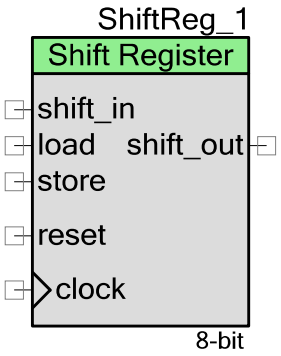
Shift Register (ShiftReg)

1.60

Features



- Adjustable shift register size: 2 to 32 bits
- Simultaneous shift in and shift out
- Right shift or left shift
- Reset input forces shift register to all 0s
- Shift register value readable by CPU or DMA
- Shift register value writable by CPU or DMA

General Description

The Shift Register (ShiftReg) component provides synchronous shifting of data into and out of a parallel register. The parallel register can be read or written to by the CPU or DMA. The Shift Register component provides universal functionality similar to standard 74xxx series logic shift registers including: 74164, 74165, 74166, 74194, 74299, 74595 and 74597. In most applications the Shift Register component will be used in conjunction with other components and logic to create higher-level application-specific functionality, such as a counter to count the number of bits shifted.

In general usage, the Shift Register component functions as a 2- to 32-bit shift register that shifts data on the rising edge of the clock input. The shift direction is configurable and allows a right shift where the MSB shifts in the input and the LSB shifts out the output, or a left shift where the LSB shifts in the input and the MSB shifts out the output.

The Shift Register value can be written by the CPU or DMA at any time. The rising edge of the component clock transfers pending FIFO data (previously written by the CPU or DMA) to the Shift Register when the load signal is set. A rising edge of the component clock transfers the current Shift Register value to the FIFO when a rising edge of the optional store input has been detected, where it can later be read by the CPU.

The Shift Register component can generate an interrupt signal on any combination of the load, store or reset signals.

When to Use a Shift Register

One of the most common uses of a shift register is to convert between serial and parallel interfaces. This is useful because many circuits work on groups of bits in parallel, but serial interfaces are simpler to construct.

The shift register can also be used as a simple delay circuit. In most cases, the shift register requires additional application-specific circuitry to function the way your application requires. An example is a counter or state machine to store the shifted data after a number of events has occurred.

A common use of shift registers is to shift in or out eight bits of data based on a clock, as is done in the SPI protocol. If you are building a communication protocol, check to see if there is an existing higher-level component for that communication protocol already.

Input/Output Connections

This section describes the various input and output connections for Shift Register. 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.

shift_in – Input *

Serial data input to the Shift Register MSB or LSB depending on shift direction. This terminal is displayed if the **Use Shift In** check box is selected.

load – Input *

The load input signal triggers the transfer of pending input FIFO data (previously written to the FIFO by CPU or DMA) to the Shift Register. A transfer occurs on the first rising edge of the component clock when the load signal is set. The load input is asynchronous to the clock input. This terminal is displayed if the **Use Load** check box is selected. Note that multiple clock edges during Load high state can cause multiple load events (see the Use Load section for details).

store – Input *

The store input signal triggers the transfer of the current shift register value into the output FIFO. A transfer occurs on the first rising edge of the component clock after the store signal rising edge has been detected. Store signal should be low for at least one component clock period before the next store event (see the Use Store section for details). The ShiftReg_ReadData() API routine can then be used to read the data from the FIFO. The store input is asynchronous to the clock input (still synchronous to the system). This terminal is displayed if the **Use Store** check box is selected.

reset – Input

The reset input (active high) causes the entire Shift Register to be set to zeros. This input does not affect the contents of the FIFOs. The reset input is synchronous to the clock input.

clock – Input

Clock source for the component. In some configurations this signal acts as an enable rather than a clock.

shift_out – Output *

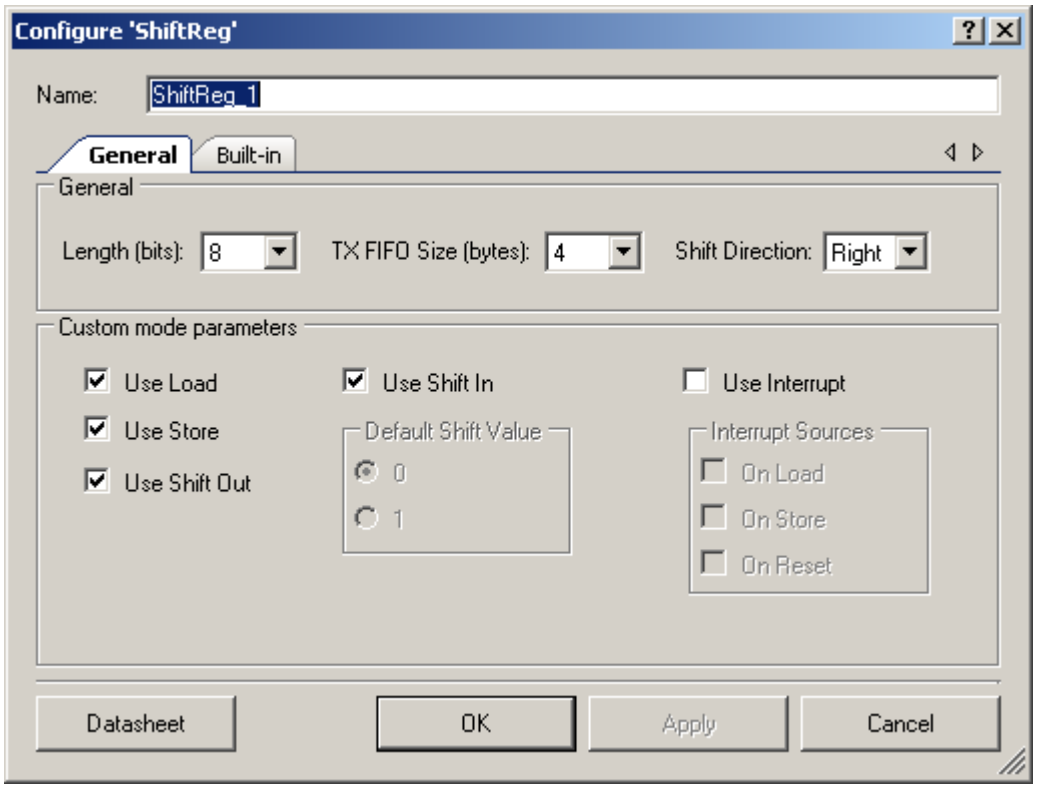
Outputs serial data from the Shift Register MSB or LSB based on shift direction. This terminal is displayed if the **Use Shift Out** check box is selected.

interrupt – Output *

Interrupt signal generated by the shift register component. Interrupts are generated based on the specified parameters. This terminal is displayed if the **Use Interrupt** check box is selected.

Component Parameters

Drag a Shift Register component onto your design and double-click it to open the **Configure** dialog.



Length (bits)

This parameter determines the length of the shift register in bits. Valid values are 2 through 32 bits. The default is **8**.

TX FIFO Size (bytes)

This parameter defines the number of shift register words the input and output FIFOs can hold. Choose either **1** or **4**.

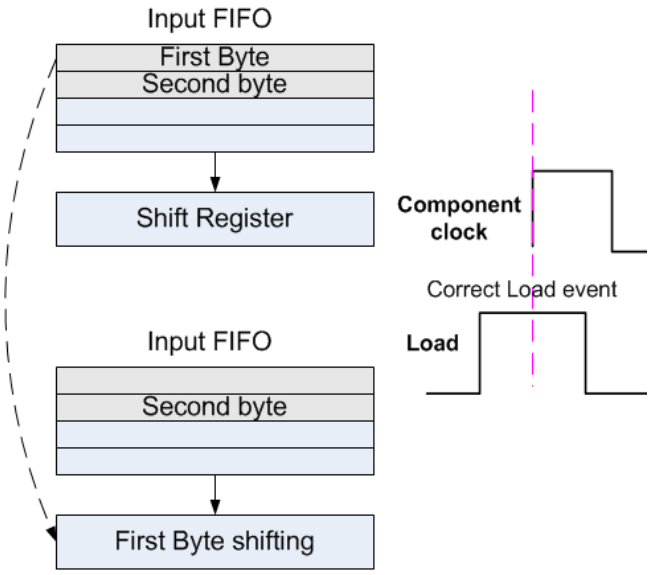
Shift Direction

This parameter determines the shift direction, **Right** or **Left**. The default is **Right** (LSB first).

