Features

- 3- to 16-bit data width
- Four SPI operating modes
- Bit rate up to 9 Mbps\(^1\)

General Description

The SPI Master component provides an industry-standard, 4-wire master SPI interface. It can also provide a 3-wire (bidirectional) SPI interface. Both interfaces support all four SPI operating modes, allowing communication with any SPI slave device. In addition to the standard 8-bit word length, the SPI Master supports a configurable 3- to 16-bit word length for communicating with nonstandard SPI word lengths.

SPI signals include the standard Serial Clock (SCLK), Master In Slave Out (MISO), Master Out Slave In (MOSI), bidirectional Serial Data (SDAT), and Slave Select (SS).

When to Use the SPI Master

You can use the SPI Master component any time the PSoC device must interface with one or more SPI slave devices. In addition to “SPI slave” labeled devices, the SPI Master can be used with many devices implementing a shift-register-type serial interface.

You should use the SPI Slave component in instances in which the PSoC device must communicate with an SPI master device. You should use the Shift Register component in situations where its low-level flexibility provides hardware capabilities not available in the SPI Master component.

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\(^1\) This value is valid only for MOSI+MISO (Full Duplex) interfacing mode (see DC and AC Electrical Characteristics for details) and is restricted up to 1 Mbps in Bidirectional mode because of internal bidirectional pin constraints.
**Input/Output Connections**

This section describes the various input and output connections for the SPI 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.

**miso – Input ***

The miso input carries the Master In Slave Out (MISO) signal from a slave device. This input is visible when the **Data Lines** parameter is set to **MOSI + MISO**. If visible, this input must be connected.

**sdat – Inout ***

The sdat inout carries the Serial Data (SDAT) signal. This input is used when the **Data Lines** parameter is set to **Bidirectional**.

**Figure 1. SPI Bidirectional Mode (data transmission from Master to Slave)**

**Figure 2. SPI Bidirectional Mode (data transmission from Slave to Master)**
**clock – Input**

The clock input defines the bit rate of the serial communication. The bit rate is one-half the input clock frequency.

The clock input is visible when the **Clock Selection** parameter is set to **External Clock**. If visible, this input must be connected. If you select **Internal Clock**, then you must define the desired data bit rate; the required clock is solved and provided by PSoC Creator.

**reset – Input**

Resets the SPI state machine to the idle state. This throws out any data that was currently being transmitted or received but does not clear data from the FIFO that has already been received or is ready to be transmitted. Note that ES2 silicon does not support routed reset functionality, so this input should be unconnected when the component is used in ES2 silicon projects. The reset input may be left floating with no external connection. If nothing is connected to the reset line the component will assign it a constant logic 0.

**mosi – Output**

The mosi output carries the Master Out Slave In (MOSI) signal from the master device on the bus. This output is visible when the **Data Lines** parameter is set to **MOSI + MISO**.

**sclk – Output**

The sclk output carries the Serial Clock (SCLK) signal. It provides the master synchronization clock output to the slave devices on the bus.

**ss – Output**

The ss output is hardware controlled. It carries the Slave Select (SS) signal to the slave devices on the bus. You can connect a digital demultiplexer to handle multiple slave devices, or to have a completely firmware-controlled SS. See **Figure 3** and **Figure 4** for examples.
Unless inverters are put at the output of the demux, a logic ‘0’ can’t be transferred through it, because the other unselected channels will also have logic ‘0’. To compensate for this, an inverter is put at the input of demux.

Figure 4. Firmware Controlled Slave Selects

Figure 5 shows the timing correlation between SS and SCLK.
Figure 5. SS and SCLK Timing Correlation

CPHA =0:

CPHA =1:

Note SS is not set to high during a multi-byte/word transmission if the “SPI Done” condition was not generated.

rx_interrupt – Output
The interrupt output is the logical OR of the group of possible Rx interrupt sources. This signal goes high while any of the enabled Rx interrupt sources are true.

tx_interrupt – Output
The interrupt output is the logical OR of the group of possible Tx interrupt sources. This signal will go high while any of the enabled Tx interrupt sources are true.
Schematic Macro Information

By default, the PSoC Creator Component Catalog contains Schematic Macro implementations for the SPI Master component. These macros contain already connected and adjusted input and output pins and clock source. Schematic Macros are available both for 4-wire (Full Duplex) and 3-wire (Bidirectional) SPI interfacing.

Figure 6. 4-Wire (Full Duplex) Interfacing Schematic Macro

![Figure 6. 4-Wire (Full Duplex) Interfacing Schematic Macro](image)

Figure 7. 3-Wire (Bidirectional) Interfacing Schematic Macro

![Figure 7. 3-Wire (Bidirectional) Interfacing Schematic Macro](image)

Note If you do not use a Schematic Macro, configure the Pins component to deselect the Input Synchronized parameter for each of the assigned input pins (MISO or SDAT inout). The parameter is located under the Pins > Input tab of the applicable Pins Configure dialog.

Component Parameters

Drag an SPI Master component onto the design. Double click the component symbol to open the Configure dialog.

The following sections describe the SPI Master parameters, and how they are configured using the Configure dialog. They also indicate whether the options are implemented in hardware or software.
Hardware versus Software Options

Hardware configuration options change the way the project is synthesized and placed in the hardware. You must rebuild the hardware if you make changes to any of these options. Software configuration options do not affect synthesis or placement. When setting these parameters before build time you are setting their initial value, which can be modified at any time with the provided APIs. Hardware-only parameters are marked with an asterisk (*).

Configure Tab

The Configure tab contains basic parameters required for every SPI component. These parameters are the first ones that appear when you open the Configure dialog.

![Configure SPI_Master dialog](image)

**Note** The sample signal in the waveform is not an input or output of the system; it only indicates when the data is sampled at the master and slave for the mode settings selected.

**Mode** *

The Mode parameter defines the clock phase and clock polarity mode you want to use in the communication. The options are **Mode 0**, **Mode 1**, **Mode 2**, and **Mode 3**. These modes are defined in the following table. See Functional Description for more information.
<table>
<thead>
<tr>
<th>Mode</th>
<th>CPHA</th>
<th>CPOL</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Data Lines**

The **Data Lines** parameter defines which interface is used for SPI communication – 4-wire (MOSI + MISO) or 3-wire (Bidirectional).

**Data Bits** *

The number of **Data Bits** defines the bit width of a single transfer as transferred with the SPIM_ReadRxData() and SPIM_WriteTxData() functions. The default number of bits is a single byte (8 bits). Any integer from 3 to 16 is a valid setting.

**Shift Direction** *

The **Shift Direction** parameter defines the direction in which the serial data is transmitted. When set to **MSB First**, the most-significant bit is transmitted first. This is implemented by shifting the data left. When set to **LSB First**, the least-significant bit is transmitted first. This is implemented by shifting the data right.

**Bit Rate** *

If the **Clock Selection** parameter (on the Advanced tab) is set to **Internal Clock**, the **Bit Rate** parameter defines the SCLK speed in Hertz. The clock frequency of the internal clock will be 2x the SCLK rate. This parameter has no affect if the **Clock Selection** parameter is set to **External Clock**.
Advanced Tab

The Advanced tab contains parameters that provide additional functionality.

