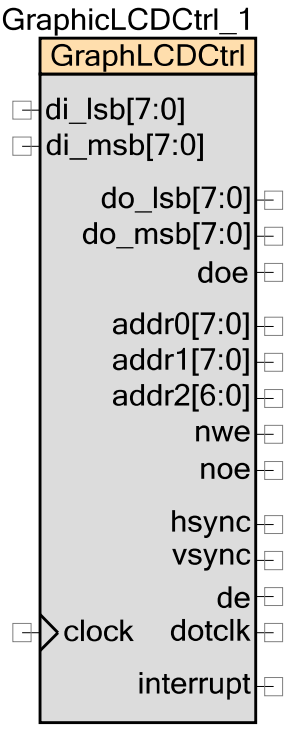
Graphic LCD Controller (GraphicLCDCtrl)

1.60

Features



- Fully programmable screen size support up to HVGA resolution including:
  - QVGA (320x240) @ 60 Hz 16 bpp
  - WQVGA (480x272) @ 60 Hz 16 bpp
  - HVGA (480x320) @ 60 Hz 16 bpp
- Virtual screen operation support
- Read and write transactions during the blanking intervals
- Generation of continuous timing signals to the panel without CPU intervention
- Supports up to a 23-bit address and a 16-bit data async SRAM device used as externally provided frame buffer
- Selectable interrupt pulse generated at the entry and exit of the horizontal and vertical blanking intervals

General Description

The Graphic LCD Controller (GraphicLCDCtrl) component provides the interface to an LCD panel that has an LCD driver, but not an LCD controller. This type of panel does not include a frame buffer. The frame buffer must be provided externally.

This component also interfaces to an externally provided frame buffer implemented using a 16-bit-wide async SRAM device.

When to Use a GraphicLCDCtrl

The GraphicLCDCtrl component supports many LCD panels. It directly drives the control signals and manages the frame buffer in an external SRAM. The component accesses data from the SRAM and displays it on the LCD through the control of the dotclk, hsync, vsync, and de outputs.

The frame buffer SRAM can only be accessed for reads and writes when it is not refreshing the LCD panel. If a read or write is requested during the refresh period, the API functions provided will wait until the refresh gets to a blanking period. During the blanking period, the read or write will be completed.

An interrupt can be used to indicate the entry and exit from blanking periods. This is particularly useful when coupled with an RTOS, which can swap in or swap out tasks that require access to the frame buffer when a blanking period is entered and exited.

Input/Output Connections

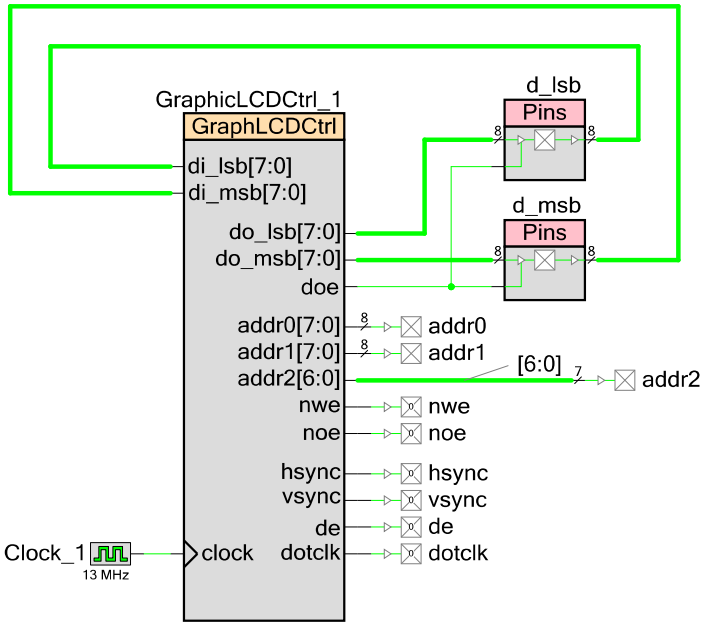
This section describes the various input and output connections for the GraphicLCDCtrl. Some I/Os may be hidden on the symbol under the conditions listed in the description of that I/O.

Input	May Be Hidden	Description
di_lsb[7:0]	N	The lower eight bits of the input data bus. Used for data during a read transaction. These signals should be connected to an input pin on the device and the “Input Synchronized” selection for these pins should be disabled. The signals themselves are synchronized already because they are being driven based on synchronous output signals.
di_msb[7:0]	N	The upper eight bits of the input data bus. Used for data during a read transaction. Only present for 16-bit interface mode. These signals should be connected to an input pin on the device and the “Input Synchronized” selection for these pins should be disabled. The signals themselves are synchronized already because they are being driven based on synchronous output signals.
clock	N	The clock that operates this component. It is twice the frequency of the dotclk.

Output	May Be Hidden	Description
do_lsb[7:0]	N	The lower eight bits of the output data bus. Used for data during a write transaction.
do_msb[7:0]	N	The upper eight bits of the output data bus. Used for data during a write transaction.
doe	N	The output enable for the data bus component within PSoC. Normally connected to the output enable of the Input/Output pin component for the data buses.
addr0[7:0]	N	The lowest eight bits of the address bus connected to the frame buffer.
addr1[7:0]	N	The middle eight bits of the address bus connected to the frame buffer.
addr2[6:0]	N	The upper seven bits of the address bus connected to the frame buffer. The number of data bits needed by the frame buffer is dependent on the SRAM device used.
nwe	N	Active-low write enable for the frame buffer SRAM.
noe	N	Active-low output enable for the frame buffer.
de	N	Data enable for the panel.
hsync	N	Horizontal sync timing signal for the panel.
vsync	N	Vertical sync timing signal for the panel.
dotclk	N	Clock driven to the panel. This clock is one-half the rate of the incoming clock.
interrupt	Y	Edge-triggered interrupt signal. Hidden if no interrupt generation selected.

Schematic Macro Information

The macro is configured with the default settings to interface with the Optrex T-55343GD035JU-LW-AEN panel. The clock included in the macro is set to 13 MHz, which results in a 6.5-MHz dotclk provided to the Optrex QVGA panel.