Use Load

When this option is selected, the load input terminal is included on the Shift Register symbol. The load signal is internally routed to the control logic so that a word from the input FIFO is transferred to the Shift Register on a rising edge of the component clock and high level of the load signal.

Be careful with the load signal duration. When the load signal is asserted, the next FIFO word is loaded into the Shift Register on each rising edge of the component clock. If the load signal is held high for too long, multiple load events can occur. If the FIFO is empty when a load event occurs, arbitrary data is loaded into the Shift Register.



If **Use Load** is selected, the ShiftReg_WriteRegValue(), ShiftReg_ReadRegValue(), and ShiftReg_GetIntStatus() APIs are generated to work with the output FIFO. The *component.h* file has the necessary API prototypes and #define constants.

If **Use Load** is not selected, the load terminal is not shown on the component symbol and the associated API routines are not generated.

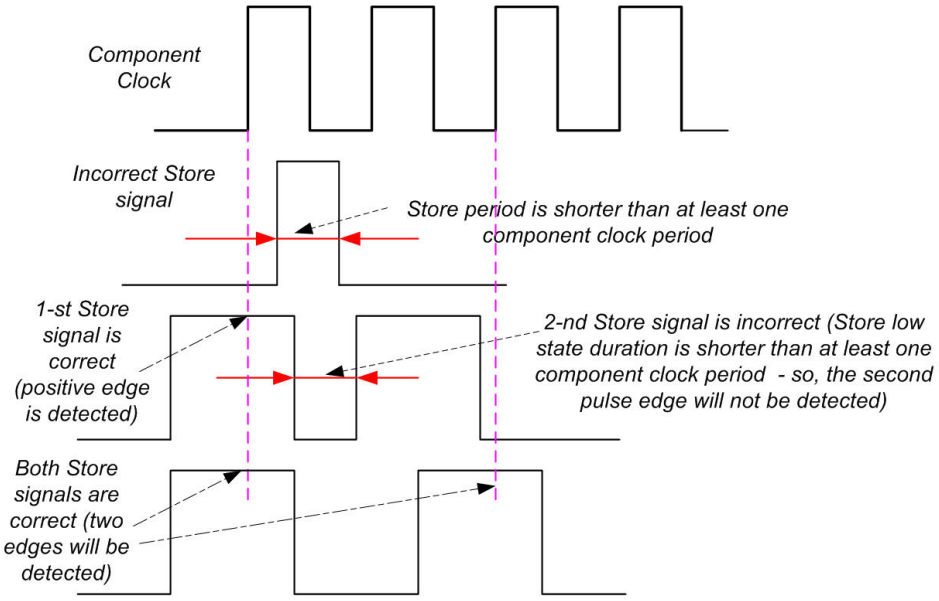
Use Store

When this option is selected, the store input terminal is included on the Shift Register symbol. The store signal is internally routed to the control logic such that on a rising edge of the component clock after the store signal rising edge has been detected, the current word in the Shift Register is transferred to the output FIFO.

Notes

1. The store signal pulse duration should be longer than at least one component clock period.
2. The store signal should be low for at least one component clock period before the next store event.

If these conditions are not met, the store edge will not be detected.



If **Use Store** is selected, the ShiftReg_WriteRegValue(), ShiftReg_ReadRegValue(), and ShiftReg_GetIntStatus() APIs are generated for working with the output FIFO. The *component.h* file has the necessary API prototypes and #define constants.

Caution

Be careful when using the ShiftReg_ReadRegValue() API routine in conjunction with the **Use Store** output FIFO functionality. The ShiftReg_ReadRegValue() API implementation transfers the current Shift Register ALU value into the output FIFO and then reads this data from the FIFO. Any data previously captured in the output FIFO using the Store signal, but not yet read by the application, will be lost.

If **Use Store** is not selected, the store terminal is not shown on the component symbol and the associated API routines are not generated.

Use Shift Out

This parameter determines if the shift_out output of the Shift Register symbol is provided. It is selected by default.

Use Shift In

This parameter determines if the shift_in input of the Shift Register symbol is provided. It is selected by default.

Default Shift Value

This parameter allows you to define a default value for the input to the Shift Register. This parameter is only used if the **Use Shift In** parameter is not checked. The valid values for the **Default Shift Value** parameter are **0** and **1**.

Use Interrupt

If this parameter is selected, the interrupt output terminal displays on the symbol. This enables the use of interrupts generated by the Shift Register.

If **Use Interrupt** is not selected, the interrupt terminal is not shown on the symbol and the associated API routines are generated.

Interrupt Sources

This parameter becomes enabled if you select **Use Interrupt**. The interrupt signal is used to indicate that one of the specified conditions has occurred. You can enable or disable interrupt generation and specify the events that will trigger an interrupt: **On Load**, **On Store** or **On Reset**.

Clock Selection

Any signal can be used as the Shift Register component clock input. Data is shifted on the rising edge of the clock input signal.

Placement

The Shift Register component is implemented using UDB array resources. The necessary UDB resources are allocated by the tool placement algorithms.

Resources

Resolution	Digital Blocks					API Memory (Bytes)		Pins (per External I/O)
	Datapaths	Macro cells	Status Registers	Control Registers	Counter7	Flash	RAM	
8 bits	1	2	1	1	0	554	4	6
16 bits	2	2	1	1	0	630	6	6
24 bits	3	2	1	1	0	668	8	6
32 bits	4	2	1	1	0	668	10	6

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 “ShiftReg_1” to the first instance of a component in a given design. You can rename it 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 “ShiftReg.”

Function	Description
ShiftReg_Start()	Starts the Shift Register and enables all selected interrupts
ShiftReg_Stop()	Disables the Shift Register
ShiftReg_EnableInt()	Enables the Shift Register interrupt
ShiftReg_DisableInt()	Disables the Shift Register interrupt
ShiftReg_SetIntMode()	Sets the interrupt source for the interrupt
ShiftReg_GetIntStatus()	Gets the Shift Register interrupt status
ShiftReg_WriteRegValue()	Writes a value directly to the shift register
ShiftReg_ReadRegValue()	Reads the current value from the shift register
ShiftReg_WriteData()	Writes data to the shift register input FIFO
ShiftReg_ReadData()	Reads data from the shift register output FIFO
ShiftReg_GetFIFOStatus ()	Returns current status of input or output FIFO
ShiftReg_Sleep()	Stops the component and saves all nonretention registers
ShiftReg_Wakeup()	Restores all nonretention registers and starts component

Function	Description
ShiftReg_Init()	Initializes or restores default Shift Register configuration
ShiftReg_Enable()	Enables the Shift Register
ShiftReg_SaveConfig()	Saves configuration of Shift Register
ShiftReg_RestoreConfig()	Restores configuration of Shift Register

Global Variables

Variable	Description
ShiftReg_initVar	Indicates whether the Shift Register has been initialized. The variable is initialized to 0 and set to 1 the first time ShiftReg_Start() is called. This allows the component to restart without reinitialization after the first call to the ShiftReg_Start() routine. If reinitialization is required, then the ShiftReg_Init() function can be called before the ShiftReg_Start() or ShiftReg_Enable() function.

void ShiftReg_Start(void)

Description: This is the preferred method to begin component operation. ShiftReg_Start() sets the initVar variable, calls the ShiftReg_Init() function, and then calls the ShiftReg_Enable() function.

Parameters: None

Return Value: None

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

void ShiftReg_Stop(void)

Description: Disables the Shift Register.

Parameters: None

Return Value: None

Side Effects: None

void ShiftReg_EnableInt(void)

Description: Enables the Shift Register interrupts.

Parameters: None

Return Value: None

Side Effects: None

void ShiftReg_DisableInt(void)

Description: Disables the Shift Register interrupts.

