**Specification Coverage -** Quick Reference  
UVVM Support Component

The Specification Coverage feature is an efficient method of verifying the requirement specification.

***The first page of this QuickRef is just for references - for an introduction to the Specification Coverage concept, please see page 2 of this QuickRef.***

|  |
| --- |
| **UVVM VHDL Methods – see Table 11 for details** |
| **start\_req\_cov**(req\_to\_tc\_map\_file, output\_file) |
| **log\_req\_cov**(requirement, testcase[, passed][, fail\_on\_alert\_mismatch\_severity]) |
| **end\_req\_cov**(VOID) |

Script Usage – run\_spec\_vs\_verif.py

Call the run\_spec\_cov.py from a terminal, using e.g.:

* *python run\_spec\_cov.py <see Table 12 for script arguments>*

If the output parameter is specified, the output will be placed in this directory. If the output parameter is not specified, the current directory will be used. Python 3.x required.

File Formats – Basic usage

Required files

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **File** | Requirement to Testcase map file | CSV | Output from UVVM test suite | CSV | Output from run\_spec\_cov.py | CSV |
| **Layout** | *“Requirement”; “Description” [; “Testcase”]* | | *“Requirement”; “Testcase”; “PASS/FAIL”* | | *“Requirement”; “COMPLIANT / NON COMPLIANT”* | |
| **Example** | FPGA\_SPEC\_1; UART all bits 0 ; TC\_UART\_1  FPGA\_SPEC\_2; UART start bit polarity; TC\_UART\_2  FPGA\_SPEC\_3; UART start bit delay; TC\_UART\_3 | | FPGA\_SPEC\_1; TC\_UART\_1; PASS  FPGA\_SPEC\_2; TC\_UART\_2; PASS  FPGA\_SPEC\_3; TC\_UART\_3; FAIL | | FPGA\_SPEC\_1; COMPLIANT  FPGA\_SPEC\_2; COMPLIANT  FPGA\_SPEC\_3; NON COMPLIANT | |

Optional files

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **File** | Requirement to sub-requirement map file (**optional**) | CSV | Test result file list (**optional**) | txt | Script config file (**optional**) | txt |
| **Layout** | *“Requirement”; “Sub-requirement”; “Sub-requirement”; …;”Sub-requirement”* | | *“path/to/result\_file.csv”* | | *--argument value OR -a value* | |
| **Example** | FPGA\_SPEC\_1; FPGA\_SPEC\_1.a; FPGA\_SPEC\_1.b | | path/to/first/ result\_file.csv  path/to/second/result\_file.csv  third\_result\_file.csv | | --requirements path/to/requirements.csv  -F test\_suite\_input\_files.txt  --subreqs path/to/subrequirements.csv | |

Specification Coverage Concept

An important step of design verification is to check that all requirements have been met. Requirements can be very different depending on the project management, the product sector and standardized design methodology. In some projects requirements hardly exists, and the functionality is based on a brief description. However, in projects where safety and reliability is key the requirements are an essential part of the project management flow. In some standards the requirements and the corresponding testcases that verifies the requirements need to be defined, reviewed and accepted by a third party assessor before even starting the verification flow. This UVVM Verification IP is intended for projects where requirements are essential in the work flow. Examples of requirements can be seen in Table 1.

Table 1 Requirement examples

|  |  |
| --- | --- |
| **Requirement Number** | **Description** |
| FPGA\_TOP\_SPEC\_1 | The device UART interface shall accept a baud rate of 9600kbps. |
| FPGA\_TOP\_SPEC\_2 | The device reset shall be active low. |

A typical verification flow starts with the verification engineer specifying several testcases to verify all requirements. Simplified testcases mapped to the requirements in Table 1 is listed in Table 2. Note that this testcase description does not specify in detail how the test is performed. Requirements related to this varies between standards and methodologies.