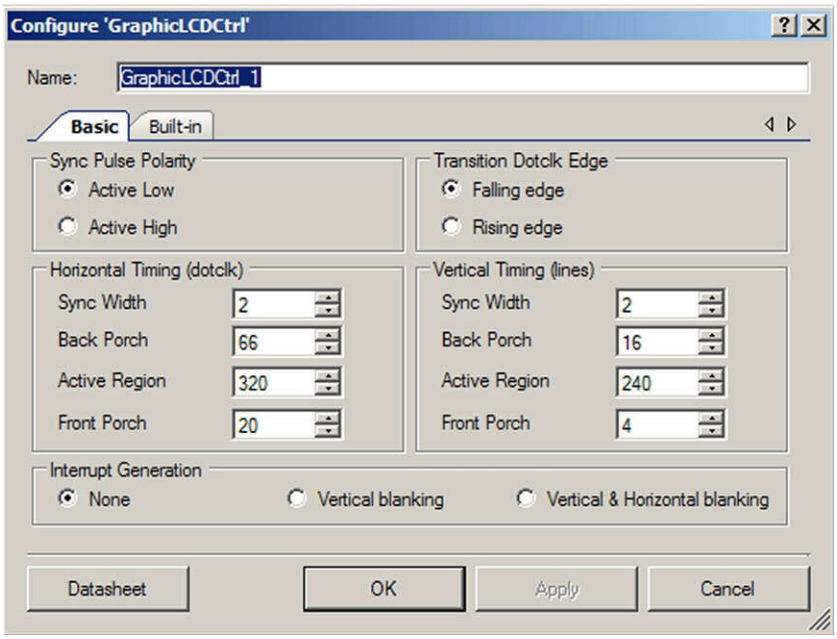
Typically, only some of the bits of the upper address bits (addr2) are used to connect to the frame buffer. This depends on the size of the SRAM used. Based on the number of address bits needed, you can use the following steps to adjust the size of that bus.

- Configure the addr2 output pin component and set the “Number of Pins.”
- Right-click on the signal driving the output pin and select “Edit Name And Width.” Then adjust the “Left Index” to reflect the width of the output pin.

The "Input Synchronized" option is unchecked on all of the data pins and the generation of API functions for all of the pins is turned off.

Component Parameters

Drag a GraphicLCDCtrl component onto your design and double-click it to open the **Configure** dialog. The default GraphicLCDCtrl settings are configured for operation with the Optrex panel.



The **Configure GraphicLCDCtrl** dialog contains the following parameters. All of these settings are compile-time selections; there is no need to change these settings at run time. They are all characteristics of the panel and frame buffer SRAM being used.

Sync Pulse Polarity

Based on this setting, the hsync and vsync signals will either be **Active High** (pulse generated is a high pulse) or **Active Low**. hsync and vsync polarity are both controlled by this single selection. The default setting is **Active Low**.

Transition Dotclk Edge

Dotclk is the clock that is sent to the panel, off of which the panel operates. When the transition is set to **Rising edge**, all of the associated signals such as hsync, vsync, and de transition on the rising edge of dotclk. When set to **Falling edge** they transition on the falling edge of dotclk.

Typically, if the panel specifies a setup and hold time to one edge of dotclk, you'll want to configure this setting to the other edge of the clock. This provides approximately one-half clock cycle of both setup and hold. The default setting is **Falling edge**.

Horizontal Timing (dotclk)

- **Sync Width** – Defines the horizontal sync width in dotclks. This value can be set between 1 and 256 clock cycles. The default setting is **2**.

- **Back Porch** – Defines the horizontal back porch width in dotclks. This value can be set between 6 and 256 clock cycles. A minimum of 6 is used to give an early enough indication to the state machine to prevent a read or write access that could not complete before the active screen area begins. Some panel specifications consider the back porch as the region between the end of the sync signal and the start of the active region. Other panel specifications consider the back porch to be the region from the start of the sync pulse to the start of the active region. This component measures the back porch as the period from the end of the sync pulse to the start of the active region. The default setting is **66**.
- **Active Region** – Defines the horizontal active region width in dotclks. The active region is implemented using a setting that is a multiple of 4. This allows for regions as large as 1024 x 1024 while only using 8-bit counters. All popular screen sizes are multiples of 4 in both directions. This value can be set between 4 and 1024 (must be a multiple of 4) clock cycles. The default setting is **320**.
- **Front Porch** – Defines the horizontal front porch width in dotclks. This value can be set between 1 and 256 clock cycles. The default setting is **20**.

Vertical Timing (lines)

- **Sync Width** – Defines the vertical sync width in lines. This value can be set between 1 and 256 clock cycles. The default setting is **2**.
- **Back Porch** – Defines the vertical back porch width in lines. This value can be set between 1 and 256 lines. Some panel specifications consider the back porch as the region between the end of the sync signal and the start of the active region. Other panel specifications consider the back porch to be the region from the start of the sync pulse to the start of the active region. This component measures the back porch as the period from the end of the sync pulse to the start of the active region. The default setting is **16**.
- **Active Region** – Defines the vertical active region width in lines. The active region is implemented using a setting that is a multiple of 4. This allows for regions as large as 1024 x 1024 while only using 8-bit counters. All popular screen sizes are multiples of 4 in both directions. This value can be set between 4 and 1024 (must be a multiple of 4) lines. The default setting is **240**.
- **Front Porch** – Defines the vertical front porch width in lines. This value can be set between 1 and 256 lines. The default setting is **4**.

Interrupt Generation

Defines the settings for interrupt generation. The default setting is **None**.

- If set to **Vertical blanking**, an interrupt pulse is generated at the start and end of the vertical blanking interval.

- If set to **Vertical & Horizontal blanking**, an interrupt pulse is generated at the start and end of every active region.

  During the active vertical region, this is an interrupt at the start and end of the active region for each line. For the vertical blanking region, this is a single interrupt at the end of the last active line and another interrupt at the start of the first active line.

Clock Selection

There is no internal clock in this component. You must attach a clock source. The clock rate provided must be two times the desired clock rate for the output dotclk clock to the panel.

Placement

The GraphicLCDCtrl is placed throughout the UDB array and all placement information is provided to the API through the *cyfitter.h* file.

Resources

Resource Type				API Memory (Bytes)		
Datapath Cells	PLDs	Status Cells	Control/ Count7 Cells	Flash	RAM	Pins (per External I/O)
7	11	1	1	421	6	45

Application Programming Interface

Application Programming Interface (API) routines allow you to configure the component using software. The following table lists and describes the interface to each function. The subsequent sections cover each function in more detail.

By default, PSoC Creator assigns the instance name “GraphicLCDCtrl_1” to the first instance of a component in a given design. You can rename the instance to any unique value that follows the syntactic rules for identifiers. The instance name becomes the prefix of every global function name, variable, and constant symbol. For readability, the instance name used in the following table is “GraphicLCDCtrl.”

Function	Description
GraphicLCDCtrl_Start()	Starts the GraphicLCDCtrl interface.
GraphicLCDCtrl_Stop()	Disables the GraphicLCDCtrl interface.
GraphicLCDCtrl_Write()	Initiates a write transaction to the frame buffer.

