SBI BFM – Quick Reference

sbi_bfm_pkg.vhd

sbi_write (addr_value, data_value, msg, clk, sbi_if, [scope, [msg_id_panel, [config]]])

Example: sbi_write(x"1000", x"40", "Set baud rate to 9600", clk, sbi_if);

***Suggested usage**: sbi_write(C_ADDR_UART_TX, C_BAUD_9600, "Set baud rate to 9600"); -- Suggested usage requires local overload (see section 5)*

sbi_read (addr_value, data_value, msg, clk, sbi_if, [scope, [msg_id_panel, [config, [proc_name]]]])

Example: sbi_read(x"1000", v_data_out, "Read UART baud rate", clk, sbi_if);

***Suggested usage**: sbi_read(C_ADDR_UART_BAUD, v_data_out, "Read UART baud rate"); -- Suggested usage requires local overload (see section 5)*

sbi_check (addr_value, data_exp, msg, clk, sbi_if, [alert_level, [scope, [msg_id_panel, [config]]]])

Example: sbi_check(x"1155", x"3B", *"Check data from UART RX"*, clk, sbi_if);

***Suggested usage**: sbi_check(C_ADDR_UART_RX, x"3B", "Check data from UART RX"); -- Suggested usage requires local overload (see section 5)*

sbi_poll_until (addr_value, data_exp, max_polls, timeout, msg, clk, sbi_if, terminate_loop, [alert_level, [scope, [msg_id_panel, [config]]]])

Example: sbi_poll_until(x"1155", x"0D", 10, 100 ns, *"Read UART until CR is found"*, clk, sbi_if, terminate_loop);

***Suggested usage**: sbi_poll_until(C_ADDR_UART_RX, x"0D", "Read UART until CR is found"); -- Suggested usage requires local overload (see section 5)*

init_sbi_if_signals (addr_width, data_width)

Example: sbi_if <= init_sbi_if_signals(addr_width, data_width);

BFM Configuration record ´**t_sbi_bfm_config**´

Record element	Type	C_SBI_BFM_CONFIG_DEFAULT
max_wait_cycles	integer	10
max_wait_cycles_severity	t_alert_level	FAILURE
use_fixed_wait_cycles_read	boolean	false
fixed_wait_cycles_read	natural	0
clock_period	time	-1 ns
clock_period_margin	time	0 ns
clock_margin_severity	t_alert_level	TB_ERROR
setup_time	time	-1 ns
hold_time	time	-1 ns
bfm_sync	t_bfm_sync	SYNC_ON_CLOCK_ONLY
match_strictness	t_match_strictness	MATCH_EXACT
id_for_bfm	t_msg_id	ID_BFM
id_for_bfm_wait	t_msg_id	ID_BFM_WAIT
id_for_bfm_poll	t_msg_id	ID_BFM_POLL
use_ready_signal	boolean	true

Signal record ´**t_sbi_if**´

Record element	Type
cs	std_logic
addr	unsigned
wena	std_logic
rena	std_logic
wdata	std_logic_vector
ready	std_logic
rdata	std_logic_vector

Note: BFM calls can also be made with listing of single signals rather than t_sbi_if.

Note: If using non-ready version, set ready to '1' or set use_ready_signal to false.

VHDL 2008 only

BFM non-signal parameters

Name	Type	Example(s)	Description
addr_value	unsigned	x”5A”	The address of a software accessible register.
data_value	std_logic_vector	x”D3”	The data value to be written to the addressed register
data_exp	std_logic_vector	x”0D”	The data value to expect when reading the addressed register. A mismatch results in an alert with severity ‘alert_level’
max_polls	integer	1	The maximum number of polls (reads) before the expected data must be found. Exceeding this limit results in an alert with severity ‘alert_level’.
timeout	time	100 ns	The maximum time to pass before the expected data must be found. Exceeding this limit results in an alert with severity ‘alert_level’.
alert_level	t_alert_level	ERROR or TB_WARNING	Set the severity for the alert that may be asserted by the BFM procedure.
msg	string	“Write to Peripheral 1”	A custom message to be appended in the log/alert.
scope	string	"SBI BFM"	A string describing the scope from which the log/alert originates. In a simple single sequencer typically "SBI BFM". In a verification component typically "SBI_VVC ".
msg_id_panel	t_msg_id_panel	shared_msg_id_panel	Optional msg_id_panel, controlling verbosity within a specified scope. Defaults to a common ID panel defined in the adaptations package.
config	t_sbi_bfm_config	C_SBI_BFM_CONFIG_DEFAULT	Configuration of BFM behaviour and restrictions. See section 2 for details.

