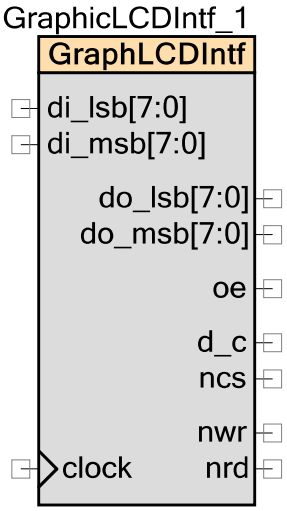
Graphic LCD Interface (GraphicLCDIntf)

1.60

Features

- 8- or 16-bit interface to Graphic LCD Controller
- Compatible with many graphic controller devices
- Read and write transaction
- 2 to 255 cycles for read low pulse width
- 1 to 255 cycles for read high pulse width
- Implements typical i8080 interface



General Description

The Graphic LCD Interface (GraphicLCDIntf) component provides the interface to a graphic LCD controller and driver device. These devices are commonly integrated into an LCD panel. The interface to these devices is commonly referred to as an i8080 interface. This is a reference to the historic parallel bus interface protocol of the Intel 8080 microprocessor.

When to Use a GraphicLCDIntf

LCD controllers and driver devices are commonly integrated into an LCD panel. They either include or provide the interface to the frame buffer for the display and manage that buffer. The GraphicLCDIntf component performs read and write transactions to this controller. These transactions have the following parameters:

- Read or write
- Address: A one-bit address driven on the d_c pin
- Data (8 or 16 bits). Sent on “do” for writes and read on “di” for reads

The GraphicLCDIntf component supports a large number of controllers. There are three parameters to use when you configure this component.

- Clock frequency: The frequency for the clock driving this component is often limited by minimum pulse width low for the write signal (this value can be found in the Graphic LCD

Controller datasheet). The write pulse is low for a single clock period, so set the clock frequency to satisfy this requirement.

- Read pulse width high: This setting in the customizer is measured in clock cycles. The clock period times the number of cycles set for the pulse width high must satisfy the requirement for read pulse width high for the controller.
- Read pulse width low: This parameter is set in the same way that the read pulse width high parameter is set. The timing for the read pulse width low must satisfy the controller's requirement for the read pulse width and the requirement for read access time. The data is sampled one clock cycle before the end of the active low read pulse, so the pulse width must be long enough that the access time will be satisfied

The following lists the settings for the applicable LCD controller:

Solomon Systech SSD1289

- Clock frequency: 20 MHz (50 ns)
- Read pulse width high: 10 clock cycles (500 ns)
- Read pulse width low: 10 clock cycles (500 ns)

Solomon Systech SSD2119

- Clock frequency: 25 MHz (40 ns)
- Read pulse width high: 13 clock cycles (500 ns)
- Read pulse width low: 13 clock cycles (500 ns)

Himax HX8347A

- Clock frequency: 28.5 MHz (35 ns)
- Read pulse width high: 3 clock cycles (105 ns)
- Read pulse width low: 11 clock cycles (385 ns)

ILITEK ILI9325

- Clock frequency: 20 MHz (50 ns)
- Read pulse width high: 3 clock cycles (150 ns)
- Read pulse width low: 3 clock cycles (150 ns)

Epson S1D13743

- Clock frequency: 33 MHz (33.3 ns)
- Read pulse width high: 2 clock cycles (67 ns)
- Read pulse width low: 5 clock cycles (167 ns)

Input/Output Connections

This section describes the various input and output connections for the GraphicLCDIntf component. An asterisk (*) in the list of I/Os indicates that the I/O may be hidden on the symbol under the conditions listed in the description of that I/O.

clock

The clock that operates this component. GraphicLCDIntf operates entirely from a single clock connected to the component.

di_lsb[7:0]

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 this pin should be disabled. The signals themselves are inherently synchronized because they are being driven based on synchronous output signals.

di_msb[7:0] *

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 this pin should be disabled. The signals themselves are inherently synchronized because they are being driven based on synchronous output signals.