Table 2 Testcase to requirement mapping examples

|  |  |  |
| --- | --- | --- |
| **Testcase** | **Verifies requirement** | **Description (simplified!)** |
| TC\_UART\_BAUDRATE | FPGA\_TOP\_SPEC\_1 | A set of random UART messages shall be sent to the DUT UART interface, with a baud rate of 9600kbps. It will be verified that all messages are received correctly by the DUT. |
| TC\_TOP\_RESET | FPGA\_TOP\_SPEC\_2 | The reset will be set low and it will be verified that all I/O are set in their defined reset state. The reset shall then be set high and it will be verified that the DUT can be operated as normal. |

After all testcases passes, the verification engineer will write a report stating that all the requirements have been verified. One of the key components in a verification report is the compliancy statements, which is a requirement to testcase mapping. An example of this can be seen in Table 3.

Table 3 Requirement to testcase mapping in the verification report

|  |  |  |
| --- | --- | --- |
| **Requirement Number** | **Tested by testcase** | **Compliancy** |
| FPGA\_TOP\_SPEC\_1 | TC\_UART\_BAUDRATE | COMPLIANT |
| FPGA\_TOP\_SPEC\_2 | TC\_TOP\_RESET | COMPLIANT |

In many cases it is sufficient to do this process manually. However, when working on larger projects with multiple re-iterations or testcases that are constantly changing, it is a good idea to automate this process. By outsourcing requirement compliancy reporting to the VHDL testbench, the verification engineer does not have to constantly evaluate each testcase to verify that it still addresses the requirement it is supposed to verify. Additionally, it will save time for the verification engineer if a report is generated where each requirement is listed as compliant or non-compliant. This list can be used directly in the verification report.

The UVVM Specification Coverage support component is an extension to the UVVM package, consisting of a set of new VHDL methods for logging requirement compliancy and a post-processing Python script for generating a report based on a requirement specification and the simulation results. Figure 1 shows an example of basic Specification Coverage usage.

Table 4 gives a description of each step in Figure 1. See the front-page of this QuickRef for a description of the input-files used in each step. In this basic example the testcase column is omitted from the Requirement To Testcase map file.