BFM signal parameters

Name	Type	Description
clk	std_logic	The clock signal used to read and write data in/out of SBI BFM.
sbi_if	t_sbi_if	See table “Signal record ‘t_sbi_if’”
terminate_loop	std_logic	External control of loop termination to e.g. stop polling prematurely

Note 1: All signals are active high.
Note 2: Record sbi_if can be replaced with the signals listed in said record.

BFM details

1 BFM procedure details and examples

Procedure	Description

sbi_write()	**sbi_write(addr_value, data_value, msg, clk, sbi_if, [scope, [msg_id_panel, [config]]])**
	
	The sbi_write() procedure writes the given data to the given address on the DUT, using the SBI protocol:
	1. At 'config.clock_period'/4 before the first rising clock edge the bus lines are set:
	a. cs and wena are set to '1'
	b. rena is set to '0'
	c. addr is set to addr_value
	d. wdata is set to data_value
	2. With ready-signalling:
	a. on the first rising edge the DUT ready signal is evaluated:
	- If ready is '1', cs and wena are set to '0' again 'config.clock_period'/4 after the last rising edge and the write procedure was successful
	- If ready is '0', the procedure will wait one clock cycle and evaluate the ready signal again. This will repeat until ready is set to '1', or invoke an error if the process has repeated 'config.max_wait_cycles' times. A log message with ID config.id_for_bfm_wait is logged at the first wait.
	2. Without ready-signalling:
	a. cs and wena are set to '0' again 'config.clock_period'/4 after the first rising edge
	
	- The default value of scope is C_SCOPE ("SBI BFM")
	- The default value of msg_id_panel is shared_msg_id_panel, defined in UVVM_Util.
	- The default value of config is C_SBI_BFM_CONFIG_DEFAULT, see table on the first page.
	- A log message is written if message ID 'config.id_for_bfm' is enabled for the specified message ID panel.
	
	The procedure reports an alert if:
	- ready signal is not set to '1' within 'config.max_wait_cycles' after cs and wena are set to '1' (alert_level: 'config.max_wait_cycles_severity').
	
	Examples:
	`sbi_write(x"1000", x"55", "Write data to Peripheral 1", clk, sbi_if);`
	`sbi_write(x"1000", x"55", "Write data to Peripheral 1", clk, sbi_if, C_SCOPE, shared_msg_id_panel, C_SBI_BFM_CONFIG_DEFAULT);`
	
	Suggested usage (requires local overload, see section 5):
	`sbi_write(C_ADDR_UART_TX, x"40", "Set baud rate to 9600");`
	
	Note: Record sbi_if can be replaced with the signals cs, addr, rena, wena, ready, wdata.

sbi_read()

sbi_read(addr_value, data_value, msg, clk, sbi_if, [scope, [msg_id_panel, [config, [proc_name]]]])

The sbi_read() procedure reads data from the DUT at the given address, using the SBI protocol:

1. At 'config.clock_period'/4 before the first rising clock edge the bus lines are set:
    a. cs and rena are set to '1'
    b. wena is set to '0'
    c. addr is set to addr_value
2. With ready-signalling:
    a. On the first rising edge the DUT ready signal is evaluated:
        - If ready is '1', the data on the rdata line is returned to the reader in 'data_value'.
        - If ready is '0', the procedure will wait one clock cycle and evaluate the ready signal again. This will repeat until ready is set to '1', or invoke an error if the process has repeated 'config.max_wait_cycles' times. A log message with ID config.id_for_bfm_wait is logged at the first wait.
2. Without ready-signalling:
    a. On the first rising edge the data on the rdata line is returned to the reader in 'data_value'.
3. After 'config.clock_period'/4 cs and rena are set to '0' again

- The default value of scope is C_SCOPE ("SBI BFM")
- The default value of msg_id_panel is shared_msg_id_panel, defined in UVVM_Util.
- The default value of config is C_SBI_BFM_CONFIG_DEFAULT, see table on the first page.
- The default value of proc_name is "sbi_read". This argument is intended to be used internally, when procedure is called by sbi_check() or sbi_poll_until().
- A log message is written if 'config.id_for_bfm' ID is enabled for the specified message ID panel. This will only occur if the argument proc_name is left unchanged.