do_lsb[7:0]

The lower eight bits of the output data bus. Used for data during a write transaction.

do_msb[7:0] *

The upper eight bits of the output data bus. Used for data during a write transaction. Only present for 16-bit interface mode.

oe

The output enable for the data bus. Normally connected to the output enable of the Input/Output pin component for the data buses. Refer to the Schematic Macro Information to see how this signal is used.

d_c

Data/Command signal. Indicates a data transaction when high and command transaction when low.

ncs

Active-low chip select.

nwr

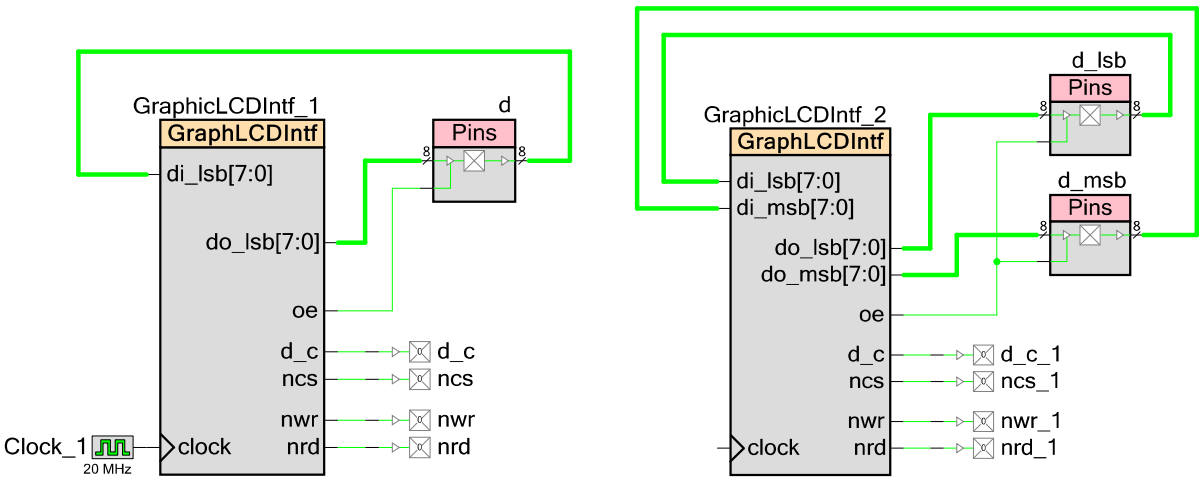
Active-low write control signal.

nrd

Active-low read control signal.

Schematic Macro Information

Two macros are supplied in addition to the standard symbol entry in the catalog. One macro is for an 8-bit implementation connected to pins and a clock. The other is for a 16-bit implementation connected to pins and a clock.