Clock Selection *

The Clock Selection parameter allows you to choose between an internally configured clock or an externally configured clock for data rate and SCLK generation. When set to Internal Clock, the required clock frequency is calculated and configured by PSoC Creator based on the Bit Rate parameter. When set to External Clock, the component does not control the data rate but will display the expected bit rate based on the user-connected clock source. If this parameter is set to Internal Clock, the clock input is not visible on the symbol.

Note When setting the bit rate or external clock frequency value, make sure that PSoC Creator can provide this value using the current system clock frequency. Otherwise, a warning about the clock accuracy range is generated while building the project. This warning contains the actual clock value set by PSoC Creator. Choose whether the system clock or component clock should be changed to fit the clocking system requirements and achieve an optimal value.
RX Buffer Size *

The **RX Buffer Size** parameter defines the size (in bytes/words) of memory allocated for a circular data buffer. If this parameter is set to 1 to 4, the fourth byte/word of the FIFO is implemented in the hardware. Values 1 to 3 are available only for compatibility with the previous versions; using them causes an error icon to display that the value is incorrect. All other values up to 255 bytes/words use the 4-byte/word FIFO and a memory array controlled by the supplied API.

TX Buffer Size *

The **TX Buffer Size** parameter defines the size (in bytes/words) of memory allocated for a circular data buffer. If this parameter is set to 1 to 4, the fourth byte/word of the FIFO is implemented in the hardware. Values 1 to 3 are available only for compatibility with the previous versions; using them causes an error icon to display that the value is incorrect. All other values up to 255 use the 4-byte/word FIFO and a memory array controlled by the supplied API.

Enable TX / RX Internal Interrupt

The **Enable TX / RX Internal Interrupt** options allow you to use the predefined Tx and Rx ISRs of the SPI Master component, or supply your own custom ISRs. If enabled, you may add your own code to these predefined ISRs if small changes are required. If the internal interrupt is deselected, you may supply an external interrupt component with custom code connected to the interrupt outputs of the SPI Master.

If the Rx or Tx buffer size is greater than 4, the component automatically sets the appropriate parameters, as the internal ISR is needed to handle transferring data from the hardware FIFO to the Rx buffer, the Tx buffer, or both.

The interrupt output pins of the SPI Master are always visible and usable, but there are limited cases where these signals should be used in conjunction with an internal interrupt. These signals can be used as hardware signals for digital logic functions or debugging. DMA operation with these pins will not operate properly if a software buffer (buffer size >4) is being used. Interrupt operation with these pins results in two interrupts that are triggered by the same condition. This is better handled by adding code to the predefined ISRs.

Notes:

- When Rx buffer size is greater than 4 bytes/words, the ‘RX FIFO NOT EMPTY’ interrupt is always enabled and cannot be disabled, because it causes incorrect buffer functionality.
- When Tx buffer size is greater than 4 bytes/words, the ‘TX FIFO NOT FULL’ interrupt is always enabled and cannot be disabled, because it causes incorrect buffer functionality.
- For buffer sizes greater than 4 bytes/words, the SPI Master automatically enables the internal interrupt. In addition, the global interrupt enable must be explicitly enabled for proper buffer handling.
Interrupts

The **Interrupts** selection parameters allow you to configure the internal events that are enabled to cause an interrupt. Interrupt generation is a masked OR of all of the enabled Tx and Rx status register bits. The bits chosen with these parameters define the mask implemented with the initial component configuration.

Clock Selection

When the internal clock configuration is selected, PSoC Creator calculates the needed frequency and clock source, and generates the clocking resource needed for implementation. Otherwise, you must supply the clock component and calculate the required clock frequency. That frequency is 2x the desired bit rate and SCLK frequency.

**Note** When setting the bit rate or external clock frequency value, make sure that PSoC Creator can provide this value by using the current system clock frequency. Otherwise, a warning about the clock accuracy range is generated while building the project. This warning contains the real clock value set by PSoC Creator. Choose whether the system clock or component clock should be changed to fit the clocking system requirements and achieve an optimal value.

Placement

The SPI Master component is placed into the UDB array and all placement information is provided to the API through the `cyfitter.h` file.

Resources

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Digital Blocks</th>
<th>API Memory (Bytes)</th>
<th>Pins (per External I/O)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Datapath Cells</td>
<td>PLDs</td>
<td>Status Cells</td>
</tr>
<tr>
<td>SPI Master 8-bit (MOSI+MISO)</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>SPI Master 8-bit (Bidirectional)</td>
<td>1</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>SPI Master 16-bit (MOSI+MISO)</td>
<td>2</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
Application Programming Interface

Application Programming Interface (API) routines allow you to configure the component using software at runtime. 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 “SPIM_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 the instance. For readability, the instance name used in the following table is “SPIM.”

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_Start()</td>
<td>Calls both SPIM_Init() and SPIM_Enable(). Should be called the first time the component is started.</td>
</tr>
<tr>
<td>SPIM_Stop()</td>
<td>Disables SPI Master operation.</td>
</tr>
<tr>
<td>SPIM_EnableTxInt()</td>
<td>Enables the internal Tx interrupt irq.</td>
</tr>
<tr>
<td>SPIM_EnableRxInt()</td>
<td>Enables the internal Rx interrupt irq.</td>
</tr>
<tr>
<td>SPIM_DisableTxInt()</td>
<td>Disables the internal Tx interrupt irq.</td>
</tr>
<tr>
<td>SPIM_DisableRxInt()</td>
<td>Disables the internal Rx interrupt irq.</td>
</tr>
<tr>
<td>SPIM_SetTxInterruptMode()</td>
<td>Configures the Tx interrupt sources enabled.</td>
</tr>
<tr>
<td>SPIM_SetRxInterruptMode()</td>
<td>Configures the Rx interrupt sources enabled.</td>
</tr>
<tr>
<td>SPIM_ReadTxStatus()</td>
<td>Returns the current state of the Tx status register.</td>
</tr>
<tr>
<td>SPIM_ReadRxStatus()</td>
<td>Returns the current state of the Rx status register.</td>
</tr>
<tr>
<td>SPIM_WriteTxData()</td>
<td>Places a byte/word in the transmit buffer which will be sent at the next available bus time.</td>
</tr>
<tr>
<td>SPIM_ReadRxData()</td>
<td>Returns the next byte/word of received data available in the receive buffer.</td>
</tr>
<tr>
<td>SPIM_GetRxBufferSize()</td>
<td>Returns the size (in bytes/words) of received data in the Rx memory buffer.</td>
</tr>
</tbody>
</table>
### Function Description

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_GetTxBufferSize()</td>
<td>Returns the size (in bytes/words) of data waiting to transmit in the Tx memory buffer.</td>
</tr>
<tr>
<td>SPIM_ClearRxBuffer()</td>
<td>Clears the Rx buffer memory array and Rx FIFO of all received data.</td>
</tr>
<tr>
<td>SPIM_ClearTxBuffer()</td>
<td>Clears the Tx buffer memory array and Tx FIFO of all transmit data.</td>
</tr>
<tr>
<td>SPIM_TxEnable()</td>
<td>If configured for bidirectional mode, sets the SDAT inout to transmit.</td>
</tr>
<tr>
<td>SPIM_TxDisable()</td>
<td>If configured for bidirectional mode, sets the SDAT inout to receive.</td>
</tr>
<tr>
<td>SPIM_PutArray()</td>
<td>Places an array of data into the transmit buffer.</td>
</tr>
<tr>
<td>SPIM_ClearFIFO()</td>
<td>Clears any received data from the Rx hardware FIFO.</td>
</tr>
<tr>
<td>SPIM_Sleep()</td>
<td>Prepares SPI Master component for low-power modes by calling SPIM_SaveConfig() and SPIM_Stop() functions.</td>
</tr>
<tr>
<td>SPIM_Wakeup()</td>
<td>Restores and re-enables the SPI Master component after waking from low-power mode.</td>
</tr>
<tr>
<td>SPIM_Init()</td>
<td>Initializes and restores the default SPI Master configuration.</td>
</tr>
<tr>
<td>SPIM_Enable()</td>
<td>Enables the SPI Master to start operation.</td>
</tr>
<tr>
<td>SPIM_SaveConfig()</td>
<td>Saves SPI Master hardware configuration.</td>
</tr>
<tr>
<td>SPIM_RestoreConfig()</td>
<td>Restores SPI Master hardware configuration.</td>
</tr>
</tbody>
</table>

