System Verilog Assertion API

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Change Log

Version	Date	Authors	Description
0.1	11/25/2002	João	First draft proposal for incorporating Synopsys assertions API donation into SV framework.
0.2	12/03/2002	João	Updated with comments/suggestions for sv-cc face to face meeting on 12/3/2002. Major changes: API changed to an extension of VPI, making all names consistent with naming scheme, additional static information APIs. Also synch-ed up terminology to current state of sv-ac (eg assertion → property)
0.3	1/8/2003	João	Updated VPI numeric assignments to fit within assigned range for assertions (700-799), minor updates as per last review, added "stepping" API as per discussions with Bassam. Also changed returned expressions from textual representation to vpiHandles to said expressions.
0.4	1/14/2003	João	Updates as per comments during today's (1/14/2003) sv-cc phone conference.

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1 Requirements

To provide an API into the SV assertion capabilities providing sufficient capabilities to:
1. enable user's C code to react to temporal property events
2. enable 3rd party temporal property "waveform" dumping tools to be written
3. enable 3rd party temporal property coverage tools to be written
4. enable 3rd party temporal property debug tools to be written

The interface should also be readily extensible/adaptable so that it can easily be kept in sync with progress made by the sv-ac committee.
In addition, this interface should not unnecessarily duplicate any existing PLI/VPI interfaces.

1.1 Naming conventions[1]

All elements added by this interface will conform to the vpi interface naming conventions:

1. all names will be prefixed by vpi
2. type names will start with "vpi" followed by Capitalized words with no separators, eg vpiAssertCheck
3. all function names will start with "vpi_" followed by all lowercase words separated by '_', eg vpi_get_assert_info()

1.2 Nomenclature

Temporal property: also known as assertions. A declarative expression (1 or more clock cycles) describing the behavior of a system over time.
Directive: a type applied to a temporal expression describing how the results of the temporal expression are to be captured and/or interpreted.
Property clock: the Verilog event expression that indicates to a temporal property when time has advanced (and when HDL signals can be sampled etc)

2 Extensions to VPI enumerations[2]

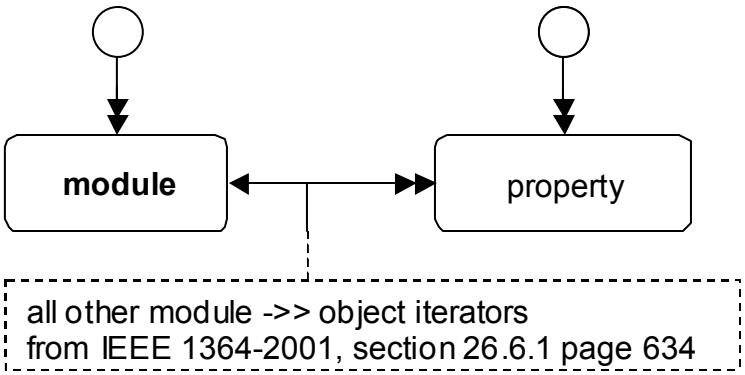
1. Object types (reserve range 700-729 for types & properties):
    1. #define vpiProperty 700 /* temporal property */
2. Object properties
    1. #define vpiAssertProperty 701
    2. #define vpiAssumeProperty 702
    3. #define vpiRestrictProperty 703
    4. #define vpiCoverProperty 704
    5. #define vpiCheckProperty 705 /* inlined behavioral property */
    6. #define vpiPropertyDirective 706 /* method to obtain property directive */
3. Callbacks (reserve range 700-719 for callbacks)
    1. Property related

[1] João comment: these rules are meant to be consistent with the naming conventions used by PLI and VPI interfaces
[2] To be merged to the contents of the "vpi_user.h", described in 1364-2001, Annex G, pages 764-777
The numbers in the range 700-799 will be reserved for the assertion portion of VPI

3 Static Information

3.1 Obtaining assertion handles

Extend the VPI module (actually, instance) iterator model to encompass assertions.



