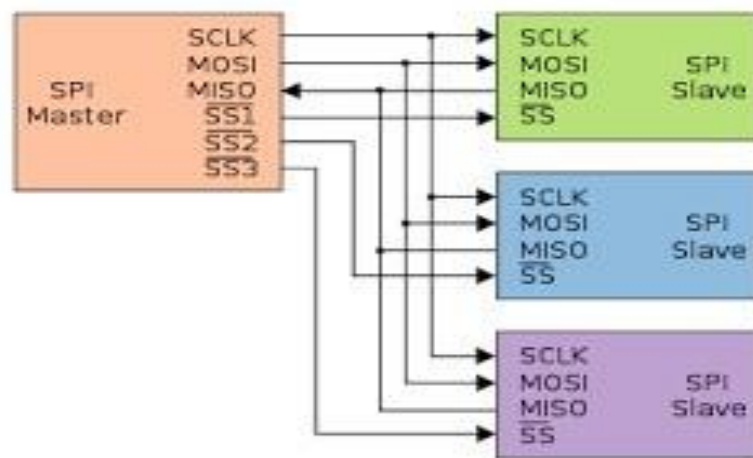




Serial Peripheral Interface

Advanced Logic Design



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Part I: Master Module

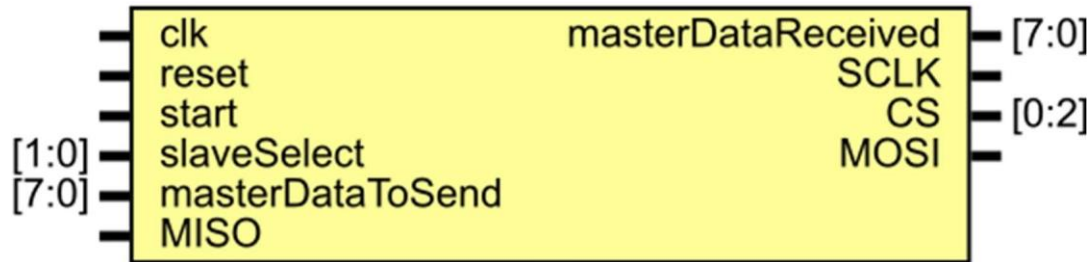


Figure 1: Master Prototype

A. Ports:

Port Name	Type / Size	Description
clk	Input	The synchronous clock generated from the Microcontroller feeding the master of SPI.
reset	Input	Resets the Register's Data to 0 (Asynchronous reset).
start	Input	The bit which trigger the transmission and receiving process.
slaveSelect	Input [1:0]	The number of the slave to be connected to.
masterDataToSend	Input [7:0]	The 8-bits data we put in the Register to be sent in the transmission process.
MISO	Input	The bit received by the master from slave at each clock pulse.
masterDataRecieved	Output reg [7:0]	The 8-bits data which The Slave Receives at the end of receiving process.
SCLK	output	The Synchronous clock of The Master.
CS	Output [0:2]	Enable bit of The Transmission (Active-Low).

MOSI	Output reg	The bit transmitted to the slave from the master at each clock pulse.
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B. Local and Unported Signals:

Name	Type / Size	Description
counter	integer	A counter that counts the number of bets
flag	reg	A bit raised to high when the transmission and receiving process are terminated.
buffer	Reg [7:0]	- The Register inside the master - A normal shift Register with MISO as its IL and MOSI as its IR.

C. Processes and The Data Flow:

- At the raising edge of start:
 - The master read the slaveSelect.
 - Sent the CS bit for each slave (in the same time)
 - Initialize the masterDataRecieved by unknowns.
 - Initialize the buffer by masterDataToSend.
 - Initialize the counter by 1
 - Initialize the flag by zero
- At the rising edge of SCLK (shifting process):
 - Shifting the LSB in the buffer into the MISO.
- At the falling edge of SCLK (Sampling process):
 - Shifting the MOSI bit into the Register from the left.
 - Updating the SlaveDataReceived to contain the same bits as the Register.
- At the raising edge of flag:
 - Both transmission and receiving process are terminated.

PART II: Self-Checking Testbench for the Master Module

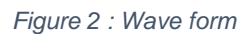
A. Local and Unported Signals:

Name	Type	Description
CLK	reg	Input to Master
Start	reg	Input to Master
Slave Select	reg [1:0]	Input to Master
reset	reg	Input to Master
MISO	reg	Input to Master
SCLK	wire	Output from Master
CS	wire [0:2]	Output from Master
MOSI	wire	Output from Master
masterDataToSend	reg [7:0]	Input to Master
masterDataReceived	wire [7:0]	output from master module
ExpectedSlaveDataToReceive	reg [7:0]	The 8-bits data which the Slave is expected to receive at the end of transmission
testcase_SlaveDataToSend	wire [7:0] array [1:4]	The 4-element array of 8-bit data which is expected to be sent by Master in transmission
testcase_MasterDataToSend	wire [7:0] array [1:4]	The 4-element array of 8-bit data which is an input to Master in transmission (masterDataToSend)