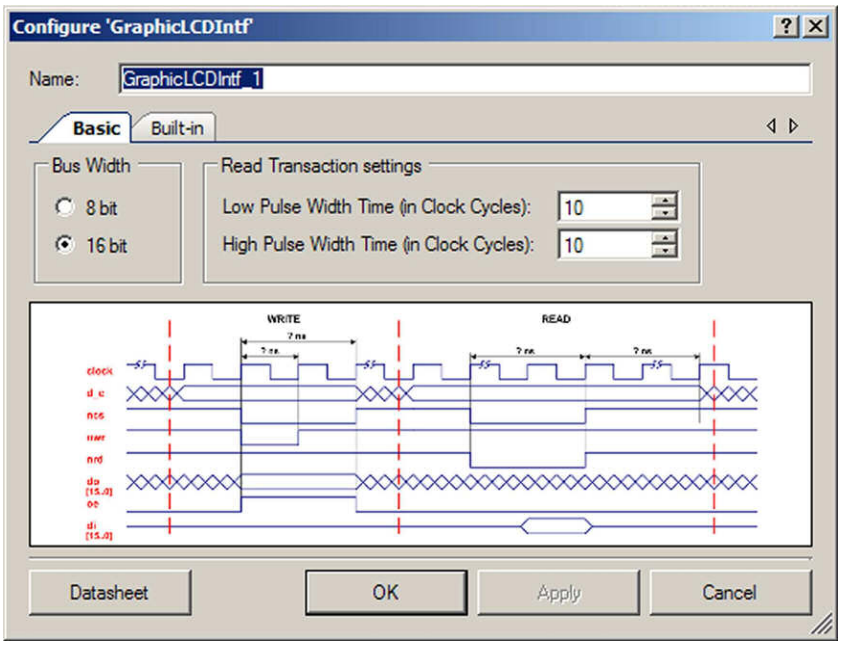


For each of the macros, the clock is set to 20 MHz and the pulse width settings are left at the default. These are the correct settings for the SSD1289 Controller.

The “Input Synchronized” option is unchecked on all of the data pins and the generation of APIs for all of the pins is turned off.

Component Parameters

Drag a GraphicLCDIntf component onto your design and double-click it to open the **Configure** dialog. The default GraphicLCDIntf settings are the proper settings for operation with the Solomon Systech SSD1289 Controller.



Bus Width

Determines whether an 8- or 16-bit parallel interface to a graphic LCD controller is supported. The default setting is **16 bit**.

Low Pulse Width Time

Determines the number of clock cycles required for the read pulse width low for the controller. This value can be set between 2 and 255 clock cycles (minimum is 2 because the read value needs to be sampled one clock before the end of the pulse). The default setting is **10**.

High Pulse Width Time

Determines the number of clock cycles required for read pulse width high for the controller. This value can be set between 1 and 255 clock cycles. The default setting is **10.**

Clock Selection

There is no internal clock in this component. You must attach a clock source. This component operates from a single clock connected to the component.

Placement

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

Resources

Resources	Resource Type			API Memory (Bytes)		Pins (per External I/O)
	Datapath Cells	PLDs	Status Cells	Flash	RAM	
8-bit interface	1	4	2	109	1	12
16-bit interface	2	4	3	120	1	20

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 “GraphicLCDIntf_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 generated for the component. For readability, the instance name used in the following table is “GraphicLCDIntf.”

Function	Description
GraphicLCDIntf_Start()	Starts the GraphicLCDIntf interface.
GraphicLCDIntf_Stop()	Disables the GraphicLCDIntf interface.
GraphicLCDIntf_Write8()	Initiates a write transaction on the 8-bit parallel interface.
GraphicLCDIntf_Write16()	Initiates a write transaction on the 16-bit parallel interface.
GraphicLCDIntf_Read8()	Initiates a read transaction on the 8-bit parallel interface.
GraphicLCDIntf_Read16()	Initiates a read transaction on the 16-bit parallel interface.
GraphicLCDIntf_Sleep()	Saves configuration and disables the GraphicLCDIntf.
GraphicLCDIntf_Wakeup()	Restores configuration and enables the GraphicLCDIntf.

Function	Description
GraphicLCDIntf_Init()	Initializes or restores default GraphicLCDIntf configuration.
GraphicLCDIntf_Enable()	Enables the GraphicLCDIntf.
GraphicLCDIntf_SaveConfig()	Saves configuration of GraphicLCDIntf.
GraphicLCDIntf_RestoreConfig()	Restores configuration of GraphicLCDIntf.

Global Variables

Variable	Description
GraphicLCDIntf_initVar	Indicates whether the Graphic LCD Interface has been initialized. The variable is initialized to 0 and set to 1 the first time GraphicLCDIntf_Start() is called. This allows the component to restart without reinitialization after the first call to the GraphicLCDIntf_Start() routine. If reinitialization of the component is required then the GraphicLCDIntf_Init() function can be called before the GraphicLCDIntf_Start() or GraphicLCDIntf_Enable() function.

void GraphicLCDIntf_Start(void)

Description: Enables Active mode power template bits or clock gating as appropriate. Configures the component for operation.

