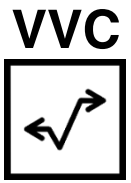
I2C VVC – Quick Reference

For general information see UVVM VVC Framework Essential Mechanisms located in uvvm_vvc_framework/doc. **CAUTION**: shaded code/description is preliminary



I2C Master

i2c_master_transmit (VVCT, vvc_instance_idx, addr, data, msg, [action_when_transfer_is_done, [scope]])

Example: i2c_master_transmit(I2C_VVCT, 1, C_SLAVE_ADDR, x"AF", "Sending data from master VVC to slave DUT");

i2c_master_check (VVCT, vvc_instance_idx, addr, data, msg, [action_when_transfer_is_done, [alert_level, [scope]]])

Example: i2c_master_check(I2C _VVCT, 1, C_SLAVE_0_ADDR, x"42", "Expect data from slave DUT");

i2c_master_receive (VVCT, vvc_instance_idx, addr, num_bytes, [TO_SB,] msg, [action_when_transfer_is_done, [scope]])

Example: i2c_master_receive(I2C _VVCT, 1, C_SLAVE_0_ADDR, 1, "Receive1 byte from slave DUT and store data in VVC. To be retrieved using fetch_result() ");
i2c_master_receive(I2C _VVCT, 1, C_SLAVE_0_ADDR, 3, TO_SB "Receive3 bytes from slave DUT and send to scoreboard for checking");

i2c_master_quick_command (VVCT, vvc_instance_idx, addr, msg, [rw_bit, [exp_ack, [action_when_transfer_is_done, [alert_level, [scope]]]]])

Example: i2c_master_quick_command(I2C _VVCT, 1, C_SLAVE_0_ADDR, "Quick Command to Slave 0");

I2C Slave

i2c_slave_transmit (VVCT, vvc_instance_idx, data, msg, [scope])

Example: i2c_slave_transmit(I2C _VVCT, 2, x"DB", "Sending data from slave VVC to master DUT");

i2c_slave_check (VVCT, vvc_instance_idx, {data, rw_bit}, msg, [alert_level, [scope]])

Example: i2c_slave_check(I2C _VVCT, 2, x"42", "Expect data from master DUT");

i2c_slave_receive (VVCT, vvc_instance_idx, num_bytes, [TO_SB,] msg, [scope])

Example: i2c_slave_receive(I2C _VVCT, 1, 1, "Receive1 byte from slave DUT and store data in VVC. To be retrieved using fetch_result()");
i2c_slave_receive(I2C _VVCT, 1, 6, TO_SB, "Receive 6 bytes from slave DUT and send to scoreboard for checking");

UVVM™

VHDL 2008 only

I2C VVC Configuration record ´**vvc_config**´ -- accessible via **shared_i2c_vvc_config**

Record element	Type	C_I2C_VVC_CONFIG_DEFAULT
inter_bfm_delay	t_inter_bfm_delay	C_I2C_INTER_BFM_DELAY_DEFAULT
[cmd/result]_queue_count_max	natural	C_[CMD/RESULT]_QUEUE_COUNT_MAX
[cmd/result]_queue_count_threshold	natural	C_[CMD/RESULT]_QUEUE_COUNT_THRESHOLD
[cmd/result]_queue_count_threshold_severity	t_alert_level	C_[CMD/RESULT]_QUEUE_COUNT_THRESHOLD_SEVERITY
bfm_config	t_i2c_bfm_config	C_I2C_BFM_CONFIG_DEFAULT
msg_id_panel	t_msg_id_panel	C_VVC_MSG_ID_PANEL_DEFAULT

I2C VVC Status record signal ´**vvc_status**´ -- accessible via **shared_i2c_vvc_status**

Record element	Type
current_cmd_idx	natural
previous_cmd_idx	natural
pending_cmd_cnt	natural

Common VVC procedures applicable for this VVC

- See UVVM Methods QuickRef for details.