Function	Description
GraphicLCDCtrl_Read()	Initiates a read transaction from the frame buffer.
GraphicLCDCtrl_WriteFrameAddr()	Sets the starting frame buffer address used when refreshing the screen.
GraphicLCDCtrl_ReadFrameAddr()	Reads the starting frame buffer address used when refreshing the screen.
GraphicLCDCtrl_WriteLineIncr()	Sets the address spacing between adjacent lines.
GraphicLCDCtrl_ReadLineIncr()	Reads the address increment between lines.
GraphicLCDCtrl_Sleep()	Saves configuration and disables the GraphicLCDCtrl
GraphicLCDCtrl_Wakeup()	Restores configuration and enables the GraphicLCDCtrl
GraphicLCDCtrl_Init()	Initializes or restores the component parameters to the settings provided with the component customizer
GraphicLCDCtrl_Enable()	Enables the GraphicLCDCtrl
GraphicLCDCtrl_SaveConfig()	Saves the configuration of GraphicLCDCtrl
GraphicLCDCtrl_RestoreConfig()	Restores the configuration of GraphicLCDCtrl

Global Variables

Variable	Description
GraphicLCDCtrl_initVar	GraphicLCDCtrl_initVar indicates whether the Graphic LCD Controller has been initialized. The variable is initialized to 0 and set to 1 the first time GraphicLCDCtrl_Start() is called. This allows the component to restart without reinitialization after the first call to the GraphicLCDCtrl_Start() routine. If reinitialization of the component is required, then the GraphicLCDCtrl_Init() function can be called before the GraphicLCDCtrl_Start() or GraphicLCDCtrl_Enable() function.

void GraphicLCDCtrl_Start(void)

Description: Enables Active mode power template bits or clock gating as appropriate. This is the preferred method to begin component operation. GraphicLCDCtrl_Start() sets the initVar variable, calls the GraphicLCDCtrl_Init() function, and then calls the GraphicLCDCtrl_Enable() function.

Parameters: None

Return Value: None

Side Effects: If the initVar variable is already set, this function only calls the GraphicLCDCtrl_Enable() function.

void GraphicLCDCtrl_Stop(void)

Description: Disables Active mode power template bits or gates clocks as appropriate.

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDCtrl_Write(uint32 addr, uint16 data)

Description: Initiates a write transaction to the frame buffer using the address and data provided. The write is a posted write, so this function returns before the write has actually completed on the interface. If the command queue is full, this function does not return until space is available to queue this write request

Parameters: addr: Address to be sent on the address lines of the component (addr2[6:0], addr1[7:0], addr0[7:0]).

data: Data sent on the do_msb[7:0] (most significant byte) and do_lsb[7:0] (least significant byte) pins

Return Value: None

Side Effects: None

uint16 GraphicLCDCtrl_Read(uint32 addr)

Description: Initiates a read transaction from the frame buffer. The read executes after all currently posted writes have completed. This function waits until the read completes and then returns the read value.

Parameters: addr: Address to be sent on the address lines of the component (addr2[6:0], addr1[7:0], addr0[7:0])

Return Value: Read value from the di_msb[7:0] (most significant byte) and di_lsb[7:0] (least significant byte) pins

Side Effects: None

void GraphicLCDCtrl_WriteFrameAddr(uint32 addr)

Description: Sets the starting frame buffer address used when refreshing the screen. This register is read during each vertical blanking interval. To implement an atomic update of this register it should be written during the active refresh region.

Parameters: addr: Address of the start of the frame buffer

Return Value: None

Side Effects: None

uint32 GraphicLCDCtrl_ReadFrameAddr(void)

Description: Reads the starting frame buffer address used when refreshing the screen.

Parameters: None

Return Value: Address of the start of the frame buffer

Side Effects: None

void GraphicLCDCtrl_WriteLineIncr(uint32 incr)

Description: Sets the address spacing between adjacent lines. By default this is the display size of a line. This setting can be used to align lines to a different word boundary or to implement a virtual line length that is larger than the display region.

Parameters: incr: Address increment between lines. Must be at least the display size of a line.

Return Value: None

Side Effects: None

uint32 GraphicLCDCtrl_ReadLineIncr(void)

Description: Reads the address increment between lines.

Parameters: None

Return Value: Address increment between lines

Side Effects: None

void GraphicLCDCtrl_Sleep(void)

Description: This is the preferred routine to prepare the component for sleep. The GraphicLCDCtrl_Sleep() routine saves the current component state. Then it calls the GraphicLCDCtrl_Stop() function and calls GraphicLCDCtrl_SaveConfig() to save the hardware configuration.

Call the GraphicLCDCtrl_Sleep() function before calling the CyPmSleep() or the CyPmHibernate() function. Refer to the PSoC Creator *System Reference Guide* for more information about power management functions.

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDCtrl_Wakeup(void)

Description: This is the preferred routine to restore the component to the state when GraphicLCDCtrl_Sleep() was called. The GraphicLCDCtrl_Wakeup() function calls the GraphicLCDCtrl_RestoreConfig() function to restore the configuration. If the component was enabled before the GraphicLCDCtrl_Sleep() function was called, the GraphicLCDCtrl_Wakeup() function will also re-enable the component.

Parameters: None

Return Value: None

Side Effects: Calling the GraphicLCDCtrl_Wakeup() function without first calling the GraphicLCDCtrl_Sleep() or GraphicLCDCtrl_SaveConfig() function may produce unexpected behavior.

void GraphicLCDCtrl_Init(void)

Description: This API initializes or restores the component parameters to the settings provided with the component customizer. The compile time configuration that defines timing generation is restored to the settings provided with the customizer. The run time configuration for the frame buffer address is set to 0; for the line increment it is set to the display line size.

Parameters: None

Return Value: None

Side Effects: The component must be disabled by GraphicLCDCtrl_Stop() before this function call, otherwise the component behavior can be unexpected. This reinitializes the component with the following exceptions: it does not clear data from the FIFOs and does not reset component hardware state machines.

void GraphicLCDCtrl_Enable(void)

Description: Activates the hardware and begins component operation. It is not necessary to call GraphicLCDCtrl_Enable() because the GraphicLCDCtrl_Start() routine calls this function, which is the preferred method to begin component operation.

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDCtrl_SaveConfig(void)

Description: This function saves the component configuration and nonretention registers. It also saves the current component parameter values, as defined in the Configure dialog or as modified by appropriate APIs. This function is called by the GraphicLCDCtrl_Sleep() function.

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDCtrl_RestoreConfig(void)

Description: This function restores the component configuration and nonretention registers. It also restores the component parameter values to what they were before calling the GraphicLCDCtrl_Sleep() function.

Parameters: None

Return Value: None

Side Effects: If this API is called before GraphicLCDCtrl_SaveConfig(), the component configurations will be restored to their default settings. The run time configuration for the frame buffer address is set to 0; for the line increment it is set to the display line size.

Sample Firmware Source Code

PSoC Creator provides numerous example projects that include schematics and example code in the Find Example Project dialog. For component-specific examples, open the dialog from the Component Catalog or an instance of the component in a schematic. For general examples, open the dialog from the Start Page or **File** menu. As needed, use the **Filter Options** in the dialog to narrow the list of projects available to select.