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDIntf_Stop(void)

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

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDIntf_Write8(uint8 d_c, uint8 data)

Description: Initiates a write transaction on the 8-bit parallel interface. 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: d_c: Data (1) or Command (0) indication. Passed to the d_c pin

data: Data sent on the do_lsb[7:0] pins

Return Value: None

Side Effects: None

void GraphicLCDIntf_Write16(uint8 d_c, uint16 data)

Description: Initiates a write transaction on the 16-bit parallel interface. 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: d_c: Data (1) or Command (0) indication. Passed to the d_c pin

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

uint8 GraphicLCDIntf_Read8(uint8 d_c)

Description: Initiates a read transaction on the 8-bit parallel interface. The read executes after all currently posted writes have completed. This function waits until the read completes and then returns the read value.

Parameters: d_c: Data (1) or Command (0) indication. Passed to the d_c pin.

Return Value: 8-bit read value from the di_lsb[7:0] pins

Side Effects: None

uint16 GraphicLCDIntf_Read16(uint8 d_c)

Description: Initiates a read transaction on the 16-bit parallel interface. The read executes after all currently posted writes have completed. This function waits until the read completes and then returns the read value.

Parameters: d_c: Data (1) or Command (0) indication. Passed to the d_c pin.

Return Value: 16-bit read value from the di_msb[7:0] (most significant byte) and di_lsb[7:0] (least significant byte) pins

Side Effects: None

void GraphicLCDIntf_Sleep(void)

Description: This is the preferred routine to prepare the component for sleep. The GraphicLCDIntf_Sleep() routine saves the current component state. Then it calls the GraphicLCDIntf_Stop() function and calls GraphicLCDIntf_SaveConfig() to save the hardware configuration. Disables Active mode power template bits or clock gating as appropriate.

Call the GraphicLCDIntf_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 GraphicLCDIntf_Wakeup(void)

Description: This is the preferred routine to restore the component to the state when GraphicLCDIntf_Sleep() was called. The GraphicLCDIntf_Wakeup() function calls the GraphicLCDIntf_RestoreConfig() function to restore the configuration. If the component was enabled before the GraphicLCDIntf_Sleep() function was called, the GraphicLCDIntf_Wakeup() function will also re-enable the component. Enables Active mode power template bits or clock gating as appropriate.

Parameters: None

Return Value: None

Side Effects: Calling the GraphicLCDIntf_Wakeup() function without first calling the GraphicLCDIntf_Sleep() or GraphicLCDIntf_SaveConfig() function may produce unexpected behavior.

void GraphicLCDIntf_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call GraphicLCDIntf_Init() because the GraphicLCDIntf_Start() routine calls this function and is the preferred method to begin component operation. Only the static component configuration that defines Read Low and High Pulse Widths will be restored to its initial values.

Parameters: None

Return Value: None

Side Effects: This reinitializes the component but it does not clear data from the FIFOs, and it does not reset the component hardware state machine. The current transaction is performed on the bus.

void GraphicLCDIntf_Enable(void)

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

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDIntf_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 GraphicLCDIntf_Sleep() function. The compile-time component configuration that defines Read Low and High Pulse Widths is stored.

Parameters: None

Return Value: None

Side Effects: None

void GraphicLCDIntf_RestoreConfig(void)

Description: Restores the configuration of GraphicLCDIntf nonretention registers. The API is called by GraphicLCDIntf_Wakeup to restore component nonretention registers.

Parameters: None

Return Value: None

Side Effects: If this API is called before GraphicLCDIntf_SaveConfig(), the component configuration for Read Low and High Pulse Widths is restored to its values provided with the customizer.

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

Bus Transactions

This interface can perform either a read or a write transaction. These transactions have the following parameters:

- Read or write
- Address – In this case it is just a one bit address driven on the d_c pin
- Data (8 or 16 bits) – Sent on “do” for writes and read on “di” for reads.

The implementation assumes that the CPU sends a command byte to the component using a FIFO (the same FIFO that is used for data). That command byte indicates read or write and provides the d_c bit.