Parameters: None

Return Value: None

Side Effects: None

void ShiftReg_SetIntMode(uint8 interruptSource)

Description: Sets the interrupt source for the interrupt. Multiple sources may be ORed together.

Parameters: uint8 InterruptSource: Bit field containing the constant for the selected interrupt sources. Multiple sources can be ORed together to select multiple interrupts.

Return Value	Description
ShiftReg_LOAD_INT_EN	Enables the Load interrupt
ShiftReg_STORE_INT_EN	Enables the Store interrupt
ShiftReg_RESET_INT_EN	Enables the Reset interrupt

Return Value: None

Side Effects: None

uint8 ShiftReg_GetIntStatus(void)

Description: Gets the interrupt status for the Shift Register interrupts.

Parameters: None

Return Value: Bit field containing the status for the selected interrupt sources.

Return Value	Description
ShiftReg_LOAD	Load interrupt occurred
ShiftReg_STORE	Store interrupt occurred
ShiftReg_RESET	Reset interrupt occurred

Side Effects: Clears the Interrupt Status register.

void ShiftReg_WriteRegValue(uint8/16/32 shiftData)

Description: Writes a value directly to the Shift Register.

Parameters: unit8/16/32 shiftData: Data to be written. Data type is determined by the Shift Register Length parameter.

Return Value: None

Side Effects: The component must be stopped to use this API function.

Note The written value is available for reading after one component clock period.

uint8/16/32 ShiftReg_ReadRegValue(void)

Description: Returns the current value from the shift register.

Parameters: None

Return Value: unit8/16/32 Shift Register value. Data type is determined by the Length parameter

Side Effects: Clears the shift register output FIFO. Wait at least one component clock period after calling ShiftReg_WriteRegValue() before calling this function.

Caution

Be careful when using the ShiftReg_ReadRegValue() API routine in conjunction with the **Use Store** output FIFO functionality. The ShiftReg_ReadRegValue() API implementation transfers the current Shift Register ALU value into the output FIFO and then reads this data from the FIFO. Any data previously captured in the output FIFO using the Store signal, but not yet read by the application, will be lost.

cystatus ShiftReg_WriteData(uint8/16/32 shiftData)

Description: Writes data to the shift register input FIFO. A data word is transferred to the shift register on a rising edge of the load input

Parameters: unit8/16/32 shiftData: Data to be written. Data type is determined by the Shift Register Length parameter.

Return Value: cystatus: Returns an error if the FIFO is full or CYRET_SUCCESS on successful operation. If the input FIFO is full then the data will not be written to the FIFO.

Return Value	Description
CYRET_SUCCESS	Successful operation
CYRET_INVALID_STATE	Input FIFO is full

Side Effects: None

uint8/16/32 ShiftReg_ReadData(void)

Description: Reads data from the shift register output FIFO. A data word is transferred to the output FIFO on a rising edge of the store input.

Parameters: None

Return Value: unit8/16/32: next available data word. Data type is determined by the Shift Register Length parameter.

Side Effects: None

uint8 ShiftReg_GetFIFOStatus (uint8 fifoId)

Description: Returns the current status of the input or output FIFO.

Parameters: uint8 FifoID: identifies which FIFO status is read.

FifoID Value	Description
ShiftReg_IN_FIFO	Used to read status of the input FIFO
ShiftReg_OUT_FIFO	Used to read status of the output FIFO

Return Value: unit8: FIFO Status of one of defined values.

Return Value	Description
ShiftReg_RET_FIFO_FULL	FIFO is full
ShiftReg_RET_FIFO_NOT_FULL	FIFO is not full
ShiftReg_RET_FIFO_EMPTY	FIFO is empty

Side Effects: None

void ShiftReg_Sleep(void)

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

Call the ShiftReg_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 ShiftReg_Wakeup(void)

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

Parameters: None

Return Value: None

Side Effects: Calling the ShiftReg_Wakeup() function without first calling the ShiftReg_Sleep() or ShiftReg_SaveConfig() function may produce unexpected behavior.

void ShiftReg_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call ShiftReg_Init() because the ShiftReg_Start() routine calls this function and is the preferred method to begin component operation.

Parameters: None

Return Value: None

Side Effects: All registers will be set to values according to the Configure dialog.

void ShiftReg_Enable(void)

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

Parameters: None

Return Value: None

Side Effects: None

void I2S_SaveConfig(void)

Description: This function saves the component configuration and nonretention registers. This function 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 ShiftReg_Sleep() function.

Parameters: None

Return Value: None

Side Effects: None

void I2S_RestoreConfig(void)

Description:	This function restores the component configuration and nonretention registers. This function also restores the component parameter values to what they were prior to calling the ShiftReg_Sleep() function
Parameters:	None
Return Value:	None
Side Effects:	Call this routine only after calling the ShiftReg_SaveConfig() function. Calling it independently of the ShiftReg_SaveConfig() function overwrites the current settings with the initial settings.

Defines

ShiftReg_SR_SIZE – Defines Shift Register length in bits.

ShiftReg_USE_INPUT_FIFO – Indicates that an input FIFO is defined in the project.

Note The output FIFO is always defined because it is used for Software Capture.

ShiftReg_FIFOSize – Defines the size of the Input FIFO in Shift Register words. The Shift Register word size is determined by the **Length** (in bytes) parameter value.

ShiftReg_DIRECTION – Defines the direction of the shift (0 = Left Shift , 1 = Right Shift).

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.

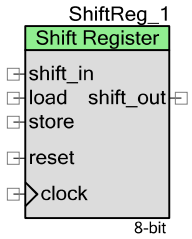
Functional Description

The Shift Register parameters allow for considerable flexibility in the configuration of the component. This section provides additional explanation of the Shift Register operation and how the parameters can be used to customize the component for your application. The Shift Register can be used standalone, or in conjunction with other components to create application-specific functionality.

Default Configuration

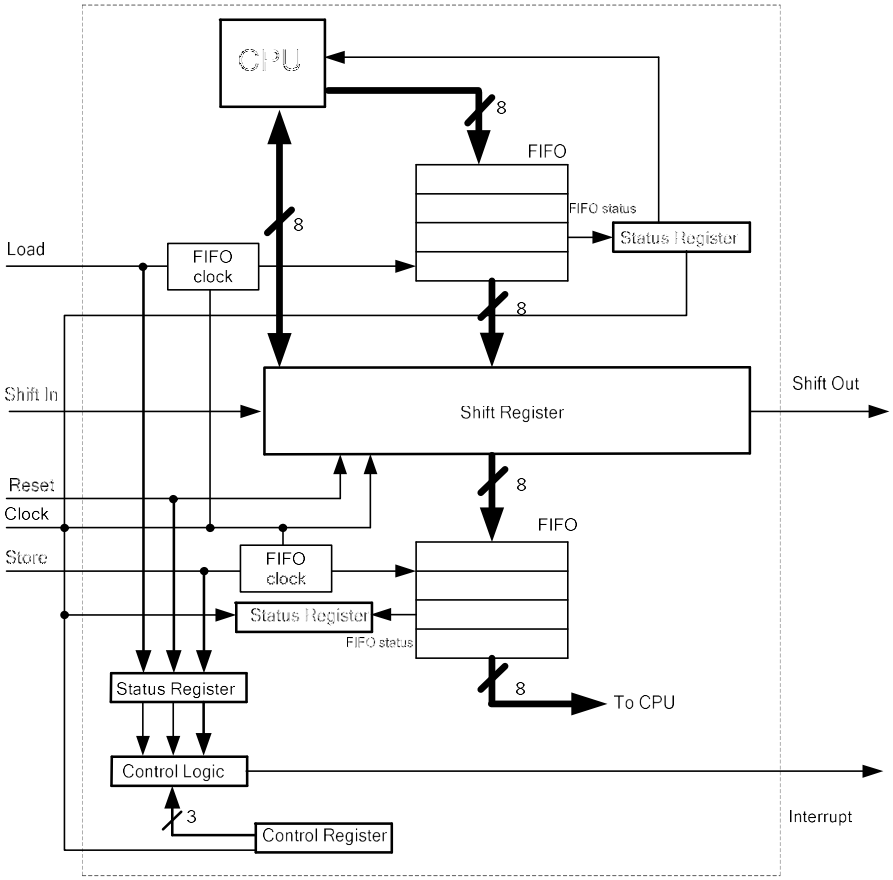
The default configuration of the Shift Register component provides basic parallel shift register functionality similar to standard 7400 series logic shift registers. This functionality includes

synchronous shifting of data into and out off a parallel register on the rising edge of the clock input. Serial bit stream data is shifted into the shift_in terminal and shifted from the shift_out output terminal.