Refer to the “Find Example Project” topic in the PSoC Creator Help for more information.

Functional Description

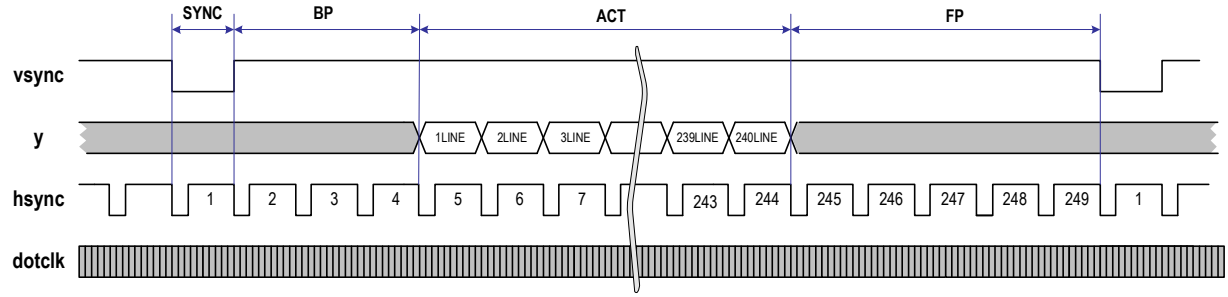
This component generates continuous timing signals to the panel without CPU intervention. During the refresh period, the component also generates read requests to the frame buffer scanning through a frame of 16-bit pixel data. During the blanking intervals (horizontal and vertical) the component can generate read or write transactions on the frame buffer interface.

Screen Refresh and Timing

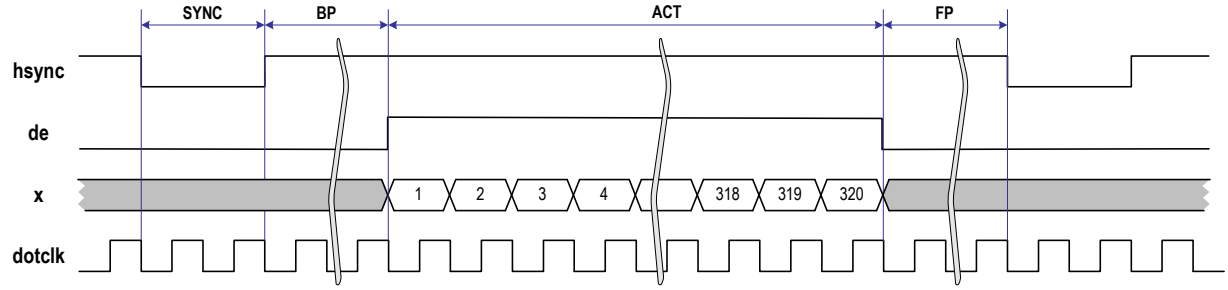
Throughout a frame time the component generates the configured vertical timing pattern on vsync, and throughout each line of the frame the component generates the configured horizontal pattern on hsync. In addition to hsync and vsync, some panels require a de (data enable) signal that is active high during the active portion of the screen refresh. All panels operate in the same

way, although the timing of each of the segments of the refresh period differs. The following is the timing diagram for a typical panel.

Vertical timing:



Horizontal timing:



The sequence for each frame for the vertical signal and the sequence for each line for the horizontal signal follow the following pattern:

- Sync pulse: Period where the sync pulse is active
- Back Porch: Period from the end of the sync pulse until the active display area
- Active: Display area on the screen
- Front Porch: Period from the end of the active display until the sync pulse starts

Address Generation

As the screen is refreshed the component must scan through the frame buffer generating the addresses for the pixels on the screen. Each pixel requires one 16-bit read from the frame buffer. For the beginning of each frame, the index into the frame buffer is reset to the designated starting point for the frame buffer. The value is set to 0 initially and can then be modified using API functions. The frame buffer address does not impact the read and write API functions, it only impacts the refresh operation.

Frame Buffer Transactions

The controller component can perform either read or write transactions. These transactions have the following parameters:

- Read or write
- Address – Up to a 23-bit address
- Data – 16-bit value. Sent on “do” (data out) for writes and read on “di” (data in) for reads.

The implementation used for this component combines the 23 bits of address with a 1-bit read/write indicator. This allows the address and transaction type to be transferred to the component in three bytes. It also allows the transaction type and address to stay together in the datapath FIFO.

Read and write transactions are performed during the horizontal and vertical blanking intervals.

Idle Condition

When neither a read nor a write is occurring on the frame buffer interface, the interface is in the idle state. The idle state control signals are the same as the values for reading. The values for the output pins in the idle condition are as follows:

- do: don’t care (may be left at its last state)
- doe: 0
- addr: don’t care (may be left at its last state)
- nwe: 1
- noe: 0

Any signal not listed in the description of the read and write transactions is in the idle state.

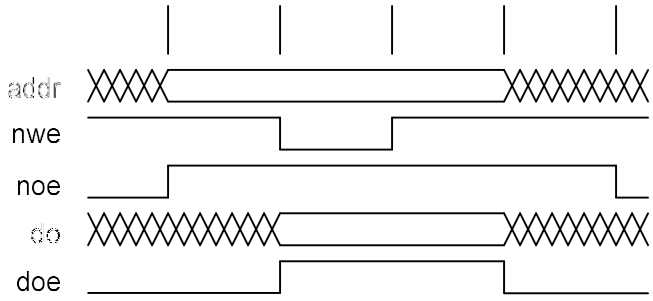
Write Transaction

The component implements the timing diagram shown in Figure 1 for a write transaction. This diagram shows that the write transaction requires four dotclk cycles (all diagrams are in dotclk cycles). This transaction can be immediately preceded or followed by another read or write transaction or may be in the idle state before or after a write transaction.

The interface to the CPU allows the CPU to make posted write requests (request a write providing the address and data and then proceed before the transaction is actually completed to the frame buffer). The implementation allows the CPU to have four write requests outstanding without stalling the CPU.

Note the pattern of the noe and doe signals, which prevents the data bus from being driven by both the component and the frame buffer regardless of the skew of the signals.

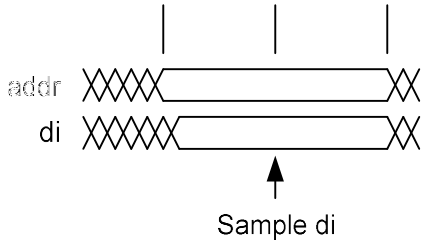
Figure 1. Write Transaction Timing Diagram



Read Transaction

This component implements the timing diagram shown in Figure 2 for a read transaction. This transaction can be immediately preceded or followed by another read or write transaction or may be in the idle state before or after a write transaction.