await_completion()

enable_log_msg()

disable_log_msg()

flush_command_queue()

terminate_current_command()

terminate_all_commands()

insert_delay()

get_last_received_cmd_idx()

VVC target parameters

Name	Type	Example(s)	Description
VVCT	t_vvc_target_record	I2C_VVCT	VVC target type compiled into each VVC in order to differentiate between VVCs.
vvc_instance_idx	integer	1	Instance number of the VVC

VVC functional parameters

Name	Type	Example(s)	Description
addr	unsigned	x"AF"	Slave address to interact with when VVC is in master mode.
data	std_logic_vector(7 downto 0) t_byte_array	x"94" or [x"FF", x"AA", x"DB"]	The data to be transmitted (in i2c_<master/slave>_transmit) or the expected data (in i2c_<master/slave>_check). Either a single byte or a byte array.
msg	string	"Send to peripheral 1"	A custom message to be appended in the log/alert
action_when_transfer_is_done	t_action_when_transfer_is_done	RELEASE_LINE_AFTER_TRANSFER or HOLD_LINE_AFTER_TRANSFER	This parameter sets whether the VVC (in master mode) shall occupy the bus after the current transaction is finished. 'HOLD_LINE_AFTER_TRANSFER' means that the VVC will not generate a stop condition at the end of the current transaction. When the next transaction starts, the master VVC generates a start condition that will be interpreted by the slave(s) as a repeated start condition.
alert_level	t_alert_level	ERROR or TB_WARNING	Set the severity for the alert that may be asserted by the method.
rw_bit	std_logic	'0' or '1'	Bit set in the R/W# slot of the Quick Command
exp_ack	boolean	true or false	Expected ack bit during a Quick Command. Can be used to e.g. identify if a slave is present on the bus.
scope	string	"I2C VVC"	A string describing the scope from which the log/alert originates. In a simple single sequencer typically "I2C BFM". In a verification component typically "I2C VVC ".

VVC entity generic constants

Name	Type	Default	Description
GC_INSTANCE_IDX	natural	1	Instance number to assign the VVC
GC_MASTER_MODE	boolean	true	Master mode enabled when set to 'true'. The VVC may then only use the 'i2c_master_<transmit/check>' methods. When set to 'false' the VVC will act as an I2C slave and may only use the 'i2c_slave_<transmit/check>' methods.
GC_I2C_CONFIG	t_i2c_bfm_config	C_I2C_BFM_CONFIG_DEFAULT	Configuration for the I2C BFM, see I2C BFM documentation.
GC_CMD_QUEUE_COUNT_MAX	natural	1000	Absolute maximum number of commands in the VVC command queue
GC_CMD_QUEUE_COUNT_THRESHOLD	natural	950	An alert will be generated when reaching this threshold to indicate that the command queue is almost full. The queue will still accept new commands until it reaches C_CMD_QUEUE_COUNT_MAX.
GC_CMD_QUEUE_COUNT_THRESHOLD_SEVERITY	t_alert_level	WARNING	Alert severity which will be used when command queue reaches GC_CMD_QUEUE_COUNT_THRESHOLD.
GC_RESULT_QUEUE_COUNT_MAX	natural	1000	Maximum number of unfetched results before result_queue is full.
GC_RESULT_QUEUE_COUNT_THRESHOLD	natural	950	An alert with severity 'result_queue_count_threshold_severity' will be issued if result queue exceeds this count. Used for early warning if result queue is almost full. Will be ignored if set to 0.
GC_RESULT_QUEUE_COUNT_THRESHOLD_SEVERITY	t_alert_level	WARNING	Severity of alert to be initiated if exceeding result_queue_count_threshold

VVC entity signals

Name	Type	Direction	Description
scl	std_logic	Inout	I2C SCL signal
sda	std_logic	Inout	I2C SDA signal

VVC details

All VVC procedures are defined in vvc_methods_pkg (dedicated this VVC), and uvvm_vvc_framework.td_vvc_framework_common_methods_pkg (common VVC procedures). It is also possible to send a multicast to all instances of a VVC with ALL_INSTANCES as parameter for vvc_instance_idx.
Note: Every procedure here can be called without the optional parameters enclosed in [ ].

