
|------------------------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

In SwivelView 0°, these bits set the horizontal coordinates (*x*) of the PIP⁺ window’s right edge. Increasing *x* moves the right edge towards the right in steps of (32 ÷ bits-per-pixel) (see Table 8-1:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window X End Position so that

$$\text{PIP}^+ \text{ Window X End Position} = x \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

In SwivelView 90°, these bits set the vertical coordinates (*y*) of the PIP⁺ window’s bottom edge. Increasing *y* moves the bottom edge downward in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window X End Position so that

$$\text{PIP}^+ \text{ Window X End Position} = y$$

In SwivelView 180°, these bits set the horizontal coordinates (x) of the PIP⁺ window's left edge. Increasing x moves the left edge towards the right in steps of (32 ÷ bits-per-pixel) (see Table 8-1:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window X End Position so that

$$\text{PIP}^+ \text{ Window X End Position} = (\text{panel width} - x - 1) \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

In SwivelView 270°, these bits set the vertical coordinates (y) of the PIP⁺ window's top edge. Increasing y moves the top edge downwards in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window X End Position so that

$$\text{PIP}^+ \text{ Window X End Position} = \text{panel width} - y - 1$$

PIP⁺ X Start Position

The PIP⁺ X Start Position bits determine the horizontal position of the start of the PIP⁺ window in 0° and 180° SwivelView orientations. These bits determine the vertical start position in 90° and 270° SwivelView. For further information on defining the value of the X Start Position, see Section 8.2, "Picture-In-Picture-Plus Examples" on page 53.

The register increments differently based on the SwivelView orientation. For 0° and 180° SwivelView the X Start Position is incremented by X pixels where X is relative to the current color depth. For 90° and 270° SwivelView the X Start Position is incremented in 1 line increments.

Table 8-2: 32-bit Address Increments for Color Depth

| Bits-per-pixel (Color Depth) | Pixel Increment (X) |
|------------------------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

In SwivelView 0°, these bits set the horizontal coordinates (x) of the PIP⁺ windows's left edge. Increasing x moves the left edge towards the right in steps of (32 ÷ bits-per-pixel) (see Table 8-2:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window X Start Position so that

$$\text{PIP}^+ \text{ Window X Start Position} = x \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

In SwivelView 90°, these bits set the vertical coordinates (y) of the PIP⁺ window's top edge. Increasing y moves the top edge downward in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window X Start Position so that

$$\text{PIP}^+ \text{ Window X Start Position} = y$$

In SwivelView 180°, these bits set the horizontal coordinates (x) of the PIP⁺ window's right edge. Increasing x moves the right edge towards the right in steps of (32 ÷ bits-per-pixel) (see Table 8-2:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window X Start Position so that

$$\text{PIP}^+ \text{ Window X Start Position} = (\text{panel width} - x - 1) \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

In SwivelView 270°, these bits set the vertical coordinates (y) of the PIP⁺ window's bottom edge. Increasing y moves the bottom edge downwards in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window X Start Position so that

$$\text{PIP}^+ \text{ Window X Start Position} = \text{panel width} - y - 1$$

| PIP ⁺ Y Positions Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[5Ch] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | PIP ⁺ Y End Position bits 9-0 | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | PIP ⁺ Y Start Position bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

PIP⁺ Y End Position

The PIP⁺ Y End Position bits determine the vertical end position of the PIP⁺ window in 0° and 180° SwivelView orientations. These bits determine the horizontal end position in 90° and 270° SwivelView. For further information on defining the value of the Y End Position, see Section 8.2, "Picture-In-Picture-Plus Examples" on page 53.

The register increments differently based on the SwivelView orientation. For 0° and 180° SwivelView the Y End Position is incremented in 1 line increments. For 90° and 270° SwivelView the Y End Position is incremented by *Y* pixels where *Y* is relative to the current color depth.

Table 8-3: 32-bit Address Increments for Color Depth

| Bits-Per-Pixel (Color Depth) | Pixel Increment (Y) |
|------------------------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

In SwivelView 0°, these bits set the vertical coordinates (y) of the PIP⁺ windows' bottom edge. Increasing y moves the bottom edge downwards in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window Y End Position so that
$$\text{PIP}^+ \text{ Window Y End Position} = y$$

In SwivelView 90°, these bits set the horizontal coordinates (x) of the PIP⁺ window's left edge. Increasing x moves the left edge towards the right in steps of (32 ÷ bits-per-pixel) (see Table 8-3:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window Y End Position so that
$$\text{PIP}^+ \text{ Window Y End Position} = (\text{panel height} - x - 1) \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

In SwivelView 180°, these bits set the vertical coordinates (y) of the PIP⁺ window's top edge. Increasing y moves the top edge downwards in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window Y End Position so that
$$\text{PIP}^+ \text{ Window Y End Position} = \text{panel height} - y - 1$$

In SwivelView 270°, these bits set the horizontal coordinates (x) of the PIP⁺ window's right edge. Increasing x moves the right edge towards the right in steps of (32 ÷ bits-per-pixel) (see Table 8-3:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window Y End Position so that
$$\text{PIP}^+ \text{ Window Y End Position} = x \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

PIP⁺ Y Start Position

The PIP⁺ Y Start Position bits determine the vertical start position of the PIP⁺ window in 0° and 180° SwivelView orientations. These bits determine the horizontal start position in 90° and 270° SwivelView. For further information on defining the value of the Y Start Position, see Section 8.2, "Picture-In-Picture-Plus Examples" on page 53.

The register increments differently based on the SwivelView orientation. For 0° and 180° SwivelView the Y Start Position is incremented in 1 line increments. For 90° and 270° SwivelView the Y Start Position is incremented by Y pixels where Y is relative to the current color depth.

Table 8-4: 32-bit Address Increments for Color Depth

| Bits-Per-Pixel (Color Depth) | Pixel Increment (Y) |
|------------------------------|---------------------|
| 1 bpp | 32 |
| 2 bpp | 16 |
| 4 bpp | 8 |
| 8 bpp | 4 |
| 16 bpp | 2 |

In SwivelView 0°, these bits set the vertical coordinates (y) of the PIP⁺ windows's top edge. Increasing y moves the top edge downwards in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window Y Start Position so that

$$\text{PIP}^+ \text{ Window Y Start Position} = y$$

In SwivelView 90°, these bits set the horizontal coordinates (x) of the PIP⁺ window's right edge. Increasing x moves the right edge towards the right in steps of $(32 \div \text{bits-per-pixel})$ (see Table 8-4:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window Y Start Position so that

$$\text{PIP}^+ \text{ Window Y Start Position} = (\text{panel height} - x - 1) \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

In SwivelView 180°, these bits set the vertical coordinates (y) of the PIP⁺ window's bottom edge. Increasing y moves the bottom edge downwards in 1 line steps. The vertical coordinates start at line 0.

Program the PIP⁺ Window Y Start Position so that

$$\text{PIP}^+ \text{ Window Y Start Position} = \text{panel height} - y - 1$$

In SwivelView 270°, these bits set the horizontal coordinates (x) of the PIP⁺ window's left edge. Increasing x moves the left edge towards the right in steps of $(32 \div \text{bits-per-pixel})$ (see Table 8-4:). The horizontal coordinates start at pixel 0.

Program the PIP⁺ Window Y Start Position so that

$$\text{PIP}^+ \text{ Window Y Start Position} = x \div (32 \div \text{bits-per-pixel})$$

Note

Truncate the fractional part of the above equation.

8.2 Picture-In-Picture-Plus Examples

8.2.1 SwivelView 0° (Landscape Mode)

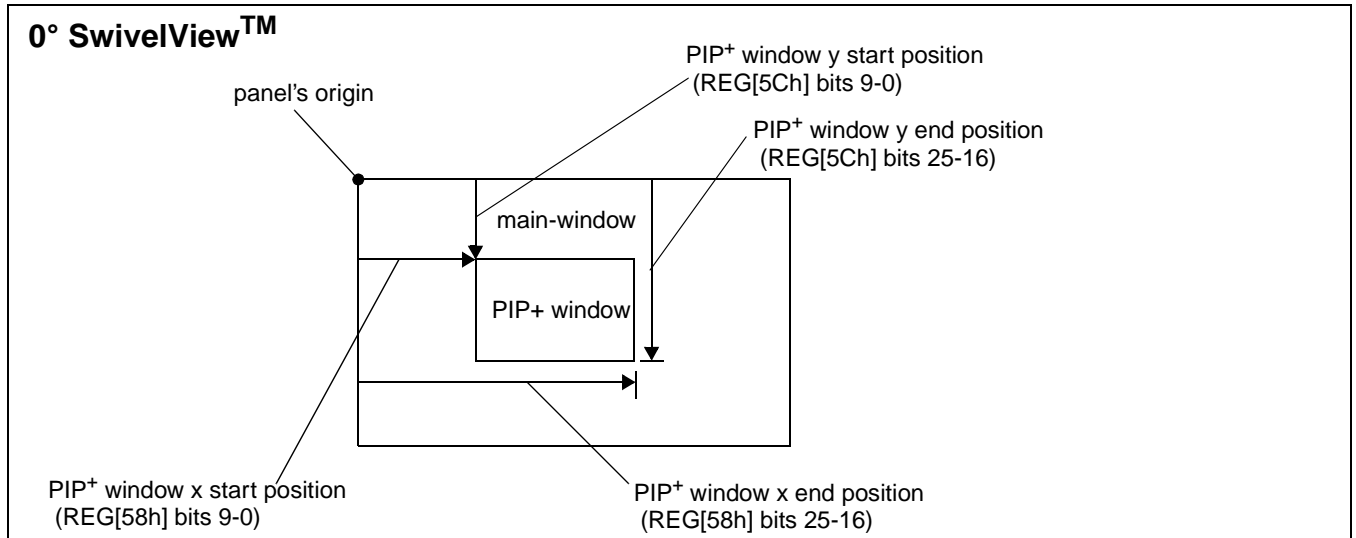


Figure 8-2: Picture-in-Picture Plus with SwivelView disabled

SwivelView 0° (or landscape) is a mode in which both the main and PIP+ window are non-rotated. The images for each window are typically placed consecutively, with the main window image starting at address 0 and followed by the PIP+ window image. In addition, both images must start at addresses which are dword-aligned (the last two bits of the starting address must be 0).

Note

It is possible to use the same image for both the main window and PIP+ window. To do so, set the PIP+ Line Address Offset register (REG[54h]) to the same value as the Main Window Line Address Offset register (REG[44h]).

Example 5: Program the PIP⁺ window registers for a 320x240 panel at 4 bpp, with the PIP⁺ window positioned at (80, 60) with a width of 160 and a height of 120.

1. Determine the value for the PIP⁺ Window X Positions and PIP⁺ Window Y Positions registers. Let the top left corner of the PIP⁺ window be (x1, y1), and let the bottom right corner be (x2, y2), where $x2 = x1 + \text{width} - 1$ and $y2 = y1 + \text{height} - 1$. The PIP⁺ Window X Positions register sets the horizontal coordinates of the PIP⁺ window's top left and bottom right corners. The PIP⁺ Window Y Positions register sets the vertical coordinates of the PIP⁺ window's top left and bottom right corners.

The required values are calculated as follows:

X Start Position

$$\begin{aligned} &= x1 \div (32 \div \text{bpp}) \\ &= 80 \div (32 \div 4) \\ &= 10 \\ &= 0Ah \end{aligned}$$

Y Start Position

$$\begin{aligned} &= y1 \\ &= 60 \\ &= 3Ch \end{aligned}$$

X End Position

$$\begin{aligned} &= x2 \div (32 \div \text{bpp}) \\ &= (80 + 160 - 1) \div (32 \div 4) \\ &= 29.875 \\ &= 1Dh \text{ (truncated fractional part)} \end{aligned}$$

Y End Position

$$\begin{aligned} &= y2 \\ &= 60 + 120 - 1 \\ &= 179 \\ &= B3h \end{aligned}$$

2. Program the PIP⁺ Window X Positions register with the X Start Position in bits 9-0 and the X End Position in bits 25-16. REG[58h] is set to 001D000Ah.
Program the PIP⁺ Window Y Positions register with the Y Start Position in bits 9-0 and the Y End Position in bits 25-16. REG[5Ch] is set to 00B3003Ch.

Due to truncation, the dimensions of the PIP⁺ window may have changed. Recalculate the PIP⁺ window width and height below:

PIP⁺ Width

$$\begin{aligned}
 &= ((\text{REG}[58\text{h}] \text{ bits } 25:16) - (\text{REG}[58\text{h}] \text{ bits } 9:0) + 1) \times (32 \div \text{bpp}) \\
 &= (1\text{Dh} - 0\text{Ah} + 1) \times (32 \div 4) \\
 &= 160 \text{ pixels}
 \end{aligned}$$

PIP Height

$$\begin{aligned}
 &= (\text{REG}[5\text{Ch}] \text{ bits } 25:16) - (\text{REG}[5\text{Ch}] \text{ bits } 9:0) + 1 \\
 &= \text{B3h} - 3\text{Ch} + 1 \\
 &= 120 \text{ lines}
 \end{aligned}$$

3. Determine the PIP⁺ display start address.
The main window image must take up $320 \times 240 \text{ pixels} \times \text{bpp} \div 8 = 9600\text{h}$ bytes. If the main window starts at address 0h, the PIP⁺ window can start at 9600h.

PIP⁺ display start address

$$\begin{aligned}
 &= \text{desired byte address} \div 4 \\
 &= 9600\text{h} \div 4 \\
 &= 2580\text{h}.
 \end{aligned}$$

Program the PIP⁺ Display Start Address register. REG[50h] is set to 00002580h.

4. Determine the PIP⁺ line address offset.

number of dwords per line

$$\begin{aligned}
 &= \text{image width} \div (32 \div \text{bpp}) \\
 &= 160 \div (32 \div 4) \\
 &= 20 \\
 &= 14\text{h}
 \end{aligned}$$

Program the PIP⁺ Line Address Offset register. REG[54h] is set to 00000014h.

5. Enable the PIP⁺ window.

Program the PIP⁺ Window Enable bit. REG[10h] bit 19 is set to 1.

8.2.2 SwivelView 90°

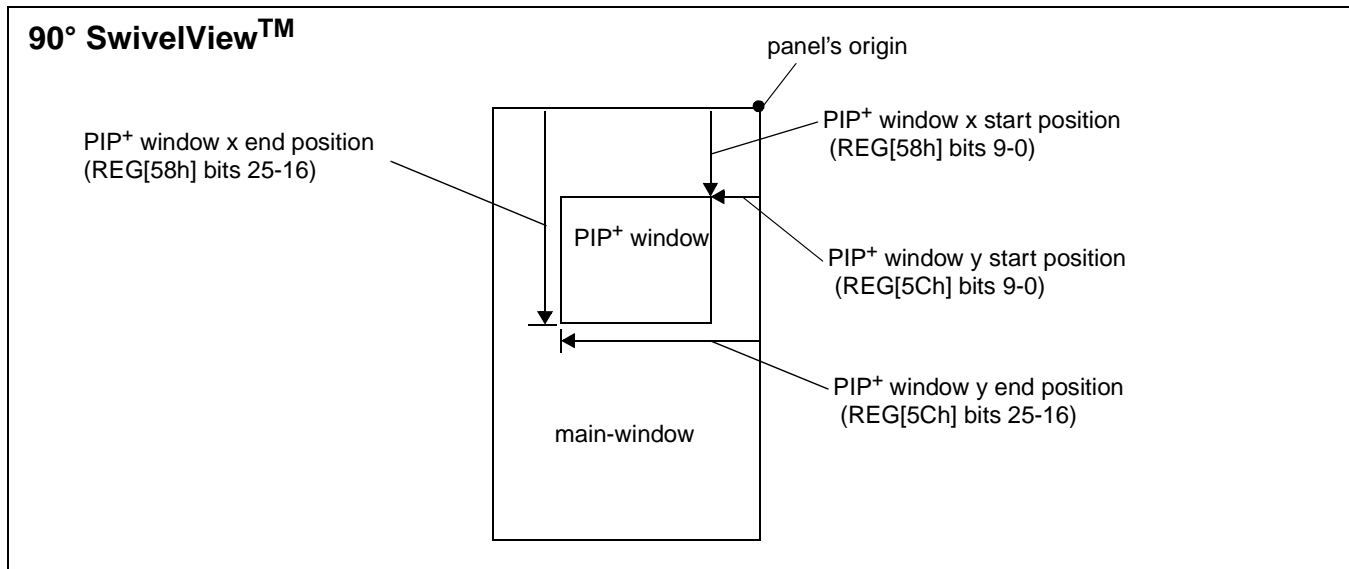


Figure 8-3: Picture-in-Picture Plus with SwivelView 90° enabled

SwivelView 90° is a mode in which both the main and PIP+ windows are rotated 90° counter-clockwise when shown on the panel. The images for each window are typically placed consecutively, with the main window image starting at address 0 and followed by the PIP+ window image. In addition, both images must start at addresses which are dword-aligned (the last two bits of the starting address must be 0).

Note

It is possible to use the same image for both the main window and PIP+ window. To do so, set the PIP+ Line Address Offset register (REG[54h]) to the same value as the Main Window Line Address Offset register (REG[44h]).

Example 6: In SwivelView 90°, program the PIP+ window registers for a 320x240 panel at 4 bpp, with the PIP+ window positioned at SwivelView 90° coordinates (60, 80) with a width of 120 and a height of 160.

1. Determine the value for the PIP+ Window X Positions and PIP+ Window Y Positions registers. Let the top left corner of the PIP+ window be (x1, y1), and let the bottom right corner be (x2, y2), where $x2 = x1 + \text{width} - 1$ and $y2 = y1 + \text{height} - 1$. The PIP+ Window X Positions register sets the vertical coordinates of the PIP+ window's top right and bottom left corners. The PIP+ Window Y Positions register sets the horizontal coordinates of the PIP+ window's top right and bottom left corners.

The required values are calculated as follows:

X Start Position

$$\begin{aligned} &= y1 \\ &= 80 \\ &= 50h \end{aligned}$$

Y Start Position

$$\begin{aligned} &= (\text{panel height} - x2 - 1) \div (32 \div \text{bpp}) \\ &= (240 - (60 + 120 - 1) - 1) \div (32 \div 4) \\ &= 7.5 \\ &= 07h \text{ (truncated fractional part)} \end{aligned}$$

X End Position

$$\begin{aligned} &= y2 \\ &= 80 + 160 - 1 \\ &= 239 \\ &= EFh \end{aligned}$$

Y End Position

$$\begin{aligned} &= (\text{panel height} - x1 - 1) \div (32 \div \text{bpp}) \\ &= (240 - 60 - 1) \div (32 \div 4) \\ &= 22.375 \\ &= 16h \text{ (truncated fractional part)} \end{aligned}$$

2. Program the PIP⁺ Window X Positions register with the X Start Position in bits 9-0 and the X End Position in bits 25-16. REG[58h] is set to 00EF0050h.
Program the PIP⁺ Window Y Positions register with the Y Start Position in bits 9-0 and the Y End Position in bits 25-16. REG[5Ch] is set to 00160007h.

Due to truncation, the dimensions of the PIP⁺ window may have changed. Recalculate the PIP⁺ window width and height below:

PIP⁺ Width

$$\begin{aligned}
 &= ((\text{REG}[5\text{Ch}] \text{ bits } 25:16) - (\text{REG}[5\text{Ch}] \text{ bits } 9:0) + 1) \times (32 \div \text{bpp}) \\
 &= (16\text{h} - 07\text{h} + 1) \times (32 \div 4) \\
 &= 128 \text{ pixels (note that this is different from the desired width)}
 \end{aligned}$$

PIP Height

$$\begin{aligned}
 &= (\text{REG}[58\text{h}] \text{ bits } 25:16) - (\text{REG}[58\text{h}] \text{ bits } 9:0) + 1 \\
 &= \text{EFh} - 50\text{h} + 1 \\
 &= 160 \text{ lines}
 \end{aligned}$$

3. Determine the PIP⁺ display start address.
The main window image must take up $320 \times 240 \text{ pixels} \times \text{bpp} \div 8 = 9600\text{h}$ bytes. If the main window starts at address 0h, then the PIP⁺ window can start at 9600h.

PIP⁺ display start address

$$\begin{aligned}
 &= ((\text{desired byte address} + (\text{PIP}^+ \text{ width} \times \text{bpp} \div 8) \\
 &\quad + ((4 - (\text{PIP}^+ \text{ width} \times \text{bpp} \div 8)) \& 03\text{h}) \div 4) - 1 \\
 &= ((9600\text{h} + (128 \times 4 \div 8) + ((4 - (128 \times 4 \div 8)) \& 03\text{h})) \div 4) - 1 \\
 &= 9615 \\
 &= 258\text{Fh}
 \end{aligned}$$

Program the PIP⁺ Display Start Address register. REG[50h] is set to 0000258Fh.

4. Determine the PIP⁺ line address offset.

number of dwords per line

$$\begin{aligned}
 &= \text{image width} \div (32 \div \text{bpp}) \\
 &= 128 \div (32 \div 4) \\
 &= 16 \\
 &= 10\text{h}
 \end{aligned}$$

Program the PIP⁺ Line Address Offset register. REG[54h] is set to 00000010h.

5. Enable the PIP⁺ window.

Program the PIP⁺ Window Enable bit. REG[10h] bit 19 is set to 1.

8.2.3 SwivelView 180°

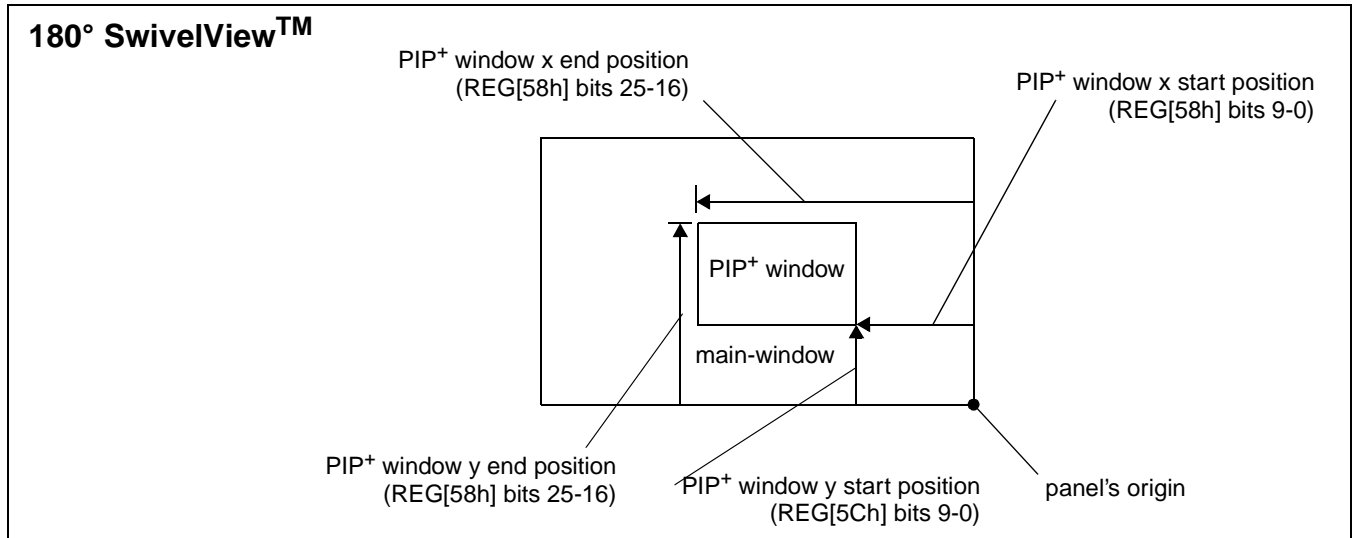


Figure 8-4: Picture-in-Picture Plus with SwivelView 180° enabled

SwivelView 180° is a mode in which both the main and PIP+ windows are rotated 180° counter-clockwise when shown on the panel. The images for each window are typically placed consecutively, with the main window image starting at address 0 and followed by the PIP+ window image. In addition, both images must start at addresses which are dword-aligned (the last two bits of the starting address must be 0).

Note

It is possible to use the same image for both the main window and PIP+ window. To do so, set the PIP+ Line Address Offset register (REG[54h]) to the same value as the Main Window Line Address Offset register (REG[44h]).

Example 7: In SwivelView 180°, program the PIP⁺ window registers for a 320x240 panel at 4 bpp, with the PIP⁺ window positioned at SwivelView 180° coordinates (80, 60) with a width of 160 and a height of 120.

1. Determine the value for the PIP⁺ Window X Positions and PIP⁺ Window Y Positions registers. Let the top left corner of the PIP⁺ window be (x1, y1), and let the bottom right corner be (x2, y2), where $x2 = x1 + \text{width} - 1$ and $y2 = y1 + \text{height} - 1$. The PIP⁺ Window X Positions register sets the horizontal coordinates of the PIP⁺ window's bottom right and top left corner. The PIP⁺ Window Y Positions register sets the vertical coordinates of the PIP⁺ window's bottom right and top left corner.

The required values are calculated as follows:

X Start Position

$$\begin{aligned} &= (\text{panel width} - x2 - 1) \div (32 \div \text{bpp}) \\ &= (320 - (80 + 160 - 1) - 1) \div (32 \div 4) \\ &= 10 \\ &= 0Ah \end{aligned}$$

Y Start Position

$$\begin{aligned} &= \text{panel height} - y2 - 1 \\ &= 240 - (60 + 120 - 1) - 1 \\ &= 60 \\ &= 3Ch \end{aligned}$$

X End Position

$$\begin{aligned} &= (\text{panel width} - x1 - 1) \div (32 \div \text{bpp}) \\ &= (320 - 80 - 1) \div (32 \div 4) \\ &= 29.875 \\ &= 1Dh \text{ (truncated fractional part)} \end{aligned}$$

Y End Position

$$\begin{aligned} &= \text{panel height} - y1 - 1 \\ &= 240 - 60 - 1 \\ &= 179 \\ &= B3h \end{aligned}$$

Program the PIP⁺ Window X Positions register with the X Start Position in bits 9-0 and the X End Position in bits 25-16. REG[58h] is set to 001D000Ah.

Program the PIP⁺ Window Y Positions register with the Y Start Position in bits 9-0 and the Y End Position in bits 25-16. REG[5Ch] is set to 00B3003Ch.

Due to truncation, the dimensions of the PIP⁺ window may have changed. Recalculate the PIP⁺ window width and height below:

PIP⁺ Width

$$\begin{aligned} &= ((\text{REG}[58h] \text{ bits } 25:16) - (\text{REG}[58h] \text{ bits } 9:0) + 1) \times (32 \div \text{bpp}) \\ &= (1Dh - 0Ah + 1) \times (32 \div 4) \\ &= 160 \text{ pixels} \end{aligned}$$

PIP Height

$$\begin{aligned} &= (\text{REG}[5Ch] \text{ bits } 25:16) - (\text{REG}[5Ch] \text{ bits } 9:0) + 1 \\ &= B3h - 3Ch + 1 \\ &= 120 \text{ lines} \end{aligned}$$

2. Determine the PIP⁺ display start address.
The main window image must take up $320 \times 240 \text{ pixels} \times \text{bpp} \div 8 = 9600\text{h}$ bytes. If the main window starts at address 0h, then the PIP⁺ window can start at 9600h.

PIP⁺ Stride

$$\begin{aligned} &= \text{image width} \times \text{bpp} \div 8 \\ &= 160 \times 4 \div 8 \\ &= 80 \\ &= 50\text{h} \end{aligned}$$

PIP⁺ display start address

$$\begin{aligned} &= ((\text{desired byte address} + (\text{PIP}^+ \text{ Stride} \times (\text{PIP}^+ \text{ height} - 1)) \\ &\quad + (\text{PIP}^+ \text{ width} \times \text{bpp} \div 8) + ((4 - (\text{PIP} \text{ width} \times \text{bpp} \div 8)) \& 03\text{h})) \div 4) - 1 \\ &= ((9600\text{h} + (80 \times (120 - 1)) + (160 \times 4 \div 8) + ((4 - (160 \times 4 \div 8)) \& 03\text{h})) \div 4) - 1 \\ &= 11999 \\ &= 2EDF\text{h} \end{aligned}$$

Program the PIP⁺ Display Start Address register. REG[50h] is set to 00002EDFh.

3. Determine the PIP⁺ line address offset.

number of dwords per line

$$\begin{aligned} &= \text{image width} \div (32 \div \text{bpp}) \\ &= 160 \div (32 \div 4) \\ &= 20 \\ &= 14\text{h} \end{aligned}$$

Program the PIP⁺ Line Address Offset register. REG[54h] is set to 00000014h.

4. Enable the PIP⁺ window.

Program the PIP⁺ Window Enable bit. REG[10h] bit 19 is set to 1.

8.2.4 SwivelView 270°

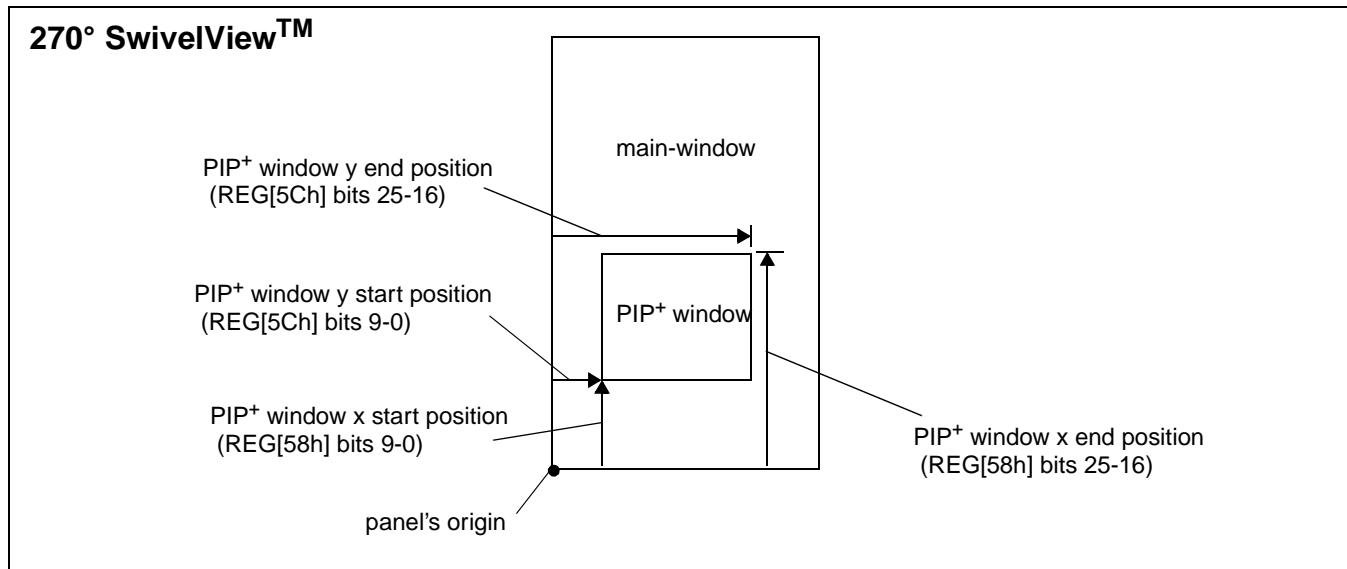


Figure 8-5: Picture-in-Picture Plus with SwivelView 270° enabled

SwivelView 270° is a mode in which both the main and PIP+ windows are rotated 270° counter-clockwise when shown on the panel. The images for each window are typically placed consecutively, with the main window image starting at address 0 and followed by the PIP+ window image. In addition, both images must start at addresses which are dword-aligned (the last two bits of the starting address must be 0).

Note

It is possible to use the same image for both the main window and PIP+ window. To do so, set the PIP+ Line Address Offset register (REG[54h]) to the same value as the Main Window Line Address Offset register (REG[44h]).

Example 8: In SwivelView 270°, program the PIP+ window registers for a 320x240 panel at 4 bpp, with the PIP+ window positioned at SwivelView 270° coordinates (60, 80) with a width of 120 and a height of 160.

1. Determine the value for the PIP+ Window X Positions and PIP+ Window Y Positions registers. Let the top left corner of the PIP+ window be (x1, y1), and let the bottom right corner be (x2, y2), where $x2 = x1 + \text{width} - 1$ and $y2 = y1 + \text{height} - 1$. The PIP+ Window X Positions register sets the vertical coordinates of the PIP+ window's top right and bottom left corner. The PIP+ Window Y Positions register sets the horizontal coordinates of the PIP+ window's top right and bottom left corner.

The required values are calculated as follows:

X Start Position

$$\begin{aligned} &= \text{panel width} - y2 - 1 \\ &= 320 - (80 + 160 - 1) - 1 \\ &= 80 \\ &= 50\text{h} \end{aligned}$$

Y Start Position

$$\begin{aligned} &= x1 \div (32 \div \text{bpp}) \\ &= 60 \div (32 \div 4) \\ &= 7.5 \\ &= 07\text{h (truncated fractional part)} \end{aligned}$$

X End Position

$$\begin{aligned} &= \text{panel width} - y1 - 1 \\ &= 320 - 80 - 1 \\ &= 239 \\ &= \text{EFh} \end{aligned}$$

Y End Position

$$\begin{aligned} &= x2 \div (32 \div \text{bpp}) \\ &= (60 + 120 - 1) \div (32 \div 4) \\ &= 22.375 \\ &= 16\text{h (truncated fractional part)} \end{aligned}$$

2. Program the PIP⁺ Window X Positions register with the X Start Position in bits 9-0 and the X End Position in bits 25-16. REG[58h] is set to 00EF0050h.
Program the PIP⁺ Window Y Positions register with the Y Start Position in bits 9-0 and the Y End Position in bits 25-16. REG[5Ch] is set to 00160007h.

Due to truncation, the dimensions of the PIP⁺ window may have changed. Recalculate the PIP⁺ window width and height below:

PIP⁺ Width

$$\begin{aligned} &= ((\text{REG}[5\text{Ch}] \text{ bits } 25:16) - (\text{REG}[5\text{Ch}] \text{ bits } 9:0) + 1) \times (32 \div \text{bpp}) \\ &= (16\text{h} - 07\text{h} + 1) \times (32 \div 4) \\ &= 128 \text{ pixels (note that this is different from the desired width)} \end{aligned}$$

PIP Height

$$\begin{aligned} &= (\text{REG}[58\text{h}] \text{ bits } 25:16) - (\text{REG}[58\text{h}] \text{ bits } 9:0) + 1 \\ &= \text{EFh} - 50\text{h} + 1 \\ &= 160 \text{ lines} \end{aligned}$$

3. Determine the PIP⁺ display start address.
The main window image must take up $320 \times 240 \text{ pixels} \times \text{bpp} \div 8 = 9600\text{h}$ bytes. If the main window starts at address 0h, then the PIP⁺ window can start at 9600h.

PIP⁺ Stride

$$\begin{aligned} &= \text{image width} \times \text{bpp} \div 8 \\ &= 128 \times 4 \div 8 \\ &= 64 \\ &= 40\text{h} \end{aligned}$$

PIP⁺ display start address

$$\begin{aligned} &= (\text{desired byte address} + ((\text{PIP}^+ \text{ height} - 1) \times \text{PIP}^+ \text{ Stride})) \div 4 \\ &= (9600\text{h} + ((160 - 1) \times 64)) \div 4 \\ &= 12144 \\ &= 2\text{F}70\text{h} \end{aligned}$$

Program the PIP⁺ Display Start Address register. REG[50h] is set to 00002F70h.

4. Determine the PIP⁺ line address offset.

number of dwords per line

$$\begin{aligned} &= \text{image width} \div (32 \div \text{bpp}) \\ &= 128 \div (32 \div 4) \\ &= 16 \\ &= 10\text{h} \end{aligned}$$

Program the PIP⁺ Line Address Offset register. REG[54h] is set to 00000010h.

5. Enable the PIP⁺ window.

Program the PIP⁺ Window Enable bit. REG[10h] bit 19 is set to 1.

8.3 Limitations

8.3.1 SwivelView 0° and 180°

The PIP⁺ Line Address Offset register (REG[54h]) requires the PIP⁺ window image *width* to be a multiple of $(32 \div \text{bits-per-pixel})$. If this formula is not satisfied, then the PIP⁺ Line Address Offset register must be programmed to the next larger value that satisfies the formula.

8.3.2 SwivelView 90° and 270°

The PIP⁺ Line Address Offset register (REG[54h]) requires the PIP⁺ window image *width* to be a multiple of $(32 \div \text{bits-per-pixel})$. If this formula is not satisfied, then the PIP⁺ Line Address Offset register must be programmed to the next larger value that satisfies the formula.

9 2D BitBLT Engine

BitBLT is an acronym for Bit Block Transfer. The 2D BitBLT Engine in the S1D13A05 is designed to increase the speed of the most common GUI operations by off-loading work from the CPU, reducing traffic on the system bus and freeing the CPU sooner for other tasks.

All BitBLTs require a destination - a place to write the data. Most BitBLTs have a source of data for the BitBLT and many also incorporate a pattern. The pattern, source, and destination operands are combined using logical AND, OR, XOR and NOT operations. The combining process is called a Raster Operation (ROP) and results in the final pixel data to be written to the destination address.

The S1D13A05 2D BitBLT engine supports a total of sixteen ROPs and works at 8 bpp and 16 bpp color depths. This section describes the BitBLT registers and provides some sample BitBLT operations.

9.1 Registers

The S1D13A05 BitBLT registers are located 8000h bytes from the start of S1D13A05 address space. The registers are labelled, according to their byte offset, as REG[8000h] through REG[8024h]. The following is a description of all BitBLT registers.

| BitBLT Control Register | | | | | | | | | | | | | | Read/Write | | | | | |
|-------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------------------|--------------------------|----------------------------|--|--|--|
| REG[8000h] | | | | | | | | | | | | | | Default = 00000000h | | | | | |
| n/a | | | | | | | | | | | | | | Color Format Select | Dest Linear Select | Source Linear Select | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | | |
| n/a | | | | | | | | | | | | | | | | BitBLT Enable (WO) | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | |

Color Format Select

The Color Format Select bit indicates to the BitBLT engine what color depth to assume for the BitBLT operation. The BitBLT engine uses this information to set the step size for internal counters.

When this bit = 0, 8 bpp is selected and when this bit = 1, 16 bpp is selected.

Destination Linear Select

The Destination Linear Select bit determines how the BitBLT destination address pointer is updated when the BitBLT reaches the end of a row.

When the end of a row is reached and rectangular is selected the destination address is updated to point to the beginning of the next row of a rectangular area. The offset to the start of the next row is contained in the BitBLT Memory Address Offset register (REG[8014h]).

When the end of a row is reached and destination linear is selected the destination address is updated to the next available memory offset. The result is data which is jammed together with one row immediately following the next in display memory. This is useful when it is desired to compactly save a rectangular area into off screen memory.

When this bit = 0, the BitBLT destination is stored as a rectangular region of memory. When this bit = 1, the BitBLT destination is stored as a contiguous linear block of memory.

Source Linear Select

The Source Linear Select bit determines how the source address pointer is updated when the BitBLT reaches the end of a row.

When the end of a row is reached and rectangular is selected the source address is updated to point to the beginning of the next row of a rectangular area. The offset to the start of the next row is contained in the BitBLT Memory Address Offset register (REG[8014h]).

When the end of a row is reached and source linear is selected the source address is updated to the next available memory offset. The result is data, which was jammed together with one row immediately following the next in display memory, can now be expanded back to a rectangular area.

When this bit = 0, the BitBLT source is stored as a rectangular region of memory. When this bit = 1, the BitBLT source is stored as a contiguous linear block of memory.

BitBLT Enable

This bit is write only.

Setting this bit to 1 begins the 2D BitBLT operation. **This bit must not be set to 0 while a BitBLT operation is in progress.**

Note

To determine the status of a BitBLT operation use the BitBLT Busy Status bit (REG[8004h] bit 0).

| BitBLT Status Register | | | | | | | | | | | | | | | | | |
|--------------------------------|----|----|-----------------------------|----|----|----|----|-----|----|----|--|----------------|------------------|-----|----|--|--------------------|
| REG[8004h] Default = 00000000h | | | | | | | | | | | Read Only | | | | | | |
| n/a | | | Number of Used FIFO Entries | | | | | n/a | | | Number of Free FIFO Entries (0 means full) | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | | | | | | | | | | | FIFO Not Empty | FIFO Half Full | FIFO Full Status | n/a | | | BitBLT Busy Status |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

Number of Used FIFO Entries

This is a read-only status.

This field indicates the minimum number of FIFO entries currently in use. If these bits return a 0, the FIFO is empty.

Number of Free FIFO Entries

This is a read-only status bit

This field indicates the number of empty FIFO entries available. If these bits return a 0, the FIFO is full.

FIFO Not-Empty

This is a read-only status bit.

When this bit = 0, the BitBLT FIFO is empty. When this bit = 1, the BitBLT FIFO has at least one data. To reduce system latency, software can monitor this bit prior to a BitBLT read burst operation.

The following table shows the number of words available in the BitBLT FIFO under different status conditions.

Table 9-1: BitBLT FIFO Words Available

| BitBLT FIFO Full Status (REG[8004h] Bit 4) | BitBLT FIFO Half Full Status (REG[8004h] Bit 5) | BitBLT FIFO Not Empty Status (REG[8004h] Bit 6) | Number of Words available in BitBLT FIFO |
|---|--|--|--|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 1 to 6 |
| 0 | 1 | 1 | 7 to 14 |
| 1 | 1 | 1 | 15 to 16 |

BitBLT FIFO Half Full Status

This is a read-only status bit.

When this bit = 1, the BitBLT FIFO is half full or greater than half full. When this bit = 0, the BitBLT FIFO is less than half full.

BitBLT FIFO Full Status

This is a read-only status bit.

When this bit = 1, the BitBLT FIFO is full. When this bit = 0, the BitBLT FIFO is not full.

BitBLT Busy Status

This bit is a read-only status bit.

When this bit = 1, the BitBLT operation is in progress. When this bit = 0, the BitBLT operation is complete.

Note

During a BitBLT Read operation, the BitBLT engine does not attempt to keep the FIFO full. If the FIFO becomes full, the BitBLT operation stops temporarily as data is read out of the FIFO. The BitBLT will restart only when less than 14 values remain in the FIFO.

| BitBLT Command Register | | | | | | | | | | | | Read/Write | | | |
|-------------------------|----|----|----|----|----|----|----|----|----|----|----|---------------------------|----|----|----|
| REG[8008h] | | | | | | | | | | | | Default = 00000000h | | | |
| n/a | | | | | | | | | | | | BitBLT ROP Code bits 3-0 | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | | BitBLT Operation bits 3-0 | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT ROP Code

The BitBLT ROP Code specifies the Raster Operation to be used for Write and Move BitBLTs. In addition, for Color Expansion, the BitBLT ROP Code bits 2-0 specify the start bit position for Color Expansion BitBLTs.

Table 9-2 : BitBLT ROP Code/Color Expansion Function Selection

| BitBLT ROP Code Bits [3:0] | Boolean Function for Write BitBLT and Move BitBLT | Boolean Function for Pattern Fill | Start Bit Position for Color Expansion |
|----------------------------|---|--|--|
| 0000 | 0 (Blackness) | 0 (Blackness) | bit 0 |
| 0001 | $\sim S \cdot \sim D$ or $\sim(S + D)$ | $\sim P \cdot \sim D$ or $\sim(P + D)$ | bit 1 |
| 0010 | $\sim S \cdot D$ | $\sim P \cdot D$ | bit 2 |
| 0011 | $\sim S$ | $\sim P$ | bit 3 |
| 0100 | $S \cdot \sim D$ | $P \cdot \sim D$ | bit 4 |
| 0101 | $\sim D$ | $\sim D$ | bit 5 |
| 0110 | $S \wedge D$ | $P \wedge D$ | bit 6 |
| 0111 | $\sim S + \sim D$ or $\sim(S \cdot D)$ | $\sim P + \sim D$ or $\sim(P \cdot D)$ | bit 7 |
| 1000 | $S \cdot D$ | $P \cdot D$ | bit 0 |
| 1001 | $\sim(S \wedge D)$ | $\sim(P \wedge D)$ | bit 1 |
| 1010 | D | D | bit 2 |
| 1011 | $\sim S + D$ | $\sim P + D$ | bit 3 |
| 1100 | S | P | bit 4 |
| 1101 | $S + \sim D$ | $P + \sim D$ | bit 5 |
| 1110 | $S + D$ | $P + D$ | bit 6 |
| 1111 | 1 (Whiteness) | 1 (Whiteness) | bit 7 |

Note

S = Source, D = Destination, P = Pattern.
 \sim = NOT, \cdot = Logical AND, $+$ = Logical OR, \wedge = Logical XOR

BitBLT Operation

The BitBLT Operation selects which BitBLT operation performed. The following table lists the available BitBLT operations.

Table 9-3 : BitBLT Operation Selection

| BitBLT Operation Bits [3:0] | BitBLT Operation |
|-----------------------------|--|
| 0000 | Write BitBLT with ROP This operation refers to BitBLTs where data is to be transferred from system memory to display memory |
| 0001 | Read BitBLT This operation refers to BitBLTs where data is to be transferred from display memory to system memory |
| 0010 | Move BitBLT in positive direction with ROP This operation is used to transfer data from display memory to display memory |
| 0011 | Move BitBLT in negative direction with ROP This operation is used to transfer data from display memory to display memory |
| 0100 | Transparent Write BitBLT Like the Write BitBLT this operation is used when transferring data from system memory to display memory, the difference is that destination pixels will be left "as is" when source pixels of a specified color are encountered. |
| 0101 | Transparent Move BitBLT in positive direction As with the Move BitBLTs this operation is used to transfer data from display memory to display memory. The difference is that destination pixels will be left "as is" when source pixels of a specified color are encountered. |
| 0110 | Pattern Fill with ROP Fills the specified area of display memory with a repeating pattern stored in display memory. |
| 0111 | Pattern Fill with transparency As with the Pattern Fill, this BitBLT fills a specified area of display memory with a repeating pattern, destination pixels will be left "as is" when source pixels of a specified color are encountered. |
| 1000 | Color Expansion This BitBLT expands the bits of the source data into full pixels at the destination. If a source bit is 0 the destination pixel will be background color and if the source bit is 1 the destination pixel will be of foreground color. The source data for Color Expansion BitBLTs is always system memory. |
| 1001 | Color Expansion with transparency Like the Color Expansion BitBLT, this operations expands each bit of the source data to occupy a full destination pixel. The difference, is that destination pixels corresponding to source bits of 0 will be left "as is". The data source is system memory |
| 1010 | Move BitBLT with Color Expansion This BitBLT works the same as the Color Expansion BitBLT however the source of the BitBLT is display memory. |
| 1011 | Move BitBLT with Color Expansion and transparency This BitBLT works the same as the Color Expansion with Transparency BitBLT however the source of the BitBLT is display memory. |
| 1100 | Solid Fill BitBLT Use this BitBLT to fill a given area with one solid color. |
| Other combinations | Reserved |

| BitBLT Source Start Address Register | | | | | | | | | | | Read/Write | | | | |
|---------------------------------------|----|----|----|----|----|----|----|----|----|----|--|----|----|----|----|
| REG[800Ch] | | | | | | | | | | | Default = 00000000h | | | | |
| n/a | | | | | | | | | | | BitBLT Source Start Address bits 20-16 | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Source Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Source Start Address

This register has multiple meanings depending on the BitBLT operation being performed. It can be either:

- the start address in display memory of the source data for BitBLTs where the source is display memory (i.e. Move BitBLTs).
- in pattern fill operations, the BitBLT Source Start Address determines where in the pattern to begin the BitBLT operation and is defined by the following equation:

$$\text{Value programmed to the Source Start Address Register} = \text{Pattern Base Address} + \text{Pattern Line Offset} + \text{Pixel Offset}.$$
- the data alignment for 16 bpp BitBLTs where the source of BitBLT data is the CPU (i.e. Write BitBLTs).

The following table shows how Source Start Address Register is defined for 8 and 16 bpp color depths.

Table 9-4 : BitBLT Source Start Address Selection

| Color Format | Pattern Base Address[20:0] | Pattern Line Offset[2:0] | Pixel Offset[3:0] |
|--------------|-----------------------------------|----------------------------------|----------------------------------|
| 8 bpp | BitBLT Source Start Address[20:6] | BitBLT Source Start Address[5:3] | BitBLT Source Start Address[2:0] |
| 16 bpp | BitBLT Source Start Address[20:7] | BitBLT Source Start Address[6:4] | BitBLT Source Start Address[3:0] |

| BitBLT Destination Start Address Register | | | | | | | | | | | Read/Write | | | | |
|--|----|----|----|----|----|----|----|----|----|----|---|----|----|----|----|
| REG[8010h] | | | | | | | | | | | Default = 00000000h | | | | |
| n/a | | | | | | | | | | | BitBLT Destination Start Address bits 20-16 | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Destination Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Destination Start Address

This register specifies the initial destination address for BitBLT operations. For rectangular destinations this address represents the upper left corner of the BitBLT rectangle. If the operation is a Move BitBLT in a Negative Direction, these bits define the address of the lower right corner of the rectangle.

| BitBLT Memory Address Offset Register | | | | | | | | | | | | | | | |
|---------------------------------------|----|----|----|----|----|--|----|----|----|----|----|----|----|----|----|
| REG[8014h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Memory Address Offset bits 10-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Memory Address Offset

This register specifies the 11-bit address offset from the starting word of line n to the starting word of line $n + 1$. The offset value is only used for address calculation when the BitBLT is configured as rectangular.

| BitBLT Width Register | | | | | | | | | | | | | | | |
|-------------------------------------|----|----|----|----|----|-----------------------|----|----|----|----|----|----|----|----|----|
| REG[8018h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Width bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Width

This register specifies the width of a BitBLT in pixels - 1.

$$\text{BitBLT width (in pixels)} = \text{REG}[8018\text{h}] + 1$$

| BitBLT Height Register | | | | | | | | | | | | | | | |
|-------------------------------------|----|----|----|----|----|------------------------|----|----|----|----|----|----|----|----|----|
| REG[801Ch] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Height bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Height

This register specifies the height of the BitBLT in lines - 1.

$$\text{BitBLT height (in lines)} = \text{REG}[801\text{Ch}] + 1$$

| BitBLT Background Color Register | | | | | | | | | | | | | | | |
|-------------------------------------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| REG[8020h] Default = 00000000h | | | | | | | | | | | | | | | |
| Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Background Color bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Background Color

This register specifies either:

- the BitBLT background color for Color Expansion

or

- the key color for Transparent BitBLT. For 8 bpp BitBLTs, bits 7-0 are used to specify the key color and for 16 bpp BitBLTs, bits 15-0 are used.

| BitBLT Foreground Color Register | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|---------------------|----|------------|--|
| REG[8024h] | | | | | | | | | | | | | | Default = 00000000h | | Read/Write | |
| n/a | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| BitBLT Foreground Color bits 15-0 | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |

BitBLT Foreground Color

This register specifies the foreground color for Color Expansion or Solid Fill BitBLTs. For 8 bpp BitBLTs, bits 7-0 are used to specify the color and for 16 bpp BitBLTs, bits 15-0 are used.

| 2D Accelerator (BitBLT) Data Memory Mapped Region Register | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|----|----|----|----|------------|----|
| AB16-AB0 = 10000h-1FFFEh, even addresses | | | | | | | | | | | | | | Read/Write | |
| BitBLT Data bits 31-16 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Data bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

BitBLT Data bits

This register is used by the local CPU to send data to the BitBLT engine for Write and Color Expansion BitBLTs and is used to read data from the BitBLT engine for Read BitBLTs. The register should be treated as any other register it is however loosely decoded from 10000h to 1FFFEh.

Note

The BitBLT data registers are 32 bits wide but are accessed on WORD boundaries using 16 bit accesses. Byte access to the BitBLT data registers is not allowed.

Note

Accesses to this register, other than for purposes of a BitBLT operation may cause the 13A05 to stop responding and the system to hang.

9.2 BitBLT Descriptions

The S1D13A05 supports 13 fundamental BitBLT operations:

- Write BitBLT with ROP
- Read BitBLT
- Move BitBLT in positive direction with ROP
- Move BitBLT in negative direction with ROP
- Transparent Write BitBLT
- Transparent Move BitBLT in positive direction
- Pattern Fill with ROP
- Pattern Fill with Transparency
- Color Expansion
- Color Expansion with Transparency
- Move BitBLT with Color Expansion
- Move BitBLT with Color Expansion and Transparency
- Solid Fill

Most of the 13 operations are self completing. This means once the BitBLT operation begins it completes without further assistance from the local CPU. No data transfers are required to or from the local CPU. Five BitBLT operations (Write BitBLT with ROP, Transparent Write BitBLT, Color Expansion, Color Expansion with Transparency, Read BitBLT) require data to be written to/read from the BitBLT engine. This data must be transferred one word (16-bits) at a time. This does not imply only 16-bit CPU instructions are acceptable. If a system is able to separate one DWORD write into two WORD writes and the CPU writes the low word before the high word, then 32-bit CPU instructions are acceptable. Otherwise, 16-bit CPU instructions are required.

The data is not directly written to/read from the display buffer. It is written to/read from the BitBLT FIFO through the 64K byte BitBLT aperture specified at the address of REG[10000h]. The 16 word FIFO can be written to only when not full and can be read from only when not empty. Failing to monitor the FIFO status can result in a BitBLT FIFO overflow or underflow.

While the FIFO is being written to by the CPU, it is also being emptied by the S1D13A05. If the S1D13A05 empties the FIFO faster than the CPU can fill it, it may not be possible to cause an overflow/underflow. In these cases, performance can be improved by not monitoring the FIFO status. However, this is very much platform dependent and must be determined for each system.

9.2.1 Write BitBLT with ROP

Write BitBLTs increase the speed of transferring data from system memory to the display buffer. The Write BitBLT with ROP accepts data from the CPU and *writes* it into display memory. This BitBLT is typically used to copy a bitmap image from system memory to the display buffer.

Write BitBLTs support 16 ROPs, the most frequently used being ROP 0Ch (Copy Source to Destination). Write BitBLTs support both rectangular and linear destinations. Using a linear destination it is possible to move an image to off screen memory in a compact format for later restoration using a Move BitBLT.

During a Write BitBLT operation the BitBLT engine expects to receive a particular number of WORDs and it is the responsibility of the CPU to provide the required amount of data.

When performing BitBLT at 16 bpp color depth the number of WORDS to be sent is the same as the number of pixels to be transferred as each pixel is one WORD wide. The number of WORD writes the BitBLT engine expects is calculated using the following formula.

$$\begin{aligned}\text{WORDS} &= \text{Pixels} \\ &= \text{BitBLTWidth} \times \text{BitBLTHeight}\end{aligned}$$

When the color depth is 8 bpp the formula must take into consideration that the BitBLT engine accepts only WORD accesses and each pixel is one BYTE. This may lead to a different number of WORD transfers than there are pixels to transfer.

The number of WORD accesses is dependant on the position of the first pixel within the first WORD of each row. Is the pixel stored in the low byte or the high byte of the WORD? This aspect of the BitBLT is called phase and is determined as follows:

Source phase is 0 when the first pixel is in the low byte and the second pixel is in the high byte of the WORD. When the source phase is 0, bit 0 of the Source Start Address Register is 0. The Source Phase is 1 if the first pixel of each row is contained in the high byte of the WORD, the contents of the low byte are ignored. When the source phase is 1, bit 0 of the Source Start Address Register is set.

Depending on the Source Phase and the BitBLT Width, the last WORD may contain only one pixel. In this case it is always in the low byte. The number of WORD writes the BitBLT engine expects for 8 bpp color depths is shown in the following formula.

$$\text{WORDS} = ((\text{BitBLTWidth} + 1 + \text{SourcePhase}) \div 2) \times \text{BitBLTHeight}$$

The BitBLT engine requires this number of WORDS to be sent from the local CPU before it will end the Write BitBLT operation.

Note

The BitBLT engine counts WORD writes made to the BitBLT register space. This does not imply only 16-bit CPU instructions are acceptable. If a system is able to separate one DWORD write into two WORD writes **and** the CPU writes the low word before the high word, then 32-bit CPU instructions are acceptable. Otherwise, 16-bit CPU instructions are required.

Example 9: Write a 100 x 20 rectangle at the screen coordinates $x = 25$, $y = 38$ using a 320x240 display at a color depth of 8 bpp.

1. Calculate the destination address (upper left corner of the screen BitBLT rectangle) using the following formula.

$$\begin{aligned} \text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (38 \times 320) + (25 \times 1) \\ &= 12185 \\ &= 2F99\text{h} \end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 320 for 8 bpp

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 2F99h.

2. Program the BitBLT Width Register to 100 - 1. REG[8018h] is set to 63h (99 decimal).
3. Program the BitBLT Height Register to 20 - 1. REG[801Ch] is set to 13h (19 decimal).
4. Program the Source Phase in the BitBLT Source Start Address Register. In this example the data is WORD aligned, so the source phase is 0. REG[800Ch] is set to 00h.
5. Program the BitBLT Operation Register to select the Write BitBLT with ROP. REG[8008h] bits 3-0 are set to 0h.
6. Program the BitBLT ROP Code Register to select Destination = Source. REG[8008h] bits 19-16 are set to 0Ch.
7. Program the BitBLT Color Format Select bit for 8 bpp operations. REG[8000h] bit 18 is set to 0.
8. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS:

$$\begin{aligned} \text{BLTMemoryOffset} &= \text{DisplayWidthInPixels} \div \text{BytesPerPixel} \\ &= 320 \div 2 \\ &= \text{A0h} \end{aligned}$$

REG[8014h] is set to A0h.