Idle Condition

When neither a read nor a write is occurring on the interface the interface is in the idle state. The values for the output pins in that condition are:

- d_c: don’t care (may be left at its last state)
- ncs: 1

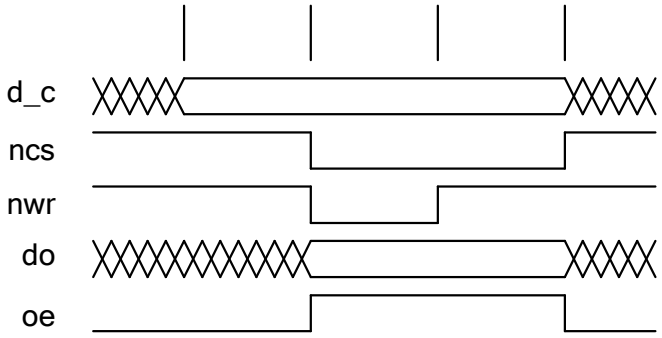
- nwr: 1
- nrd: 1
- do: don’t care (may be left at its last state)
- oe: 0

In the description of the read and write transactions, any signal not listed is idle.

Write Transaction

The timing diagram for a write transaction on the parallel interface is shown in Figure 1.

Figure 1. Write Transaction Timing Diagram



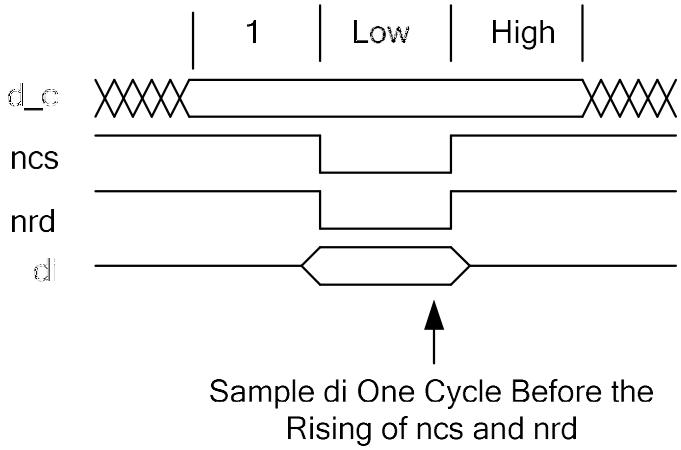
This diagram shows that the write transaction requires three clock cycles. The timing diagram is the same regardless of the bit width. This transaction can be immediately preceded or followed by another read or write transaction or may be in the idle state before or after a write transaction.

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 on parallel bus). The implementation allows the CPU to have two write requests outstanding without stalling the CPU.

Read Transaction

The timing diagram for a read transaction on the parallel interface is shown in Figure 2.