1. Iterate over all properties in the design: use a NULL reference handle (ref) to vpi_iterate()

```
itr = vpi_iterate(vpiProperty, NULL);
while (assertion = vpi_scan(itr)) {
      /* process property */
}
```

5. Iterate over all properties in an instance: pass appropriate instance handle as reference handle to vpi_iterate()

```
itr = vpi_iterate(vpiProperty, instanceHandle);
while (assertion = vpi_scan(itr)) {
      /* process property */
}
```

6. Obtain assertion by name: extend vpi_handle_by_name to also search for assertion names in the appropriate scope(s)

```
vpiHandle = vpi_handle_by_name(assertName, scope)
```

Note that this operation only works for named assertions! Unnamed assertions cannot be found by name.

NOTE: as with all vpi handles, assertion handles are handles to a specific instance of a specific assertion.
NOTE: these iterators will return both temporal properties and immediate non-temporal checks.

3.2 Obtaining static assertion information

The following information about an assertion is considered to be "static":

1. Assertion name
2. Instance in which the assertion occurs
3. Module definition containing the assertion
4. Assertion directive[3]:
    a. assert
    b. check
    c. assume
    d. cover
    e. etc as necessary by assertion updates in sv-ac

[3] Exact directives will have to be adjusted as per developments in the sv-ac committee

5. Assertion source information
   file, line and column where assertion defined
6. Assertion clocking domain/expression[4]

Static information can be obtained directly from an svaAssertID without requiring any assertion attempts to be started or completed.

```
typedef struct t_vpi_source_info {
            PLI_BYTE* *fileName;
            PLI_INT32 startLine;
            PLI_INT32 startColumn;
            PLI_INT32 endLine;
            PLI_INT32 endColumn;
} s_vpi_source_info, *p_vpi_source_info;
typedef struct t_vpi_property_info {
            PLI_BYTE8 *name;     /* name of property */
            vpiHandle instance; /* instance containing property */
            PLI_BYTE8 modname;   /* name of module/interface containing
                                    assertion */

            vpiHandle clock;    /* clocking expression[5] */
            PLI_INT32 directive; /* vpiAssume, … */
            s_vpi_source_info sourceInfo;
} s_vpi_property_info, *p_vpi_property_info;
int vpi_get_property_info(assert_handle, p_vpi_property_info);
```

This call is used to obtain all the static information associated with an temporal property. **Note:** a single call returns all the information for efficiency reasons, as most clients will require most of the data; for efficiency one roundtrip through the API is better than multiple roundtrips. The inputs are a valid handle to a temporal property and a pointer to an existing s_vpi_property_info datastructure. On success the function returns TRUE and the s_vpi_property_info datastructure will be filled in as appropriate. On failure, the function returns FALSE and the contents of the property info datastructure are unpredictable.

NOTE temporal properties can occur in modules or interfaces. Existing VPI has not been extended to encompass interfaces, so if a temporal property occurs inside an interface, the instance handle will be NULL for that temporal property. Once VPI is extended with these concepts, the instance handle will represent a handle to either a module instance or an interface instance.

In addition to the above new VPI function, the following existing VPI functions will also be extended:

vpi_get(), vpi_get_str()

The following vpi properties can be queried from a handle to a temporal property through vpi_get():

1. vpiPropertyDirective
   returns one of vpiAssertProperty .. vpiCheckProperty
2. vpiLineNo
   returns the line number where the property is declared

[4] Specific clocking domain info will have to be adjusted as per developments in the sv-ac committee

[5] The property clock is an event expression supplied as the clocking expression to the temporal property declaration. Thus this is a handle to an arbitrary Verilog event expression

The following vpi properties can be obtained from temporal property handle through vpi_get_str():

1. vpiFileName
   returns the filename of the source file where the property was declared
2. vpiName
   returns the name of the property
3. vpiFullName
   returns the fully qualified name of the property

3.2.1 Additional static information

There are additional items that could be obtained statically from assertion, including:

1. Structure of assertion
2. Set of HDL variables used by assertion
3. Set of HDL expressions used by assertion

No proposal for these items.