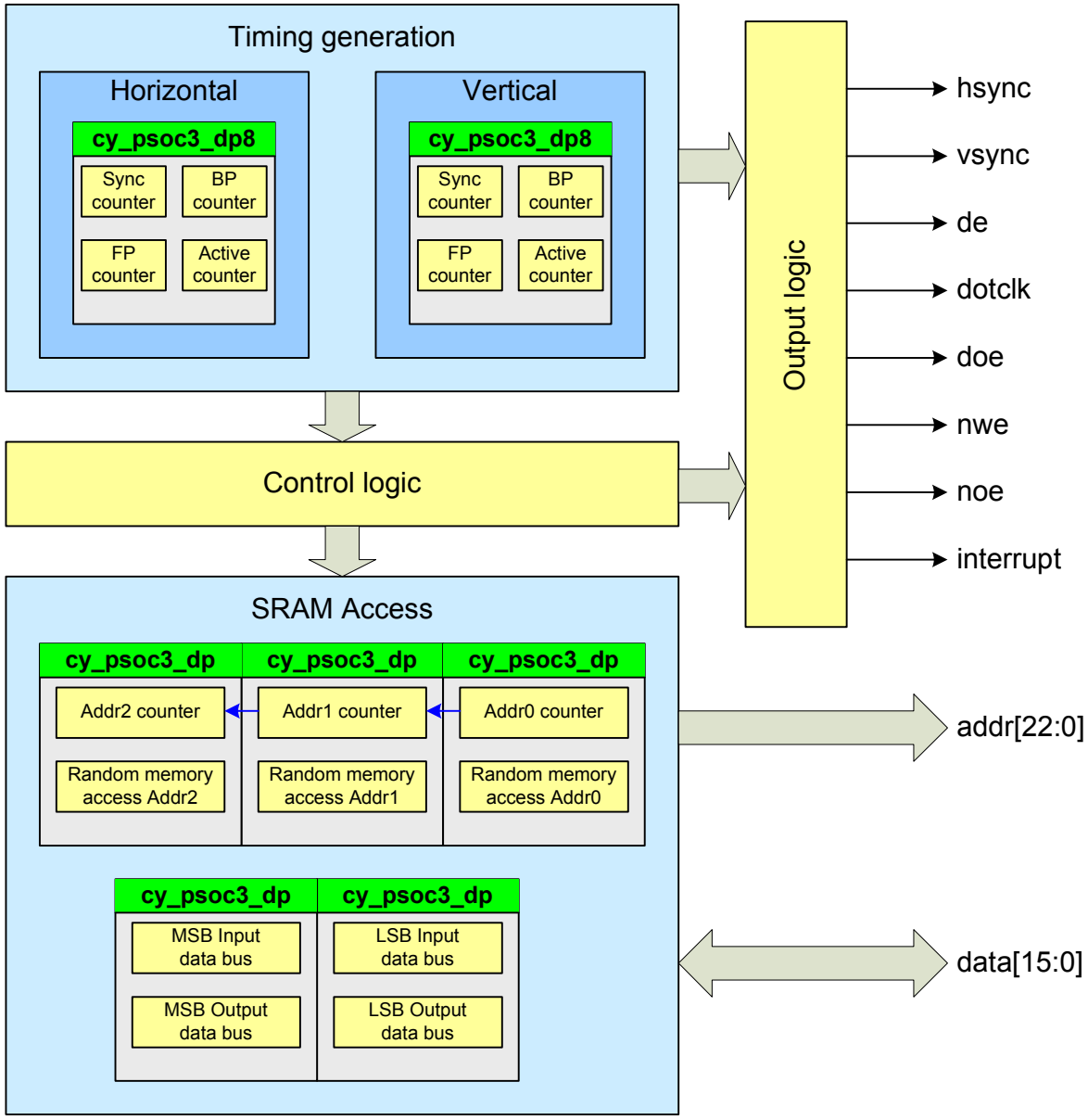
Figure 2. Read Transaction Timing Diagram



Block Diagram and Configuration

The GraphicLCDCtrl component is implemented as a set of configured UDBs. The implementation is shown in Figure 3.

Figure 3. Block Diagram



Registers

GraphicLCDCtrl_STATUS_REG

Bits	7	6	5	4	3	2	1	0
Value	reserved				v_blanking	h_blanking	avail	full

- full: Set if command/data FIFO is full
- avail: Set if read data is valid for the CPU
- h_blanking: Set during the horizontal blanking interval
- v_blanking: Set during the vertical blanking interval

DC and AC Electrical Characteristics

The following values indicate expected performance and are based on initial characterization data.

Timing Characteristics “Maximum with Nominal Routing”

Parameter	Description	Min	Typ	Max [1]	Unit
f_{DOTCLK}	Dotclk frequency	–	–	15	MHz
f_{CLOCK}	Component clock frequency	$2*f_{DOTCLK}$	–	–	MHz
t_{DOTCLK}	Dotclk period	$1/f_{DOTCLK}$	–	–	ns
t_{CKL}	Dotclk low time	–	0.5	–	$1/f_{DOTCLK}$
t_{CKH}	Dotclk high time	–	0.5	–	$1/f_{DOTCLK}$
Screen Refresh and Data Transaction Timing					
t_{HSYNC}	Horizontal sync pulse period	1	–	256	t_{DOTCLK}
t_{HBP}	Horizontal back porch period	6	–	256	t_{DOTCLK}
$t_{HACTIVE}$	Horizontal active region period	4	–	1024	t_{DOTCLK}
t_{HFP}	Horizontal front porch period	1	–	256	t_{DOTCLK}

[1] These “Nominal” numbers provide a maximum safe operating frequency of the component under nominal routing conditions. It is possible to run the component at higher clock frequencies, at which point you will need to validate the timing requirements with STA results.