### Global Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_initVar</td>
<td>Indicates whether the SPI Master has been initialized. The variable is initialized to 0 and set to 1 the first time SPIM_Start() is called. This allows the component to restart without reinitialization after the first call to the SPIM_Start() routine. If reinitialization of the component is required, then the SPIM_Init() function can be called before the SPIM_Start() or SPIM_Enable() function.</td>
</tr>
<tr>
<td>SPIM_txBufferWrite</td>
<td>Transmits buffer location of the last data written into the buffer by the API.</td>
</tr>
<tr>
<td>SPIM_txBufferRead</td>
<td>Transmits buffer location of the last data read from the buffer and transmitted by SPI Master hardware.</td>
</tr>
<tr>
<td>SPIM_rxBufferWrite</td>
<td>Receives buffer location of the last data written into the buffer after received by SPI Master hardware.</td>
</tr>
<tr>
<td>SPIM_rxBufferRead</td>
<td>Receives buffer location of the last data read from the buffer by the API.</td>
</tr>
<tr>
<td>SPIM_rxBufferFull</td>
<td>Indicates the software buffer has overflowed.</td>
</tr>
<tr>
<td>SPIM_RXBUFFER[]</td>
<td>Used to store received data.</td>
</tr>
<tr>
<td>SPIM_TXBUFFER[]</td>
<td>Used to store data for sending.</td>
</tr>
</tbody>
</table>
void SPIM_Start(void)
Description: This function calls both SPIM_Init() and SPIM_Enable(). This should be called the first time the component is started.
Parameters: None
Return Value: None
Side Effects: None

void SPIM_Stop(void)
Description: Disables SPI Master operation by disabling the internal clock and internal interrupts, if the SPI Master is configured that way.
Parameters: None
Return Value: None
Side Effects: None

void SPIM_EnableTxInt(void)
Description: Enables the internal Tx interrupt irq.
Parameters: None
Return Value: None
Side Effects: None

void SPIM_EnableRxInt(void)
Description: Enables the internal Rx interrupt irq.
Parameters: None
Return Value: None
Side Effects: None

void SPIM_DisableTxInt(void)
Description: Disables the internal Tx interrupt irq.
Parameters: None
Return Value: None
Side Effects: None
void SPIM_DisableRxInt(void)

**Description:** Disables the internal Rx interrupt irq.

**Parameters:** None

**Return Value:** None

**Side Effects:** None

void SPIM_SetTxInterruptMode(uint8 intSrc)

**Description:** Configures which status bits trigger an interrupt event.

**Parameters:**
- uint8 intSrc: Bit field containing the interrupts to enable.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_INT_ON_SPI_DONE</td>
<td>Enable interrupt due to SPI done</td>
</tr>
<tr>
<td>SPIM_INT_ON_TX_EMPTY</td>
<td>Enable interrupt due to Tx FIFO empty</td>
</tr>
<tr>
<td>SPIM_INT_ON_TX_NOT_FULL</td>
<td>Enable interrupt due to Tx FIFO not full</td>
</tr>
<tr>
<td>SPIM_INT_ON_BYTE_COMP</td>
<td>Enable interrupt due to byte/word complete</td>
</tr>
<tr>
<td>SPIM_INT_ON_SPI_IDLE</td>
<td>Enable interrupt due to SPI IDLE</td>
</tr>
</tbody>
</table>

Based on the bit-field arrangement of the Tx status register. This value must be a combination of Tx status register bit masks defined in the header file.

For more information, see Defines.

**Return Value:** None

**Side Effects:** None
void SPIM_SetRxInterruptMode(uint8 intSrc)

Description: Configures which status bits trigger an interrupt event.
Parameters: uint8 intSrc: Bit field containing the interrupts to enable.

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_INT_ON_RX_FULL</td>
<td>Enable interrupt due to Rx FIFO Full</td>
</tr>
<tr>
<td>SPIM_INT_ON_RX_NOT_EMPTY</td>
<td>Enable interrupt due to Rx FIFO Not Empty</td>
</tr>
<tr>
<td>SPIM_INT_ON_RX_OVER</td>
<td>Enable interrupt due to Rx Buf Overrun</td>
</tr>
</tbody>
</table>

Based on the bit-field arrangement of the Rx status register. This value must be a combination of Rx status register bit masks defined in the header file. For more information, see Defines.

Return Value: None
Side Effects: None

uint8 SPIM_ReadTxStatus(void)

Description: Returns the current state of the Tx status register. For more information, see Status Register Bits.
Parameters: None
Return Value: uint8: Current Tx status register value

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_STS_SPI_DONE</td>
<td>SPI done</td>
</tr>
<tr>
<td>SPIM_STS_TX_FIFO_EMPTY</td>
<td>Tx FIFO empty</td>
</tr>
<tr>
<td>SPIM_STS_TX_FIFO_NOT_FULL</td>
<td>Tx FIFO not full</td>
</tr>
<tr>
<td>SPIM_STS_BYTE_COMPLETE</td>
<td>Byte/Word complete</td>
</tr>
<tr>
<td>SPIM_STS_SPI_IDLE</td>
<td>SPI IDLE</td>
</tr>
</tbody>
</table>

Side Effects: Tx Status register bits are cleared on read.
uint8 SPIM_ReadRxStatus(void)

Description: Returns the current state of the Rx status register. For more information, see Status Register Bits.

Parameters: None

Return Value: uint8: Current Rx status register value

<table>
<thead>
<tr>
<th>Bit</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPIM_STS_RX_FIFO_FULL</td>
<td>Rx FIFO Full</td>
</tr>
<tr>
<td>SPIM_STS_RX_FIFO_NOT_EMPTY</td>
<td>Rx FIFO Not Empty</td>
</tr>
<tr>
<td>SPIM_STS_RX_FIFO_OVERRUN</td>
<td>Rx Buf Overrun</td>
</tr>
</tbody>
</table>

Side Effects: Rx Status register bits are cleared on read.

void SPIM_WriteTxData(uint8/uint16 txData)

Description: Places a byte/word in the transmit buffer to be sent at the next available SPI bus time.

Parameters: uint8/uint16 txData: The data value to transmit from the SPI.

Return Value: None

Side Effects: Data may be placed in the memory buffer and will not be transmitted until all other previous data has been transmitted. This function blocks until there is space in the output memory buffer.

Clears the Tx status register of the component.

uint8/uint16 SPIM_ReadRxData(void)

Description: Returns the next byte/word of received data available in the receive buffer.

Parameters: None

Return Value: uint8/uint16: The next byte/word of data read from the FIFO.