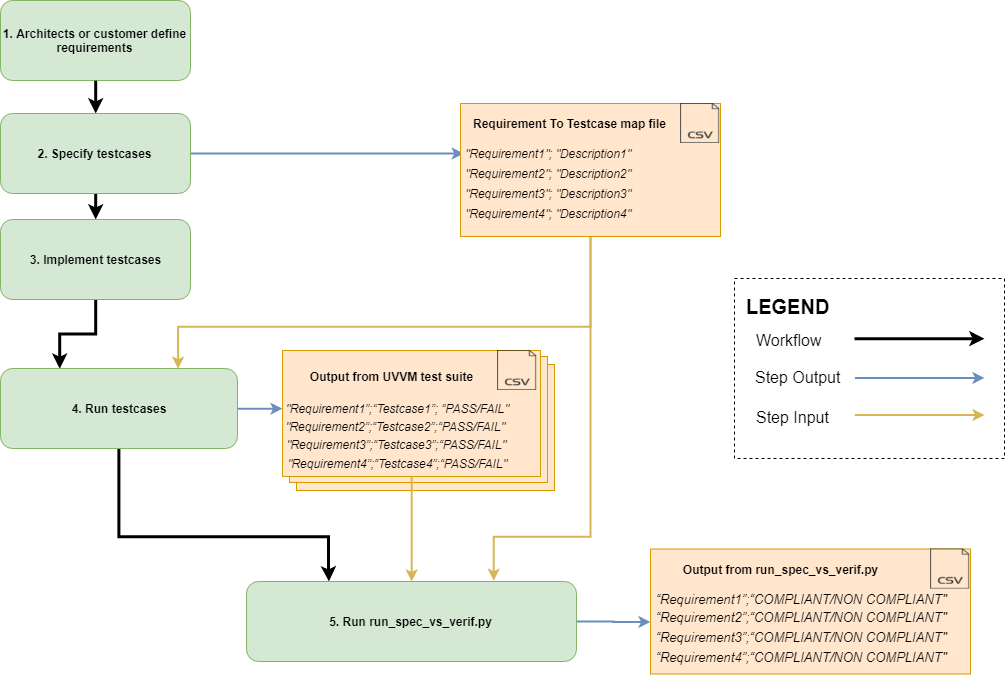


Figure 1 Basic Specification Coverage Typical Usage

Table 4 Basic Specification Coverage Typical Usage Description

|  |  |
| --- | --- |
| **Step** | **Description** |
| 1. Architect or customer define requirements | This step typically occurs prior to the FPGA designer involvement. The system architect or the customer defines system level requirements for the design, that will later be used to create a detailed design description. These requirements are often broad and incomplete. |
| 2. Specify testcases | In this step the designer will specify testcases that will cover all the requirements specified in the previous steps. In this simple example, the testcase column is omitted from the requirement To Testcase mapping file, making this file a simple list of requirement and descriptions. This can be useful when it is not really important which testcases the requirement was verified in, and hence the testcase input is irrelevant in this step.  Note that ‘Designer’ in some cases will be a dedicated ‘Verification Engineer’.  More information on this CSV-file can be seen on the first page of this QuickRef. Note that the “Testcase” input is optional unless the *shared\_req\_vs\_cov\_strict\_testcase\_checking* variable is set true, as described in Table 9. |
| 3. Implement testcases | After all the testcases have been defined, the designer will implement the testcases in VHDL.  The VHDL functions for starting (start\_reg\_cov()) and ending (end\_req\_cov()) the requirement coverage shall be used at the beginning and end of the testcases, and the log\_req\_cov() procedure shall be used to log results for every single requirement.  Typically, the log\_req\_cov() procedure will be used where a requirement is verified in the testcase. E.g. if a requirement states that the DUT shall set signal X when signal Y is received, the log\_req\_cov() is called with either pass or fail as the *passed*-argument when this feature has been tested. The log\_req\_cov() procedure will also check if there are any alert mismatches, and if so the requirement will be marked as failed. The VHDL procedures are documented in Table 11. |
| 4. Run testcases | When the tests have been implemented, all testcases shall be run. The testcases can be run sequentially, in parallel, or as soon as each testcase is developed. In the latter case, step 3 and 4 will be run simultaneously. The tests that are run in this step will generate one or more result files where the log\_req\_cov() results are stored. The output files are specified with the start\_req\_cov() procedure, as described in Table 11. |
| 5. Run run\_spec\_cov.py | The final step, after all tests have been run, is to run the Python script *run\_spec\_cov.py*. This script will check the output from step 2 against the output file(s) from step 4 and create a report file where all requirements are marked as COMPLIANT or NON-COMPLIANT. A description of the script parameters can be found in Table 12. |

For a practical example of the Specification Coverage concept, see the example design under the *demo* directory.

Advanced Concept Usage

In some cases, the designer would want to extend or even split up broad requirements in order to have simple, testable requirements. This is allowed in the specification coverage concept by extending step 1, as illustrated by Figure 2. In this case, a new CSV file with a mapping from (broad) requirement to (sub) requirements is created as part of step 1b, and used later on when running the Python script in step 5. A description of how to use this feature is documented in Table 11.

