UVM Notes

1. Overview

   1. What is UVM

      - UVM is a standardized methodology, a set of pre-defined libraries using syntax and semantics of SystemVerilog.

   b. Why UVM

   Increases reusability

      - The components(driver, sequencer. etc) are modules that can be re-used across projects.

      - Stimulus are separate from the actual testbench hierarchy and can be re-used or replaced by new stimulus.

      - Factory mechanisms make modifications of components easy. Create each components using factory enables them to be overridden in different tests/environments without changing the code base.

   c. UVM class hierarchy

      - UVM provides a set of base classes that more complex classes can be built by inheritance.

      - Two main branches. The verification components are underneath uvm_component, and data objects consumed and operated by components are underneath uvm_transaction.
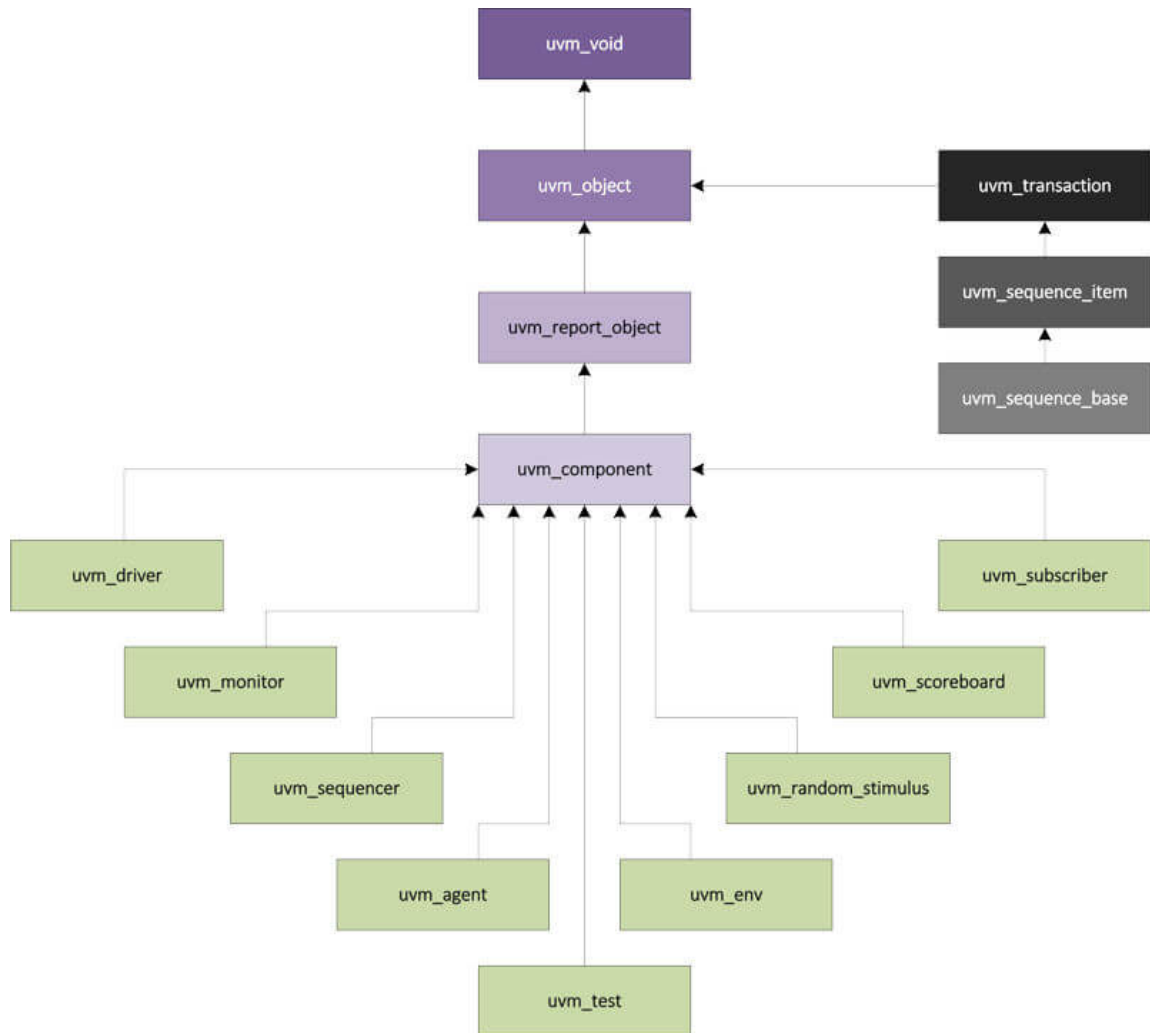
- Sequence is a container for the actual stimulus to the design. Stimulus classes are inherited from uvm_sequence.