Side Effects: Returns invalid data if the FIFO is empty. Call SPIM_GetRxBufferSize(), and if it returns a nonzero value then it is safe to call the SPIM_ReadRxData() function.
uint8 SPIM_GetRxBufferSize(void)

Description: Returns the number of bytes/words of received data currently held in the Rx buffer.

- If the Rx software buffer is disabled, this function returns 0 = FIFO empty or 1 = FIFO not empty.
- If the Rx software buffer is enabled, this function returns the size of data in the Rx software buffer. FIFO data not included in this count.

Parameters: None
Return Value: uint8: Integer count of the number of bytes/words in the Rx buffer.
Side Effects: Clears the Rx status register of the component.

uint8 SPIM_GetTxBufferSize(void)

Description: Returns the number of bytes/words of data ready to transmit currently held in the Tx buffer.

- If Tx software buffer is disabled, this function returns 0 = FIFO empty, 1 = FIFO not full, or 4 = FIFO full.
- If the Tx software buffer is enabled, this function returns the size of data in the Tx software buffer. FIFO data not included in this count.

Parameters: None
Return Value: uint8: Integer count of the number of bytes/words in the Tx buffer
Side Effects: Clears the Tx status register of the component.

void SPIM_ClearRxBuffer(void)

Description: Clears the Rx buffer memory array and Rx hardware FIFO of all received data. Clears the Rx RAM buffer by setting both the read and write pointers to zero. Setting the pointers to zero indicates that there is no data to read. Thus, writing resumes at address 0, overwriting any data that may have remained in the RAM.

Parameters: None
Return Value: None
Side Effects: Any received data not read from the RAM buffer and FIFO is lost when overwritten by new data.
void SPIM_ClearTxBuffer(void)

Description: Clears the Tx buffer memory array of data waiting to transmit. Clears the Tx RAM buffer by setting both the read and write pointers to zero. Setting the pointers to zero indicates that there is no data to transmit. Thus, writing resumes at address 0, overwriting any data that may have remained in the RAM.

Parameters: None
Return Value: None
Side Effects: Does not clear data already placed in the Tx FIFO. Any data not yet transmitted from the RAM buffer is lost when overwritten by new data.

void SPIM_TxEnable(void)

Description: If the SPI Master is configured to use a single bidirectional pin, this sets the bidirectional pin to transmit.

Parameters: None
Return Value: None
Side Effects: None

void SPIM_TxDiSable(void)

Description: If the SPI master is configured to use a single bidirectional pin, this sets the bidirectional pin to receive.

Parameters: None
Return Value: None
Side Effects: None

void SPIM_PutArray(uint8/uint16 * buffer, uint8/uint16 byteCount)

Description: Places an array of data into the transmit buffer

Parameters: uint8 * buffer: Pointer to the location in RAM containing the data to send
uint8/uint16 byteCount: The number of bytes/words to move to the transmit buffer.

Return Value: None
Side Effects: The system will stay in this function until all data has been transmitted to the buffer. This function is blocking if there is not enough room in the Tx buffer. It may get locked in this loop if data is not being transmitted by the master and the Tx buffer is full.
void SPIM_ClearFIFO(void)

Description: Clears any received data from the Tx and Rx FIFOs.
Parameters: None
Return Value: None
Side Effects: Clears status register of the component.

void SPIM_Sleep(void)

Description: Prepares the SPI Master for low-power modes by calling the SPIM_SaveConfig() and SPIM_Stop() functions.
Parameters: None
Return Value: None
Side Effects: None

void SPIM_Wakeup(void)

Description: Prepares the SPI Master to wake up from a low-power mode. Calls the SPIM_RestoreConfig() and SPIM_Enable() functions. Clears all data from the Rx buffer, Tx buffer, and hardware FIFOs.
Parameters: None
Return Value: None
Side Effects: None

void SPIM_Init(void)

Description: Initializes or restores the component according to the customizer Configure dialog settings. It is not necessary to call SPIM_Init() because the SPIM_Start() routine calls this function and is the preferred method to begin component operation.
Parameters: None
Return Value: None
Side Effects: When this function is called, it initializes all of the necessary parameters for execution. These include setting the initial interrupt mask, configuring the interrupt service routine, configuring the bit-counter parameters, and clearing the FIFO and Status Register.
void SPIM_Enable(void)

Description: Enables the SPI Master for operation. Starts the internal clock if the SPI Master is configured that way. If it is configured for an external clock it must be started separately before calling this function. The SPIM_Enable() function should be called before SPI Master interrupts are enabled. This is because this function configures the interrupt sources and clears any pending interrupts from device configuration, and then enables the internal interrupts if there are any. A SPIM_Init() function must have been previously called.

Parameters: None
Return Value: None
Side Effects: None

void SPIM_SaveConfig(void)

Description: Saves the SPI Master hardware configuration before entering a low-power mode.

Parameters: None
Return Value: None
Side Effects: None

void SPIM_RestoreConfig(void)

Description: Restores the SPI Master hardware configuration saved by the SPIM_SaveConfig() function after waking from a lower-power mode.

Parameters: None
Return Value: None
Side Effects: If this function is called without first calling SPIM_SaveConfig() then in the following registers will be restored to the default values from the Configure dialog:

SPIM_STATUS_MASK_REG
SPIM_COUNTER_PERIOD_REG

Defines

- **SPIM_TX_INIT_INTERRUPTS_MASK** – Defines the initial configuration of the interrupt sources chosen in the Configure dialog. This is a mask of the bits in the Tx status register that have been enabled at configuration as sources for the interrupt. See Status Register Bits for bit-field details.

- **SPIM_RX_INIT_INTERRUPTS_MASK** – Defines the initial configuration of the interrupt sources chosen in the Configure dialog. This is a mask of the bits in the Rx status register that have been enabled at configuration as sources for the interrupt. See Status Register Bits for bit-field details.
Status Register Bits

**SPIM_TXSTATUS**

<table>
<thead>
<tr>
<th>Bits</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Interrupt</td>
<td>Unused</td>
<td>Unused</td>
<td>SPI IDLE</td>
<td>Byte/Word Complete</td>
<td>Tx FIFO Not Full</td>
<td>Tx FIFO Empty</td>
<td>SPI Done</td>
</tr>
</tbody>
</table>

- Byte/Word Complete: Set when a byte/word of data transmit has completed.
- Rx FIFO Overrun: Set when Rx Data has overrun the 4-byte/word FIFO without being moved to the Rx buffer memory array (if one exists)
- Rx FIFO Not Empty: Set when the Rx Data FIFO is not empty. That is, at least one byte/word is in the Rx FIFO (does not indicate the Rx buffer RAM array conditions).
- Rx FIFO Full: Set when the Rx Data FIFO is full (does not indicate the Rx buffer RAM array conditions).
- Tx FIFO Not Full: Set when the Tx Data FIFO is not full (does not indicate the Tx buffer RAM array conditions).
- Tx FIFO Empty: Set when the Tx Data FIFO is empty (does not indicate the Tx buffer RAM array conditions).
- SPI Done: Set when all of the data in the transmit FIFO has been sent. This may be used to signal a transfer complete instead of using the byte/word complete status. (Set when Byte/Word Complete has been set and Tx Data FIFO is empty.)
- SPI IDLE: Set when the SPI Master state machine is in the IDLE State. This is the default state after the component starts. It is also the next state after SPI Done. IDLE is still set until Tx FIFO Not Empty status has been detected.