1 VVC procedure details and examples

Procedure	Description

i2c_master_transmit()	**i2c_master_transmit (VVCT, vvc_instance_idx, addr, data, msg, [action_when_transfer_is_done, [scope]])**
	
	The i2c_master_transmit() VVC procedure adds a master transmit command to the I2C VVC executor queue, that will run as soon as all preceding commands have completed. When the master transmit command is scheduled to run, the executor calls the I2C BFM i2c_master_transmit() procedure, described in the I2C BFM QuickRef. The i2c_master_transmit() procedure can only be called when the I2C VVC is instantiated in master mode, i.e. setting the VVC entity generic constant 'GC_MASTER_MODE' to 'true'.
	
	Examples:
	`i2c_master_transmit(I2C_VVCT, 1, C_SLAVE_0_ADDR, x"0D", "Transmitting data to slave 0");`
	`i2c_master_transmit(I2C_VVCT, 1, C_SLAVE_1_ADDR, byte_array(0 to 3), "Transmitting byte array to slave 1 without generating stop condition at the end", HOLD_LINE_AFTER_TRANSFER, C_SCOPE);`

i2c_master_check()	**i2c_master_check (VVCT, instance_idx, addr, data, msg, [action_when_transfer_is_done, [alert_level, [scope]]])**
	
	The i2c_master_check () VVC procedure adds a master check command to the I2C VVC executor queue, which will run as soon as all preceding commands have completed. When the master check command is scheduled to run, the executor calls the I2C BFM i2c_master_check() procedure, described in the I2C BFM QuickRef. The received data will not be stored by this procedure. The i2c_master_check() procedure can only be called when the I2C VVC is instantiated in master mode, i.e. setting the VVC entity generic constant 'GC_MASTER_MODE' to 'true'.
	
	Examples:
	`i2c_master_check(I2C_VVCT, 1, C_SLAVE_0_ADDR, byte_array(0 to 20), "Expecting byte array from Slave 0");`
	`i2c_master_check(I2C_VVCT, 1, C_SLAVE_1_ADDR, x"AD", "Expecting data from Slave 1 without generating stop condition at the end", HOLD_LINE_AFTER_TRANSFER, WARNING, C_SCOPE);`

i2c_master_receive()

i2c_master_receive (VVCT, instance_idx, channel, [TO_SB,] msg, [scope])

The i2c_master_receive() VVC procedure adds a receive command to the I2C VVC executor queue, that will run as soon as all preceding commands have completed. When the receive command is scheduled to run, the executor calls the I2C BFM i2c_slave_receive () procedure, described in the I2C BFM QuickRef.
The received data will not be returned in this procedure call since it is non-blocking for the sequencer/caller, but the received data will be stored in the VVC for a potential future fetch (see example with *fetch_result* below).

If the option TO_SB is applied, the received data will be sent to the I2C dedicated scoreboard. There, it is checked against the expected value (provided by the testbench).

Example:

```
i2c_master_receive (I2C_VVCT, 1, C_I2C_SLAVE_ADDR, 4, "Receiving 4 bytes from I2C Slave with address C_I2C_SLAVE_ADDR", C_SCOPE);
```

Example with fetch_result() call: Result is placed in **`v_byte_array`**

```
variable v_cmd_idx         : natural;      -- Command index for the last read
variable v_byte_array      : bitvis_vip_i2c.vvc_cmd_pkg.t_vvc_result;
(…)
i2c_master_receive(I2C_VVCT, 1, C_I2C_SLAVE_ADDR, 4, "Master receives 4 bytes from Slave with address C_I2C_SLAVE_ADDR");
v_cmd_idx := get_last_received_cmd_idx(I2C_VVCT, 1);
await_completion(I2C_VVCT, 1, 50 ms);
fetch_result(I2C_VVCT,1, v_cmd_idx, v_byte_array, "Fetching result from receive operation");
```

i2c_slave_transmit()

i2c_slave_transmit (VVCT, vvc_instance_idx, data, msg, [scope])

The i2c_slave_transmit() VVC procedure adds a slave transmit command to the I2C VVC executor queue, that will run as soon as all preceding commands have completed. When the slave transmit command is scheduled to run, the executor calls the I2C BFM i2c_slave_transmit() procedure, described in the I2C BFM QuickRef. The i2c_slave_transmit() procedure can only be called when the I2C VVC is instantiated in slave mode, i.e. setting the VVC entity generic constant 'GC_MASTER_MODE' to 'false'.