- Data objects that are driven to DUT are sequence items and are inherited from uvm_sequence_item.

- UVM utilizes TLM(transaction level modeling) which helps to send data between components in the form of transactions and class objects. It also can broadcast a packet to its listeners without creating specific channels and attach to it.

- Phases enable every component to sync with each other before proceeding to the next phases. Every component goes through the build phase when it gets instantiated, connects with each other during

the connect phase, consumes simulation time during the run phase, and stops together in the final phase.

2. UVM Common Utilities

1. Base Classes

- uvm_root
  - It is an implicit top_level UVM component that is automatically created when simulation is run.
  - Users can access it via the global variable, uvm_top. Any components whose parent is set to null becomes a child of uvm_top.
  - uvm_top checks for errors during end_of_elaboration phase and issue uvm_fatal error to stop simulation.
- uvm_report_object
  - All messages, warnings, errors issued by components go via this interface.
  - A report has ID String, Severity, Verbosity Level, and Test Message parts. If the verbosity level is GREATER than the configured maximum verbosity level, it is ignored. For example, if maximum verbosity level is UVM_MEDIUM, and a info is assigned to verbosity level UVM_HIGH, then this message will not be seen in the output.

b. UVM utility & field macros

- UVM uses the concept of a factory where all objects are registered.
- Utility Macros
  - The utils macro is used to register an object or component with the factory.
  - Required to be used inside every user-defined class derived from uvm_object
  - Object Utility
    - All classes derived directly from uvm_object or uvm_transaction required to be registered using `uvm_object_utils macro.

- It is mandatory for the new function to be explicitly defined for every class, and take the name of the class instance as an argument.

  uvm_sequence is inherited from uvm_sequence_item, uvm_transaction, then uvm_object.

  ```
  class fc_sequence extends uvm_sequence #(fc_transaction);
      //register fc_sequence, this user-defined class with the factory
      `uvm_object_utils(fc_sequence)
      function new(string name = "fc_sequence");
          super.new(name);
      endfunction
  endclass
  ```

- Component Utility
  - All classes derived directly or indirectly from uvm_component are required to be registered with the factory using `uvm_component_utils macro.
  - It is mandatory for the new function to be explicitly defined for every class, and takes the name of the class instance and a handle to the parent class where this object is instantiated.
- Macro Expansion
  - `uvm_object_utils gets expanded into its *_begin and *_end form with nothing in between.
  - *_begin implements other macros, such as
    - `m_uvm_object_registry_internal(T,T), which implements the function get_type() and get_object_type() that returns a factory proxy object for the requested type
    - `m_uvm_object_create_func(T) which instantiates an object of the specified type by calling its no-args constructor
    - `m_uvm_get_type_name_func(T) which return the type_name as a string.

- `uvm_field_utils_begin(T) which registers the type with UVM factory
- Creation of class object
    - Recommend all class objects are created by calling the type_idLLcreate() method which is defined using the macro `m_uvm_object_create_func(T). (this macro utilizes the new() function. When creating component object, two arguments are taken which are the name and parent).

```
fc_drv = fc_driver::type_id::create("fc_drv", this);
```

- Field Macros
    - `uvm_field_* macros that were used begween *_begin and *_end provide automatic implementations of core methods like copy and compare.
    - `uvm_field_* corresponding to the data type of variables been used. Variables of type int, bit, byte should use `uvm_field_int, type string should use `uvm_field_string and so on.
    - The macro accepts at least two arguments, ARG and FLAG. ARG is the name of the variable, FLAG specifics which data method implementations will not be included(except UVM_ALL_ON and UVM_DEFAULT).
        - UVM_ALL_ON: all operations are turned on
        - UVM_DEFAULT: enables all operations, equivalent to UVM_ALL_ON
        - UVM_NOCOPY, UVM_NOCOMPARE, UVM_NOPRINT, UVM_NOPACK: do not copy, compare, print, pack/unpack the given variable
        - UVM_REFERENE: operate only on handles.
- UVM Object Print

- After using type_id create to create an object, we can randomize it and print it using obj.randomize() and obj.print().