**SPIM_RXSTATUS**

<table>
<thead>
<tr>
<th>Bits</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>Interrupt</td>
<td>Rx Buf. Overrun</td>
<td>Rx FIFO Not Empty</td>
<td>Rx FIFO Full</td>
<td>Unused</td>
<td>Unused</td>
<td>Unused</td>
<td>Unused</td>
</tr>
</tbody>
</table>

- Byte/Word Complete: Set when a byte/word of data transmit has completed.
- Rx FIFO Overrun: Set when Rx Data has overrun the 4-byte/word FIFO without being moved to the Rx buffer memory array (if one exists)
- Rx FIFO Not Empty: Set when the Rx Data FIFO is not empty. That is, at least one byte/word is in the Rx FIFO (does not indicate the Rx buffer RAM array conditions).
- Rx FIFO Full: Set when the Rx Data FIFO is full (does not indicate the Rx buffer RAM array conditions).
- Tx FIFO Not Full: Set when the Tx Data FIFO is not full (does not indicate the Tx buffer RAM array conditions).
- Tx FIFO Empty: Set when the Tx Data FIFO is empty (does not indicate the Tx buffer RAM array conditions).
- SPI Done: Set when all of the data in the transmit FIFO has been sent. This may be used to signal a transfer complete instead of using the byte/word complete status. (Set when Byte/Word Complete has been set and Tx Data FIFO is empty.)
- SPI IDLE: Set when the SPI Master state machine is in the IDLE State. This is the default state after the component starts. It is also the next state after SPI Done. IDLE is still set until Tx FIFO Not Empty status has been detected.

**SPIM_TXBUFFERSIZE**

Defines the amount of memory to allocate for the Tx memory array buffer. This does not include the four bytes/words included in the FIFO. If this value is greater than 4, interrupts are implemented that move automatically data to the FIFO from the circular memory buffer.
SPIM_RXBUFFERSIZE
Defines the amount of memory to allocate for the Rx memory array buffer. This does not include the four bytes/words included in the FIFO. If this value is greater than 4, interrupts are implemented that automatically move data from the FIFO to the circular memory buffer.

SPIM_DATAWIDTH
Defines the number of bits per data transfer chosen in the Configure dialog.

Sample Firmware Source Code
PSoC Creator provides many 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

Default Configuration
The default configuration for the SPI Master is as an 8-bit SPI Master with Mode 0 configuration. By default, the Internal clock is selected with a bit rate of 1 Mbps.

Modes
The following four waveforms show the component’s status bits and the signal values that they assume during data transmission. They are based on the assumption that five data bytes are transmitted (four bytes are written to the SPI Master’s Tx buffer at the beginning of transmission and the fifth is thrown after the first byte has been loaded into the A0 register). The numbers in circles on the waveforms represent the following events:

1 – Tx FIFO Empty is cleared when four bytes are written to the Tx buffer.
2 – Tx FIFO Not Full is cleared because Tx FIFO is full after four bytes are written.
3 – SPI IDLE state bit is cleared because of bytes detected in the Tx buffer.
4 – Tx FIFO Not Full status is set when the first byte has been loaded into the A0 register and cleared after the fifth byte has been written to the empty place in the Tx buffer.
5 – Slave Select line is set low, indicating beginning of the transmission.
6 – Tx FIFO Not Full status is set when the second bit is loaded to the A0. Rx Not Empty status is set when the first received byte is loaded into the Rx buffer. Byte/Word Complete is also set.
7 – At the moment the fourth byte is received, Rx FIFO Full is set along with Byte/Word Complete.

8 – Tx FIFO Empty status is set at the moment that the last byte to be sent is loaded into the A0 register (to simplify, this is not shown in detail).

9 – Byte/Word Complete, SPI Done, and Rx Overrun are set because all bytes have been transmitted and an attempt to load data into the full Rx buffer has been detected.

10 – SS line is set high to indicate that transmission is complete. SPI IDLE state is also set.

11 – Rx FIFO Full is cleared when the first byte has been read from the Rx buffer and Rx FIFO Empty is set when all of them have been read.

**SPI Master Mode: 0 (CPHA == 0, CPOL == 0)**

Mode 0 has the following characteristics:
SPI Master Mode: 1 (CPHA == 0, CPOL == 1)

Mode 1 has the following characteristics:

SPI Master Mode: 2 (CPHA == 1, CPOL == 0)

Mode 2 has the following characteristics:
SPI Master Mode: 3 (CPHA == 1, CPOL == 1)

Mode 3 has the following characteristics:

- **SCLK**
- **Rx Data (A1)**
- **Tx Data (A0)**
- **SS**
- **SPI Idle**
- **TX FIFO Empty**
- **TX FIFO Not Full**
- **RX FIFO Full**
- **RX FIFO Not Empty**
- **RX FIFO Overrun**
- **Byte/Word Complete**
- **SPI Done**

---

**Block Diagram and Configuration**

The SPI Master is only available as a UDB configuration. The registers are described here to define the hardware implementation of the SPI Master.
The implementation is described in the following block diagram.

```
+-------------------------+       +-------------------------+
| CPU Access             |       | TX/RX Shift Register    |
|                         |       |                         |
| misc                   |       | Bit-Counter             |
|                         |       |                         |
| clock*                 |       | Control Logic           |
| reset                  |       |

+-------------------------+       +-------------------------+
| Clock 2x BitRate        |       | mosi                   |
|                         |       |                         |
| sclk                   |       | sS                     |

```

**Registers**

**Tx Status Register**

The Tx status register is a read-only register that contains the various transmit status bits defined for a given instance of the SPI Master component. Assuming that an instance of the SPI Master is named “SPIM,” you can get the value of this register using the SPIM_ReadTxStatus() function.

The interrupt output signal is generated by ORing the masked bit fields within the Tx status register. You can set the mask using the SPIM_SetTxInterruptMode() function. Upon receiving an interrupt, you can retrieve the interrupt source by reading the Tx status register with the SPIM_ReadTxStatus() function.

Sticky bits in the Tx status register are cleared on reading, so the interrupt source is held until the SPIM_ReadTxStatus() function is called. All operations on the Tx status register must use the following defines for the bit fields, because these bit fields may be moved within the Tx status register at build time. Sticky bits used to generate an interrupt or DMA transaction must be cleared with either a CPU or DMA read to avoid continuously generating the interrupt or DMA.

There are several bit fields defined for the Tx status registers. Any combination of these bit fields may be included as an interrupt source. The bit fields indicated with an asterisk (*) in the following list are configured as sticky bits in the Tx status register. All other bits are configured as real-time indicators of status. Sticky bits latch a momentary state so that they may be read at a later time and cleared on read. The following #defines are available in the generated header file (for example, *SPIM.h*):
- **SPIM_STS_SPI_DONE** * – Set high as the data-latching edge of SCLK (edge is mode dependent) is output. This happens after the last bit of the configured number of bits in a single SPI word is output onto the MOSI line and the transmit FIFO is empty. Cleared when the SPI Master is transmitting data or the transmit FIFO has pending data. Tells you when the SPI Master is complete with a multi-word transaction.

- **SPIM_STS_TX_FIFO_EMPTY** – Reads high while the transmit FIFO contains no data pending transmission. Reads low if data is waiting for transmission.