Parameter	Description	Min	Typ	Max [1]	Unit
t_{HBLANK}	Horizontal blanking period	–	t_{HSYNC} + t_{HBP} + t_{HFP}	–	t_{DOTCLK}
H_{CYCLE}	Horizontal cycle	–	t_{HBLANK} + $t_{HACTIVE}$	–	t_{DOTCLK}
t_{VSYNC}	Vertical sync pulse period	1	–	256	H_{CYCLE}
t_{VBP}	Vertical back porch period	1	–	256	H_{CYCLE}
$t_{VACTIVE}$	Vertical active region period	4	–	1024	H_{CYCLE}
t_{VFP}	Vertical front porch period	1	–	256	H_{CYCLE}
t_{VBLANK}	Horizontal cycle	–	t_{VSYNC} + t_{VBP} + t_{VFP}	–	H_{CYCLE}
V_{CYCLE}	Vertical cycle	–	t_{VBLANK} + $t_{VACTIVE}$	–	H_{CYCLE}
Pixel Timing					
t_{HV}	Phase difference of sync signal falling edge	–	t_{HFP}	–	t_{DOTCLK}
t_{VSYS}	Vertical sync setup time	–	0.5	–	t_{DOTCLK}
t_{VSYH}	Vertical sync hold time	–	0.5	–	t_{DOTCLK}
t_{HSYS}	Horizontal sync setup time	–	0.5	–	t_{DOTCLK}
t_{HSYH}	Horizontal sync hold time	–	0.5	–	t_{DOTCLK}
t_{DS}	Data setup time to LCD panel	–	0.5	–	t_{DOTCLK}
t_{DH}	Data hold time to LCD panel	–	0.5	–	t_{DOTCLK}
Frame Buffer Transaction Timing					
t_{AS}	Address setup time	1	–	–	t_{DOTCLK}
t_{AH}	Address hold time	–	2	–	t_{DOTCLK}
t_{PWE}	NWE pulse width	–	1	–	t_{DOTCLK}
t_{DSW}	Data setup time to frame buffer	–	1	–	t_{DOTCLK}
t_{DHW}	Data hold time to frame buffer	–	1	–	t_{DOTCLK}
t_{CYCLE}	Clock cycle time				
	Write cycle	4	–	–	t_{DOTCLK}
	Read cycle	2	–	–	t_{DOTCLK}
t_{ACC}	Data access time	–	1	–	t_{DOTCLK}
t_{OH}	Output hold time	–	0	–	t_{DOTCLK}

Timing Characteristics "Maximum with All Routing"

Parameter	Description	Min	Typ	Max [1]	Unit
f_{DOTCLK}	Dotclk frequency	–	–	7	MHz
f_{CLOCK}	Component clock frequency	$2*f_{DOTCLK}$	–	–	MHz
t_{DOTCLK}	Dotclk period	$1/f_{DOTCLK}$	–	–	ns
t_{CKL}	Dotclk low time	–	0.5	–	$1/f_{DOTCLK}$
t_{CKH}	Dotclk high time	–	0.5	–	$1/f_{DOTCLK}$
Screen Refresh and Data Transaction Timing					
t_{HSYNC}	Horizontal sync pulse period	1	–	256	t_{DOTCLK}
t_{HBP}	Horizontal back porch period	6	–	256	t_{DOTCLK}
$t_{HACTIVE}$	Horizontal active region period	4	–	1024	t_{DOTCLK}
t_{HFP}	Horizontal front porch period	1	–	256	t_{DOTCLK}
t_{HBLANK}	Horizontal blanking period	–	$t_{HSYNC} + t_{HBP} + t_{HFP}$	–	t_{DOTCLK}
H_{CYCLE}	Horizontal cycle	–	$t_{HBLANK} + t_{HACTIVE}$	–	t_{DOTCLK}
t_{VSYNC}	Vertical sync pulse period	1	–	256	H_{CYCLE}
t_{VBP}	Vertical back porch period	1	–	256	H_{CYCLE}
$t_{VACTIVE}$	Vertical active region period	4	–	1024	H_{CYCLE}
t_{VFP}	Vertical front porch period	1	–	256	H_{CYCLE}
t_{VBLANK}	Horizontal cycle	–	$t_{VSYNC} + t_{VBP} + t_{VFP}$	–	H_{CYCLE}
V_{CYCLE}	Vertical cycle	–	$t_{VBLANK} + t_{VACTIVE}$	–	H_{CYCLE}
Pixel Timing					
t_{HV}	Phase difference of sync signal falling edge	–	t_{HFP}	–	t_{DOTCLK}
t_{VSYS}	Vertical sync setup time	–	0.5	–	t_{DOTCLK}
t_{VSYH}	Vertical sync hold time	–	0.5	–	t_{DOTCLK}
t_{HSYS}	Horizontal sync setup time	–	0.5	–	t_{DOTCLK}

[1] Maximum for "All Routing" is calculated by <nominal>/2 rounded to the nearest integer. This value allows you to not worry about meeting timing if the component is running at or below this frequency.

Parameter	Description	Min	Typ	Max [1]	Unit
t_{HSYH}	Horizontal sync hold time	–	0.5	–	t_{DOTCLK}
t_{DS}	Data setup time to LCD panel	–	0.5	–	t_{DOTCLK}
t_{DH}	Data hold time to LCD panel	–	0.5	–	t_{DOTCLK}
Frame Buffer Transaction Timing					
t_{AS}	Address setup time	1	–	–	t_{DOTCLK}
t_{AH}	Address hold time	–	2	–	t_{DOTCLK}
t_{PWE}	NWE pulse width	–	1	–	t_{DOTCLK}
t_{DSW}	Data setup time to frame buffer	–	1	–	t_{DOTCLK}
t_{DHW}	Data hold time to frame buffer	–	1	–	t_{DOTCLK}
t_{CYCLE}	Clock cycle time				
	Write cycle	4	–	–	t_{DOTCLK}
	Read cycle	2	–	–	t_{DOTCLK}
t_{ACC}	Data access time	–	1	–	t_{DOTCLK}
t_{OH}	Output hold time	–	0	–	t_{DOTCLK}