- do_print()

  - using automation macros introduces additional codes and reduces simulator performance.

  - We can use do_* callback. For example, we can use do_print inside the derived object. do_print is called by the print function by default.

```systemverilog
virtual function void do_print(uvm_printer printer);
    super.do_print(printer);
    printer.print_string();
    //can control the radix of the given varaible, such as UVM_HEX or UVM_DEC
    printer.print_field_int();
endfunction
```

- UVM Object Copy/Clone

  - we can use obj2.copy(obj1) method to copy the content of obj1 into obj2

  - do_copy()

    - A generic uvm_object called "rhs" is received and type casted into Packet pkt. Then m_addr is copied from the type-casted _pkt to the variable of the current class.

      "rhs" does not contain o_bool as its only a parent handle. We cast this rhs into child data type and access it using child handle. We then copy content of casted handle into local variables.

```systemverilog
class Packet extends uvm_object;
    rand bit[15:0] m_addr;
    ...
    virtual function void do_copy(uvm_object rhs);
        Packet _pkt;
        super.do_copy(rhs);
        $cast(_pkg, rhs);
        m_addr = _pkg.m_addr;
    endfunction
    ...
endclass

class Object extends uvm_object;
    rand Packet m_pkg;
    rand bool o_bool;
    ...
    virtual function void do_copy(uvm_object rhs);
        Object _obj;
        super.do_copy(rhs);
        $cast(_obj, rhs);
        o_bool = _obj.o_bool;
        m_pkg.copy(_obj.m_pkg);
    endfunction
endclass
```

- Clone
    - Clone will return an object with the copied contents, so no need of creating the second object before copy.
- UVM Object Compare
    - we can use something like obj2.compare(obj1).
    - do_compare

```
//inslde Packet class
virtual function bit do_compare(uvm_object rhs, uvm_comparer comparer);
    bit res;
    Packet _pkt;
    $cast(_pkt, rhs);
    super.do_compare(_pkt, comparer);
    res = super.do_compare(_pkt, comparer) & m_addr = _pkt.m_addr;
    return res;
endfunction

virtual function bit do_compare(uvm_object rhs, uvm_comparer comparer);
    bit res;
    Object _obj;
    $cast(_obj, rhs);
    res = super.do_compare(_obj, comparer) & o_bool == _obj.o_bool
    & m_pkg.do_compare(_obj.m_pkt,comparer);
    return res;
endfunction
```
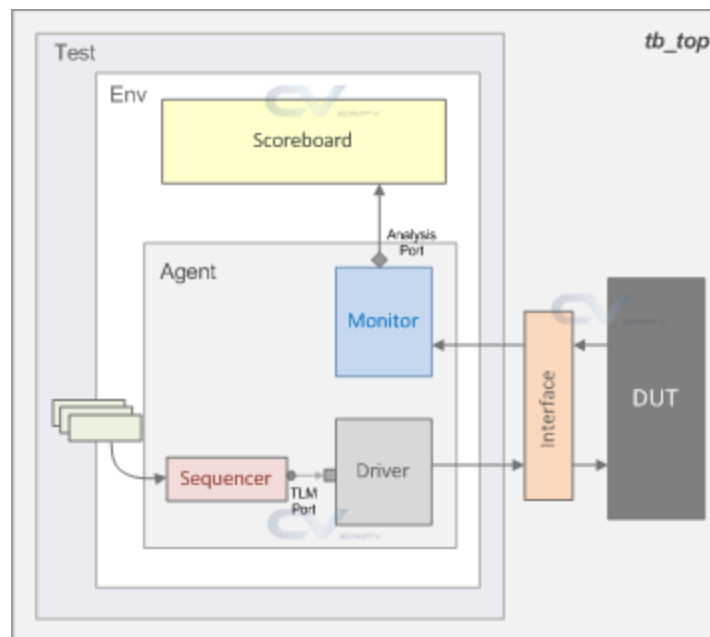
3. Testbench Structures

   1. UVM Testbench Top

      - All verification components, interfaces, and DUT are instantiated in a top level module called testbench.