- **SPIM_STS_TX_FIFO_NOT_FULL** – Reads high while the transmit FIFO is not full and has room to write more data. Reads low if the FIFO is full of data pending transmit and there is no room for more writes at this time. Tells you when it is safe to pend more data into the transmit FIFO.

- **SPIM_STS_BYTE_COMPLETE** * – Set high as the last bit of the configured number of bits in a single SPI word is output onto the MOSI line. Cleared* as the data latching edge of SCLK (edge is mode dependent) is output.

- **SPIM_STS_SPI_IDLE** * – This bit is set high as long as the component state machine is in the SPI IDLE state (component is waiting for Tx data and is not transmitting any data).

### RX Status Register

The Rx status register is a read-only register that contains the various receive status bits defined for the SPI Master. You can get the value of this register using the `SPIM_ReadRxStatus()` function.

The interrupt output signal is generated by ORing the masked bit fields within the Rx status register. You can set the mask using the `SPIM_SetRxInterruptMode()` function. Upon receiving an interrupt, you can retrieve the interrupt source by reading the Rx status register with the `SPIM_ReadRxStatus()` function.

Sticky bits in the Rx status register are cleared on reading, so the interrupt source is held until the `SPIM_ReadRxStatus()` function is called. All operations on the Rx status register must use the following defines for the bit fields, because these bit fields may be moved within the Rx status register at build time. Sticky bits used to generate an interrupt or DMA transaction must be cleared with either a CPU or DMA read to avoid continuously generating the interrupt or DMA.

There are several bit fields defined for the Rx status register. Any combination of these bit fields can be included as an interrupt source. The bit fields indicated with an asterisk (*) in the following list are configured as sticky bits in the Rx status register. All other bits are configured as real-time indicators of status. Sticky bits latch a momentary state so that they may be read at a later time and cleared when read. The following #defines are available in the generated header file (for example, `SPIM.h`):

- **SPIM_STS_RX_FIFO_FULL** – Reads high when the receive FIFO is full and has no more room to store received data. Reads low if the FIFO is not full and has room for additional received data. Tells you if there is room for new received data to be stored.
- **SPIM_STS_RX_FIFO_NOT_EMPTY** – Reads high when the receive FIFO is not empty. Reads low if the FIFO is empty and has room for additional received data.

- **SPIM_STS_RX_FIFO_OVERRUN** – Reads high when the receive FIFO is already full and additional data was written to it. Tells you if data has been lost from the FIFO because of slow FIFO servicing.

## Tx Data Register

The Tx data register contains the transmit data value to send. This is implemented as a FIFO in the SPI Master. There is an optional higher-level software state machine that controls data from the transmit memory buffer. It handles large amounts of data to be sent that exceed the FIFO's capacity. All APIs that involve transmitting data must go through this register to place the data onto the bus. If there is data in this register and the control state machine indicates that data can be sent, then the data is transmitted on the bus. As soon as this register (FIFO) is empty, no more data will be transmitted on the bus until it is added to the FIFO. DMA can be set up to fill this FIFO when empty, using the TXDATA_REG address defined in the header file.

## Rx Data Register

The Rx data register contains the received data. This is implemented as a FIFO in the SPI Master. There is an optional higher-level software state machine that controls data movement from this receive FIFO into the memory buffer. Typically, the Rx interrupt indicates that data has been received. At that time, that data has several routes to the firmware. DMA can be set up from this register to the memory array, or the firmware can simply call the `SPIM_ReadRxData()` function. DMA must use the RXDATA_REG address defined in the header file.

## Conditional Compilation Information

The SPI Master requires only one conditional compile definition to handle the 8- or 16-bit datapath configuration necessary to implement the configured NumberOfDataBits. The API must conditionally compile for the data width defined. APIs should never use these parameters directly but should use the following define:

- **SPIM_DATAWIDTH** – This defines how many data bits will make up a single “byte” transfer. Valid range is 3 to 16 bits.
### DC and AC Electrical Characteristics

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

#### Timing Characteristics “Maximum with Nominal Routing”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Config</th>
<th>Min</th>
<th>Typ</th>
<th>Max ²</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>fSCLK</td>
<td>SCLK frequency</td>
<td>Config 1 ³</td>
<td>–</td>
<td>–</td>
<td>9</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 2 ⁴</td>
<td>–</td>
<td>–</td>
<td>9</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 3 ⁵</td>
<td>–</td>
<td>–</td>
<td>8</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 4 ⁶</td>
<td>–</td>
<td>–</td>
<td>8</td>
<td>MHz</td>
</tr>
<tr>
<td>fCLOCK</td>
<td>Component clock frequency</td>
<td>Config 1 ³</td>
<td>2 × fSCLK</td>
<td>–</td>
<td>18</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 2 ⁴</td>
<td>2 × fSCLK</td>
<td>–</td>
<td>18</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 3 ⁵</td>
<td>2 × fSCLK</td>
<td>–</td>
<td>16</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 4 ⁶</td>
<td>2 × fSCLK</td>
<td>–</td>
<td>16</td>
<td>MHz</td>
</tr>
<tr>
<td>tCKH</td>
<td>SCLK high time</td>
<td>–</td>
<td>0.5</td>
<td>–</td>
<td>–</td>
<td>1/fSCLK</td>
</tr>
<tr>
<td>tCKL</td>
<td>SCLK low time</td>
<td>–</td>
<td>0.5</td>
<td>–</td>
<td>–</td>
<td>1/fSCLK</td>
</tr>
<tr>
<td>tS_MISO</td>
<td>MISO input setup time</td>
<td>25</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>tH_MISO</td>
<td>MISO input hold time</td>
<td>–</td>
<td>0</td>
<td>–</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>tSS_SCLK</td>
<td>SS active to SCLK active</td>
<td>–20</td>
<td>–</td>
<td>20</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>tSCLK_SS</td>
<td>SCLK inactive to SS inactive</td>
<td>–20</td>
<td>–</td>
<td>20</td>
<td>–</td>
<td>ns</td>
</tr>
</tbody>
</table>

² The maximum component clock frequency is derived from tSCLK_MISO in combination with the routing path delays of the SCLK input and the MISO output (described later in this document). 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.