B. Processes and The Data Flow:

1. Initializing Local and unported signals:
 - Initialize start with 0 then 1 (triggering the start signal to start transmission).
 - Initialize input data loaded to Master and expected data to receive.
 - Initialize slave select.
2. At the rising edge of CLK (mimicking shifting process of Slave):
 - Setting MISO with i_{th} bit of testcase_SlaveDataToSend.
 - Increasing i by 1.
3. At the falling edge of CLK (sampling process):

- ### C. Wave of Master simulation



```
# Running test set 1
# Received Successfully : (Expected: 00001001, Received: 00001001)
# Sent Successfully : (Expected: 01010011, Send: 01010011)
# Running test set 2
# Received Successfully : (Expected: 10011000, Received: 10011000)
# Sent Successfully : (Expected: 00111100, Send: 00111100)
# Running test set 3
# Received Successfully : (Expected: 11111111, Received: 11111111)
# Sent Successfully : (Expected: 01010101, Send: 01010101)
# Running test set 4
# Received Successfully : (Expected: 10011000, Received: 10011000)
# Sent Successfully : (Expected: 01011111, Send: 01011111)
# SUCCESS: All 4 testcases have been successful
```

Figure 3 : Transcript

Part III: Slave Module

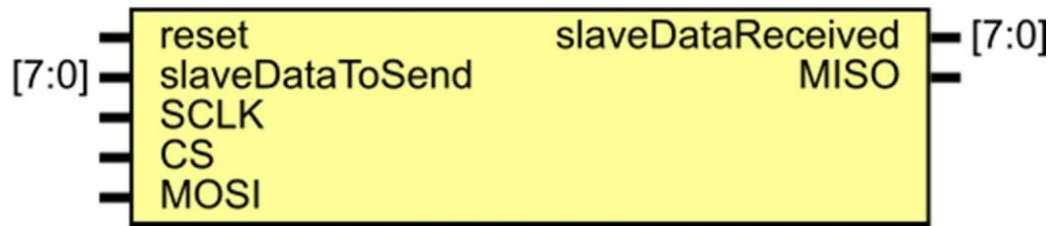


Figure 4 Slave

A. Ports:

Port Name	Type / Size	Description
reset	Input	Resets the Register's Data to 0 (Asynchronous reset).
slaveDataToSend	Input [7:0]	The 8-bits data we put in the Register to send in the transmission process.
slaveDataReceived	output reg [7:0]	The 8-bits data which The Slave Receives at the end of transmission.
SCLK	Input	The Synchronous clock of The Master.
CS	Input	Enable bit of The Transmission (Active-Low).
MOSI	Input	The bit received by slave from the master at each clock pulse.
MISO	Output reg	The bit transmitted to the master from slave at each clock pulse.

B. Local and Unported Signals:

Name	Type / Size	Description
Reg Data	reg [7:0]	- The Register inside The Slave - A normal shift Register with MOSI as its IL and MISO as its IR.

C. Processes and The Data Flow:

1. At the falling edge of CS:
 - Indicates the start of the transmission.
 - The Slave loads the data that will be transmitted into the register.
2. At the rising edge of CS:
 - Indicates the end of the transmission
 - Setting MISO to high-z.
3. At the rising edge of SCLK (shifting process):
 - Shifting the LSB in the register into the MISO.
4. At the falling edge of SCLK (Sampling process):
 - Shifting the MOSI bit into the Register from the left.
 - Updating the SlaveDataReceived to contain the same bits as the Register.

Part IV: Self-Checking Testbench for the Slave Module

A. Local and Unported Signals:

Name	Type	Description
reset	reg	Input to Slave
SCLK	reg	Input to Slave
CS	reg	Input to Slave
MOSI	reg	Input to Slave
MISO	wire	output from Slave
slaveDataToSend	reg [7:0]	Input to Slave
slaveSataReceived	wire [7:0]	output from slave module
ExpectedMasterDataToReceive	reg [7:0]	The 8-bits data which the Master is expected to receive at the end of transmission
testcase_MasterDataToSend	wire [7:0] array [1:4]	The 4-element array of 8-bit data which is expected to be sent by Master in transmission
testcase_SlaveDataToSend	wire [7:0] array [1:4]	The 4-element array of 8-bit data which is an input to Slave in transmission (slaveDataToSend)

B. Processes and The Data Flow:

1. Initializing Local and unported signals:
 - Initialize CS with 1 then 0 (triggering falling edge of CS).
 - Initialize input data loaded to Slave.
2. Set CS =1:
 - Triggering rising edge of CS.
 - Checking if data received and sent by Slave is as Expected and display an indicative message.
3. At the rising edge of SCLK (mimicking the shifting process of Master):
 - Setting MOSI with i_{th} bit of testcase_MasterDataToSend.
 - Increase i by 1.
4. At the falling edge of SCLK (sampling process):

- Updating the ExpectedMasterDataToReceive to contain all the bits shifted by Slave and sampled by Master.