Examples:

```
i2c_slave_transmit(I2C_VVCT, 2,  x"0D", "Transmitting a single byte to master", C_SCOPE);
i2c_slave_transmit(I2C_VVCT, 2,  byte_array(0 to 9), "Transmitting an array of bytes to master", C_SCOPE);
```

i2c_slave_check()

i2c_slave_check (VVCT, instance_idx, data, msg, [alert_level, [scope]])
i2c_slave_check (VVCT, instance_idx, rw_bit, msg, [alert_level, [scope]])

The i2c_slave_check () VVC procedure adds a slave check command to the I2C VVC executor queue, which will run as soon as all preceding commands have completed. When the slave check command is scheduled to run, the executor calls the I2C BFM i2c_slave_check() procedure, described in the I2C BFM QuickRef. The received data will not be stored by this procedure. The i2c_slave_check() procedure can only be called when the I2C VVC is instantiated in slave mode, i.e. setting the VVC entity generic constant 'GC_MASTER_MODE' to 'false'.

Examples:

```
i2c_slave_check(I2C_VVCT, 2, x"0D", "Expecting data from master");
i2c_slave_check(I2C_VVCT, 2, x"0D", "Expecting data from master", WARNING, C_SCOPE);
i2c_slave_check(I2C_VVCT, 2, '0', "Expecting write type Quick Command from master", WARNING, C_SCOPE);
```

i2c_slave_receive()

i2c_slave_receive (VVCT, instance_idx, num_bytes, [TO_SB,] msg, [scope])

If the option TO_SB is applied, the received data will be sent to the I2C dedicated scoreboard. There, it is checked against the expected value (provided by the testbench).

See description and fetch_result() example in the description for i2c_master_receive()

Example:

```
i2c_slave_receive(I2C_VVCT, 1, 1, "One byte from master to slave", C_SCOPE);
```

2 VVC Configuration

Record element	Type	C_I2C_VVC_CONFIG_DEFAULT	Description
inter_bfm_delay	t_inter_bfm_delay	C_I2C_INTER_BFM_DELAY_DEFAULT	Delay between any requested BFM accesses towards the DUT. - TIME_START2START: Time from a BFM start to the next BFM start (A TB_WARNING will be issued if access takes longer than TIME_START2START). - TIME_FINISH2START: Time from a BFM end to the next BFM start. Any insert_delay() command will add to the above minimum delays, giving for instance the ability to skew the BFM starting time.
cmd_queue_count_max	natural	C_MAX_COMMAND_QUEUE	Maximum pending number in command queue before queue is full. Adding additional commands will result in an ERROR.
cmd_queue_count_threshold	natural	C_CMD_QUEUE_COUNT_THRESHOLD	An alert with severity “cmd_queue_count_threshold_severity” will be issued if command queue exceeds this count. Used for early warning if command queue is almost full. Will be ignored if set to 0.
cmd_queue_count_threshold_severity	t_alert_level	C_CMD_QUEUE_COUNT_THRESHOLD_SEVERITY	Severity of alert to be triggered if command count exceeding cmd_queue_count_threshold
result_queue_count_max	natural	C_RESULT_QUEUE_COUNT_MAX	Maximum number of unfetched results before result_queue is full.
result_queue_count_threshold	natural	C_RESULT_QUEUE_COUNT_THRESHOLD	An alert with severity 'result_queue_count_threshold_severity' will be issued if result queue exceeds this count. Used for early warning if result queue is almost full. Will be ignored if set to 0.
result_queue_count_threshold_severity	t_alert_level	C_ RESULT_QUEUE_COUNT_THRESHOLD_SEVERITY	Severity of alert to be initiated if exceeding result_queue_count_threshold
bfm_config	t_i2c_bfm_config	C_I2C_BFM_CONFIG_DEFAULT	Configuration for I2C BFM. See QuickRef for I2C BFM
msg_id_panel	t_msg_id_panel	C_VVC_MSG_ID_PANEL_DEFAULT	VVC dedicated message ID panel. See section 16 of uvvm_vvc_framework/doc/UVVM_VVC_Framework_Essential_Mechanisms.pdf for how to use verbosity control.