9. Calculate the number of WORDS the BitBLT engine expects to receive.

$$\begin{aligned}
 \text{WORDS} &= ((\text{BLTWidth} + 1 + \text{SourcePhase}) \div 2) \times \text{BLTHeight} \\
 &= (100 + 1) \div 2 \times 20 \\
 &= 1000 \\
 &= 3E8h
 \end{aligned}$$

10. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8004h] bit 0 returns a 1.

11. Prior to writing any data to the BitBLT FIFO, confirm the BitBLT FIFO is not full (REG[8004h] bit 4 returns a 0).

If the BitBLT FIFO Not Empty Status (REG[8004h] bit 6) returns a 0, the FIFO is empty. Write up to 16 WORDS to the BitBLT data register area.

If the BitBLT FIFO Not Empty Status (REG[8004h] bit 6) returns a 1 and the BitBLT FIFO Half Full Status (REG[8004h] bit 5) returns a 0 then you can write up to 8 WORDS.

If the BitBLT FIFO Full Status returns a 1, do not write to the BitBLT FIFO until it returns a 0.

The following table summarizes how many words can be written to the BitBLT FIFO.

Table 9-5: Possible BitBLT FIFO Writes

| BitBLT Status Register (REG[8004h]) | | | Word Writes Available |
|-------------------------------------|-----------------------|------------------|-----------------------|
| FIFO Not Empty Status | FIFO Half Full Status | FIFO Full Status | |
| 0 | 0 | 0 | 16 |
| 1 | 0 | 0 | 8 |
| 1 | 1 | 0 | up to 8 |
| 1 | 1 | 1 | 0 (do not write) |

Note

The sequence of register initialization is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.2 Color Expansion BitBLT

Similar to the Write BitBLT, the Color Expansion BitBLT requires the CPU to feed data to the BitBLT data register. It differs in that bits set to one in the source data become a complete pixel of foreground color. Source bits set to zero are converted to a pixel of background color. The intended use of this BitBLT operation is to increase the speed of writing text to display memory. As with the Write BitBLT, all data sent to the BitBLT engine must be WORD (16-bit) writes.

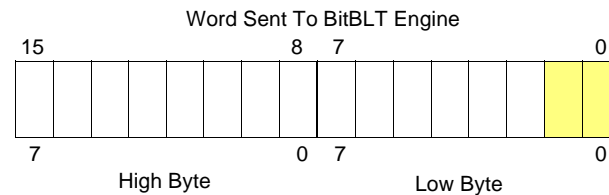
The BitBLT engine expands first the low byte, then the high byte starting at bit 7 of each byte. The start byte of the first WORD to be expanded and the start bit position within this byte must be specified. The start byte position is selected by setting source address bit 0 to 0 to start expanding the low byte or 1 to start expanding the high byte.

Partially “masked” color expansion BitBLTs can be used when drawing a portion of a pattern (i.e. a portion of a character) on the screen. The following examples illustrate how one WORD is expanded using the Color Expansion BitBLT.

1. To expand bits 0-1 of the word:

Source Address = 0
Start Bit Position = 1
BitBLT Width = 2

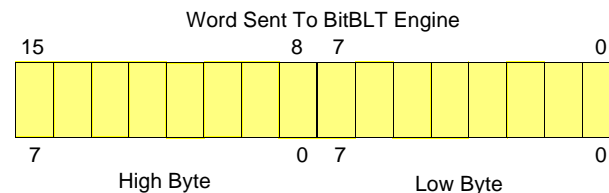
The following bits are expanded.



2. To expand bits 0-15 of the word (entire word)

Source Address = 0
Start Bit Position = 7 (bit seven of the low byte)
BitBLT Width = 16

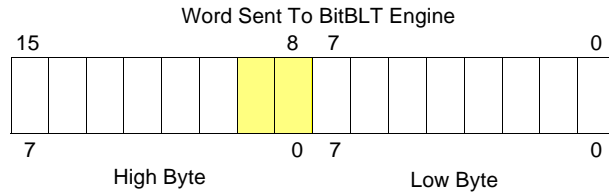
The following bits are expanded.



3. To expand bits 8-9 of the word

Source Address = 1
 Start Bit Position = 1
 BitBLT Width = 2

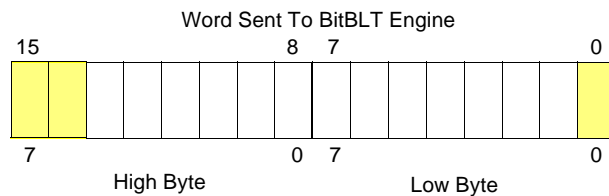
The following bits are expanded.



4. To expand bits 0,15-14 of the word

Source Address = 0
 Start Bit Position = 0
 BitBLT Width = 3

The following bits are expanded.

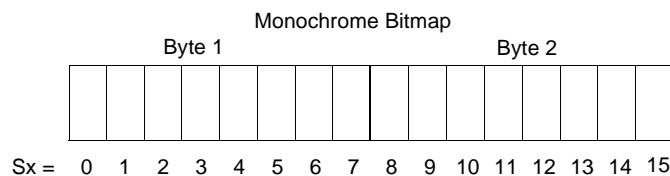


All subsequent WORDS in one BitBLT line are then serially expanded starting at bit 7 of the low byte until the end of the BitBLT line. All unused bits in the last WORD are discarded. It is extremely important that the exact number of WORDS is provided to the BitBLT engine. The number of WORDS is calculated from the following formula. This formula is valid for all color depths (8/16 bpp).

$$\text{WORDS} = ((Sx \text{ MOD } 16 + \text{BitBLTWidth} + 15) \div 16) \times \text{BitBLTHeight}$$

where:

Sx is the X coordinate of the starting pixel in a word aligned monochrome bitmap.



**Example 10: Color expand a rectangle of 12 x 18 starting at the coordinates
Sx = 125, Sy = 17 using a 320x240 display at a color depth of 8 bpp.**

This example assumes a monochrome, WORD aligned bitmap of dimensions 300 x 600 with the origin at an address A. The color expanded rectangle will be displayed at the screen coordinates X = 20, Y = 30. The foreground color corresponds to the LUT entry at index 134, the background color to index 124.

1. First we need to calculate the address of the WORD within the monochrome bitmap containing the pixel x = 125, y = 17.

$$\begin{aligned}
 \text{SourceAddress} &= \text{BitmapOrigin} + (y \times \text{SourceStride}) + (x \div 8) \\
 &= A + (S_y \times \text{SourceStride}) + (S_x \div 8) \\
 &= A + (17 \times 38) + (125 \div 8) \\
 &= A + 646 + 15 \\
 &= A + 661
 \end{aligned}$$

where:

$$\begin{aligned}
 \text{SourceStride} &= (\text{BitmapWidth} + 15) \div 16 \\
 &= (300 + 15) \div 16 \\
 &= 19 \text{ WORDS per line} \\
 &= 38 \text{ BYTES per line}
 \end{aligned}$$

2. Calculate the destination address (upper left corner of the screen BitBLT rectangle) using the following formula.

$$\begin{aligned}
 \text{DestinationAddress} &= (Y \times \text{ScreenStride}) + (X \times \text{BytesPerPixel}) \\
 &= (30 \times 320) + (20 \times 1) \\
 &= 9620 \\
 &= 2594h
 \end{aligned}$$

where:

$$\text{BytesPerPixel} = 1 \text{ for } 8 \text{ bpp}$$

$$\text{ScreenStride} = \text{DisplayWidthInPixels} \times \text{BytesPerPixel} = 320 \text{ for } 8 \text{ bpp}$$

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 2594h.

3. Program the BitBLT Width Register to 12 - 1. REG[8018h] is set to 0Bh (11 decimal).
4. Program the BitBLT Height Register to 18 - 1. REG[801Ch] is set to 11h (17 decimal).
5. Program the Source Phase in the BitBLT Source Start Address Register. In this example the source address equals A + 661 (odd), so REG[800Ch] is set to 1.

Since only bit 0 flags the source phase, more efficient code would simply write the low byte of the SourceAddress into REG[800Ch] directly -- not needing to test for an odd/even address. Note that in 16 bpp color depths the Source address is guaranteed to be even.

6. Program the BitBLT Operation Register to select the Color Expand BitBLT. REG[8008h] bits 3-0 are set to 8h.

7. Program the Color Expansion Register. The formula for this example is as follows.

$$\begin{aligned} \text{Color Expansion} &= 7 - (Sx \text{ MOD } 8) \\ &= 7 - (125 \text{ MOD } 8) \\ &= 7 - 5 \\ &= 2 \end{aligned}$$

REG[8008h] is set to 2h.

8. Program the Background Color Register to the background color. REG[8020h] is set to 7Ch (124 decimal).
9. Program the Foreground Color Register to the foreground color. REG[8024h] is set to 86h (134 decimal).
10. Program the BitBLT Color Format Register for 8 bpp operation. REG[8000h] bit 18 is set to 0.
11. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned} \text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \div 2 \\ &= \text{A0h} \end{aligned}$$

REG[8014h] is set to A0h.

12. Calculate the number of WORDS the BitBLT engine expects to receive.

First, the number of WORDS in one BitBLT line must be calculated as follows.

$$\begin{aligned} \text{WordsOneLine} &= ((125 \text{ MOD } 16) + 12 + 15) \div 16 \\ &= (13 + 12 + 15) \div 16 \\ &= 40 \div 16 \\ &= 2 \end{aligned}$$

Therefore, the total WORDS the BitBLT engine expects to receive is calculated as follows.

$$\begin{aligned} \text{WORDS} &= \text{WordsOneLine} \times 18 \\ &= 2 \times 18 \\ &= 36 \end{aligned}$$

13. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8004h] bit 0 returns a 1.

14. Prior to writing all WORDS to the BitBLT FIFO, confirm the BitBLT FIFO is not full (REG[8004h] bit 4 returns a 0). One WORD expands into 16 pixels which fills all 16 FIFO words in 16 bpp or 8 FIFO words in 8 bpp.

The following table summarizes how many words can be written to the BitBLT FIFO.

Table 9-6: Possible BitBLT FIFO Writes

| BitBLT Status Register (REG[8004h]) | | | 8 bpp Word Writes Available | 16 bpp Word Writes Available |
|-------------------------------------|-----------------------|------------------|--------------------------------|---------------------------------|
| FIFO Not Empty Status | FIFO Half Full Status | FIFO Full Status | | |
| 0 | 0 | 0 | 2 | 1 |
| 1 | 0 | 0 | 1 | 0 (do not write) |
| 1 | 1 | 0 | 0 (do not write) | |
| 1 | 1 | 1 | | |

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.3 Color Expansion BitBLT With Transparency

This BitBLT operation is virtually identical to the Color Expand BitBLT, the difference is in how background bits are handled. Bits in the source bitmap which are set to zero result in the destination pixel remaining untouched. Bits set to one are expanded to the foreground color.

Use this BitBLT operation to overlay text onto any background while leaving the background intact.

Refer to the Color Expansion BitBLT for sample calculations and keep the following points in mind:

- Program the BitBLT operation bits, REG[8008h] bits 3-0, to 09h instead of 08h.
- Setting a background color, REG[8020h], is not required.

9.2.4 Solid Fill BitBLT

The Solid Fill BitBLT fills a rectangular area of the display buffer with a solid color. This operation is used to paint large screen areas or to set areas of the display buffer to a given value.

This BitBLT operation is self completing. After setting the width, height, destination start position and (foreground) color the BitBLT engine is started. When the region of display memory is filled with the given color the BitBLT engine will automatically stop.

Example 11: Fill a red 9 x 301 rectangle at the screen coordinates $x = 100$, $y = 10$ using a 320x240 display at a color depth of 16 bpp.

1. Calculate the destination address (upper left corner of the destination rectangle) using the following formula.

$$\begin{aligned}\text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (10 \times (320 \times 2)) + (100 \times 2) \\ &= 6600 \\ &= 19C8\text{h}\end{aligned}$$

where:

BytesPerPixel = 2 for 16 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 640 for 16 bpp.

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 19C8h.

2. Program the BitBLT Width Register to 9 - 1. REG[8018h] is set to 08h.
3. Program the BitBLT Height Register to 301 - 1. REG[801Ch] is set to 12Ch (300 decimal).
4. Program the BitBLT Foreground Color Register. REG[8024h] is set to F800h (Full intensity red in 16 bpp is F800h).
5. Program the BitBLT Operation Register to select Solid Fill. REG[8008h] bits 3-0 are set to 0Ch.
6. Program the BitBLT Color Format Register for 16 bpp operations. REG[8000h] bit 18 is set to 1.
7. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned}\text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \\ &= 140\text{h}\end{aligned}$$

REG[8014h] is set to 0140h.

8. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.5 Move BitBLT in a Positive Direction with ROP

The Move BitBLT is used to copy one area of display memory to another area in display memory.

The source and the destination areas of the BitBLT may be either rectangular or linear. Performing a rectangular to rectangular Move BitBLT creates an exact copy of one portion of video memory at the second location. Selecting a rectangular source to linear destination would be used to compactly store an area of displayed video memory into non-displayed video memory. Later, the area could be restored by performing a linear source to rectangular destination Move BitBLT.

The Move BitBLT in a Positive Direction with ROP is a self completing operation. Once the width, height and the source and destination start addresses are setup and the BitBLT is started the BitBLT engine will complete the operation automatically.

Should the source and destination areas overlap a decision has to be made as to whether to use a Positive or Negative direction so that source data is not overwritten by the move before it is used. Refer to Figure 9-1: to see when to make the decision to switch to the Move BitBLT in a Negative direction. When the destination area overlaps the original source area and the destination address is greater then the source address, use the Move BitBLT in Negative Direction with ROP.

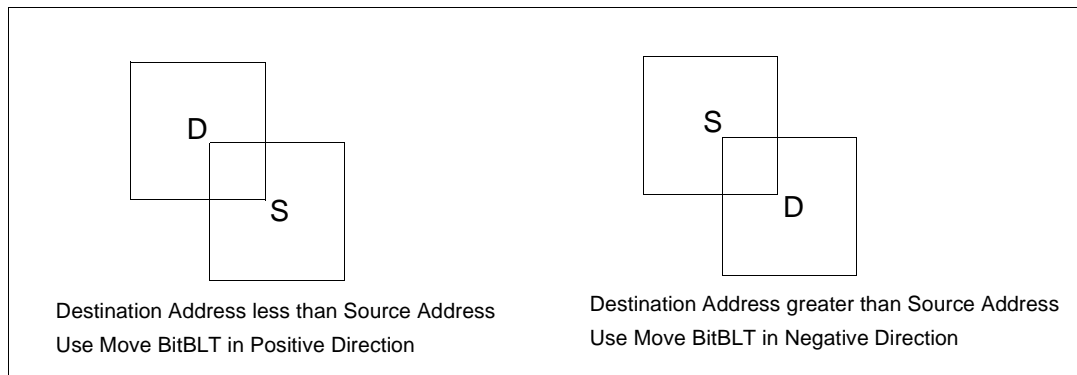


Figure 9-1: Move BitBLT Usage

Example 12: Copy a 9 x 101 rectangle at the screen coordinates $x = 100$, $y = 10$ to screen coordinates $x = 200$, $y = 20$ using a 320x240 display at a color depth of 16 bpp.

1. Calculate the source and destination addresses (upper left corners of the source and destination rectangles), using the following formula.

$$\begin{aligned} \text{SourceAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (10 \times (320 \times 2)) + (100 \times 2) \\ &= 6600 \\ &= 19C8h \end{aligned}$$

$$\begin{aligned} \text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (20 \times (320 \times 2)) + (200 \times 2) \\ &= 13200 \\ &= 3390h \end{aligned}$$

where:

BytesPerPixel = 2 for 16 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 640 for 16 bpp

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 19C8h.

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 3390h.

2. Program the BitBLT Width Register to 9 - 1. REG[8018h] is set to 08h.
3. Program the BitBLT Height Register to 101 - 1. REG[801Ch] is set to 64h (100 decimal).
4. Program the BitBLT Operation Register to select the Move BitBLT in Positive Direction with ROP. REG[8008h] bits 3-0 are set to 2h.
5. Program the BitBLT ROP Code Register to select Destination = Source. REG[8008h] bits 19-16 are set to 0Ch.
6. Program the BitBLT Color Format Select bit for 16 bpp operations. REG[8000h] bit 18 is set to 1.
7. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned} \text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \\ &= 140h \end{aligned}$$

REG[8014h] is set to 0140h.

8. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.6 Move BitBLT in Negative Direction with ROP

The Move BitBLT in Negative Direction with ROP is similar to the Move BitBLT in Positive direction. Use this BitBLT operation when the source and destination BitBLT areas overlap and the destination address is greater than the source address. Refer to Figure 9-1: on page 84 to see when to make the decision to switch to the Move BitBLT in a Positive direction.

When using the Move BitBLT in Negative Direction it is necessary to calculate the addresses of the last pixels as opposed to the first pixels. This means calculating the addresses of the lower right corners as opposed to the upper left corners.

Example 13: Copy a 9 x 101 rectangle at the screen coordinates $x = 100, y = 10$ to screen coordinates $X = 105, Y = 20$ using a 320x240 display at a color depth of 16 bpp.

In the following example, the coordinates of the source and destination rectangles intentionally overlap.

1. Calculate the source and destination addresses (**lower right** corners of the source and destination rectangles) using the following formula.

SourceAddress

$$\begin{aligned} &= ((y + \text{Height} - 1) \times \text{ScreenStride}) + ((x + \text{Width} - 1) \times \text{BytesPerPixel}) \\ &= ((10 + 101 - 1) \times (320 \times 2)) + ((100 + 9 - 1) \times 2) \\ &= 70616 \\ &= 113D8h \end{aligned}$$

DestinationAddress

$$\begin{aligned} &= ((Y + \text{Height} - 1) \times \text{ScreenStride}) + ((X + \text{Width} - 1) \times \text{BytesPerPixel}) \\ &= ((20 + 101 - 1) \times (320 \times 2)) + ((105 + 9 - 1) \times 2) \\ &= 77026 \\ &= 12CE2h \end{aligned}$$

where:

BytesPerPixel = 2 for 16 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 640 for 16 bpp

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 113D8h.

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 12CE2h.

2. Program the BitBLT Width Register to 9 - 1. REG[8018h] is set to 08h.
3. Program the BitBLT Height Register to 101 - 1. REG[801Ch] is set to 64h (100 decimal).
4. Program the BitBLT Operation Register to select the Move BitBLT in Negative Direction with ROP. REG[8008] bits 3-0 are set to 3h.
5. Program the BitBLT ROP Code Register to select Destination = Source. REG[8008h] bits 19-16 are set to 0Ch.

6. Program the BitBLT Color Format Select bit for 16 bpp operations. REG[8000h] bit 18 is set to 1.
7. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned} \text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \\ &= 140\text{h} \end{aligned}$$

REG[8014h] is set to 0140h.

8. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.7 Transparent Write BitBLT

Transparent Write BitBLTs are similar to the Write BitBLT with ROP with two differences; first, a specified color in the source data leaves the destination pixel untouched and second ROPs are not supported.

This operation is used to copy a bitmap image from system memory to the display buffer with one source color treated as transparent. Pixels of the transparent color are not transferred. This allows fast display of non-rectangular or masked images. For example, consider a source bitmap having a red circle on a blue background. By selecting the blue as the transparent color and using the Transparent Write BitBLT on the whole rectangle, the effect is a BitBLT of the red circle only.

During a Transparent Write BitBLT operation the BitBLT engine expects to receive a particular number of WORDs and it is the responsibility of the CPU to provide the required amount of data.

When performing BitBLTs at 16 bpp color depth the number of WORDS to be sent is the same as the number of pixels as each pixel is one WORD wide. The number of WORD writes the BitBLT engine expects is calculated using the following formula.

$$\begin{aligned} \text{WORDS} &= \text{Pixels} \\ &= \text{BitBLTWidth} \times \text{BitBLTHeight} \end{aligned}$$

When the color depth is 8 bpp the formula must take into consideration that the BitBLT engine accepts only WORD accesses and each pixel is one BYTE. This may lead to a different number of WORD transfers than there are pixels to transfer.

The number of WORD accesses is dependant on the position of the first pixel within the first WORD of each row. Is the pixel stored in the low byte or the high byte of the WORD? This aspect of the BitBLT is called phase and is determined as follows:

Source phase is 0 when the first pixel is in the low byte and the second pixel is in the high byte of the WORD. When the source phase is 0, bit 0 of the Source Start Address Register is 0. The Source Phase is 1 if the first pixel of each row is contained in the high byte of the WORD, the contents of the low byte are ignored. When the source phase is 1, bit 0 of the Source Start Address Register is set.

Depending on the Source Phase and the BitBLT Width, the last WORD may contain only one pixel. In this case it is always in the low byte. The number of WORD writes the BitBLT engine expects for 8 bpp color depths is shown in the following formula.

$$\text{WORDS} = ((\text{BitBLTWidth} + 1 + \text{SourcePhase}) \div 2) \times \text{BitBLTHeight}$$

Once the Transparent Write BitBLT begins, the BitBLT engine remains active until all pixels have been written. The BitBLT engine requires the correct number of WORDS to be sent from the local CPU before it ends the Transparent Write BitBLT operation.

Note

The BitBLT engine counts WORD writes made to the BitBLT register. This does not imply only 16-bit CPU instructions are acceptable. If a system is able to separate one DWORD write into two WORD writes **and** the CPU writes the low word before the high word, then 32-bit CPU instructions are acceptable. Otherwise, 16-bit CPU instructions are required.

Example 14: Write 100 x 20 pixels at the screen coordinates x = 25, y = 38 using a 320x240 display at a color depth of 8 bpp. Transparent color is high intensity blue (assume LUT Index 124).

1. Calculate the destination address (upper left corner of the screen BitBLT rectangle), using the formula:

$$\begin{aligned} \text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (38 \times 320) + (25 \times 1) \\ &= 12185 \\ &= 2F99\text{h} \end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 320 for 8 bpp

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 2F99h.

2. Program the BitBLT Width Register to 100 - 1. REG[8018h] is set to 63h (99 decimal).
3. Program the BitBLT Height Register to 20 - 1. REG[801Ch] is set to 13h (19 decimal).
4. Program the Source Phase in the BitBLT Source Start Address Register. In this example, the data is WORD aligned, so the source phase is 0. REG[800Ch] is set to 00h.

5. Program the BitBLT Operation Register to select Transparent Write BitBLT. REG[8008h] bits 3-0 are set to 4h.
6. Program the BitBLT Background Color Register to select transparent color. REG[8020h] is set to 7Ch (124 decimal).
7. Program the BitBLT Color Format Select bit for 8 bpp operations. REG[8000h] bit 18 is set to 0.
8. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned} \text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \div 2 \\ &= 160 \\ &= \text{A0h} \end{aligned}$$

REG[8014h] is set to 0A0h.

9. Calculate the number of WORDS the BitBLT engine expects to receive.

$$\begin{aligned} \text{WORDS} &= ((\text{BLTWidth} + 1 + \text{SourcePhase}) \div 2) \times \text{BLTHeight} \\ &= (100 + 1 + 0) \div 2 \times 20 \\ &= 1000 \\ &= \text{3E8h} \end{aligned}$$

10. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8004h] bit 0 returns a 1.

11. Prior to writing any data to the BitBLT FIFO, confirm the BitBLT FIFO is not full (REG[8004h] bit 4 returns a 0).
If the BitBLT FIFO Not Empty Status (REG[8004h] bit 6) returns a 0, the FIFO is empty. Write up to 16 WORDS to the BitBLT data register area.
If the BitBLT FIFO Not Empty Status (REG[8004h] bit 6) returns a 1 and the BitBLT FIFO Half Full Status (REG[8004h] bit 5) returns a 0 then you can write up to 8 WORDS.
If the BitBLT FIFO Full Status returns a 1, do not write to the BitBLT FIFO until it returns a 0.

The following table summarizes how many words can be written to the BitBLT FIFO.

Table 9-7: Possible BitBLT FIFO Writes

| BitBLT Status Register (REG[8004h]) | | | Word Writes Available |
|-------------------------------------|-----------------------|------------------|-----------------------|
| FIFO Not Empty Status | FIFO Half Full Status | FIFO Full Status | |
| 0 | 0 | 0 | 16 |
| 1 | 0 | 0 | 8 |
| 1 | 1 | 0 | less than 8 |
| 1 | 1 | 1 | 0 (do not write) |

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.8 Transparent Move BitBLT in Positive Direction

The Transparent Move BitBLT in Positive Direction combines the capabilities of the Move BitBLT with the ability to define a transparent color. Use this operation to copy a masked area of display memory to another area in display memory.

The source and the destination areas of the BitBLT may be either rectangular or linear. Performing a rectangular to rectangular Move BitBLT creates an exact copy of one portion of video memory at the second location. Selecting a rectangular source to linear destination would be used to compactly store an area of displayed video memory into non-displayed video memory. Later, the area could be restored by performing a linear source to rectangular destination Move BitBLT.

The transparent color is not copied during this operation, whatever pixel color existed in the destination will be there when the BitBLT completes. This allows fast display of non-rectangular images. For example, consider a source bitmap having a red circle on a blue background. By selecting the blue color as the transparent color and using the Transparent Move BitBLT on the whole rectangle, the effect is a BitBLT of the red circle only.

Note

The Transparent Move BitBLT is supported **only** in a positive direction.

Example 15: Copy a 9 x 101 rectangle at the screen coordinates $x = 100$, $y = 10$ to screen coordinates $X = 200$, $Y = 20$ using a 320x240 display at a color depth of 16 bpp. Transparent color is blue.

1. Calculate the source and destination addresses (upper left corners of the source and destination rectangles), using the formula:

$$\begin{aligned} \text{SourceAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (10 \times (320 \times 2)) + (100 \times 2) \\ &= 6600 \\ &= 19C8\text{h} \end{aligned}$$

$$\begin{aligned} \text{DestinationAddress} &= (Y \times \text{ScreenStride}) + (X \times \text{BytesPerPixel}) \\ &= (20 \times (320 \times 2)) + (200 \times 2) \\ &= 13200 \\ &= 3390\text{h} \end{aligned}$$

where:

BytesPerPixel = 2 for 16 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 640 for 16 bpp

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 19C8h.

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 3390h.

2. Program the BitBLT Width Register to 9 - 1. REG[8018h] is set to 08h.
3. Program the BitBLT Height Register to 101 - 1. REG[801Ch] is set to 64h (100 decimal).

4. Program the BitBLT Operation Register to select the Transparent Move BitBLT in Positive Direction. REG[8008h] bits 3-0 are set to 05h.
5. Program the BitBLT Background Color Register to select blue as the transparent color. REG[8020h] is set to 001Fh (Full intensity blue in 16 bpp is 001Fh).
6. Program the BitBLT Color Format Register to select 16 bpp operations. REG[8000h] bit 18 is set to 1.
7. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned}\text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \\ &= 140\text{h}\end{aligned}$$

REG[8014h] is set to 0140h.

8. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The order of register setup is irrelevant as long as all relevant registers are programmed before the BitBLT is initiated.

9.2.9 Pattern Fill BitBLT with ROP

The Pattern Fill BitBLT with ROP fills a specified area of display memory with a pattern. The pattern is repeated until the fill area is completely filled. The fill pattern is limited to an eight by eight pixel array and must be loaded to off-screen video memory before starting the BitBLT. The pattern can be logically combined with the destination using any of the 16 ROP codes, but typically the copy pattern ROP is used (ROP code 0Ch).

A pattern is defined to be an array of 8x8 pixels and the pattern data must be stored in consecutive bytes of display memory (64 consecutive bytes for 8 bpp color depths and 128 bytes for 16 bpp color depths). For 8 bpp color depths the pattern must begin on a 64 byte boundary, for 16 bpp color depths the pattern must begin on a 128 byte boundary.

This operation is self completing. Once the parameters have been entered and the BitBLT started the BitBLT engine will fill all of the specified memory with the pattern.

To fill an area using the pattern BitBLT, the BitBLT engine requires the location of the pattern, the destination rectangle position and size, and the ROP code. The BitBLT engine also needs to know which pixel from the pattern is the first pixel in the destination rectangle (the pattern start phase). This allows seamless redrawing of any part of the screen using the pattern fill.

Example 16: Fill a 100 x 150 rectangle at the screen coordinates $x = 10$, $y = 20$ with the pattern in off-screen memory at offset 3C000h using a 320x240 display at a color depth of 8 bpp. The first pixel (upper left corner) of the rectangle is the pattern pixel at $x = 3$, $y = 4$.

1. Calculate the destination address (upper left corner of the destination rectangle), using the formula:

$$\begin{aligned} \text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (20 \times 320) + (10 \times 1) \\ &= 6410 \\ &= 190Ah \end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 320 for 8 bpp

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 190Ah.

2. Calculate the source address. This is the address of the pixel in the pattern that is the origin of the destination fill area. The pattern begins at offset 240K, but the first pattern pixel is at $x = 3$, $y = 4$. Therefore, an offset within the pattern itself must be calculated.

SourceAddress

$$\begin{aligned} &= \text{PatternOffset} + \text{StartPatternY} \times 8 \times \text{BytesPerPixel} + \text{StartPatternX} \times \text{BytesPerPixel} \\ &= 240K + (4 \times 8 \times 1) + (3 \times 1) \\ &= 240K + 35 \\ &= 245795 \\ &= 3C023h \end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 3C023h.

3. Program the BitBLT Width Register to 100 - 1. REG[8018h] is set to 63h (99 decimal).
4. Program the BitBLT Height Register to 150-1. REG[801Ch] is set to 95h (149 decimal).
5. Program the BitBLT Operation Register to select the Pattern Fill with ROP. REG[8008h] bits 3-0 are set to 6h.
6. Program the BitBLT ROP Code Register to select Destination = Source. REG[8008h] bits 19-16 are set to 0Ch.
7. Program the BitBLT Color Format Select bit for 8 bpp operations. REG[8000h] bit 18 is set to 0.

8. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned}\text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \div 2 \\ &= 160 \\ &= \text{A0h}\end{aligned}$$

REG[8014h] is set to 00A0h.

9. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.10 Pattern Fill BitBLT with Transparency

This operation is very similar to the Pattern Fill BitBLT with the difference being that one color can be specified to be transparent. Whenever the Transparent color is encountered in the pattern data the destination is left as is. This operation is useful to create hatched or striped patterns where the original image shows through the hatching.

The requirements for this BitBLT are the same as for the Pattern Fill BitBLT the only change in programming is that the BitBLT Operation field of REG[8008h] must be set to 07h and the BitBLT Background color register, REG[8020h] must be set to the desired color.

Example 17: Fill a 100 x 150 rectangle at the screen coordinates $x = 10$, $y = 20$ with the pattern in off-screen memory at offset 3C000h using a 320x240 display at a color depth of 8 bpp. The first pixel (upper left corner) of the rectangle is the pattern pixel at $x = 3$, $y = 4$. Transparent color is blue (assumes LUT index 1).

1. Calculate the destination address (upper left corner of destination rectangle), using the formula:

$$\begin{aligned}\text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (20 \times 320) + (10 \times 1) \\ &= 6410 \\ &= 190\text{Ah}\end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 320 for 8 bpp

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 190Ah.

2. Calculate the source address. This is the address of the pixel in the pattern that is the origin of the destination fill area. The pattern begins at offset 240K, but the first pattern pixel is at $x = 3$, $y = 4$. Therefore, an offset within the pattern itself must be calculated.

SourceAddress

$$\begin{aligned}
 &= \text{PatternOffset} + \text{StartPatternY} \times 8 \times \text{BytesPerPixel} + \text{StartPatternX} \times \text{BytesPerPixel} \\
 &= 240\text{K} + (4 \times 8 \times 1) + (3 \times 1) \\
 &= 240\text{K} + 35 \\
 &= 245795 \\
 &= 3\text{C}023\text{h}
 \end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 3C0023h.

3. Program the BitBLT Width Register to 100 - 1. REG[8018h] is set to 63h (99 decimal).
4. Program the BitBLT Height Register to 150-1. REG[801Ch] is set to 95h (149 decimal).
5. Program the BitBLT Operation Register to select the Pattern Fill BitBLT with Transparency. REG[8008h] bits 3-0 are set to 7h.
6. Program the BitBLT Background Color Register to select transparent color. This example uses blue (LUT index 1) as the transparent color. REG[8020h] is set to 01h.
7. Program the BitBLT Color Format Select bit for 8 bpp operations. REG[8000h] bit 18 is set to 0.
8. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned}
 \text{BlMemoryOffset} &= \text{ScreenStride} \div 2 \\
 &= 320 \div 2 \\
 &= 160 \\
 &= \text{A}0\text{h}
 \end{aligned}$$

REG[8014h] is set to A0h.

9. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.11 Move BitBLT with Color Expansion

The Move BitBLT with Color Expansion takes a monochrome bitmap as the source and color expands it into the destination. All bits set to one in the source are expanded to destination pixels of the selected foreground color. All bits set to zero in the source are expanded to pixels of the selected background color.

The Move BitBLT with Color Expansion is used to accelerate text drawing. A monochrome bitmap of a font, in off-screen video memory, occupies very little space and takes advantage of the hardware acceleration. Since the foreground and background colors are programmable, text of any color can be created.

The Move BitBLT with Color Expansion can move data from one rectangular area to another, or either the source or destination may be specified to be linear. Storing rectangular display data in linear format in off screen memory results in a tremendous space saving.

Example 18: Color expand a 9 x 16 rectangle using the pattern in off-screen memory at 3C000h and move it to the screen coordinates x = 200, y = 20. Assume a 320x240 display at a color depth of 16 bpp, Foreground color of black, and background color of white.

1. Calculate the destination and source addresses (upper left corner of the destination and source rectangles), using the formula.

$$\begin{aligned}\text{DestinationAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (20 \times (320 \times 2)) + (200 \times 2) \\ &= 13200 \\ &= 3390\text{h}\end{aligned}$$

where:

BytesPerPixel = 2 for 16 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 640 for 16 bpp

$$\begin{aligned}\text{SourceAddress} &= 240\text{K} \\ &= 3\text{C}000\text{h}\end{aligned}$$

Program the BitBLT Destination Start Address Register. REG[8010h] is set to 3390h.

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 3C000h.

2. Program the BitBLT Width Register to 9 - 1. REG[8018h] is set to 08h.
3. Program the BitBLT Height Register to 16 - 1. REG[801Ch] is set to 0Fh.
4. Program the BitBLT ROP Code/Color Expansion Register. REG[8008h] bits 19-16 are set to 7h.
5. Program the BitBLT Operation Register to select the Move BitBLT with Color Expansion. REG[8008h] bits 3-0 are set to 0Bh.
6. Program the BitBLT Foreground Color Register to select black (in 16 bpp black = 0000h). REG[8024h] is set to 0000h.

7. Program the BitBLT Background Color Register to select white (in 16 bpp white = FFFFh). REG[8024h] is set to FFFFh.
8. Program the BitBLT Color Format Select bit for 16 bpp operations. REG[8000h] bit 18 is set to 1.
9. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned} \text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \\ &= 140\text{h} \end{aligned}$$

REG[8014h] is set to 0140h.

10. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8000h] bit 0 is set to 1.

Note

The sequence of register setup is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.2.12 Transparent Move BitBLT with Color Expansion

The Transparent Move BitBLT with Color Expansion is virtually identical to the Move BitBLT with Color Expansion. This operation expands bits set to one in the source bitmap to the foreground color in the destination. Bits set to zero in the source bitmap leave the corresponding destination pixel as is.

Setup and use this operation exactly as the Move BitBLT with Color Expansion.

9.2.13 Read BitBLT

This Read BitBLT increases the speed of transferring data from the video memory to system memory. This BitBLT complements the Write BitBLT and is typically used to save a part of the display buffer to the system memory. Once the Read BitBLT begins, the BitBLT engine remains active until all the pixels have been read.

During a Read BitBLT operation the BitBLT engine expects to send a particular number of WORDs to the CPU, and it is the responsibility of the CPU to read the required amount of data.

When performing BitBLT at 16 bpp color depth the number of WORDs to be sent is the same as the number of pixels to be transferred as each pixel is one WORD wide. The number of WORD writes the BitBLT engine expects is calculated using the following formula.

$$\begin{aligned}\text{WORDS} &= \text{Pixels} \\ &= \text{BitBLTWidth} \times \text{BitBLTHeight}\end{aligned}$$

When the color depth is 8 bpp the formula must take into consideration that the BitBLT engine accepts only WORD accesses and pixels are only one BYTE. This may lead to a different number of WORD transfers than there are pixels to transfer.

The number of WORD accesses is dependant on the position of the first pixel within the first WORD of each destination row. Is the pixel stored in the low byte or the high byte of the WORD? Read BitBLT phase is determined as follows:

Destination phase is 0 when the first pixel is in the low byte and the second pixel is in the high byte of the WORD. When the destination phase is 0, bit 0 of the Destination Start Address Register is 0. The destination phase is 1 if the first pixel of each destination row is contained in the high byte of the WORD, the contents of the low byte are ignored. When the destination phase is 1, bit 0 of the Destination Start Address Register is set.

Depending on the destination phase and the BitBLT width, the last WORD may contain only one pixel. In this case it is always in the low byte. The number of WORD writes the BitBLT engine expects for 8 bpp color depths is shown in the following formula.

$$\text{WORDS} = ((\text{BitBLTWidth} + 1 + \text{DestinationPhase}) \div 2) \times \text{BitBLTHeight}$$

The BitBLT engine requires this number of WORDS to be sent from the local CPU before it will end the Write BitBLT operation.

Example 19: Read 100 x 20 pixels at the screen coordinates x = 25, y = 38 and save to system memory. Assume a display of 320x240 at a color depth of 8 bpp.

1. Calculate the source address (upper left corner of the screen BitBLT rectangle), using the formula.

$$\begin{aligned}\text{SourceAddress} &= (y \times \text{ScreenStride}) + (x \times \text{BytesPerPixel}) \\ &= (38 \times 320) + (25 \times 1) \\ &= 12185 \\ &= 2F99\text{h}\end{aligned}$$

where:

BytesPerPixel = 1 for 8 bpp

ScreenStride = DisplayWidthInPixels \times BytesPerPixel = 320 for 8 bpp

Program the BitBLT Source Start Address Register. REG[800Ch] is set to 2F99h.

2. Program the BitBLT Width Register to 100 - 1. REG[8018h] is set to 63h (99 decimal).
3. Program the BitBLT Height Register to 20 - 1. REG[801Ch] is set to 13h (19 decimal).

4. Program the Destination Phase in the BitBLT Destination Start Address Register. In this example, the data is WORD aligned, so the destination phase is 0. REG[8010h] is set to 00h.
5. Program the BitBLT Operation to select the Read BitBLT. REG[8008h] bits 3-0 are set to 1h.
6. Program the BitBLT Color Format Select bit for 8 bpp operations. REG[8000h] bit 18 is set to 0.
7. Program the BitBLT Memory Offset Register to the ScreenStride in WORDS.

$$\begin{aligned} \text{BltMemoryOffset} &= \text{ScreenStride} \div 2 \\ &= 320 \div 2 \\ &= 160 \\ &= \text{A0h} \end{aligned}$$

REG[8014h] is set to 0A0h.

8. Calculate the number of WORDS the BitBLT engine expects to receive.

$$\begin{aligned} \text{WORDS} &= ((\text{BLTWidth} + 1 + \text{DestinationPhase}) \div 2) \times \text{BLTHeight} \\ &= (100 + 1 + 0) \div 2 \times 20 \\ &= 1000 \\ &= 3E8\text{h} \end{aligned}$$

9. Program the BitBLT Destination/Source Linear Select bits for a rectangular BitBLT (BitBLT Destination Linear Select = 0, BitBLT Source Linear Select = 0).

Start the BitBLT operation. REG[8004h] bit 0 returns a 1.

10. Prior to reading from the BitBLT FIFO, confirm the BitBLT FIFO is not empty (REG[8004h] bit 4 returns a 1). If the BitBLT FIFO Not Empty Status (REG[8004h] bit 6) returns a 1 and the BitBLT FIFO Half Full Status (REG[8004h] bit 5) returns a 0 then you can read up to 8 WORDS. If the BitBLT FIFO Full Status returns a 1, read up to 16 WORDS. If the BitBLT FIFO Not Empty Status returns a 0 (the FIFO is empty), do not read from the BitBLT FIFO until it returns a 1.

The following table summarizes how many words can be read from the BitBLT FIFO.

Table 9-8: Possible BitBLT FIFO Reads

| BitBLT Status Register (REG[8004h]) | | | Word Reads Available |
|-------------------------------------|-----------------------|------------------|----------------------|
| FIFO Not Empty Status | FIFO Half Full Status | FIFO Full Status | |
| 0 | 0 | 0 | 0 (do not read) |
| 1 | 0 | 0 | up to 8 |
| 1 | 1 | 0 | 8 |
| 1 | 1 | 1 | 16 |

Note

The sequence of register initialization is irrelevant as long as all required registers are programmed before the BitBLT is started.

9.3 BitBLT Synchronization

A BitBLT operation can only be started if the BitBLT engine is not busy servicing another BitBLT. Before a new operation is started, software must confirm the BitBLT Busy Status bit (REG[8004h] bit 0) is set to zero. The status of this bit can either be tested **after** each BitBLT operation, or **before** each BitBLT operation.

Testing the BitBLT Status After

Testing the BitBLT Active Status after starting a new BitBLT is simpler and less prone to errors.

To test after each BitBLT operation, perform the following.

1. Program and start the BitBLT engine.
2. Wait for the current BitBLT operation to finish -- Poll the BitBLT Busy Status bit (REG[8004h] bit 0) until it returns a 0.
3. Continue with program execution.

Testing the BitBLT Status Before

Testing the BitBLT Active Status before starting a new BitBLT results in better performance, as both CPU and BitBLT engine can be running at the same time. This is most useful for BitBLTs that are self completing (once started they don't require any CPU assistance). While the BitBLT engine is busy, the CPU can do other tasks. To test before each BitBLT operation, perform the following.

1. Wait for the current BitBLT operation to finish -- Poll the BitBLT Busy Status bit (REG[8004h] bit 0) until it returns a 0.
2. Program and start the new BitBLT operation.
3. Continue with program execution (CPU and BitBLT engine work independently).

This approach can pose problems when mixing CPU and BitBLT access to the display buffer. For example, if the CPU writes a pixel while the BitBLT engine is running and the CPU writes a pixel before the BitBLT finishes, the pixel may be overwritten by the BitBLT. To avoid this scenario, always assure no BitBLT is in progress before accessing the display buffer with the CPU, or don't use the CPU to access the display buffer at all.

9.4 Known Limitations

The S1D13A05 BitBLT engine has the following limitations.

- The 2D Accelerator Data Memory Mapped register must not be accessed except during BitBLT operations. Read from the register only during Read BitBLT operations and write to the register only during Write and Color Expand BitBLTs. Accessing the register at any other time may result in S1D13A05 stopping to respond and the system to freeze.
- The Read and Write BitBLT operations are not available when the S1D13A05 is configured for the Redcap or Dragonball without DTACK host bus interfaces.
- A BitBLT operation cannot be terminated once it has been started.

9.5 Sample Code

Sample code demonstrating how to program the S1D13A05 BitBLT engine is provided in the files **A05src.zip**. This file is available on the internet at www.erd.epson.com.

10 Programming the USB Controller

USB (Universal Serial Bus) is an external bus designed to ease the connection and use of peripheral devices. USB incorporates a host/client architecture in which the host initiates all data transactions and the client either receives or supplies data to the host.

USB offers the following features to the end user:

- Single plug type for all peripheral devices.
- Support for up to 127 simultaneous devices.
- Speeds up to 12 Megabits per second.
- “hot-plugging” peripherals.

The S1D13A05 USB controller supports revision 1.1 of the USB specification. The S1D13A05 USB controller handles many common USB tasks without requiring local processor intervention. For example, setup and data transfers are handled automatically by the S1D13A05 controller. The controller notifies the local CPU, through an interrupt, when data is ready to be read from the FIFO or when data has been transmitted to the host.

This section demonstrates how to program and use the S1D13A05 USB controller. Topics covered include:

- Basic concepts such as registers and interrupts
- Initialization and data transfers
- S1D13A05 USB known issues.

10.1 Registers and Interrupts

10.1.1 Registers

Configuration, interrupt notification, and data transfers are all done using the S1D13A05 USB registers. The USB registers are located 4000h bytes past the beginning of S1D13A05 address space and should be written/read using 16 bit accesses.

On most systems the start of S1D13A05 address space, is fixed by the system design. The S1D13A05 evaluation board uses a PCI interface, thus the start of S1D13A05 address space may vary from one session to the next. Example code is written using a pointer to the USB registers (pUSB). The USB examples do not show how to obtain the register address. For a description of how to get the register address when using the S1D13A05 evaluation board, refer to the function `halAcquireController()` in Section 11, “Hardware Abstraction Layer” on page 119.

10.1.2 Interrupts

The S1D13A05 uses an interrupt to notify the local CPU when a USB event, which requires servicing, occurs. Events, such as USB reset and data transfer notifications generate interrupts.

It is beyond the scope of this document to explain how to setup and configure the interrupt system for the variety of platforms the S1D13A05 supports. The examples and flowcharts assume there is one interrupt handling routine which will determine the cause of the interrupt and call the appropriate handler function. It is assumed the user understands the mechanics and architecture of their system well enough setup a routine which will receive an interrupt notification and determine the cause of the interrupt.

10.2 Initialization

Initialization describes the process of setting the registers state to enable the USB controller for use. There are two cases where the USB registers need to be initialized. When the system is powered up and the registers need to be prepared for first use. The second time the registers need to be initialized is after receiving a RESET request from the host controller.

Refer to Section 10.2.2, “USB Registers” on page 103 for an example of the register initialization sequence.

10.2.1 GPIO Setup

The S1D13A05 shares four lines between GPIO and USB use. Before **any** accesses are made to the USB section the GPIO lines **must** be configured. To set the GPIO lines write the binary value 0010xxxx-1101xxxx-00000000-xxxxxxxx (2xDx00xxh) to REG[64h], the GPIO Status and Control register.

Note

X's represent a don't care state. Depending on other system configuration (i.e. panel technology) certain don't care bits may have to be set also. See the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001, for more information regarding the bits in the GPIO Status and Control register.

10.2.2 USB Registers

The steps described below are typical of the startup of the S1D13A05 USB controller.

- registers are set to an initial value
- the S1D13A05 is connected to a USB host controller
- the host controller issues a RESET command
- the USB registers are re-initialized

As initialization for both steps are similar it is recommended that one routine perform the sequence. The following table depicts a typical register initialization sequence.

Table 10-1: USB Controller Initialization Sequence

| Register | | Value (hex) | Notes |
|-------------|----------------------------------|-------------|---|
| REG[4040h] | USBFC INPUT CONTROL | 40 | Enable the USB differential input receiver and indicate we are a bulk transfer self powered device. (for ISOchronous mode, use 43h) |
| REG[4044] | PIN IO STATUS DATA | 01 | USBPUP must be set to enable the USB interface and registers. REG[4000h] to REG[403Ah] cannot be written until this bit is set. |
| REG[4000] | CONTROL | 84 | Enable the clocks and USB GPIO pins. |
| REG[4024] | EP3 RECEIVE FIFO STATUS | 1C | Clear EP3 status. |
| REG[402C] | USB EP4 TX FIFO STATUS | 1C | Clear EP4 status |
| REG[4032] | USB STATUS | 7E | Clear EP2 valid bit |
| REG[4004] | INTERRUPT STATUS 0 | FF | Clear any pending USB interrupts |
| REG[4010] | EP1 INDEX | 00 | Set EP1 index to zero |
| REG[4018] | EP2 INDEX | 00 | Set EP2 index to zero |
| ext REG[00] | VENDOR ID MSB | ?? | Provide appropriate vendor ID |
| ext REG[01] | VENDOR ID LSB | ?? | |
| ext REG[02] | PRODUCT ID MSB | ?? | Provide appropriate product ID |
| ext Reg[03] | PRODUCT ID LSB | ?? | |
| ext REG[0C] | FIFO CONTROL | 01 | Enable EP4 (FIFO) valid transfer mode. |
| REG[4002] | INT ENABLE 0 | 0A | Enable interrupts for EP1 and EP3 |
| REG[4004] | INT STATUS 0 | 0A | Make sure any pending interrupts are cleared. |
| REG[4046] | INTERRUPT CONTROL ENABLE 0 | 02 | Enable RESET and endpoints notifications |
| REG[4048] | INTERRUPT CONTROL ENABLE 1 | 01 | |
| REG[404A] | INTERRUPT CONTROL STATUS/CLEAR 0 | 7F | Clear ALL interrupt status... |
| REG[404C] | INTERRUPT CONTROL STATUS/CLEAR 1 | 7F | |
| REG[4000] | CONTROL | A4 | Enable the USB port for use |

The USB controller is ready for operation with the following configuration:

- Endpoint 1 (mailbox receive) is configured for bulk OUT and Endpoint 2 (mailbox transmit) is configured for interrupt IN. The functionality of these endpoints cannot be altered.
- Endpoint 3 (FIFO receive) is configured for bulk in and Endpoint 4 (FIFO transmit) is configured for bulk out. Endpoints 3 and 4 may also be configured for isochronous operation.

When the S1D13A05 is connected to a host controller, the host will issue a RESET command to the S1D13A05. In response to the RESET the S1D13A05 clears all USB registers in the range REG[4000h] to REG[403Ah]. The client software must respond to the reset and reprogram the USB registers. A host controller may issue a RESET at any time during operation.

After the S1D13A05 receives the RESET and re-initializes the registers, the host controller starts the USB SETUP phase. The SETUP sequence is handled entirely by the S1D13A05 USB controller. After the setup is complete the S1D13A3 is ready to begin transferring data.

Note

Prior to initializing the registers, host controller accesses are responded to with NAKs. After being configured, host controller accesses will be handled in the normal way.

Note

A Vendor ID can be obtained through the USB Implementers Forum at <http://www.usb.org>.

10.3 Data Transfers

The S1D13A05 USB requires very little local CPU assistance during data transfers. For the most part data transfers from the host involve reading a FIFO data register when notified of that the transfer is complete or writing a FIFO register and setting a 'ready' bit to send data to the host.

The following sections expand on the data transfer mechanism.

10.3.1 Receiving Data from the Host - the OUT command

Data transferred from the host to the S1D13A05 is directed to either EndPoint 1 (the mailbox) or EndPoint 3 (the FIFO). When the data packet has been successfully received the S1D13A05 generates an interrupt.

On receipt of the interrupt the local CPU examines the masked interrupt status registers REG[404Eh] and REG[4050h] to determine the source of the interrupt. If the interrupt came from bit 0 of the Negative Interrupt Masked Status register, REG[4050h], the next step is to examine REG[4004] to determine the exact cause of the interrupt.

Endpoint 1 - Mailbox Receive

If the cause of the interrupt is determined to be EndPoint 1 (REG[4004h] bit 1 = 1), then the data is read from the EndPoint 1 data register (REG[4012h]). The following figure shows the procedure for the CPU to read the mailbox register.

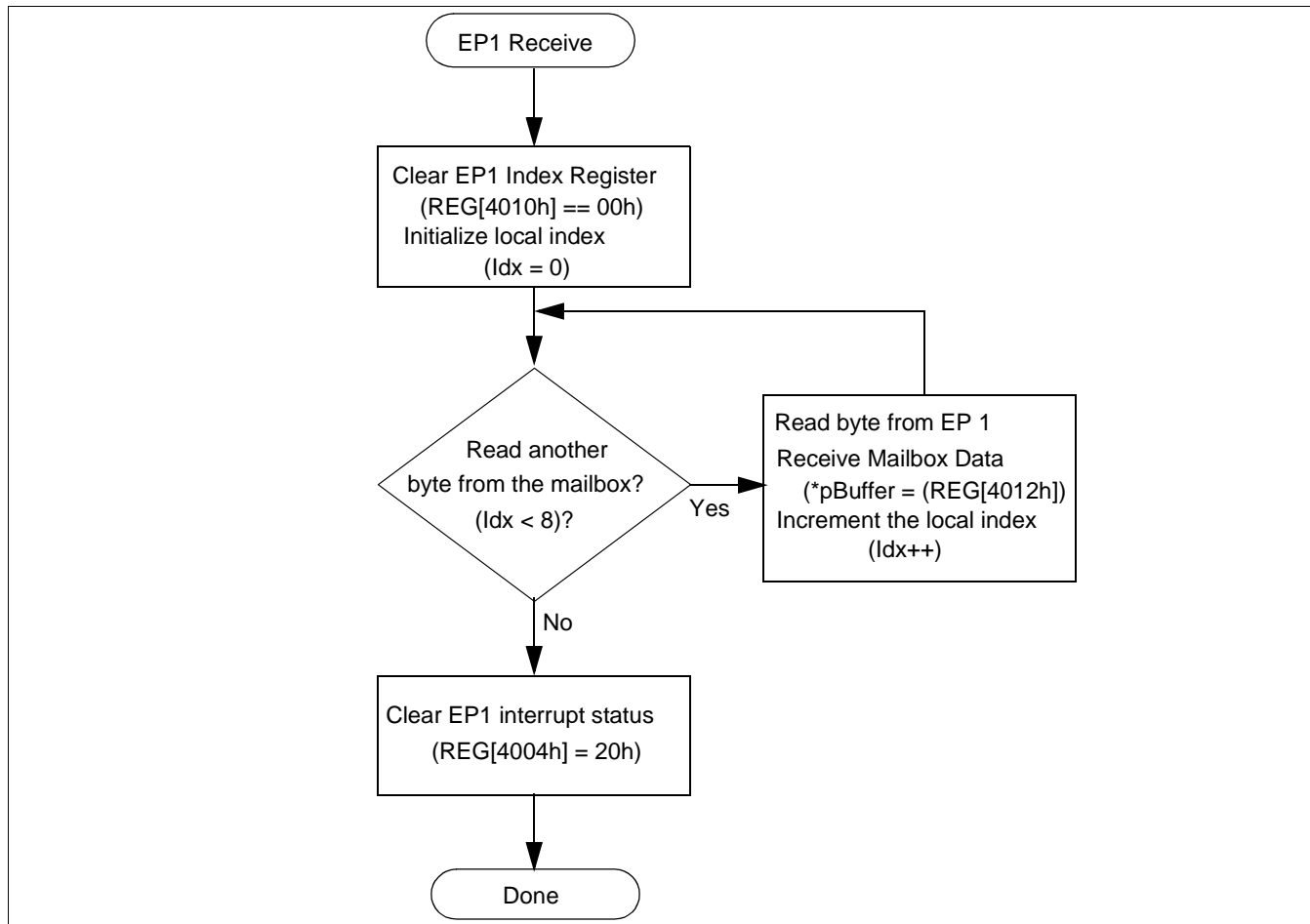


Figure 10-1: Endpoint 1 Data Reception

Note

In this diagram reference is made to two pseudo-variables:

Idx is an integer used as a loop counter

pBuffer is a pointer to eight bytes of memory to store the EP1 data

Endpoint 3 - FIFO Receive

If the cause of the interrupt is determined to be EndPoint 3, REG[4004h] bit 3 = 1b, then the host controller has sent data to EndPoint 3. Figure 10-2: shows the procedure for reading data from EndPoint 3.

An EndPoint 3 interrupt is generated when the number of bytes in the receive FIFO equal the value in the Receive FIFO Almost Full Threshold register (REG[403Ah], Index[06h]). The default value is sixty bytes. On systems where bulk transfers are used, the default value for the receive FIFO threshold should be satisfactory.

Systems with slow processors, high interrupt service latency, or configured for isochronous operation may have to decrease this value to allow the CPU time to begin reading data before the data transfer overflows the FIFO.

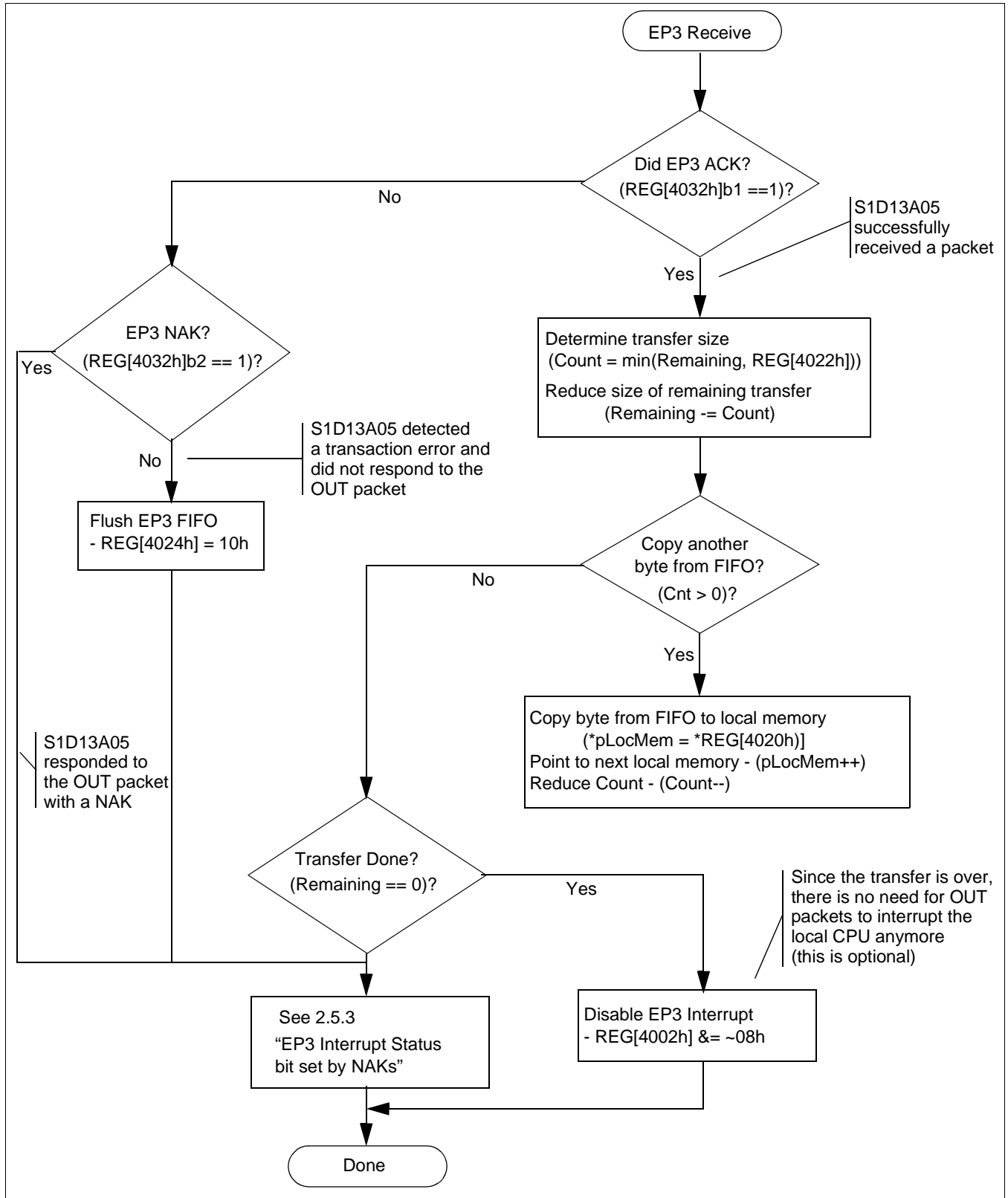


Figure 10-2: Endpoint 3 Data Reception

10.3.2 Sending Data to the Host - the IN command

Data transfers to the host controller occur when the host issues an IN command. The data comes from EndPoint 2 (the mailbox) or EndPoint 4 (the FIFO). The data transfer is handled automatically by the S1D13A05 and requires no CPU assistance.