C. Simulation of Slave:

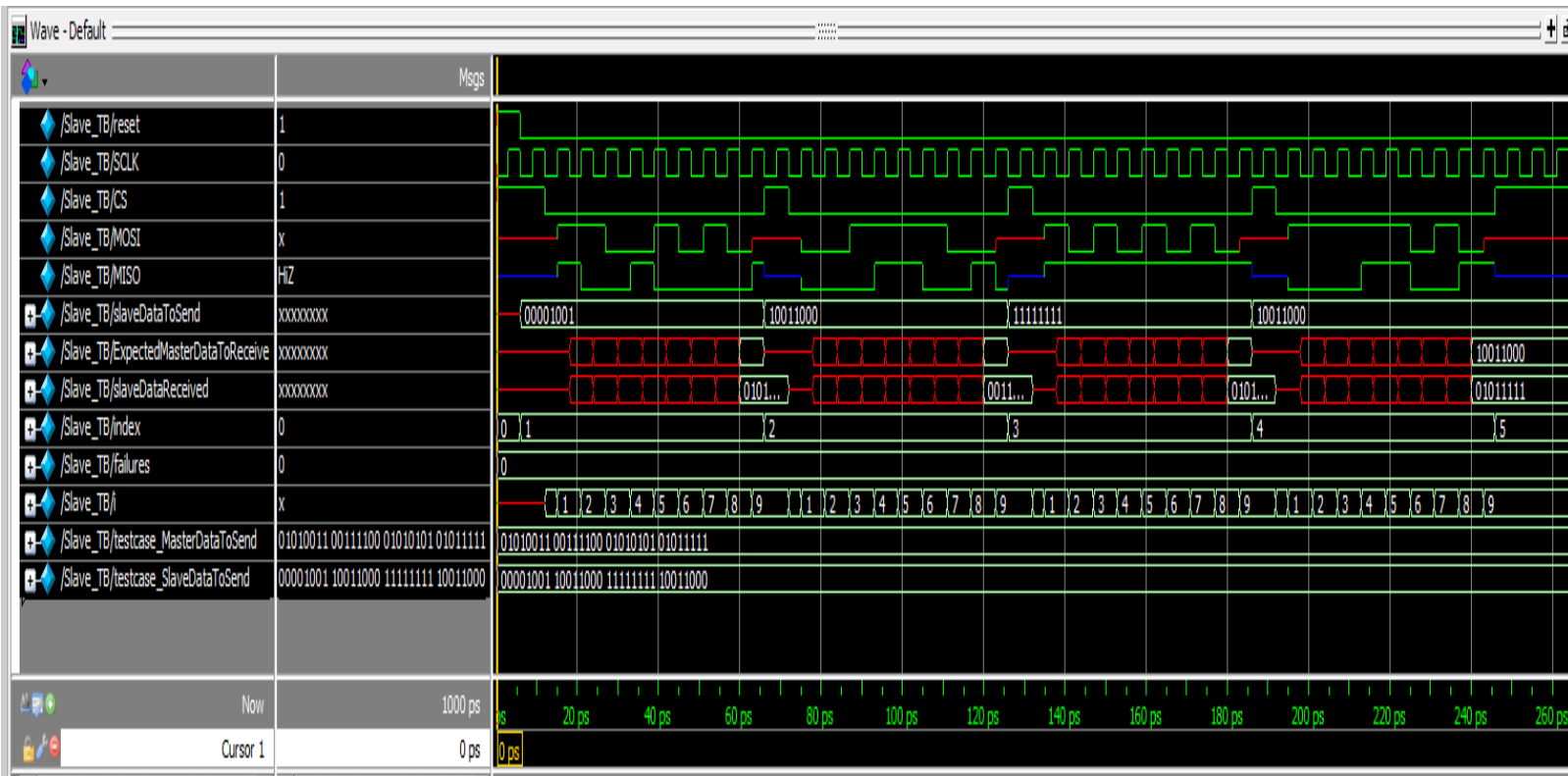


Figure 5: Wave form

```
VSIM 4> run
# Running test set 1
# Received Successfully : (Expected: 01010011, Received: 01010011)
# Sent Successfully : (Expected: 00001001, Send: 00001001)
# Running test set 2
# Received Successfully : (Expected: 00111100, Received: 00111100)
# Sent Successfully : (Expected: 10011000, Send: 10011000)
# Running test set 3
# Received Successfully : (Expected: 01010101, Received: 01010101)
# Sent Successfully : (Expected: 11111111, Send: 11111111)
# Running test set 4
# Received Successfully : (Expected: 01011111, Received: 01011111)
# Sent Successfully : (Expected: 10011000, Send: 10011000)
# SUCCESS: All 4 testcases have been successful
```