Block Diagram and Configuration

Figure 1. Shift Register Block Diagram



The Shift Register is a UDB-based component that consists of an input FIFO (F0), a direct shift register (A0 and A1 with duplicated value for providing the software capture), an output FIFO (F1), and control and status registers.

The input FIFO F0 is configured to input mode. This means that this FIFO can be written by the CPU (using the ShiftReg_WriteData() API function) and this value can be loaded into the A0

register for shifting. This function checks the current FIFO status before each cycle using the ShiftReg_GetFIFOStatus() function.

The value to be shifted can be also written directly to the A0 register by calling ShiftReg_WriteRegValue(). Because of internal hardware implementation it is strongly recommended to stop component operation (by using ShiftReg_Stop() function or stopping input clock) when using ShiftReg_WriteRegValue(). Otherwise, writing the A0 register during the shift operation will lead to incorrect data being written.

The Load operation has the hardware restriction that the load event can be provided only when input FIFO is not empty.

To provide the shift functionality, the UDB datapaths are used in the following configuration:

State == 100 (4)	Shift Operation (Left or Right)
State == 101 (5)	Reset (XOR A0 A0)
State == 110 (6)	Load A0 <=F0
State == 111 (7)	Reset (XOR A0 A0)

All operations except store are controlled from the datapath control store. Shift is a default operation (cs_addr = “000”). The load input is connected to the cs_addr[1] line and the reset input to cs_addr[0]. If some of these lines change their level it causes the control store address to change immediately. On the positive edge of the datapath clock (component clock in this case), the corresponding operation will be executed. The load causes the loading value to change from F0 to A0. The reset command causes the clearing of A0. In this case, the load value is ignored.

Two mechanisms are used to read the shifted value: hardware and software capture. The hardware capture event happens on each positive edge on the store input. It causes the Shift Register value to be written to the output FIFO. This value can be read by the ShiftReg_ReadData() API function. The store input has a hardware restriction that the store input will be active only if output FIFO is not full.

Software capture happens each time the ShiftReg_ReadRegValue() function is called. This function reads the A1 value where it duplicates the value of A0. This operation reduces the A1 value to be automatically written to the output FIFO F1 (because F1 is configured to software capture from A1). Before providing the software capture, the ShiftReg_ReadRegData() function clears the output FIFO. Therefore, you should be careful when using it.

Note Using this function, the actual value in the A1 will be available in the next clock cycle after writing the Shift Register.

The interrupt generation mechanism is implemented using the status register. It has three bits, which represent three interrupt sources: Load, Store, and Reset. When one of these bits changes its value from 0 to 1, the interrupt pulse on the appropriate status register output is automatically generated. These three bits are in “clear-on-read” mode.

The second status register is used for storing the current input and output FIFO's status. All status bits are in “sticky” mode (are not cleared after reading).

When the Shift Register size is more than 8, the datapath's chaining connectivity is provided to connect 2, 3, or 4 datapaths between each other to implement component size 16, 24, or 32. To implement a Shift Register size that does not coincide with the datapath's measures, a verilog-controlled MSB is used with the datapath's configurations.

The component is started and stopped using the CLK_EN bit of the control register.

Registers

ShiftReg_SR_CONTROL

Bits	7	6	5	4	3	2	1	0
Value	Reserved							clk_en

- clk_en : Enables Shift Register operation

ShiftReg_SR_STATUS

Bits	7	6	5	4	3	2	1	0
Value		F1_not_ empty	F1_full	F0_not_full	F0_empty	reset	store	load

- load: Load status bit
- store: Store status bit
- reset: Reset status bit
- F0_empty: Input FIFO is empty
- F0_not_full: Input FIFO is not full
- F1_full: Output FIFO full
- F1_not_empty: Output FIFO is not empty

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	Config.	Min	Typ	Max	Units
f_{CLOCK}	Component clock frequency	8-bit	–	–	66	MHz
		16-bit	–	–	66	MHz
		24-bit	–	–	58	MHz
		32-bit	–	–	55	MHz
t_{CLOCKH}	Input clock high time [1]	N/A	–	0.5	–	$1/f_{CLOCK}$
t_{CLOCKL}	Input clock low time [1]	N/A	–	0.5	–	$1/f_{CLOCK}$
Inputs						
t_{PD_ps}	Input path delay, pin to sync [2]	1	–	–	STA [3]	ns
t_{PD_ps}	Input path delay, pin to sync [4]	2	–	–	8.5	ns
t_{PD_IE}	Input path delay to component cock (edge-sensitive input)	1,2	t_{PD_ps} + t_{SYNC} + t_{PD_si}	–	t_{PD_ps} + t_{SYNC} + t_{PD_si} + t_{I_clk}	ns
t_{PD_si}	Sync output to input path delay (route)	1,2,3,4	–	–	STA [3]	ns
t_{I_clk}	Alignment of clockX and clock	1,2,3,4	0	–	1	t_{CY_clock}
t_{IH}	Input high time	1,2	t_{CY_clock}	–	–	ns
t_{IL}	Input low time	1,2	t_{CY_clock}	–	–	ns
t_{PD_IE}	Input path delay to component clock (edge-sensitive input)	3,4	t_{SYNC} + t_{PD_si}	–	t_{SYNC} + t_{PD_si} + t_{I_clk}	ns

[1] $t_{CY\_clock} = 1/f_{CLOCK}$ - Cycle time of one clock period

[2] t_{PD_ps} is found in the Static Timing Results as described later. The number listed here is a nominal value based on STA analysis on many inputs.

[3] t_{PD_ps} and t_{PD_si} are route path delays. Because routing is dynamic, these values can change and will directly affect the maximum component clock and sync clock frequencies. The values must be found in the Static Timing Analysis results.

[4] t_{PD_ps} in configuration 2 is a fixed value defined per pin of the device. The number listed here is a nominal value of all of the pins available on the device.

Parameter	Description	Config.	Min	Typ	Max	Units
t_{IH}	Input high time	1,2,3,4	t_{CY_clock}	–	–	ns
t_{IL}	Input low time	1,2,3,4	t_{CY_clock}	–	–	ns

Timing Characteristics "Maximum with All Routing"

Parameter	Description	Config.	Min	Typ	Max [1]	Units
f_{CLOCK}	Component clock frequency	8-bit	–	–	33	MHz
		16-bit	–	–	33	MHz
		24-bit	–	–	29	MHz
		32-bit	–	–	27	MHz
t_{CLOCKH}	Input clock high time [2]	N/A	–	0.5	–	$1/f_{CLOCK}$
t_{clockL}	Input clock low time [2]	N/A	–	0.5	–	$1/f_{CLOCK}$
Inputs						
t_{PD_ps}	Input path delay, pin to sync [3]	1	–	–	STA [4]	ns
t_{PD_ps}	Input path delay, pin to sync [5]	2	–	–	8.5	ns
t_{PD_IE}	Input path delay to component clock (edge-sensitive input)	1,2	$t_{PD\_ps} + t_{sync} + t_{PD\_si}$	–	$t_{PD\_ps} + t_{sync} + t_{PD\_si} + t_{I\_clk}$	ns
t_{PD_si}	Sync output to input path delay (route)	1,2,3,4	–	–	STA [4]	ns
t_{I_clk}	Alignment of clockX and clock	1,2,3,4	0	–	1	t_{CY_clock}
t_{IH}	Input high time	1,2	t_{CY_clock}	–	–	ns
t_{IL}	Input low time	1,2	t_{CY_clock}	–	–	ns

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

[2] $t_{CY\_clock} = 1/f_{CLOCK}$ - Cycle time of one clock period

[3] t_{PD_ps} is found in the Static Timing Results as described later. The number listed here is a nominal value based on STA analysis on many inputs.