Figure 4. Screen Refresh and Data Transaction Timing Diagram

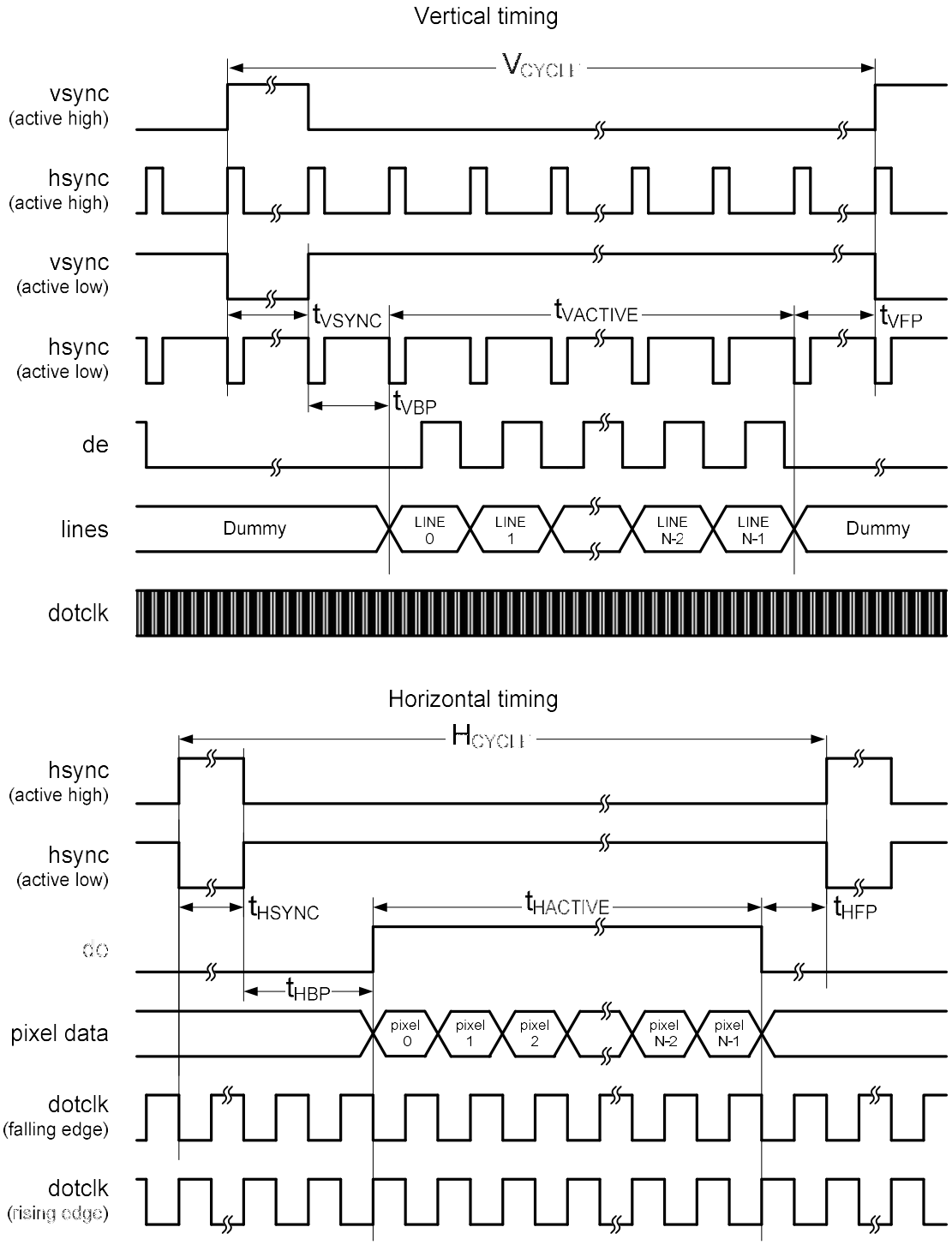


Figure 5. Pixel Timing Diagram

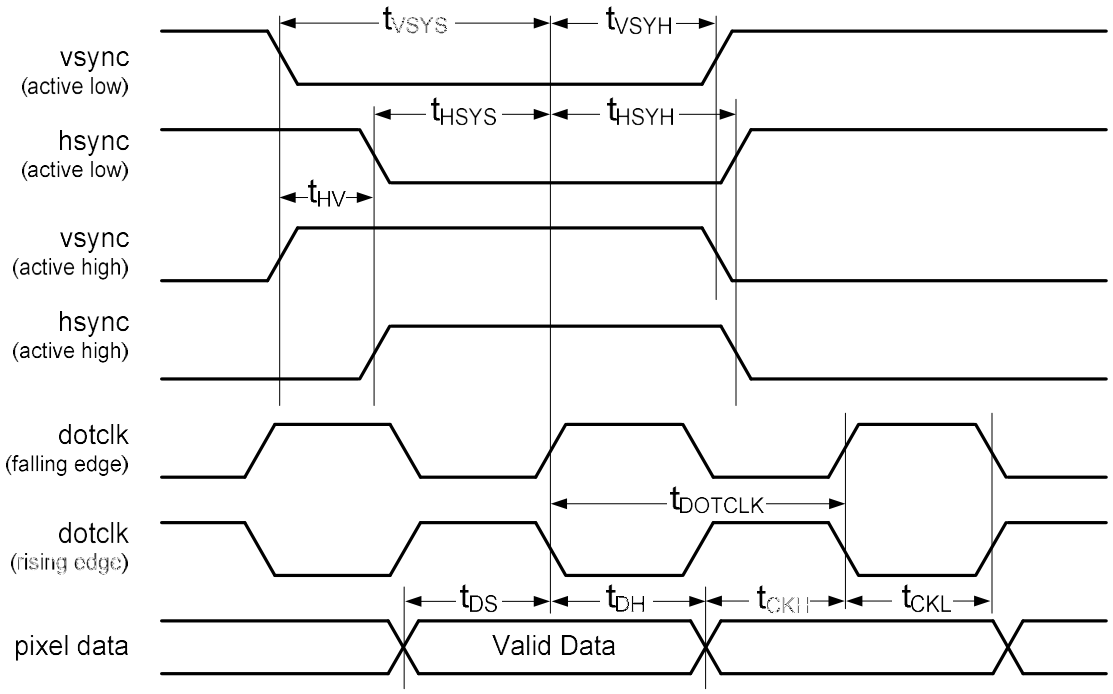
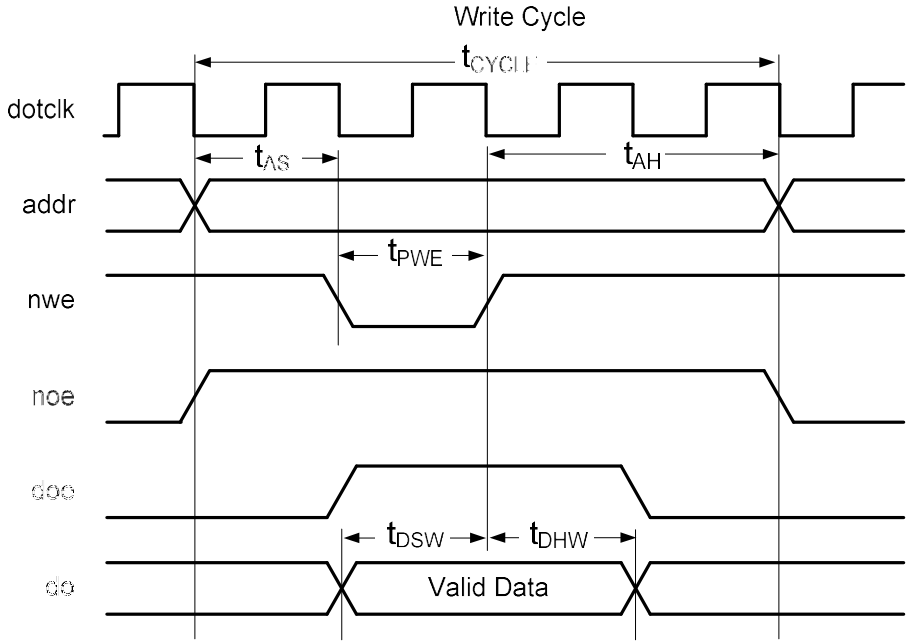
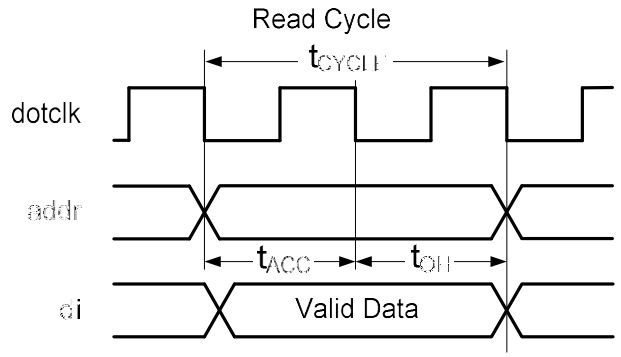


Figure 6. Frame Buffer Data Transaction Timing Diagram





How to Use STA Results for Characteristics Data

Nominal route maximums are gathered through multiple test passes with Static Timing Analysis (STA). You can calculate the maximums for your designs using the STA results using the following methods:

f_{clock} Maximum component clock frequency appears in Timing results in the clock summary as the named external clock. The graphic below shows an example of the clock limitations.