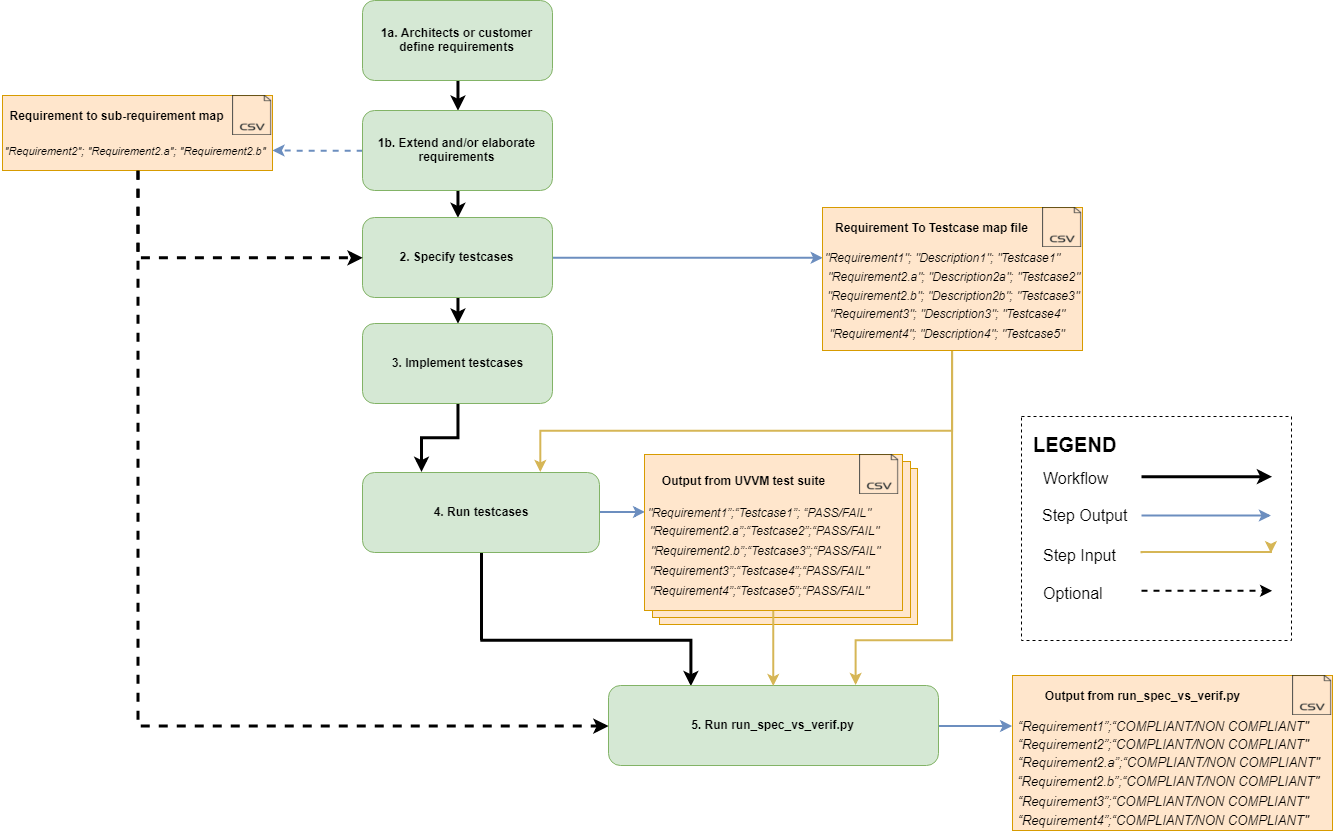


Figure 2 Advanced Specification Coverage Typical Usage

Table 5 Advanced Specification Coverage Typical Usage Description

|  |  |
| --- | --- |
| **Step** | **Description** |
| 1a. Architects or customer define requirements | See Table 4, step 1. |
| 1b. Extend and/or elaborate requirements | As mentioned in the above step, the requirements defined by the customer or architect often specify broad requirements. In these cases, the designer may create sub-requirements for each step in the broad requirement. For example, if the requirement states:   * FPGA\_SPEC\_1: “UART shall handle baud-rate of 9600bps and data shall be sent LSB first.   This requirement could be replaced and split into two sub-requirements:   * FPGA\_SPEC\_1.a: “UART shall handle baud-rate of 9600bps.” * FPGA\_SPEC\_1.b: “UART shall handle data being sent LSB first”   An optional map of requirement to sub-requirements can be created during this step. This mapping can be used later by the script in step 5 to check and report the original requirement and not just the sub-requirement.  In some cases, the designer will also want to add additional requirements to the requirement list in this step, e.g. if a requirement is relevant for how the design is implemented. |
| 2. Specify testcases | See Table 4, step 2.  In the cases where a requirement has been split into sub-requirement, the original requirement shall not be part of this map-file. In this example the testcase information is also added to the CSV file created in this step. |
| 3. Implement testcases | See Table 4, step 3. |
| 4. Run testcases | See Table 4, step 4. |
| 5. Run run\_spec\_cov.py | See Table 4, step 5.  In addition to the requirements, the sub-requirements will also be listed as either compliant or non-compliant. |

When minimum one testcase must pass

In some cases, a requirement will require that at least one of many testcases must pass for the requirement to be compliant. However, not all testcases must pass for the requirement to be compliant. This is supported by the Specification Coverage extension. To instruct the tool that only one testcase is required to pass, the requirement is specified as shown in the table below, entered in the Requirement to Testcase map file. In this example, the requirement FPGA\_SPEC\_3 is tested by testcase TC\_UART\_3.a, b, c and d, and at least one of these testcases needs to pass for the requirement to be compliant.