³ Config 1 options:
- Data Lines: MOSI+MISO
- Data Bits: 8

⁴ Config 2 options:
- Data Lines: MOSI+MISO
- Data Bits: 16

⁵ Config 3 options:
- Data Lines: Bidirectional
- Data Bits: 8

⁶ Config 4 options:
- Data Lines: Bidirectional
- Data Bits: 16

⁷ Component clock is equal to the bit rate × 2. It is also used to clock the status registers. Routing may limit the maximum frequency of this parameter; therefore, the maximum is listed with nominal routing results.
### Timing Characteristics “Maximum with All Routing”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Config</th>
<th>Min</th>
<th>Typ</th>
<th>Max&lt;sup&gt;8&lt;/sup&gt;</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f_{SCLK} )</td>
<td>SCLK frequency (is always equal to one-half of the ( f_{CLOCK} ))</td>
<td>Config 1&lt;sup&gt;9&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>4.5 MHz</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 2&lt;sup&gt;10&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>4.5 MHz</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 3&lt;sup&gt;11&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>4 MHz</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 4&lt;sup&gt;12&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>4 MHz</td>
<td>MHz</td>
</tr>
<tr>
<td>( f_{CLOCK} )</td>
<td>Component clock frequency&lt;sup&gt;13&lt;/sup&gt;</td>
<td>Config 1&lt;sup&gt;9&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>2 ( \times f_{SCLK} )</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 2&lt;sup&gt;10&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>2 ( \times f_{SCLK} )</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 3&lt;sup&gt;11&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>2 ( \times f_{SCLK} )</td>
<td>MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Config 4&lt;sup&gt;12&lt;/sup&gt;</td>
<td>–</td>
<td>–</td>
<td>2 ( \times f_{SCLK} )</td>
<td>MHz</td>
</tr>
<tr>
<td>( t_{CKH} )</td>
<td>SCLK high time</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1/( f_{SCLK} )</td>
<td></td>
</tr>
<tr>
<td>( t_{CKL} )</td>
<td>SCLK low time</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1/( f_{SCLK} )</td>
<td></td>
</tr>
<tr>
<td>( t_{S_MISO} )</td>
<td>MISO input setup time</td>
<td>25</td>
<td>–</td>
<td>–</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>( t_{H_MISO} )</td>
<td>MISO input hold time</td>
<td>–</td>
<td>0</td>
<td>–</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>( t_{SS_SCLK} )</td>
<td>SS active to SCLK active</td>
<td>–20</td>
<td>–</td>
<td>20 ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( t_{SCLK_SS} )</td>
<td>SCLK inactive to SS inactive</td>
<td>–20</td>
<td>–</td>
<td>20 ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>8</sup> The Maximum for All Routing timing numbers are calculated by derating the Nominal Routing timing numbers by a factor of 2. If your component instance operates at or below these speeds, then meeting timing should not be a concern for this component.

<sup>9</sup> Config 1 options:
- Data Lines: MOSI+MISO
- Data Bits: 8

<sup>10</sup> Config 2 options:
- Data Lines: MOSI+MISO
- Data Bits: 16

<sup>11</sup> Config 3 options:
- Data Lines: Bidirectional
- Data Bits: 8

<sup>12</sup> Config 4 options:
- Data Lines: Bidirectional
- Data Bits: 16

<sup>13</sup> Component clock is equal to the bit rate \( \times 2 \). It is also used to clock the status registers. Routing may limit the maximum frequency of this parameter; therefore, the maximum is listed with nominal routing results.
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 with the following mechanisms:
The maximum frequency of SCLK (or the maximum bit rate) is not provided directly in the STA. However, the data provided in the STA results indicates some of the internal logic timing constraints. To calculate the maximum bit rate, you must consider several factors. You will need board layout and slave communication device specs to fully understand the maximum. The main limiting factor in this parameter is the round trip path delay from the falling edge of SCLK at the pin of the master, to the slave and the path delay of the MISO output of the slave back to the master.

**Figure 10 Calculating Maximum fSCLK Frequency**

In this case, the component must meet the setup time of MISO at the Master using the equation below:

\[
t_{RT\_PD} < 1 + \left\{ \left[ \frac{1}{2} \times f_{SCLK} \right] - t_{CLK\_SCLK(master)} - t_{S\_MISO(master)} \right\}
\]

-- OR --

\[
f_{SCLK} < 1 + \left\{ 2 \times T_{RT\_PD} + t_{CLK\_SCLK(master)} + t_{S\_MISO(master)} \right\}
\]

Where:

- \( t_{CLK\_SCLK(master)} \) is the path delay of the input CLK to the SCLK output. This is provided in the STA results clock to output section as shown below:

**- Clock To Output Section**

**- SPIM_1_IntClock**

<table>
<thead>
<tr>
<th>Source</th>
<th>Destination</th>
<th>Delay (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net 25/q</td>
<td>SCLK 1(D) PAO</td>
<td>24.500</td>
</tr>
</tbody>
</table>
t_{\text{S\_MISO(Master)}} is the path delay from MISO input pin to internal logic of the master component. This is provided in the STA results input to clock section as shown below:

- **Input To Clock Section**

- **SPIM_1_IntClock**

<table>
<thead>
<tr>
<th>Source</th>
<th>Destination</th>
<th>Delay (ns)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIS0</td>
<td>SPIM_1(IntClock)</td>
<td>20.005</td>
</tr>
</tbody>
</table>

**Note** There are two values in the report: setup times to the component clock at register A0 and register A1. You should select the larger one for calculation.

And t_{RT\_PD} is defined as:

$$t_{RT\_PD} = [SCLK_{PD\_PCB} + t_{PD\_SCLK(slave)} + t_{SCLK\_MISO(slave)} + t_{PD\_MISO(slave)} + MISO_{PD\_PCB}]$$

and:

SCLK_{PD\_PCB} is the PCB path delay of SCLK from the pin of the master component to the pin of the slave component.

t_{PD\_SCLK(slave)} + t_{SCLK\_MISO(slave)} + t_{PD\_MISO(slave)} must come from the slave device datasheet.

MISO_{PD\_PCB} is the PCB path delay of MISO from the pin of the slave component to the pin of the master component.

The final equation that provides the maximum frequency of SCLK, and therefore the maximum bit rate, is:

$$f_{SCLK \ (Max.)} = \frac{1}{2 \times [t_{CLK\_SCLK(master)} + SCLK_{PD\_PCB} + t_{PD\_SCLK(slave)} + t_{SCLK\_MISO(slave)} + t_{PD\_MISO(slave)} + MISO_{PD\_PCB} + t_{S\_MISO(master)}]}$$

f_{CLOCK} Maximum component clock frequency is provided in Timing results in the clock summary as the IntClock (if internal clock is selected) or the named external clock. An example of the internal clock limitations from the STA report file is shown below:

**Clock Summary Section**

<table>
<thead>
<tr>
<th>Clock</th>
<th>Type</th>
<th>Nominal Frequency (MHz)</th>
<th>Required Frequency (MHz)</th>
<th>Maximum Frequency (MHz)</th>
<th>Violation</th>
</tr>
</thead>
<tbody>
<tr>
<td>BUS CLK</td>
<td>Sync</td>
<td>60.000</td>
<td>60.000</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>ClockBlock/clk</td>
<td>Async</td>
<td>60.000</td>
<td>60.000</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>ClockBlock/dclk 0</td>
<td>Async</td>
<td>15.000</td>
<td>15.000</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>ILO</td>
<td>Async</td>
<td>0.001</td>
<td>0.001</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>TMD</td>
<td>Async</td>
<td>3.000</td>
<td>3.000</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>MASTER CLK</td>
<td>Sync</td>
<td>60.000</td>
<td>60.000</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>PLL OUT</td>
<td>Async</td>
<td>60.000</td>
<td>60.000</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>SPIM_1 IntClock</td>
<td>Sync</td>
<td>15.000</td>
<td>15.000</td>
<td>61.870</td>
<td></td>
</tr>
</tbody>
</table>

Its value is limited to either 2x of the f_{CLOCK} or by the number from the STA report but in practice the limitation is 2x of the f_{CLOCK}.