The configuration record can be accessed from the Central Testbench Sequencer through the shared variable array, e.g.:

```
shared_i2c_vvc_config(1).inter_bfm_delay.delay_in_time := 10 ms;
shared_i2c_vvc_config(1).bfm_config.i2c_bit_time       := 100 ns;
```

3 VVC Status

The current status of the VVC can be retrieved during simulation. This is done by reading from the shared variable shared_i2c_vvc_status record from the test sequencer. The record contains status for both channels, specified with the channel axis of the shared_i2c_vvc_status array. The record contents can be seen below:

Record element	Type	Description
current_cmd_idx	natural	Command index currently running
previous_cmd_idx	natural	Previous command index to run
pending_cmd_cnt	natural	Pending number of commands in the command queue

4 Activity watchdog

The VVCs support a centralized VVC activity register which the activity watchdog uses to monitor the VVC activities. The VVCs will register their presence to the VVC activity register at start-up, and report when ACTIVE and INACTIVE, using dedicated VVC activity register methods, and trigger the global_trigger_vvc_activity_register signal during simulations. The activity watchdog is continuously monitoring the VVC activity register for VVC inactivity and raises an alert if no VVC activity is registered within the specified timeout period.

Include `activity_watchdog(num_exp_vvc, timeout, [alert_level, [msg]])` in the testbench to start using the activity watchdog.
Note that setting the exact number of expected VVCs in the VVC activity register can be omitted by setting `num_exp_vvc = 0`.

More information can be found in UVVM Essential Mechanisms PDF in the UVVM VVC Framework doc folder.

5 Transaction Info

This VVC supports transaction info, a UVVM concept for distributing transaction information in a controlled manner within the complete testbench environment. The transaction info may be used in many different ways, but the main purpose is to share information directly from the VVC to a DUT model.

*Table 5.1 I2C transaction info record fields. Transaction type: t_base_transaction (BT) **- accessible via shared_i2c_vvc_transaction_info.bt.***

Info field	Type	Default	Description
operation	t_operation	NO_OPERATION	Current VVC operation, e.g. INSERT_DELAY, POLL_UNTIL, READ, WRITE.
addr	unsigned(9 downto 0)	0x0	Slave address to interact with when VVC is in master mode.
data	t_byte_array(0 to 63)	(others => (others => '0'))	The data to be transmitted (in i2c_<master/slave>_transmit) or the expected data (in i2c_<master/slave>_check). Either a single byte or a byte array.
num_bytes	natural	0	Number of bytes to be transmitted (in i2c_<master/slave>_transmit) or the expected data (in i2c_<master/slave>_check).
action_when_transfer_is_done	t_action_when_transfer_is_done	RELEASE_LINE_AFTER_TRANSFER	This parameter sets whether the VVC (in master mode) shall occupy the bus after the current transaction is finished. 'HOLD_LINE_AFTER_TRANSFER' means that the VVC will not generate a stop condition at the end of the current transaction. When the next transaction starts, the master VVC generates a start condition that will be interpreted by the slave(s) as a repeated start condition.
exp_ack	boolean	true	Expected ack bit during a Quick Command. Can be used to e.g. identify if a slave is present on the bus.
rw_bit	sl	0	Bit set in the R/W# slot of the Quick Command
vvc_meta	t_vvc_meta	C_VVC_META_DEFAULT	VVC meta data of the executing VVC command.
→ msg	string	" "	Message of executing VVC command.
→ cmd_idx	integer	-1	Command index of executing VVC command.
transaction_status	t_transaction_status	C_TRANSACTION_STATUS_DEFAULT	Set to INACTIVE, IN_PROGRESS, FAILED or SUCCEEDED during a transaction.