The procedure reports an alert if:

- ready signal is not set to '1' within 'config.max_wait_cycles' after cs and wena are set to '1' (alert_level: 'config.max_wait_cycles_severity')

Examples:

```
sbi_read(x"1000", v_data_out, "Read from Peripheral 1", clk, sbi_if);
sbi_read(x"1000", v_data_out, "Read from Peripheral 1", clk, sbi_if,, C_SCOPE, shared_msg_id_panel, C_SBI_BFM_CONFIG_DEFAULT);
```

Suggested usage (requires local overload, see section 5):

```
sbi_read(C_ADDR_UART_BAUD, v_data_out, "Read UART baud rate");
```

Note: Record sbi_if can be replaced with the signals cs, addr, rena, wena, ready, rdata.

sbi_check()

sbi_check(addr_value, data_exp, msg, clk, sbi_if, [alert_level, [scope, [msg_id_panel, [config]]]])

The sbi_check() procedure reads data from the DUT at the given address, using the SBI protocol described under sbi_read(). After reading data from the SBI bus, the read data is compared with the expected data, 'data_exp'.

- The default value of alert_level is ERROR
- The default value of scope is C_SCOPE ("SBI BFM")
- The default value of msg_id_panel is shared_msg_id_panel, defined in UVVM_Util.
- The default value of config is C_SBI_BFM_CONFIG_DEFAULT, see table on the first page.
- If the check was successful, and the read data matches the expected data, a log message is written with ID 'config.id_for_bfm' (if this ID has been enabled).
- If the read data did not match the expected data, an alert with severity 'alert_level' will be reported.

The procedure will also report alerts for the same conditions as the sbi_read() procedure.

Examples:

```
sbi_check(x"1155", x"3B", "Check data from Peripheral 1", clk, sbi_if);
sbi_check(x"1155", x"3B", "Check data from Peripheral 1", clk, sbi_if, ERROR, C_SCOPE, shared_msg_id_panel,
          C_SBI_BFM_CONFIG_DEFAULT);
```

Suggested usage (requires local overload, see section 5):

```
sbi_check(C_ADDR_UART_RX, x"3B", "Check data from UART RX buffer");
```

Note: Record sbi_if can be replaced with the signals cs, addr, rena, wena, ready, rdata.

sbi_poll_until()

sbi_poll_until(addr_value, data_exp, max_polls, timeout, msg, clk, sbi_if, terminate_loop, [alert_level, [scope, [msg_id_panel, [config]]]])

The sbi_poll_until() procedure reads data from the DUT at the given address, using the SBI protocol described under sbi_read(). After reading data from the DUT, the read data is compared with the expected data, 'data_exp'. If the read data does not match the expected data, the process is repeated until one or more of the following occurs:

1. The read data matches the expected data, 'data_exp'
2. The number of read retries is equal to 'max_polls'
3. The time between start of sbi_poll_until procedure and now is greater than 'timeout'
4. 'terminate_loop' signal is set to '1'

If the procedure exits because of 2. or 3. an alert with severity 'alert_level' is issued. If either 'max_polls' or 'timeout' is set to 0 (ns), this constraint will be ignored and interpreted as no limit.

- The default value of alert_level is ERROR
- The default value of scope is C_SCOPE ("SBI BFM")
- The default value of msg_id_panel is shared_msg_id_panel, defined in UVVM_Util.
- The default value of config is C_SBI_BFM_CONFIG_DEFAULT, see table on the first page.
- If the check was successful, and the read data matches the expected data, a log message is written with ID 'config.id_for_bfm' (if this ID has been enabled).
- If the procedure is terminated using 'terminate_loop' a log message with ID ID_TERMINATE_CMD will be issued.
- If the read data did not match the expected data, an alert with severity 'alert_level' will be reported.

The procedure will also report alerts for the same conditions as the sbi_read() procedure.