Data transfers, from the S1D13A05 to the host controller, are performed by writing the data into either EndPoint 2 (mailbox) or EndPoint 4 (FIFO) data registers. After writing the data to the registers a control bit indicating that mailbox or FIFO data is valid is set.

Endpoint 2 - Mailbox Transmit

Figure 10-3: shows the logical flow for sending data to the host controller using EndPoint 2, the mailbox.

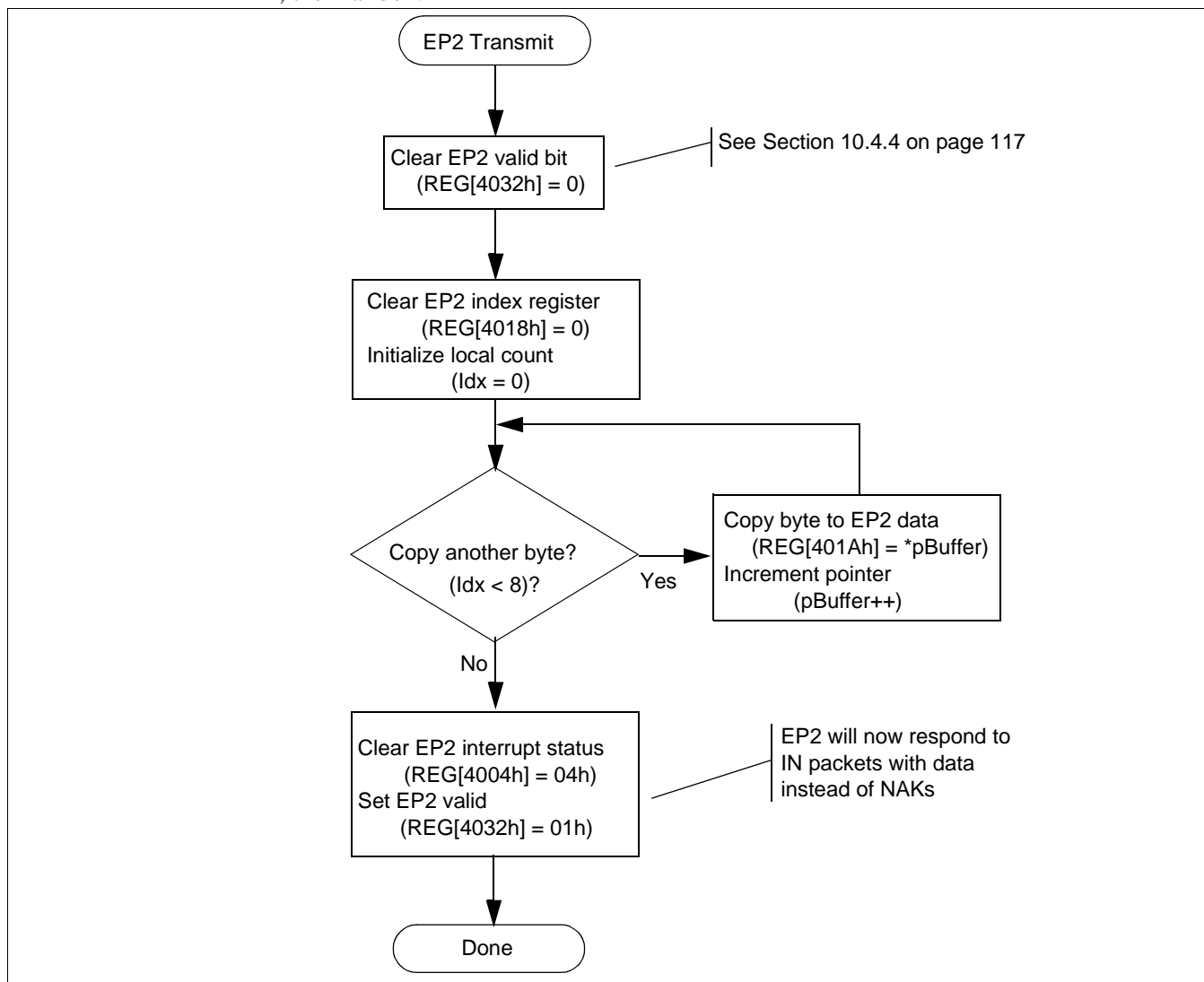


Figure 10-3: EndPoint 2 Data Transmission

Note

In this diagram reference is made to two pseudo-variables:

Idx is an integer used as a loop counter

pBuffer is a pointer to eight bytes of memory to send to the host

Endpoint 4 - Data Transmit

Transferring data to the host controller using the FIFO controller has additional overhead as this routine must run tests to ensure error free data transmission.

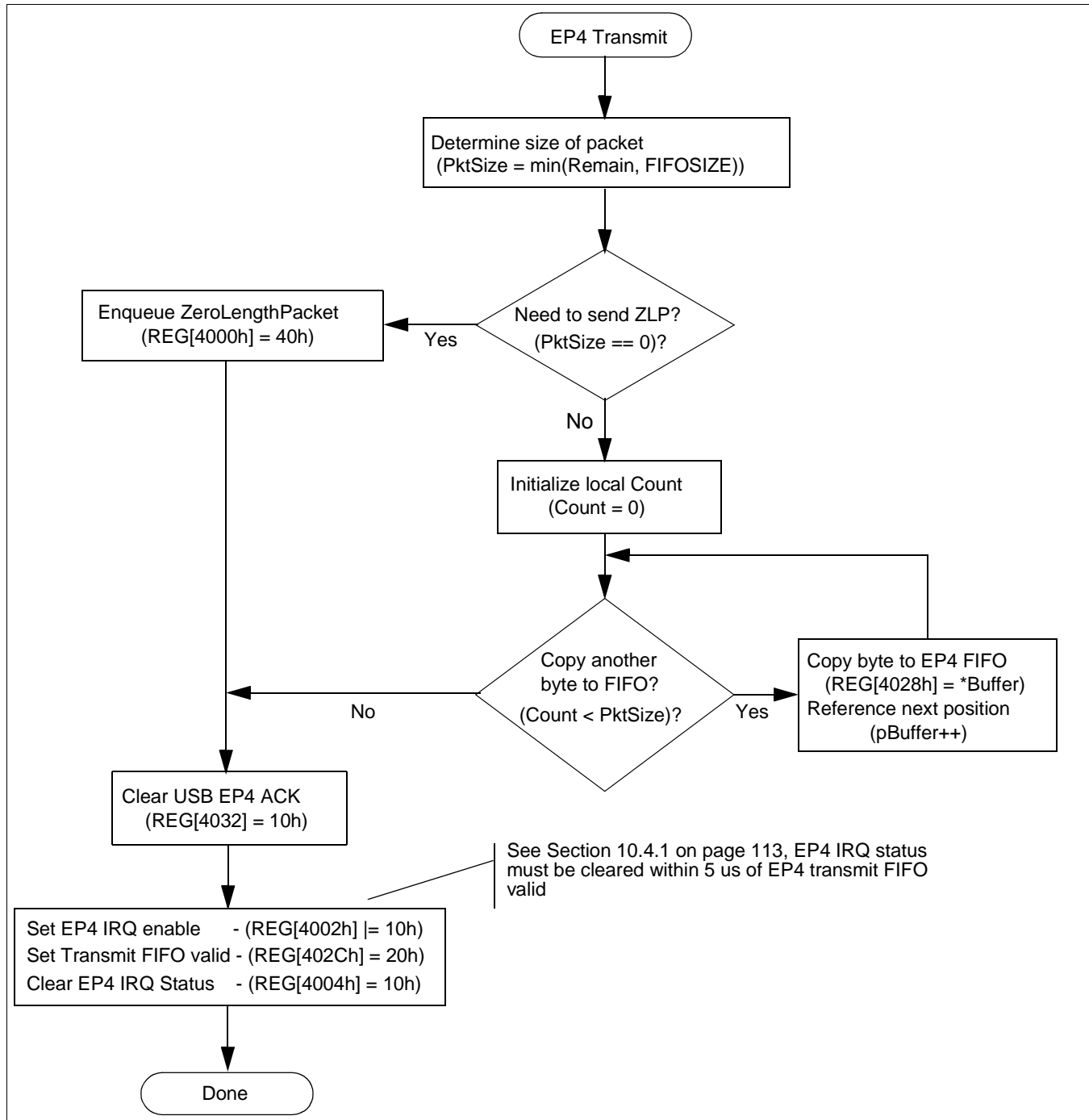


Figure 10-4: Endpoint 4 Data Transmission

Note

In this example there are three variables:

PktSize is an integer containing the number of bytes to transfer in this packet

Count is an integer used for local loop control

pBuffer is a pointer to an array of at least FIFOSIZE bytes.

To ensure the host controller receives the packet error free, an interrupt handler for EndPoint 4 must be configured and the flow control as shown in the following diagram must be implemented.

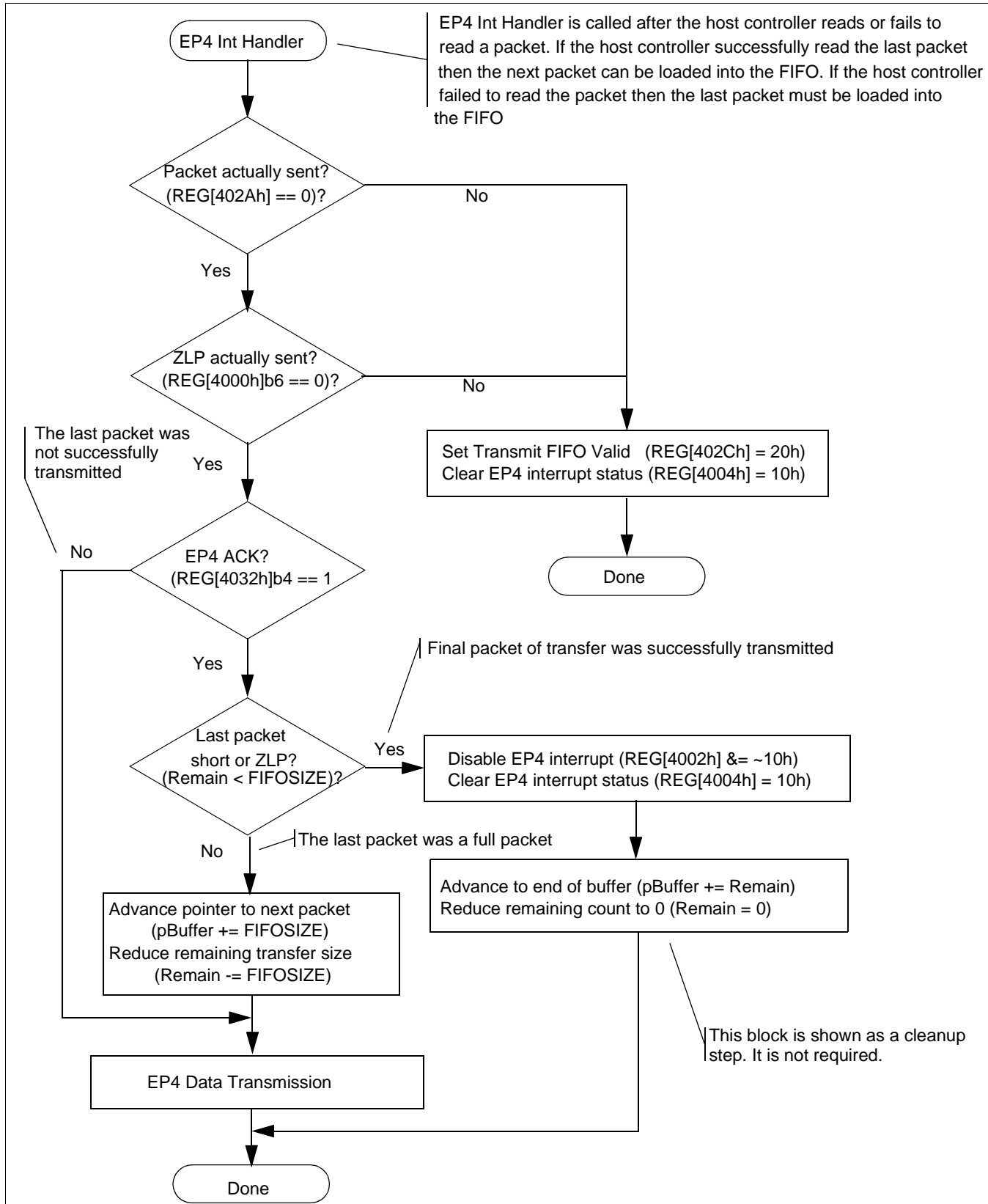


Figure 10-5: Endpoint 4 Interrupt Handling

Note

In the diagram the variables:

pBuffer is a pointer to the local memory buffer containing the data to be transferred to the host controller

Remain is an integer tracking the number of bytes still to be sent.

10.4 Known Issues

This section presents known issues with USB transfers when using the S1D13A05 USB controller.

10.4.1 EP4 NAK Status not set correctly in USB Status Register

The EP4 NAK status bit is not set in the USB Status Register (REG4032h) when the S1D13A05 responds to an IN request on EP4 with a NAK. As a result, a local CPU receiving an “EP4 Packet Transmitted” interrupt may mistakenly believe a bus error occurred in the most recently transmitted packet.

Work Around

Disable the EP4 Packet Transmitted interrupt when no data is queued for transmission to the local CPU. The basic flow is:

In Chip Initialization Code

Do not enable ‘EP4 Packet Transmitted’ bit in Interrupt Enable Register 0 (REG[4002h]).

When Local Side Wishes to Send Data

1. Put data to transmit in FIFO.
2. Enable ‘EP4 Packet Transmitted’ bit in Interrupt Enable Register 0.
3. Set FIFO Valid (if using FIFO Valid Mode == TRUE). See Section 10.4.2 on page 114 for more information on setting the FIFO Valid.
4. Clear ‘EP4 Packet Transmitted’ status bit in Interrupt Status Register 0 (REG[4004]).

Note

Step 4 is time-critical. It must be performed within 5 μ s after Step 3.

In Packet Transmitted Interrupt Routine

Disable ‘EP4 Packet Transmitted’ bit in Interrupt Enable Register 0.

10.4.2 Write to EP4 FIFO Valid bit cleared by NAK

After the local CPU sets EP4 FIFO Valid (in Endpoint 4 FIFO Status Register, REG[402Ch]), the S1D13A05 will erroneously clear the EP4 valid bit if the S1D13A05 is concurrently sending a NAK handshake in response to a previous IN token to EP4.

Work Around

The work-around is in the 'EP4 Packet Transmitted' interrupt routine. It requires the interrupt routine to know whether the recently queued packet was a zero-length packet or not, so that must be stored as a bit when the packet was loaded into the FIFO. On entry to the 'EP4 Packet Transmitted' interrupt routine:

For a non-zero-length Packet

Check the FIFO count. If it is non-zero, this error occurred. In that case, set FIFO Valid again, clear the interrupt status bit, and exit the interrupt routine.

For a zero-length Packet

Check the Software EOT bit (in Control Register, REG[4000h]). If it is set, the FIFO Valid write failed. In that case, set FIFO Valid again, clear the interrupt status bit, and exit the interrupt routine

10.4.3 EP3 Interrupt Status bit set by NAKs

When receiving Bulk OUT packets from a Host PC, the S1D13A05 "Endpoint 3 Interrupt Status" interrupt typically is used to notify the peripheral firmware that a packet has been received. This bit also serves as the "Receive FIFO Valid" bit, so additional packets addressed to Endpoint 3 are NAKed until this status bit is cleared. Once cleared, however, it may become set by another packet which is NAKed by the S1D13A05, causing the Receive FIFO to become "Valid" again. The Host PC may immediately attempt to re-transmit the NAKed packet. The firmware should be written to prevent a cycle in which the FIFO is "Valid" each time that the Host PC sends an OUT packet.

The following rules govern the S1D13A05's behavior regarding packets received on Endpoint 3:

Rule A. At the end of a received OUT token to EP3 (and before the data is received), the S1D13A05 decides to NAK the packet if the "EP3 Interrupt Status" bit is set, and will therefore throw away data received.

Rule B. At the end of a received packet (including one which is NAKed), the S1D13A05 sets the "EP3 Interrupt Status" bit.

Rule C. Local firmware should clear the "EP3 Interrupt Status" bit after reading all bytes out of the EP3 Receive FIFO.

The following figure shows how a repeating cycle of NAKed OUT packets may occur.

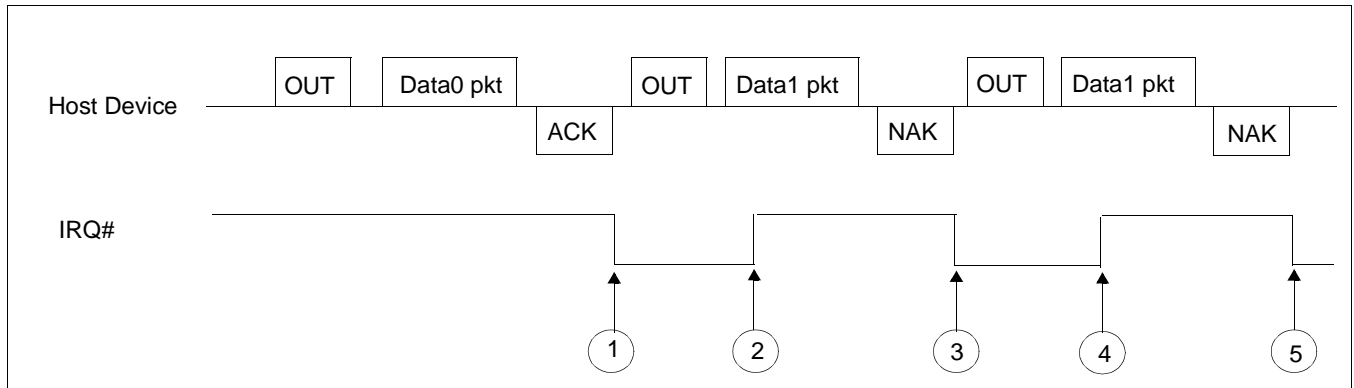


Figure 10-6: Firmware Looping Continuously on Received OUT packets

At Point 1, the EP3 Interrupt activates because a packet has been received. In response, the firmware reads the bytes out of the packet and clears the interrupt at Point 2. A second packet is already being received at Point 2, and the S1D13A05 has already decided to NAK this packet due to Rule A. At point 3, the S1D13A05 has NAKed the packet and asserts the Interrupt status bit.

Again, the local firmware responds to the interrupt, and seeing it is only a “NAK” interrupt, clears the interrupt condition at Point 4. However, the Host PC has begun to retry the second packet already, so the packet will again get NAKed due to Rule B. This cycle could continue until something changes the flow of OUT packets – for instance, an SOF at the beginning of the next frame, or packet traffic directed at another device or endpoint.

Work Around

The normal program flow for a packet which the S1D13A05 NAKs is as follows:

1. S1D13A05 asserts IRQ# after NAKing a received packet on EP3.
2. Local CPU is interrupted, enters interrupt routine.
3. Local CPU reads Interrupt Status Register 0 (REG[4004h]) and sees “EP3 Packet Received” interrupt bit.
4. Local CPU reads USB Status Register (REG[4032h]) and sees “NAK” bit set.
5. Local CPU clears Interrupt Status Register 0 (REG[4004h]) “EP3 Packet Status” interrupt bit.
6. Local CPU clears USB Status Register (REG[4032]) “NAK” bit.

The technique for avoiding this potential pitfall depends on the speed of the peripheral CPU. The critical timing parameter is the time from the S1D13A05 asserting IRQ# to the firmware clearing the “EP3 Packet Received” bit in Interrupt Status Register 0.

For a Fast CPU

A CPU which can clear the Interrupt Status Register 0 bit within 10 msec after the S1D13A05 asserts the IRQ# signal requires no extra code to prevent the potential cycling. In this case, the CPU is fast enough to clear a NAKed packet's Interrupt Status Register 0 bit before another packet can be received.

For a Slow CPU

A CPU which can't meet the timing requirements for a fast CPU above will require some additional firmware to eliminate the potential for this cycle. After successfully receiving a packet on Endpoint 3 and emptying received data out of the FIFO, the firmware should follow the flow in the following figure.

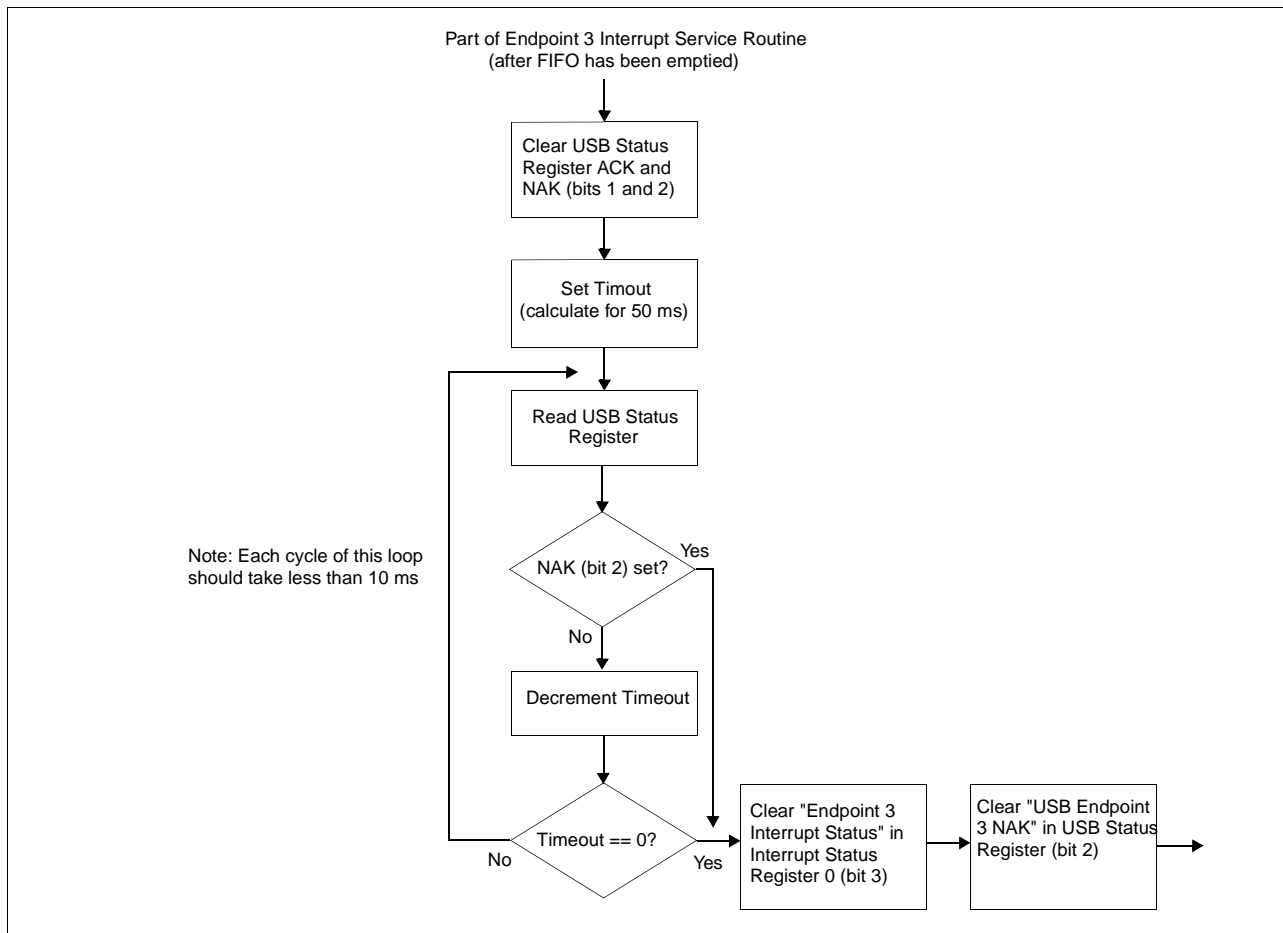


Figure 10-7: Endpoint 3 Program Flow for Slow CPU

10.4.4 “EP2 Valid Bit” in USB Status can be erroneously set by firmware

“Endpoint 2 Valid” is the only bit in USB Status which is not written as a “Yes/CLR” bit. Therefore, the firmware must do a read-modify-write sequence when clearing other bits in Interrupt Status Register 0 (REG[4004h]), to preserve the state of “Endpoint 2 Valid”. However, this read-modify-write could lead to erroneously setting the EP2 Valid bit if the following sequence occurs with “EP2 Valid” set True:

1. Firmware reads Interrupt Status Register 0 to do a read-modify-write
2. Data from EP2 is sent to Host PC, causing S1D13A05 to clear EP2 Valid
3. Firmware writes modified value to Interrupt Status Register 0

In this case, the firmware has set EP2 Valid in Step 3 after it was cleared by the Host PC, erroneously validating EP2 for the next IN token from the Host.

Work Around

First, the firmware should do the read-modify-write operation as described above anytime it is modifying bits in “USB Status”.

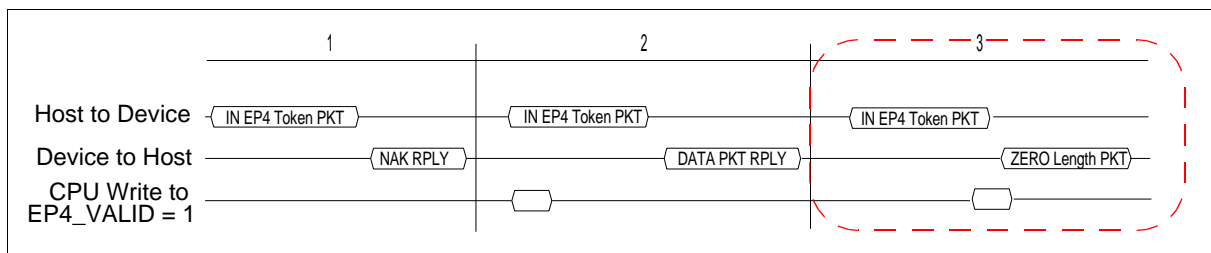
Second, when the firmware recognizes an interrupt for “EP2 Packet Transmitted”, it should immediately write a ‘0’ to USB Status Register. This will clear the EP2 Valid bit in the unlikely event that it was erroneously set during a read-modify-write operation.

10.4.5 Setting EP4 FIFO Valid bit while NAKing IN token

Bit 5 of REG[402Ch] indicates to the S1D13A05 controller when data in the endpoint 4 FIFO is ready to be transferred to the host computer. Changing the state of this bit at certain times may generate an error.

When the S1D13A05 USB controller receives an endpoint 4 IN request and endpoint 4 is not ready to transmit data (REG[402Ch] bit 5 = 0), the response is a NAK packet. If endpoint 4 is toggled to a ready to transmit state just before a NAK response packet is sent, the controller may erroneously send a zero length packet instead. When this happens, the data toggle state will be incorrectly set for the next endpoint 4 data transmit.

The following timing diagram shows the error occurring in section 3.



This unexpected occurrence of a zero length packet may cause file system handling errors for some operating systems.

Work Around

There are two software solutions for this occurrence.

Disable USB Receiver before setting the EP4 FIFO Valid bit

The first solution involves disabling the USB receiver to avoid responding to an EP4 IN packet. During the time the USB receiver is disabled the EP4 FIFO Valid bit is set.

When the local CPU is ready to send data on endpoint 4 the steps to follow are:

2. Disable the USB differential input receiver (REG[4040h] bit 6 = 0)
3. Wait a minimum of 1 μ s. If needed, delays may be added
4. Enable the EP4 FIFO Valid bit (REG[402Ch] bit 5 = 1)
5. Clear the EP4 Interrupt status bit (REG[4004h] bit 4 = 1)
6. Enable the USB differential input receiver (REG[4040h] bit 6 = 1)

Note

Steps 1 through 5 are time critical and must be performed in less than 6 μ s.

Note

To comply with “EP4 NAK Status not set correctly in USB Status register”, steps 3 and 4 must be completed within 5 μ s of each other. For further information on “EP4 NAK Status not set correctly in USB Status register”, see Section 10.4.1, “EP4 NAK Status not set correctly in USB Status Register” .

EP4 FIFO Valid bit set after NAK and before the next IN token

The second solution is to wait until immediately after the USB has responded to an IN request with a NAK packet before setting the transmit FIFO valid bit. This solution is recommended only for fast processors.

When the local CPU is ready to send data on endpoint 4, it must first detect that a NAK packet has been sent. This is done by reading the EP4 Interrupt Status bit (REG[4004h] bit 4). If the EP4 FIFO Valid bit was not set, the EP4 Interrupt Status bit is set only if a NAK packet has been sent. When the local CPU detects the NAK it must immediately set the EP4 FIFO Valid bit (before responding to the next IN token).

After filling the EP4 FIFO the steps to follow before setting the EP4 FIFO Valid bit are:

1. Clear the EP4 Interrupt Status bit (REG[4004h] bit 4)
2. Read the EP4 Interrupt Status bit (REG[4004h] bit 4) until it is set
3. Set the EP4 FIFO Valid bit (REG[402Ch] bit 5 = 1)

The setting of the EP4 FIFO Valid bit is time critical. The EP4 FIFO Valid bit must be set within 3 μ s after the EP4 Interrupt Status has been set internally by the S1D13A05.

11 Hardware Abstraction Layer

11.1 Introduction

The S1D13A05 Hardware Abstraction Layer (HAL) is a collection of routines intended to simplify the programming for the S1D13A05 evaluation board. Programmers can use the HAL to assist in rapid software prototyping for the S1D13A05 evaluation board.

The HAL routines are divided into discrete functional blocks. The functions for startup and clock control offer specific support for the S1D13A05 evaluation board, while other routines demonstrate memory and register access techniques. For a complete list, see Table 11-1; “HAL Library API” .

11.2 API for the HAL Library

The following table lists the functions provided by the S1D13A05 HAL library.

Table 11-1: HAL Library API

| Function | Description |
|------------------------|--|
| Startup | |
| halAcquireController | This routine loads the driver required to access the S1D13A05, locates the and returns the address of the controller. |
| halInitController | Initializes the controller for use. This includes setting the programmable clock and initializing registers as well as setting the lookup table and clearing video memory. |
| Memory Access | |
| halReadDisplay8 | Reads one byte from display memory |
| halReadDisplay16 | Reads one word from display memory |
| halReadDisplay32 | Reads one double word from display memory |
| halWriteDisplay8 | Writes one byte to display memory |
| halWriteDisplay16 | Writes on word to display memory |
| halWriteDisplay32 | Writes on double word to display memory |
| Register Access | |
| halReadReg8 | Reads one byte from a control register |
| halReadReg16 | Reads one word from a control register |
| halReadReg32 | Reads one dword from a control register |
| halWriteReg8 | Writes one byte to a control register |
| halWriteReg16 | Writes one word to a control register |
| halWriteReg32 | Writes one dword to a control registers |
| Clock Support | |
| halSetClock | Programs the ICD2061A Programmable Clock Generator. |
| halGetClock | Returns the frequency of the requested ICD2061A clock |
| Miscellaneous | |
| halGetVersionInfo | Returns a standardized startup banner message |
| halGetLastError | Returns the numerical value of the last error and optionally an ASCII string describing the error |
| halInitLUT | This routine sets the LUT to uniform values for color/mono panels at all color depths |

11.2.1 Startup Routines

There are two routines dedicated to startup and initializing the S1D13A05. Typically these two functions are the first two HAL routines a program will call.

The startup routines locate the S1D13A05 controller and initialize HAL data structures. As the name suggests, the initialization routine prepares the S1D13A05 for use. Splitting the startup functionality allows programs to start and locate the S1D13A05 but delay or possibly never initialize the controller.

Boolean `halAcquireController(UInt32 * pMem, UInt32 * pReg)`

Description: This routine initializes data structures and initiates the link between the application software and the hardware. When the S1D13A05 HAL is used this routine must be the first HAL function called.

On PCI platforms, the routine attempts to load the S1D13xxx driver. If the driver loads successfully, then a check is made for the existence of an S1D13A05 evaluation board.

Parameters: `pMem` Pointer to an unsigned 32-bit integer which will receive the offset to the first byte of display memory. The offset may be cast to a pointer to access display memory.

`pReg` Pointer to an unsigned 32-bit integer which will receive the offset to the first byte of register space. The offset may be cast to a pointer and to access S1D13A05 registers.

On Win32 systems the returned offsets correspond to a linear addresses within the callers address space.

Return Value: `TRUE` (non-zero) if the routine is able to locate an S1D13A05.
`pMem` will contain the offset to the first byte of display memory.
`pRegs` will contain the address of the first 13A05 control register.

`FALSE` (zero) if an S1D13A05 is not located.
`pMem` and `pRegs` will be undefined.
If additional error information is required call `halGetLastError()`.

Note

1. This routine **must** be called before any other HAL routine is called.
2. For programs written for the S1D13A05 evaluation board, an application may call this routine to obtain pointers to the registers and display memory and then perform all S1D13A05 accesses directly.
3. This routine does not modify S1D13A05 registers or memory.

Boolean halInitController(UInt32 Flags)

- Description:** This routine performs the initialization portion of the startup sequence. Initialization of the S1D13A05 evaluation board consists of several steps:
- Program the ICD2061A clock generator
 - Set the initial state of the control
 - Set the LUT to its default value
 - Clear video memory
- All display memory and nearly every control register can or will be affected by the initialization.
- Any, or all, of the initialization steps may be bypassed according to values contained in the Flags parameter. This allows for conditional run-time changes to the initialization.
- Parameters:** Flags contains initialization specific information. The default action of the HAL is to perform all initialization steps. Flags contain specific instructions for bypassing certain initialization steps. The values for Flags are:
- fDONT_SET_CLOCKS**
Setting this flag causes initialization to skip programming the ICD2061A clock generator. Normally the clock on the S1D13A05 is programmed to configured values during initialization.
- fDONT_INIT_REGS**
Bypass register initialization. Normally the initialization process sets the register values to a known state. Setting this flag bypasses this step.
- fDONT_INIT_LUT**
Bypass look-up table initialization.
- fDONT_CLEAR_MEM**
The final step of the initialization process is to clear video display memory. Setting this flag will bypass this step.
- Return Value:** TRUE (non-zero) if the initialization was successful.
FALSE (zero) if the HAL was unable to initialize the S1D13A05
If additional error information is required call halGetLastError()

11.2.2 Memory Access

The S1D13A05 HAL includes six memory access functions. The primary purpose of the memory access functions is to demonstrate how to access display memory using the C programming language. Most programs that need to access memory will bypass the HAL and access memory directly.

UInt8 halReadDisplay8(UInt32 Offset)

Description: Reads and returns the value of one byte of display memory.

Parameters: Offset A 32 bit offset to the byte to be read from display memory

Return Value: The value of the byte at the requested offset.

UInt16 halReadDisplay16(UInt32 Offset)

Description: Reads and returns the value of one word of display memory.

Parameters: Offset A 32 bit byte offset to the word to be read from display memory
To prevent system slowdowns and possibly memory faults, Offset should be a word multiple.

Return Value: The value of the word at the requested offset.

UInt32 halReadDisplay32(UInt32 Offset)

Description: Reads and returns the value of one dword of display memory.

Parameters: Offset A 32 bit byte offset to the dword to be read from display memory.
To prevent system slowdowns and possibly memory faults, Offset should be a dword multiple.

Return Value: The value of the dword at the requested offset.

void halWriteDisplay8(UInt32 Offset, UInt8 Value, UInt32 Count)

Description: Writes a byte into display memory at the requested address.

Parameters: Offset A 32 bit byte offset to the byte to be written to display memory.

Value The byte value to be written to display memory.

Count The number of times to repeat Value in memory. By including a count (or loop) value this function can efficiently fill display memory.

Return Value: Nothing.

void halWriteDisplay16(UInt32 Offset, UInt16 Value, UInt32 Count)

Description: Writes a word into display memory at the requested offset.

Parameters:

| | |
|--------|---|
| Offset | a 32 bit byte offset to the byte to be written to display memory. To prevent system slowdowns and possibly memory faults, Offset should be a word multiple. |
| Value | the word value to be written to display memory. |
| Count | the number of times to repeat the Value in memory. By including a count (or loop) value this function can efficiently fill display memory. |

Return Value: Nothing.

void halWriteDisplay32(UInt32 Offset, UInt32 Value, UInt32 Count)

Description: Writes a dword into display memory at the requested offset.

Parameters:

| | |
|--------|--|
| Offset | A 32 bit byte offset to the byte to be written to display memory. To prevent system slowdowns and possibly memory faults, Offset should be a dword multiple. |
| Value | The dword value to be written to display memory. |
| Count | The number of times to repeat the Value in memory. By including a count (or loop) value this function can efficiently fill display memory. |

Return Value: Nothing.

11.2.3 Register Access

The S1D13A05 HAL includes six register access functions. The primary purpose of the register access functions is to demonstrate how to access the S1D13A05 control registers using the C programming language. Most programs that need to access the registers will bypass the HAL and access the registers directly.

UInt8 halReadReg8(UInt32 Index)

Description: Reads and returns the contents of one byte of an S1D13A05 register at the requested offset. No S1D13A05 registers are changed.

Parameters:

| | |
|-------|---|
| Index | 32 bit offset to the register to read. Index is zero based from the beginning of register address space. (e.g. if Index == 04h then the Memory Clock Configuration register will be read and if Index == 8000h then the BitBLT Control Register will be read) |
|-------|---|

Return Value: The value read from the register.

Use caution in selecting the index and when interpreting values returned from halReadReg8() to ensure the correct meaning is given to the values. Changing between big endian and little endian will move relative register offsets.

UInt16 halReadReg16(UInt32 Index)

Description: Reads and returns the contents of one word of an S1D13A05 register at the requested offset. No S1D13A05 register are changed.

Parameters: Index 32 bit offset to the register to read. Index is zero based from the beginning of register address space. (e.g. if Index == 04h then the Memory Clock Configuration register will be read and if Index == 8000h then the BitBLT Control Register will be read)

Return Value: The word value read from the register.

Use caution in determining the index and interpreting the values returned from halReadReg16() to ensure the correct meaning is given to the values. Changing between big and little endian will move relative register offsets resulting in different values.

UInt16 halReadReg32(UInt32 Index)

Description: Reads and returns the dword value of an S1D13A05 register at the requested offset. No S1D13A05 register are changed.

Parameters: Index 32 bit offset to the register to read. Index is zero based from the beginning of register address space. (e.g. if Index == 04h then the Memory Clock Configuration register will be read and if Index == 8000h then the BitBLT Control Register will be read)

Return Value: The dword value read from the register.

void halWriteReg8(UInt32 Index, UInt8 Value)

Description: Writes an 8 bit value to the register at the requested offset.

Parameters: Index 32 bit offset to the register to write. Index is zero based from the beginning of register address space. (e.g. if Index == 04h then the Memory Clock Configuration register will be written to and if Index == 8000h then the BitBLT Control Register will be written to)

Value The byte value to write to the register. Changing between big and little endian will move relative register offsets. Use caution in interpreting the index and values to write to registers using the halWriteReg8() function to ensure that register are programmed correctly.

Return Value: Nothing.

void halWriteReg16(UInt32 Index, UInt16 Value)

Description: Writes a 16 bit value to the S1D13A05 register at the requested offset.

Parameters:

| | |
|-------|---|
| Index | 32 bit byte offset to the register to write. Index is zero based from the beginning of register address space. (e.g. if Index == 04h then the Memory Clock Configuration register will be written to and if Index == 8000h then the BitBLT Control Register will be written to) |
| Value | The word value to write to the register. |

Return Value: Nothing.

Changing between big and little endian will move relative register offsets. Use caution in interpreting the index and values to write to registers using the halWriteReg8() function to ensure that register are programmed correctly.

void halWriteReg32(UInt32 Index, UInt32 Value)

Description: Writes a 32 bit value (dword) to the register at the requested offset.

Parameters:

| | |
|-------|---|
| Index | 32 bit byte offset to the register to write. Index is zero based from the beginning of register address space. (e.g. if Index == 04h then the Memory Clock Configuration register will be written to and if Index == 8000h then the BitBLT Control Register will be written to) |
| Value | The dword value to write to the register. |

Return Value: Nothing.

11.2.4 Clock Support

To maximize flexibility, S1D13A05 evaluation boards include a programmable clock. The following HAL routines provide support for the programmable clock.

Boolean halSetClock(UInt32 ClkiFreq, UInt32 Clki2Freq)

Description: This routine program the ICD2061A programmable clock generator to the specified frequency.

Parameters:

| | |
|-------------|--|
| ClkiFreq | The desired frequency, in Hz, for CLKI. |
| Clki2Freq | The desired frequency, in Hz, for CLKI2. |
| dwFrequency | The desired frequency (in Hz). |

Return Value: TRUE (non-zero) if the function was successful in setting the clock.

FALSE (zero) if there was an error detected while trying to set the clock.
If additional error information is required call halGetLastError().

UInt32 halGetClock(CLOCKSELECT Clock)

- Description:** Returns the frequency of the clock input identified by 'Clock'.
- Parameters:** Clock Indicates which clock to read. This value can be CLKI or CLKI2.
- Return Value:** The frequency, in Hz, of the requested clock.

11.2.5 Miscellaneous

The miscellaneous function are an assortment of routines, determined to be beneficial to a number of programs and hence warranted being included in the HAL.

void halGetVersionInfo(const char * szProgName, const char * szDesc, const char * szVersion, char * szRetStr, int nLength)

- Description:** This routine creates a standardized startup banner by merging program and HAL specific information. The newly formulated string is returned to the calling program for display.

The final formatted string will resemble:

```
13A05PROGRAM - Internal test and diagnostic program - Build: 1234 [HAL: 1234]
Copyright (c) 2000,2001 Epson Research and Development, Inc.
All Rights Reserved.
```

- Parameters:**
- szProgName Pointer to an ASCIIZ string containing the name of the program. (e.g. "PROGRAM")
 - szDesc Pointer to an ASCIIZ string containing a description of what this program is intended to do. (e.g. "Internal test and diagnostic program")
 - szVersion Pointer to an ASCIIZ string containing the build info for this program. This should be the revision info string as updated by VSS. (e.g. "\$Revision: 30 \$")
 - szRetStr Pointer to a buffer into which the product and version information will be formatted into.
 - nLength Total number of bytes in the string pointed to by szRetStr. This function will write nLength or fewer bytes to the buffer pointed to by szRetStr.
- Return Value:** Nothing.

int halGetLastError(char * ErrMsg, int MaxSize)

Description: This routine retrieves the last error detected by the HAL.

Parameters: ErrMsg When halGetLastError() returns ErrMsg will point to the textual error message. If ErrMsg is NULL then only the error code will be returned.

MaxSize Maximum number of bytes, including the final '\0' that can be placed in the string pointed to by ErrMsg.

Return Value: The numerical value of the internal error number.

HALEXTERN void hallnitLUT(void)

Description: To standardize the appearance of test and validation programs, it was decided the HAL would have the ability to set the lookup table to uniform values.

The routine cracks the color depth and display type to determine which LUT values to use and proceeds to write the LUT entries.

Parameters: None

Return Value: Nothing.

12 Sample Code

Example source code demonstrating programming the S1D13A05 using the HAL library is available on the internet at www.erd.epson.com.

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READ-ONLY CONFIGURATION REGISTERS

| Product Information Register REG[00h] Default = 2Dxx402Dh Read Only | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|---------------|----|--------------|-----------------|----|----|----|----|---------------|----|
| Product Code | | | | | | Revision Code | | n/a | CNF[6:0] Status | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| Display Buffer Size | | | | | | | | Product Code | | | | | | Revision Code | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

CLOCK CONFIGURATION REGISTERS

| Memory Clock Configuration Register REG[04h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|----|----|----|----|--------------------|----|-----|----|--------------------|----|
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | MCLK Divide Select | | n/a | | BCLK Source Select | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| Pixel Clock Configuration Register REG[08h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|----|----|--------------------|----|----|-----|----|--------------------|
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | PCLK Divide Select | | | n/a | | PCLK Source Select |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

PANEL CONFIGURATION REGISTERS

| Panel Type & MOD Rate Register REG[0Ch] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----------------|-----|----------------|--------------------------|-------------------------|------------------|----|----------|-----|------------|--|
| n/a | | | | | | FPSHIFT Invert | n/a | | MOD Rate | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | HR-TFT PS Mode | Panel Data Format Select | Color/Mono Panel Select | Panel Data Width | | Reserved | n/a | Panel Type | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

| Display Settings Register REG[10h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|----|----|-------------------------|-----------------------|---------------|-------------------|---|-----------------|--------------------|-----|-------------------------|
| n/a | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Pixel Doubling Vertical | Pixel Doubling Horiz. | Display Blank | Dithering Disable | Display Blank Polarity | SW Video Invert | PIP* Window Enable | n/a | Swivel/View Mode Select |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| n/a | | | | | | | | | | | | Bits-per-pixel Select (actual value: 1, 2, 4, 8, 16 bpp) | | | | |

| Power Save Configuration Register REG[14h] Default = 00000010h Read/Write | | | | | | | | | | | | | | | |
|--|----|----|----|----|----|----|----|------------------|-------------------------------|-----|-------------------|-----|----|----------|----|
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | VNDP Status (RO) | Memory Power Save Status (RO) | n/a | Power Save Enable | n/a | | Reserved | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

LOOK-UP TABLE REGISTERS

| Look-Up Table Write Register REG[18h] Default = 00000000h Write Only | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|--------------------|----|---------------------|----|----|----|----|----|-----|----|
| LUT Write Address | | | | | | LUT Red Write Data | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| LUT Green Write Data | | | | | | n/a | | LUT Blue Write Data | | | | | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

| Look-Up Table Read Register REG[1Ch] Default = 00000000h Write Only (bits 31-24)/Read Only | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|-------------------|----|--------------------|----|----|----|----|----|-----|----|
| LUT Read Address (write only) | | | | | | LUT Red Read Data | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| LUT Green Read Data | | | | | | n/a | | LUT Blue Read Data | | | | | | n/a | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

DISPLAY MODE REGISTERS

| | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|----|----|---|-----|----|----|----|------------------------------|----|--------|----|
| Horizontal Total Register REG[20h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Horizontal Total bits 6-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Horizontal Display Period Register REG[24h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Horizontal Display Period bits 6-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Horizontal Display Period Start Position Register REG[28h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Horizontal Display Period Start Position bits 9-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| FPLINE Register REG[2Ch] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | FPLINE Polarity | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | FPLINE Pulse Width bits 6-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Vertical Total Register REG[30h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Vertical Total bits 9-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Vertical Display Period Register REG[34h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Vertical Display Period bits 9-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Vertical Display Period Start Position Register REG[38h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Vertical Display Period Start Position bits 9-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| FPFRAME Register REG[3Ch] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | FPFRAME Polarity | 22 | 21 | 20 | 19 | FPFRAME Pulse Width bits 2-0 | 18 | 17 | 16 |
| n/a | | | | | | | | FPFRAME Pulse Start Position bits 9-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Main Window Display Start Address Register REG[40h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | bit 16 | |
| Main Window Display Start Address bits 15-0 | | | | | | | | | | | | | | | 16 | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Main Window Line Address Offset Register REG[44h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Main Window Line Address Offset bits 9-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Extended Panel Type Register REG[48h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | Data Compare Invert Enable | n/a | | | | Extended Panel Type bits 3-0 | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

PICTURE-IN-PICTURE PLUS (PIP+) REGISTERS

| | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|--|----|----|----|----|----|----|----|----|--------|------------|
| PIP+ Display Start Address Register REG[50h] Default = 00000000h | | | | | | | | | | | | | | | | Read/Write |
| n/a | | | | | | | | | | | | | | | bit 16 | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| PIP+ Window Display Start Address bits 15-0 | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| PIP+ Window Line Address Offset Register REG[54h] Default = 00000000h | | | | | | | | | | | | | | | | Read/Write |
| n/a | | | | | | | | | | | | | | | bit 16 | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | PIP+ Window Line Address Offset bits 9-0 | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| PIP+ Window X Positions Register REG[58h] Default = 00000000h | | | | | | | | | | | | | | | | Read/Write |
| n/a | | | | | | PIP+ Window X End Position bits 9-0 | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | PIP+ Window X Start Position bits 9-0 | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| PIP+ Window Y Positions Register REG[5Ch] Default = 00000000h | | | | | | | | | | | | | | | | Read/Write |
| n/a | | | | | | PIP+ Window Y End Position bits 9-0 | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | PIP+ Window Y Start Position bits 9-0 | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

MISCELLANEOUS REGISTERS

| | | | | | | | | | | | | | | | | | | |
|---|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|----------------------------------|-------------------------|-------------------------|-------------------------|-------------------------|-------------------------------|-------------------------|-------------------------|--------------|--------------|--------------|
| Reserved REG[60h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | | | |
| n/a | | | | | | | | Reserved | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| n/a | | | | | | | | Reserved | Reserved | Reserved | Reserved | Reserved | n/a | Reserved | n/a | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| GPIO Status and Control Register REG[64h] Default = 20000000h Read/Write | | | | | | | | | | | | | | | | | | |
| GPIO7 Input Enable | GPIO6 Input Enable | GPIO5 Input Enable | GPIO4 Input Enable | GPIO3 Input Enable | GPIO2 Input Enable | GPIO1 Input Enable | GPIO0 Input Enable | GPIO7 IO Config | GPIO6 IO Config | GPIO5 IO Config | GPIO4 IO Config | GPIO3 IO Config | GPIO2 IO Config | GPIO1 IO Config | GPIO0 IO Config | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| n/a | | | | | | | | GPIO7 IO Control/Status | GPIO6 IO Control/Status | GPIO5 IO Control/Status | GPIO4 IO Control/Status | GPIO3 IO Control/Status | GPIO2 IO Control/Status | GPIO1 IO Control/Status | GPIO0 IO Control/Status | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| GPO Control Register REG[68h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| n/a | | | | | | | | GPO10 Control | GPO9 Control | GPO8 Control | GPO7 Control | GPO6 Control | GPO5 Control | GPO4 Control | GPO3 Control | GPO2 Control | GPO1 Control | GPO0 Control |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| Brightness (PWM) Configuration Register REG[70h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| n/a | | | | | | | | PWM Clock Divide Select bits 3-0 | | | | PWM Clock Force High | PWMCLK Source Select bits 1-0 | | PWM Clock Enable | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| Brightness (PWM) Duty Cycle Register REG[74h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| n/a | | | | | | | | PWMOUT Duty Cycle bits 7-0 | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| Scratch Pad A Register REG[80h] Default = not applicable Read/Write | | | | | | | | | | | | | | | | | | |
| Scratch Pad A bits 31-24 | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| Scratch Pad A bits 15-0 | | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| Scratch Pad B Register REG[84h] Default = not applicable Read/Write | | | | | | | | | | | | | | | | | | |
| Scratch Pad B bits 31-24 | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| Scratch Pad B bits 15-0 | | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |
| Scratch Pad C Register REG[88h] Default = not applicable Read/Write | | | | | | | | | | | | | | | | | | |
| Scratch Pad C bits 31-24 | | | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | | |
| Scratch Pad C bits 15-0 | | | | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | |

EXTENDED PANEL REGISTERS

| | | | | | | | | | | | | | | | | |
|---|-----|--|----|----|----|-----|-----------------------------|------------------------------------|--|----------------------------|--------------------|--------------------|----------------------------|---------------------|----|--|
| HR-TFT Mode 2 CLS Width Register REG[A0h] Default = 0000012Ch Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | CLS Pulse Width bits 8-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| HR-TFT Mode 2 PS1 Rising Edge Register REG[A4h] Default = 00000032h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | PS1 Rising Edge bits 5-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| HR-TFT Mode 2 PS2 Rising Edge Register REG[A8h] Default = 00000064h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | PS2 Rising Edge bits 7-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| HR-TFT Mode 2 PS2 Toggle Width Register REG[ACh] Default = 0000000Ah Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | PS2 Toggle Width bits 6-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| HR-TFT Mode 2 PS3 Signal Width Register REG[B0h] Default = 00000064h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | PS3 Signal Width bits 6-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| HR-TFT Mode 2 REV Toggle Point Register REG[B4h] Default = 0000000Ah Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | REV Toggle Point bits 4-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| HR-TFT Mode 2 PS1/2 End Register REG[B8h] Default = 00000007h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | | | | | PS1/2 End bits 7-0 | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Type 2 TFT Configuration Register REG[BCh] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| POL Type | n/a | AP Pulse Width bits 2-0 | | | | n/a | AP Rising Position bits 1-0 | | | n/a | VCLK Hold bits 1-0 | | n/a | VCLK Setup bits 1-0 | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Casio TFT Timing Register REG[C0h] Default = 09180E09h Read/Write | | | | | | | | | | | | | | | | |
| n/a | 30 | GPCK Rising Edge to STH Pulse bits 5-0 | | | | | | n/a | GRES Falling Edge to FRP Toggle Point bits 6-0 | | | | | | | |
| 31 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | | |
| n/a | 14 | GRES Falling Edge to GPCK Rising Edge bits 5-0 | | | | | | n/a | GPCK Rising Edge to GRES Rising Edge bits 5-0 | | | | | | | |
| 15 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
| Type 3 TFT Configuration Register 0 REG[D8h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| POL Toggle Position bits 7-0 | | | | | | | | OE Pulse Width bits 7-0 | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| OE Rising Edge Position bits 7-0 | | | | | | | | n/a | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Type 3 TFT Configuration Register 1 REG[DCh] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| XOEV Falling Edge Position bits 7-0 | | | | | | | | XOEV Rising Edge Position bits 7-0 | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| CPV Pulse Width bits 7-0 | | | | | | | | VCOM Toggle Position bits 7-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| Type 3 TFT PCLK Divide Register REG[E0h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 | |
| n/a | | | | | | | | | | PCLK2 Divide Rate bits 1-0 | | | PCLK1 Divide Rate bits 3-0 | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |

| | | | | | | | | | | | | | | | |
|---|----|---|----|---------------------------|----|----------------------------------|----|-----|----|--|-----------------------------|----------------------------------|-----------------------|-----------------------|-----------------------|
| Type 3 TFT Partial Mode Display Area Control Register REG[E4h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | Partial Mode Display Refresh Cycle bits 5-0 | | | | | | n/a | | | Partial Mode Display Enable | Partial Mode Display Type Select | Area 2 Display Enable | Area 1 Display Enable | Area 0 Display Enable |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Type 3 TFT Partial Area 0 Positions Register REG[E8h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | Partial Area 0 Y End Position bits 5-0 | | | | | | n/a | | Partial Area 0 X End Position bits 5-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | Partial Area 0 Y Start Position bits 5-0 | | | | | | n/a | | Partial Area 0 X Start Position bits 5-0 | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Type 3 TFT Partial Area 1 Positions Register REG[ECh] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | Partial Area 1 Y End Position bits 5-0 | | | | | | n/a | | Partial Area 1 X End Position bits 5-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | Partial Area 1 Y Start Position bits 5-0 | | | | | | n/a | | Partial Area 1 X Start Position bits 5-0 | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Type 3 TFT Partial Area 2 Positions Register REG[F0h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | Partial Area 2 Y End Position bits 5-0 | | | | | | n/a | | Partial Area 2 X End Position bits 5-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | Partial Area 2 Y Start Position bits 5-0 | | | | | | n/a | | Partial Area 2 X Start Position bits 5-0 | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Type 3 TFT Command Store Register REG[F4h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | Command 1 Store bits 11-0 | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | Command 0 Store bits 11-0 | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| Type 3 TFT Miscellaneous Register REG[F8h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | Source Driver IC Number bits 1-0 | | n/a | | | | | | Command Send Request | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