Figure 2. Read Transaction Timing Diagram



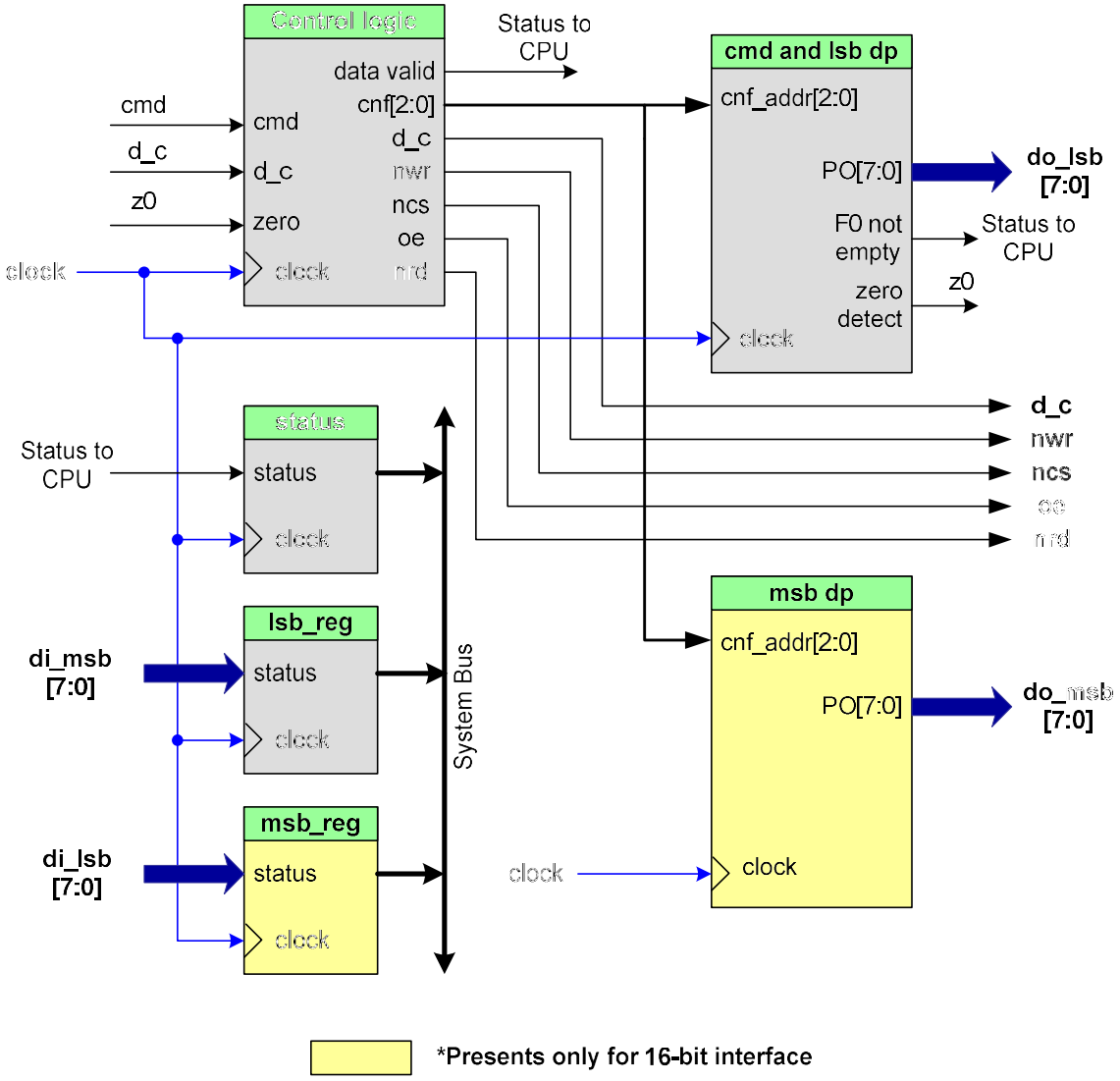
This diagram shows that the read transaction requires a variable number of clock cycles depending on the setting for the high and low read pulse widths. The timing diagram is the same regardless of the bit width. Note that the data input is sampled one clock cycle before the end of the ncs and nrd low pulses. 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 read transaction.

The ordering of reads and writes is maintained (reads occur before posted writes have completed). Reads require the CPU to wait for the completion of the read transaction before proceeding.

Block Diagram and Configuration

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

Figure 3. Block Diagram



Registers

GraphicLCDIntf_STATUS_REG

Bits	7	6	5	4	3	2	1	0
Value	reserved						data_valid	F0_half_ empty

- F0_half_empty: If set, there is at least two bytes of room in the command/data FIFO.
- data_valid: Set if read data is valid for the CPU. This bit is cleared when CPU reads the register.

GraphicLCDIntf_DIN_LSB_DATA_REG

Bits	7	6	5	4	3	2	1	0
Value	di_lsb[7:0]							

- The lower eight bits of the input data bus for read transaction

You can read the register value with the GraphicLCDIntf_Read8() API function for an 8-bit interface. It is the least significant byte of returned value from the GraphicLCDIntf_Read16() API function for a 16-bit interface.

GraphicLCDIntf_DIN_MSB_DATA_REG

Bits	7	6	5	4	3	2	1	0
Value	di_msb[7:0]							

- The upper eight bits of the input data bus for read transaction

The register value is the most significant byte of returned value from GraphicLCDIntf_Read16() API function for a 16-bit interface.