[4] t_{PD_ps} and t_{PD_si} are route path delays. Because routing is dynamic, these values can change and will directly affect the maximum component clock and sync clock frequencies. The values must be found in the Static Timing Analysis results.

[5] t_{PD_ps} in configuration 2 is a fixed value defined per pin of the device. The number listed here is a nominal value of all of the pins available on the device.

Parameter	Description	Config.	Min	Typ	Max [1]	Units
t_{PD_IE}	Input path delay to component clock (edge-sensitive input)	3,4	$t_{sync} + t_{PD\_si}$	–	$t_{sync} + t_{PD\_si} + t_{l\_clk}$	ns
t_{IH}	Input high time	1,2,3,4	t_{CY_clock}	–	–	ns
t_{IL}	Input low time	1,2,3,4	t_{CY_clock}	–	–	ns

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 from the *_timing.html*:

-Clock Summary

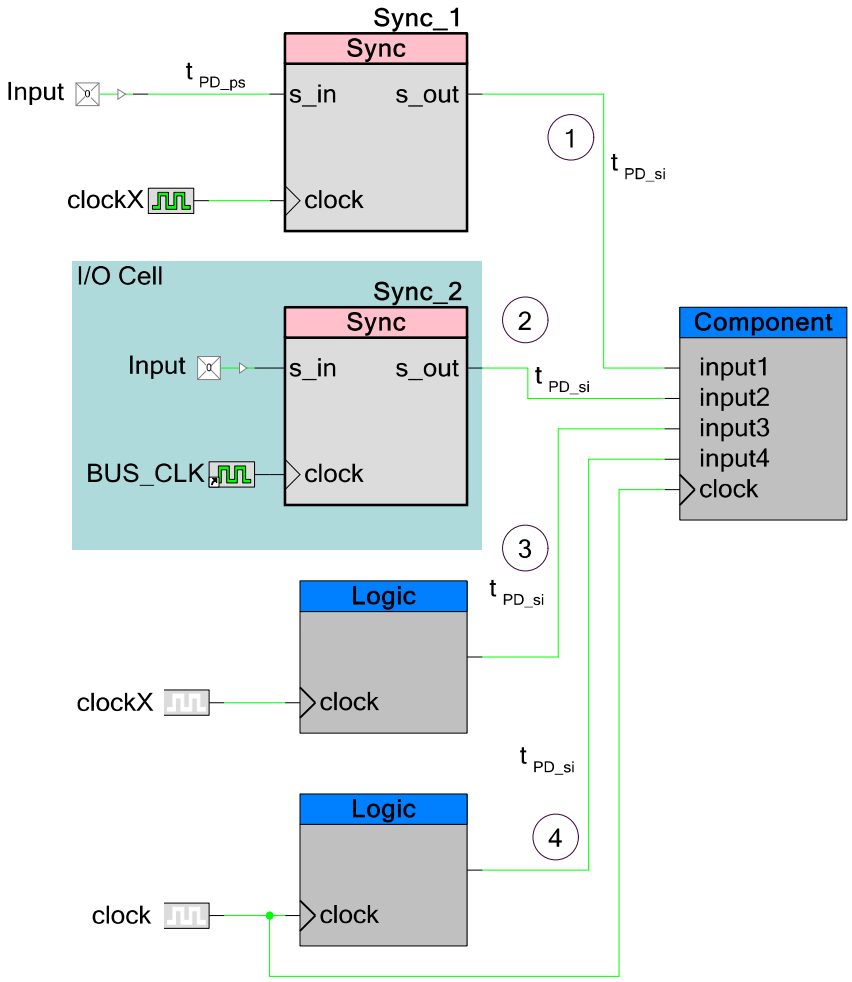
Clock	Actual Freq	Max Freq	Violation
BUS_CLK	24.000 MHz	118.683 MHz	
clock	24.000 MHz	56.967 MHz	

Input Path Delay and Pulse Width

When characterizing the functionality of inputs, all inputs, no matter how you have configured them, look like one of four possible configurations, as shown in Figure 2.

All inputs must be synchronized. The synchronization mechanism depends on the source of the input to the component. To fully interpret how your system will work you must understand which input configuration you have set up for each input and the clock configuration of your system. This section describes how to use the Static Timing Analysis (STA) results to determine the characteristics of your system.

Figure 2. Input Configurations for Component Timing Specifications



Configuration	Component Clock	Synchronizer Clock (Frequency)	Figures
1	master_clock	master_clock	Figure 7
1	clock	master_clock	Figure 5
1	clock	clockX = clock [1]	Figure 3
1	clock	clockX > clock	Figure 4
1	clock	clockX < clock	Figure 6
2	master_clock	master_clock	Figure 7
2	clock	master_clock	Figure 5

[1] Clock frequencies are equal but alignment of rising edges is not guaranteed.

Configuration	Component Clock	Synchronizer Clock (Frequency)	Figures
3	master_clock	master_clock	Figure 12
3	clock	master_clock	Figure 10
3	clock	clockX = clock [1]	Figure 8
3	clock	clockX > clock	Figure 9
3	clock	clockX < clock	Figure 11
4	master_clock	master_clock	Figure 12
4	clock	clock	Figure 8

1. The input is driven by a device pin and synchronized internally with a “sync” component. This component is clocked using a different internal clock than the clock the component uses (all internal clocks are derived from master_clock).

   When characterizing inputs configured in this way, clockX may be faster, equal to, or slower than the component clock. It may also be equal to master_clock, which produces the characterization parameters shown in Figure 3, Figure 4, Figure 6, and Figure 7.
2. The input is driven by a device pin and synchronized at the pin using master_clock.

   When characterizing inputs configured in this way, master_clock is faster than or equal to the component clock (it is never slower than). This produces the characterization parameters shown in Figure 4 and Figure 7.

Figure 3. Input Configuration 1 and 2; Sync Clock Frequency = Component Clock Frequency (Edge alignment of clock and clockX is not guaranteed)

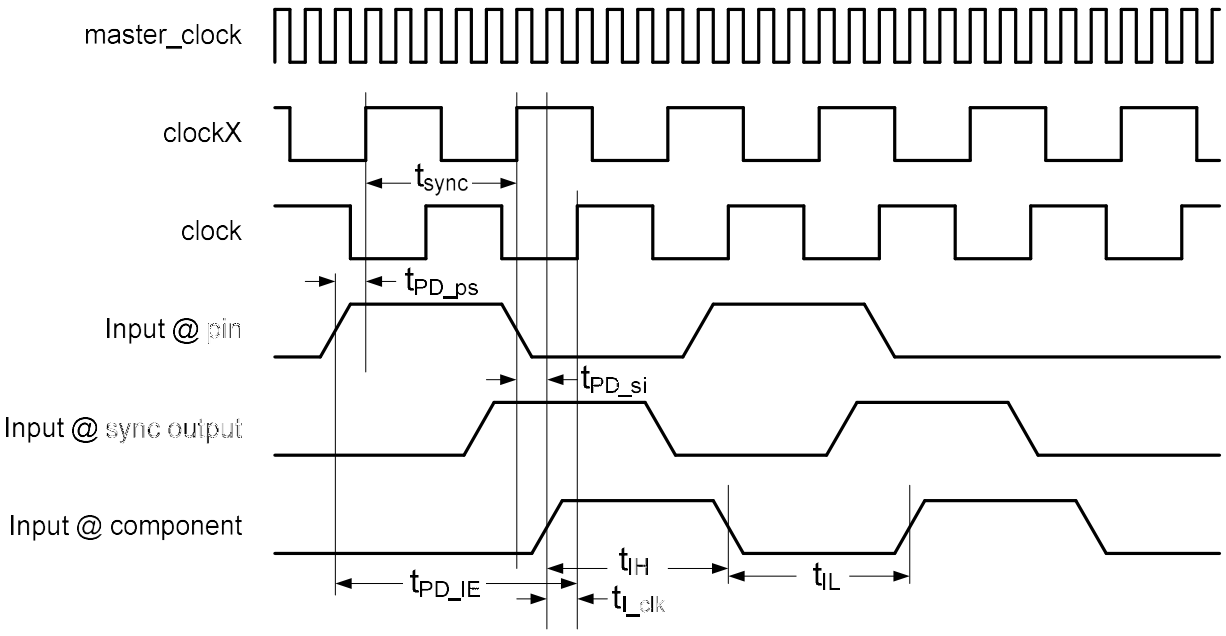


Figure 4. Input Configuration 1 and 2; Sync Clock Frequency > Component Clock Frequency