6 Scoreboard

This VVC has built in Scoreboard functionality where data can be routed by setting the `TO_SB` parameter in supported method calls, e.g. `i2c_master_receive()`. Note that the data is only stored in the scoreboard and not accessible with the `fetch_result()` method when the `TO_SB` parameter is applied.

The I2C scoreboard is per default a 64 bits wide standard logic vector. When sending expected data to the scoreboard, where the data width is smaller than the default scoreboard width, we recomment zero-padding the data with the `pad_i2d_sb()` function.I.e. `I2C_VVC_SB.add_expected(<I2C VVC instance number>, pad_i2c_sb(<exp data>));`

See the Generic Scoreboard Quick Reference PDF in the Bitvis VIP Scoreboard document folder for a complete list of available commands and additional information. The I2C scoreboard is accessible from the testbench as a shared variable `I2C_VVC_SB`, located in the `vvc_methods_pkg.vhd`. All of the listed Generic Scoreboard commands are available for the I2C VVC scoreboard using this shared variable.

7 Additional Documentation

Additional documentation about UVVM and its features can be found under "/uvvm_vvc_framework/doc/".
For additional documentation on the I2C protocol, please see the NXP I2C specification "UM10204 I2C-bus specification and user manual Rev. 6", available from NXP Semiconductors.

8 Compilation

The I2C VVC must be compiled with VHDL 2008.
It is dependent on the following libraries

- ***UVVM Utility Library (UVVM-Util), version 2.15.0 and up***
- ***UVVM VVC Framework, version 2.11.0 and up***
- ***I2C BFM***
- ***Bitvis VIP Scoreboard***

Before compiling the I2C VVC, make sure that uvvm_vvc_framework, uvvm_util and bitvis_vip_scoreboard have been compiled.

See UVVM Essential Mechanisms located in uvvm_vvc_framework/doc for information about compile scripts.

Compile order for the I2C VVC:

Compile to library	File	Comment
bitvis_vip_i2c	i2c_bfm_pkg.vhd	I2C BFM
bitvis_vip_i2c	transaction_pkg.vhd	I2C transaction package with DTT types, constants etc.
bitvis_vip_i2c	vvc_cmd_pkg.vhd	I2C VVC command types and operations
bitvis_vip_i2c	../uvvm_vvc_framework/src_target_dependent/td_target_support_pkg.vhd	UVVM VVC target support package, compiled into the I2C VVC library
bitvis_vip_i2c	../uvvm_vvc_framework/src_target_dependent/td_vvc_framework_common_methods_pkg.vhd	UVVM framework common methods compiled into the I2C VVC library
bitvis_vip_i2c	vvc_methods_pkg.vhd	I2C VVC methods
bitvis_vip_i2c	../uvvm_vvc_framework/src_target_dependent/td_queue_pkg.vhd	UVVM queue package, compiled into the I2C VVC library
bitvis_vip_i2c	../uvvm_vvc_framework/src_target_dependent/td_vvc_entity_support_pkg.vhd	UVVM VVC entity methods compiled into the I2C VVC library
bitvis_vip_i2c	i2c_vvc.vhd	I2C VVC

9 Simulator compatibility and setup

See README.md for a list of supported simulators.
For required simulator setup see ***UVVM-Util*** Quick reference.

IMPORTANT
This is a simplified Verification IP (VIP) for I2C.
The given VIP complies with the basic I2C protocol and thus allows a normal access towards an I2C interface. This VIP is not an I2C protocol checker.
For a more advanced VIP please contact Bitvis AS at support@bitvis.no