Note DIN_LSB_DATA_REG and DIN_MSB_DATA_REG bits are cleared when CPU firmware reads these registers.

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_{CLOCK}	Component clock frequency		–	–	33	MHz
t_{AS}	Address setup time		1	–	–	t_{CY_clock} [2]
t_{PWLW}	Pulse width low write		–	1	–	t_{CY_clock}
t_{PWHW}	Pulse width high write		3	–	–	t_{CY_clock}
t_{PWLR}	Pulse width low read		2	–	255	t_{CY_clock}
t_{PWHR}	Pulse width high read		1	–	255	t_{CY_clock}
t_{AH}	Address hold time					
		Write	2	–	–	t_{CY_clock}
		Read	t_{PWHR}	–	–	t_{CY_clock}
t_{CYCLE}	Clock cycle time					
		Write cycle	4	–	–	t_{CY_clock}
		Read cycle	t_{PWLR} + t_{PWRH} + 1	–	–	t_{CY_clock}
t_{DSW}	Data setup time		–	1	–	t_{CY_clock}
t_{DHW}	Data hold time		–	1	–	t_{CY_clock}
t_{ACC}	Data access time		–	t_{PWHR} – 1	–	t_{CY_clock}
t_{DHR}	Output hold time		–	0	–	t_{CY_clock}

[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.

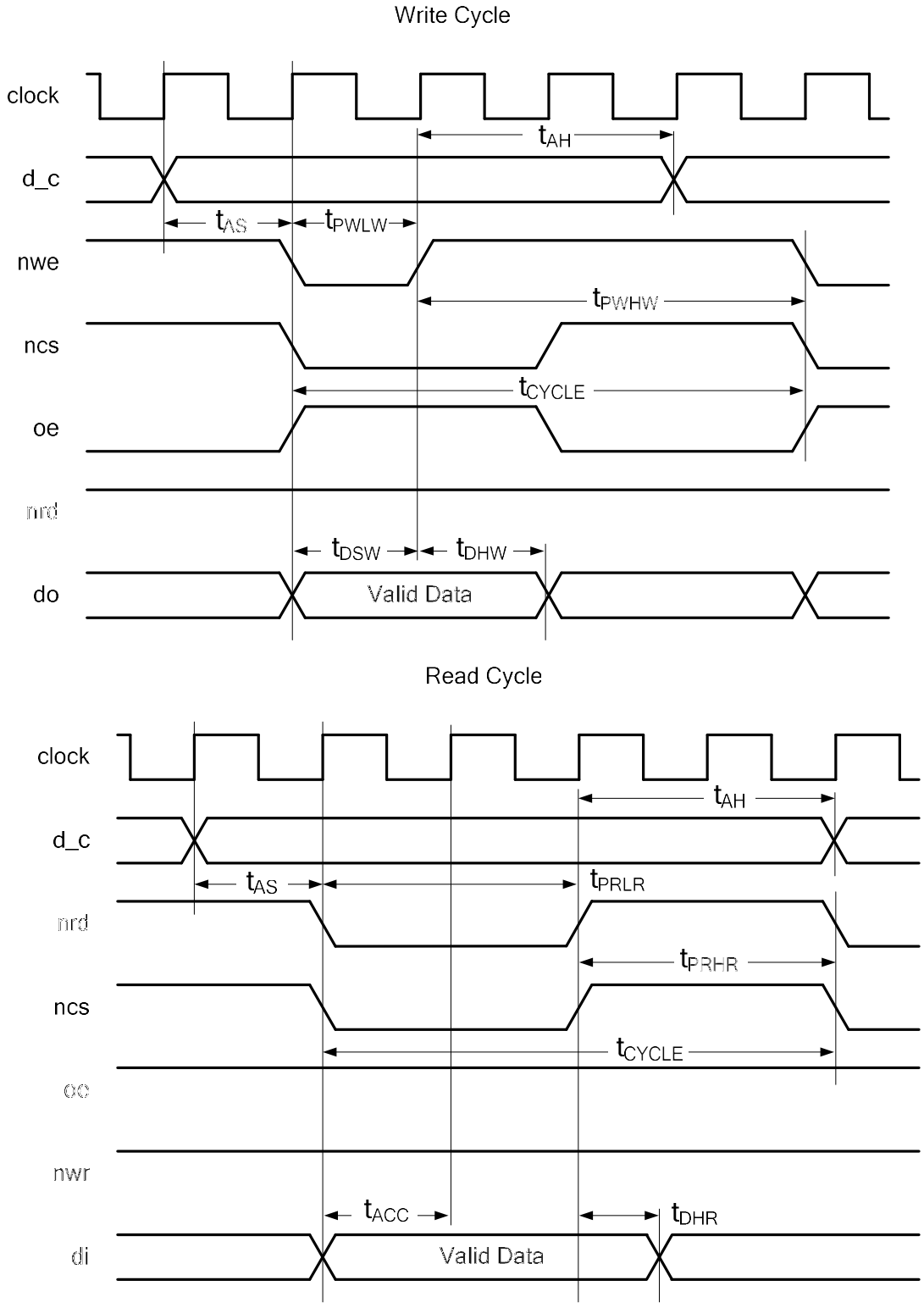
[2] $t_{CY\_clock} = 1/f_{CLOCK}$. This is the cycle time of one clock period