USB REGISTERS

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|---|---|---|---|---|---|---|---|---|---|--|---|------------------------|-------------------------------|--------------------------------|-----------------------------|-----------------------------|------------------------------------|--|--|--|--|--|--|--|
| Control Register REG[4000h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | USBClk Enable | Software EOT | USB Enable | Endpoint 4 Stall | Endpoint 3 Stall | USB Setup | Reserved | Reserved | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interrupt Enable Register 0 REG[4002h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Suspend Request Interrupt Enable | SOF Interrupt Enable | Reserved | Endpoint 4 Interrupt Enable | Endpoint 3 Interrupt Enable | Endpoint 2 Interrupt Enable | Endpoint 1 Interrupt Enable | n/a | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interrupt Status Register 0 REG[4004h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Suspend Request Interrupt Status | SOF Interrupt Status | Reserved | Endpoint 4 Interrupt Status | Endpoint 3 Interrupt Status | Endpoint 2 Interrupt Status | Endpoint 1 Interrupt Status | Upper Interrupt Active (read only) | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interrupt Enable Register 1 REG[4006h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Transmit FIFO Almost Empty Interrupt Enable | Receive FIFO Almost Full Interrupt Enable | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Interrupt Status Register 1 REG[4008h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Transmit FIFO Almost Empty Status | Receive FIFO Almost Full Status | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 1 Index Register REG[4010h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 1 Index bits 2-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 1 Receive Mailbox Data Register REG[4012h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 1 Receive Mailbox Data bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 2 Index Register REG[4018h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 2 Index bits 2-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 2 Transmit Mailbox Data Register REG[401Ah] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 2 Transmit Mailbox Data bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 2 Interrupt Polling Interval Register REG[401Ch] Default = FFh | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 2 Interrupt Polling Interval bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 3 Receive FIFO Data Register REG[4020h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 3 Receive FIFO Data bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 3 Receive FIFO Count Register REG[4022h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 3 Receive FIFO Count bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 3 Receive FIFO Status Register REG[4024h] Default = 01h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Receive FIFO Flush | Receive FIFO Overflow | Receive FIFO Underflow | Receive FIFO Full (read only) | Receive FIFO Empty (read only) | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 3 Maximum Packet Size Register REG[4026h] Default = 08h | | | | | | | | | | | | | | | | Read/Write | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 3 Max Packet Size bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 4 Transmit FIFO Data Register REG[4028h] Default = 00h | | | | | | | | | | | | | | | | Write Only | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 4 Transmit FIFO Data bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Endpoint 4 Transmit FIFO Count Register REG[402Ah] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | Endpoint 4 Transmit FIFO Count bits 7-0 | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | | |
|---|-----------------|-----------------|-----------------|----------|----------|-----|----------|---|--------------------------|---|----------------------|------------------------|--------------------|--------------------------------|---------------------------------|--------------------|------------------|------------|--|---|--|--|--|
| Endpoint 4 Transmit FIFO Status Register REG[402Ch] Default = 01h | | | | | | | | | | | | | | | | Read/Write | | | | | | | |
| n/a | | | | | | | | | | Transmit FIFO Valid | Transmit FIFO Flush | Transmit FIFO Overflow | Reserved | Transmit FIFO Full (read only) | Transmit FIFO Empty (read only) | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Endpoint 4 Maximum Packet Size Register REG[402Eh] Default = 08h | | | | | | | | | | | | | | | | Read/Write | | | | | | | |
| n/a | | | | | | | | | | Endpoint 4 Max Packet Size bits 7-0 | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Revision Register REG[4030h] Default = 01h | | | | | | | | | | | | | | | | Read Only | | | | | | | |
| n/a | | | | | | | | | | Chip Revision bits 7-0 | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| USB Status Register REG[4032h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | |
| n/a | | | | | | | | | | Suspend Control | USB Endpoint 4 STALL | USB Endpoint 4 NAK | USB Endpoint 4 ACK | USB Endpoint 3 STALL | USB Endpoint 3 NAK | USB Endpoint 3 ACK | Endpoint 2 Valid | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Frame Counter MSB Register REG[4034h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | |
| n/a | | | | | | | | | | Frame Counter bits 10-8 | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Frame Counter LSB Register REG[4036h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | | |
| n/a | | | | | | | | | | Frame Counter bits 7-0 | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Extended Register Index REG[4038h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | | |
| n/a | | | | | | | | | | Extended Register Index bits 7-0 | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Extended Register Data REG[403Ah] Default = 04h | | | | | | | | | | | | | | | | Read/Write | | | | | | | |
| n/a | | | | | | | | | | Extended Register Data bits 7-0 | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Vendor ID MSB REG[403Ah], Index[00h] Default = 04h | | | | | | | | Read/Write | | Vendor ID LSB REG[403Ah], Index[01h] Default = B8h | | | | | | | | Read/Write | | | | | |
| Vendor ID bits 15-8 | | | | | | | | Vendor ID bits 7-0 | | | | | | | | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Product ID MSB REG[403Ah], Index[02h] Default = 88h | | | | | | | | Read/Write | | Product ID LSB REG[403Ah], Index[03h] Default = 21h | | | | | | | | Read/Write | | | | | |
| Product ID bits 15-8 | | | | | | | | Product ID bits 7-0 | | | | | | | | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Release Number MSB REG[403Ah], Index[04h] Default = 01h | | | | | | | | Read/Write | | Release Number LSB REG[403Ah], Index[05h] Default = 00h | | | | | | | | Read/Write | | | | | |
| Release Number bits 15-8 | | | | | | | | Release Number bits 7-0 | | | | | | | | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Receive FIFO Almost Full Threshold REG[403Ah], Index[06h] Default = 3Ch | | | | | | | | Read/Write | | Transmit FIFO Almost Empty Threshold REG[403Ah], Index[07h] Default = 04h | | | | | | | | Read/Write | | | | | |
| n/a | | | | | | | | Receive FIFO Almost Full Threshold bits 5-0 | | | | n/a | | | | | | | | Transmit FIFO Almost Empty Threshold bits 5-0 | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| USB Control REG[403Ah], Index[08h] Default = 01h | | | | | | | | Read/Write | | Maximum Power Consumption REG[403Ah], Index[09h] Default = FAh | | | | | | | | Read/Write | | | | | |
| n/a | | | | | | | | USB String Enable | Maximum Current bits 7-0 | | | | | | | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Packet Control REG[403Ah], Index[0Ah] Default = 00h | | | | | | | | Read/Write | | Reserved REG[403Ah], Index[0Bh] Default = 00h | | | | | | | | Read/Write | | | | | |
| EP4 Data Toggle | EP3 Data Toggle | EP2 Data Toggle | EP1 Data Toggle | Reserved | Reserved | n/a | Reserved | n/a | | | | | | | | Reserved | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| FIFO Control REG[403Ah], Index[0Ch] Default = 00h | | | | | | | | Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | Transmit FIFO Valid Mode | | | | | | | | | | | | | | | |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | | | | | | | | | |
| USBFC Input Control Register REG[4040h] Default = 0Dh | | | | | | | | | | | | | | | | Read/Write | | | | | | | |
| n/a | | | | | | | | | | USCPEN | Reserved | Reserved | ISO | WAKEUP | Reserved | Reserved | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |
| Reserved REG[4042h] Default = 1Dh | | | | | | | | | | | | | | | | Read Only | | | | | | | |
| n/a | | | | | | | | | | Reserved | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | | |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|----|----|----|----|----|---|---|---|---|---|---|---|---|---|--------------------------------|----------------------|----------|----------|----------|----------|-------------------------|-----|
| Pin Input Status / Pin Output Data Register REG[4044h] Default = depends on USB input pin state | | | | | | | | | | | | | | | | Read/Write | | | | | | |
| n/a | | | | | | | | | | | | | | USBDETECT Input Pin Status (read only) | USBPUP Output Pin Status | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| Interrupt Control Enable Register 0 REG[4046h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | |
| n/a | | | | | | | | | | | | | | USB Host Connected | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| Interrupt Control Enable Register 1 REG[4048h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | |
| n/a | | | | | | | | | | | | | | USB Host Disconnect | Reserved | Device Configured | Reserved | Reserved | Reserved | Reserved | Reserved | INT |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| Interrupt Control Status/Clear Register 0 REG[404Ah] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | |
| n/a | | | | | | | | | | | | | | USB Host Connected | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| Interrupt Control Status/Clear Register 1 REG[404Ch] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | |
| n/a | | | | | | | | | | | | | | USB Host Disconnect | Reserved | Device Configured | Reserved | Reserved | Reserved | Reserved | INT | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| Interrupt Control Masked Status Register 0 REG[404Eh] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | |
| n/a | | | | | | | | | | | | | | USB Host Connected | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | Reserved | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| Interrupt Control Masked Status Register 1 REG[4050h] Default = 00h | | | | | | | | | | | | | | | | Read Only | | | | | | |
| n/a | | | | | | | | | | | | | | USB Host Disconnect | Reserved | Device Configured | Reserved | Reserved | Reserved | Reserved | INT | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| USB Software Reset Register REG[4052h] Default = 00h | | | | | | | | | | | | | | | | Write Only | | | | | | |
| n/a | | | | | | | | | | | | | | USB Software Reset (Code = 10100100) bits 7-0 | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |
| USB Wait State Register REG[4054h] Default = 00h | | | | | | | | | | | | | | | | Read/Write | | | | | | |
| n/a | | | | | | | | | | | | | | n/a | | | | | | | USB Wait State bits 1-0 | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | | | | | | |

2D ACCELERATION (BitBLT) REGISTERS

| | | | | | | | | | | | | | | | |
|---|----|----|----|--|----|------------------------|----|----------------|----------------|---|-----|--|---------------------------|--------------------|----------------------|
| BitBLT Control Register REG[8000h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | Color Format Select | Dest Linear Select | Source Linear Select |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | | | BitBLT Enable (WO) | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Status Register REG[8004h] Default = 00000000h Read Only | | | | | | | | | | | | | | | |
| n/a | | | | Number of Used FIFO Entries | | | | | | n/a | | Number of Free FIFO Entries (0 means full) | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | FIFO Not Empty | FIFO Half Full | FIFO Full Status | n/a | | | BitBLT Busy Status | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Command Register REG[8008h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | BitBLT ROP Code bits 3-0 | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | | | | | | | | BitBLT Operation bits 3-0 | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Source Start Address Register REG[800Ch] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | BitBLT Source Start Address bits 20-16 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Source Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Destination Start Address Register REG[8010h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | BitBLT Destination Start Address bits 20-16 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Destination Start Address bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Memory Address Offset Register REG[8014h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | BitBLT Memory Address Offset bits 10-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | BitBLT Memory Address Offset bits 10-0 | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Width Register REG[8018h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | BitBLT Width bits 9-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Width bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Height Register REG[801Ch] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | BitBLT Height bits 9-0 | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| n/a | | | | | | BitBLT Height bits 9-0 | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Background Color Register REG[8020h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| BitBLT Background Color bits 15-0 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| BitBLT Foreground Color Register REG[8024h] Default = 00000000h Read/Write | | | | | | | | | | | | | | | |
| n/a | | | | | | | | | | | | | | | |
| BitBLT Foreground Color bits 15-0 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| 2D Accelerator (BitBLT) Data Memory Mapped Region Register AB16-AB0 = 10000h-1FFFEh, even addressesRead/Write | | | | | | | | | | | | | | | |
| BitBLT Data bits 31-16 | | | | | | | | | | | | | | | |
| 31 | 30 | 29 | 28 | 27 | 26 | 25 | 24 | 23 | 22 | 21 | 20 | 19 | 18 | 17 | 16 |
| BitBLT Data bits 15-0 | | | | | | | | | | | | | | | |
| 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |

EPSON®



S1D13A05 LCD/USB Companion Chip

13A05CFG Configuration Program

Document Number: X40A-B-001-01

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13A05CFG

13A05CFG is an interactive Windows® program that calculates register values for a user-defined S1D13A05 configuration. The configuration information can be used to directly alter the operating characteristics of the S1D13A05 utilities or any program built with the Hardware Abstraction Layer (HAL) library. Alternatively, the configuration information can be saved in a variety of text file formats for use in other applications.

Note

This program is a Windows desktop application suitable for configuring software for a given implementation of an Epson LCD controller. However, it is not a display driver for any Windows desktop operating system. Epson does not provide display drivers for any of the Windows desktop operating systems.

S1D13A05 Supported Evaluation Platforms

13A05CFG runs on PC system running Windows 9x/ME/XP/NT/2000 and can modify Win32 .exe files and .s9 format files.

Installation

Create a directory for **13a05cfg.exe** and copy the files **13a05cfg.exe** and **panels.def** to that directory. **Panels.def** contains configuration information for a number of panels and must reside in the same directory as **13a05cfg.exe**.

Usage

To start 13A05CFG from the Windows desktop, double-click on the My Computer icon and run the program **13a05cfg.exe** from the installed directory.

To start 13A05CFG from a Windows command prompt, change to the directory **13a05cfg.exe** was installed to and type the command **13A05cfg**.

The basic procedure for using 13A05CFG is:

1. Start 13A05CFG as described above.
2. Open an existing file to serve as a starting reference point (this step is optional).
3. Modify the configuration. For specific information on editing the configuration, see “13A05CFG Configuration Tabs” on page 7.
4. Save the new configuration. The configuration information can be saved in two ways; as an ASCII text file or by modifying an executable image on disk.

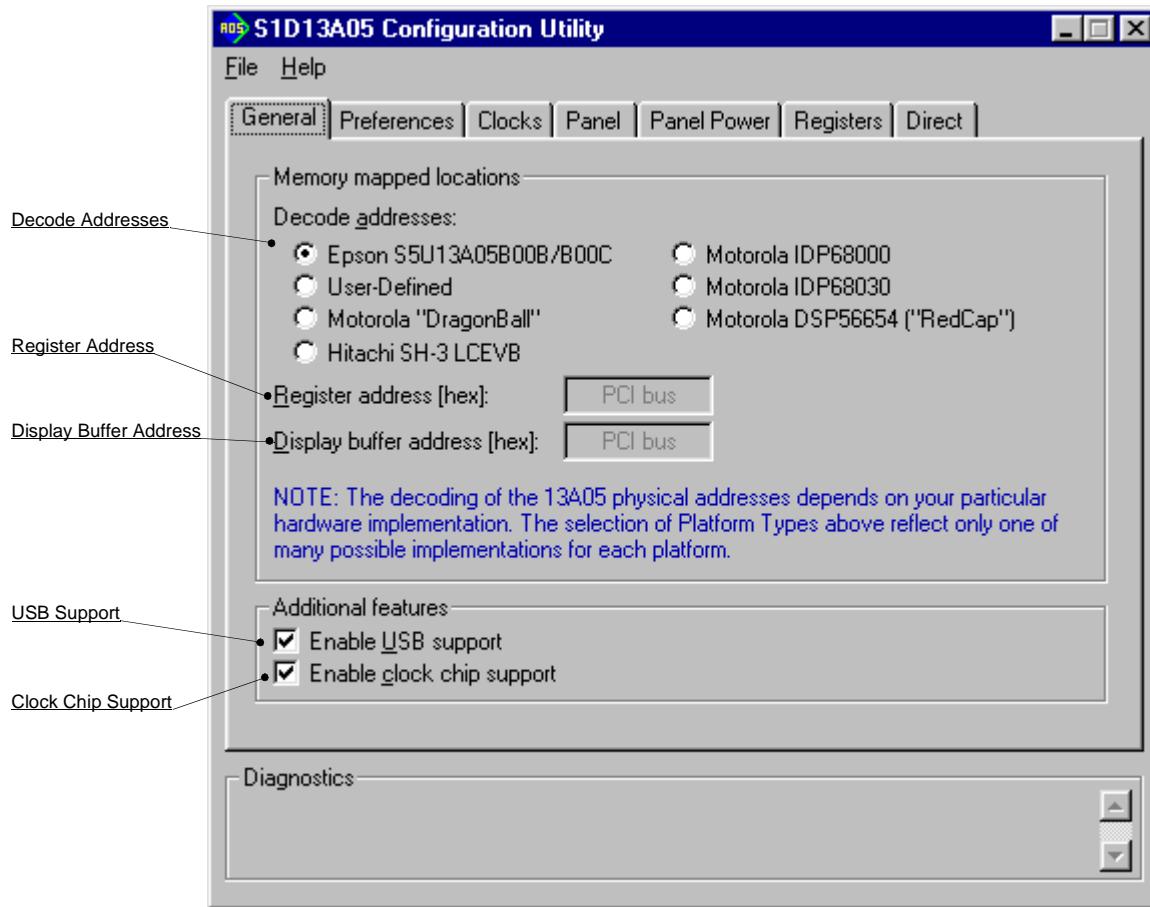
Several ASCII text file formats are supported. Most are formatted C header files used to build display drivers or standalone applications.

Utility files based on the Hardware Abstraction Layer (HAL) can be modified directly by 13A05CFG.

13A05CFG Configuration Tabs

13A05CFG displays a series of tabs which can be selected at the top of the main window. Each tab allows the configuration of a specific aspect of S1D13A05 operation. The following sections describe the purpose and use of each of the tabs.

General Tab



The General tab contains settings that define the S1D13A05 operating environment.

Decode Addresses

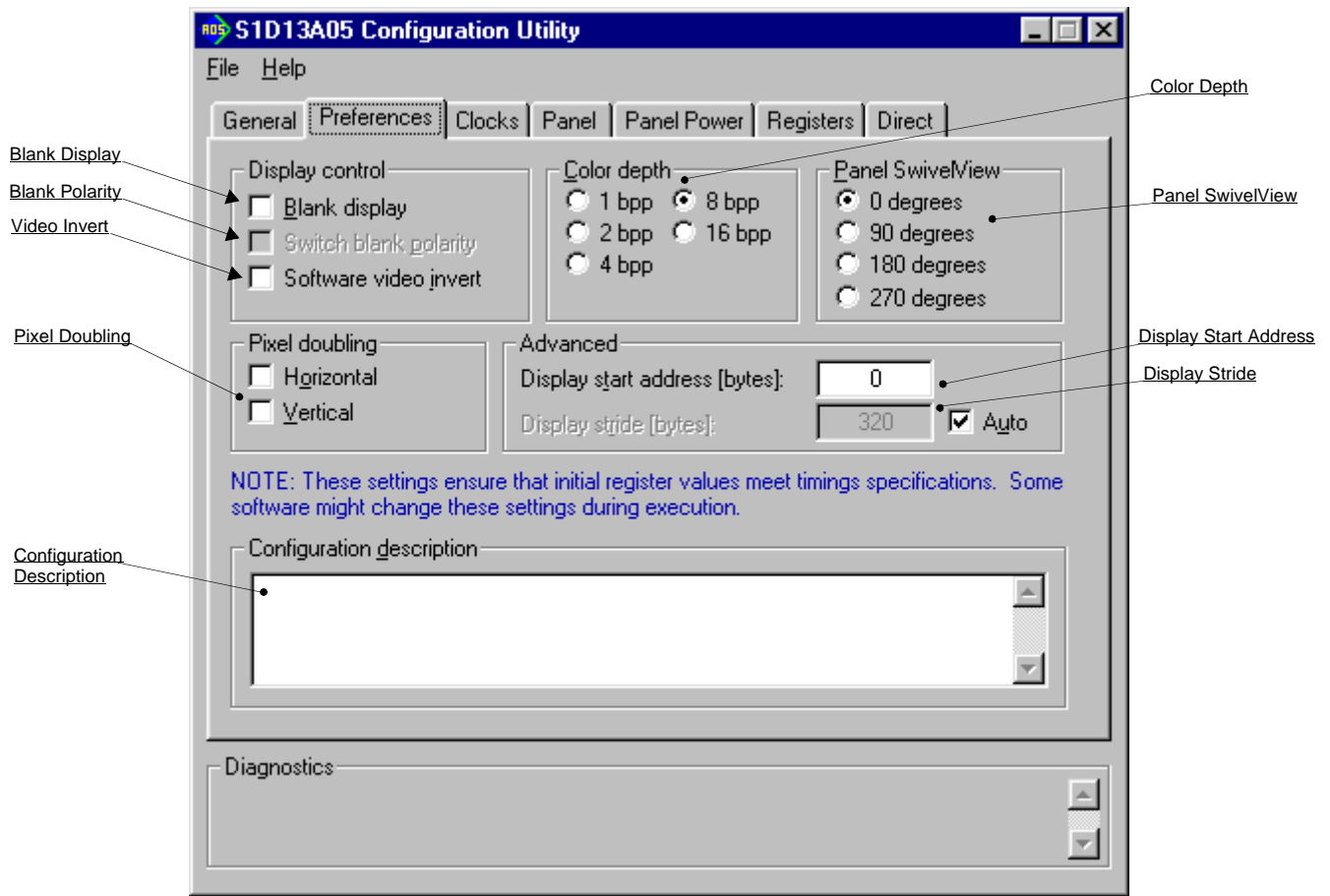
Selecting one of the listed evaluation platforms changes the values for the “Register address” and “Display buffer address” fields. The values used for each evaluation platform are examples of possible implementations as used by the Epson evaluation board. If your hardware implementation differs from the addresses used, select the User-Defined option and enter the correct values for “Register address” and “Display buffer address”.

Note

When “Epson S5U13A05B00B/B00C Evaluation Board” is selected, the register and display buffer addresses are blanked because the evaluation board uses the PCI interface and the decode addresses are determined by the system BIOS during boot-up.

| | |
|------------------------|--|
| Register Address | <p>The physical address of the start of register decode space (in hexadecimal).</p> <p>This field is automatically set according to the Decode Address unless the “User-Defined” decode address is selected.</p> |
| Display Buffer Address | <p>The physical address of the start of display buffer decode space (in hexadecimal).</p> <p>This field is automatically set according to the Decode Address unless the “User-Defined” decode address is selected.</p> |
| USB Support | <p>The S1D13A05 contains a USB client controller. If this box is checked, chip initialization configures GPIO[7:4] for use by the USB controller. For further information on the S1D13A05 USB implementation, see the <i>S1D13A05 Hardware Functional Specification</i>, document number X40A-A-001-xx.</p> |
| Clock Chip Support | <p>The S1D13A05 evaluation board implements a Cypress ICD2061A Clock Synthesizer which can be used to generate CLKI and CLKI2. When this box is checked, GPIO[3:1] are reserved for Clock Synthesizer support. Selecting a HR-TFT, Type 2 TFT, Type 3 TFT, or Casio TFT panel will disable this feature as the HR-TFT requires GPIO[3:0].</p> <p>This feature is only available when using the S1D13A05 evaluation board.</p> |

Preferences Tab



The Preference tab contains settings pertaining to the initial display state. During runtime these settings may be changed.

Blank Display

The S1D13A05 can blank the LCD display by forcing all FPDAT lines used by the panel to either zeros or ones (as selected by the Switch Blank Polarity option). When this box is checked the display is blanked.

Blank Polarity

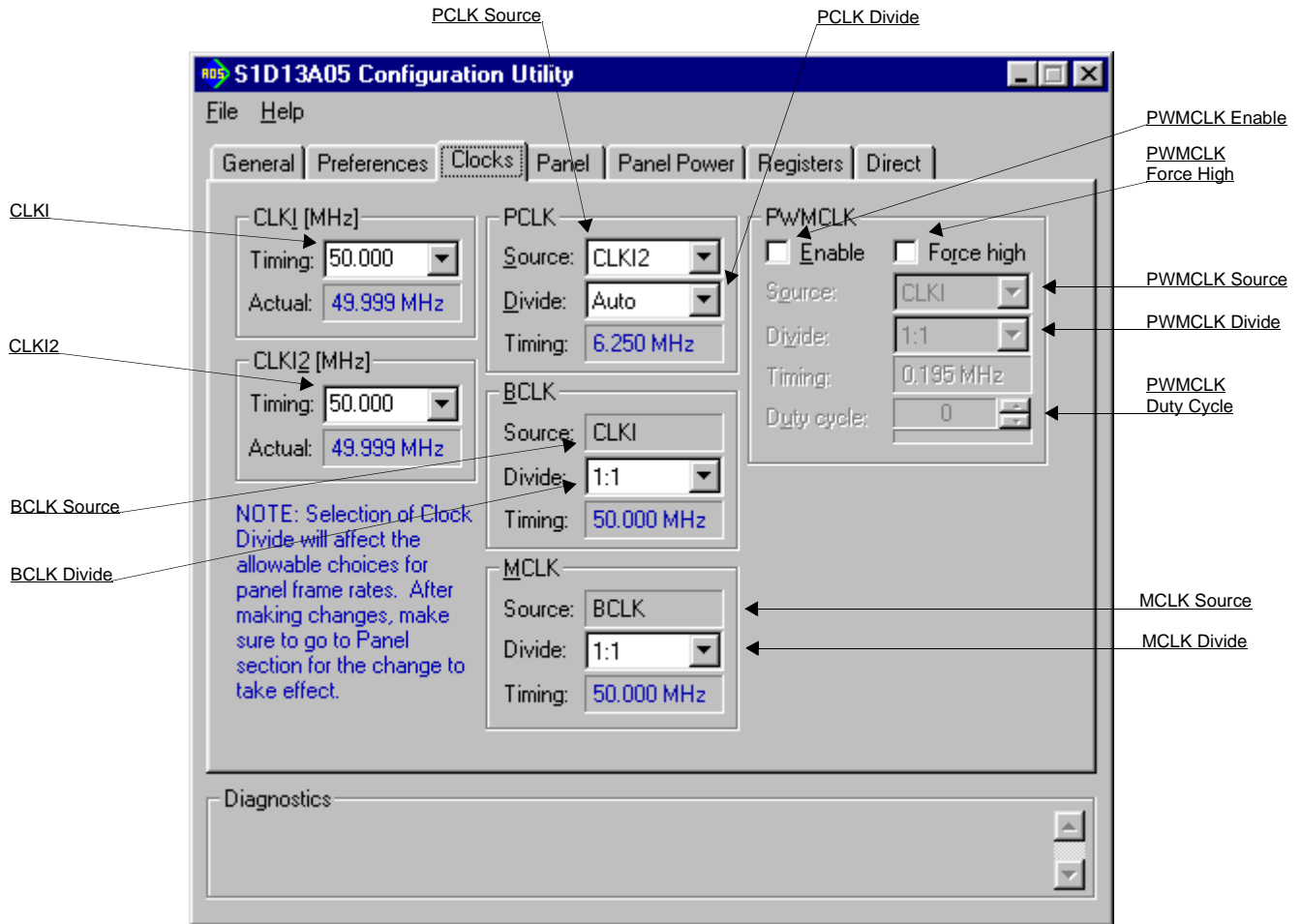
When this box is checked the FPDAT lines are forced to ones instead of zeros when the LCD display is blanked. When the box remains un-checked the FPDAT lines are forced to zeros when the LCD display is blanked. This option only has an effect when Blank Display is enabled.

Video Invert

The S1D13A05 can invert the display data going to the LCD panel. When this box is checked, video data is inverted. Display data is inverted after the Look-Up Table, which means colors are truly inverted.

| | |
|---------------------------|---|
| Pixel Doubling | These settings allow the Pixel Doubling feature to be configured independently in the horizontal and vertical dimensions. Pixel doubling causes each pixel of display data to be extended to two pixels. This feature can be useful for using existing software on larger panels. |
| Horizontal | When this box is checked, pixel doubling in the horizontal direction is enabled. Note that the S1D13A05 does not support horizontal pixel doubling for SwivelView 90° or 270° modes. |
| Vertical | When this box is checked, pixel doubling in the vertical direction is enabled. Note that the S1D13A05 does not support vertical pixel doubling for SwivelView 90° or 270° modes. |
| Configuration Description | This field allows the user to enter a description for a particular configuration. This field is saved in the HAL information and is displayed when a HAL-based utility is run. |
| Color Depth | Sets the initial color depth on the LCD panel. If there is insufficient display buffer for the selected width and height then a warning is displayed in the diagnostic area. |
| Panel SwivelView | The S1D13A05 SwivelView feature is capable of rotating the image displayed on an LCD panel 90°, 180°, or 270° in a counter-clockwise direction. This setting determines the initial orientation of the panel. |
| Advanced | These settings allow fine tuning of the start address and stride. The start address defines the offset into the display buffer (video memory) of the pixel which will be displayed in the top left corner of the panel. Stride defines the number of bytes required to step from the first pixel on one row to the first pixel on the next row (i.e. 160 pixel wide display at 16 bpp requires 320 bytes per horizontal row). |
| Display Start Address | This option sets the start address for the main window of the panel. Typically the start address is set to zero. |
| Display Stride | This option sets the stride for the main window of the panel. To set the stride equal to the size of the display, select the “auto” box. To increase the stride, uncheck the “auto” box and enter the desired stride. Note |
| | The stride value must be greater than or equal to the number of bytes required by one line of display memory. |

Clocks Tab



The Clocks tab simplifies the selection of input clock frequencies and the sources of internal clocking signals. For further information regarding clocking and clock sources, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The CLKI and CLKI2 frequencies represent clock values the system provides to the S1D13A05. It is the responsibility of the system designer to ensure that the correct clock frequencies are supplied to the S1D13A05. The S1D13A05 may use one or two clock sources. Two clock sources allow greater flexibility in the selection of display type and memory speed.

Note

Changing clock values may modify or invalidate Panel settings. Confirm all settings on the Panel tab after changing any clock settings.

When “Enable clock chip support” is selected on the General Tab, 13A05CFG performs calculations to determine the nearest actual clock frequency generated by the programmable clock. When clock chip support is disabled, 13A05CFG assumes the input clocks will be derived from a clock source of exactly the indicated frequency.

| | |
|--------------|---|
| CLKI | This setting determines the frequency of CLKI. |
| Timing | Set this value by selecting a preset frequency from the drop down list or entering the desired frequency (MHz) in the edit box. |
| Actual | This field displays the actual value of the CLKI frequency. If “Enable clock chip support” is selected on the General Tab, then this value may differ slightly from the value entered in the timing control. |
| CLKI2 | This setting determines the frequency of CLKI2. |
| Timing | Set this value by selecting a preset frequency from the drop down list or entering the desired frequency (MHz) in the edit box. |
| Actual | This field displays the actual value of the CLKI2 frequency. If “Enable clock chip support” is selected on the General Tab, then this value may differ slightly from the value entered in the timing control. |
| PCLK | These settings select the clock source and divisor for the internal pixel clock (PCLK). |
| Source | Selects the PCLK source. Possible sources include CLKI, CLKI2, BCLK or MCLK. Note that BCLK and MCLK may be previously divided from CLKI or CLKI2. |
| Divide | Specifies the divide ratio for the clock source. The divide ratio is applied to the PCLK source to derive PCLK. Selecting “Auto” for the divisor allows the configuration program to calculate the best clock divisor. Unless a very specific clocking is being specified, it is best to leave this setting on “Auto”. |
| Timing | This field shows the actual PCLK used by the configuration process. |

BCLK

These settings select the clock source and divisor for the internal bus interface clock (BCLK).

Source

The BCLK source is always CLKI.

Divide

Specifies the divide ratio for the clock source. The divide ratio is applied to the BCLK source to derive BCLK.

Timing

This field shows the actual BCLK frequency used by the configuration process.

MCLK

These settings select the clock source and input clock divisor for the internal memory clock (MCLK). For the best performance, MCLK should be set as close to the maximum (50 MHz) as possible.

Source

The MCLK source is always BCLK.

Divide

Specifies the divide ratio for the clock source. The divide ratio is applied to the MCLK source to derive MCLK.

This divide ratio should be left at 1:1 unless the resultant MCLK is greater than 50MHz.

Timing

This field shows the actual MCLK frequency used by the configuration process.

PWMCLK

These controls configure various PWMCLK settings. The PWMCLK is the internal clock used by the Pulse Width Modulator for output to the panel.

Enable

When this box is checked, the PWMCLK circuitry is enabled.

Force High

The signal PWMOUT is forced high when this box is checked. When not checked, PWMOUT will be low if PWM is not enabled or will change state according to the configured values when PWM is enabled.

Source

Selects the PWMCLK source. Possible sources include CLKI, CLKI2, MCLK, and PCLK.

Divide

Specifies the divide ratio for the clock source. The divide ratio is applied to the PWMCLK source to derive PWMCLK.

Note

After this divide is applied, PWMCLK is further divided by 256 to achieve the final PWMCLK frequency.

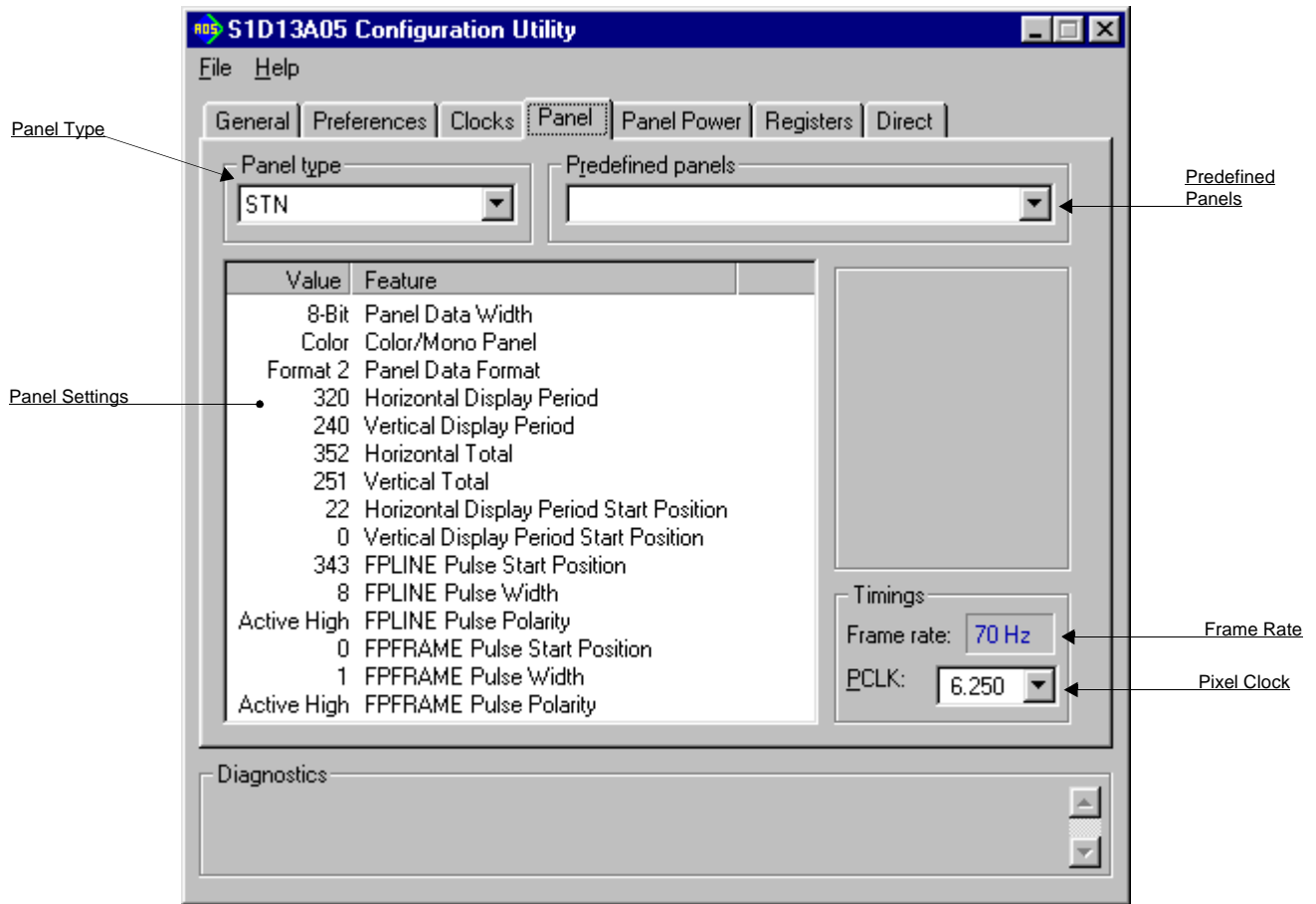
Timing

This field shows the actual PWMCLK frequency used by the configuration process.

Duty Cycle

Selects the number of cycles that PWMOUT is high out of 256 clock periods.

Panel Tab



The S1D13A05 supports several panel types. This tab allows configuration of most panel related settings such as dimensions, type and timings.

Panel Type

Selects the panel type (i.e. STN, TFT, HR-TFT, etc).

Some “Panel Settings” options may change or become unavailable when this control is changed. Re-confirm all settings on this tab after the Panel Type is changed.

Predefined Panels

13A05CFG uses a file (**panels.def**) which contains predefined settings for a number of LCD panels. If the file **panels.def** is present in the same directory as **13A05cfg.exe**, the predefined panels are available in the drop-down list. If a panel is selected from the list, 13A05CFG pre-configures its settings to nominal panel values.

| | |
|--|--|
| Panel Settings | <p>This area allows the user to configure a number of panel specific settings. Items listed here change according to the panel type selected.</p> <p>The following settings can be changed within this pane. For more details on any of the following settings, see the <i>S1D13A05 Hardware Functional Specification</i>, document number X40A-A-001-xx.</p> |
| Panel Data Width | <p>Selects the panel data width. Panel data width is the number of bits of data transferred to the LCD panel on each clock cycle and shouldn't be confused with color depth which determines the number of displayed colors.</p> <p>When a passive panel type is selected, the available options are 4, 8, and 16 bit. When an active panel type (TFT/HR-TFT) is selected, the available options are 9, 12, and 18 bit.</p> |
| Color/Mono Panel | Selects between a monochrome or color panel. |
| Panel Data Format | <p>Selects the color STN panel data format. This option only applies to 8-bit color STN panels. Most new panels use the format 2 data format.</p> <p>See the <i>S1D13A05 Hardware Functional Specification</i>, document number X40A-A-001-xx, for description of format 1 / format 2 data formats.</p> |
| Horizontal and Vertical Display Period | <p>These fields specify the panel width and height. A number of common widths and height are available in the selection boxes. If the width/height of your panel is not listed, enter the actual panel dimensions into the edit field.</p> <p>For passive panels, manually entered pixel widths must be a minimum of 32 pixels and can be increased by multiples of 16. For TFT panels, manually entered pixel widths must be a minimum of 8 pixels and can be increased by multiples of 8. If a value is entered that does not meet these requirements, 13A05CFG rounds up the value to the next allowable width. The changed value is reported in the diagnostics portion of the window.</p> |

Horizontal Total

Sets the number of pixels on each line of the display. This value is the sum of both the visible (Horizontal Display Period) and non-visible (Horizontal Non-Display Period) values. It is recommended that the automatically generated values be used. However, manual adjustment may be used to improve the quality of the displayed image by fine tuning the horizontal display total.

Refer to *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx, for a complete description of the Display Total settings.

Note

If the horizontal total is set too small, 13A05CFG will display a yellow warning message in the diagnostics portion of the window.

Vertical Total

Sets the number of lines of the display. This value is the sum of both the visible (Vertical Display Period) and non-visible (Vertical Non-Display Period) values. It is recommended that the automatically generated values be used. However, manual adjustment may be used to improve the quality of the displayed image by fine tuning the vertical display total.

Refer to *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx, for a complete description of the Display Total settings.

Note

If the vertical total is set too small, 13A05CFG will display a yellow warning message in the diagnostics portion of the window.

Horizontal Display Period Start Position

It is recommended that the automatically generated values be used. However, manual adjustment may be used to improve the quality of the displayed image by fine tuning the horizontal display period start positions.

Refer to *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx, for a complete description of the Display Start settings.

Note

If the horizontal display start values are set to values that violate the *S1D13A05 Hardware*

Functional Specification, 13A05CFG will display a yellow warning message in the diagnostics portion of the window.

Vertical Display Period Start Position

It is recommended that the automatically generated values be used. However, manual adjustment may be used to improve the quality of the displayed image by fine tuning the vertical display period start positions.

Refer to *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx, for a complete description of the Display Start settings.

Note

If the vertical display start values are set to values that violate the *S1D13A05 Hardware Functional Specification*, 13A05CFG will display a yellow warning message in the diagnostics portion of the window.

FPLINE Start Position Specifies the delay (in pixels) from the start of the horizontal non-display period to the leading edge of the FPLINE pulse.

FPLINE Pulse Width Specifies the width (in pixels) of the horizontal sync signal (FPLINE).

FPLINE Pulse Polarity Specifies the polarity (active high or active low) of the horizontal sync signal (FPLINE).

Note

Selecting the wrong pulse polarity may damage the panel.

FPFRAME Start Position Specifies the delay (in lines) from the start of the vertical non-display period to the leading edge of the FPFRAME pulse.

FPFRAME Pulse Width Specifies the pulse width (in lines) of the vertical sync signal (FPFRAME).

FPFRAME Pulse Polarity Specifies the polarity (active high or active low) of the vertical sync signal (FPFRAME).

Note

Selecting the wrong pulse polarity may damage the panel.

| | |
|-------------------------|---|
| CLS Pulse Width | Sets the width of CLS signals in PCLKs. This setting is used for HR-TFT panels only. |
| PS1 Rising Edge | Selects the number of PCLKs between the CLS falling edge and the PS1 rising edge. This setting is used for HR-TFT panels only. |
| PS2 Rising Edge | Selects the number of PCLKs between the CLS falling edge and the PS2 rising edge. This setting is used for HR-TFT panels only. |
| PS2 Toggle Width | Sets the width of the PS2 signal before toggling (in number of PCLKs). This setting is used for HR-TFT panels only. |
| PS3 Signal Width | Sets the width of the PS3 signal in PCLKs. This setting is used for HR-TFT panels only. |
| REV Toggle Point | Sets the width in PCLKs to toggle the REV signal to LP rising edge. This setting is used for HR-TFT panels only. |
| PS1/2 End | Allows the PS signal to continue into vertical non-display period (in lines). This setting is used for HR-TFT panels only. |
| POL Type | Selects how often the POL signal is toggled (as either ever line or every frame). This setting is used for Type 2 TFT panels only. |
| AP Pulse Width | Selects the AP width used for the TFT Type 2 interface (in PCLKs). This setting is used for Type 2 TFT panels only. |
| AP Rising Edge Position | Controls the TFT Type 2 AC timing parameter from the rising edge of FPLINE (STB) to the rising edge of GP101 (AP) (in PCLKs). This setting is used for Type 2 TFT panels only. |
| VCLK Hold | Controls the AC timing parameter from the rising edge of FPLINE (STB) to the falling edge of GPIO0 (VCLK) (in PCLKs). This setting is used for Type 2 TFT panels only. |
| VCLK Setup | Controls the AC timing parameter from the rising edge of GPIO0 (VCLK) to the rising edge of FPLINE (STB) (in PCLKs). This setting is used for Type 2 TFT panels only. |

| | |
|------------------------------------|---|
| POL Toggle Position | Sets the toggle position of the POL signal in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| OE Pulse Width | Sets the pulse width of the OE signal in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| OE Rising Edge Position | Sets the rising edge position of the OE signal in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| XOEV Falling Edge Position | Sets the falling edge position of the XOEV signal in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| XOEV Rising Edge Position | Sets the rising edge position of the XOEV signal in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| CPV Pulse Width Position | Sets the pulse width of the CPV in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| VCOM Toggle Position | Sets the toggle position of the VCOM signal in 2 pixel resolution. This setting is used for Type 3 TFT panels only. |
| PCLK2 Divide Rate | Selects the divide rate for PCLK2 (GPO5). This setting is used for Type 3 TFT panels only. |
| PCLK1 Divide Rate | Selects the divide rate for PCLK1 (GPO4). This setting is used for Type 3 TFT panels only. |
| Partial Mode Display Refresh Cycle | Selects the refresh cycle for the Partial Mode Display (as value from 0 to 63). This setting is used for Type 3 TFT panels only. |
| Partial Mode Display Enable | Enables the Partial Mode Display. This setting is used for Type 3 TFT panels only. |
| Partial Mode Display Type | Selects the type of Partial Mode Display. Stripe means that only the Y Position registers are used in calculating the partial display, where Block means that both the X and Y Position registers are used. This setting is used for Type 3 TFT panels only. |
| Partial Mode Display Area 2 Enable | Enables the Area 2 for Partial Mode Display. This setting is used for Type 3 TFT panels only. |

Partial Mode Display Area 1 Enable Enables the Area 1 for Partial Mode Display.
This setting is used for Type 3 TFT panels only.

Partial Mode Display Area 0 Enable Enables the Area 0 for Partial Mode Display.
This setting is used for Type 3 TFT panels only.

Partial Area 0 Y End PositionSelects the Y End Position of Partial Area 0 in 8 line resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 0 X End PositionSelects the X End Position of Partial Area 0 in 8 pixel resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 0 Y Start PositionSelects the Y Start Position of Partial Area 0 in 8 line resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 0 X Start PositionSelects the X Start Position of Partial Area 0 in 8 pixel resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 1 Y End PositionSelects the Y End Position of Partial Area 1 in 8 line resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 1 X End PositionSelects the X End Position of Partial Area 1 in 8 pixel resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 1 Y Start PositionSelects the Y Start Position of Partial Area 1 in 8 line resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 1 X Start PositionSelects the X Start Position of Partial Area 1 in 8 pixel resolution. **This setting is used for Type 3 TFT panels only.**

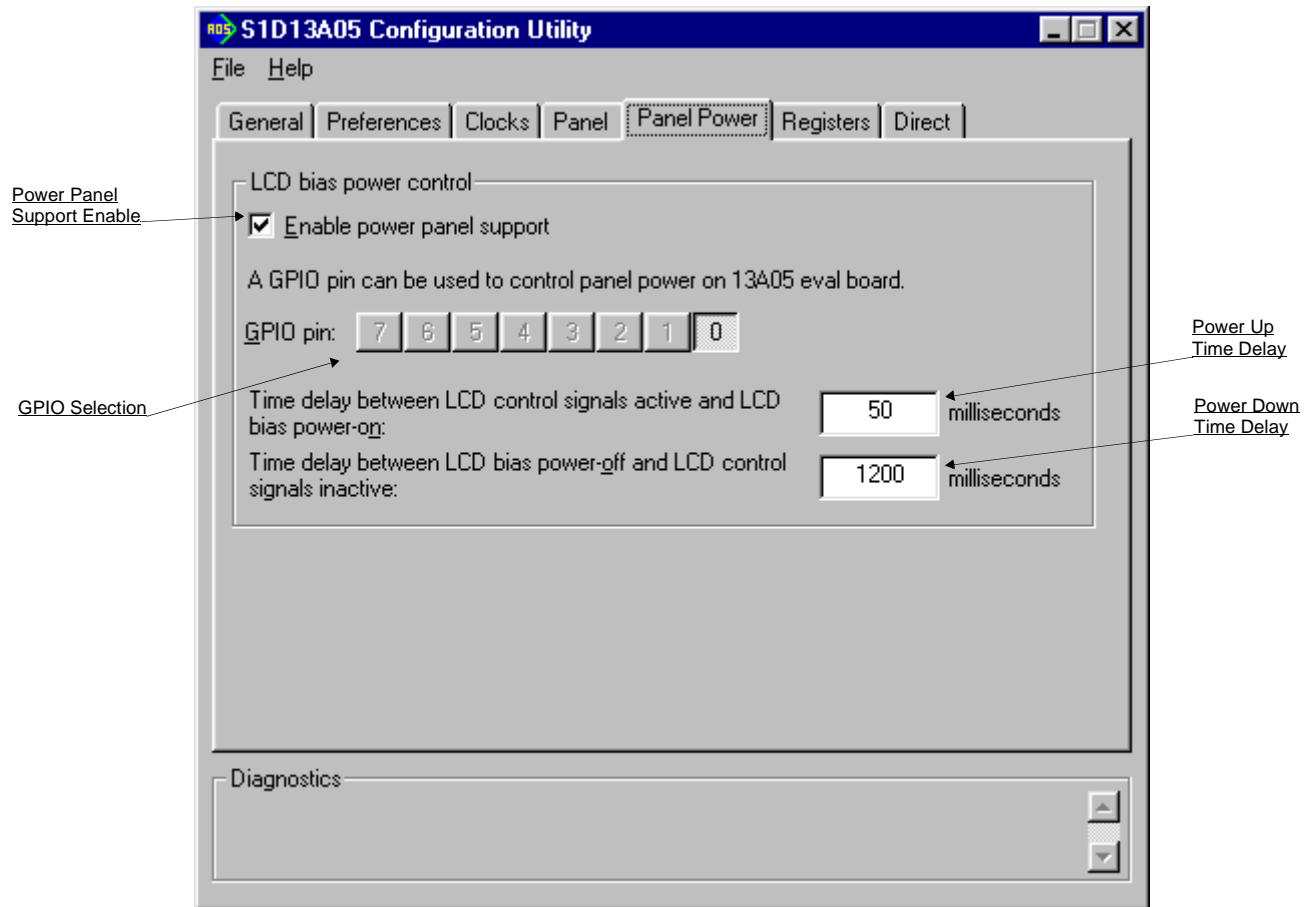
Partial Area 2 Y End PositionSelects the Y End Position of Partial Area 2 in 8 line resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 2 X End PositionSelects the X End Position of Partial Area 2 in 8 pixel resolution. **This setting is used for Type 3 TFT panels only.**

Partial Area 2 Y Start PositionSelects the Y Start Position of Partial Area 2 in 8 line resolution. **This setting is used for Type 3 TFT panels only.**

| | |
|---------------------------------------|--|
| Partial Area 2 X Start Position | Selects the X Start Position of Partial Area 2 in 8 pixel resolution. This setting is used for Type 3 TFT panels only. |
| Command 1 Store | Stores command 1 for the TFT Type 3 Interface. This setting is used for Type 3 TFT panels only. |
| Command 0 Store | Stores command 0 for the TFT Type 3 Interface. This setting is used for Type 3 TFT panels only. |
| Source Driver IC Number | Selects the number of Source Driver ICs. This setting is used for Type 3 TFT panels only. |
| Command Send Request | Enables the S1D13A05 to send the command in the next non-display period. This setting is used for Type 3 TFT panels only. |
| GPCK Rising Edge to STH Pulse | Sets the number of PCLKs from GPCK rising edge to STH pulse. This setting is used for Casio TFT panels only. |
| GRES Falling Edge to FRP Toggle Point | Sets the number of PCLKs from GRES falling edge to FRP toggle point. This setting is used for Casio TFT panels only. |
| GRES Falling Edge to GPCK Rising Edge | Sets the number of PCLKs from GRES falling edge to GPCK rising edge. This setting is used for Casio TFT panels only. |
| GPCK Rising Edge to GRES Rising Edge | Sets the number of PCLKs from GPCK rising edge to GRES rising edge. This setting is used for Casio TFT panels only. |
| Frame Rate | <p>The Frame Rate (in Hz) is calculated and displayed based on the current settings as selected on the various tabs. If the resulting Frame Rate is not acceptable, adjust the settings to change the frame rate.</p> <p>Panel dimensions are fixed therefore frame rate can only be adjusted by changing either the PCLK frequency or display total values.</p> |
| Pixel Clock | Select the desired Pixel Clock (in MHz) from the drop-down list. The range of frequencies displayed is dependent on the PCLK source and divide settings as selected on the Clocks tab. |

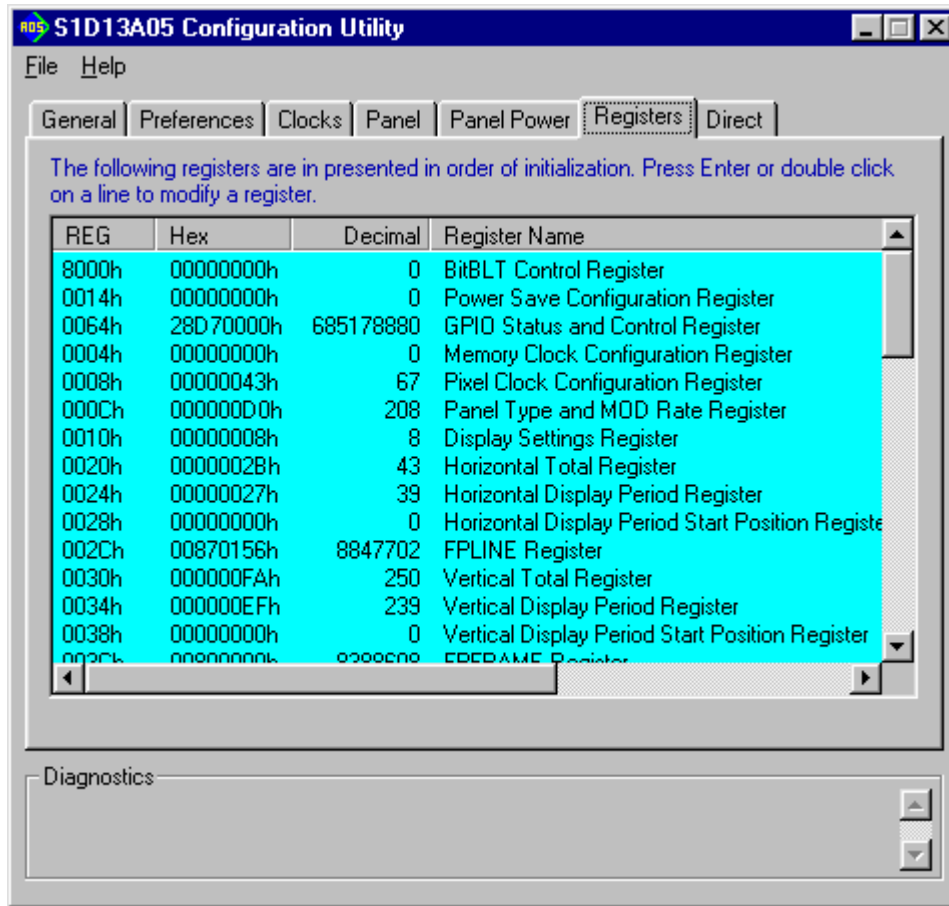
Panel Power Tab



The S1D13A05 evaluation board is designed to use a GPIO signal to control the LCD bias power. The following settings configure panel power support.

| | |
|----------------------------|---|
| Power Panel Support Enable | When this box is checked, the LCD bias power to the panel is controlled by the selected GPIO pin. When this box is unchecked, the LCD bias power must be controlled by the CPU or some other means. |
| GPIO Selection | This setting selects the GPIO pin used to control the LCD bias power. The default is GPIO0 (GPIO0 is used on the S1D13A05 evaluation board). |
| Power Up Time Delay | <p>This setting controls the maximum time delay between when the S1D13A05 control signals are turned on and the LCD panel is powered-on. This setting must be configured according to the specification for the panel being used.</p> <p>This value is used by Epson evaluation software designed for the S1D13A05 evaluation board.</p> |
| Power Down Time Delay | <p>This setting controls the minimum time delay between when the LCD panel is powered-off and when the S1D13A05 control signals are turned off. This setting must be configured according to the specification for the panel being used.</p> <p>This value is used by Epson evaluation software designed for the S1D13A05 evaluation board.</p> |

Registers Tab



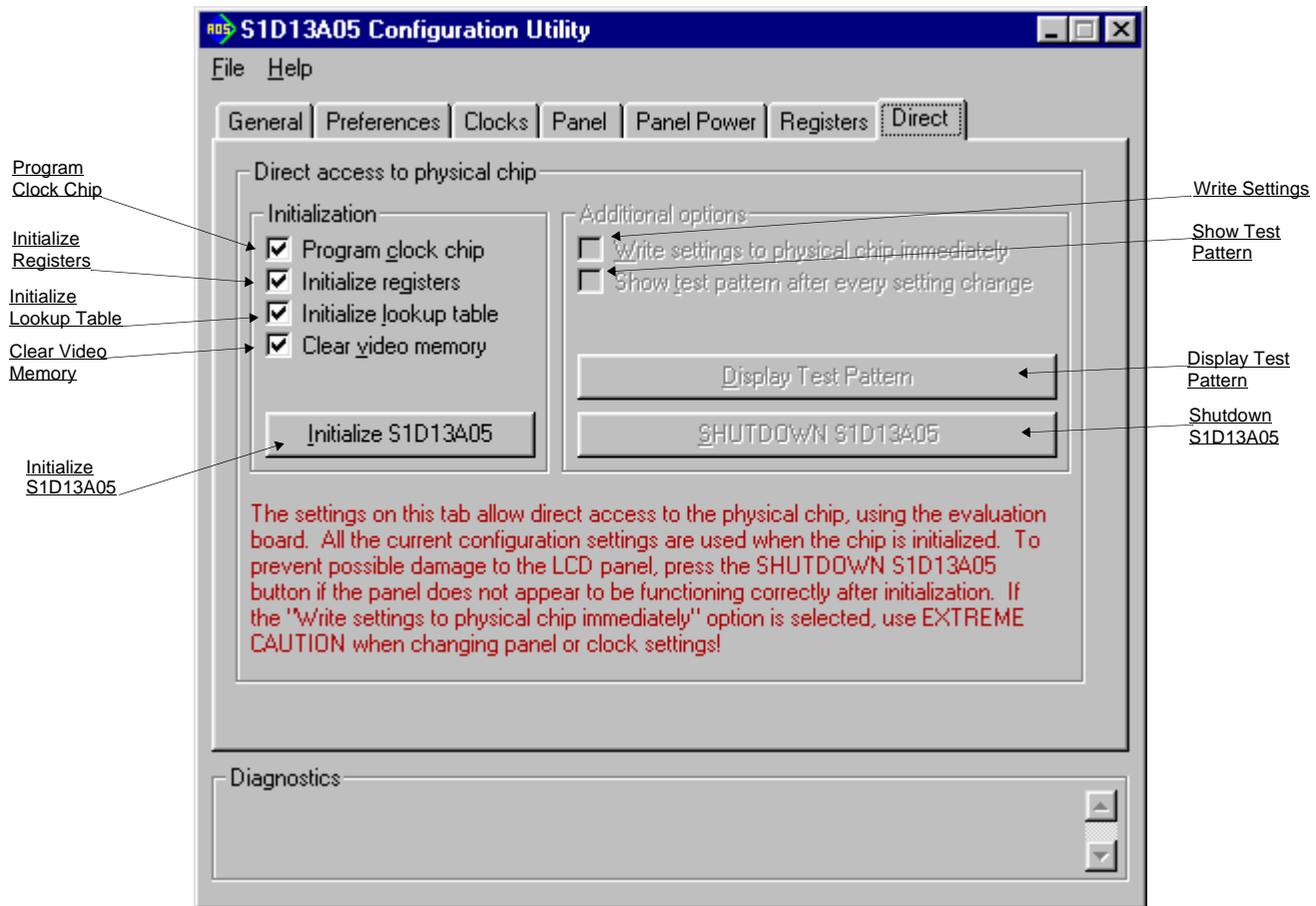
The Registers tab allows viewing and editing of the S1D13A05 register values.