- At the start of simulation, set the interface handle as a config object in UVM database(uvm_config_db::set). This if can be retrieved in the test using the get() method.

- run_test("test_name") accepts test name as argument, and the test_name case will be run for simulation

- tb_top is a static container

2. UVM Test

- We can put the entire testbench into a container, environment, and use same environment for different test. Each testcase can manipulate agents, and run different sequences on many sequencers in the environment.

- As shown in the above top-level picture, we can start a virtual/normal sequence on a given sequencer in the run_phase of the test. Remember to raise and drop the objection

- A base test sets up all basic environment parameters and configurations that can be overridden by derivative tests. For the new test, we can define the phases we want to change, the the object will call its parent's phases that's not explicitly defined.

3. UVM Environment

- A UVM environment contains multiple reusable verification components and defined their default configuration as required.

- It is possible to instantiate agents and scoreboards directly in uvm_test, but tests become non-reusable because

  - They rely on a specific environment structure.

  - The test writer would need to know how to configure the environment

- uvm_env is the base class for hierarchical containers of other components that make up a complete environment

- We need to connect verification components together in the connect_phase

4. UVM Driver

- UVM driver drives transactions to a particular interface of the design. Transaction level objects are obtained from the sequencer and the UVM driver drivers them to the design via an interface handle.

- UVM Driver-Sequencer handshake

  - The UVM driver uses following methods to interact with the sequencer.

    - get_next_item: blocks until a request item is available from the sequencer. Should be followed by item_done to complete the handshake.

    - try_next_item: non_blocking method which return null is a request object is not available from the sequencer. Else returns a pointer to the object

    - item_done: non_blocking method which completes the driver-sequencer handshake. Should be called after get_next_item or a successful try_next_item call.

  - A driver-sequencer handshake allow the driver to get a series of transaction objects from the sequence and respond back to the sequence after it finishes driving the given item, so it can get the next sequence

    - get_next_item + item_done

      - fininsh_item call in the sequence finishes only after the driver returns item_done call

```
virtual task run_phase (uvm_phase phase);
    my_data req_item;
    forever begin
        seq_item_port.get_next_item(req_item);
        @(posedge vif.clk);
        vif.en <= 1;
        seq_item_port.item_done();
    end
endtask
```

- get + put
    - The driver gets the next item and send back the sequence handshake in one go, before the UVM driver processes the item
    - The driver uses the put method to indicate that the item has been finished later.
    - So finish_item call in the sequence is finished as soon as get() is done
  - A virtual interface handle vif is declared and assigned later in the build phase
  - Real interface object is retrieved from the database directly into a local variable using uvm_config_db:;get()

5. UVM Sequencer
  - A sequencer generates data transactions as class objects and sends it to the Driver for execution
  - The uvm_sequener base class is parameterized by the request and response item types and can be handled by the sequencer. By default, response type is the same as the request type.

6. UVM Sequence
  - UVM sequences are made up of several data items.

- Executed by assigned sequencer(s) which then send(s) data items to the driver. Sequences are core stimuli of any verification plan.

- We can make the body task virtual so child classes can override the task definition

- We can use pre_body() and post_body() callbacks

- We can use `uvm_do() sequence macros, which we have to provide a uvm_sequence_item object or a sequence and it does the following internally:

    - create the item using `uvm_create if necessary.

    - randomize the item or sequence.

    - call the start_item() and finish_item() if its a uvm_sequence_item object.

    - call the start() task if its a sequence.

7. UVM Monitor

    - A UVM monitor is responsible for capturing signal activity from the design interface and translate it into transaction level data objects that can be sent to other components. It should have a virtual interface handle to the actual interface that this monitor is trying to monitor, and TLM analysis port declarations to broadcast captured data to others

    - Its functionality should be limited to basic monitoring that is always required. High level functional checking should be done in a scoreboard.

8. UVM Agent

    - An agent encapsulates a sequencer, driver, and monitor into a single entity. We can have active or passive agent, which only instantiate the monitor and is used for checking and coverage only. We can use uvm_config_db::set to configure a passive or active agent by using is_active variable.