Figure 6: Slave Displayed Messages

D.Simulation of Development TestBench:

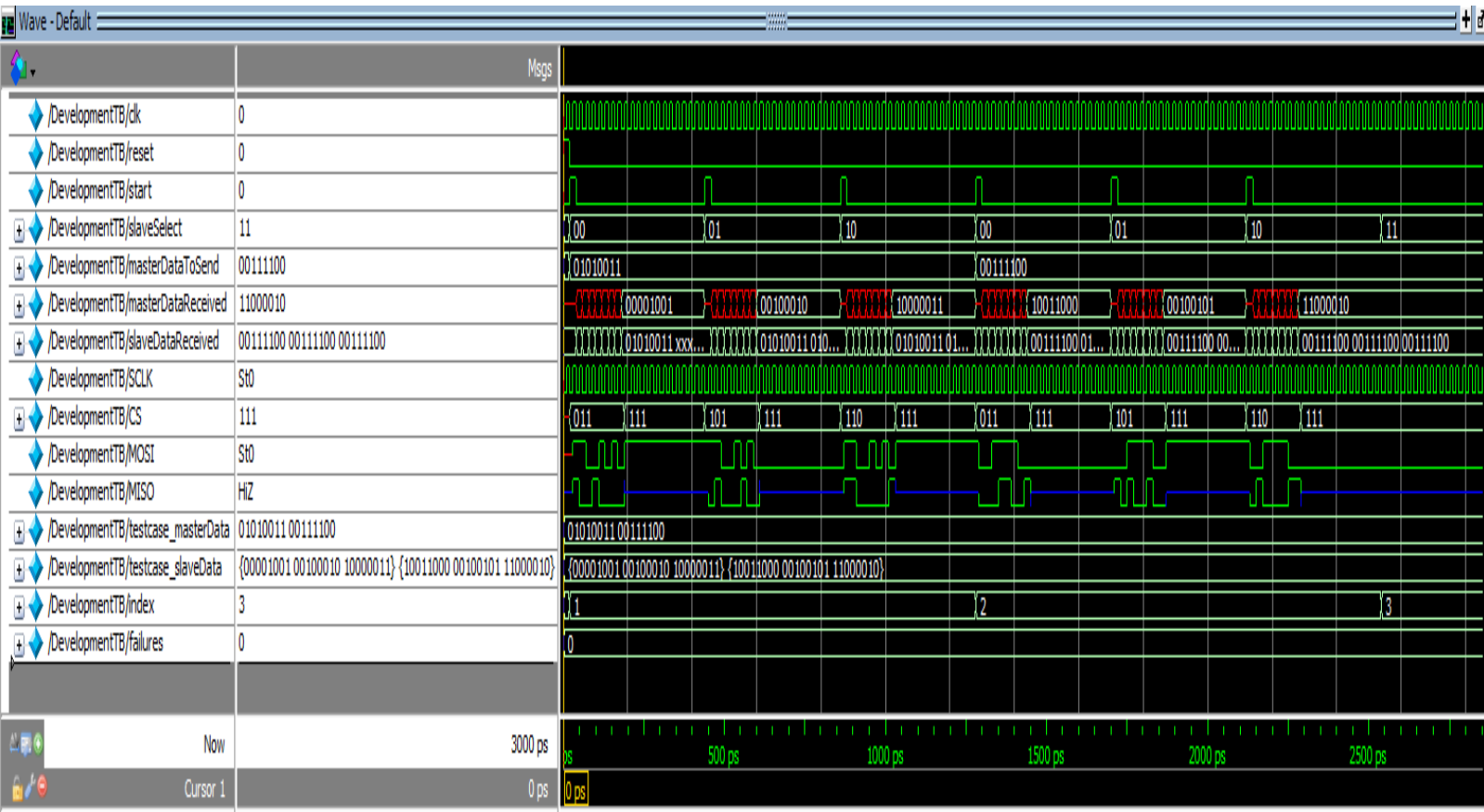


Figure 7 : Development Wave Form

```
# Running test set 1
# From Slave 0 to Master: Success
# From Master to Slave 0: Success
# From Slave 1 to Master: Success
# From Master to Slave 1: Success
# From Slave 2 to Master: Success
# From Master to Slave 2: Success
# Running test set 2
# From Slave 0 to Master: Success
# From Master to Slave 0: Success
# From Slave 1 to Master: Success
# From Master to Slave 1: Success
# From Slave 2 to Master: Success
# From Master to Slave 2: Success
# SUCCESS: All 12 testcases have been successful
```

Figure 8 : Development Displayed Message