Examples:

```
sbi_poll_until(x"1155", x"0D", 10, 100 ns, "Poll for data from Peripheral 1", clk, sbi_if, terminate_loop);
sbi_poll_until(x"1155", x"0D", 10, 100 ns, "Poll for data from Peripheral 1", clk, sbi_if, terminate_loop, ERROR, C_SCOPE,
               shared_msg_id_panel, C_SBI_BFM_CONFIG_DEFAULT);
```

Suggested usage (requires local overload, see section 5):

```
sbi_poll_until(C_ADDR_UART_RX, x"0D", "Poll UART RX buffer until CR is found");
sbi_poll_until(C_ADDR_UART_RX, x"0D", C_MAX_POLLS, C_TIMEOUT, "Poll UART RX buffer until CR is found");
```

Note: Record sbi_if can be replaced with the signals cs, addr, rena, wena, ready, rdata.

init_sbi_if_signals()

init_sbi_if_signals(addr_width, data_width)

This function initializes the SBI interface. All the BFM outputs are set to zeros ('0'), and BFM inputs are set to 'Z'.
Example:

```
sbi_if  <= init_sbi_if_signals(addr_width, data_width)
```

2 BFM Configuration record

Type name: t_sbi_bfm_config

Record element	Type	C_SBI_BFM_CONFIG_DEFAULT	Description
max_wait_cycles	integer	10	The maximum number of clock cycles to wait for the DUT ready signal before reporting a timeout alert.
max_wait_cycles_severity	t_alert_level	failure	The above timeout will have this severity
use_fixed_wait_cycles_read	boolean	false	When true, wait 'fixed_wait_cycles_read' after asserting ‘rena’ signal, before sampling ‘rdata from DUT’
fixed_wait_cycles_read	natural	0	Number of clock cycles to wait after asserting ‘rena’ signal, before sampling ‘rdata’ from DUT.
clock_period	time	-1 ns	Period of the clock signal.
clock_period_margin	time	0 ns	Input clock period margin to specified clock_period. Will check T/2 if input clock is low when BFM is called and T if input clock is high
clock_margin_severity	t_alert_level	TB_ERROR	The above margin will have this severity
setup_time	time	-1 ns	Generated signals setup time. Suggested value is clock_period/4. An alert is reported if setup_time exceed clock_period/2.
hold_time	time	-1 ns	Generated signals hold time. Suggested value is clock_period/4. An alert is reported if hold_time exceed clock_period/2.
bfm_sync	t_bfm_sync	SYNC_ON_CLOCK_ONLY	When set to SYNC_ON_CLOCK_ONLY the BFM will enter on the first falling edge, estimate the clock period, synchronise the output signals and exit ¼ clock period after a succeeding rising edge. When set to SYNC_WITH_SETUP_AND_HOLD the BFM will use the configured setup_time, hold_time and clock_period to synchronise output signals with clock edges.
match_strictness	t_match_strictness	MATCH_EXACT	Matching strictness for std_logic values in check procedures. MATCH_EXACT requires both values to be the same. Note that the expected value can contain the don’t care operator ‘-‘. MATCH_STD allows comparisons between ‘H’ and ‘1’, ‘L’ and ‘0’ and ‘-‘ in both values.
id_for_bfm	t_msg_id	ID_BFM	The message ID used as a general message ID in the SBI BFM
id_for_bfm_wait	t_msg_id	ID_BFM_WAIT	The message ID used for logging waits in the SBI BFM
id_for_bfm_poll	t_msg_id	ID_BFM_POLL	The message ID used for logging polling in the SBI BFM
use_ready_signal	boolean	true	Whether or not to use the interface ‘ready’ signal

3 Additional Documentation

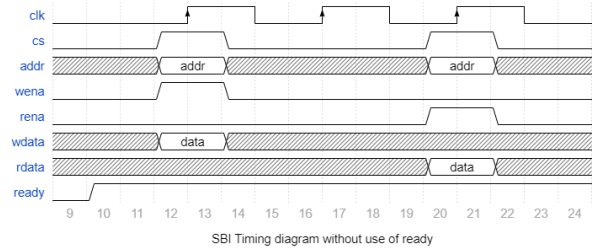
The SBI BFM is used in the IRQC example provided with the UVVM Utility Library. Thus, you can find info under:
- ‘Making a simple, structured and efficient VHDL testbench – Step-by-step’ (PPT)

There is also a webinar available on ‘Making a simple, structured and efficient VHDL testbench – Step-by-step’ (via Aldec[1].)