Scroll up and down the list to view register values which are determined from the configuration settings of the previous tabs. Hovering over a register displays a pop-up help box which describes the functionality of the bits in that register. Register settings may be changed by double-clicking on the register in the listing. **Manual changes to the registers are not checked for errors, so caution is warranted when directly editing these values.** It is strongly recommended that the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx be referred to before making any manual register settings.

Note

Manually entered values may be changed by 13A05CFG if further configuration changes are made on other tabs. In this case, the user is notified.

Direct Tab



This tab allows the user to directly interact with the S1D13A05 configuration process. The effect of register changes on the displayed image can be observed before writing any configuration files. Fine tuning adjustments may be made to achieve the best possible image on the panel.

Using this tab requires that a S1D13A05 evaluation board is installed in the computer and a panel is attached.

Initialization

These settings define which actions will be carried out when the Initialize S1D13A05 button is clicked.

Program Clock Chip

The S5U13A05B00C evaluation board design includes a clock chip which can provide the signals for CLKI and CLKI2. Checking this box will include programming the clock chip as part of the S1D13A05 initialization.

Initialize Registers

When this box is checked the S1D13A05 registers will be programmed to their configured values as part of the initialization.

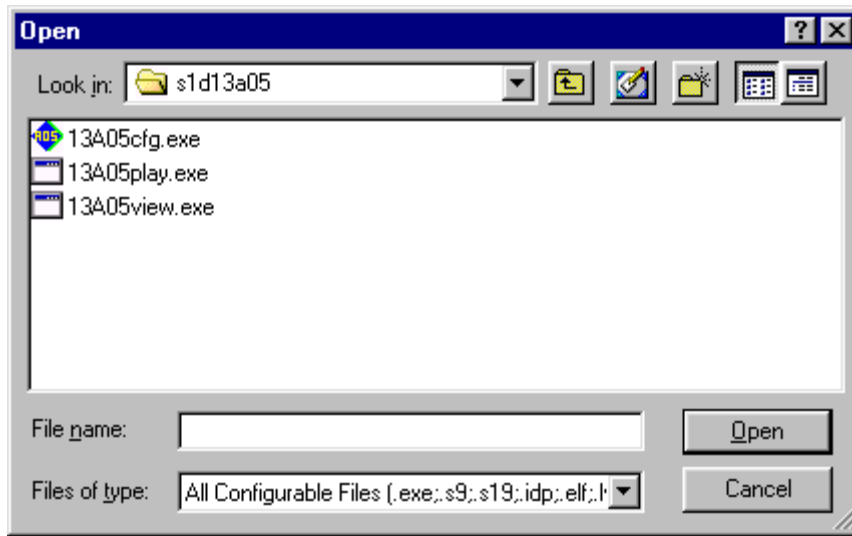
| | |
|-------------------------|---|
| Initialize Lookup Table | When this box is checked the S1D13A05 Lookup Table is programmed as part of the initialization. |
| Clear Video Memory | When this box is checked the S1D13A05 display buffer will be cleared (set to zeros) as part of the initialization. |
| Initialize S1D13A05 | Clicking this button initializes the S1D13A05 according to the options selected. |
| Additional Options | After initializing the S1D13A05, these further options become available. |
| Write Settings | This setting should be used with caution. Checking this box will cause setting changes on any tab to immediately update the associated register(s). |
| Show Test Pattern | Checking this box will update the test pattern in the display buffer after every setting change. This is useful when fine tuning panel settings as the results of the change are immediately visible. |
| Display Test Pattern | Clicking this button causes 13A05CFG to draw a test pattern into display memory. The pattern is based on the configured width, height, rotation and color depth. |
| Shutdown S1D13A05 | Clicking this button shuts down the S1D13A05. This feature is necessary should a setting change appear to be damaging or harmful to the attached panel. |

13A05CFG Menus

The following sections describe each of the options in the File and Help menus.

Open...

From the Menu Bar, select “File”, then “Open...” to display the Open File Dialog Box.



The Open option allows 13A05CFG to read the configuration information from programs based on the HAL library. When 13A05CFG opens a file it scans the file for an identification string, and if found, reads the configuration information. This feature may be used to quickly arrive at a starting point for register configuration. The only requirement is that the file being opened must contain a valid S1D13A05 HAL library information block.

13A05CFG supports a variety of executable file formats. Select the file type(s) 13A05CFG should display in the Files of Type drop-down list and then select the filename from the list and click on the Open button.

Note

13A05CFG is designed to work with utilities programmed using a given version of the HAL. If the configuration structure contained in the executable file differs from the version 13A05CFG expects the Open will fail and an error message is displayed. This may happen if the version of 13A05CFG is substantially older, or newer, than the file being opened.

Save

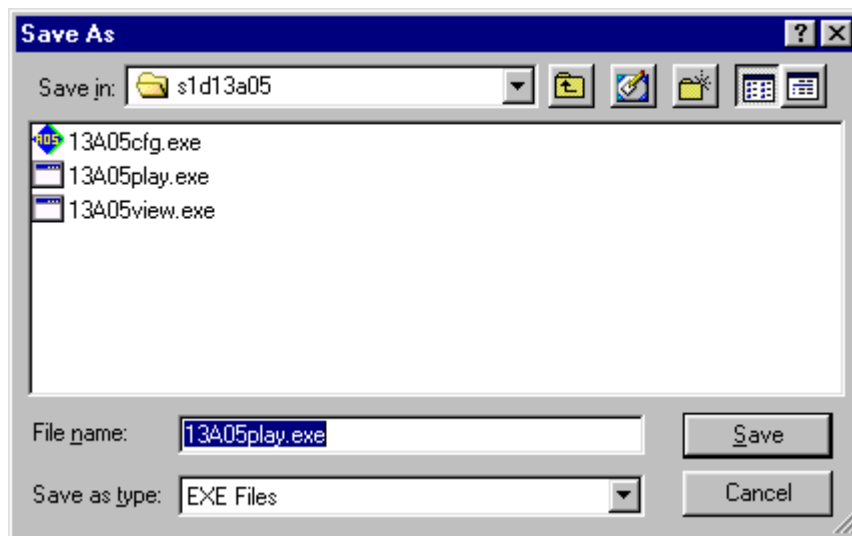
From the Menu Bar, select “File”, then “Save” to initiate the save action. The Save menu option allows a fast save of the configuration information to a file that was opened with the Open menu option.

Note

This option is only available once a file has been opened.

Save As...

From the Menu Bar, select “File”, then “Save As...” to display the Save As Dialog Box.



“Save as” is very similar to Save except a dialog box is displayed allowing the user to name the file before saving.

Using this technique a tester can configure a number of files differing only in configuration information and name (e.g. BMP60Hz.EXE, BMP72Hz.EXE, BMP75Hz.EXE where only the frame rate changes in each of these files).

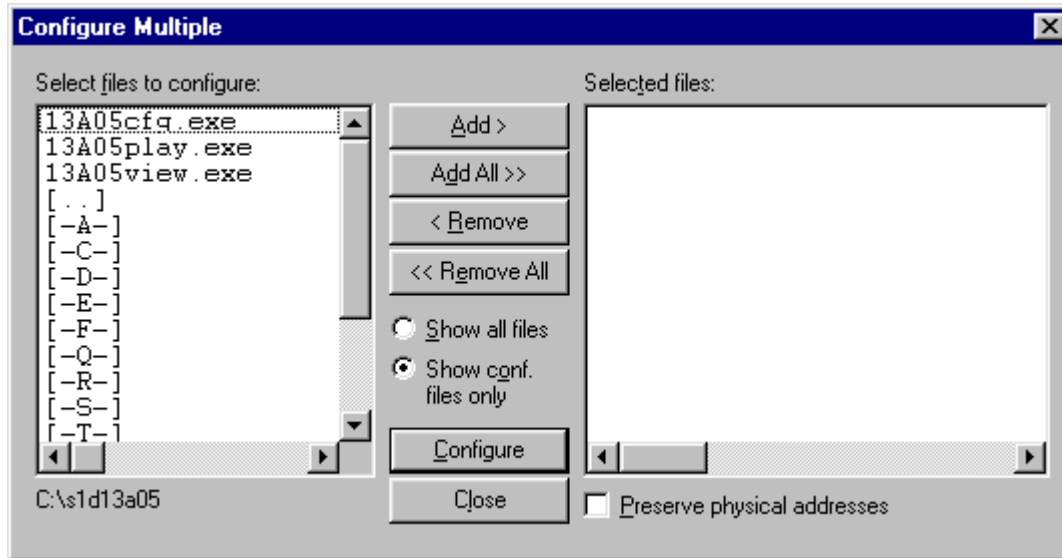
Note

When “Save As” is selected then an exact duplicate of the file as opened by the “Open” option is created containing the new configuration information.

Configure Multiple

After determining the desired configuration, “Configure Multiple” allows the information to be saved into one or more executable files built with the HAL library.

From the Menu Bar, select “File”, then “Configure Multiple” to display the Configure Multiple Dialog Box. This dialog box is also displayed when a file(s) is dragged onto the 13A05CFG window.



The left pane lists files available for configuration; the right pane lists files that have been selected for configuration. Files can be selected by clicking the “Add” or “Add All” buttons, double clicking any file in the left pane, or by dragging the file(s) from Windows Explorer.

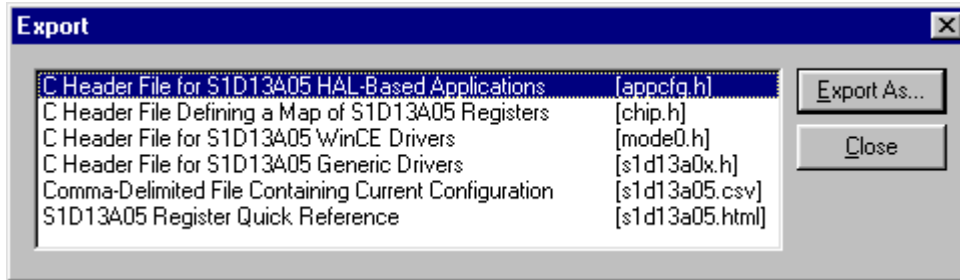
Selecting “Show all files” displays all files in the selected directory, whereas selecting “Show conf. files only” will display only files that can be configured using 13A05CFG (i.e. .exe, .s9).

Checking “Preserve Physical Addresses” instructs 13A05CFG to use the register and display buffer address values the files were previously configured with. Addresses specified in the General Tab are discarded. This is useful when configuring several programs for various hardware platforms at the same time. For example, if configuring PCI, MPC and IDP based programs at the same time for a new panel type, the physical addresses for each are retained. This feature is primarily intended for the test lab where multiple hardware configurations exist and are being tested.

Export

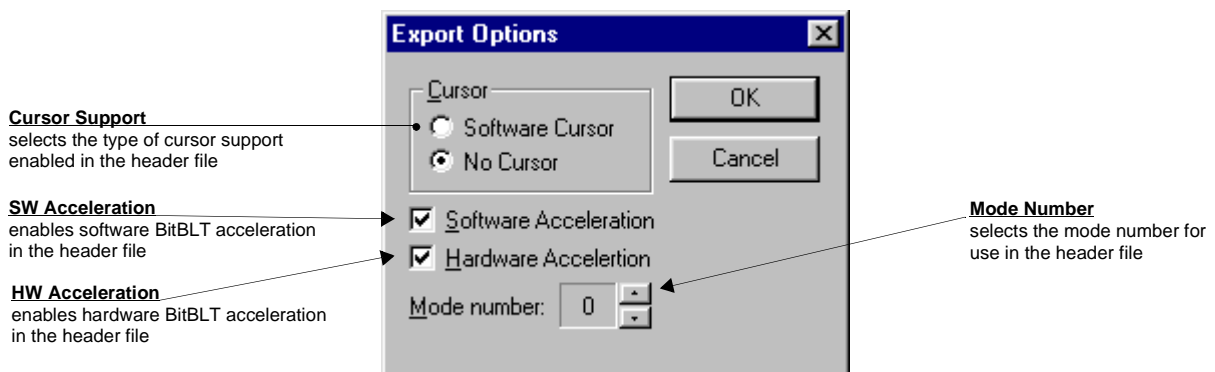
After determining the desired configuration, “Export” permits the user to save the register information as a variety of ASCII text file formats. The following is a list and description of the currently supported output formats:

- a C header file for use in writing HAL library based applications.
- a C header file which lists each register and the value it should be set to.
- a C header file for use in developing Window CE display drivers.
- a C header file for use in developing display drivers for other operating systems such as Linux, QNX, and VxWorks WindML.
- a comma delimited text file containing an offset, a value, and a description for each S1D13A05 register.
- a .html based reference guide to the S1D13A05 registers.



After selecting the file format, click the “Export As...” button to display the file dialog box which allows the user to enter a filename before saving. Clicking the “Preview” button uses Notepad or the web browser to display a copy of the file to be saved.

When the **C Header File for S1D13A05 WinCE Drivers** option is selected as the export type, additional options are available and can be selected by clicking on the Options button. The options dialog appears as:



Enable Tooltips

Tooltips provide useful information about many of the items on the configuration tabs. Placing the mouse pointer over nearly any item on any tab generates a popup window containing helpful advice and hints.

To enable/disable tooltips check/uncheck the “Tooltips” option from the “Help” menu.

Note

Tooltips are enabled by default.

Tooltip Delay

This option sets the length of time the cursor must be left over an item before its associated tooltip is displayed.

ERD on the Web

This “Help” menu item is actually a hotlink to the Epson Research and Development website. Selecting “Help” then “ERD on the Web” starts the default web browser and points it to the ERD product web site.

The latest software, drivers, and documentation for the S1D13A05 is available at this website.

Update Common Controls

13A05CFG uses some of the latest common control DLLs. On systems using earlier versions of the common controls, certain controls may not appear correctly. This option updates the Common Controls required for proper operation of 13A05CFG.

About 13A05CFG

Selecting the “About 13A05CFG” option from the “Help” menu displays the about dialog box for 13A05CFG. The about dialog box contains version information and the copyright notice for 13A05CFG.

Comments

- On any tab particular options may be grayed out if selecting them would violate the operational specification of the S1D13A05 (i.e. Selecting TFT or STN on the Panel tab enables/disables options specific to the panel type).
- The file **panels.def** is a text file containing operational specifications for several supported, and tested, panels. This file can be edited with any text editor.
- 13A05CFG allows manually altering register values. The manual changes may violate memory and LCD timings as specified in the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx. If this is done, unpredictable results may occur. Epson Research and Development, Inc. does not assume liability for any damage done to the display device as a result of configuration errors.
- Yellow diagnostic warnings are designed to draw attention to important errors in the configuration and should be corrected before saving the configuration.
- **13A05CFG** can be configured by making a copy of the file 13A05cfg.exe and configuring the copy. It is not possible to configure the original while it is running. The newly saved information becomes the default configuration for that copy of 13A05cfg.exe.

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EPSON®



S1D13A05 LCD/USB Companion Chip

13A05PLAY Diagnostic Utility

Document Number: X40A-B-002-01

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13A05PLAY

13A05PLAY is a diagnostic utility which allows read/write access to all the registers and display buffer of the S1D13A05. Commands are received from the standard input device, and messages are sent to the standard output device. On Intel platforms the console provides standard input/output. For most embedded systems the serial device provides these functions.

Commands may be entered interactively by a user, or be executed from a script file. Scripting is a powerful feature which allows command sequences to be used repeatedly without re-entry.

Note

This program is a utility program for testing and evaluating Epson LCD controllers. It is not a display driver for any operating system but a utility program intended to aid in testing and evaluating Epson LCD controller hardware.

This user manual is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

S1D13A05 Supported Evaluation Platforms

13A05PLAY is available as an executable for PCs running Windows® 9x/ME/NT/2000/XP and as C source code which can be modified and recompiled to allow 13A05PLAY to run on other platforms.

Note

In order to run 13A05PLAY on PCs running Windows, the device driver **13xxx.vxd** must be installed. For further information on this device driver, see the *S1D13XXX 32-Bit Windows Device Drivers Installation Guide*, document number X00A-E-003-xx.

The latest version of both the executable and source code is available on the Epson Research and Development website at www.erd.epson.com.

Installation

PC platform

Copy the file **13A05play.exe** to any directory (e.g. c:\s1d13a05).

Embedded platform

Download the program **13A05play** to the system.

Usage

PC platform

At the prompt, type:

13A05play [/?]

Where:

`/?` displays copyright and program version information.

Embedded platform

Execute **13A05play** and enter commands at the prompt. The “/?” command provides copyright and program version information.

Commands

The following commands are intended for use at 13A05PLAY command prompt. However, simple commands can also be executed from the command line (e.g. **13A05play f 0 14000 AB q**).

CLKI freq

Sets the frequency of CLKI.

Where:

freq The desired frequency for CLKI (in MHz).

CLKI2 freq

Sets the frequency of CLKI2.

Where:

freq The desired frequency for CLKI2 (in MHz).

D[8|16|32] [startaddr [endaddr|len]]

Displays a memory dump from the specified display buffer address range.

Where:

8|16|32 The unit size: 8-bit (bytes), 16-bit (words), 32-bit (dwords). If a unit size is not specified, this command uses the unit size from the last Dump command performed. If no previous Dump command has been issued, the unit size defaults to 8-bit.

startaddr The starting address to read data from. Specifying a period (.) uses the same starting address as the last Dump command performed. Specifying a startaddr of two periods (..) will back the start address by the size of *len*.

endaddr|len Determines how many units to continue dumping the contents of the display buffer. A number without a prefix represents a physical ending address. If an "L" prefix is used, the number that follows represents *len*, which is the number of bytes/words/dwords to be dumped. *Len* is based on the unit size. For example, 'L8' when the unit size is 16-bit would cause the Dump command to dump 8 words from the starting address.

F[8|16|32] startaddr endaddr|len data1 [data2 data3 ...]

Fills a specified address range in the display buffer with the given data.

Where:

| | |
|-----------------|--|
| 8 16 32 | The unit size: 8-bit (bytes), 16-bit (words), 32-bit (dwords). If a unit size is not specified, this command uses the unit size from the last Fill command performed. If no previous Fill command has been issued, the unit size defaults to 8-bit. |
| startaddr | The starting address to begin filling at. Specifying a period (.) uses the same starting address as the last Fill command performed. |
| endaddr len | Determines how many units to fill the display buffer with. A number without a prefix represents a physical ending address. If a “L” prefix is used, the number that follows represents <i>len</i> , or the number of bytes/words/dwords to be filled. <i>Len</i> is based on the unit size. For example, 'L8' when the unit size is 16-bit would cause the Fill command to fill 8 words from the starting address. |
| data1 data2 ... | The value(s) used to fill the display buffer. If multiple values are given, the pattern repeats through memory. Values can be combinations of 'text' or numbers. Numbers are assumed to be hexadecimal values unless otherwise specified with the correct suffix (binary = i, octal = o, decimal = t, hexadecimal = h). For example, 101i = 101 binary. To specify text values, enclose text data inside quotes. |

H [lines]

Sets the number of lines of data that are displayed at a time. The display is halted after the specified number of lines. Setting the number of lines to 0 disables the halt function and allows the data to continue displaying until all data has been shown.

This command is useful when large blocks of the display buffer or the contents of the LUT are being viewed.

Where:

| | |
|-------|---|
| lines | Number of lines that are shown before halting the displayed data (decimal value). |
|-------|---|

I

Initializes the S1D13A05 registers with the default register settings as configured by the utility 13A05CFG. To initialize the S1D13A05 with different register values, reconfigure 13A05PLAY using 13A05CFG. For further information on 13A05CFG, see the *13A05CFG User Manual*, document number X40A-B-001-xx.

Note

13A05PLAY must be configured using 13A05CFG before using the “I” command. If the “I” command is used before 13A05PLAY is configured, an error message is displayed and no further action is taken.

L index [red green blue]

Reads/writes the red, green, and blue Look-Up Table (LUT) components. If the red, green, and blue components are not specified, the LUT for the given index is read and the RGB values are displayed.

Where:

| | |
|-------|-----------------------------------|
| index | Index into the LUT (hex). |
| red | Red component of the LUT (hex). |
| green | Green component of the LUT (hex). |
| blue | Blue component of the LUT (hex). |

Note

Only bits 7-2 of each color are used in the LUT. The least significant two bits of the colors are discarded. For example, the command **L 0 1 2 3** will set each RGB component of LUT index 0 to 0, as the values 1, 2, and 3 use only the least significant bits.

LA

Reads and displays all LUT values.

M [bpp]

Sets the color depth (bpp). If no color depth is provided, information about the current settings are displayed.

Where:

| | |
|-----|---|
| bpp | Color depth to be set (1/2/4/8/16 bpp). |
|-----|---|

Note

This command reads and interprets the S1D13A05 control registers. To function correctly the registers must have been initialized using the 'I' command.

N

This option sets the display format for register reads/writes. When the "N" option is selected, register reads/writes are displayed in a simple value format. The "V" option selects a more graphical representation of the register structure and values. The "N" option is the default setting.

Q

Quits the program.

R[8|16|32] [addr1 addr2 addr3 ...]

Reads the display buffer at the address locations given.

Where:

| | |
|---------|---|
| 8 16 32 | The unit size: 8-bit (bytes), 16-bit (words), 32-bit (dwords). If a unit size is not specified, this command uses the unit size from the last Read command performed. If no previous Read command has been issued, the unit size defaults to 8-bit. |
| addr | The address to read data from. Multiple addresses can be given. |

Run scriptfile

This command opens the file scriptfile and executes each line as if it were typed from the command prompt. For more information on script files, see **Section , “Script Files” on page 12.**

Where:

scriptfile A file containing 13A05PLAY commands

S[8|16|32] startaddr endaddr|len data1 [data2 data3 data4 ...]

Search the display buffer for the given data.

Where:

| | |
|-------------|---|
| 8 16 32 | The unit size: 8-bit (bytes), 16-bit (words), 32-bit (dwords). If a unit size is not specified, this command uses the unit size from the last Search command performed. If no previous Search command has been issued, the unit size defaults to 8-bit. |
| startaddr | The starting address to begin the search from. Specifying a period (.) uses the same starting address as the last Search command performed. |
| endaddr len | Determines how many units of the display buffer will be searched through. A number without a prefix represents a physical ending address. If a “L” prefix is used, the number that follows represents <i>len</i> , or the number of bytes/words/dwords to be searched through. <i>Len</i> is based on the unit size. For example, 'L8' when the unit size is 16-bit would cause the Search command to search 8 words from the starting address. |
| data | The value(s) to search the display buffer for. Values can be combinations of 'text' or numbers. Numbers are assumed to be hexadecimal values unless otherwise specified with the correct suffix (binary = i, octal = o, decimal = t, hexadecimal = h). For example, 101i = 101 binary. To specify text data, enclose the search string inside quotes. |

Show

Shows a test pattern on the display. The test pattern is based on current register settings and may not display correctly if the registers are not configured properly.

Use this command to display an image during testing. After adjusting a register value, use the show command to view the effect on the display.

U index [data]

Reads/writes data to the USB register at index. If no data is specified, the command reads and displays the contents from the USB register at index.

Where:

| | |
|-------|--|
| index | Index into the USB registers (hex). |
| data | The value to be written to the register. Numbers are assumed to be hexadecimal values unless otherwise specified with the correct suffix (binary = i, octal = o, decimal = t, hexadecimal = h). For example, 101i = 101 binary. |

UA

Reads and displays the contents of all the USB registers.

UX index [data]

This command automates the writes/reads into the indexed USB registers located at REG[4038h] and REG[403Ah]. Index represents the value that would be written into REG[4038h] if separate operations were done to access the index and data registers. If no data is specified, the command reads and displays the contents of the specified extended USB register.

Where:

| | |
|-------|---|
| index | Index into USB registers at REG[403Ah] (hex). |
| data | The value to be written to the indexed data register. Numbers are assumed to be hexadecimal values unless otherwise specified with the correct suffix (binary = i, octal = o, decimal = t, hexadecimal = h). For example, 101i = 101 binary. |

V

This option sets the display format for register reads/writes. When the “V” option is selected, register reads/writes are displayed using a graphical representation of the register structure and values. The “N” option selects a simple value format.

W[8|16|32] [startaddr [data1 data2 data3 data4 ...]]

Writes the given data sequence to the display buffer starting at startaddr location.

Where:

| | |
|-----------|--|
| 8 16 32 | The unit size: 8-bit (bytes), 16-bit (words), 32-bit (dwords). If a unit size is not specified, this command uses the unit size from the last Write command performed. If no previous Write command has been issued, the unit size defaults to 8-bit. |
| startaddr | The starting address to write data to. Specifying a period (.) uses the same starting address as the last Write command performed. |
| data | Values to write to the display buffer. If no data is given, then this function enters MODIFY mode. This mode prompts the user with the address and it's current data. While in this mode, the user can type any of the following. <ul style="list-style-type: none"> - new values (in hex) - ENTER or SPACE - moves to the next memory location (if data is specified the previous memory location is updated, if no data is specified no change is made) - "-" - moves to the previous memory location - "Q" or "." - exits MODIFY mode |

X[8|16|32] [index [data]]

Reads/writes data to the register at index. If no data is specified, the register is read and the contents are displayed.

Where:

| | |
|---------|---|
| 8 16 32 | The unit size: 8-bit (bytes), 16-bit (words), 32-bit (dwords). If a unit size is not specified, this command uses the unit size from the last X command performed. If no previous X command has been issued, the unit size defaults to 8-bit. |
| index | Index into the registers (hex). |
| data | The value to be written to the register. Numbers are assumed to be hexadecimal values unless otherwise specified with the correct suffix (binary = i, octal = o, decimal = t, hexadecimal = h). For example, 101i = 101 binary. |

XA

Reads and displays the contents of all the S1D13A05 registers.

?

Displays the help screen. The help screen contains a summary of all available commands.

13A05PLAY Example

1. Configure **13A05PLAY** using the utility **13A05CFG**. For further information on 13A05CFG, see the *13A05CFG User Manual*, document number X40A-B-001-xx.
2. Type **13A05PLAY** to start the program.
3. Type **?** for help.
4. Type **i** to initialize the registers.
5. Type **xa** to display the contents of the registers.
6. Type **x 80** to read register 80h.
7. Type **x 80 10** to write 10h to register 80h.
8. Type **f 0 ffff aa** to fill the first 10000h bytes of the display buffer with AAh.
9. Type **d 0 ff** to read the first 100h bytes of the display buffer.
10. Type **show** to display a test pattern.
11. Type **m** to display current mode information.
12. Type **m 2** to set the color depth to 2 bpp.
13. Type **show** to display a test pattern.
14. Type **q** to exit the program.

Script Files

13A05PLAY can be controlled by a script file. This is useful when:

- there is no display to monitor command keystroke accuracy.
- various registers must be quickly changed to view results.

A script file is an ASCII text file with one 13A05PLAY command per line. Script files can be executed from within 13A05PLAY using the Run command (e.g. = run dumpregs.scr). Alternately, the script file can be executed from the OS command prompt. On a PC platform, a typical script command line might be:

```
13A05PLAY run dumpregs.scr > results
```

This causes the file **dumpregs.scr** to be interpreted as commands by 13A05PLAY and the results to be redirected to the file **results**.

Example 1: Create a script file that reads all registers.

```
; This file initializes the S1D13A05 and reads the registers.  
; Note: after a semicolon (;), all characters on a line are ignored.
```

```
; Initialize the S1D13A05  
i
```

```
; Read all registers  
xa
```

EPSON®



S1D13A05 LCD/USB Companion Chip

13A05VIEW Demonstration Program

Document Number: X40A-B-003-01

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13A05VIEW

13A05VIEW is a demonstration utility used to show the S1D13A05 display capabilities by rendering bitmap images on the display device. The program supports files in . bmp, .gif, and .jpg format. 13A05VIEW supports SwivelView™ (90°, 180°, and 270° hardware rotation of the display image is supported by pre-configuring 13A05VIEW for the correct SwivelView mode using 13A05CFG).

The 13A05VIEW demonstration utility must be configured to work with your hardware configuration. The program 13A05CFG can be used to configure 13A05VIEW. For further information on 13A05CFG, refer to the *13A05CFG Users Manual*, document number X40A-B-001-xx.

This user manual is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

S1D13A05 Supported Evaluation Platforms

13A05VIEW is available as an executable for PCs running Windows® 9x/ME/NT/2000/XP and as C source code which can be modified and recompiled to allow 13A05VIEW to run on other evaluation platforms.

The latest version of both the executable and source code is available on the Epson Research and Development website at www.erd.epson.com.

Installation

Copy the file **13A05view.exe** to any directory (e.g. c:\s1d13a05).

Usage

At the prompt, type:

13A05view imagefile [/A[time]] [/noinit] [/?]

Where:

| | |
|-----------|--|
| imagefile | Specifies the filename of the image file (.bmp, .gif, .jpg) to be displayed. |
| /A[time] | Automatically displays the image for the specified <i>time</i> . If no time is specified then a default time of 5 seconds is used. |
| /noinit | Bypasses register initialization of the S1D13A05 chip |
| /? | Displays the help message. |

13A05VIEW Examples

To display a .bmp image in the main window of the LCD, type the following:

13A05view imagefile.bmp

To display a .gif image in the main window of the LCD for 10 seconds, type the following:

13A05view imagefile.gif /A10

To display a .jpg image in the main window of the LCD and skip register initialization, type the following:

13A05view imagefile.jpg /noinit

Note

13A05VIEW does not directly support the S1D13A05 SwivelView feature. To display an image file using SwivelView, configure **13a05view.exe** for the selected SwivelView mode (90°, 180°, 270°) using the configuration program 13A05CFG. For further information on 13A05CFG, see the *13A05CFG User Manual*, document number X40A-B-001-xx.

Comments

- If an image smaller than the physical panel size is displayed it will appear centered on the display.
- If an image larger than the physical panel size (but small enough to fit in display memory) is loaded, a virtual display is created. This allows the user to see the entire image using panning and scrolling. To navigate around the image use the following keys.
 - Scroll Up - “8”
 - Scroll Down - “2”
 - Pan Left - “4”
 - Pan Right - “6”
- If an image larger than the physical panel size which cannot fit entirely in display memory is loaded, the image is cropped to the physical panel size.
- 24-bit true color bitmaps are displayed at a color depth of 16 bit-per-pixel.
- Only the green component of the image is seen on a monochrome panel.

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S1D13A05 LCD/USB Companion Chip

Windows® CE 3.x Display Driver

Document Number: X40A-E-002-01

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WINDOWS® CE 3.0 DISPLAY DRIVER

Windows CE v3.0 display driver for the S1D13A05 LCD/USB Companion Chip is intended as “reference” source code for OEMs developing for the Microsoft Window CE platform. The driver supports 4, 8 and 16 bit-per-pixel color depths in landscape mode (no rotation), and 8 and 16 bit-per-pixel color depths in SwivelView™ 90 degree, 180 degree and 270 degree modes. The source code is written for portability and contains functionality for most features of the S1D13A05. Source code modification is required to provide a smaller driver for mass production.

The Windows CE v3.0 display driver is designed around a common configuration include file called **mode0.h**, which is generated by the configuration utility 13A05CFG. This design allows for easy customization of display type, clocks, decode addresses, rotation, etc. by OEMs. For further information on 13A05CFG, see the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx.

Note

The Windows CE display driver is provided as “reference” source code only. They are intended to provide a basis for OEMs to develop their own drivers for Microsoft Windows CE v3.0.

This document and the source code for the Windows CE v3.0 driver is updated as appropriate. Before beginning any development, please check the Epson Research and Development Website at www.erd.epson.com for the latest revisions.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

Example Driver Builds

The following section describes how to build the Windows CE display driver for Windows CE Platform Builder 3.00 using the GUI interface.

Build for CEPC (X86) on Windows CE Platform Builder 3.00 using the GUI Interface

1. Install Microsoft Windows 2000 Professional, or Windows NT Workstation version 4.0 with Service Pack 5 or later.
2. Install Platform Builder 3.00.
3. Start Platform Builder by double-clicking on the Microsoft Windows CE Platform Builder icon.
4. Create a new project.
 - a. Select File | New.
 - b. In the dialog box, select the Platforms tab.
 - c. In the platforms dialog box, select “WCE Platform”, set a location for the project (such as x:\myproject), set the platform name (such as myplatform), and set the processor to “Win32 (WCE x86)”.
 - d. Click the OK button.
 - e. In the dialog box “WCE Platform - Step 1 of 2”, select CEPC.
 - f. Click the Next button.
 - g. In the dialog box “WCE Platform - Step 2 of 2”, select Maximum OS (Maxall).
 - h. Click the Finish button.
 - i. In the dialog box “New Platform Information”, click the OK button.
5. Set the active configuration to “Win32 (WCE x86) Release”.
 - a. From the Build menu, select “Set Active Configuration”.
 - b. Select “MYPLATFORM - Win32 (WCE x86) Release”.
 - c. Click the OK button.

6. Add the environment variable DDI_S1D13A05.
 - a. From the Platform menu, select “Settings”.
 - b. Select the “Environment” tab.
 - c. In the Variable box, type “DDI_S1D13A05”.
 - d. In the Value box, type “1”.
 - e. Click the Set button.
 - f. Click the OK button.
7. Create a new directory S1D13A05, under **x:\wince300\platform\cepc\drivers\display**, and copy the S1D13A05 driver source code into this new directory.
8. Add the S1D13A05 driver component.
 - a. From the Platform menu, select “Insert | User Component”.
 - b. Set “Files of type:” to “All Files (*.*)”.
 - c. Select the file **x:\wince300\platform\cepc\drivers\display\s1d13a05\sources**.
 - d. Click the OK button.
 - e. In the “User Component Target File” dialog box, select browse and then select the path and the file name of “sources” as in step c.
 - f. Click the OK button.
9. Delete the component “ddi_flat”.
 - a. In the Platform window, select the ComponentView tab.
 - b. Show the tree for MYPLATFORM components by clicking on the ‘+’ sign at the root of the tree.
 - c. Right-click on the ddi_flat component.
 - d. Select “Delete”.
 - e. From the File menu, select “Save Workspace”.

10. From the Platform window, click the ParameterView Tab. Show the tree for MY-PLATFORM Parameters by clicking the '+' sign at the root of the tree. Expand the WINCE300 tree and then click on "Hardware Specific Files" and then double click "PLATFORM.BIB". Edit the file **platform.bib** and make the following two changes:

- a. Insert the following text after the line "IF ODO_NODISPLAY !":

```
IF DDI_S1D13A05
    ddi.dll $(_FLATRELEASEDIR)\S1D13A05.dll NK SH
ENDIF
```

- b. Find the section shown below, and insert the lines as marked:

```
IF CEPC_DDI_FLAT !
IF DDI_S1D13A05!           ;Insert this line
IF CEPC_DDI_S3VIRGE !
IF CEPC_DDI_CT655X !
IF CEPC_DDI_VGA8BPP !
IF CEPC_DDI_S3TRIO64 !
IF CEPC_DDI_ATI !
    ddi.dll $(_FLATRELEASEDIR)\ddi_flat.dll NK SH
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF
ENDIF           ;Insert this line
ENDIF
```

11. Modify **mode0.h**.

The file **mode0.h** (located in `x:\wince300\platform\cepc\drivers\display\s1d13a05`) contains the register values required to set the screen resolution, color depth (bpp), display type, display rotation, etc.

Before building the display driver, refer to the descriptions in the file **mode0.h** for the default settings of the console driver. If the default does not match the configuration you are building for then **mode0.h** will have to be regenerated with the correct information.

Use the program 13A05CFG to generate the header file. For information on how to use 13A05CFG, refer to the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx

After selecting the desired configuration, choose “File->Export” and select the “C Header File for S1D13A05 WinCE Driver” option. Save the new configuration as **mode0.h** to replace the original configuration file in the directory `\wince300\platform\cepc\drivers\display`.

12. From the Platform window, click the ParameterView Tab. Show the tree for MY-PLATFORM Parameters by clicking the ‘+’ sign at the root of the tree. Expand the WINCE300 tree and click on “Hardware Specific Files”, then double click “PLATFORM.REG”. Edit the file **platform.reg** to match the screen resolution, color depth, and rotation information in **mode0.h**.

For example, the display driver section of platform.reg should be as follows when using a 320x240 LCD panel with a color depth of 8 bpp and a SwivelView mode of 0° (landscape):

```
; Default for EPSON Display Driver
; 320x240 at 8 bits/pixel, LCD display, no rotation
; Useful Hex Values
; 640=0x280 480=0x1E0 320=140 240=0xF0
[HKEY_LOCAL_MACHINE\Drivers\Display\S1D13A05]
“Width”=dword:140
“Height”=dword:F0
“Bpp”=dword:8
“Rotation”=dword:0
```

13. From the Build menu, select “Rebuild Platform” to generate a Windows CE image file (**nk.bin**) in the project directory `x:\myproject\myplatform\reldir\x86_release\nk.bin`.

Installation for CEPC Environment

Once the **nk.bin** file is built, the CEPC environment can be started by booting either from a floppy or hard drive configured with a Windows 9x operating system. The two methods are described below.

1. To start CEPC from a floppy drive:
 - a. Create a bootable floppy disk.
 - b. Copy **himem.sys** to the floppy disk and edit **config.sys** on the floppy disk to contain only the following line:

```
device=a:\himem.sys
```
 - c. Edit **autoexec.bat** on the floppy disk to contain the following lines:

```
loadcepc /B:38400 /C:1 c:\nk.bin
```
 - d. Search for **loadcepc.exe** in the Windows CE directories and copy **loadcepc.exe** to the bootable floppy disk.
 - e. Copy **nk.bin** to c:\.
 - f. Boot the system from the bootable floppy disk.
2. To start CEPC from a hard drive:
 - a. Search for **loadcepc.exe** in the Windows CE directories and copy **loadcepc.exe** to C:\.
 - b. Edit **config.sys** on the hard drive to contain only the following line:

```
device=c:\himem.sys
```
 - c. Edit **autoexec.bat** on the hard drive to contain the following lines:

```
loadcepc /B:38400 /C:1 c:\nk.bin
```
 - d. Copy **nk.bin** to c:\.
 - e. Boot the system.
3. To start CEPC using Eboot:

Eboot is one of three boot loader models used by Platform Builder v3.0 to load a Windows CE image onto a target machine. The Eboot method uses an ethernet network card to move the image from the host computer to the target computer.

The Microsoft supplied version of Eboot does not function correctly with several Epson evaluation boards. These evaluation boards set the PCI class identifier field to "undefined PCI device". The Microsoft Eboot loader does not allow undefined PCI classes and the boot process halts. The Epson supplied version of eboot.bin fixes the "undefined PCI class" limitation. The following describes the steps required to use the Epson supplied eboot.bin with the Microsoft Eboot loader. Please refer to Platform Builder and MSDN documentation for more information regarding the use of Eboot.

In this example, *host machine* refers to the computer on which Platform Builder has been installed and where the **nk.bin** image is located. *Target machine* refers to the computer on which the Windows CE image is to be run. It is assumed that before attempting to eboot the target machine the Windows CE image will be built and ready on the host machine.

- a. Create a bootable floppy disk.

The following files must be present on the disk:

| | |
|---------------------|---|
| himem.sys | (found on your CE development platform) |
| loadcepc.exe | (found on your CE development platform) |
| eboot.bin | (supplied by Epson) |
| config.sys | (supplied by Epson) |
| autoexec.bat | (supplied by Epson) |

Note: The **config.sys** and **autoexec.bat** files are configured to allow loading of a local copy of the **nk.bin** image also.

- b. Modify **autoexec.bat**

It may be necessary to modify the network card settings in **autoexec.bat**. Locate the lines containing “set NET_IRQ” and “set NET_IOBASE” and ensure the values match the settings of your network card. If necessary, change the values to reflect the settings on your card (typically IRQ: 5 and IOBASE: 340).

- c. Boot the target CEPC machine using the floppy disk and choose the eboot option.
- d. Configure remote services on the host machine. This must be done only once.

i. On the host machine, open the project workspace in Platform Builder. From the Platform Builder menu select “Target”, and then select “Configure Remote Services”.

ii. Under the Services tab, set the top two drop down boxes to “Ethernet”.

iii. Under the Ethernet tab, a CEPC machine should appear in the New Devices box. Select the CEPC machine and click on the arrow button to the right of it.

- e. Normal Eboot Operation

a. On the host machine, open the project workspace in Platform Builder then select the menu option “Target”, and then select “Configure Remote Services”.

b. Select the Ethernet tab and ensure that “Current Device:” is the intended target machine. If not, select the machine from the list or configure a new remote service (see step d)

c. Select the menu option “Target”, and select “Download Image”. The download may take a few minutes.

Note: Problems with steps d or e may be due to incorrect synchronization between the host and target machines. Try re-booting the target machine from the floppy and repeating the step.

Configuration

There are several issues to consider when configuring the display driver. The issues cover debugging support, register initialization values and memory allocation. Each of these issues is discussed in the following sections.

Compile Switches

There are several switches, specific to the S1D13A05 display driver, which affect the display driver.

The switches are added or removed from the compile switches in the file **sources**.

WINCEVER

This option is automatically set to the numerical version of WinCE for version 2.12 or later. If the environment variable, `_WINCEOSVER` is not defined, then `WINCEVER` will default to 2.11. The S1D13A05 display driver may test against this option to support different WinCE version-specific features.

EnablePreferVmem

This option enables the use of off-screen video memory. When this option is enabled, WinCE can optimize some BLT operations by using off-screen video memory to store images. You may need to disable this option if your off-screen video memory is limited.

ENABLE_CLOCK_CHIP

This option is used to enable support for the ICD2061A clock generator. This clock chip is used on the S1D13A05 evaluation board. The S1D13A05 display drivers can program the clock chip to support the frequencies required in the `MODE` tables.

If you are not using the S1D13A05 evaluation board, you should disable this option.

EpsonMessages

This debugging option enables the display of EPSON-specific debug messages. These debug messages are sent to the serial debugging port. This option should be disabled unless you are debugging the display driver, as they will significantly impact the performance of the display driver.

DEBUG_MONITOR

This option enables the use of the debug monitor. The debug monitor can be invoked when the display driver is first loaded and can be used to view registers, and perform a few debugging tasks. The debug monitor is still under development and is **UNTESTED**.

This option should remain disabled unless you are performing specific debugging tasks that require the debug monitor.

MonoPanel

This option is intended for the support of monochrome panels only.

The option causes palette colors to be grayscaled for correct display on a mono panel. For use with color panels this option should not be enabled.

DEBUG_BLT

This option enables special BLT debugging messages on the debugging serial port. This option, when enabled, will drastically impact display driver performance, and should only be used to track down failures in the BLT operations.

This option should be disabled unless doing BLT debugging.

Mode File

A second variable which will affect the finished display driver is the register configurations contained in the mode file.

The MODE tables (contained in files **mode0.h**, **mode1.h**, **mode2.h** . . .) contain register information to control the desired display mode. The MODE tables must be generated by the configuration program **13a05cfg.exe**. The display driver comes with one example MODE table:

- MODE0.H - LCD 8-bit STN color, 320x240, 8bpp, 70Hz

By default, only **mode0.h** is used by the display driver. New mode tables can be created using the 13A05CFG program. Edit the #include section of **mode0.h** to add the new mode table.

If you only support a single mode table, you do not need to add any information to the WinCE registry. If, however, you support more than one display mode, you should create registry values (see below) that will establish the initial display mode. If your display driver contains multiple mode tables, and if you do not add any registry values, the display driver will default to the first mode table in your list.

To select which display mode the display driver should use upon boot, add the following lines to your **platform.reg** file:

```
[HKEY_LOCAL_MACHINE\Drivers\Display\S1D13A05]
```

```
“Width”=dword:140  
“Height”=dword:F0  
“Bpp”=dword:8  
“Rotation”=dword:0
```

Note that all dword values are in hexadecimal, therefore 140h = 320 and F0h = 240. When the display driver starts, it will read these values in the registry and attempt to match a mode table against them. All values must be present and valid for a match to occur, otherwise the display driver will default to the first mode table in your list.

A WinCE desktop application (or control panel applet) can change these registry values, and the display driver will select a different mode upon warmboot. This allows the display driver to support different display configurations and/or orientations. An example application that controls these registry values will be made available upon the next release of the display driver; preliminary alpha code is available by special request.

Resource Management Issues

The Windows CE 3.0 OEM must deal with certain display driver issues relevant to Windows CE 3.0. These issues require the OEM balance factors such as: system vs. display memory utilization, video performance, and power off capabilities.

The section “Simple Display Driver Configuration” on page 14 provides a configuration which should work with most Windows CE platforms. This section is only intended as a means of getting started. Once the developer has a functional system, it is recommended to optimize the display driver configuration as described below in “Description of Windows CE Display Driver Issues”.

Description of Windows CE Display Driver Issues

The following are some issues to consider when configuring the display driver to work with Windows CE:

1. When Windows CE enters the Suspend state (power-off), the LCD controller and display memory may lose power, depending on how the OEM sets up the system. If display memory loses power, all images stored in display memory are lost.

If power-off/power-on features are required, the OEM has several options:

- If display memory power is turned off, add code to the display driver to save any images in display memory to system memory before power-off, and add code to restore these images after power-on.
- If display memory power is turned off, instruct Windows CE to redraw all images upon power-on. Unfortunately it is not possible to instruct Windows CE to redraw any off-screen images, such as icons, slider bars, etc., so in this case the OEM must also configure the display driver to never use off-screen memory.
- Ensure that display memory never loses power.

2. Using off-screen display memory significantly improves display performance. For example, slider bars appear more smooth when using off-screen memory. To enable or disable the use of off-screen memory, edit the file **x:\wince300\platform\cepc\drivers\display\S1D13A05\sources**. In the file **sources**, there is a line which, when uncommented, will instruct Windows CE to use off-screen display memory (if sufficient display memory is available):

```
CDEFINES=$(CDEFINES) -DEnablePreferVmem
```

3. In the file **project.reg** under CE 3.0, there is a key called **PORepaint** (search the Windows CE directories for **project.reg**). **PORepaint** is relevant when the Suspend state is entered or exited. **PORepaint** can be set to 0, 1, or 2 as described below:

- a. **PORepaint=0**

- This mode tells Windows CE not to save or restore display memory on suspend or resume.
- Since display data is not saved and not repainted, this is the FASTEST mode.
- Main display data in display memory must NOT be corrupted or lost on suspend. The memory clock must remain running.
- Off-screen data in display memory must NOT be corrupted or lost on suspend. The memory clock must remain running.
- This mode cannot be used if power to the display memory is turned off.

- b. **PORepaint=1**

- This is the default mode for Windows CE.
- This mode tells Windows CE to save the main display data to the system memory on suspend.
- This mode is used if display memory power is going to be turned off when the system is suspended, and there is enough system memory to save the image.
- Any off-screen data in display memory is LOST when suspended. Therefore off-screen memory usage must either be disabled in the display driver (i.e: **EnablePreferVmem** not defined in the file **sources**), or new OEM-specific code must be added to the display driver to save off-screen data to system memory when the system is suspended, and restored when resumed.
- If off-screen data is used (provided that the OEM has provided code to save off-screen data when the system suspends), additional code must be added to the display driver's surface allocation routine to prevent the display driver from allocating the "main memory save region" in display memory. When WinCE OS attempts to allocate a buffer to save the main display data, WinCE OS marks the allocation request as preferring display memory. We believe this is incorrect. Code must be added to prevent this specific allocation from being allocated in display memory - it MUST be allocated from system memory.
- Since the main display data is copied to system memory on suspend, and then simply copied back on resume, this mode is FAST, but not as fast as mode 0.

c. PORepaint=2

- This mode tells WinCE to not save the main display data on suspend, and causes WinCE to REPAINT the main display on resume.
- This mode is used if display memory power is going to be turned off when the system is suspended, and there is not enough system memory to save the image.
- Any off-screen data in display memory is LOST, and since there is insufficient system memory to save display data, off-screen memory usage MUST be disabled.
- When the system is resumed, WinCE instructs all running applications to repaint themselves. This is the SLOWEST of the three modes.

Simple Display Driver Configuration

The following display driver configuration should work with most platforms running Windows CE. This configuration disables the use of off-screen display memory and forces the system to redraw the main display upon power-on.

1. This step disables the use of off-screen display memory.

Edit the file `x:\wince300\platform\cepc\drivers\display\S1D13A05\sources` and change the line

```
CDEFINES=$(CDEFINES) -DEnablePreferVmem
```

to

```
#CDEFINES=$(CDEFINES) -DEnablePreferVmem
```

2. This step causes the system to redraw the main display upon power-on. This step is only required if display memory loses power when Windows CE is shut down. If display memory is kept powered up (set the S1D13A05 in powersave mode), then the display data will be maintained and this step can be skipped.

Search for the file **project.reg** in your Windows CE directories, and inside **project.reg** find the key PORepaint. Change PORepaint as follows:

```
“PORepaint”=dword:2
```

Comments

- The display driver is CPU independent, allowing use of the driver code for several Windows CE Platform Builder supported platforms. The file **s1dflat.cpp** will require editing for the correct values of PhysicalPortAddr, PhysicalVmemAddr, etc.
- The sample code defaults to a 320x240 8-bit color passive LCD panel in SwivelView 0° mode (landscape) with a color depth of 8 bpp. To support other settings, use **13a05cfg.exe** to generate a proper **mode0.h** file. For further information, refer to the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx.
- By default, the 13A05CFG program assumes PCI addressing for the S1D13A05 evaluation board. This means that the display driver will automatically locate the S1D13A05 by scanning the PCI bus (currently only supported for the CEPC platform). If you select the address option “Other” and fill in your own custom addresses for the registers and video memory, then the display driver will not scan the PCI bus and will use the specific addresses you have chosen.
- If you are running the display driver on hardware other than the S1D13A05 evaluation board, you must ensure that your hardware provides the correct clock frequencies for CLKI and CLKI2. 13A05CFG defaults to 50MHz for both CLKI and CLKI2.

On the evaluation board, the display driver will correctly program the clock chip to support the CLKI and CLKI2 frequencies. On customer hardware, you must ensure that the clocks you provide to all clock inputs match the settings you chose in the Clocks tab of the 13A05CFG program. For more information on setting the clocks, see the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx.

If you run the S1D13A05 with a single clock source, make sure your clock sources for PCLK, BCLK, and MCLK are correctly set to use the correct clock input source. Also ensure that you enable the clock dividers as required for different display hardware.

- If you are using 13a05cfg.exe to produce multiple MODE tables, make sure you change the Mode Number setting for each mode table you generate. The display driver supports multiple mode tables, but only if each mode table has a unique mode number. For more information on setting the mode number, see the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx.
- 13A05CFG assumes you are using the S1D13A05 evaluation board, and defaults the Panel Power control to GPIO0. 13A05CFG allows you to change the GPIO pin used to control panel power, or to disable the use of GPIO pins altogether. If this is changed from the default, your driver will no longer be able to control panel power on the S1D13A05 evaluation board, and your panel may not be powered up correctly.
- At this time, the driver has been tested on the x86 CPUs and have been run with Platform Builder v3.00.

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EPSON®



S1D13A05 LCD/USB Companion Chip

Wind River WindML v2.0 Display Drivers

Document Number: X40A-E-003-01

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Wind River WindML v2.0 DISPLAY DRIVERS

The Wind River WindML v2.0 display drivers for the S1D13A05 LCD/USB Companion Chip are intended as “reference” source code for OEMs developing for Wind River’s WindML v2.0. The driver package provides support for both 8 and 16 bit-per-pixel color depths. The source code is written for portability and contains functionality for most features of the S1D13A05. Source code modification is required to produce a smaller, more efficient driver for mass production.

The WindML display drivers are designed around a common configuration include file called **mode0.h** which is generated by the configuration utility 13A05CFG. This design allows for easy customization of display type, clocks, decode addresses, rotation, etc. by OEMs. For further information on 13A05CFG, see the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx.

Note

The WindML display drivers are provided as “reference” source code only. They are intended to provide a basis for OEMs to develop their own drivers for WindML v2.0.

These drivers are not backwards compatible with UGL v1.2. For information on UGL v1.2 display drivers, contact us via email at erdvdcsw_info@erd.epson.com.

This document and the source code for the WindML display drivers is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revisions before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

Building a WindML v2.0 Display Driver

The following instructions produce a bootable disk that automatically starts the UGL demo program. These instructions assume that Wind River's Tornado platform is already installed.

Note

For the example steps where the drive letter is given as "x:". Substitute "x" with the drive letter that your development environment is on.

1. Create a working directory and unzip the WindML display driver into it.

From a command prompt or GUI interface create a new directory (e.g. x:\13a05).

Unzip the file **13a05windml.zip** to the newly created working directory. The files will be unzipped to the directories **x:\13a05\8bpp** and **x:\13a05\16bpp**.

2. Configure for the target execution model.

This example build creates a VxWorks image that fits onto and boots from a single floppy diskette. In order for the VxWorks image to fit on the disk certain modifications are required.

Replace the file **x:\tornado\target\config\pcpentium\config.h** with the file **x:\13a05\8bpp\file\config.h** (or **x:\13a05\16bpp\file\config.h**). The new **config.h** file removes the networking components and configures the build image to boot from a floppy disk.

Note

Rather than simply replacing the original **config.h** file, rename it so the file can be stored for reference purposes.

3. Build a boot ROM image.

From the Tornado tool bar, select Build -> Build Boot ROM. Select "pcPentium" as the BSP and "bootrom_uncmp" as the image.

4. Create a bootable disk (in drive A:).

From a command prompt change to the directory **x:\tornado\host\x86-win32\bin** and run the batch file **torvars.bat**. Next, change to the directory **x:\tornado\target\config\pcPentium** and type:

```
mkboot a: bootrom_uncmp
```


5. If necessary, generate a new **mode0.h** configuration file.

The file **mode0.h** contains the register values required to set the screen resolution, color depth (bpp), display type, rotation, etc. The **mode0.h** file included with the drivers, may not contain applicable values and must be regenerated using the configuration program 13A05CFG. If building for 8 bpp, place the new **mode0.h** file in the directory **x:\13a05\8bpp\file**. If building for 16 bpp, place the new **mode0.h** file in **x:\13a05\16bpp\file**.

For more information on 13A05CFG, see the *13A05CFG Configuration Program User Manual*, document number X37A-B-001-xx available at www.erd.epson.com.

6. Build the WindML v2.0 library.

From a command prompt change to the directory **x:\tornado\host\x86-win32\bin** and run the batch file **torvars.bat**. Next, change to the directory **x:\tornado\target\src\ugl** and type the command:
make CPU=PENTIUM ugl

7. Open the S1D13A05 workspace.

From the Tornado tool bar, select File->Open Workspace...->Existing->Browse... and select the file **x:\13a05\8bpp\13A05.wsp** (or **x:\13a05\16bpp\13a05.wsp**).

8. Add support for single line comments.

The WindML v2.0 display driver source code uses single line comment notation, “//”, rather than the ANSI conventional comments, “/*...*/”.

To add support for single line comments follow these steps:

- a. In the Tornado “Workspace Views” window, click on the “Builds” tab.
- b. Expand the “8bpp Builds” (or “16bpp Builds”) view by clicking on the “+” next to it. The expanded view will contain the item “default”. Right-click on “default” and select “Properties...”. A “Properties:” window will appear.
- c. Select the “C/C++ compiler” tab to display the command switches used in the build. Remove the “-ansi” switch from the line that contains “-g -mpentium -ansi -nostdinc -DRW_MULTI_THREAD”.
(Refer to GNU ToolKit user's guide for details)

9. Compile the VxWorks image.

Select the “Builds” tab in the Tornado “Workspace Views” window.

Right-click on “8bpp files” (or “16bpp files”) and select “Dependencies...”. Click on “OK” to regenerate project file dependencies for “All Project files”.

Right-click on “8bpp files” (or “16bpp files”) and select “ReBuild All(vxWorks)” to build VxWorks.

10. Copy the VxWorks file to the diskette.

From a command prompt or through the Windows interface, copy the file **x:\13a05\8bpp\default\vxworks** (or **x:\13a05\16bpp\default\vxworks**) to the bootable disk created in step 4.

11. Start the VxWorks demo.

Boot the target PC with the VxWorks bootable diskette to run the UGL demo program automatically.

References

Documents

- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.
- Epson Research and Development, Inc., *13A05CFG Configuration Utility User Manual*, Document Number X40A-B-001-xx.

Document Sources

- Epson Research and Development Website: www.erd.epson.com.

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S1D13A05 LCD/USB Companion Chip

Linux Console Driver

Document Number: X40A-E-004-01

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Linux Console Driver

The Linux console driver for the S1D13A05 LCD/USB Companion Chip is intended as “reference” source code for OEMs developing for Linux. It supports color depths of 4, 8, and 16 bit-per-pixel. The source code is written for portability and contains functionality for most features of the S1D13A05. Source code modification is required to provide a smaller driver for mass production.

A Graphical User Interface (GUI) such as Gnome can obtain the frame buffer address from this driver allowing the Linux GUI the ability to update the display.

The console driver is designed around a common configuration include file, called **s1d13a05.h**, which is generated by the configuration utility 13A05CFG. This design allows for easy customization of display type, clocks, decode addresses, rotation, etc. by OEMs. For further information on 13A05CFG, see the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx.

Note

The Linux console driver is provided as “reference” source code only. The driver is intended to provide a basis for OEMs to develop their own drivers for Linux.

This document and the source code for the Linux console drivers are updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revisions or before beginning any development.

We appreciate your comments on our documentation. Please contact us via e-mail at documentation@erd.epson.com.