-Clock Summary

Clock	Actual Freq	Max Freq	Violation
BUS_CLK	60.000 MHz	UNKNOWN	
Clock	20.000 MHz	27.820 MHz	

The remaining parameters are implementation-specific and are measured in clock cycles. They can be divided into two categories.

- The parameters that should be used to configure the component are:

  Screen Refresh and Data Transaction Timing Parameters

  f_{DOTCLK} Clock driven to the panel. This clock is one-half the rate of the incoming clock. The component allows you to change the dotclk edge for the signal transition to the panel. The setting can be set to ‘rising edge’ or ‘falling edge’. If the rising edge is set then all output signals change on the rising edge of dotclk. If the falling edge is set then the output transitions occur at the same time as the falling edge of dotclk. That allows those signals to then be sampled by the panel on the opposite edge of dotclk and satisfy setup and hold times.

  t_{HSYNC} The period where the horizontal hsync pulse is active in dotclks. The signal can either be active high (pulse generated is a high pulse) or active low (pulse generated is a low pulse). The polarity of the signal is set in the component customizer.

  t_{HBP} The period from the end of the hsync pulse to the start of the active region in dotclks.

  $t_{HACTIVE}$ Defines the horizontal active region period (display area) in dotclks.

t_{HFP} Period from the end of the active display until the hsync pulse starts in dotclks.

t_{VSYNC} The period where the vertical sync pulse is active in H_{CYCLE}. The signal can either be active high (pulse generated is a high pulse) or active low (pulse generated is a low pulse). The polarity of the signal is set in the component customizer.

t_{VBP} The period from the end of the vsync pulse to the start of the active region in H_{CYCLE}.

$t_{VACTIVE}$ Defines the vertical active region period (display area) in H_{CYCLE}.

t_{VFP} Period from the end of the active display until the vsync pulse starts in H_{CYCLE}.

V_{CYCLE} The period during one whole frame is updated. Defined as the sum of t_{VSYNC}, t_{VBP}, $t_{VACTIVE}$ and t_{VFP} periods.

t_{VBLANK} The number of blanking lines for the frame period. During this period the frame buffer can be updated (component initiates write/read transaction to the frame buffer). There is no data flow to an LCD panel during blanking period. The period is the sum of t_{VSYNC}, t_{VBP}, and t_{VFP} intervals.

H_{CYCLE} The period during one horizontal line is updated. Defined as the sum of t_{HSYNC}, t_{HBP}, $t_{HACTIVE}$ and t_{HFP} periods.

t_{HBLANK} The number of blanking pixels for the one horizontal line. During this period the frame buffer can be updated (component initiates write/read transaction to the frame buffer). There is no data flow to an LCD panel during blanking period. The period is the sum of t_{HSYNC}, t_{HBP}, and t_{HFP} intervals.

- The parameters that are fixed based on the component implementation are:

  Pixel Timing Parameters

  t_{DOTCLK} Period of dotclk signal.

  t_{CKL} The component generates a 50-percent duty cycle dotclk.

  t_{CKH} The component generates a 50-percent duty cycle dotclk.

  t_{VSYS} The minimum amount of time the vsync signal is valid before the active edge of the dotclk signal.

  t_{VSYH} The minimum amount of time the vsync signal is valid after the active edge of the dotclk signal.

  t_{HSYS} The minimum amount of time the hsync signal is valid before the active edge of the dotclk signal.

  t_{HSYH} The minimum amount of time the hsync signal is valid after the active edge of the dotclk signal.

  Note that t_{VSYS}, t_{VSYH}, t_{HSYS}, t_{HSYH} parameters are defined by the relation between dotclk and vsync for vertical timing and dotclk and hsync for horizontal timing. The component allows you to change the dotclk edge for the signal transition to the panel. That allows those signals to then be sampled by the panel on the opposite edge of

dotclk and satisfy setup and hold times. That allows having near a full half dotclk cycle of setup and hold time that t_{VSYS}, t_{VSYH}, t_{HSYS}, t_{HSYH} signals.

t_{HV} Phase difference of sync signal active edge. In the component implementation, vertical counting is done at the first cycle of the horizontal front porch, so the phase difference of vsync before hsync is equal to the horizontal front porch period (t_{HFP}).

t_{DS} The minimum amount of time the data is valid on the input to the panel before the active edge of the dotclk signal.

t_{DH} The minimum amount of time the data is valid on the input to the panel after the active edge of the dotclk signal.

To determine these parameters, the timing for the SRAM that is used as frame buffer must be considered together with GraphicLCDCtrl component implementation. As the screen is refreshed, the component scans through the frame buffer generating the addresses for the pixels on the screen. The addresses to the frame buffer change on active dotclk edge. The delay between dotclk and address signals is near zero, since both of these signals are generated on the internal component clock and then propagated to the output pins. This allows having almost a full half dotclk cycle of hold time. Setup time is calculated as full half period of dotclk minus t_{AA} for the SRAM frame buffer. t_{AA} can be found in respective SRAM datasheet.

Frame Buffer Data Transaction Parameters

t_{AS} The minimum amount of time the address signal is valid before the falling edge of the nwe signal.

t_{AH} The minimum amount of time the address signal is valid after the rising edge of the nwe signal.

t_{PWE} The minimum pulse width low time for the write signal.

t_{CYCLE} The period of time during which a single transaction (write/read) is performed on the interface to the frame buffer.

t_{DSW} The minimum amount of time the data is valid before the falling edge of the write signal.

t_{DHW} The minimum amount of time the data is valid after the rising edge of the write signal.

t_{ACC} The minimum amount of time the data is sampled after the address is valid for the read transaction.

t_{OH} The minimum amount of time the data should be valid after active edge of the dotclk signal the data is sampled.

Component Changes

This section lists the major changes in the component from the previous version.

Version	Description of Changes	Reason for Changes / Impact
1.60.a	Removed references to associated kits from datasheet.	
1.60	Resampled FIFO block status signals to DP clock.	Allows component to function with the same timing results for all PSoC3 and PSoC5 silicons.
	Minor datasheet edits and updates	

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