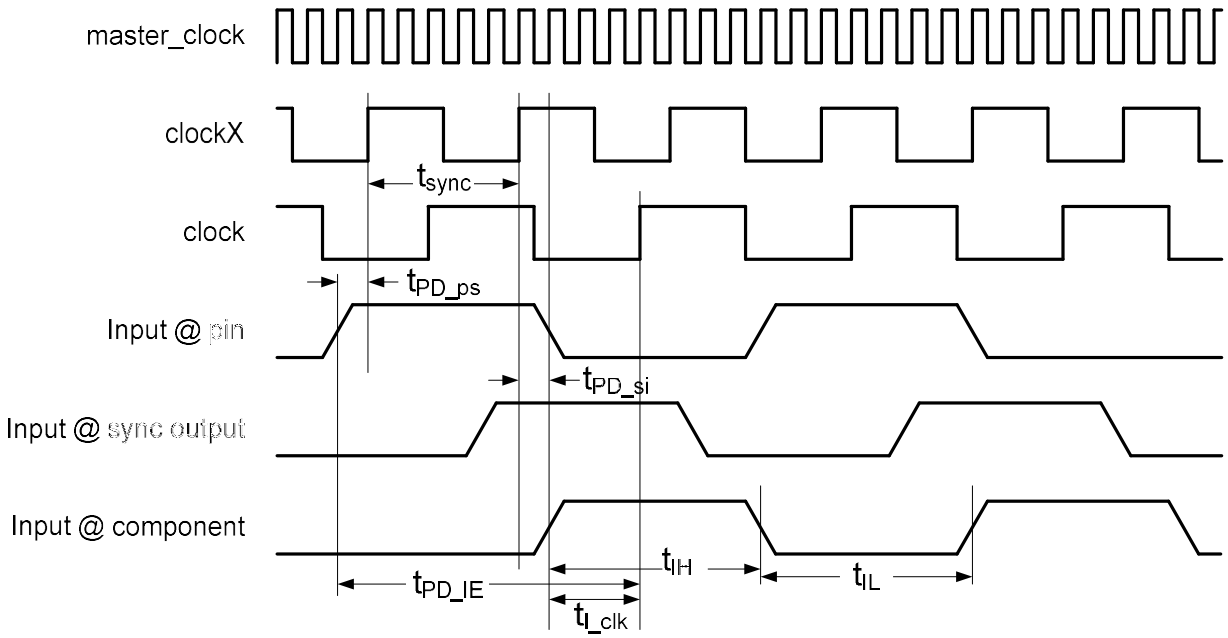


Figure 5. Input Configuration 1 and 2; [Sync Clock Frequency == master_clock] > Component Clock Frequency

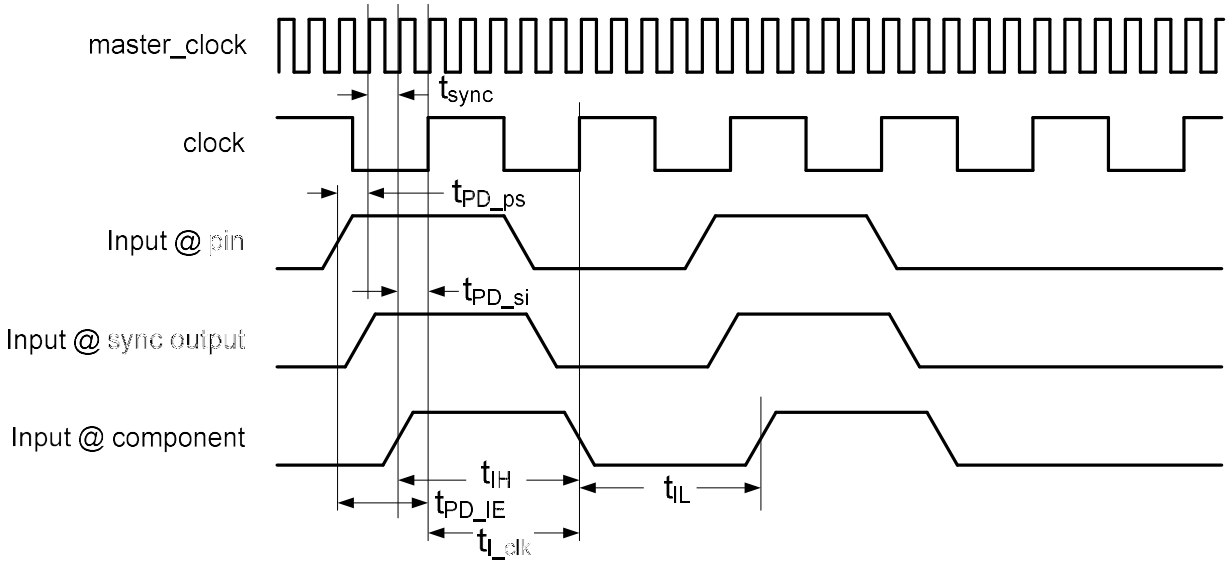


Figure 6. Input Configuration 1; Sync Clock Frequency < Component Clock Frequency

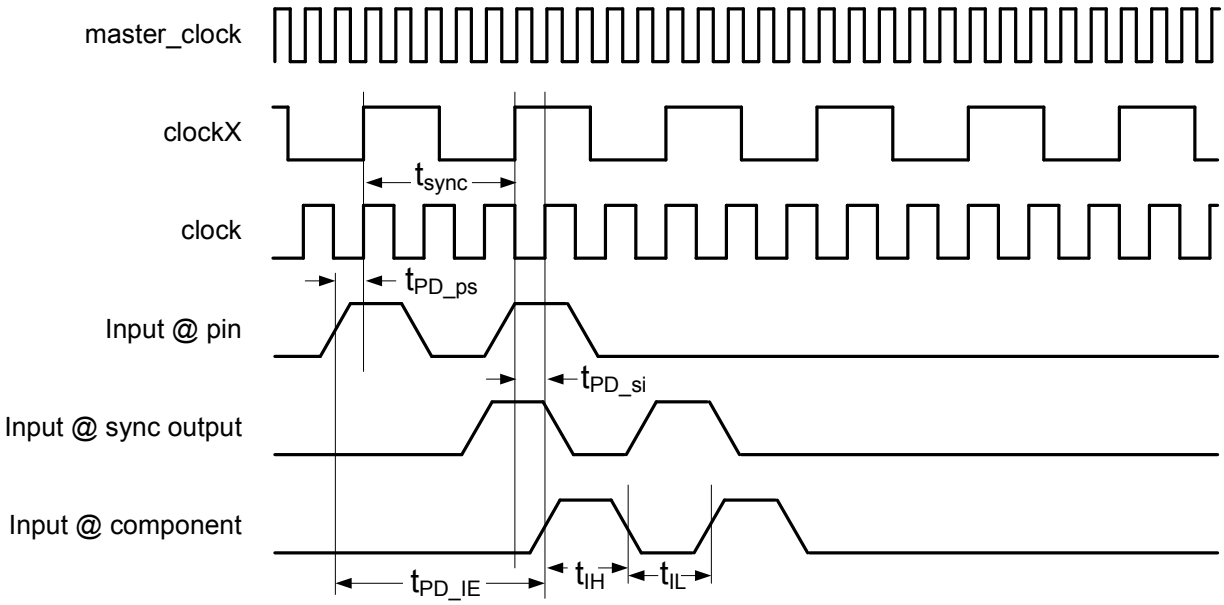
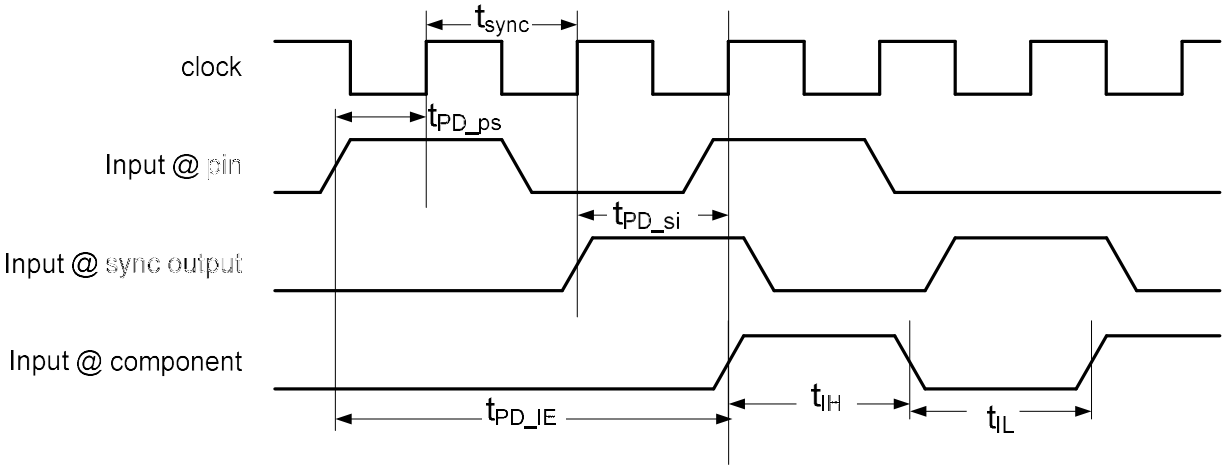