Building the Console Driver for Linux Kernel 2.2.x

The following steps create a copy of the Linux operating system with the S1D13A05 LCD controller as the console display device. These instructions assume that the GNU development environment is installed and the user is familiar with GNU and the Linux operating system.

1. Acquire the Linux kernel source code.

The Linux kernel source code is available from your Linux supplier or on the internet at <ftp://ftp.kernel.org>.

The S1D13A05 reference driver for Linux kernel 2.2.x was built using Red Hat Linux 6.1, kernel version 2.2.17. For information on building the kernel refer to the readme file at <ftp://ftp.linuxberg.com/pub/linux/kernel/README>.

Note

Before continuing with modifications for the S1D13A05, you should ensure that you can build and start the Linux operating system.

2. Unzip the console driver files.

Unzip the S1D13A05 archive to a temporary directory (e.g. /tmp). When completed the following files should be located in the temporary directory.

```
s1d13xxxfb.c
s1d13a05.h
config.in
fbmem.c
fbcon-cfb4.c
makefile
```

3. Copy the console driver files to the build directory.

Copy the following files from the temporary directory to the directory **/usr/src/linux/drivers/video**.

```
s1d13xxxfb.c
s1d13a05.h
```

Replace the existing source files of the same name in the directory **/usr/src/linux/drivers/video** with the following files from the temporary directory.

```
config.in
fbmem.c
fbcon-cfb4.c
makefile
```

Note

If your kernel version is not 2.2.17, or you want greater control of the build process, use a text editor to add the sections dealing with the Epson driver into the corresponding files.

4. Modify **s1d13a05.h**

The file **s1d13a05.h** contains the register values required to set the screen resolution, color depth (bpp), display type, active display (LCD), display rotation, etc.

Before building the console driver, refer to the descriptions in the file **s1d13a05.h** for the default settings of the console driver. If the default does not match the configuration of the target system, then **s1d13a05.h** must be regenerated with the correct information. Use the program 13A05CFG to generate the header file. For information on how to use 13A05CFG, refer to the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx, available at www.erd.epson.com

After selecting the desired configuration in 13A05CFG, choose “File->Export” and select the “C Header File for S1D13A05 Generic Drivers” option. Save the new configuration as **s1d13a05.h** in the directory **/usr/src/linux/drivers/video**, replacing the original configuration file.

5. Configure the video options.

From the command prompt in the directory **/usr/src/linux** run the command:
make menuconfig

This command starts a text based interface which allows the selection of build time parameters. From the text interface under “Console drivers”, select:

- “Support for frame buffer devices”
- “Epson LCD/CRT controllers support”
- “S1D13A05 support”
- “Advanced low level driver options”
- “xBpp packed pixels support” *

* where x is the color depth being compile for.

If you are using the Epson S1D13A05 evaluation board select:

- “Epson PCI Bridge adapter support”

Once the kernel options are configured, save and exit the configuration utility.

6. Compile and install the kernel.

Build the kernel with the following sequence of commands.

```
make dep
make clean
make bzImage
/sbin/lilo (if running lilo)
```

7. Boot the Linux operating system.

If you are using lilo (Linux Loader), modify the lilo configuration file as discussed in the kernel build README file. If no errors are reported during the build, from the command prompt run:

lilo

8. Reboot the system.

Note

In order to use the S1D13A05 console driver with X server, the X server must be configured to use the FBDEV device. Instructions for this process are available on the Internet at www.xfree86.org.

Building the Console Driver for Linux Kernel 2.4.x

The following steps create a copy of the Linux operating system with the S1D13A05 LCD controller as the console display device. These instructions assume that the GNU development environment is installed and the user is familiar with GNU and the Linux operating system.

1. Acquire the Linux kernel source code.

The Linux kernel source code is available from your Linux supplier or on the internet at <ftp://ftp.kernel.org>.

The S1D13A05 reference driver for Linux kernel 2.4.x or greater was built using Red Hat Linux 6.1, kernel version 2.4.5. For information on building the kernel refer to the readme file at <ftp://ftp.linuxberg.com/pub/linux/kernel/README>.

Note

Before continuing with modifications for the S1D13A05, you should ensure that you can build and start the Linux operating system.

2. Unzip the console driver files.

Unzip the S1D13A05 archive to a temporary directory (e.g. /tmp). When completed the following files should be located in the temporary directory.

- config.in
- fbmem.c
- fbcon-cfb4.c
- makefile

The following files should be located in a sub-directory called `epson` within the temporary directory (e.g. /tmp/epson)

- makefile
- s1d13xxfb.c
- s1d13a05.h

3. Make the directory `/usr/src/linux/drivers/video/epson`.

4. Copy the console driver files to the build directory.

Copy the following files from the temporary directory (e.g. /tmp/epson/) to the directory **/usr/src/linux/drivers/video/epson**.

```
s1d13xxfb.c  
s1d13a05.h  
makefile
```

Replace the existing source files of the same name in the directory **/usr/src/linux/drivers/video** with the following files from the temporary directory (e.g. /tmp/).

```
config.in  
fbmem.c  
fbcon-cfb4.c  
makefile
```

Note

If your kernel version is not 2.4.5, or you want greater control of the build process, use a text editor to add the sections dealing with the Epson driver into the corresponding files.

5. Modify **s1d13a05.h**

The file **s1d13a05.h** contains the register values required to set the screen resolution, color depth (bpp), display type, active display (LCD/CRT), display rotation, etc.

Before building the console driver, refer to the descriptions in the file **s1d13a05.h** for the default settings of the console driver. If the default does not match the configuration of the target system, then **s1d13a05.h** must be regenerated with the correct information. Use the program 13A05CFG to generate the header file. For information on how to use 13A05CFG, refer to the *13A05CFG Configuration Program User Manual*, document number X40A-B-001-xx, available at www.erd.epson.com

After selecting the desired configuration in 13A05CFG, choose “File->Export” and select the “C Header File for S1D13A05 Generic Drivers” option. Save the new configuration as **s1d13a05.h** in the directory **/usr/src/linux/drivers/video**, replacing the original configuration file.

6. Configure the video options.

From the command prompt in the directory **/usr/src/linux** run the command:
make menuconfig

This command starts a text based interface which allows the selection of build time parameters. From the options presented select:

- “Code maturity level” options
- “Prompt for development and/or incomplete drivers”
- “Console drivers” options
- “Frame-buffer support”
 - “Support for frame buffer devices (EXPERIMENTAL)”
 - “EPSON LCD/CRT/TV controller support”
 - “EPSON S1D13A05 Support”
- “Advanced low-level driver options”
 - “xbpp packed pixels support” *

* where x is the color depth being compiled for.

If you are using the Epson S1D13A05 evaluation board select:

- “Epson PCI Bridge adapter support”

Once the kernel options are configured, save and exit the configuration utility.

7. Compile and install the kernel

Build the kernel with the following sequence of commands:

- make dep
- make clean
- make bzImage
- /sbin/lilo (if running lilo)

8. Boot to the Linux operating system

If you are using lilo (Linux Loader), modify the lilo configuration file as discussed in the kernel build README file. If no errors are reported during the build, from the command prompt run:

lilo

9. Reboot your system.

Note

In order to use the S1D13A05 console driver with X server, the X server must be configured to use the FBDEV device. Instructions for this process are available on the Internet at www.xfree86.org.

References

Documents

- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.
- Epson Research and Development, Inc., *13A05CFG Configuration Utility User Manual*, Document Number X40A-B-001-xx.

Document Sources

- Epson Research and Development Website: www.erd.epson.com.

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EPSON®



S1D13A05 LCD/USB Companion Chip

Windows® CE 3.x USB Driver

Document Number: X40A-E-006-01

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WINDOWS® CE 3.0 USB DRIVER

The Windows CE v3.0 USB driver for the S1D13A05 LCD/USB Companion Chip is a client driver, which supports Microsoft ActiveSync 3.1. This driver is intended as “reference” source code for OEMs developing for the Microsoft Window CE platform and provide a basis for OEMs to develop their own drivers.

This document and the source code for the Windows CE v3.0 USB driver is updated as appropriate. Before beginning any development, please check the Epson Research and Development Website at www.erd.epson.com for the latest revisions.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

Example Driver Builds

Build for CEPC (X86) on Windows CE Platform Builder 3.00 using the GUI Interface

1. Install Microsoft Windows NT v4.0, Windows 2000, or Windows XP.
2. Install Platform Builder 3.00.
3. Start Platform Builder by double-clicking on the Microsoft Windows CE Platform Builder icon or by selecting it through the start menu.
4. Create a new project.
 - a. Select File | New.
 - b. In the dialog box, select the Platforms tab.
 - c. In the Platforms dialog box:
 - select “WCE Platform”
 - set a location for the project (such as **x:\myproject**)
 - set the platform name (such as myplatform)
 - set the processor to “Win32 (WCE x86)”
 - d. Click the OK button.
 - e. In the WCE Platform - Step 1 of 2 dialog box, select “CEPC”.
 - f. Click the Next button.
 - g. In the WCE Platform - Step 2 of 2 dialog box, select “Maximum OS (Maxall)”.
 - h. Click the Finish button.
 - i. In the New Platform Information dialog box, click the OK button.
5. Set the active configuration to “Win32 (WCE x86) Release”.
 - a. From the Build menu, select “Set Active Configuration”.
 - b. Select “MYPLATFORM - Win32 (WCE x86) Release”.
 - c. Click the OK button.
6. Add the environment variable USB_S1D13A05.
 - a. From the Platform menu, select “Settings”.
 - b. Select the “Environment” tab.
 - c. In the Variable box, type “USB_S1D13A05”.
 - d. In the Value box, type “1”.
 - e. Click the Set button.
 - f. Click the OK button.

7. Create a new directory 13A05USB, under **x:\wince300\platform\cepc\drivers**, and copy the 13A05USB driver source code into this new directory.
8. Add the 13A05USB driver component.
 - a. From the Platform menu, select “Insert | User Component”.
 - b. Set Files of type: to “All Files (*.*)”.
 - c. Select the file **x:\wince300\platform\cepc\drivers\13A05USB\sources**.
 - d. Click the OK button.
 - e. In the User Component Target File dialog box, select browse and then select the path/filename of the file **sources**.
 - f. Click the OK button.
9. Click the Parameter View Tab on the bottom of the platform window. Show the tree for MYPLATFORM Parameters by clicking on the ‘+’ sign at the root of the tree. Expand the WINCE300 tree and then click the “Hardware Specific Files” and then double click the “PLATFORM.BIB”. Find the section shown below, and insert the lines as marked:

```

IF IMGUSB
IF CEPC_UHCI
    uhci.dll    $_FLATRELEASEDIR)\uhci.dll        NK SH
ENDIF
IF CEPC_OHCI
    ohci.dll    $_FLATRELEASEDIR)\ohci.dll        NK SH
ENDIF
    usbd.dll    $_FLATRELEASEDIR)\usbd.dll        NK SH
    usbhid.dll  $_FLATRELEASEDIR)\usbhid.dll      NK SH
ENDIF
IF USB_S1D13A05                                ;Insert this line
13a05usb.dll    $_FLATRELEASEDIR)\13a05usb.dll NK SH ;Insert this line
ENDIF                                                ;Insert this line
ENDIF

```

10. Save the file **platform.bib**.

11. From the Platform window, click the Parameter View Tab. Show the tree for MY-PLATFORM Parameters by clicking on the '+' sign at the root of the tree. Expand the WINCE300 tree and click the "Hardware Specific Files", then double click the "PLATFORM.REG". Insert the following section at the top of the file **platform.reg** to include the settings for 13A05USB driver.

```
[HKEY_LOCAL_MACHINE\Drivers\BuiltIn\13A0XUSB]
```

```
"Dll"="13A05USB.dll"
```

```
"Prefix"="COM"
```

```
"Tsp"="Unimodem.dll"
```

```
"DeviceArrayIndex"=dword:1
```

```
"Order"=dword:2
```

```
"DeviceType"=dword:0
```

```
"FriendlyName"="S1D13A05 USB"
```

```
"DevConfig"=hex: 10,00, 00,00, 05,00,00,00, 10,01,00,00, 00,4B,00,00, 00,00, 08,  
00, 00, 00,00,00,00
```

```
; "PhysicalAddress"=dword:0x08000000 ; for non-cepc environment only
```

```
; "IRQ"=dword:05 ; for non-cepc environment only
```

12. Save the file **platform.reg**.
13. From the Build menu, select "Rebuild Platform" to generate a Windows CE image file (**nk.bin**) in the project directory **x:\myproject\myplatform\reldir\x86_release\nk.bin**.

Installation and Execution from CEPC Environment

Once the **nk.bin** file is built, the CEPC environment can be started by booting from a floppy (step 1) or a hard drive (step 2) configured with a Windows 9x operating system or EBOOT (step 3) across a network. All methods are described below.

1. To start CEPC by booting from a floppy drive:
 - a. Create a bootable floppy disk.
 - b. Copy **himem.sys** to the floppy disk.
 - c. Edit **config.sys** on the floppy disk to contain only the following line:

device=a:\himem.sys
 - d. Edit **autoexec.bat** on the floppy disk to contain the following line:

loadcepc /B:38400 /C:1 c:\nk.bin
 - e. Search for **loadcepc.exe** in your Windows CE directories, and copy the file to the bootable floppy disk.
 - f. Copy **nk.bin** to c:\.
 - g. Boot the system from the bootable floppy disk.
2. To start CEPC by booting from a hard drive:
 - a. Search for **loadcepc.exe** in the Windows CE directories, and copy the file to C:\.
 - b. Edit **config.sys** on the hard drive to contain only the following line:

device=c:\himem.sys
 - c. Edit **autoexec.bat** on the hard drive to contain the following line:

loadcepc /B:38400 /C:1 c:\nk.bin
 - d. Copy **nk.bin** to C:\.
 - e. Boot the system
3. To start CEPC using Eboot:

Eboot is one of three boot loader models used by Platform Builder v3.0 to load a Windows CE image onto a target machine. The Eboot method uses an ethernet network card to move the image from the host computer to the target computer.

The Microsoft supplied version of Eboot does not function correctly with several Epson evaluation boards. These evaluation boards set the PCI class identifier field to "undefined PCI device". The Microsoft Eboot loader does not allow undefined PCI classes and the boot process halts. The Epson supplied version of eboot.bin fixes the "undefined PCI class" limitation. The following describes the steps required to use the Epson supplied eboot.bin with the Microsoft Eboot loader. Please refer to Platform

Builder and MSDN documentation for more information regarding the use of Eboot.

In this example, *host machine* refers to the computer on which Platform Builder has been installed and where the **nk.bin** image is located. *Target machine* refers to the computer on which the Windows CE image is to be run. It is assumed that before attempting to eboot the target machine the Windows CE image will be built and ready on the host machine.

- a. Create a bootable floppy disk.

The following files must be present on the disk:

| | |
|---------------------|---|
| himem.sys | (found on your CE development platform) |
| loadcepc.exe | (found on your CE development platform) |
| eboot.bin | (supplied by Epson) |
| config.sys | (supplied by Epson) |
| autoexec.bat | (supplied by Epson) |

Note: The **config.sys** and **autoexec.bat** files are configured to allow loading of a local copy of the **nk.bin** image also.

- b. Modify **autoexec.bat**

It may be necessary to modify the network card settings in **autoexec.bat**. Locate the lines containing “set NET_IRQ” and “set NET_IOBASE” and ensure the values match the settings of your network card. If necessary, change the values to reflect the settings on your card (typically IRQ: 5 and IOBASE: 340).

- c. Boot the target CEPC machine using the floppy disk and choose the eboot option.
- d. Configure remote services on the host machine. This must be done only once.

i. On the host machine, open the project workspace in Platform Builder. From the Platform Builder menu select “Target”, and then select “Configure Remote Services”.

ii. Under the Services tab, set the top two drop down boxes to “Ethernet”.

iii. Under the Ethernet tab, a CEPC machine should appear in the New Devices box. Select the CEPC machine and click on the arrow button to the right of it.

- e. Normal Eboot Operation

a. On the host machine, open the project workspace in Platform Builder then select the menu option “Target”, and then select “Configure Remote Services”.

b. Select the Ethernet tab and ensure that “Current Device:” is the intended target machine. If not, select the machine from the list or configure a new remote service (see step d)

c. Select the menu option “Target”, and select “Download Image”. The download may take a few minutes.

Note: Problems with steps d or e may be due to incorrect synchronization between the host and target machines. Try re-booting the target machine from the floppy and repeating the step.

4. Install Microsoft Windows on a host machine.
5. Install ActiveSync 3.1 on the host machine.
6. Install the included **wceusbsh.sys** on the host machine, by following the procedures below:
 - a. Unzip the file **wceusbsh.zip** to a directory on your hard drive.
 - b. Locate the file **wceusbsh.inf**.
 - c. Right click the “WCEUSBSH.INF” file icon.
 - d. Select Install.
7. Connect a USB cable from the USB device (S5U13A05B00C board) to the USB host machine.
8. Boot the Windows CE machine from a floppy (created in step 1) or from the hard drive (created in step 2).
9. From the Windows CE desktop:
 - click the Start button
 - click Run
 - click Browse.
10. Find the file **repllog.exe** (by default it resides in \windows) and select it.
11. Click the OK button. The ActiveSync window on the host desktop is automatically invoked, and the New Partnership window is opened automatically. This window prompts: “Would you like to set up a partnership?”
12. Select “No”.
13. Click the Next button.
14. The Microsoft ActiveSync Window is opened automatically and should display “Guest connected”.
15. Click the “Explore” button from the Microsoft ActiveSync window. File transfers are now possible through the USB cable.

Compile Switches

There are switches specific to the S1D13A05 USB driver which affect the USB driver. These switches are added or removed from the compile switches in the file **sources**.

CEPC

This option must be set for the CEPC platform and removed for all other platforms.

EPSONMESSAGES

This debugging option enables the display of EPSON-specific debug messages. These debug messages are sent to the serial debugging port. This option should be disabled unless you are debugging the USB driver, as they will significantly impact the performance of the USB driver.

Address and IRQ Modifications

- The USB driver is CPU independent, and it can be used on other platforms that support USB under Windows CE Platform Builder 3.0. If this driver is to support non-cepc platforms, the file **project.reg** requires editing to set the correct values of “PhysicalAddress” and “IRQ”.
- The variables `DEFAULT_PHYSICAL_ADDRESS` and `DEFAULT_IRQ` in the file **13a0xhw.h** must be changed to reflect the values required by each implementation.
- If the entries of “PhysicalAddress” and “IRQ” are removed from the **project.reg** file, the USB driver uses the values of `DEFAULT_PHYSICAL_ADDRESS` and `DEFAULT_IRQ` contained in the file **13a0xhw.h**.

Comments

- S5U13A05B00C Evaluation Board must be configured to enable USB support. This includes configuration changes to the dip switch and confirming that the proper USBCLK is available on U13. See the *S5U13A05B00C Rev. 1.0 Evaluation Board User Manual*, document number X40A-G-004-xx.
- This USB driver is independent of the S1D13A05 Windows CE v3.x display driver, but may be run together with S1D13A05 display driver. For information on the S1D13A05 CE Display Driver, see the *Windows CE 3.x Display Driver*, document number X40A-E-002-xx.
- At this time, the driver has been tested on the x86 CPUs and has been run with Platform Builder v3.00.
- The Microsoft ActiveSync files **wceusbsh.inf** (installer) and **wceusbsh.sys** (host side USB driver) have been included because the S1D13A0x USB controller uses fixed endpoint mapping that differs from that used by the Microsoft supplied ActiveSync USB host driver. Neither the ActiveSync driver nor the S1D13A0x endpoints can be dynamically modified, therefore the ActiveSync driver was replaced with a version that understands the S1D13A0x endpoint structure.

After installing ActiveSync on your development machine, use the included installer to update the host USB driver.

When device development is complete, the updated **wceusbsh.sys** must be included in your distribution package replacing the Microsoft supplied **wceusbsh.sys**. This version of **wceusbsh.sys** is backwards compatible with previous versions.

References

Documents

- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.
- Epson Research and Development, Inc., *13A05CFG Configuration Utility User Manual*, Document Number X40A-B-001-xx.

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S1D13A05 LCD/USB Companion Chip

Interfacing to the Toshiba MIPS TMPR3905/3912 Microprocessors

Document Number: X40A-G-002-01

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1 Introduction

This application note describes the hardware and software environment necessary to provide an interface between the S1D13A05 USB/LCD Companion Chip and the Toshiba MIPS TMPR3905/3912 processors.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

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2 Interfacing to the TMPR3905/12

2.1 The Toshiba TMPR3905/12 System Bus

The TMPR39XX family of processors features a high-speed system bus typical of modern MIPS RISC microprocessors. This section provides an overview of the operation of the CPU bus in order to establish interface requirements.

2.1.1 Overview

The TMPR3905/12 is a highly integrated controller developed for handheld products. The microprocessor is based on the R3900 MIPS RISC processor core. The TMPR3905/12 implements an external 26-bit address bus and a 32-bit data bus allowing it to communicate with its many peripheral units. The address bus is multiplexed (A[12:0]) using an address latch signal (ALE) which controls the driving of the address onto the address bus. The full 26-bit address bus (A[25:0]) is generated to devices not capable of receiving a multiplexed address, using external latches (controlled by ALE).

The TMPR3905/12 provides two, revision 2.01 compliant, PC Card slots. The 16-bit PC Card slots provide a 26-bit multiplexed address and additional control signals which allow access to three 64M byte address ranges: IO, memory, and attribute space. The signal CARDREG* selects memory space when high and attribute or IO space when low. Memory and attribute space are accessed using the write and read enable signals (WE* and RD*). When CARDREG* is low, card IO space is accessed using separate write (CARDIOWR*) and read (CARDIORD*) control signals.

2.1.2 Card Access Cycles

A data transfer is initiated when the address is placed on the PC Card bus and one, or both, of the card enable signals (CARD1CSL* and CARD1CSH*) are driven low. CARDREG* is inactive for memory and IO cycles. If only CARD1CSL* is driven low, 8-bit data transfers are enabled and A0 specifies whether the even or odd data byte appears on the PC Card data bus lines D[7:0]. If only CARD1CSH* is driven low, an odd byte transfer occurs on PC Card data lines D[15:8]. If both CARD1CSL* and CARD1CSH* are driven low, a 16-bit word transfer takes place on D[15:0].

During a read cycle, either RD* or CARDIORD* is driven low depending on whether a memory or IO cycle is specified. A write cycle is specified by driving WE* (memory cycle) or CARDIOWR* (IO cycle) low. The cycle can be lengthened by driving CARD1WAIT* low for the time required to complete the cycle.

Figure 2-1: "Toshiba 3905/12 PC Card Memory/Attribute Cycle," illustrates a typical memory/attribute cycle on the Toshiba 3905/12 PC Card bus.

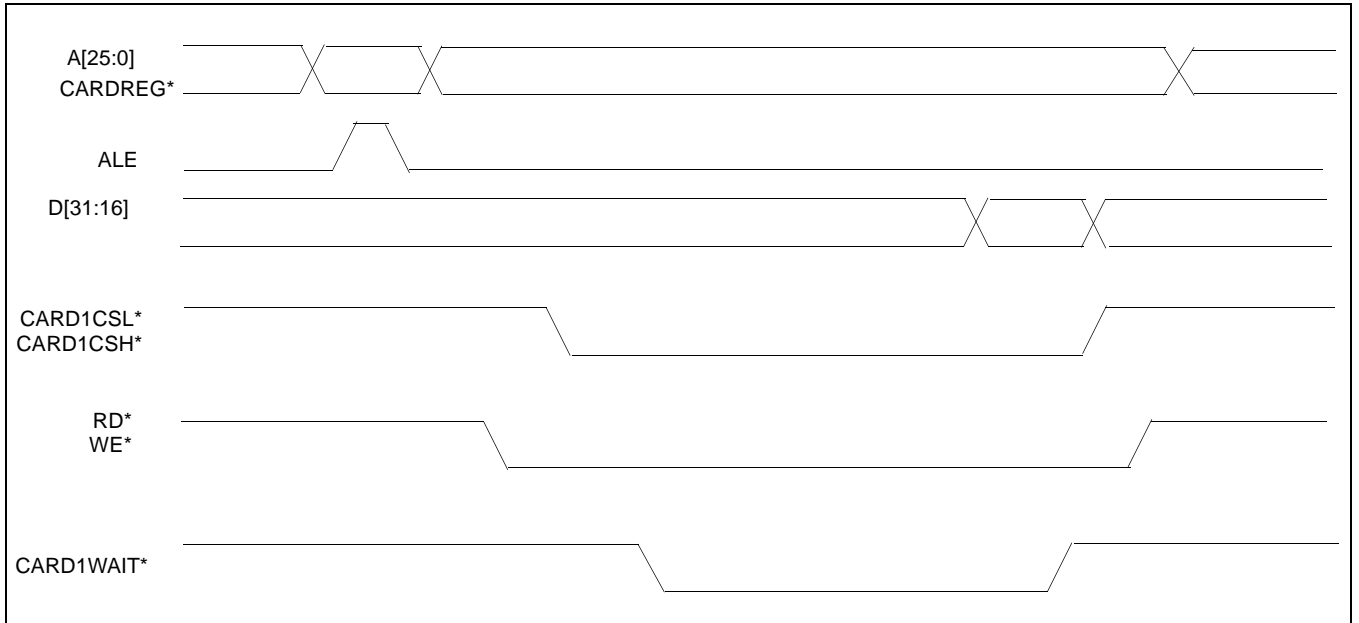


Figure 2-1: Toshiba 3905/12 PC Card Memory/Attribute Cycle

Figure 2-2: "Toshiba 3905/12 PC Card IO Cycle," illustrates a typical IO cycle on the Toshiba 3905/12 PC Card bus.

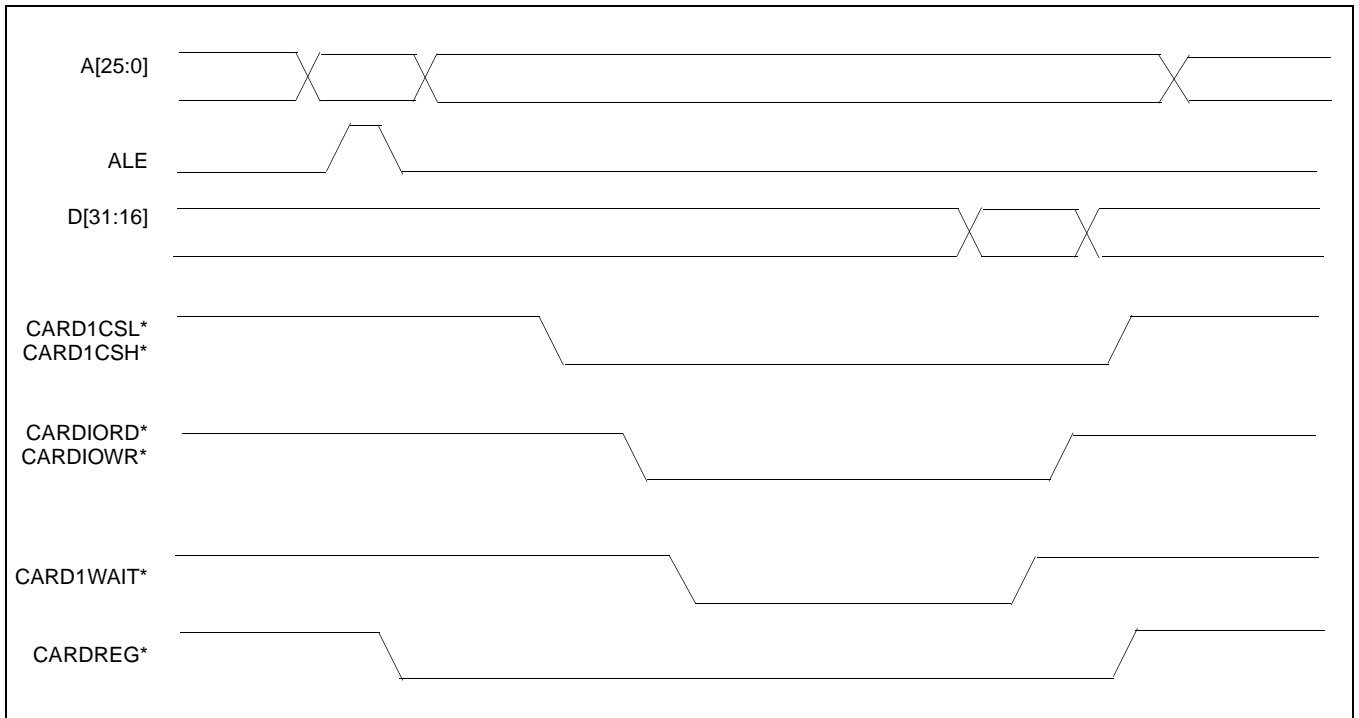


Figure 2-2: Toshiba 3905/12 PC Card IO Cycle

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #2 Host Bus Interface which is most suitable for connection to the Toshiba TMPR3905/12 microprocessor.

The Generic #2 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After releasing reset the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.2, “S1D13A05 Hardware Configuration” on page 14.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | Toshiba TMPR3905/12 |
|--------------------|--|
| AB[17:0] | External Decode |
| DB[15:8] | D[23:16] |
| DB[7:0] | D[31:24] |
| WE1# | External Decode |
| CS# | External Decode |
| M/R# | External Decode |
| CLKI | DCLKOUT |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | Connect to IO _{VDD} from the S1D13A05 |
| RD# | CARDIORD* |
| WE0# | CARDIOWR* |
| WAIT# | CARD1WAIT* |
| RESET# | system $\overline{\text{RESET}}$ |

3.2 Host Bus Interface Signals

The Host Bus Interface requires the following signals.

- CLKI is a clock input required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For example, DCLKOUT from the Toshiba TMPR3905/12.
- The address inputs AB[12:0] are connected directly to the TMPR3905/12 address bus. Since the TMPR3905/12 has a multiplexed address bus, the other address inputs A[17:13] must be generated using an external latch controlled by the address latch enable signal (ALE). The low data byte on the TMPR3905/12 data bus for 16-bit ports is D[31:24] and connects to the S1D13A05 low data byte, D[7:0]. The high data byte on the TMPR3905/12 data bus for 16-bit ports is D[23:16] and connects to the S1D13A05 high data byte, D[15:0]. The hardware engineer must ensure that CNF4 selects the proper endian mode upon reset.
- Chip Select (CS#) is driven by external decoding circuitry to select the S1D13A05.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A18, allowing system address A18 to select between memory or register accesses.
- WE1# is connected to CARD1CSH* and is the high byte enable for both read and write cycles.
- WE0# is connected to CARDIOWR* (the write enable signal) and must be driven low when the Toshiba TMPR3905/12 is writing data to the S1D13A05.
- RD# is connected to CARDIORD* (the read enable signal) and must be driven low when the Toshiba TMPR3905/12 is reading data from the S1D13A05.
- WAIT# connects to CARD1WAIT* and is a signal which is output from the S1D13A05 to the TMPR3905/12 that indicates when data is ready (read cycle) or accepted (write cycle) on the host bus. Since host CPU accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or display buffer. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete.
- The Bus Status (BS#) and Read/Write (RD#/WR#) signals are not used in this implementation of the Toshiba TMPR3905/12 using the Generic #2 Host Bus Interface. These pins must be tied high (connected to IO V_{DD}).

4 Toshiba TMPR3905/12 to S1D13A05 Interface

4.1 Hardware Description

In this implementation, the S1D13A05 occupies the TMPR3905/12 PC Card slot #1 IO address space. IO address space closely matches the timing parameters for the S1D13A05 Generic #2 Host Bus Interface.

The address bus of the TMPR3905/12 PC Card interface is multiplexed and must be demultiplexed using an advanced CMOS latch (e.g., 74AHC373).

BS# (bus start) and RD/WR# are not used in this implementation and should be tied high (connected to IO V_{DD}).

A pull-up resistor is attached to WAIT# to speed up its rise time when terminating a cycle.

The following diagram demonstrates a typical implementation of the TMPR3905/12 to S1D13A05 interface.

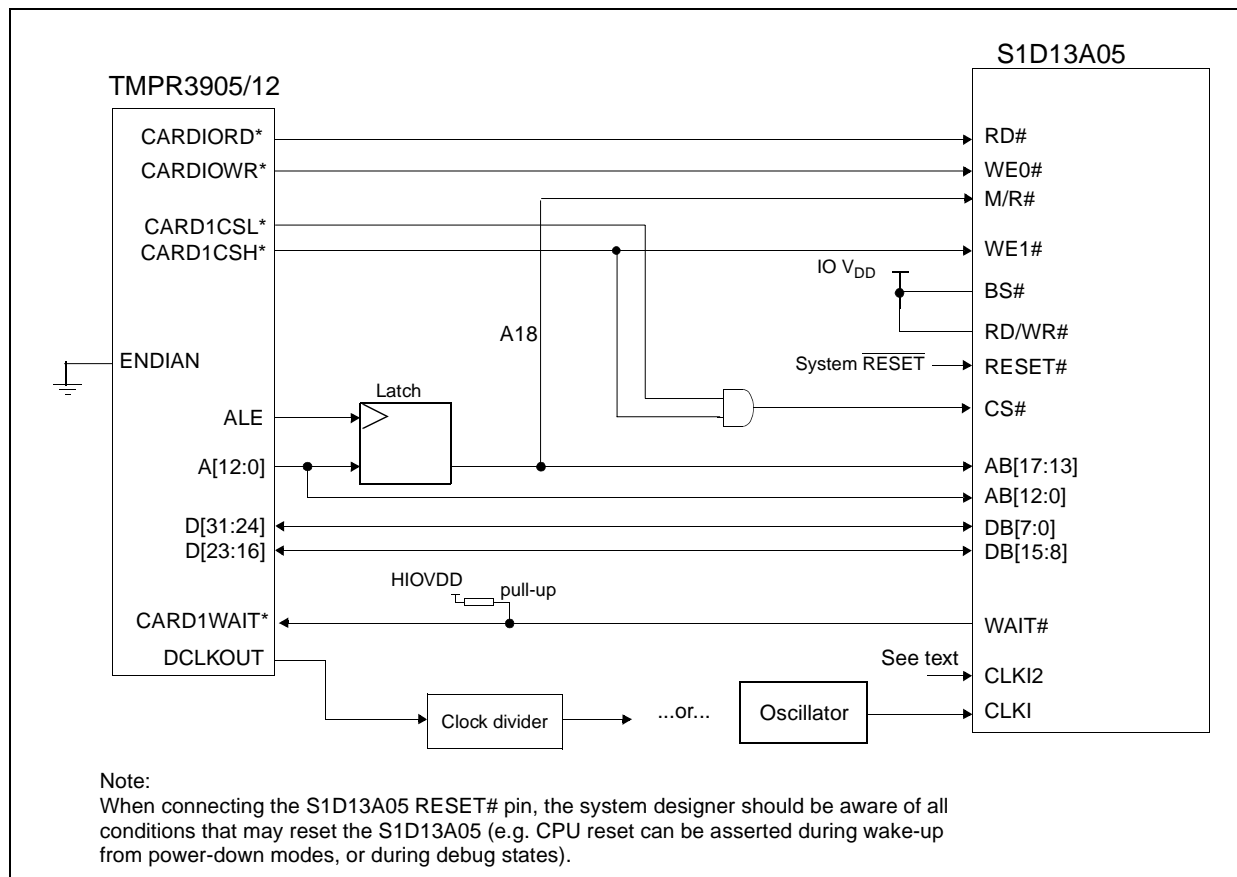


Figure 4-1: S1D13A05 to TMPR3905/12 Direct Connection

The Generic #2 Host Bus Interface control signals of the S1D13A05 are asynchronous with respect to the S1D13A05 bus clock. This gives the system designer full flexibility to choose the appropriate source (or sources) for CLKI and CLKI2. The choice of whether both clocks should be the same, and whether to use DCLKOUT (divided) as clock source, should be based on the desired:

- pixel and frame rates.
- power budget.
- part count.
- maximum S1D13A05 clock frequencies.

The S1D13A05 also has internal clock dividers providing additional flexibility.

4.2 S1D13A05 Hardware Configuration

The S1D13A05 latches CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The table below shows the configuration settings important to the Generic #2 host bus interface used by the Toshiba TMPR3905/12.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|---|-----------------------------------|------|---------------------------|------|------|----------|---|---|---|---|---------------------------|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: <table border="1"> <thead> <tr> <th>CNF4</th> <th>CNF2</th> <th>CNF1</th> <th>CNF0</th> <th>Host Bus</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>Generic #2, Little Endian</td> </tr> </tbody> </table> | | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 0 | 1 | 0 | 0 | Generic #2, Little Endian |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 0 | 1 | 0 | 0 | Generic #2, Little Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |

configuration for Toshiba TMPR3905/3912 microprocessor

4.3 Memory Mapping and Aliasing

In this implementation the TMPR3905/12 control signal CARDREG* is ignored. This means that the S1D13A05 takes up the entire PC Card slot 1.

The S1D13A05 is a memory mapped device and uses two 256K byte blocks which are selected using A18 from the TMPR3905/12 (A18 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block.

The registers occupy the range 0h through 3FFFFh while the on-chip display memory occupies the range 40000h through 68000h. Demultiplexed address lines A[25:19] are ignored. Therefore, the S1D13A05 is aliased at 256K byte intervals over the 64M byte PC Card slot #1 memory space.

Note

If aliasing is undesirable, additional decoding circuitry must be added.

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- Toshiba America Electrical Components, Inc., *TMPR3905/12 Specification*.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.

6.2 Document Sources

- Toshiba America Electrical Components Website: www.toshiba.com/taec.
- Epson Research and Development Website: www.erd.epson.com.

7 Sales and Technical Support

7.1 EPSON LCD/USB Companion Chips (S1D13A05)

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7.2 Toshiba MIPS Tmpr3905/12 Processor

<http://www.toshiba.com/taec/nonflash/indexproducts.html>

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S1D13A05 LCD/USB Companion Chip

Interfacing to the PC Card Bus

Document Number: X40A-G-005-01

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1 Introduction

This application note describes the hardware and software environment required to interface the S1D13A05 LCD/USB Companion Chip and the PC Card (PCMCIA) bus.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

2 Interfacing to the PC Card Bus

2.1 The PC Card System Bus

PC Card technology has gained wide acceptance in the mobile computing field as well as in other markets due to its portability and ruggedness. This section is an overview of the operation of the 16-bit PC Card interface conforming to the PCMCIA 2.0/JEIDA 4.1 Standard (or later).

2.1.1 PC Card Overview

The 16-bit PC Card provides a 26-bit address bus and additional control lines which allow access to three 64M byte address ranges. These ranges are used for common memory space, IO space, and attribute memory space. Common memory may be accessed by a host system for memory read and write operations. Attribute memory is used for defining card specific information such as configuration registers, card capabilities, and card use. IO space maintains software and hardware compatibility with hosts such as the Intel x86 architecture, which address peripherals independently from memory space.

Bit notation follows the convention used by most microprocessors, the high bit is the most significant. Therefore, signals A25 and D15 are the most significant bits for the address and data bus respectively.

Support is provided for on-chip DMA controllers. To find further information on these topics, refer to Section 6, “References” on page 15.

PC Card bus signals are asynchronous to the host CPU bus signals. Bus cycles are started with the assertion of either the -CE1 and/or the -CE2 card enable signals. The cycle ends once these signals are de-asserted. Bus cycles can be lengthened using the -WAIT signal.

Note

The PCMCIA 2.0/JEIDA 4.1 (and later) PC Card Standard support the two signals -WAIT and RESET which are not supported in earlier versions of the standard. The -WAIT signal allows for asynchronous data transfers for memory, attribute, and IO access cycles. The RESET signal allows resetting of the card configuration by the reset line of the host CPU.

2.1.2 Memory Access Cycles

A data transfer is initiated when the memory address is placed on the PC Card bus and one, or both, of the card enable signals (-CE1 and -CE2) are driven low. -REG must be kept inactive. If only -CE1 is driven low, 8-bit data transfers are enabled and A0 specifies whether the even or odd data byte appears on data bus lines D[7:0]. If both -CE1 and -CE2 are driven low, a 16-bit word transfer takes place. If only -CE2 is driven low, an odd byte transfer occurs on data lines D[15:8].

During a read cycle, -OE (output enable) is driven low. A write cycle is specified by driving -OE high and driving the write enable signal (-WE) low. The cycle can be lengthened by driving -WAIT low for the time needed to complete the cycle.

Figure 2-1: illustrates a typical memory access read cycle on the PC Card bus.

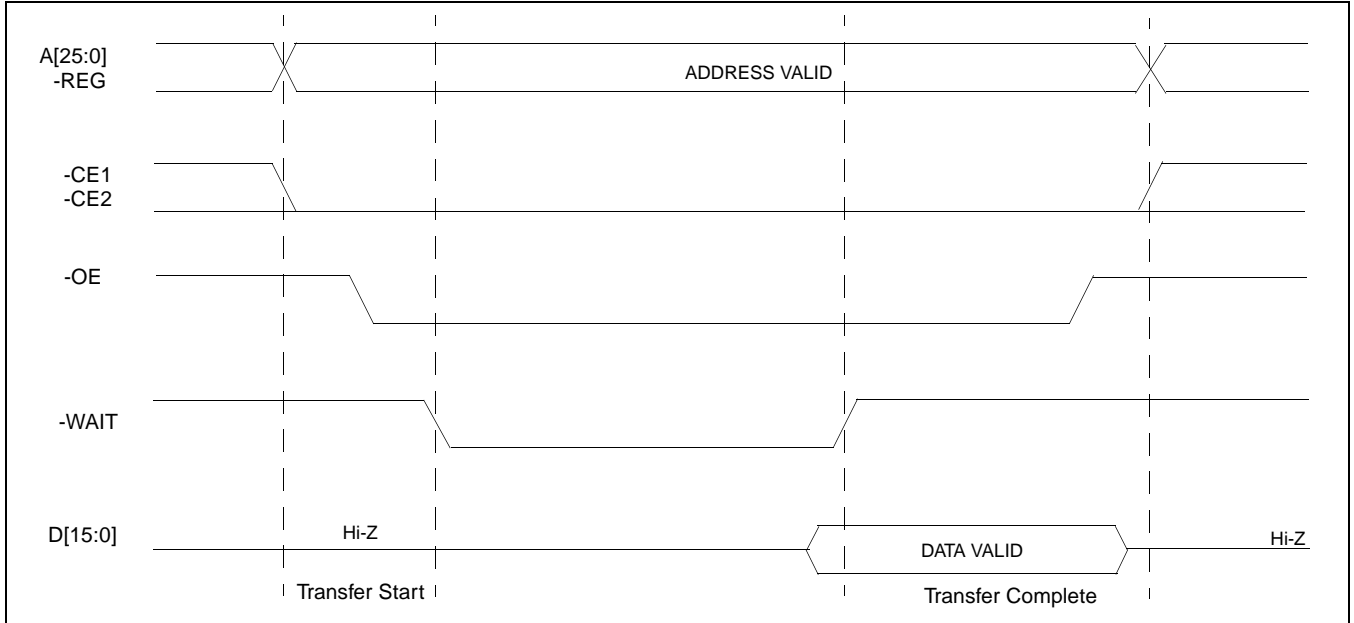


Figure 2-1: PC Card Read Cycle

Figure 2-2: illustrates a typical memory access write cycle on the PC Card bus.

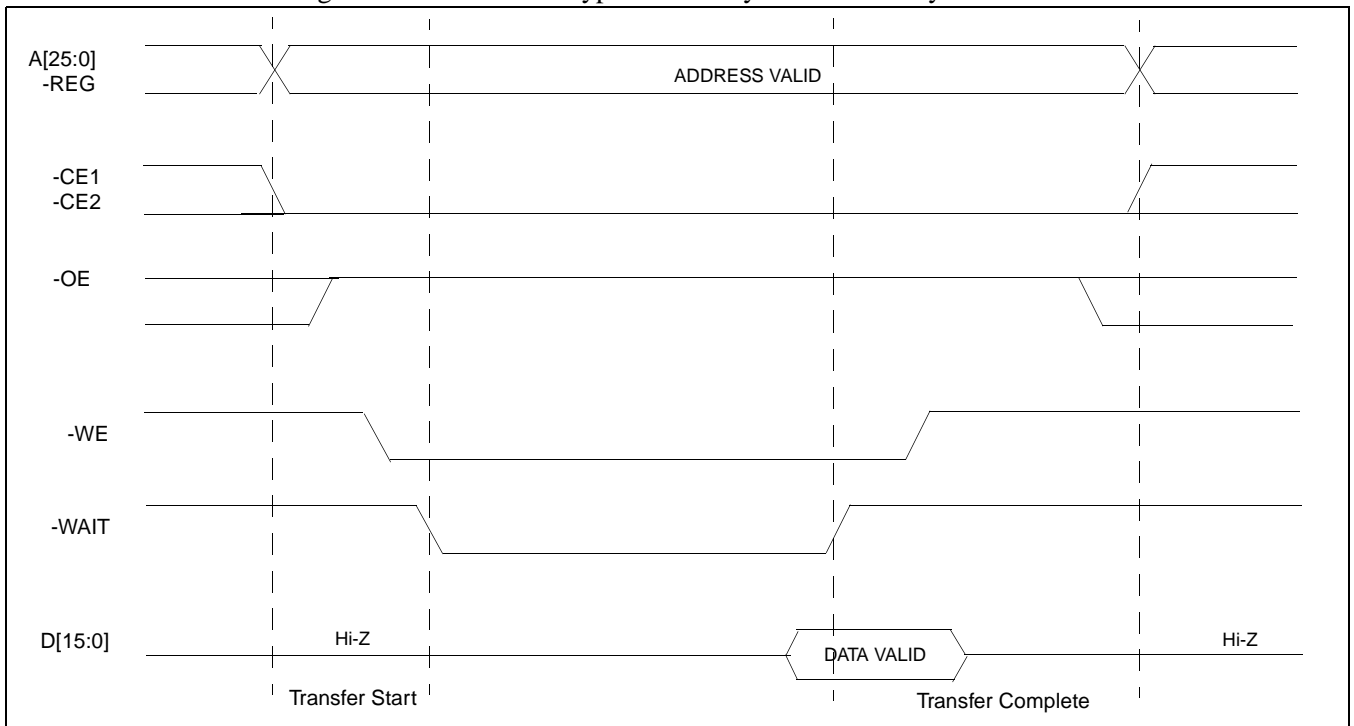


Figure 2-2: PC Card Write Cycle

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #2 Host Bus Interface which is most suitable for direct connection to the PC Card bus. Generic #2 supports an external Chip Select, shared Read/Write Enable for high byte, and individual Read/Write Enable for low byte.

The Generic #2 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After RESET# is released, the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.2, “S1D13A05 Hardware Configuration” on page 13.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | PC Card (PCMCIA) |
|--------------------|--|
| AB[17:0] | A[17:0] |
| DB[15:0] | D[15:0] |
| WE1# | -CE2 |
| CS# | External Decode |
| M/R# | A18 |
| CLKI | see note |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | Connect to IO _{VDD} from the S1D13A05 |
| RD# | -OE |
| WE0# | -WE |
| WAIT# | -WAIT |
| RESET# | Inverted RESET |

Note

Although a clock is not directly supplied by the PC Card interface, one is required by the S1D13A05 Generic #2 Host Bus Interface. For an example of how this can be accomplished see the discussion on CLKI in Section 3.2, “Host Bus Interface Signals” on page 11.

3.2 Host Bus Interface Signals

The S1D13A05 Generic #2 Host Bus Interface requires the following signals from the PC Card bus.

- CLKI is a clock input which is required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. Since the PC Card signalling is independent of any clock, CLKI can come from any oscillator already implemented. For example, the source for the CLKI2 input of the S1D13A05 may be used.
- The address inputs AB[17:0], and the data bus DB[15:0], connect directly to the PC Card address (A[17:0]) and data bus (D[15:0]), respectively. CNF4 must be set to select little endian mode.
- Chip Select (CS#) is driven by decoding the high-order address lines to select the proper register and memory address space.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A18, allowing system address A18 to select between memory or register accesses.
- WE1# connects to -CE2 (the high byte chip select signal from the PC Card interface) which in conjunction with address bit 0 allows byte steering of read and write operations.
- WE0# connects to -WE (the write enable signal from the PC Card bus) and must be driven low when the PC Card bus is writing data to the S1D13A05.
- RD# connects to -OE (the read enable signal from the PC Card bus) and must be driven low when the PC Card bus is reading data from the S1D13A05.
- WAIT# is a signal output from the S1D13A05 that indicates the PC Card bus must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. Since PC Card bus accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or display buffer. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete.
- The Bus Status (BS#) and Read/Write (RD/WR#) signals are not used in this implementation of the PC Card bus using the Generic #2 Host Bus Interface. These pins must be tied high (connected to IO V_{DD}).
- The RESET# (active low) input of the S1D13A05 may be connected to the PC Card RESET (active high) using an inverter.

4 PC Card to S1D13A05 Interface

4.1 Hardware Connections

The S1D13A05 is interfaced to the PC Card bus with a minimal amount of glue logic. In this implementation, the address inputs (AB[17:0]) and data bus (DB[15:0]) connect directly to the CPU address (A[17:0]) and data bus (D[15:0]).

The PC Card interface does not provide a bus clock, so one must be supplied for the S1D13A05. Since the bus clock frequency is not critical, nor does it have to be synchronous to the bus signals, it may be the same as CLKI2.

BS# (bus start) and RD/WR# are not used by the Generic #2 Host Bus Interface and should be tied high (connected to IO V_{DD}).

The following diagram shows a typical implementation of the PC Card to S1D13A05 interface.

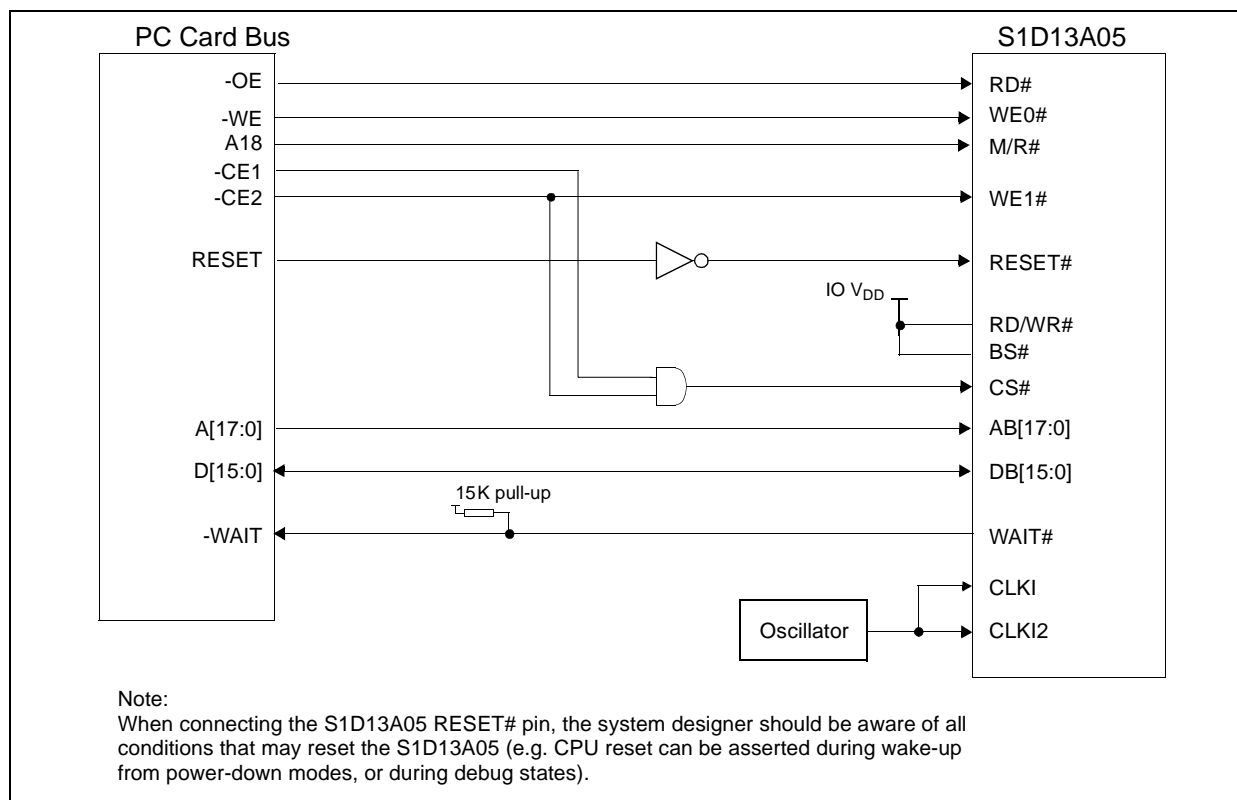


Figure 4-1: Typical Implementation of PC Card to S1D13A05 Interface

4.2 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to PC Card bus interface.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------|---|-----------------------------------|------|---------------------------|------|------|----------|---|---|---|---|---------------------------|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: <table border="1"> <thead> <tr> <th>CNF4</th> <th>CNF2</th> <th>CNF1</th> <th>CNF0</th> <th>Host Bus</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>Generic #2, Little Endian</td> </tr> </tbody> </table> | | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 0 | 1 | 0 | 0 | Generic #2, Little Endian |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 0 | 1 | 0 | 0 | Generic #2, Little Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |
| | configuration for PC Card bus | | | | | | | | | | | |

4.3 Register/Memory Mapping

The S1D13A05 is a memory mapped device. The S1D13A05 uses two 256K byte blocks which are selected using A18 from the PC Card bus (A18 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block.

The PC Card socket provides 64M bytes of memory address space. However, the S1D13A05 only needs a 512K byte block of memory to accommodate its 256K byte display buffer and register set. For this reason, only address bits A[18:0] are used while A[25:19] are ignored. The S1D13A05's memory and registers are aliased every 512K bytes in the 64M byte PC Card memory address space.

Note

If aliasing is not desirable, the upper addresses must be fully decoded.

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- PC Card (PCMCIA) Standard March 1997.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.

6.2 Document Sources

- PC Card Website: www.pc-card.com.
- Epson Research and Development Website: www.erd.epson.com.

7 Sales and Technical Support

7.1 EPSON LCD/USB Companion Chips (S1D13A05)

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7.2 PC Card Standard

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Fax: (408) 433-9558
<http://www.pc-card.com/>

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S1D13A05 LCD/USB Companion Chip

Power Consumption

Document Number: X40A-G-006-01

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1 S1D13A05 Power Consumption

S1D13A05 power consumption is affected by many system design variables.

- Input clock frequency (CLKI/CLKI2): the CLKI/CLKI2 frequency determines the LCD frame-rate, CPU performance to memory, and other functions – the higher the input clock frequency, the higher the frame-rate, performance and power consumption.
- CPU interface: the S1D13A05 current consumption depends on the BCLK frequency, data width, number of toggling pins, and other factors – the higher the BCLK, the higher the CPU performance and power consumption.
- V_{DD} voltage level: the voltage level affects power consumption – the higher the voltage, the higher the consumption.
- Display mode: the resolution and color depth affect power consumption – the higher the resolution/color depth, the higher the consumption.
- Internal CLK divide: internal registers allow the input clock to be divided before going to the internal logic blocks – the higher the divide, the lower the power consumption.

The S1D13A05 supports a software initiated power save mode. The power consumption in power save mode is affected by various system design variables.

- Clock states during the power save mode: disabling the clocks during power save mode has substantial power savings.

1.1 Conditions

The following table provides examples of typical configurations for some 320x240 panels and their effects on power consumption. The following conditions apply.

- All tests had an appropriate LCD panel connected to the LCD outputs of the S1D13A05.
- All tests were run with a static full color palette display.
- All tests were done using the Generic #1 host bus interface (BCLK = 33MHz).

Table 1-1: S1D13A05 Total Power Consumption for 320x240 panels

| Test Conditions <i>COREV_{DD} = 2.0V and IOV_{DD} = 3.3V</i> | | | | | Power Consumption (mA) | |
|---|-------------------------|------------|---|-------------|------------------------|--------|
| | | | | | S1D13A05 Active | |
| Resolution | Panel Type | Frame Rate | Clocks (MHz) | Color Depth | CORE | IO |
| 320x240 | Color 8-bit Format 2 | 94 | CLKI = 33.3 = BCLK | 4 | 2.53 | 2.96 |
| | | 94 | CLKI2 = grounded PCLK = MCLK = BCLK / 4 | 8 | 3.05 | 3.07 |
| | | 94 | USBCLK = 48 USB in Suspend Mode | 16 | 3.44 | 2.46 |
| | | 0 | CLKI = BCLK = grounded CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = grounded USB in Suspend Mode Power Save Mode | 16 | 1.50µa | 0.25µa |
| | Color 4-bit | 94 | CLKI = 33.3 = BCLK CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = 48 USB in Suspend Mode | 16 | 3.48 | 3.64 |
| | 18-bit TFT | 79 | CLKI = 33.3 = BCLK CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = 48 USB in Suspend Mode | 16 | 2.85 | 2.18 |

The following table provides an example of a 320x320 HR-TFT panel and the effects on power consumption for specific environments. The following conditions apply.

- All tests had an appropriate LCD panel connected to the LCD outputs of the S1D13A05.
- All tests were run with a static full color palette display, **except the test where the 2D BitBLT engine was running.**
- All tests were done using the Generic #1 host bus interface (BCLK = 33MHz).