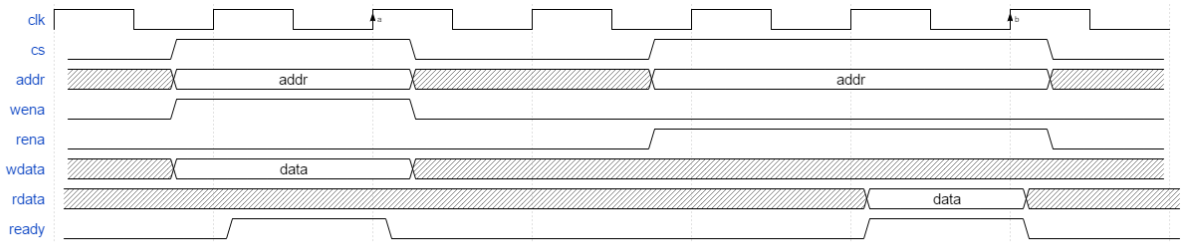
3.1 SBI protocol

SBI is our name for the simplest bus interface possible, one that has been used for decades in the electronics industry. Some think of it as a simple SRAM interface, but that is not a standard, and is probably understood and used in many different ways. Thus, we have defined a name and an exact behaviour, with some flexibility.

SBI is a single cycle bus with an optional ready-signalling. The protocol for SBI with and without ready-signalling is given below (Note that ready is always high in the without case). Data is sampled on rising edge **a** and **b**.



SBI Timing diagram without use of ready



SBI Timing diagram with ready

As can be seen from the figure all required signals including data input must be ready on the rising edge of the clock. This also applies for a read access, but the actual data output is provided combinatorial as soon as the combinational logic allows
Note that an active 'cs', a valid 'addr' and an active 'wena' or 'rena' is needed on the same active clock edge to be registered as a valid read or write. (Being active on two consecutive rising clocks will result in two consecutive accesses - with or without side-effects depending on the module's internal functional logic.) 'rdata' will just ripple out for the right combination of 'cs', 'addr' and 'rena'.
With this simple version, the designer has the option to provide input and/or output registers externally to allow a higher frequency (with added latency).
SBI has optional ready-signalling (You may choose to have ready always high). When 'ready' is used it applies to both read and write accesses. For both read and write accesses all input signals must be held until 'ready' is active. For a read access, the output data may not be used (sampled) until 'ready' is active, but must do so on the first rising edge of the clock after 'ready' active.

4 Compilation

The SBI BFM may only be compiled with VHDL 2008. It is dependent on the UVVM Utility Library (UVVM-Util), which is only compatible with VHDL 2008.
See the separate UVVM-Util documentation for more info. After UVVM-Util has been compiled, the sbi_bfm_pkg.vhd BFM can be compiled into any desired library.
See UVVM Essential Mechanisms located in uvvm_vvc_framework/doc for information about compile scripts.

4.1 Simulator compatibility and setup

See README.md for a list of supported simulators.

For required simulator setup see UVVM-Util Quick reference.

*1 https://www.aldec.com/en/support/resources/multimedia/webinars/1673

5 Local BFM overloads

A good approach for better readability and maintainability is to make simple, local overloads for the BFM procedures in the TB process.
This allows calling the BFM procedures with the key parameters only
e.g.

```
sbi_write(C_ADDR_UART_BAUDRATE, C_BAUDRATE_9600, "Set Baudrate to 9600");
```

rather than

```
sbi_write(C_ADDR_UART_BAUDRATE, C_BAUDRATE_9600, "Set Baudrate to 9600", clk, sbi_if,
          C_CLK_PERIOD, C_SCOPE, shared_msg_id_panel, C_SBI_CONFIG_DEFAULT);
```

By defining the local overload as e.g.:

```
procedure sbi_write(
  constant addr_value : in unsigned;
  constant data_value : in std_logic_vector;
  constant msg        : in string) is
begin
  sbi_write(addr_value,                  -- keep as is
            data_value,                  -- keep as is
            msg,                         -- keep as is
            sbi_if,                      -- Signal must be visible in local process scope
            C_CLK_PERIOD,                -- Just use the default
            C_SCOPE,                     -- Just use the default
            shared_msg_id_panel,         -- Use global, shared msg_id_panel
            C_SBI_CONFIG_LOCAL);         -- Use locally defined configuration or C_SBI_CONFIG_DEFAULT
end;
```

Using a local overload like this also allows the following – if wanted:

- Have address value as natural – and convert in the overload
- Set up defaults for constants. May be different for two overloads of the same BFM
- Apply dedicated message ID panel to allow dedicated verbosity control

IMPORTANT
This is a simplified Bus Functional Model (BFM) for SBI.
The given BFM complies with the basic SBI protocol and thus allows a normal access towards a SBI interface. This BFM is not a SBI protocol checker.
For a more advanced BFM please contact UVVM at info@uvvm.org