Figure 7. Input Configuration 1 and 2; Sync Clock = Component Clock = master_clock



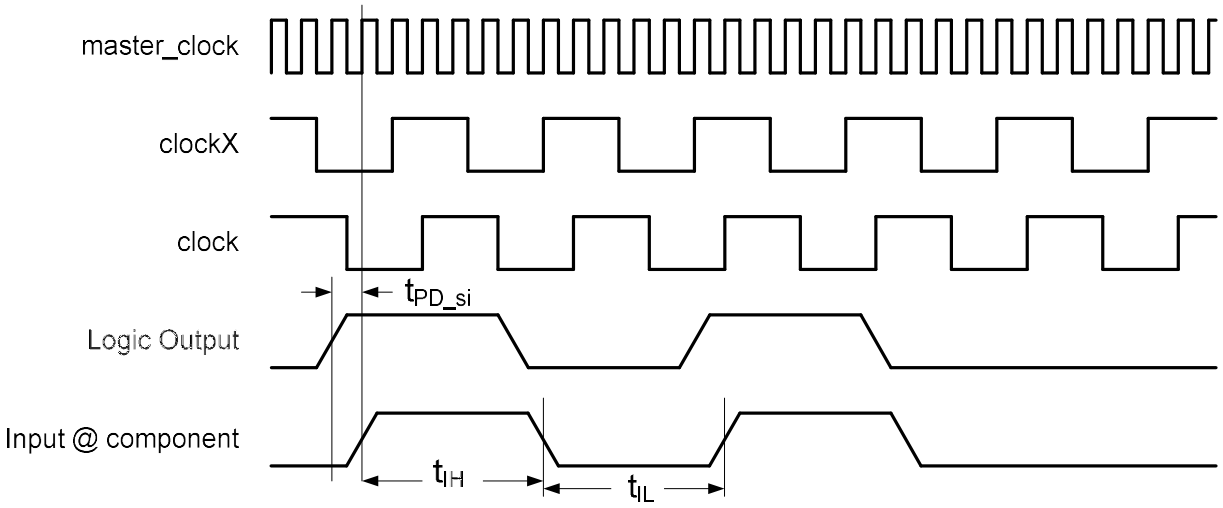
1. The input is driven by logic internal to the PSoC, which is synchronous based on a clock other than the clock the component uses (all internal clocks are derived from master_clock).

   When characterizing inputs configured in this way, the synchronizer clock is faster than, less than, or equal to the component clock, which produces the characterization parameters shown in Figure 8, Figure 9, and Figure 11.

2. The input is driven by logic internal to the PSoC, which is synchronous based on the same clock the component uses.

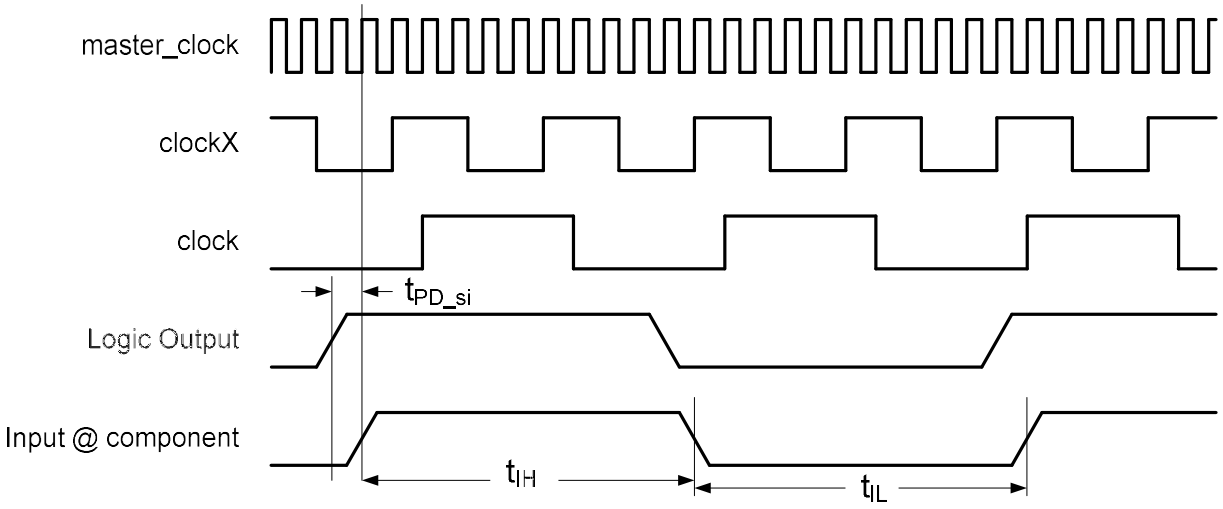
   When characterizing inputs configured in this way, the synchronizer clock will be equal to the component clock, which will produce the characterization parameters as shown in Figure 12.

Figure 8. Input Configuration 3 only; Sync Clock Frequency = Component Clock Frequency (Edge alignment of clock and clockX is not guaranteed)



This figure represents the understanding that Static Timing Analysis holds on the clocks. All clocks in the digital clock domain are synchronous to master_clock. However, it is possible that two clocks with the same frequency are not rising-edge-aligned. Therefore, the static timing analysis tool does not know which edge the clocks are synchronous to and must assume the minimum of one master_clock cycle. This means that t_{PD_si} now has a limiting effect on master_clock of the system. Master_clock setup time violations appear if this path delay is too long. You must change the synchronization clocks of your system or run master_clock at a slower frequency.

Figure 9. Input Configuration 3; Sync Clock Frequency > Component Clock Frequency



In much the same way as shown in Figure 8, all clocks are derived from master_clock. STA indicates the t_{PD_si} limitations on master_clock for one master_clock cycle in this configuration. Master_clock setup time violations appear if this path delay is too long. You must change the synchronization clocks of your system or run the master_clock at a slower frequency.