    - We can use get_is_active() to check whether to create sequencer and driver.

9. UVM Scoreboard

- It is a verification component that contains checkers and verifies the functionality of a design. It usually receives transaction level objects captured from the interfaces of a DUT via TLM Analysis Ports

- After receiving data objects, the scoreboard can either perform calculations and predict the expected value, or send it to a reference model to get expected value. The reference model is also called a predictor that mimics the functionality of the design. The scoreboard then compares the expected results with the actual output data from DUT

- It is not required to perform checks in the check_phase. Real checkers can also check during the run_phase.

- After connecting the scoreboard with other components(e.g. monitor), monitor can send data to the scoreboard via an analysis port by calling the port's write method.

10. UVM Subscriber

- Subscribers are listeners of an analysis port. They subscribe to a broadcaster and receive objects whenever an item is broadcasted via the connected analysis port.

11. UVM Virtual Sequencer

- It is a UVM sequencer that contain handles to other sequencers.

4. UVM Phases

- All testbench components are derived from uvm_component and goes through a pre-defined set of phases. It cannot proceed to the next phase until all components finish their execution in the current phase.

- We have functions that are methods that do no consume simulation time and tasks that consume simulation time

  - Build time phases. Functions

    - build_phase, used to build testbench components and create their instances

- connect_phase, used to connect between different testbench components via TLM ports

- end_of_elaboration_phase, used to display UVM topology(e.g. print_topology displays all instantiated components in the environment to help debug) and other functions required to be done after connection

- start_of_simulation_phase, used to set initial run-time configuration or display topology.

- Run time phases. Tasks

- run_phase. Actual simulation that consumes time, and runs parallel to other UVM run-time phases.

- Clean-Up phases. Functions

- extract_phase, used to extract and compute expected data from scoreboard

- check_phase, used to perform scoreboard tasks that check for errors between expected and actual values from design

- report_phase, used to display result from checkers, or summary of other test objectives

- final_phase, used to do last minute operations before existing the simulation

- Why doesn't Verilog tb need phases?

- All of its components made of static containers(modules), so each module will have a set of ports/signals that it utilizes to communicate with other tb components.

- Since a module is static, all modules will be created at the beginning of the simulation.

- Why SystemVerilog testbench require phases?

- With OOP, entities(class objects) can be reused and deployed when required.

- It is possible to create a new object in Xns, we it is possible to call a component that's not initialized.

- In addition, we need synchronization between testbench components.

5. UVM Factory Override

- UVM Factory is a mechanism to improve flexibility and scalability of the tb by allowing the user to substitute an existing class object by any of its inherited child class objects.

- Factory needs to know all types of classes created within the tb via registration.

- Why Override? With the help of the factory, we can override the type of underlying components or objects from the top-level component without having to edit the code.

  - For example, if we want to replace new_driver() with the base_drvier(), all we have to do is to override the base driver by one of the factory override methods, instead of going to code and substitute every single code that mentions base_driver();

- Factory Override Methods

  - set_type_override_by_type()/set_type_override_by_name(), which override all the objects of a particular type.

    - e.g. set factory to override "base_agent" by "child_agent" by type

      - set_type_override_by_type(base_agent::get_type(), child_agent::get_type());

    - e.g. set by name

      - uvm_factory factory = uvm_factory:;get();

      - factory.set_type_override_by_name("base_agent", "child_agent");

  - set_inst_override_by_type()/set_inst_override_by_name(), which override a type within a particular instance

    - When only a few instances of the given type has to be override, we can use instance override by type/name.

- e.g. set factory to override all instances under my_env of type "base_agent" by "child_agent".

    - set_inst_override_by_type("my_env.*", base_agent::get_type(), child_agent::get_type());

- e.g. set by name

    - uvm_factory factory = uvm_factory::get();

    - factory.set_inst_override_by_name("base_agent", "child_agent", {get_full_name(), ".my_env.*"});

6. Stimulus Generation

- Sequences can do operations on sequence items, or initiate new subsequences

    - Execute using the start() method of a sequence

    - Execute sequence items via start_item/finish_item

    - we can also use `uvm_do macro, which will identify if the argument is a sequence or sequnece_item and will call start() or start_item() accordingly.

    - We can set the default sequence to the base sequence in start_of_simulation_phase.