- **t_{CKH}** The SPI Master component generates a 50-percent duty cycle SCLK.
- **t_{CKL}** The SPI Master component generates a 50-percent duty cycle SCLK.
- **t_{CLK\_SCLK}** Internal clock to SCLK output time. Time from posedge of Internal Clock to SCLK available on master pin.
**Component Changes**

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

<table>
<thead>
<tr>
<th>Version</th>
<th>Description of Changes</th>
<th>Reason for Changes / Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.20.a</td>
<td>Minor datasheet edits and updates</td>
<td></td>
</tr>
<tr>
<td>2.20</td>
<td>Internal clock component has been updated with cy_clock_v1_60. Fixed verilog defect that caused STA warning.</td>
<td>Clock v1_60 is the latest component version. Verilog defect fixed to remove STA warning found using the updated STA tool. Screenshots in “AC and DC electrical characteristics” section are updated by report generated by the new STA tool.</td>
</tr>
<tr>
<td>2.10.a</td>
<td>Datasheet corrections (Mode 2 and Mode 3 diagram corrected)</td>
<td>Datasheet defects fixed</td>
</tr>
<tr>
<td>2.10</td>
<td>Data Bits range is changed from 2 to 16 bits to 3 to 16. “Interrupt on SPI Idle” checkbox is added to the component configure dialog. “Byte transfer complete” checkbox name is changed to the “Byte/Word transfer complete” Added characterization data to datasheet Minor datasheet edits and updates</td>
<td>Changes related to status synchronization issues fixed in current version. Component customizer defect fixed To fit the real meaning</td>
</tr>
<tr>
<td>2.0.a</td>
<td>Moved component into subfolders of the component catalog.</td>
<td></td>
</tr>
</tbody>
</table>

**t_s_MISO** To meet the setup time of the internal logic, MISO must be valid at the pin, before Internal clock is valid at the pin, by this amount of time.

**t_H_MISO** To meet the hold time of the internal logic, MISO must be valid at the pin, after Internal clock is valid at the pin, by this amount of time.

**t_SS_SCLK** To meet the internal functionality of the block, Slave Select (SS) must be valid at the pin before SCLK is valid at the pin, by this parameter.

**t_SCLK_SS** Maximum - To meet the internal functionality of the block. Slave Select (SS) must be valid at the pin after the last falling edge of SCLK at the pin, by this parameter.
<table>
<thead>
<tr>
<th>Version</th>
<th>Description of Changes</th>
<th>Reason for Changes / Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0</td>
<td><strong>Added SPIM_Sleep()/SPIM_Wakeup() and SPIM_Init()/SPIM_Enable APIs.</strong></td>
<td>To support low-power modes, and to provide common interfaces to separate control of initialization and enabling of most components.</td>
</tr>
</tbody>
</table>

**Number and positions of component I/Os have been changed:**
- The clock input is now visible in default placement (external clock source is the default setting now)
- The reset input has a different position
- The interrupt output was removed. *rx_interrupt, tx_interrupt* outputs are added instead.

**The clock input was added for consistency with SPI Slave.**
**The reset input place changed because the clock input was added. Two status interrupt registers (Tx and Rx) are now presented instead of one shared.**
**These changes be taken into account to prevent binding errors when migrating from previous SPI versions**

**Removed SPIM_EnableInt(), SPIM_DisableInt(), SPIM_SetInterruptMode(), and SPIM_ReadStatus() APIs.**
**Added SPIM_EnableTxInt(), SPIM_EnableRxInt(), SPIM_DisableTxInt(), SPIM_DisableRxInt(), SPIM_SetTxInterruptMode(), SPIM_SetRxInterruptMode(), SPIM_ReadTxStatus(), SPIM_ReadRxStatus() APIs.**

**The removed APIs are obsolete because the component now contains Rx and Tx interrupts instead of one shared interrupt. Also updated the interrupt handler implementation for Tx and Rx Buffer.**

**Renamed SPIM_ReadByte(), SPIM_WriteByte() APIs to SPIM_ReadRxData(), SPIM_WriteTxData().**

**Clarifies the APIs and how they should be used.**

---

The following changes were made to the base SPI Master component B_SPI_Master_v2_0, which is implemented using Verilog:

- **spim_ctrl internal module was replaced by a new state machine.**

**It uses fewer hardware resources and does not contain any asynchronous logic.**
<table>
<thead>
<tr>
<th>Version</th>
<th>Description of Changes</th>
<th>Reason for Changes / Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two status registers are now presented (status are separate for Tx and Rx) instead of using one common status register for both.</td>
<td>Fixed a defect found in previous versions of the component where software buffers were not working as expected.</td>
</tr>
<tr>
<td></td>
<td>/<em>SPI_Master_v1_20 status bits</em>/</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_SPI_DONE_BIT = 3'd0;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_TX_FIFO_EMPTY_BIT = 3'd1;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_TX_FIFO_NOT_FULL_BIT = 3'd2;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_RX_FIFO_FULL_BIT = 3'd3;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_RX_FIFO_NOT_EMPTY_BIT = 3'd4;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_RX_FIFO_OVERRUN_BIT = 3'd5;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SPIM_STS_BYTE_COMPLETE_BIT = 3'd6;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>/<em>SPI_Master_v2_0 status bits</em>/</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_SPI_DONE_BIT = 3'd0;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_TX_FIFO_EMPTY_BIT = 3'd1;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_TX_FIFO_NOT_FULL_BIT = 3'd2;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_BYTE_COMPLETE_BIT = 3'd3;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_SPI_IDLE_BIT = 3'd4;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_RX_FIFO_FULL_BIT = 3'd4;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_RX_FIFO_NOT_EMPTY_BIT = 3'd5;</td>
<td></td>
</tr>
<tr>
<td></td>
<td>localparam SPIM_STS_RX_FIFO_OVERRUN_BIT = 3'd6;</td>
<td></td>
</tr>
<tr>
<td>'BidirectMode' boolean parameter is added to base component.</td>
<td></td>
<td>Added Bidirectional Mode support to the component</td>
</tr>
<tr>
<td></td>
<td>Control Register with 'clock' input and SYNC mode bit is now selected to drive 'tx_enable' output for PSoC 3 Production silicon. Control Register w/o clock input drives 'tx_enable' when ES2 silicon is selected.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bufoe component is used on component schematic to support Bidirectional Mode. MOSI output of base component is connected to bufoe 'x' input. 'yfb' is connected to 'miso' input. Bufoe 'y' output is connected to 'sdat' output terminal. Routed reset is connected to datapaths, Counter7 and State Machine.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>udb_clock_enable component is added to Verilog implementation with sync = 'TRUE' parameter.</td>
<td>New requirements for all clocks used in Verilog to indicate functionality so the tool can support synchronization and Static Timing Analysis.</td>
</tr>
<tr>
<td></td>
<td><strong>'2' is replaced by '&lt;&lt; 1' in Counter7 period value.</strong></td>
<td>Verilog improvements.</td>
</tr>
<tr>
<td>Version</td>
<td>Description of Changes</td>
<td>Reason for Changes / Impact</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td></td>
<td>Maximum Bit Rate value is changed to 10 Mbps</td>
<td>Bit Rate value more than 10 Mbps is not supported (verified during the component characterization)</td>
</tr>
<tr>
<td></td>
<td>Description of the Bidirectional Mode is added</td>
<td>Data sheet defect fixed</td>
</tr>
<tr>
<td></td>
<td>Reset input description now contains the note about ES2 silicon incompatibility</td>
<td>Data sheet defect fixed</td>
</tr>
<tr>
<td></td>
<td>Timing correlation diagram between SS and SCLk signals is changed</td>
<td>Data sheet defect fixed</td>
</tr>
<tr>
<td></td>
<td>Sample firmware source code is removed</td>
<td>Reference to the component example project is added instead</td>
</tr>
<tr>
<td></td>
<td>SPI Modes diagrams are changed (Tx and Rx FIFO status values are added)</td>
<td>Data sheet defect fixed</td>
</tr>
</tbody>
</table>

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