Table 1-2: S1D13A05 Total Power Consumption for 320x320 panels

| Test Condition | | | | | Power Consumption (mA) | |
|---|---------------|------------|---|-------------|------------------------|--------|
| COREV _{DD} = 2.0V and IOV _{DD} = 3.3V | | | | | S1D13A05 Active | |
| Resolution | Panel Type | Frame Rate | Clocks (MHz) | Color Depth | CORE | IO |
| 320x320 | 18-bit HR-TFT | 64 | CLKI = 33.3 = BCLK | 4 | 2.18 | 2.75 |
| | | 64 | CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = 48 | 8 | 2.65 | 3.05 |
| | | 64 | USB in Suspend Mode | 16 | 3.02 | 3.11 |
| | | 60 | CLKI = 33.3 = BCLK MCLK = BCLK / 4 CLKI2 = 7.8 = PCLK USBCLK = 48 USB in Suspend Mode | 16 | 2.93 | 2.99 |
| | | 64 | CLKI = 33.3 = BCLK CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = 48 USB Running (loopback) ¹ | 16 | 13.99 | 3.68 |
| | | 64 | CLKI = 33.3 = BCLK CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = 48 USB in Suspend Mode 2D BitBLT engine running ² | 16 | 6.33 | 4.78 |
| | | 0 | CLKI = BCLK = grounded CLKI2 = grounded PCLK = MCLK = BCLK / 4 USBCLK = grounded USB in Suspend Mode Power Save Enabled. | 16 | 1.50µa | 0.25µa |

1. This test has the S1D13A05 USB module running a loop-back test.
2. This test has the 2D BitBLT engine performing a Move BitBLT which requires a high-level of CPU activity and a rapidly updating display.

2 Summary

The system design variables in Section 1, “S1D13A05 Power Consumption” and in the included comparison tables, show that S1D13A05 power consumption depends on the specific implementation. When the S1D13A05 is running power consumption depends on the desired CPU performance and LCD frame-rate. Power save mode consumption depends on the CPU Interface and Input Clock state.

In a typical design environment, the S1D13A05 can be configured to be an extremely power-efficient LCD Controller with high performance and flexibility.

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S1D13A05 LCD/USB Companion Chip

Interfacing to the NEC VR4102 / VR4111 Microprocessors

Document Number: X40A-G-007-01

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1 Introduction

This application note describes the hardware and software environment required to interface the S1D13A05 LCD/USB Companion Chip and the NEC VR4102/4111 microprocessor. The NEC VR4102 and VR4111 microprocessors are specifically designed to support an external LCD controller.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

2 Interfacing to the NEC VR4102/VR4111

2.1 The NEC VR41XX System Bus

The VR-Series family of microprocessors features a high-speed synchronous system bus typical of modern microprocessors. Designed with external LCD controller support and Windows® CE based embedded consumer applications in mind, the VR4102/VR4111 offers a highly integrated solution for portable systems. This section is an overview of the operation of the CPU bus to establish interface requirements.

2.1.1 Overview

The NEC VR series microprocessor is designed around the RISC architecture developed by MIPS. The VR4102 microprocessor is designed around the 66MHz VR4100 CPU core and the VR4111 is designed around the 80/100MHz VR4110 core. These microprocessors support 64-bit processing. The CPU communicates with the Bus Control Unit (BCU) through its internal SysAD bus. The BCU in turn communicates with external devices with its ADD and DATA busses which can be dynamically sized for 16 or 32-bit operation.

The NEC VR4102/VR4111 can directly support an external LCD controller through a dedicated bus interface. Specific control signals are assigned for an external LCD controller in order to provide an easy interface to the CPU. A 16M byte block of memory is assigned for the LCD controller with its own chip select and ready signals available. Word or byte accesses are controlled by the system high byte signal (SHB#).

2.1.2 LCD Memory Access Cycles

Once an address in the LCD block of memory is placed on the external address bus (ADD[25:0]) the LCD chip select (LCDCS#) is driven low. The read enable (RD#) or write enable (WR#) signals are driven low for the appropriate cycle. LCDRDY is driven low by the S1D13A05 to insert wait states into the cycle. The system high byte enable is driven low for 16-bit transfers and high for 8-bit transfers.

Figure 2-1: “NEC VR4102/VR4111 Read/Write Cycles,” shows the read and write cycles to the LCD Controller Interface.

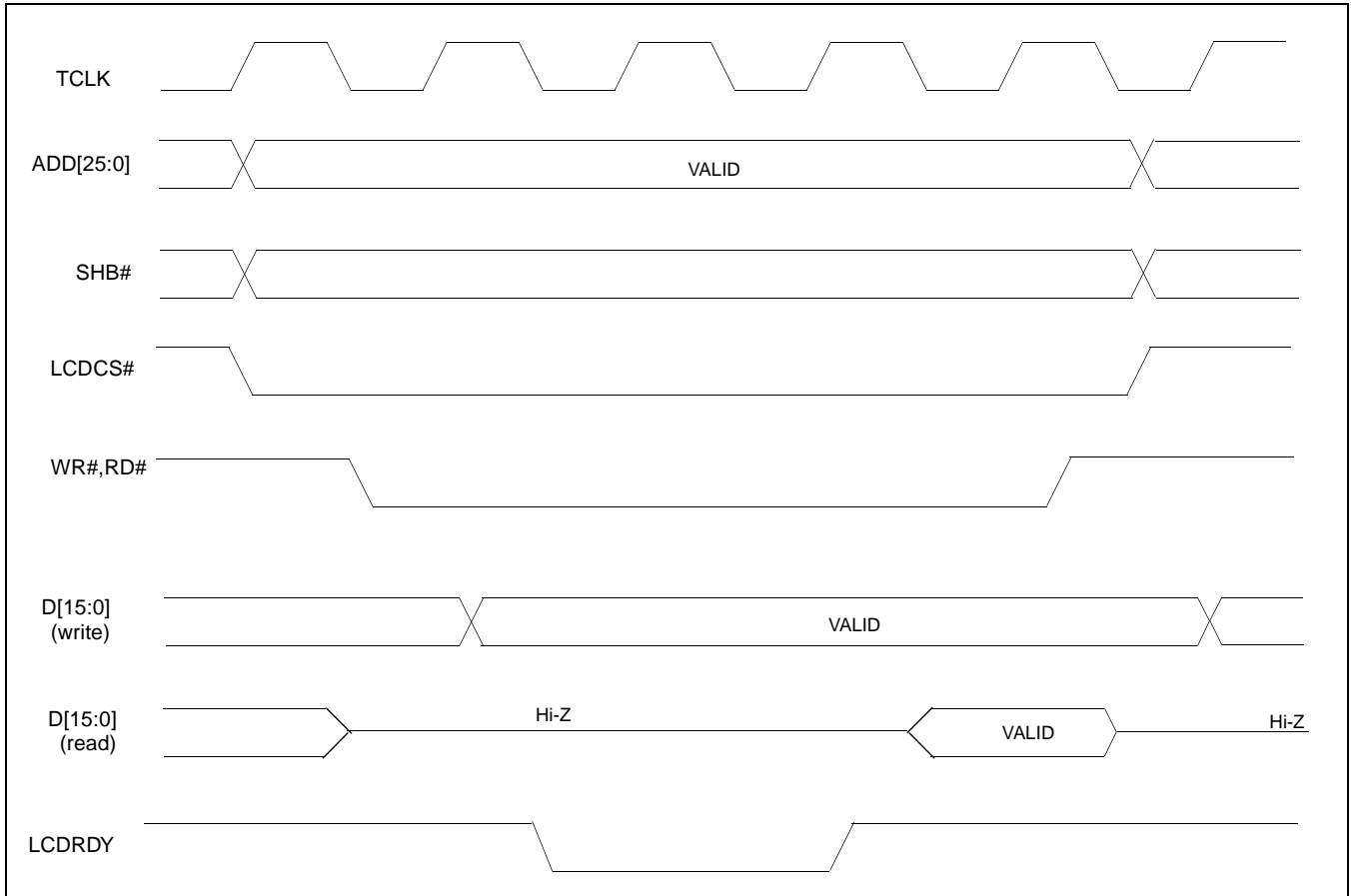


Figure 2-1: NEC VR4102/VR4111 Read/Write Cycles

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #2 Host Bus Interface which is most suitable for direct connection to the NEC VR4102/4111 microprocessor. Generic #2 supports an external Chip Select, shared Read/Write Enable for high byte, and individual Read/Write Enable for low byte.

The Generic #2 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After RESET# is released, the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.2, “S1D13A05 Hardware Configuration” on page 13.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | NEC VR4102/4111 |
|-------------------------------|--|
| AB[17:0] | ADD[17:0] |
| DB[15:0] | DAT[15:0] |
| WE1# | SHB# |
| CS# | LCDCS# |
| M/R# | ADD18 |
| CLKI | BUSCLK |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | Connect to IO _{VDD} from the S1D13A05 |
| RD# | RD# |
| WE0# | WR# |
| LCDRDY | WAIT# |
| RESET# | system $\overline{\text{RESET}}$ |

3.2 Host Bus Interface Signals

The Host Bus Interface requires the following signals:

- CLKI is a clock input which is required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For this example, BUSCLK from the NEC VR4102/4111 is used for CLKI.
- The address inputs AB[17:0], and the data bus DB[15:0], connect directly to the NEC VR4102/4111 address bus (ADD[17:0]) and data bus (DAT[15:0]), respectively. CNF4 must be set to select little endian mode.
- Chip Select (CS#) must be driven low by LCDCS# whenever the S1D13A05 is accessed by the VR4102/4111.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line ADD18, allowing system address ADD18 to select between memory or register accesses.
- WE1# connects to SHB# (the high byte enable signal from the NEC VR4102/4111) which in conjunction with address bit 0 allows byte steering of read and write operations.
- WE0# connects to WR# (the write enable signal from the NEC VR4102/4111) and must be driven low when the VR4102/4111 is writing data to the S1D13A05.
- RD# connects to RD# (the read enable signal from the NEC VR4102/4111) and must be driven low when the VR4102/4111 is reading data from the S1D13A05.
- WAIT# connects to LCDRDY and is a signal output from the S1D13A05 that indicates the VR4102/VR4111 must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. Since VR4102/VR4111 accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or display buffer. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete.
- The Bus Status (BS#) and Read/Write (RD/WR#) signals are not used in this implementation of the NEC VR4102/4111 interface using the Generic #2 Host Bus Interface. These pins must be tied high (connected to IO V_{DD}).

4 VR4102/VR4111 to S1D13A05 Interface

4.1 Hardware Description

The NEC VR4102/VR4111 microprocessor is specifically designed to support an external LCD controller by providing the internal address decoding and control signals necessary. By using the Generic # 2 Host Bus Interface, no glue logic is required to interface the S1D13A05 and the NEC VR4102/VR4111.

A pull-up resistor is attached to WAIT# to speed up its rise time when terminating a cycle.

BS# (bus start) and RD/WR# are not used by the Generic #2 Host Bus Interface and should be tied high (connected to IO V_{DD}).

The following diagram shows a typical implementation of the VR4102/VR4111 to S1D13A05 interface.

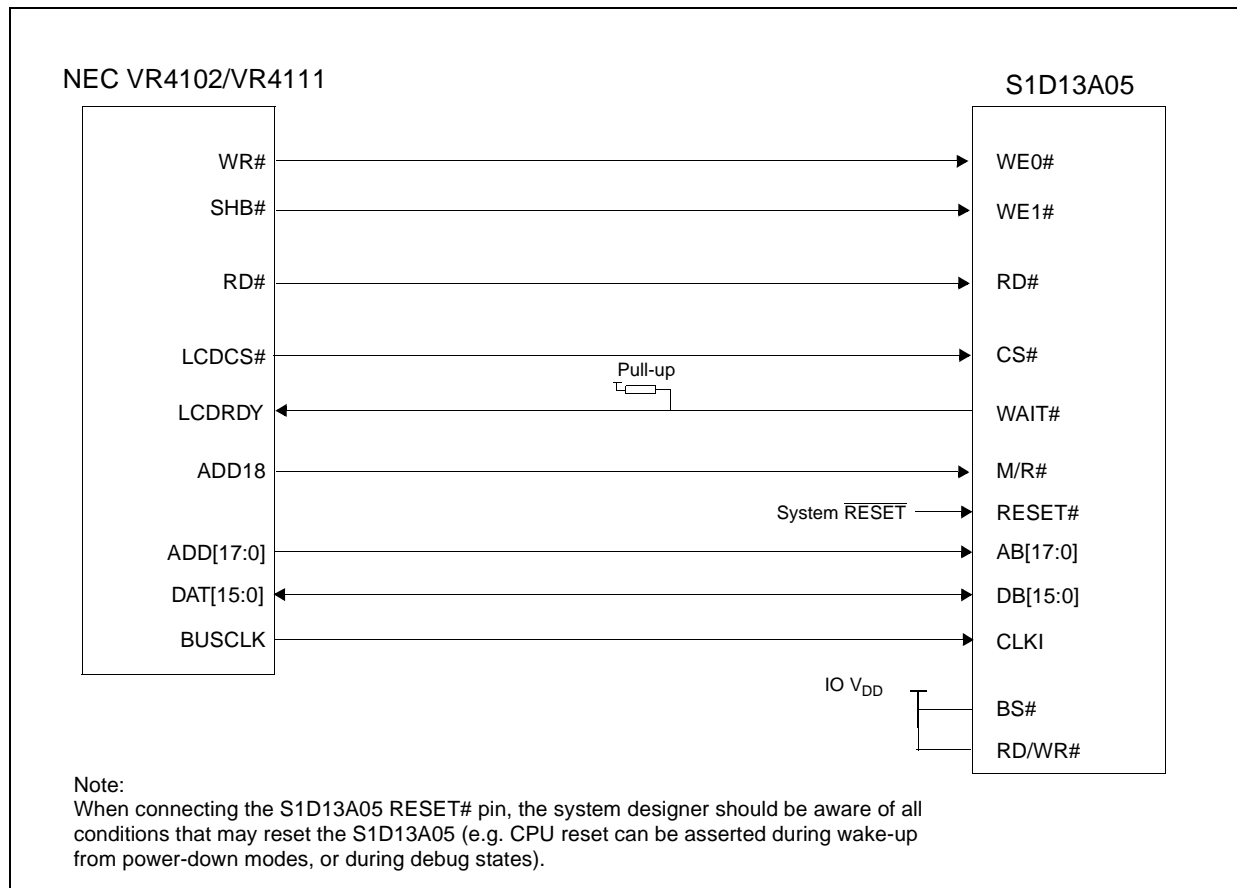


Figure 4-1: Typical Implementation of VR4102/VR4111 to S1D13A05 Interface

4.2 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to NEC VR4102/4111 interface.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|--|-----------------------------------|-------------|---------------------------|-------------|-------------|-----------------|---|---|---|---|---------------------------|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: <table style="width:100%; border:none;"> <tr> <td style="text-align:center;">CNF4</td> <td style="text-align:center;">CNF2</td> <td style="text-align:center;">CNF1</td> <td style="text-align:center;">CNF0</td> <td style="text-align:center;">Host Bus</td> </tr> <tr> <td style="text-align:center;">0</td> <td style="text-align:center;">1</td> <td style="text-align:center;">0</td> <td style="text-align:center;">0</td> <td style="text-align:center;">Generic #2, Little Endian</td> </tr> </table> | | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 0 | 1 | 0 | 0 | Generic #2, Little Endian |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 0 | 1 | 0 | 0 | Generic #2, Little Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |
| | configuration for NEC VR4102/VR4111 microprocessor | | | | | | | | | | | |

4.3 NEC VR4102/VR4111 Configuration

The NEC VR4102/4111 provides the internal address decoding necessary to map an external LCD controller. Physical address 0A00_0000h to 0AFF_FFFFh (16M bytes) is reserved for an external LCD controller by the NEC VR4102/4111.

The S1D13A05 is a memory mapped device. The S1D13A05 uses two 256K byte blocks which are selected using ADD18 from the NEC VR4102/4111 (ADD18 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block.

The starting address of the S1D13A05 internal registers is located at 0A00_0000h and the starting address of the display buffer is located at 0A04_0000h. These blocks are aliased over the entire 16M byte address space.

Note

If aliasing is not desirable, the upper addresses must be fully decoded.

The NEC VR4102/VR4111 has a 16-bit internal register named BCUCNTREG2 located at 0B00_0002h. It must be set to the value of 0001h which indicates that LCD controller accesses use a non-inverting data bus.

The 16-bit internal register named BCUCNTREG1 (located at 0B00_0000h) must have bit D[13] (ISA/LCD bit) set to 0. This reserves 16M bytes (from 0A00_0000h to 0AFF_FFFFh) for use by the LCD controller and not as ISA bus memory space.

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- NEC Electronics Inc., *VR4102/VR4111 64/32-bit Microprocessor Preliminary User's Manual*.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, document number X40A-G-003-xx.

6.2 Document Sources

- NEC Electronics Inc. Website: www.necel.com.
- Epson Research and Development Website: www.erd.epson.com.

7 Sales and Technical Support

7.1 EPSON LCD/USB Companion Chips (S1D13A05)

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Electronic Devices Marketing Division
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EPSON®



S1D13A05 LCD/USB Companion Chip

Interfacing to the NEC VR4181A™ Microprocessor

Document Number: X40A-G-008-01

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1 Introduction

This application note describes the hardware and software environment required to interface the S1D13A05 LCD/USB Companion Chip and the NEC VR4181A microprocessor. The NEC VR4181A microprocessor is specifically designed to support an external LCD controller.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

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2 Interfacing to the NEC VR4181A

2.1 The NEC VR4181A System Bus

The VR-Series family of microprocessors features a high-speed synchronous system bus typical of modern microprocessors. Designed with external LCD controller support and Windows® CE based embedded consumer applications in mind, the VR4181A offers a highly integrated solution for portable systems. This section is an overview of the operation of the CPU bus to establish interface requirements.

2.1.1 Overview

The NEC VR4181A is designed around the RISC architecture developed by MIPS. This microprocessor is designed around the 100MHz VR4110 CPU core which supports the MIPS III and MIPS16 instruction sets. The CPU communicates with external devices via an ISA interface.

While the VR4181A has an embedded LCD controller, this internal controller can be disabled to provide direct support for an external LCD controller through its external ISA bus. A 64 to 512K byte block of memory is assigned to the external LCD controller with a dedicated chip select signal (LCDCS#). Word or byte accesses are controlled by the system high byte signal (#UBE).

2.1.2 LCD Memory Access Signals

The S1D13A05 requires an addressing range of 512K bytes. When the VR4181A external LCD controller chip select signal is programmed to a window of that size, the S1D13A05 resides in the VR4181A physical address range of 133C 0000h to 133F FFFFh. This range is part of the external ISA memory space.

The following signals are required to access an external LCD controller. All signals obey ISA signalling rules.

- A[16:0] is the address bus.
- #UBE is the high byte enable (active low).
- #LCDCS is the chip select for the S1D13A05 (active low).
- D[15:0] is the data bus.
- #MEMRD is the read command (active low).
- #MEMWR is the write command (active low).
- #MEMCS16 is the acknowledge for 16-bit peripheral capability (active low).
- IORDY is the ready signal from S1D13A05.
- SYCLK is the pre-scalable bus clock (optional).

Once an address in the LCD block of memory is accessed, the LCD chip select (#LCDCS) is driven low. The read or write enable signals (#MEMRD or #MEMWR) are driven low for the appropriate cycle and IORDY is driven low by the S1D13A05 to insert wait states into the cycle. The high byte enable (UBE#) is driven low for 16-bit transfers and high for 8-bit transfers.

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #2 Host Bus Interface which is most suitable for direct connection to the NEC VR4181A microprocessor. Generic #2 supports an external Chip Select, shared Read/Write Enable for high byte, and individual Read/Write Enable for low byte.

The Generic #2 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After RESET# is released, the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.2, “S1D13A05 Hardware Configuration” on page 13.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | NEC VR4181A |
|-------------------------------|--|
| AB[17:0] | A[17:0] |
| DB[15:0] | D[15:0] |
| WE1# | #UBE |
| CS# | #LCDCS |
| M/R# | A18 |
| CLKI | SYSCLK |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | Connect to IO _{VDD} from the S1D13A05 |
| RD# | #MEMRD |
| WE0# | #MEMWR |
| WAIT# | IORDY |
| RESET# | RESET# |

3.2 Host Bus Interface Signals

The interface requires the following signals.

- CLKI is a clock input which is required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For this example, SYSCLK from the NEC VR4181A is used for CLKI.
- The address inputs AB[17:0], and the data bus DB[15:0], connect directly to the NEC VR4181A address (A[17:0]) and data bus (D[15:0]), respectively. CNF4 must be set to select little endian mode.
- Chip Select (CS#) must be driven low by #LCDCS whenever the S1D13A05 is accessed by the VR4181A.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A18, allowing system address A18 to select between memory or register accesses.
- WE1# connects to #UBE (the high byte enable signal from the NEC VR4181A) which in conjunction with address bit 0 allows byte steering of read and write operations.
- WE0# connects to #MEMWR (the write enable signal from the NEC VR4181A) and must be driven low when the NEC VR4181A is writing data to the S1D13A05.
- RD# connects to #MEMRD (the read enable signal from the NEC VR4181A) and must be driven low when the NEC VR4181A is reading data from the S1D13A05.
- WAIT# connects to IORDY and is a signal which is output from the S1D13A05 which indicates the NEC VR4181A must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. Since VR4181A accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or display buffer. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete.
- The Bus Status (BS#) and Read/Write (RD/WR#) signals are not used in this implementation of the NEC VR4181A interface using the Generic #2 Host Bus Interface. These pins must be tied high (connected to IO V_{DD}).

4 VR4181A to S1D13A05 Interface

4.1 Hardware Description

The NEC VR4181A microprocessor is specifically designed to support an external LCD controller by providing the internal address decoding and control signals necessary. By using the Generic # 2 Host Bus Interface, no glue logic is required to interface the S1D13A05 to the NEC VR4181A.

A pull-up resistor is attached to WAIT# to speed up its rise time when terminating a cycle.

#MEMCS16 of the NEC VR4181A is connected to #LCDCS to signal that the S1D13A05 is capable of 16-bit transfers.

BS# (bus start) and RD/WR# are not used by the Generic #2 Host Bus Interface and should be tied high (connected to IO V_{DD}).

The diagram below shows a typical implementation of the VR4181A to S1D13A05 interface.

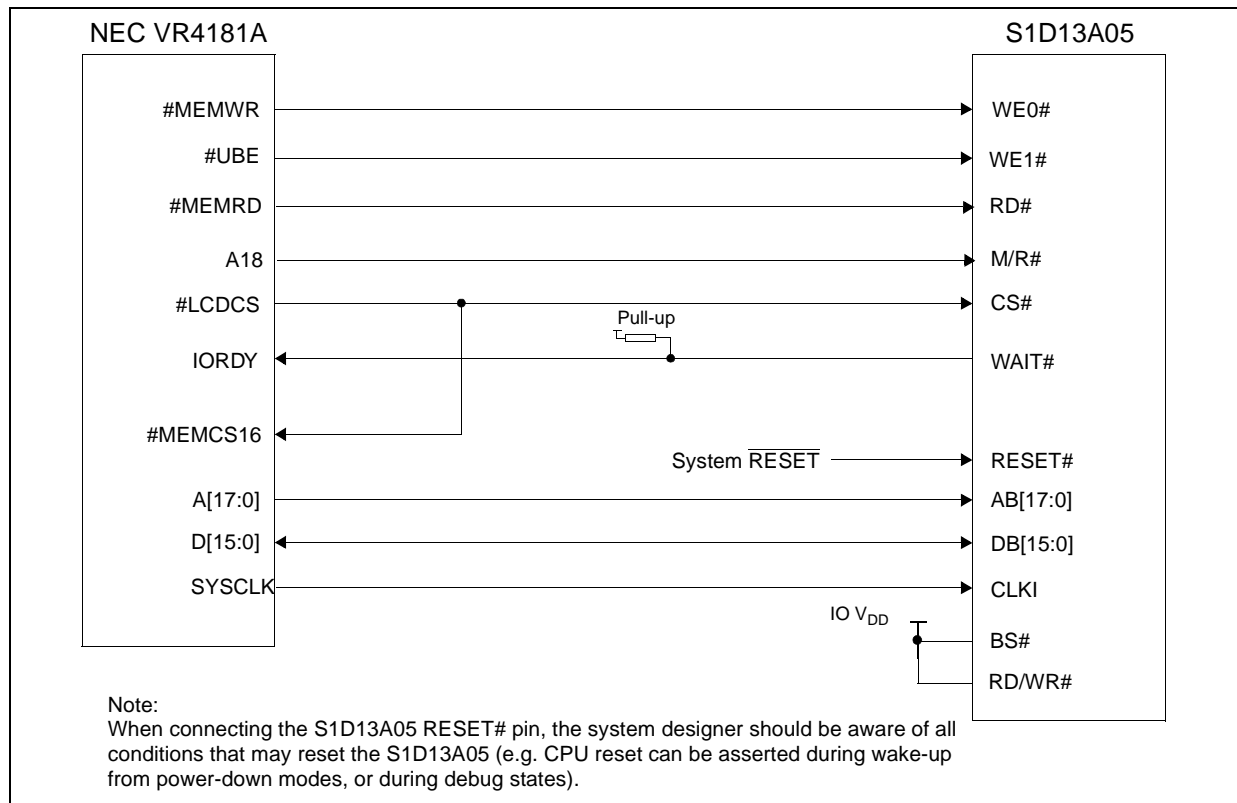


Figure 4-1: Typical Implementation of VR4181A to S1D13A05 Interface

4.2 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to NEC VR4181A interface.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|--|-----------------------------------|-------------|---------------------------|-------------|-------------|-----------------|---|---|---|---|---------------------------|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: <table style="width:100%; border:none;"> <tr> <td style="text-align:center;">CNF4</td> <td style="text-align:center;">CNF2</td> <td style="text-align:center;">CNF1</td> <td style="text-align:center;">CNF0</td> <td style="text-align:center;">Host Bus</td> </tr> <tr> <td style="text-align:center;">0</td> <td style="text-align:center;">1</td> <td style="text-align:center;">0</td> <td style="text-align:center;">0</td> <td style="text-align:center;">Generic #2, Little Endian</td> </tr> </table> | | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 0 | 1 | 0 | 0 | Generic #2, Little Endian |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 0 | 1 | 0 | 0 | Generic #2, Little Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |

configuration for NEC VR4181A microprocessor

4.3 NEC VR4181A Configuration

The S1D13A05 is a memory mapped device. The S1D13A05 uses two 256K byte blocks which are selected using A18 from the NEC VR4181A (A18 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block.

When the VR4181A embedded LCD controller is disabled, the external LCD controller chip select signal (#LCDCS) decodes either a 64K byte, 128K byte, 256K byte, or 512K byte memory block in the VR4181A external ISA memory. The S1D13A05 requires this block of memory to be set to 512K bytes. With this configuration, the S1D13A05 internal registers starting address is located at physical memory location 133C_0000h and the display buffer is located at memory location 1340_0000h.

The NEC VR4181A must be configured through its internal registers to map the S1D13A05 to the external LCD controller space. The following register values must be set.

- Register LCDGPMD at address 0B00_032Eh must be set as follows.
 - Bit 7 must be set to 1 to disable the internal LCD controller and enable the external LCD controller interface. Disabling the internal LCD controller also maps pin SHCLK to #LCDCS and pin LOCLK to #MEMCS16.
 - Bits [1:0] must be set to 11b to reserve 512Kbytes of memory address range, 133C_0000h to 133F_FFFFh for the external LCD controller.
- Register GPMD2REG at address 0B00_0304h must be set as follows.
 - Bits [9:8] (GP20MD[1:0]) must be set to 11b to map pin GPIO20 to #UBE.
 - Bits [5:4] (GP18MD[1:0]) must be set to 01b to map pin GPIO18 to IORDY.

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- NEC Electronics Inc., *NEC VR4181A Target Specification*, Revision 0.5, 9/11/98
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, document number X40A-G-003-xx.

6.2 Document Sources

- NEC Electronics Inc. Website: www.necel.com.
- Epson Research and Development Website: www.erd.epson.com.

7 Sales and Technical Support

7.1 EPSON LCD/USB Companion Chips (S1D13A05)

Japan

Seiko Epson Corporation
Electronic Devices Marketing Division
421-8, Hino, Hino-shi
Tokyo 191-8501, Japan
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Epson Taiwan Technology
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Epson Hong Kong Ltd.
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S1D13A05 LCD/USB Companion Chip

Interfacing to the Motorola MPC82x Microprocessor

Document Number: X40A-G-009-01

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1 Introduction

This application note describes the hardware and software environment required to interface the S1D13A05 LCD/USB Companion Chip and the Motorola MPC82x microprocessor.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

2 Interfacing to the MPC82x

2.1 The MPC8xx System Bus

The MPC8xx family of processors feature a high-speed synchronous system bus typical of modern RISC microprocessors. This section provides an overview of the operation of the CPU bus in order to establish interface requirements.

2.2 MPC8xx Bus Overview

The MPC8xx microprocessor family uses a synchronous address and data bus. All IO is synchronous to a square-wave reference clock called MCLK (Master Clock). This clock runs at the machine cycle speed of the CPU core (typically 25 to 50 MHz). Most outputs from the processor change state on the rising edge of this clock. Similarly, most inputs to the processor are sampled on the rising edge.

Note

The external bus can run at one-half the CPU core speed using the clock control register. This is typically used when the CPU core is operated above 50 MHz.

The MPC821 can generate up to eight independent chip select outputs, each of which may be controlled by one of two types of timing generators: the General Purpose Chip Select Module (GPCM) or the User-Programmable Machine (UPM). Examples are given using the GPCM.

It should be noted that all Power PC microprocessors, including the MPC8xx family, use bit notation opposite from the convention used by most other microprocessor systems. Bit numbering for the MPC8xx always starts with zero as the most significant bit, and increments in value to the least-significant bit. For example, the most significant bits of the address bus and data bus are A0 and D0, while the least significant bits are A31 and D31.

The MPC8xx uses both a 32-bit address and data bus. A parity bit is supported for each of the four byte lanes on the data bus. Parity checking is done when data is read from external memory or peripherals, and generated by the MPC8xx bus controller on write cycles. All IO accesses are memory-mapped meaning there is no separate IO space in the Power PC architecture.

Support is provided for both on-chip (DMA controllers) and off-chip (other processors and peripheral controllers) bus masters. For further information on this topic, refer to Section 6, "References" on page 22.

The bus can support both normal and burst cycles. Burst memory cycles are used to fill on-chip cache memory, and for certain on-chip DMA operations. Normal cycles are used for all other data transfers.

2.2.1 Normal (Non-Burst) Bus Transactions

A data transfer is initiated by the bus master by placing the memory address on address lines A0 through A31 and driving \overline{TS} (Transfer Start) low for one clock cycle. Several control signals are also provided with the memory address:

- $TSIZ[0:1]$ (Transfer Size) — indicates whether the bus cycle is 8, 16, or 32-bit.
- RD/\overline{WR} — set high for read cycles and low for write cycles.
- $AT[0:3]$ (Address Type Signals) — provides more detail on the type of transfer being attempted.

When the peripheral device being accessed has completed the bus transfer, it asserts \overline{TA} (Transfer Acknowledge) for one clock cycle to complete the bus transaction. Once \overline{TA} has been asserted, the MPC821 will not start another bus cycle until \overline{TA} has been de-asserted. The minimum length of a bus transaction is two bus clocks.

Figure 2-1: “Power PC Memory Read Cycle” illustrates a typical memory read cycle on the Power PC system bus.

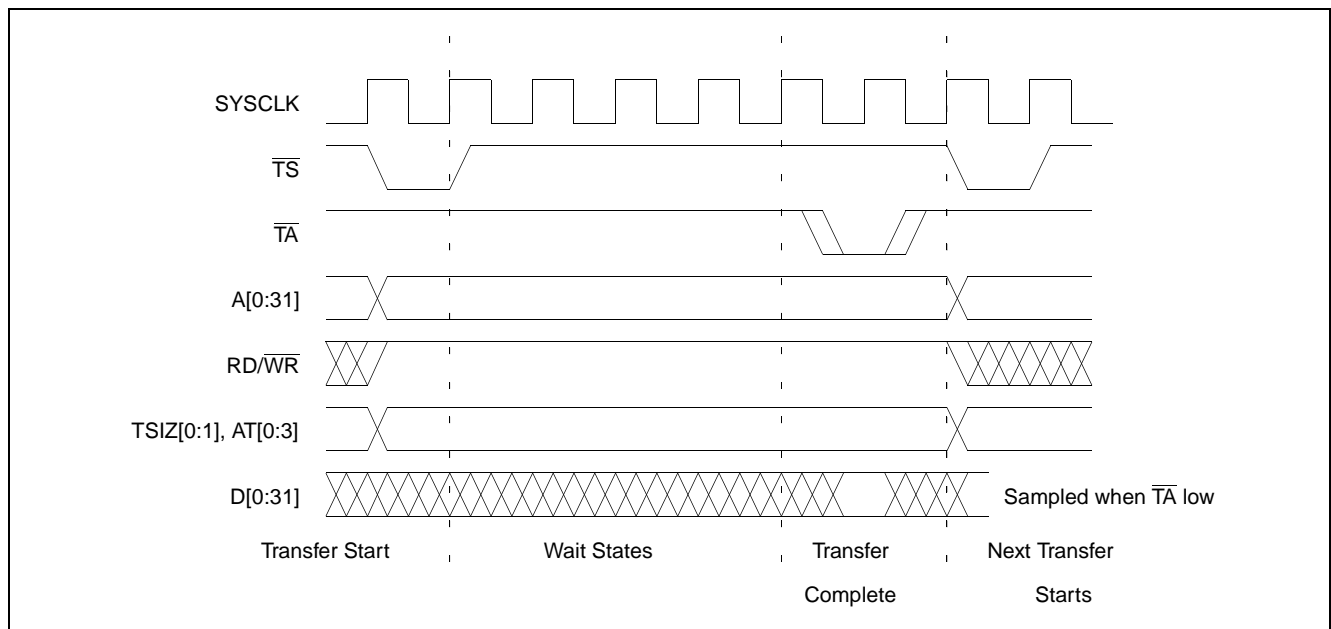


Figure 2-1: Power PC Memory Read Cycle

Figure 2-2: “Power PC Memory Write Cycle” illustrates a typical memory write cycle on the Power PC system bus.

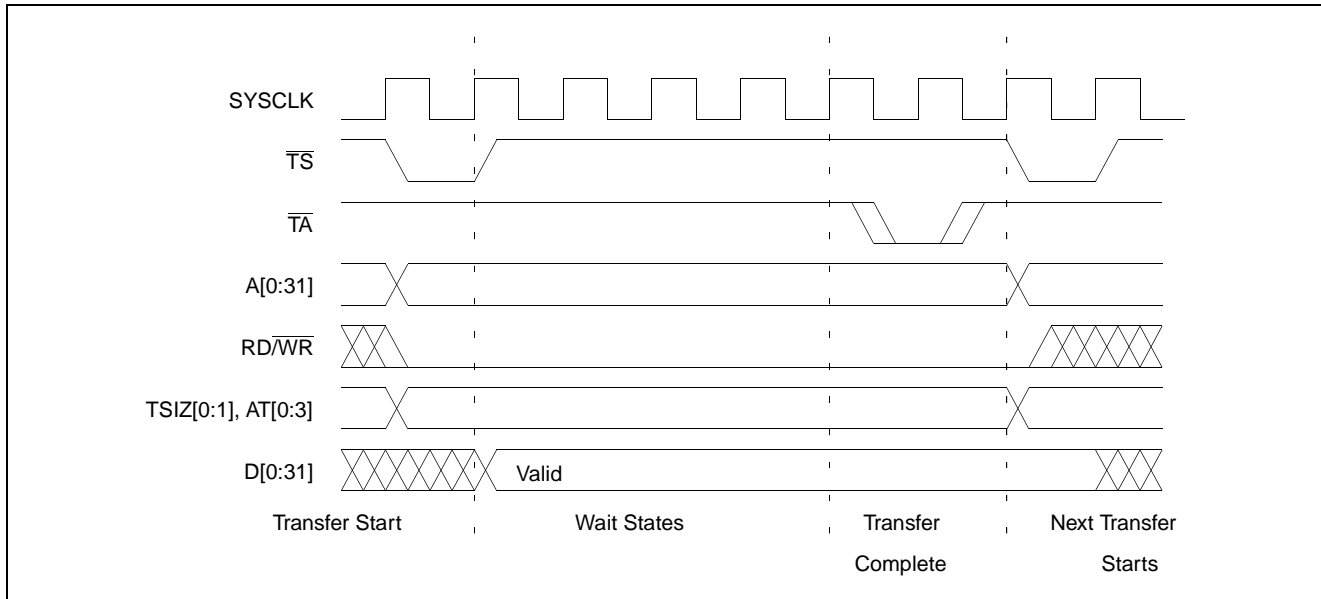


Figure 2-2: Power PC Memory Write Cycle

If an error occurs, \overline{TEA} (Transfer Error Acknowledge) is asserted and the bus cycle is aborted. For example, a peripheral device may assert \overline{TEA} if a parity error is detected, or the MPC821 bus controller may assert \overline{TEA} if no peripheral device responds at the addressed memory location within a bus time-out period.

For 32-bit transfers, all data lines (D[0:31]) are used and the two low-order address lines A30 and A31 are ignored. For 16-bit transfers, data lines D0 through D15 are used and address line A31 is ignored. For 8-bit transfers, data lines D0 through D7 are used and all address lines (A[0:31]) are used.

Note

This assumes that the Power PC core is operating in big endian mode (typically the case for embedded systems).

2.2.2 Burst Cycles

Burst memory cycles are used to fill on-chip cache memory and to carry out certain on-chip DMA operations. They are very similar to normal bus cycles with the following exceptions:

- Always 32-bit.
- Always attempt to transfer four 32-bit words sequentially.
- Always address longword-aligned memory (i.e. A30 and A31 are always 0:0).
- Do not increment address bits A28 and A29 between successive transfers; the addressed device must increment these address bits internally.

If a peripheral is not capable of supporting burst cycles, it can assert Burst Inhibit ($\overline{\text{BI}}$) simultaneously with $\overline{\text{TA}}$, and the processor reverts to normal bus cycles for the remaining data transfers.

Burst cycles are mainly intended to facilitate cache line fills from program or data memory. They are normally not used for transfers to/from IO peripheral devices such as the S1D13A05, therefore the interfaces described in this document do not attempt to support burst cycles.

2.3 Memory Controller Module

2.3.1 General-Purpose Chip Select Module (GPCM)

The General-Purpose Chip Select Module (GPCM) is used to control memory and peripheral devices which do not require special timing or address multiplexing. In addition to the chip select output, it can generate active-low Output Enable ($\overline{\text{OE}}$) and Write Enable ($\overline{\text{WE}}$) signals compatible with most memory and x86-style peripherals. The MPC821 bus controller also provides a Read/Write ($\text{RD}/\overline{\text{WR}}$) signal which is compatible with most 68K peripherals.

The GPCM is controlled by the values programmed into the Base Register (BR) and Option Register (OR) of the respective chip select. The Option Register sets the base address, the block size of the chip select, and controls the following timing parameters:

- The ACS bit field allows the chip select assertion to be delayed with respect to the address bus valid, by 0, 1/4, or 1/2 clock cycle.
- The CSNT bit causes chip select and $\overline{\text{WE}}$ to be negated 1/2 clock cycle earlier than normal.
- The TRLX (relaxed timing) bit inserts an additional one clock delay between assertion of the address bus and chip select. This accommodates memory and peripherals with long setup times.
- The EHTR (Extended hold time) bit inserts an additional 1-clock delay on the first access to a chip select.
- Up to 15 wait states may be inserted, or the peripheral can terminate the bus cycle itself by asserting $\overline{\text{TA}}$ (Transfer Acknowledge).
- Any chip select may be programmed to assert $\overline{\text{BI}}$ (Burst Inhibit) automatically when its memory space is addressed by the processor core.

Figure 2-3: “GPCM Memory Devices Timing” illustrates a typical cycle for a memory mapped device using the GPCM of the Power PC.

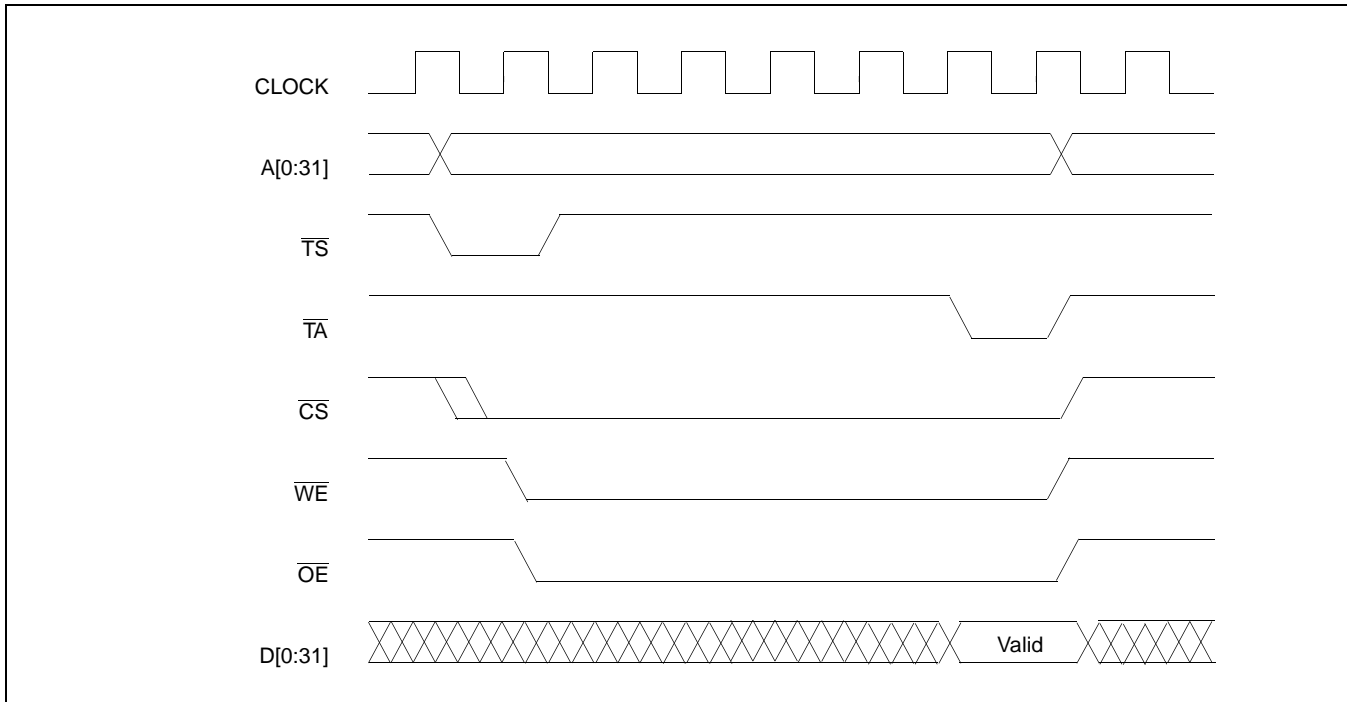


Figure 2-3: GPCM Memory Devices Timing

2.3.2 User-Programmable Machine (UPM)

The UPM is typically used to control memory types, such as Dynamic RAMs, which have complex control or address multiplexing requirements. The UPM is a general purpose RAM-based pattern generator which can control address multiplexing, wait state generation, and five general-purpose output lines on the MPC821. Up to 64 pattern locations are available, each 32 bits wide. Separate patterns may be programmed for normal accesses, burst accesses, refresh (timer) events, and exception conditions. This flexibility allows almost any type of memory or peripheral device to be accommodated by the MPC821.

In this application note, the GPCM is used instead of the UPM, since the GPCM has enough flexibility to accommodate the S1D13A05 and it is desirable to leave the UPM free to handle other interfacing duties, such as EDO DRAM.

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #1 Host Bus Interface which is most suitable for direct connection to the Motorola MPC82x microprocessor. Generic #1 supports a Chip Select and an individual Read Enable/Write Enable for each byte.

The Generic #1 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After RESET# is released, the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.3, “S1D13A05 Hardware Configuration” on page 18.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | Motorola MPC82x |
|--------------------|--|
| AB[17:0] | A[14:31] |
| DB[15:0] | D[0:15] |
| WE1# | $\overline{WE0}$ |
| CS# | $\overline{CS4}$ |
| M/R# | A13 |
| CLKI | SYSCLK |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | \overline{OE} (see note) |
| RD# | \overline{OE} (see note) |
| WE0# | $\overline{WE1}$ |
| WAIT# | \overline{TA} |
| RESET# | System \overline{RESET} |

Note

The Motorola MPC82x chip select module only handles 16-bit read cycles. As the S1D13A05 uses the chip select module to generate CS#, only 16-bit read cycles are possible and both the high and low byte enables can be driven by the MPC82x signal \overline{OE} .

3.2 Host Bus Interface Signals

The Host Bus Interface requires the following signals.

- CLKI is a clock input which is required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For this example, SYSCLK from the Motorola MPC82x is used for CLKI.
- The address inputs AB[17:0], and the data bus DB[15:0], connect directly to the MPC82x address (A[14:31]) and data bus (D[0:15]), respectively. CNF4 must be set to select big endian mode.
- Chip Select (CS#) must be driven low by $\overline{\text{CS4}}$ whenever the S1D13A05 is accessed by the Motorola MPC82x.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A13, allowing system address A13 to select between memory or register accesses.
- WE0# connects to $\overline{\text{WE1}}$ (the low byte enable signal from the MPC82x) and must be driven low when the MPC82x is writing the low byte to the S1D13A05.
- WE1# connects to $\overline{\text{WE0}}$ (the high byte enable signal from the MPC82x) and must be driven low when the MPC82x is writing the high byte to the S1D13A05.
- RD# and RD/WR# are read enables for the low-order and high-order bytes, respectively. Both signals are driven low by $\overline{\text{OE}}$ when the Motorola MPC82x is reading data from the S1D13A05.
- WAIT# connects to $\overline{\text{TA}}$ and is a signal which is output from the S1D13A05 which indicates the MPC82x must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. Since MPC82x accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or display buffer. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete.
- The Bus Status (BS#) signal is not used in this implementation of the MPC82x interface using the Generic #1 Host Bus Interface. This pin must be tied high (connected to IO V_{DD}).

4 MPC82x to S1D13A05 Interface

4.1 Hardware Description

The interface between the S1D13A05 and the MPC82x requires no external glue logic. The polarity of the WAIT# signal must be selected as active high by connecting CNF5 to IO V_{DD} (see Table 4-2: “Summary of Power-On/Reset Options,” on page 18).

BS# (bus start) is not used in this implementation and should be tied high (connected to IO V_{DD}).

The following diagram shows a typical implementation of the MPC82x to S1D13A05 interface.

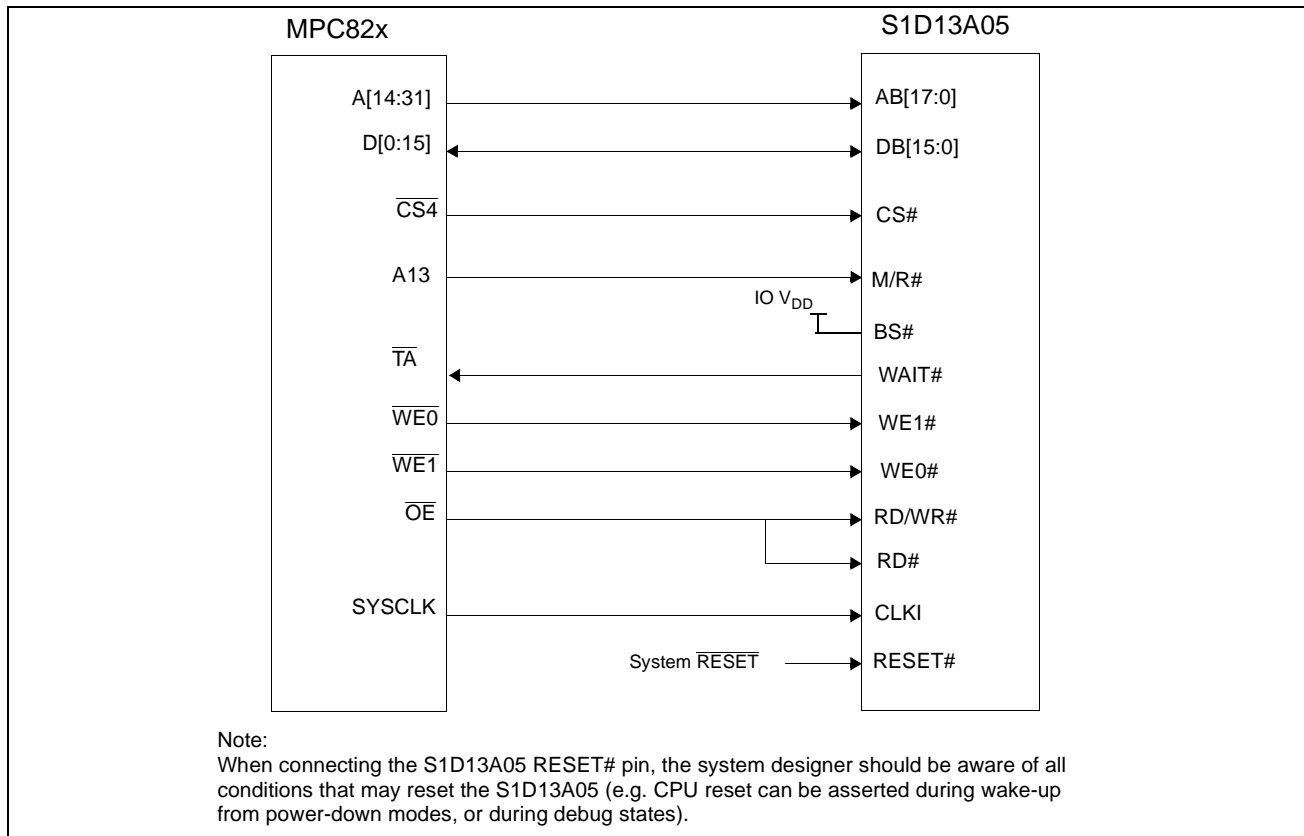


Figure 4-1: Typical Implementation of MPC82x to S1D13A05 Interface

Table 4-1: “List of Connections from MPC821ADS to S1D13A05” on page 16 shows the connections between the pins and signals of the MPC82x and the S1D13A05.

Note

The interface was designed using a Motorola MPC821 Application Development System (ADS). The ADS board has 5 volt logic connected to the data bus, so the interface included two 74F245 octal buffers on D[0:15] between the ADS and the S1D13A05. In a true 3 volt system, no buffering is necessary.

4.2 MPC821ADS Evaluation Board Hardware Connections

The following table details the connections between the pins and signals of the MPC821 and the S1D13A05.

Table 4-1: List of Connections from MPC821ADS to S1D13A05

| MPC821 Signal Name | MPC821ADS Connector and Pin Name | S1D13A05 Signal Name |
|--------------------|----------------------------------|----------------------|
| 2.0V (see note 1) | P9-D24 | COREVDD |
| 3.3V | P9-A22 | IOVDD |
| A14 (see note 2) | P6-C20 | AB17 |
| A15 (see note 2) | P6-D20 | AB16 |
| A16 (see note 2) | P6-B24 | AB15 |
| A17 (see note 2) | P6-C24 | AB14 |
| A18 (see note 2) | P6-D23 | AB13 |
| A19 (see note 2) | P6-D22 | AB12 |
| A20 (see note 2) | P6-D19 | AB11 |
| A21 (see note 2) | P6-A19 | AB10 |
| A22 (see note 2) | P6-D28 | AB9 |
| A23 (see note 2) | P6-A28 | AB8 |
| A24 (see note 2) | P6-C27 | AB7 |
| A25 (see note 2) | P6-A26 | AB6 |
| A26 (see note 2) | P6-C26 | AB5 |
| A27 (see note 2) | P6-A25 | AB4 |
| A28 (see note 2) | P6-D26 | AB3 |
| A29 (see note 2) | P6-B25 | AB2 |
| A30 (see note 2) | P6-B19 | AB1 |
| A31 (see note 2) | P6-D17 | AB0 |
| D0 (see note 3) | P12-A9 | D15 |
| D1 (see note 3) | P12-C9 | D14 |
| D2 (see note 3) | P12-D9 | D13 |
| D3 (see note 3) | P12-A8 | D12 |
| D4 (see note 3) | P12-B8 | D11 |
| D5 (see note 3) | P12-D8 | D10 |
| D6 (see note 3) | P12-B7 | D9 |
| D7 (see note 3) | P12-C7 | D8 |
| D8 (see note 3) | P12-A15 | D7 |
| D9 (see note 3) | P12-C15 | D6 |
| D10 (see note 3) | P12-D15 | D5 |
| D11 (see note 3) | P12-A14 | D4 |
| D12 (see note 3) | P12-B14 | D3 |
| D13 (see note 3) | P12-D14 | D2 |
| D14 (see note 3) | P12-B13 | D1 |
| D15 (see note 3) | P12-C13 | D0 |

Table 4-1: List of Connections from MPC821ADS to S1D13A05 (Continued)

| MPC821 Signal Name | MPC821ADS Connector and Pin Name | S1D13A05 Signal Name |
|--------------------|---|----------------------|
| SRESET | P9-D15 | RESET# |
| SYSCLK | P9-C2 | CLKI |
| CS4 | P6-D13 | CS# |
| TA | P6-B6 to inverter enabled by CS# | WAIT# |
| WE0 | P6-B15 | WE1# |
| WE1 | P6-A14 | WE0# |
| OE | P6-B16 | RD/WR#, RD# |
| A13 | P6-C21 | M/R# |
| GND | P12-A1, P12-B1, P12-A2, P12-B2, P12-A3, P12-B3, P12-A4, P12-B4, P12-A5, P12-B5, P12-A6, P12-B6, P12-A7 | Vss |

Note

1. The PCMCIA connector (P9) provides 2.0V on D[23:25] and can be used as the source for COREVDD. However, at 2.0V the S1D13A05 MCLK has a maximum frequency of 30MHz. To increase memory performance (MCLK maximum = 50MHz) an external 2.5V power supply must be connected to COREVDD.
2. The bit numbering of the Motorola MPC821 bus signals is reversed from the normal convention, e.g.: the most significant address bit is A0, the next is A1, A2, etc.
3. The bit numbering of the Motorola MPC821 data signals is reversed from the normal convention, e.g.: the most significant address bit is D0, the next is D1, D2, etc.

4.3 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to Motorola MPC82x microprocessor.

Table 4-2: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|---|-----------------------------------|------|------------------------|------|----------|---|---|---|---|------------------------|--|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: | | | | | | | | | | | |
| | <table border="1"> <thead> <tr> <th>CNF4</th> <th>CNF2</th> <th>CNF1</th> <th>CNF0</th> <th>Host Bus</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td>1</td> <td>1</td> <td>Generic #1, Big Endian</td> </tr> </tbody> </table> | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 1 | 0 | 1 | 1 | Generic #1, Big Endian | |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 1 | 0 | 1 | 1 | Generic #1, Big Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |

configuration for Motorola MPC82x microprocessor

4.4 Register/Memory Mapping

The DRAM on the MPC821 ADS board extends from address 0 through 3F FFFFh, so the S1D13A05 is addressed starting at 40 0000h. The S1D13A05 uses two 256K byte blocks which are selected using A13 from the MPC821 (A13 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block.

4.5 MPC82x Chip Select Configuration

Chip select 4 is used to control the S1D13A05. The following options are selected in the base address register (BR4).

- BA (0:16) = 0000 0000 0100 0000 0 – set starting address of S1D13A05 to 40 0000h
- AT (0:2) = 0 – ignore address type bits.
- PS (0:1) = 1:0 – memory port size is 16 bits
- PARE = 0 – disable parity checking
- WP = 0 – disable write protect
- MS (0:1) = 0:0 – select General Purpose Chip Select module to control this chip select
- V = 1 – set valid bit to enable chip select

The following options were selected in the option register (OR4).

- AM (0:16) = 1111 1111 1100 0000 0 – mask all but upper 10 address bits; S1D13A05 consumes 4M byte of address space
- ATM (0:2) = 0 – ignore address type bits
- CSNT = 0 – normal $\overline{\text{CS}}/\overline{\text{WE}}$ negation
- ACS (0:1) = 1:1 – delay $\overline{\text{CS}}$ assertion by $\frac{1}{2}$ clock cycle from address lines
- BI = 1 – assert Burst Inhibit
- SCY (0:3) = 0 – wait state selection; this field is ignored since external transfer acknowledge is used; see SETA below
- SETA = 1 – the S1D13A05 generates an external transfer acknowledge using the WAIT# line
- TRLX = 0 – normal timing
- EHTR = 0 – normal timing

4.6 Test Software

The test software to exercise this interface is very simple. It configures chip select 4 (CS4) on the MPC82x to map the S1D13A05 to an unused 512K byte block of address space and loads the appropriate values into the option register for CS4. Then the software runs a tight loop reading the S1D13A05 Revision Code Register REG[00h]. This allows monitoring of the bus timing on a logic analyzer.

The following source code was entered into the memory of the MPC821ADS using the line-by-line assembler in MPC8BUG (the debugger provided with the ADS board). Once the program was executed on the ADS, a logic analyzer was used to verify operation of the interface hardware.

It is important to note that when the MPC821 comes out of reset, its on-chip caches and MMU are disabled. If the data cache is enabled, then the MMU must be set up so that the S1D13A05 memory block is tagged as non-cacheable, to ensure that accesses to the S1D13A05 occurs in proper order, and also to ensure that the MPC821 does not attempt to cache any data read from or written to the S1D13A05 or its display buffer.