Table 6 Testcase mapping – Minimum one testcase must pass

|  |  |  |
| --- | --- | --- |
| **File** | Requirement to Testcase map file | CSV |
| **Layout** | *“Requirement”; “Description”; “Testcase 1” [; “Testcase 2”; “Testcase 3”; …; ”Testcase N”]* | |
| **Example** | FPGA\_SPEC\_1; UART all bits 0 ; TC\_UART\_1  FPGA\_SPEC\_2; UART start bit polarity; TC\_UART\_2  FPGA\_SPEC\_3; UART start bit delay; TC\_UART\_3.a; TC\_UART\_3.b; TC\_UART\_3.c;TC\_UART\_3.d | |

When multiple requirements are tested by one testcase

This is supported by the tool as shown in the table below. In the table below, testcase 2 verifies specification 2, 3 and 4.

Table 7 Testcase mapping – One testcase verifies multiple requirements

|  |  |  |
| --- | --- | --- |
| **File** | Requirement to Testcase map file | CSV |
| **Layout** | *“Requirement”; “Description”; “Testcase 1” [; “Testcase 2”; “Testcase 3”; …; ”Testcase N”]* | |
| **Example** | FPGA\_SPEC\_1; UART all bits 0 ; TC\_UART\_1  FPGA\_SPEC\_2; UART start bit polarity; TC\_UART\_2  FPGA\_SPEC\_3; UART start bit delay, minimum; TC\_UART\_2  FPGA\_SPEC\_4; UART start bit delay, maximum; TC\_UART\_2 | |

When one requirement maps to multiple testcases

It is also allowed by the tool to specify that one (complex) requirement shall be tested by multiple testcases. This is specified by adding the requirement on multiple lines, as shown in the table below. However, it is recommended that such cases are handled by splitting the complex requirement into smaller, testable sub-requirements that have one testcase per sub-requirement. This visualizes exactly what parts of the requirement that is verified by the testcase. In the example below, TC\_UART\_3.a and TC\_UART\_3.b must pass for FPGA\_SPEC\_3 to be compliant.

Table 8 Testcase mapping – Multiple testcases per requirement

|  |  |  |
| --- | --- | --- |
| **File** | Requirement to Testcase map file | CSV |
| **Layout** | *“Requirement”; “Description”; “Testcase 1” [; “Testcase 2”; “Testcase 3”; …; ”Testcase N”]* | |
| **Example** | FPGA\_SPEC\_1; UART all bits 0 ; TC\_UART\_1  FPGA\_SPEC\_2; UART start bit polarity; TC\_UART\_2  FPGA\_SPEC\_3; UART start bit delay, minimum; TC\_UART\_3.a  FPGA\_SPEC\_3; UART start bit delay, maximum; TC\_UART\_3.b | |

VHDL Package

A vital part of the specification coverage concept is the VHDL testbench methods. These methods are described in Table 11. The methods are located inside the *spec\_cov\_methods.vhd* file in the *src/* directory of this VIP.

UVVM Adaptation Package Configuration

Table 9 UVVM Adaptations Shared Variables

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Type** | **Default** | **Description** |
| shared\_req\_vs\_cov\_strict\_testcase\_checking | boolean | false | When this shared variable is set true, the Specification Coverage checking will require that the input “*Requirement to Testcase map file*” contains the testcase field. Only the testcase specified in this field will be able to verify the requirement it is supposed to test.  For example, if the *Requirement to Testcase map file* contains the following line:  *FPGA\_SPEC\_1; Start bit polarity test; TC\_UART\_1*  Then it will not be sufficient to run *log\_req\_cov* from any testcase. It will have to be reported with:  *log\_req\_cov(“FPGA\_SPEC\_1”, “TC\_UART\_1”)*  in order to pass. A mismatch between requirement and testcase will result in a warning, and the requirement will not be marked as compliant. |