Figure 10. Input Configuration 3; Synchronizer Clock Frequency = master_clock > Component Clock Frequency

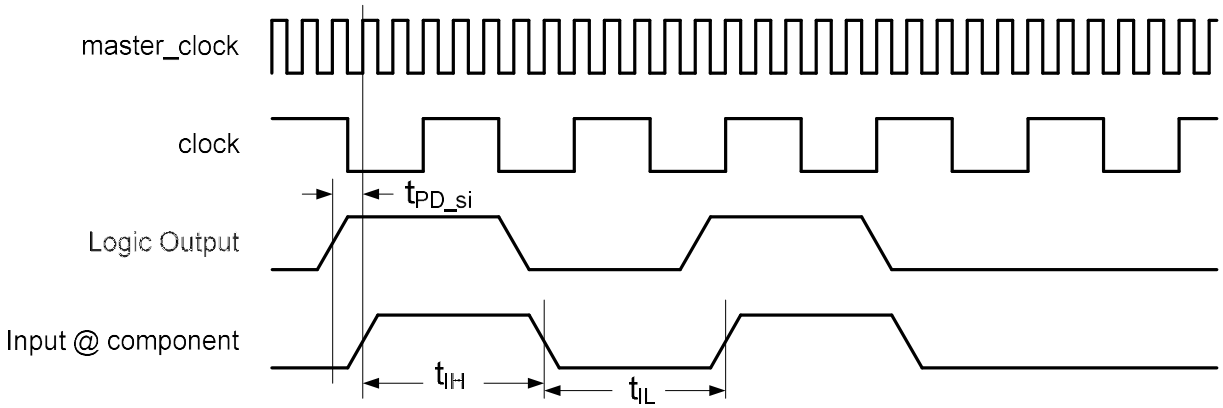
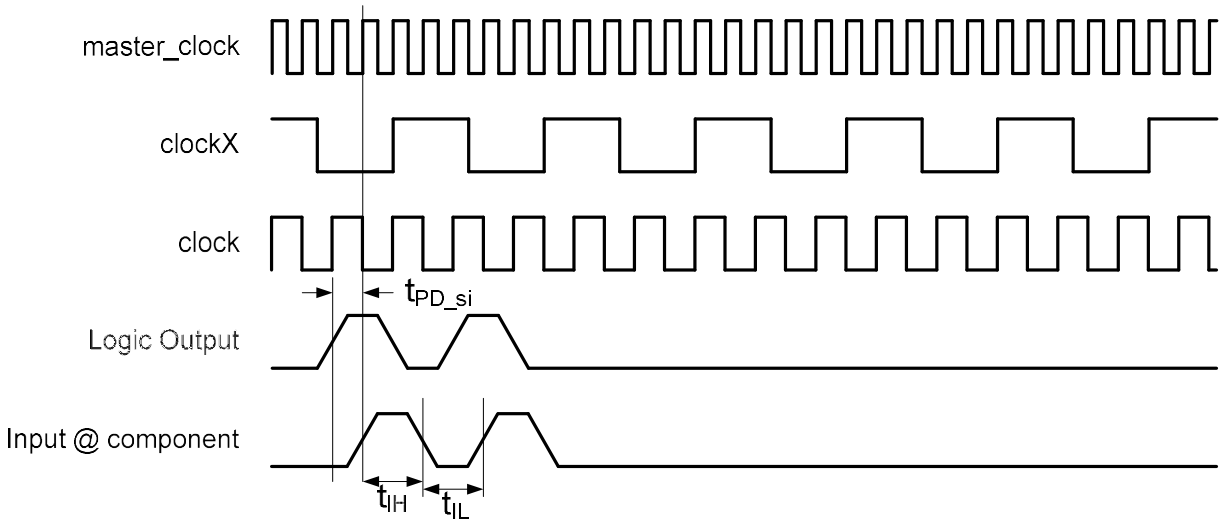
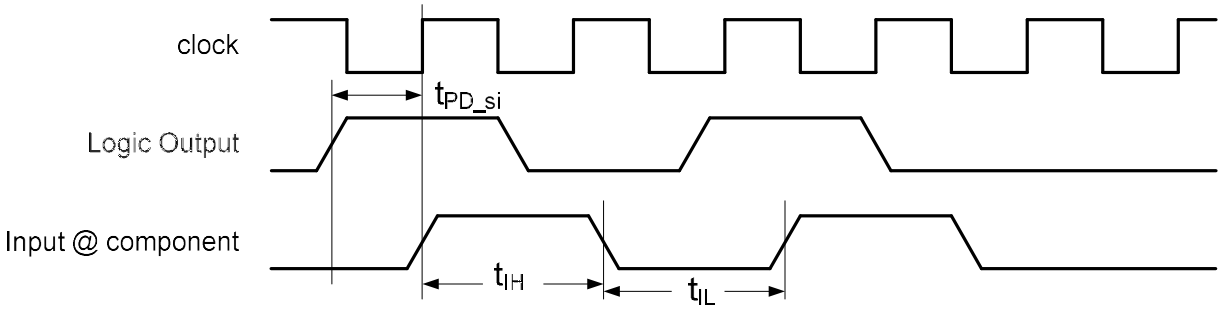


Figure 11. Input Configuration 3; Synchronizer Clock Frequency < Component Clock Frequency



In much the same way as shown in Figure 8, all clocks are derived from master_clock. STA indicates the t_{PD_si} limitations on master_clock for one master_clock cycle in this configuration. master_clock setup time violations appear if this path delay is too long. You must change the synchronization clocks of your system or run master_clock at a slower frequency.

Figure 12. Input Configuration 4 only; Synchronizer Clock = Component Clock



In all previous figures in this section, the most critical parameters to use when understanding your implementation are f_{CLOCK} and t_{PD_IE}. t_{PD_IE} is defined by t_{PD_ps} and t_{SYNC} (for configurations 1 and 2 only), t_{PD_si}, and t_{I_Clk}. Of critical importance is the fact that t_{PD_si} defines the maximum component clock frequency. t_{I_Clk} does not come from the STA results but is used to represent when t_{PD_IE} is registered. This is the margin left over after the route between the synchronizer and the component clock.

t_{PD_ps} and t_{PD_si} are included in the STA results.

To find t_{PD_ps}, look at the input setup times defined in the *_timing.html* file. The fanout of this input may be more than 1 so you will need to evaluate the maximum of these paths.

-Setup times

-Setup times to clock BUS_CLK

Start	Register	Clock	Delay (ns)
input1(0):iocell.pad_in	input1(0):iocell.ind	BUS_CLK	16.500

t_{PD_si} will be defined in the Register-to-register times. You will need to know the name of the net to use the *_timing.html* file. The fanout of this path may be more than 1 so you will need to evaluate the maximum of these paths.

-Register-to-register times

-Destination clock clock

Destination clock clock (Actual freq: 24.000 MHz)

+Source clock clock

-Source clock clock_1

Source clock clock_1 (Actual freq: 24.000 MHz)
Affected clock: BUS_CLK (Actual freq: 24.000 MHz)

Start	End	Period (ns)	Max Freq	Frequency	Violation
\Sync_1:genblk1[0]:INST\:synccell.syncq	\PWM_1:PWMUDB:runmode_enable\:macrocell.mc_d	7.843	127.508 MHz	24.000 MHz	

Output Path Delays

When characterizing the path delays of outputs, you must consider where the output is going in order to know where you can find the data in the STA results. For this component, all outputs are synchronized to the component clock. Outputs fall into one of two categories. The output goes either to another component inside the device, or to a pin to the outside of the device. In the first case, you must look at the Register-to-register times shown for the Logic-to-input descriptions above (the source clock is the component clock). For the second case, you can look at the Clock-to-Output times in the *_timing.html* STA results.

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	Datasheet corrections	
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	
1.50	Added Sleep/Wakeup and Init/Enable APIs.	To support low power modes, as well as to provide common interfaces to separate control of initialization and enabling of most components.
	Update the Configure dialog.	Changed locations of ‘Use Shift Out’ and ‘Use Shift' and changed default value of ‘Use interrupt’ check box to improve functionality.
	Changed the ShiftReg_ReadRegValue() implementation.	This provides faster Software Capture execution.
1.20	Option of selecting FIFO size is disabled when load and store are not used. Updated the Configure dialog. Removed generated code for unused parameters.	Various changes were made to fix issues with version 1.10, which was not fully functional.