The source code for this test routine is as follows:

```
BR4      equ      $120          ; CS4 base register
OR4      equ      $124          ; CS4 option register
MemStart equ      $44 0000      ; address of S1D13A05 display buffer
RevCodeReg equ     $40 0000      ; address of Revision Code Register

Start    mfspr      r1,IMMR      ; get base address of internal registers
         andis.     r1,r1,$ffff   ; clear lower 16 bits to 0
         andis.     r2,r0,0       ; clear r2
         oris      r2,r2,MemStart ; write base address
         ori       r2,r2,$0801    ; port size 16 bits; select GPCM; enable
         stw       r2,BR4(r1)    ; write value to base register
         andis.     r2,r0,0       ; clear r2
         oris      r2,r2,$ffc0    ; address mask - use upper 10 bits
         ori       r2,r2,$0708    ; normal CS negation; delay CS ½ clock;
                                   ; inhibit burst
         stw       r2,OR4(r1)    ; write to option register
         andis.     r1,r0,0       ; clear r1
         oris      r1,r1,MemStart ; point r1 to start of S1D13A05 mem space
Loop     lbz       r0,RevCodeReg(r1) ; read revision code into r1
         b         Loop          ; branch forever

end
```

Note

MPC8BUG does not support comments or symbolic equates. These have been added for clarity only.

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- Motorola Inc., *Power PC MPC821 Portable Systems Microprocessor User's Manual*, Motorola Publication no. MPC821UM/; available on the Internet at http://www.mot.com/SPS/ADC/pps/_subpgs/_documentation/821/821UM.html.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.

6.2 Document Sources

- Motorola Inc. Literature Distribution Center: (800) 441-2447.
- Motorola Inc. Website: www.mot.com.
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S1D13A05 LCD/USB Companion Chip

Interfacing to the Motorola MCF5307 "ColdFire" Microprocessor

Document Number: X40A-G-010-01

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1 Introduction

This application note describes the hardware and software environment required to interface the S1D13A05 LCD/USB Companion Chip and the Motorola MCF5307 “Coldfire” Processor.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

2 Interfacing to the MCF5307

2.1 The MCF5307 System Bus

The MCF5200/5300 family of processors feature a high-speed synchronous system bus typical of modern microprocessors. This section is an overview of the operation of the CPU bus in order to establish interface requirements.

2.1.1 Overview

The MCF5307 microprocessor family uses a synchronous address and data bus, very similar in architecture to the MC68040 and MPC8xx. All outputs and inputs are timed with respect to a square-wave reference clock called BCLK0 (Master Clock). This clock runs at a software-selectable divisor rate from the machine cycle speed of the CPU core (typically 20 to 33 MHz). Both the address and the data bus are 32 bits in width. All IO accesses are memory-mapped; there is no separate IO space in the Coldfire architecture.

The bus can support two types of cycles, normal and burst. Burst memory cycles are used to fill on-chip cache memories, and for certain on-chip DMA operations. Normal cycles are used for all other data transfers.

2.1.2 Normal (Non-Burst) Bus Transactions

A data transfer is initiated by the bus master by placing the memory address on address lines A31 through A0 and driving \overline{TS} (Transfer Start) low for one clock cycle. Several control signals are also provided with the memory address:

- $SIZ[1:0]$ (Transfer Size) — indicates whether the bus cycle is 8, 16, or 32-bit.
- R/\overline{W} — set high for read cycles and low for write cycles.
- $TT[1:0]$ (Transfer Type Signals) — provides more detail on the type of transfer being attempted.
- \overline{TIP} (Transfer In Progress) — asserts whenever a bus cycle is active.

When the peripheral device being accessed has completed the bus transfer, it asserts \overline{TA} (Transfer Acknowledge) for one clock cycle to complete the bus transaction. Once \overline{TA} has been asserted, the MCF5307 will not start another bus cycle until \overline{TA} has been de-asserted. The minimum length of a bus transaction is two bus clocks.

Figure 2-1: "MCF5307 Memory Read Cycle," illustrates a typical memory read cycle on the MCF5307 system bus.

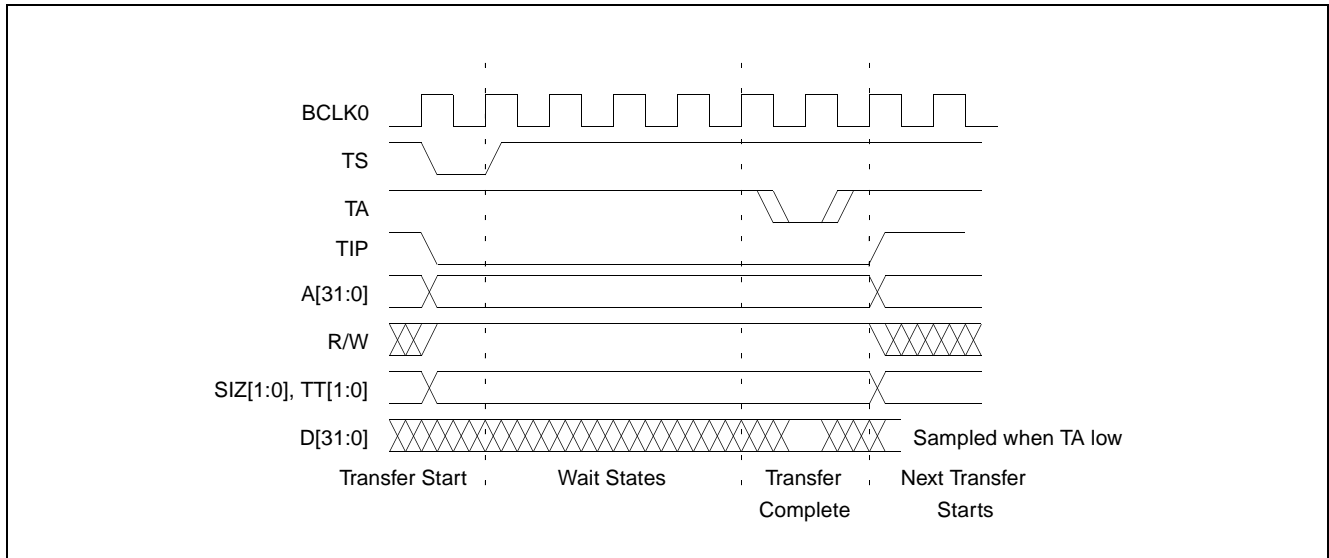


Figure 2-1: MCF5307 Memory Read Cycle

Figure 2-2: "MCF5307 Memory Write Cycle," illustrates a typical memory write cycle on the MCF5307 system bus.

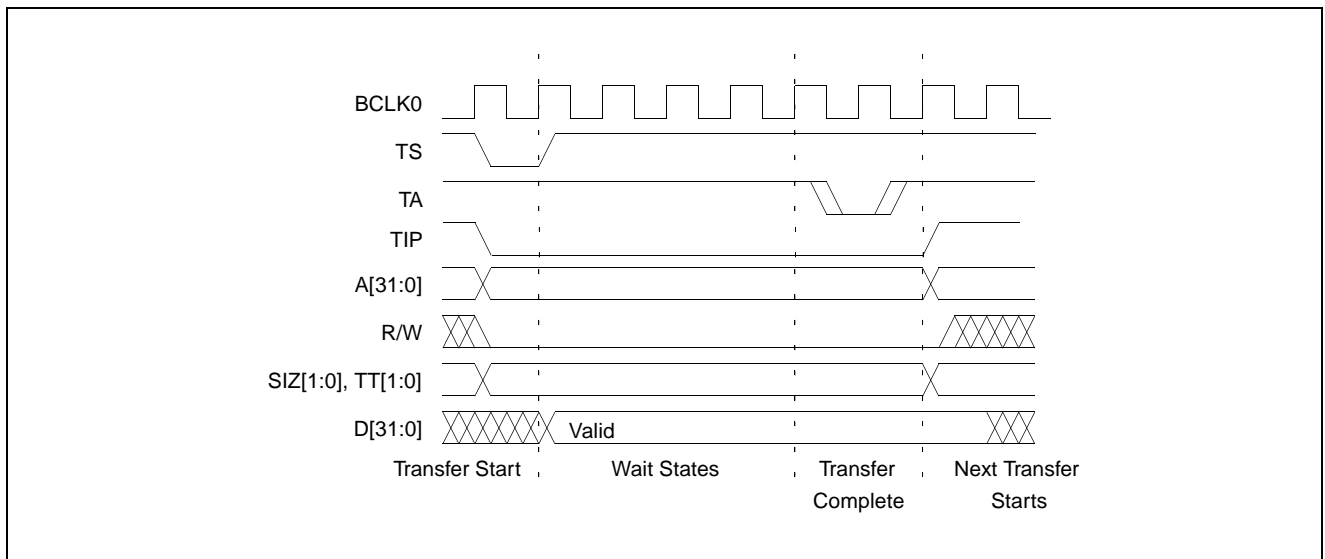


Figure 2-2: MCF5307 Memory Write Cycle

2.1.3 Burst Cycles

Burst cycles are very similar to normal cycles, except that they occur as a series of four back-to-back, 32-bit memory reads or writes. The \overline{TIP} (Transfer In Progress) output is asserted continuously through the burst. Burst memory cycles are mainly intended to fill

caches from program or data memory. They are typically not used for transfers to or from IO peripheral devices such as the S1D13A05. The MCF5307 chip selects provide a mechanism to disable burst accesses for peripheral devices which are not burst capable.

2.2 Chip-Select Module

In addition to generating eight independent chip-select outputs, the MCF5307 Chip Select Module can generate active-low Output Enable (\overline{OE}) and Write Enable (\overline{BWE}) signals compatible with most memory and x86-style peripherals. The MCF5307 bus controller also provides a Read/Write (R/\overline{W}) signal which is compatible with most 68K peripherals.

Chip selects 0 and 1 can be programmed independently to respond to any base address and block size. Chip select 0 can be active immediately after reset, and is typically used to control a boot ROM. Chip select 1 is likewise typically used to control a large static or dynamic RAM block.

Chip selects 2 through 7 have fixed block sizes of 2M bytes each. Each has a unique, fixed offset from a common, programmable starting address. These chip selects are well-suited to typical IO addressing requirements.

Each chip select may be individually programmed for:

- port size (8/16/32-bit).
- up to 15 wait states or external acknowledge.
- address space type.
- burst or non-burst cycle support.
- write protect.

Figure 2-3: “Chip Select Module Outputs Timing” illustrates a typical cycle for a memory mapped device using the GPCM of the Power PC.

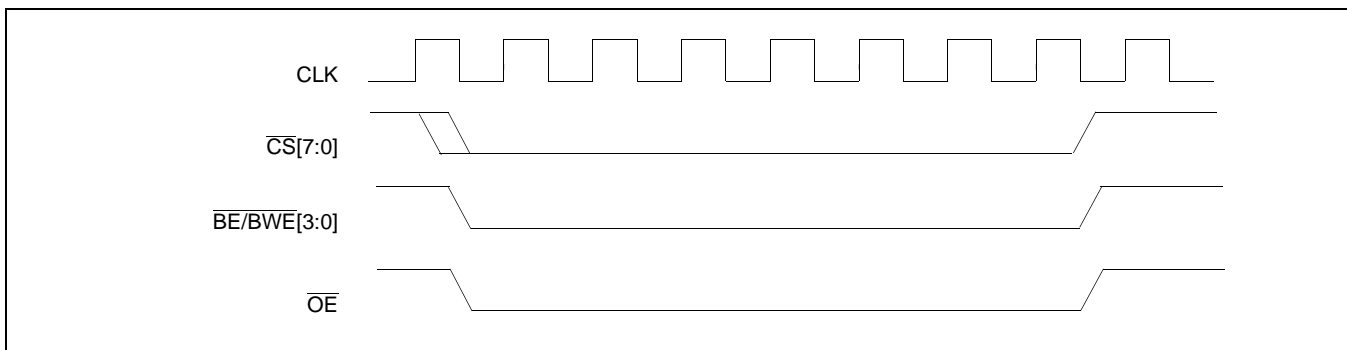


Figure 2-3: Chip Select Module Outputs Timing

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #1 Host Bus Interface which is most suitable for direct connection to the Motorola MFC5307 microprocessor. Generic #1 supports a Chip Select and an individual Read Enable/Write Enable for each byte.

The Generic #1 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After RESET# is released, the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.2, "S1D13A05 Hardware Configuration" on page 14.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | Motorola MCF5307 |
|--------------------|--|
| AB[17:0] | A[17:0] |
| DB[15:0] | D[31:16] |
| WE1# | $\overline{\text{BWE1}}$ |
| CS# | $\overline{\text{CS4}}$ |
| M/R# | A18 |
| CLKI | BCLK0 |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | $\overline{\text{OE}}$ |
| RD# | $\overline{\text{OE}}$ |
| WE0# | $\overline{\text{BWE0}}$ |
| WAIT# | $\overline{\text{TA}}$ |
| RESET# | system $\overline{\text{RESET}}$ |

3.2 Host Bus Interface Signals

The Host Bus Interface requires the following signals.

- CLKI is a clock input which is required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For this example, BCLK0 from the Motorola MCF5307 is used for CLKI.
- The address inputs AB[17:0] connect directly to the MCF5307 address bus (A[17:0]).
- DB[7:0] connects D[23:16] (the MCF5307 low order byte). DB[15:8] connects to D[31:24] (the MCF5307 high order byte). CNF4 must be set to select big endian mode.
- Chip Select (CS#) must be driven low by $\overline{\text{CS4}}$ whenever the S1D13A05 is accessed by the Motorola MCF5307.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A18, allowing system address A18 to select between memory or register accesses.
- WE0# connects to $\overline{\text{BWE0}}$ (the low byte enable signal from the MCF5307) and must be driven low when the MCF5307 is writing the low byte to the S1D13A05.
- WE1# connects to $\overline{\text{BWE1}}$ (the high byte enable signal from the MCF5307) and must be driven low when the MCF5307 is writing the high byte to the S1D13A05.
- RD# and RD/WR# are read enables for the low-order and high-order bytes, respectively. Both signals are driven low by $\overline{\text{OE}}$ when the Motorola MCF5307 is reading data from the S1D13A05.
- WAIT# connects to $\overline{\text{TA}}$ and is a signal which is output from the S1D13A05 that indicates the host CPU must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. Since host CPU accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or refresh memory. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete. This signal is active low and may need to be inverted if the host CPU wait state signal is active high.
- The Bus Status (BS#) signal is not used in the bus interface for Generic #1 mode and must be tied high to IO V_{DD} .

4 MCF5307 To S1D13A05 Interface

4.1 Hardware Description

The interface between the S1D13A05 and the MCF5307 requires no external glue logic. The polarity of the WAIT# signal must be selected as active high by connecting CNF5 to IO V_{DD} (see Table 4-1: "Summary of Power-On/Reset Options," on page 14).

The following diagram shows a typical implementation of the MCF5307 to S1D13A05 interface.

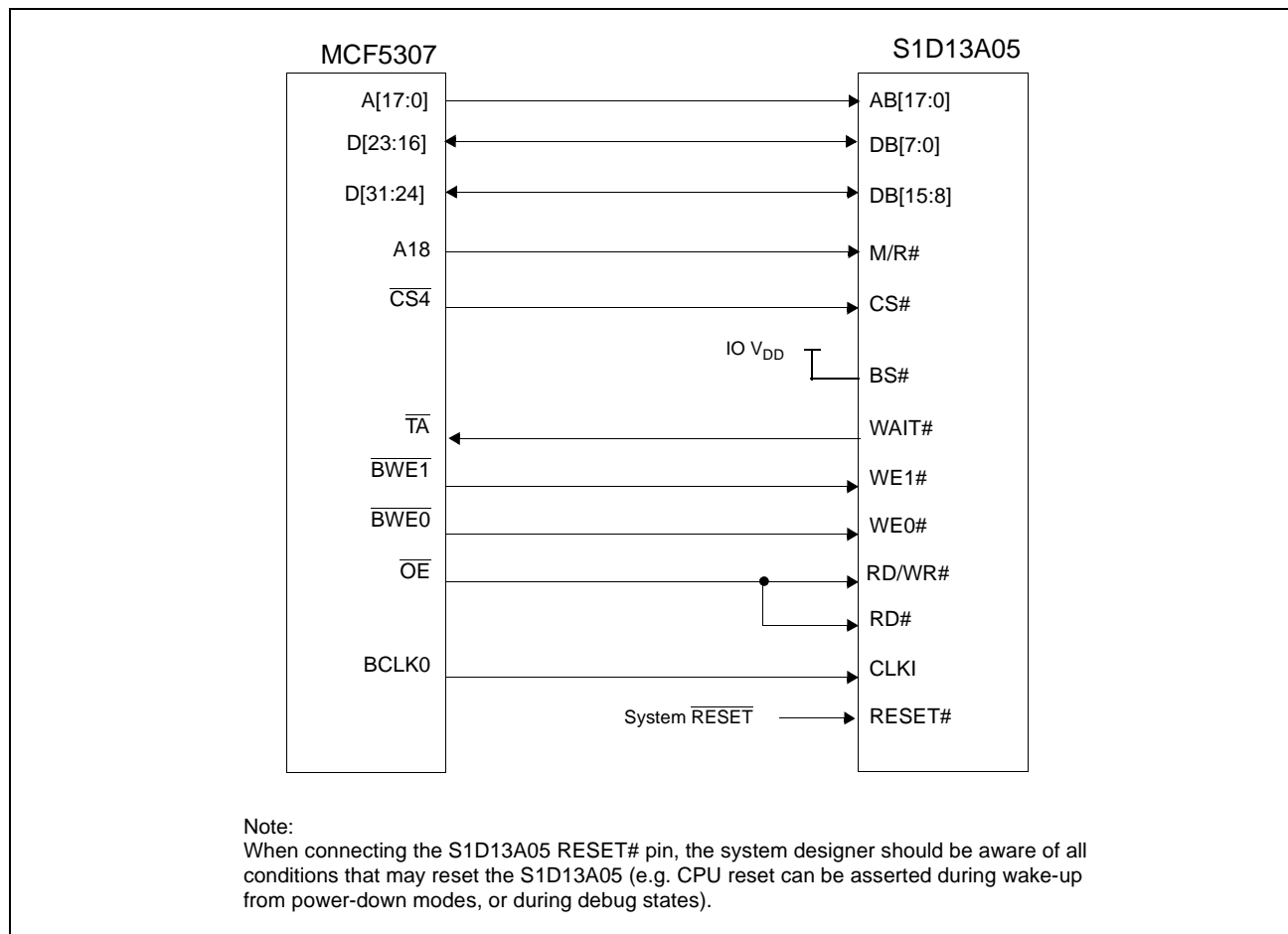


Figure 4-1: Typical Implementation of MCF5307 to S1D13A05 Interface

4.2 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to Motorola MFC5307 microprocessor.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|---|-----------------------------------|------|------------------------|------|----------|---|---|---|---|------------------------|--|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: | | | | | | | | | | | |
| | <table border="1"> <thead> <tr> <th>CNF4</th> <th>CNF2</th> <th>CNF1</th> <th>CNF0</th> <th>Host Bus</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>0</td> <td>1</td> <td>1</td> <td>Generic #1, Big Endian</td> </tr> </tbody> </table> | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 1 | 0 | 1 | 1 | Generic #1, Big Endian | |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 1 | 0 | 1 | 1 | Generic #1, Big Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |
| | configuration for Motorola MFC5307 microprocessor | | | | | | | | | | | |

4.3 Register/Memory Mapping

The S1D13A05 uses two 256K byte blocks which are selected using A18 from the MCF5307 (A18 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block. These two blocks of memory are aliased over the entire 2M byte space.

Note

If aliasing is not desirable, the upper addresses must be fully decoded.

4.4 MCF5307 Chip Select Configuration

Chip Selects 0 and 1 have programmable block sizes from 64K bytes through 2G bytes. However, these chip selects would normally be needed to control system RAM and ROM. Therefore, one of the IO chip selects CS2 through CS7 is required to address the entire address space of the S1D13A05. These IO chip selects have a fixed, 2M byte block size. In the example interface, chip select 4 is used to control the S1D13A05. The CSBAR register should be set to the upper 8 bits of the desired base address.

The following options should be selected in the chip select mask registers (CSMR4/5).

- WP = 0 – disable write protect
- AM = 0 - enable alternate bus master access to the S1D13A05
- C/I = 1 - disable CPU space access to the S1D13A05
- SC = 1 - disable Supervisor Code space access to the S1D13A05
- SD = 0 - enable Supervisor Data space access to the S1D13A05
- UC = 1 - disable User Code space access to the S1D13A05
- UD = 0 - enable User Data space access to the S1D13A05
- V = 1 - global enable (“Valid”) for the chip select

The following options should be selected in the chip select control registers (CSCR4/5).

- WS0-3 = 0 - no internal wait state setting
- AA = 0 - no automatic acknowledgment
- PS (1:0) = 1:0 – memory port size is 16 bits
- BEM = 0 – Byte enable/write enable active on writes only
- BSTR = 0 – disable burst reads
- BSTW = 0 – disable burst writes

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- Motorola Inc., *MCF5307 ColdFire® Integrated Microprocessor User's Manual*, Motorola Publication no. MCF5307UM; available on the Internet at <http://www.mot.com/SPS/HPESD/prod/coldfire/5307UM.html>.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, document number X40A-G-003-xx.

6.2 Document Sources

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1 Introduction

This application note describes the hardware and software environment required to interface the S1D13A05 LCD/USB Companion Chip and the Motorola MC68VZ328 Dragonball VZ microprocessor.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

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2 Interfacing to the MC68VZ328

2.1 The MC68VZ328 System Bus

The Motorola MC68VZ328 “Dragonball VZ” is the third generation in the Dragonball microprocessor family. The Dragonball VZ is an integrated controller designed for handheld products. It is based upon the FLX68000 microprocessor core and uses a 24-bit address bus and 16-bit data bus. The Dragonball VZ is faster than its predecessors and the DRAM controller now supports SDRAM. The bus interface consists of all the standard MC68000 bus interface signals except \overline{AS} , plus some new signals intended to simplify the interface to typical memory and peripheral devices. The 68000 signals are multiplexed with IrDA, SPI and LCD controller signals.

The MC68000 bus control signals are well documented in the Motorola user manuals, and are not be described here. The new signals are as follows.

- Output Enable (\overline{OE}) is asserted when a read cycle is in progress. It is intended to connect to the output enable control signal of a typical static RAM, EPROM, or Flash EPROM device.
- Upper Write Enable and Lower Write Enable (\overline{UWE} / \overline{LWE}) are asserted during memory write cycles for the upper and lower bytes of the 16-bit data bus. They may be directly connected to the write enable inputs of a typical memory device.

2.2 Chip-Select Module

The MC68VZ328 can generate up to 8 chip select outputs which are organized into four groups (A through D).

Each chip select group has a common base address register and address mask register allowing the base address and block size of the entire group to be set. In addition, each chip select within a group has its own address compare and address mask register to activate the chip select for a subset of the group’s address block. Each chip select may also be individually programmed to control an 8 or 16-bit device. Lastly, each chip select can either generate from 0 through 6 wait states internally, or allow the memory or peripheral device to terminate the cycle externally using the standard MC68000 \overline{DTACK} signal.

Chip select groups A and B are used to control ROM, SRAM, and Flash memory devices and have a block size of 128K bytes to 16M bytes. Chip select A0 is active immediately after reset and is a global chip select so it is typically used to control a boot EPROM device. A0 ceases to decode globally once its chip select registers are programmed. Groups C and D are special in that they can also control DRAM interfaces. These last two groups have block size of 32K bytes to 4M bytes.

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a Dragonball Host Bus Interface which directly supports the Motorola MC68VZ328 microprocessor.

The Dragonball Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After RESET# is released, the bus interface signals assume their selected configuration. For details on the S1D13A05 configuration, see Section 4.2, “S1D13A05 Hardware Configuration” on page 12.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Names | Motorola MC68VZ328 |
|--------------------|--|
| AB[17:0] | A[17:0] |
| DB[15:0] | D[15:0] |
| WE1# | \overline{UWE} |
| CS# | \overline{CSx} |
| M/R# | External Decode |
| CLKI | CLKO |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | Connect to IO _{VDD} from the S1D13A05 |
| RD# | \overline{OE} |
| WE0# | \overline{LWE} |
| WAIT# | \overline{DTACK} |
| RESET# | System \overline{RESET} |

3.2 Host Bus Interface Signals

The Host Bus Interface requires the following signals.

- CLKI is a clock input required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For this example, CLK0 from the Motorola MC68VZ328 is used for CLKI.
- The address inputs AB[17:0], and the data bus DB[15:0], connect directly to the MC68VZ328 address (A[17:0]) and data bus (D[15:0]), respectively. CNF4 must be set to one to select big endian mode.
- Chip Select (CS#) must be driven low by one of the Dragonball VZ chip select outputs from the chip select module whenever the S1D13A05 is accessed by the MC68VZ328.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A18, allowing system address A18 to select between memory or register accesses.
- WE0# connects to $\overline{\text{LWE}}$ (the low data byte write strobe enable of the MC68VZ328) and is asserted when valid data is written to the low byte of a 16-bit device.
- WE1# connects to $\overline{\text{UWE}}$ (the upper data byte write strobe enable of the MC68VZ328) and is asserted when valid data is written to the high byte of a 16-bit device.
- RD# connects to $\overline{\text{OE}}$ (the read output enable of the MC68VZ328) and is asserted during a read cycle of the MC68VZ328 microprocessor.
- RD/WR# is not used for the Dragonball host bus interface and must be tied high to IO V_{DD} .
- WAIT# connects to $\overline{\text{DTACK}}$ and is a signal which is output from the S1D13A05 indicating the MC68VZ328 must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. MC68VZ328 accesses to the S1D13A05 may occur asynchronously to the display update.
- BS# is not used for the Dragonball host bus interface and must be tied high to IO V_{DD} .

4 MC68VZ328 to S1D13A05 Interface

4.1 Hardware Description

The interface between the S1D13A05 and the MC68VZ328 does not require any external glue logic. Chip select module B is used to provide the S1D13A05 with a chip select and A18 is used to select between memory and register accesses.

In this example, the \overline{DTACK} signal is made available for the S1D13A05. Alternately, the S1D13A05 can guarantee a maximum cycle length that the Dragonball VZ handles by inserting software wait states (see Section 4.2.2, “MC68VZ328 Chip Select and Pin Configuration” on page 13). A single resistor is used to speed up the rise time of the WAIT# (\overline{DTACK}) signal when terminating the bus cycle.

The following diagram shows a typical implementation of the MC68VZ328 to S1D13A05 using the Dragonball host bus interface. For further information on the Dragonball Host Bus interface and AC Timing, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

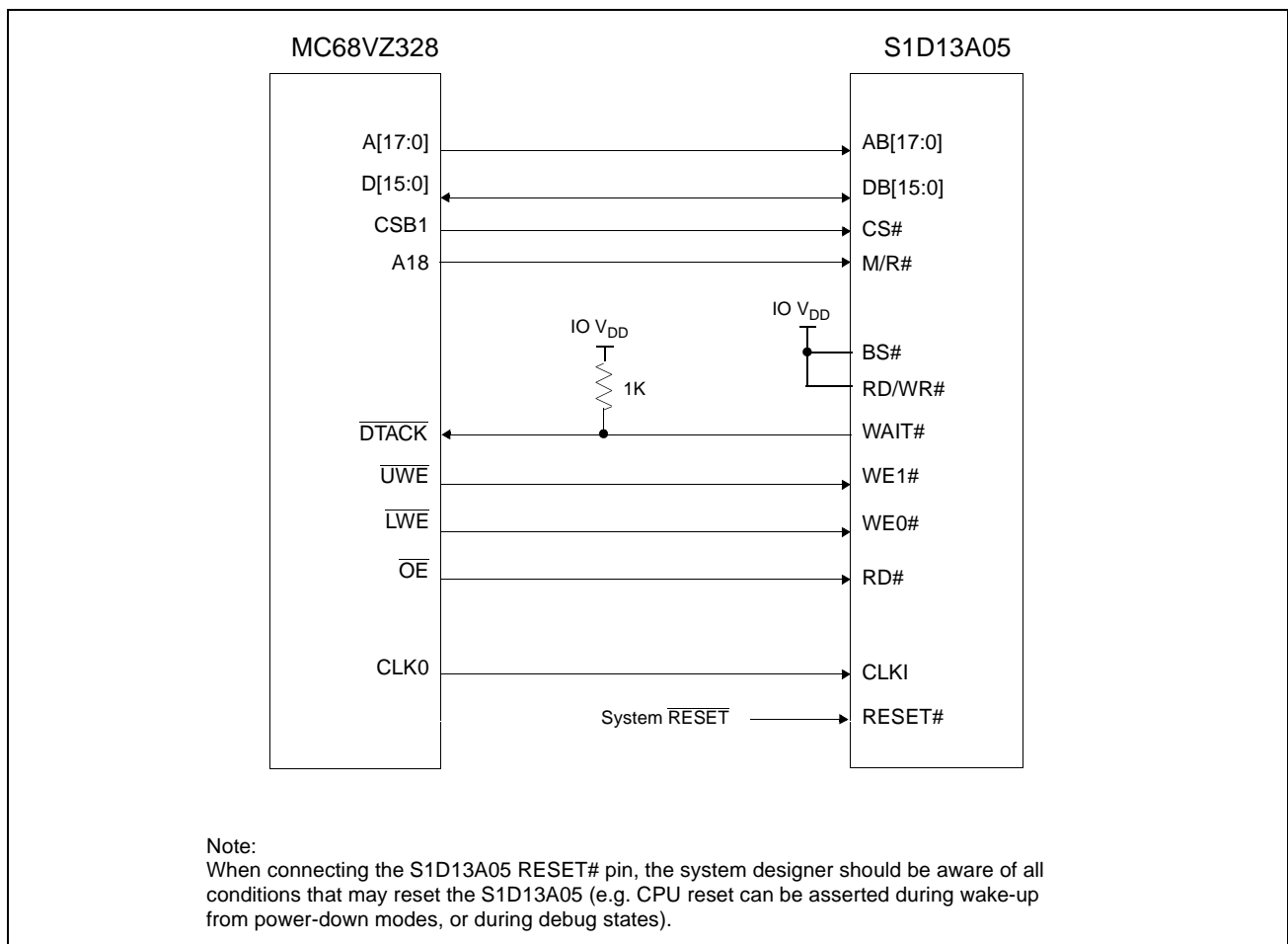


Figure 4-1: Typical Implementation of MC68VZ328 to S1D13A05 Interface

4.2 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to Motorola MC68VZ328 microprocessor.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|---|-----------------------------------|------|----------------------------------|------|----------|---|---|---|---|----------------------------------|--|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: | | | | | | | | | | | |
| | <table border="1"> <thead> <tr> <th>CNF4</th> <th>CNF2</th> <th>CNF1</th> <th>CNF0</th> <th>Host Bus</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>1</td> <td>1</td> <td>0</td> <td>Dragonball Interface, Big Endian</td> </tr> </tbody> </table> | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 1 | 1 | 1 | 0 | Dragonball Interface, Big Endian | |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 1 | 1 | 1 | 0 | Dragonball Interface, Big Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |
| | configuration for Motorola MC68VZ328 microprocessor | | | | | | | | | | | |

4.2.1 Register/Memory Mapping

The S1D13A05 requires two 256K byte segments in memory for the display buffer and its internal registers. To accommodate this block size, it is preferable (but not required) to use one of the chip selects from groups A or B. Groups A and B can have a size range of 128K bytes to 16M bytes and groups C and D have a size range of 32K bytes to 16M bytes. Therefore, any chip select other than CSA0 would be suitable for the S1D13A05 interface.

In the example interface, chip select CSB1 controls the S1D13A05. A 512K byte address space is used by setting the SIZ bits of Chip Select Register B (FFFFF116h) to 512k bytes. The S1D13A05 internal registers occupy the first 256K byte block and the 256K byte display buffer is located in the second 256K byte block. A18 from the MC68VZ328 is used to select between these two 256K byte blocks.

4.2.2 MC68VZ328 Chip Select and Pin Configuration

The chip select used to map the S1D13A05 (in this example CSB1) must have its RO (Read Only) bit set to 0, its BSW (Bus Data Width) set to 1 for a 16-bit bus, and the WS (Wait states) bits should be set to 111b to allow the S1D13A05 to terminate bus cycles externally with \overline{DTACK} . The \overline{DTACK} pin function must be enabled with Register FFFFF433, Port G Select Register, bit 0.

If Chip Select Group B is used as the chip select module for the S1D13A05, SRAM timing must be enabled by setting the Chip Select Control Register 1 (FFFFF10Ah) SR16 bit = 0b.

Early cycle detection for static memory must be disabled by setting the Chip Select Control Register 2 (FFFFF10Ch) ECDS bit = 0b.

If \overline{DTACK} is not used, then the WS bits should be set to either 4, 6, 10, or 12 software wait states depending on the divide ratio between the S1D13A05 MCLK and BCLK. The WS bits should be set as follows.

Table 4-2: WS Bit Programming

| S1D13A05 MCLK to BCLK Divide Ratio | WS Bits (wait states) |
|------------------------------------|-----------------------|
| MCLK = BCLK | 4 |
| MCLK = BCLK ÷ 2 | 6 |
| MCLK = BCLK ÷ 3 | 10 |
| MCLK = BCLK ÷ 4 | 12 |

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or at www.erd.epson.com.

6 References

6.1 Documents

- Motorola Inc., *MC68VZ328 DragonBall-VZ® Integrated Processor User's Manual*, Motorola Publication no. MC683VZ28UM; available on the Internet at <http://www.mot.com/SPS/WIRELESS/products/MC68VZ328.html>.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.

6.2 Document Sources

- Motorola Inc. Literature Distribution Center: (800) 441-2447.
- Motorola Inc. Website: www.mot.com.
- Epson Research and Development Website: www.erd.epson.com.

7 Sales and Technical Support

7.1 EPSON LCD/USB Companion Chips (S1D13A05)

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Seiko Epson Corporation
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Tel: 042-587-5812
Fax: 042-587-5564
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Temasek Avenue #36-00
Millenia Tower
Singapore, 039192
Tel: 337-7911
Fax: 334-2716
<http://www.epson.com.sg/>

7.2 Motorola MC68VZ328 Processor

- Motorola Design Line, (800) 521-6274.
- Local Motorola sales office or authorized distributor.

EPSON®



S1D13A05 LCD/USB Companion Chip

Interfacing to the Intel StrongARM SA-1110 Microprocessor

Document Number: X40A-G-013-01

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1 Introduction

This application note describes the hardware and software environment required to provide an interface between the S1D13A05 LCD/USB Companion Chip and the Intel StrongARM SA-1110 Microprocessor.

The designs described in this document are presented only as examples of how such interfaces might be implemented. This application note is updated as appropriate. Please check the Epson Research and Development website at www.erd.epson.com for the latest revision of this document before beginning any development.

We appreciate your comments on our documentation. Please contact us via email at documentation@erd.epson.com.

2 Interfacing to the StrongARM SA-1110 Bus

2.1 The StrongARM SA-1110 System Bus

The StrongARM SA-1110 microprocessor is a highly integrated communications microprocessor that incorporates a 32-bit StrongARM RISC processor core. The SA-1110 is ideally suited to interface to the S1D13A05 LCD controller and provides a high performance, power efficient solution for embedded systems.

2.1.1 StrongARM SA-1110 Overview

The SA-1110 system bus can access both variable-latency IO and memory devices. The SA-1110 uses a 26-bit address bus and a 32-bit data bus which can be used to access 16-bit devices. A chip select module with six chip select signals (each accessing 64M bytes of memory) allows selection of external devices. Only chip selects 3 through 5 (nCS[5:3]) may be used to select variable-latency devices which use RDY to extend access cycles. These chip selects are individually programmed in the SA-1110 memory configuration registers and can be configured for either a 16 or 32-bit data bus.

Byte steering is implemented using the four signals nCAS[3:0]. Each signal selects a byte on the 32-bit data bus. For example, nCAS0 selects bits D[7:0] and nCAS3 selects bits D[31:24]. For a 16-bit data bus, only nCAS[1:0] are used with nCAS0 selecting the low byte and nCAS1 selecting the high byte. The SA-1110 can be configured to support little or big endian mode.

2.1.2 Variable-Latency IO Access Overview

A data transfer is initiated when a memory address is placed on the SA-1110 system bus **and** a chip select signal (nCS[5:3]) is driven low. If all byte enable signals (nCAS[3:0]) are driven low, then a 32-bit transfer takes place. If only nCAS[1:0] are driven low, then a word transfer takes place through a 16-bit bus interface. If only one byte enable is driven low, then a byte transfer takes place on the respective data lines.

During a read cycle, the output enable signal (nOE) is driven low. A write cycle is specified by driving nOE high and driving the write enable signal (nWE) low. The cycle can be lengthened by driving RDY high for the time needed to complete the cycle.

2.1.3 Variable-Latency IO Access Cycles

The first nOE assertion occurs two memory cycles after the assertion of chip select (nCS3, nCS4, or nCS5). Two memory cycles prior to the end of minimum nOE or nWE assertion (RDF+1 memory cycles), the SA-1110 starts sampling the data ready input (RDY).

Samples are taken every half memory cycle until **three consecutive samples** (at the rising edge, falling edge, and following rising edge of the memory clock) indicate that the IO device is ready for data transfer. Read data is latched one-half memory cycle after the third successful sample (on falling edge). Then nOE or nWE is deasserted on the next rising edge and the address may change on the subsequent falling edge. Prior to a subsequent data cycle, nOE or nWE remains deasserted for RDN+1 memory cycles. The chip select and byte selects (nCAS[1:0] for 16-bit data transfers), remain asserted for one memory cycle after the final nOE or nWE deassertion of the burst.

The SA-1110 is capable of burst cycles during which the chip select remains low while the read or write command is asserted, precharged and reasserted repeatedly.

Figure 2-1: illustrates a typical variable-latency IO access read cycle on the SA-1110 bus.

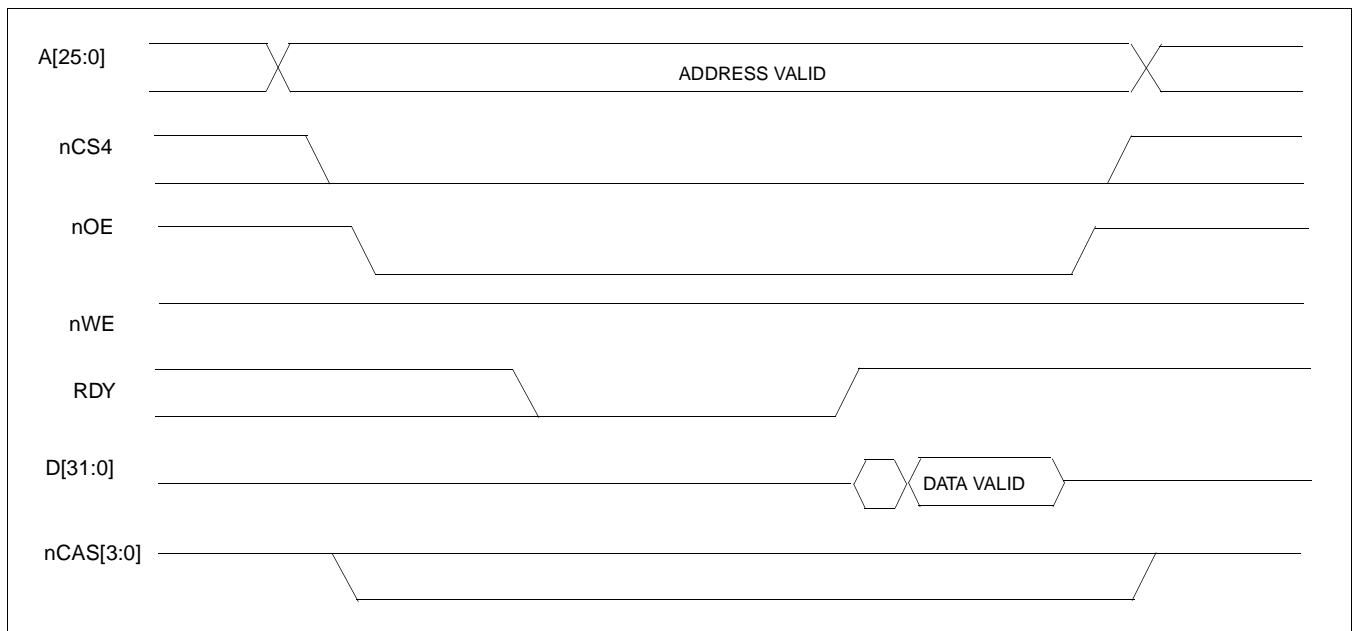
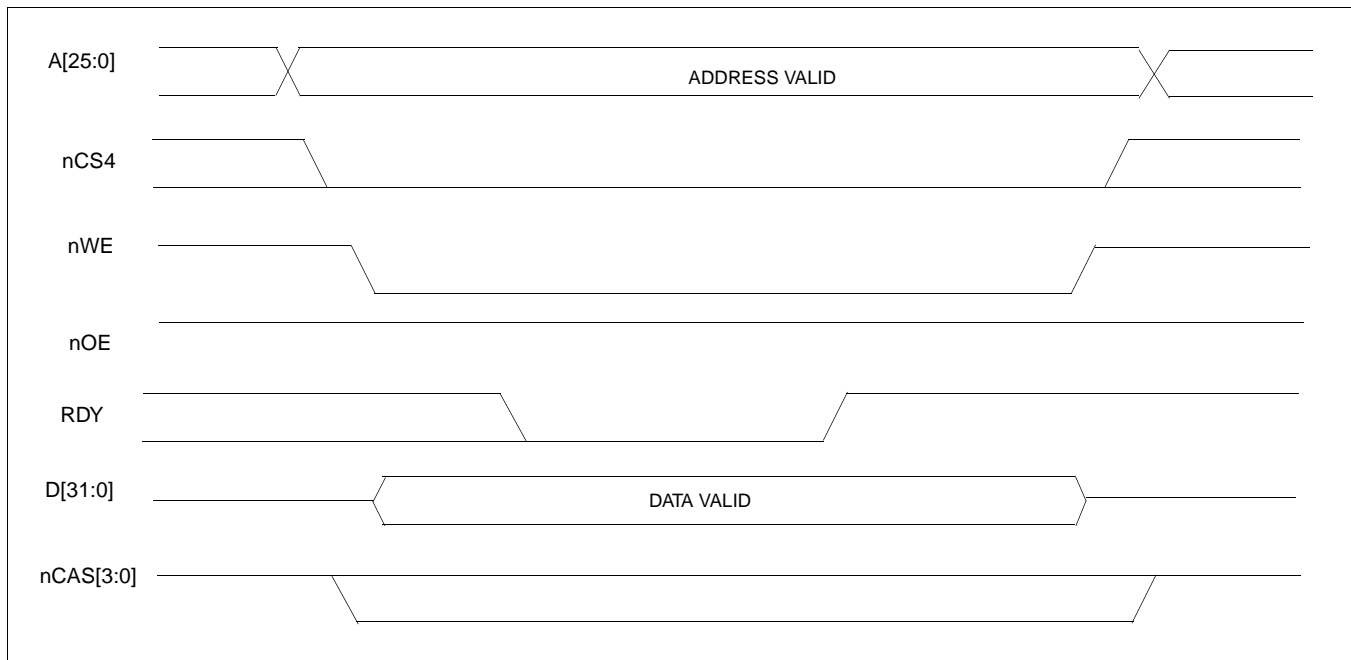


Figure 2-1: SA-1110 Variable-Latency IO Read Cycle

Figure 2-2: illustrates a typical variable-latency IO access write cycle on the SA-1110 bus.

*Figure 2-2: SA-1110 Variable-Latency IO Write Cycle*

3 S1D13A05 Host Bus Interface

The S1D13A05 directly supports multiple processors. The S1D13A05 implements a 16-bit Generic #2 Host Bus Interface which is most suitable for direct connection to the SA-1110.

The Generic #2 Host Bus Interface is selected by the S1D13A05 on the rising edge of RESET#. After releasing reset the bus interface signals assume their selected configuration. For details on S1D13A05 configuration, see Section 4.2, “S1D13A05 Hardware Configuration” on page 14.

3.1 Host Bus Interface Pin Mapping

The following table shows the functions of each Host Bus Interface signal.

Table 3-1: Host Bus Interface Pin Mapping

| S1D13A05 Pin Name | SA-1110 |
|-------------------|--|
| AB[17:0] | A[17:0] |
| DB[15:0] | D[15:0] |
| WE1# | nCAS1 |
| M/R# | A18 |
| CS# | nCS4 |
| CLKI | SDCLK2 |
| BS# | Connect to IO _{VDD} from the S1D13A05 |
| RD/WR# | Connect to IO _{VDD} from the S1D13A05 |
| RD# | nOE |
| WE0# | nWE |
| WAIT# | RDY |
| RESET# | system RESET |

3.2 Host Bus Interface Signal Descriptions

The S1D13A05 Generic #2 Host Bus Interface requires the following signals.

- CLKI is a clock input which is required by the S1D13A05 Host Bus Interface as a source for its internal bus and memory clocks. This clock is typically driven by the host CPU system clock. For this example, it is driven by one of the SA-1110 signals SDCLK1 or SDCLK2 (The example implementation in this document uses SDCLK2). For further information, see Section 4.3, “*StrongARM SA-1110 Register Configuration*” on page 15.
- The address inputs AB[17:0], and the data bus DB[15:0], connect directly to the SA-1110 address bus (A[17:0]) and data bus (D[15:0]), respectively. CNF4 must be set to select little endian mode.
- M/R# (memory/register) selects between memory or register accesses. This signal is generated by the external address decode circuitry. For this example, M/R# is connected to address line A18, allowing system address A18 to select between memory or register accesses.
- Chip Select (CS#) must be driven low by nCS_x (where x is the SA-1110 chip select used) whenever the S1D13A05 is accessed by the SA-1110.
- WE1# connects to nCAS1 (the high byte enable signal from the SA-1110) which in conjunction with address bit 0 allows byte steering of read and write operations.
- WE0# connects to nWE (the write enable signal from the SA-1110) and must be driven low when the SA-1110 is writing data to the S1D13A05.
- RD# connects to nOE (the read enable signal from the SA-1110) and must be driven low when the SA-1110 is reading data from the S1D13A05.
- WAIT# connects to RDY and is a signal output from the S1D13A05 that indicates the SA-1110 must wait until data is ready (read cycle) or accepted (write cycle) on the host bus. Since SA-1110 accesses to the S1D13A05 may occur asynchronously to the display update, it is possible that contention may occur in accessing the S1D13A05 internal registers and/or display buffer. The WAIT# line resolves these contentions by forcing the host to wait until the resource arbitration is complete.
- The Bus Start (BS#) and RD/WR# signals are not used for this Host Bus Interface and should be tied high (connected to IOV_{DD}).
- The RESET# (active low) input of the S1D13A05 may be connected to the system RESET.

4 StrongARM SA-1110 to S1D13A05 Interface

4.1 Hardware Description

The SA-1110 microprocessor provides a variable latency I/O interface that can be used to support an external LCD controller. By using the Generic # 2 Host Bus Interface, no glue logic is required to interface the S1D13A05 and the SA-1110.

A pull-up resistor is attached to WAIT# to speed up its rise time when terminating a cycle.

BS# (bus start) and RD/WR# are not used by the Generic #2 Host Bus Interface and should be tied high (connected to IO V_{DD}).

The following diagram shows a typical implementation of the SA-1110 to S1D13A05 interface.

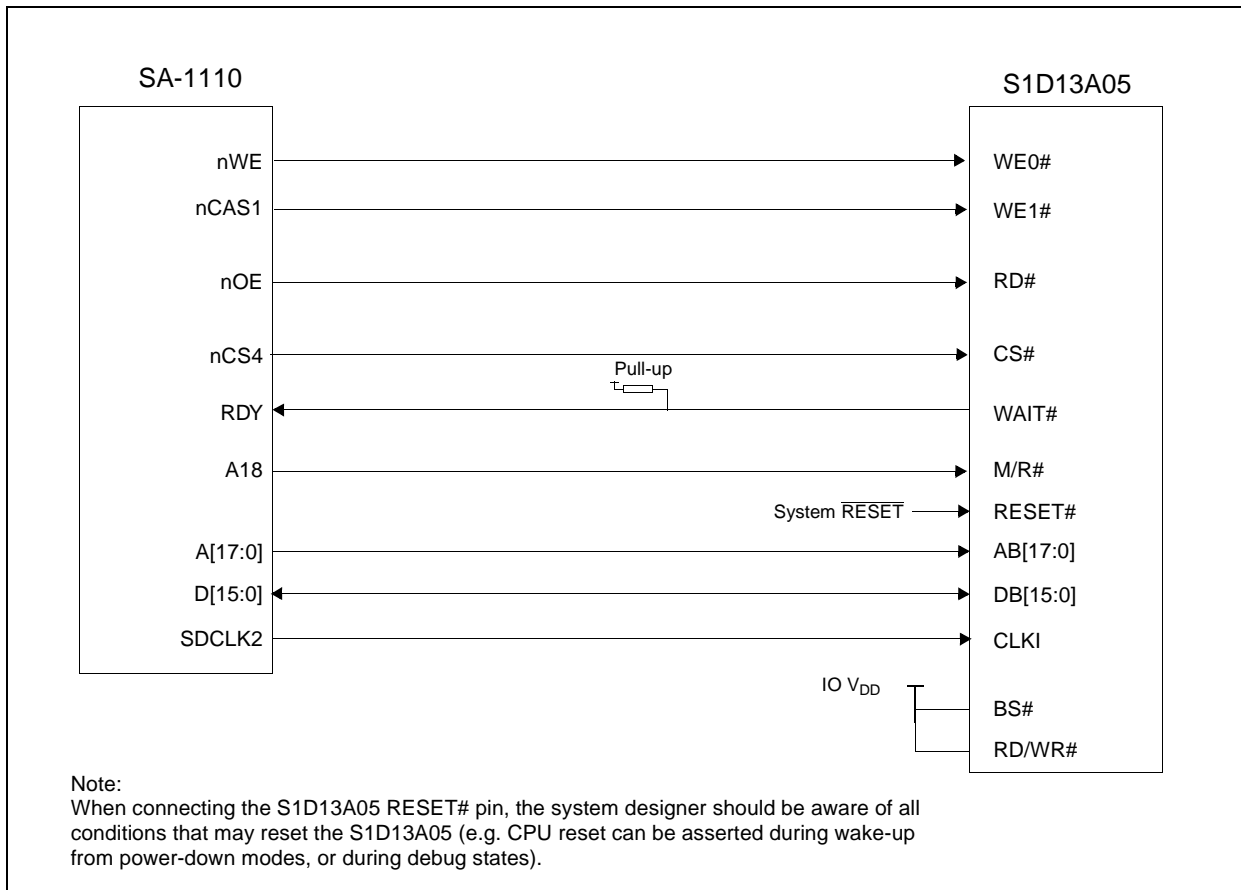


Figure 4-1: Typical Implementation of SA-1110 to S1D13A05 Interface

4.2 S1D13A05 Hardware Configuration

The S1D13A05 uses CNF6 through CNF0 to allow selection of the bus mode and other configuration data on the rising edge of RESET#. For details on configuration, refer to the *S1D13A05 Hardware Functional Specification*, document number X40A-A-001-xx.

The following table shows the configuration required for this implementation of a S1D13A05 to SA-1110 interface.

Table 4-1: Summary of Power-On/Reset Options

| S1D13A05 Configuration Input | Power-On/Reset State | | | | | | | | | | | |
|------------------------------------|---|-----------------------------------|------|---------------------------|------|------|----------|---|---|---|---|---------------------------|
| | 1 (connected to IO V _{DD}) | 0 (connected to V _{SS}) | | | | | | | | | | |
| CNF4, CNF[2:0] | Select host bus interface as follows: <table border="1"> <thead> <tr> <th>CNF4</th> <th>CNF2</th> <th>CNF1</th> <th>CNF0</th> <th>Host Bus</th> </tr> </thead> <tbody> <tr> <td>0</td> <td>1</td> <td>0</td> <td>0</td> <td>Generic #2, Little Endian</td> </tr> </tbody> </table> | | CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | 0 | 1 | 0 | 0 | Generic #2, Little Endian |
| CNF4 | CNF2 | CNF1 | CNF0 | Host Bus | | | | | | | | |
| 0 | 1 | 0 | 0 | Generic #2, Little Endian | | | | | | | | |
| CNF3 | Reserved. Must be set to 1. | | | | | | | | | | | |
| CNF5 | WAIT# is active high | WAIT# is active low | | | | | | | | | | |
| CNF6 | CLKI to BCLK divide ratio 2:1 | CLKI to BCLK divide ratio 1:1 | | | | | | | | | | |
| | configuration for SA-1110 microprocessor | | | | | | | | | | | |

4.3 StrongARM SA-1110 Register Configuration

The SA-1110 requires configuration of several of its internal registers to interface to the S1D13A05 Generic #2 Host Bus Interface.

- The Static Memory Control Registers (MSC[2:0]) are read/write registers containing control bits for configuring static memory or variable-latency IO devices. These registers correspond to chip select pairs nCS[5:4], nCS[3:2], and nCS[1:0] respectively. Each of the three registers contains two identical CNFG fields, one for each chip select within the pair. Since only nCS[5:3] controls variable-latency IO devices, MSC2 and MSC1 should be programmed based on the chip select used.

Parameter RTx[1:0] should be set to 01b (selects variable-latency IO mode).

Parameter RBWx should be set to 1 (selects 16-bit bus width).

Parameter RDFx[4:0] should be set according to the maximum desired CPU frequency as indicated in the table below.

Table 4-2: RDFx Parameter Value versus CPU Maximum Frequency

| CPU Frequency (MHz) | RDFx |
|---------------------|------|
| 57.3 - 85.9 | 1 |
| 88.5 - 143.2 | 2 |
| 147.5 - 200.5 | 3 |
| 206.4 - 221.2 | 4 |

Parameter RDNx[4:0] should be set to 0 (minimum command precharge time).

Parameter RRRx[2:0] should be set to 0 (minimum nCSx precharge time).

- The S1D13A05 endian mode is set to little endian. To program the SA-1110 for little endian, set bit 7 of the control register (register 1) to 0.
- The CLKI signal input to the S1D13A05 from one of the SDCLK[2:1] pins is a derivative of the SA-1110 internal processor speed (either divide by 2 or 4). The S1D13A05 Generic #2 Host Bus Interface has a maximum BCLK of 50MHz. Therefore, if the processor clock is higher than 100MHz, either divide the BCLK input using the S1D13A05 configuration pin CNF6 (see Table 4-1: “Summary of Power-On/Reset Options”) or set SDCLK1/SDCLK2 to CPU clock divided by four using the DRAM Refresh Control Register (MDREFR bit 26 = 1 for SDCLK2, MDREFR bit 22 = 1 for SDCLK1).

4.4 Register/Memory Mapping

The S1D13A05 is a memory-mapped device. The SA-1110 uses the memory assigned to a chip select (nCS4 in this example) to map the S1D13A05 internal registers and display buffer. The S1D13A05 uses two 256K byte blocks which are selected using A18 from the SA-1110 (A18 is connected to the S1D13A05 M/R# pin). The internal registers occupy the first 256K byte block and the 256K byte display buffer occupies the second 256K byte block.

Each variable-latency IO chip select is assigned 128M Bytes of address space. Therefore; if nCS4 is used the S1D13A05 registers will be located at 4000 0000h and the display buffer will be located at 4004 0000h. These blocks are aliased over the entire 128M byte address space.

Note

If aliasing is not desirable, the upper addresses must be fully decoded.

5 Software

Test utilities and display drivers are available for the S1D13A05. Full source code is available for both the test utilities and the drivers.

The test utilities are configurable for different panel types using a program called 13A05CFG (see document number X40A-B-001-xx), or by directly modifying the source. The display drivers can be customized by the OEM for different panel types, resolutions and color depths only by modifying the source.

The S1D13A05 test utilities and display drivers are available from your sales support contact (see Section 7, “*Sales and Technical Support*”) or www.erd.epson.com.

6 References

6.1 Documents

- Intel Corporation, *StrongARM® SA-1110 Microprocessor Advanced Developer's Manual*, Order Number 278240-001.
- Epson Research and Development, Inc., *S1D13A05 Hardware Functional Specification*, Document Number X40A-A-001-xx.
- Epson Research and Development, Inc., *S1D13A05 Programming Notes and Examples*, Document Number X40A-G-003-xx.

6.2 Document Sources

- Intel Developers Website: <http://developer.intel.com>.
- Intel Literature contact: 1(800) 548-4725.
- Epson Research and Development Website: www.erd.epson.com.

7 Sales and Technical Support

7.1 EPSON LCD/USB Companion Chips (S1D13A05)

Japan

Seiko Epson Corporation
Electronic Devices Marketing Division
421-8, Hino, Hino-shi
Tokyo 191-8501, Japan
Tel: 042-587-5812
Fax: 042-587-5564
<http://www.epson.co.jp/>

North America

Epson Electronics America, Inc.
150 River Oaks Parkway
San Jose, CA 95134, USA
Tel: (408) 922-0200
Fax: (408) 922-0238
<http://www.eea.epson.com/>

Taiwan

Epson Taiwan Technology
& Trading Ltd.
10F, No. 287
Nanking East Road
Sec. 3, Taipei, Taiwan
Tel: 02-2717-7360
Fax: 02-2712-9164
<http://www.epson.com.tw/>

Hong Kong

Epson Hong Kong Ltd.
20/F., Harbour Centre
25 Harbour Road
Wanchai, Hong Kong
Tel: 2585-4600
Fax: 2827-4346
<http://www.epson.com.hk/>

Europe

Epson Europe Electronics GmbH
Riesstrasse 15
80992 Munich, Germany
Tel: 089-14005-0
Fax: 089-14005-110
<http://www.epson-electronics.de/>

Singapore

Epson Singapore Pte., Ltd.
No. 1
Temasek Avenue #36-00
Millenia Tower
Singapore, 039192
Tel: 337-7911
Fax: 334-2716
<http://www.epson.com.sg/>

7.2 Intel StrongARM SA-1110 Processor

INTEL

Intel Customer Support (ICS) for StrongARM: (800) 628-8686

Website for StrongARM Processor <http://developer.intel.com/design/strong/>

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