Table 10 UVVM Adaptations Constants

|  |  |  |  |
| --- | --- | --- | --- |
| **Constant** | **Type** | **Default** | **Description** |
| C\_REQ\_TC\_MISMATCH\_SEVERITY | t\_alert\_level | warning | Alert level used when the log\_req\_cov() procedure does not find the specified requirement or testcase in the requirement to testcase input file. |
| C\_DEFAULT\_RESULT\_FILE\_NAME | string | "resultfile.csv" | Default file name for the result file, if none is specified in the start\_req\_cov() procedure. |
| C\_CSV\_DELIMITER | character | ‘;’ | Character used as delimiter in the CSV files. |
| C\_MAX\_NUM\_REQUIREMENTS | natural | 1000 | Maximum number of requirements in the req\_to\_tc\_map file used in start\_req\_cov(). Increase this number if the number of requirements exceeds 1000. |
| C\_MAX\_NUM\_TC\_PR\_REQUIREMENT | natural | 20 | Maximum number of testcases allowed per requirement. This is applicable when one requirement is verified by one or more testcases (as described above, under “When minimum one testcase must pass”). |
| C\_CSV\_FILE\_MAX\_LINE\_LENGTH | Positive | 256 | Maximum length of each line in the req\_to\_tc\_map CSV file. |

The specification coverage implementation uses two new message Ids, as described in the table below. All message Ids are located in the adaptations package. The specification coverage implementation uses the shared message id panel for all logging.

|  |  |
| --- | --- |
| **Message Id** | **Description** |
| ID\_FILE\_PARSER | Id used for CSV parser messages. |
| ID\_SPEC\_COV | Id used for all messages that are not directly related to CSV parsing. |

VHDL Methods Details

Table 11 VHDL Methods

|  |  |  |
| --- | --- | --- |
| **Procedure** | **Parameters and examples** | **Description** |
| start\_req\_cov() | req\_to\_tc\_map\_file(string), output\_file(string)    **Example** start\_req\_cov(“c:/test\_folder/my\_req\_to\_testcase\_map.csv”, “output\_file\_path.csv");  start\_req\_cov(GC\_REQ\_MAP\_PATH, GC\_RESULT\_PATH); -- Using generic as path | Starts the requirement coverage process in a test. The requirement to test mapping file specified in the *req\_matrix\_path* path is used to check that the requirement exists, and the description is retrieved from the file and logged to the transcript.   |  |  | | --- | --- | | - *req\_to\_tc\_map\_file:* | String with the path to the requirement to testcase map CSV file. | | - *output\_file*: | String with the location where the output file will be placed. If a file exists in the specified path, the results will be appended to the file. |   **Defaults**  output\_file <= C\_DEFAULT\_RESULT\_FILE\_NAME |
| log\_req\_cov() | requirement(string), testcase(string) [, passed(boolean) [, fail\_on\_alert\_mismatch\_severity(t\_fail\_on\_alert\_mismatch\_severity)]  **Examples**  -- Will pass if no unexpected alert occurred  log\_req\_cov(“SPEC\_FPGA\_1”, “Testcase\_1”);  -- Will fail since passed argument is set to false  log\_req\_cov(“ESA\_FPGA\_UART\_1”, “UART\_BAUDRATE\_16k\_Test”, false, WARNING);  -- Intended usage of the passed argument  if(v\_test\_result > v\_requirement\_limit) then  log\_req\_cov(“ESA\_FPGA\_UART\_2”, “UART\_Test”);  else  log\_req\_cov(“ESA\_FPGA\_UART\_2”, “UART\_Test”, false);  end if; | Evaluates and logs the specified requirement. The procedure checks the global alert mismatch status, and if an alert mismatch is present the requirement will be marked as failed. If there are no alert mismatches, the requirement will be marked as passed, unless the *passed* input is set to false.  The result is written to both the transcript and a result file, specified in the *start\_req\_cov()* procedure. The *log\_req\_cov()* will look up the specified requirement and testcase in the req\_to\_tc\_map\_file specified in *start\_req\_cov()*, and use the description from this entry as log message. The procedure will also issue a warning if the specified requirement and testcase was not found.   |  |  | | --- | --- | | - *requirement:* | String with the requirement tag. Must match a requirement tag in the file specified in start\_req\_cov(). | | - *testcase*: | String with the testcase tag. Must match a testcase tag in the file specified in start\_req\_cov(). | | - *passed:* | Boolean value with the result. True indicates passed, false indicated not passed. | | *- fail\_on\_alert\_mismatch\_severity:* | Which alert mismatch severity on the global alert counter that will cause a requirement to be considered failed. Can be either WARNING or ERROR. |   **Defaults**  passed <= true; fail\_on\_alert\_mismatch\_severity <= ERROR |
| end\_req\_cov() | VOID(t\_void)  **Example** end\_req\_cov(VOID); | Ends the requirement coverage process in a test. This procedure writes a closing check to the output file specified in start\_req\_cov. This check is used later by the run\_spec\_cov.py script. |

Additional Documentation

Additional documentation about UVVM and its features can be found under “/uvvm\_vvc\_framework/doc/”.