Timing Characteristics "Maximum with All Routing"

Parameter	Description		Min	Typ	Max[3]	Unit
f_{CLOCK}	Component clock frequency		–	–	25	MHz
t_{AS}	Address setup time		1	–	–	t_{CY_clock}
t_{PWLW}	Pulse width low write		–	1	–	t_{CY_clock}
t_{PWHW}	Pulse width high write		3	–	–	t_{CY_clock}
t_{PWLR}	Pulse width low read		2	–	255	t_{CY_clock}
t_{PWHR}	Pulse width high read		1	–	255	t_{CY_clock}
t_{AH}	Address hold time					
		Write	2	–	–	t_{CY_clock}
		Read	t_{PWHR}	–	–	t_{CY_clock}
t_{CYCLE}	Clock cycle time					
		Write	4	–	–	t_{CY_clock}
		Read	$t_{PWLR} + t_{PWRH} + 1$	–	–	t_{CY_clock}
t_{DSW}	Data setup time		–	1	–	t_{CY_clock}
t_{DHW}	Data hold time		–	1	–	t_{CY_clock}
t_{ACC}	Data access time		–	$t_{PWHR} – 1$	–	t_{CY_clock}
t_{DHR}	Output hold time		–	0	–	t_{CY_clock}

[3] Maximum for "All Routing" allows you to not worry about meeting timing if the component is running at or below this frequency.

Figure 4. Data Transition Timing Diagram



How to Use STA Results for Characteristics Data

Nominal route maximums are gathered through multiple test passes with Static Timing Analysis (STA). The maximums may be calculated for your designs using the STA results with the following mechanisms:

f_{CLOCK} Maximum component clock frequency is provided in Timing results in the clock summary as the named component clock (CLK in this case). An example of the component clock limitations is shown below:

-Clock Summary

Clock	Actual Freq	Max Freq	Violation
BUS_CLK	66.000 MHz	UNKNOWN	
CLK	33.000 MHz	43.579 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:

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

  t_{PWLR} The minimum pulse width low time for the read signal.

  t_{PWHR} The minimum pulse width high time for the read signal.

  You can find the specific description of how these parameters must be used when configuring the component in the When to Use a GraphicLCDIntf section on page 1.

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

  t_{PWHW} The minimum pulse width high time for the write signal.

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

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

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

  t_{DSW} The minimum amount of time the data is valid before the rising 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 negative edge of the read signal.

  t_{DHR} The minimum amount of time the data should be valid after rising edge of the nrd signal.

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 PSoC 3 and PSoC 5 silicons.
	Added characterization data to datasheet	
	Minor datasheet edits and updates	