Compilation

This VHDL package may only be compiled with VHDL 2008. It is dependent on the following libraries

* ***UVVM Utility Library (UVVM-Util), version 2.6.0 and up***
* ***UVVM VVC Framework, version 2.3.0 and up***

Before compiling the Specification Coverage component, make sure that uvvm\_vvc\_framework and uvvm\_util have been compiled.

See UVVM Essential Mechanisms located in uvvm\_vvc\_framework/doc for information about compile scripts.

**Compile order for the Specification vs Verification Matrix Component:**

|  |  |  |
| --- | --- | --- |
| **Compile to library** | **File** | **Comment** |
| bitvis\_vip\_spec\_cov | csv\_file\_reader\_pkg.vhd | Package for reading and parsing of CSV input files |
| bitvis\_vip\_spec\_cov | spec\_vs\_verif\_methods.vhd | Specification Coverage component implementation |

Simulator compatibility and setup

This VVC has been compiled and tested with Modelsim version 10.4b and Riviera-PRO version 2018.02.

For required simulator setup see UVVM-Util Quick reference.

Post-processing Script

The final step of the Specification Coverage usage shown in Figure 1 and Figure 2 is to run a post-processing script to evaluate all the simulation results. This script is called *run\_spec\_cov.py*. This script requires Python 3.x. The script can be called with the arguments listed in Table 12 from any command line.

Table 12 Script Arguments

|  |  |  |  |
| --- | --- | --- | --- |
| **Argument** | **Short form** | **Example** | **Description** |
| --requirements | -r | --requirements path/to/requirements.csv  -r path/to/requirements.csv | Points to the requirement list from Step 2 in  Table 4. This argument is mandatory. |
| --resultfile | -f | --resultfile path/to/resultfile.csv  -f path/to/resultfile.csv | Points to the resultfile from the VHDL simulation, discussed in Step 4 in  Table 4. Either this argument OR the --resultlistfile/-l argument is mandatory. Both can’t be used at the same time. |
| --resultlistfile | -l | --resultlistfile path/to/fileinput.txt  -l path/to/fileinput.txt | Points to a text file that contains the paths to all result files. The files listed in this file will be merged to a single resultfile. This argument can be used if the simulations have been run in more than one testbench. Either this argument OR the --resultfile/-f argument is mandatory. Both can’t be used at the same time.  Example resultfile file contents:  *path/to/first/result.csv*  *path/to/second/result.csv*  *path\_to\_third\_result.csv* |
| --output | -o | --output path/to/outputs  -o path/to/outputs | Path to directory where the output described in Step 5 in  Table 4 shall be stored. This argument is optional. If the argument is not used, the output directory will be the current directory. |
| --subrequirements | -s | --subrequirements path/to/subrequirements.csv  -s path/to/subrequirements.csv | Points to the requirement to sub-requirement map file, described in Step 1 in Table 5.  This argument is optional. If this argument is omitted, the script assumes that no sub-requirements exists. |
| --config | -c | --config path/to/configfile.txt  -c path/to/configfile.txt | Optional configuration file where all the arguments can be placed. This argument will override all other arguments. The configuration file does not need to have the .txt extension. All arguments shall be added on a new line.  Example configuration file contents:  *--requirements path/to/requirements.csv*  *-l test\_suite\_input\_files.txt*  *--subrequirements path/to/subrequirements.csv* |

The output of the post-processing is a CSV file where all requirements and sub-requirements are listed and marked as either compliant or non-compliant. The format of this file is shown on the front-page of this QuickRef. The post-processing script will also print a transcript to file, where it is indicated whether or not the script succeeded.

**INTELLECTUAL**

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