4 Dynamic Information

4.1 Placing assertion "system" callbacks

Use vpi_register_cb(), setting the cb_rtn element to the function to be invoked and the reason element of the s_cb_data structure to one of the following:

1. cbPropertySysInitialized
   Occurs after system has initialized. No assertion specific actions can be performed until after this callback occurs. Note that the property system may initialize before or after cbStartOfSimulation
2. cbPropertySysStart
   Assertion system has become active and will begin processing property attempts. Will always occur after cbPropertySysInitialized. Note that by default the property system will be "started" on simulation startup, but it is possible for a user to delay this with the appropriate use of property system control actions.
3. cbPropertySysStop
   Assertion system has been temporarily suspended. While stopped no property attempts will be processed and no property related callbacks will occur. The property system may be stopped and resumed an arbitrary number of times during a single simulation run.
4. cbPropertySysEnd
   Occurs when all assertions have completed and no new attempts will start. Once this callback occurs no more property related callbacks will occur and property related actions will have no further effect. Typically occurs after the end of simulation.
5. cbPropertySysReset
   Occurs when the assertion system is reset, eg due to a system control action

The callback routine invoked follows the normal vpi callback prototype and is passed a s_cb_data containing the callback reason and any user data provided to the vpi_register_cb() call.

4.2 Placing assertions callbacks

Use vpi_register_property_cb()[6], whose prototype is as follows:

```
vpiHandle vpi_register_property_cb(
   vpiHandle,                 /* handle to property */
   PLI_INT32 event,           /* event for which callbacks needed */
   PLI_INT32 (*cb_rtn)(       /* callback function */
       PLI_INT32 event,
       vpiHandle property,
       p_vpi_attempt_info info,
       PLI_BYTE8 *userData),
   PLI_BYTE8 *user_data       /* user data to be supplied to cb */
);
typedef struct t_vpi_property_step_info {
   PLI_INT32 matched_expression_count;
   vpiHandle *matched_exprs;              /* array of expressions */
   p_vpi_source_info *exprs_source_info;  /* array of source info */
   PLI_INT32 stateFrom, stateTo;          /* identify transition */
} s_vpi_property_step_info, *p_vpi_property_step_info;
typedef struct t_vpi_attempt_info {
   union {
      vpiHandle failExpr;
      p_vpi_property_step_info step;
   } detail;
   s_vpi_time attemptTime,
} s_vpi_attempt_info, *p_vpi_attempt_info;
```

Where event is any of the following:

1. cbPropertyStart
   An assertion attempt has started. For most assertions one attempt will start each and every clock tick
2. cbPropertySuccess
   When an assertion attempt reaches a success state
3. cbPropertyFailure
   When an assertion attempt fails to reach a success state
4. cbPropertyStepSucess
   progress of one “thread” along an attempt. Note that by default step callbacks are **not** enabled on any properties. Note also that step callbacks are enabled on a per-property/per-attempt basis, rather than on a per-property basis.
5. cbPropertyStepFailure
   failure to progress along one “thread” along an attempt. Same notes as per cbPropertyStepSuccess
6. cbPropertyDisable
   Whenever the assertion is disabled (eg as a result of a control action)
7. cbPropertyEnable
   Whenever the assertion is enabled
8. cbPropertyReset
   Whenever the assertion is reset

[6] **NOTE** can’t just use vpi_register_cb because the prototype of the callback function is different

9. cbPropertyKill
   When an attempt is killed (eg as a result of a control action)

These callbacks are specific to a given assertion; placing such a callback on one assertion will not cause the callback to trigger on an event occurring on a different assertion. If the callback is successfully placed a handle to the callback will be returned. This handle can be used to remove the callback via vpi_remove_cb(). If there were errors on placing the callback a NULL handle will be returned. As with all other calls, invoking this function with invalid arguments will have unpredictable effects.
Once the callback is placed the user-supplied function will be called each time the specified event occurs on the given property. The callback will continue to be called whenever the event occurs until the callback is removed.
The callback function will be supplied the following arguments:

the event that caused the callback,
the handle for the assertion,
a pointer to an attempt info structure
a reference to the user data supplied when the callback was placed.

The attempt info structure contains details relevant to the specific event that occurred:

a. on disable, enable, reset and kill events the info field absent (a NULL pointer is given as the value of info
b. on start and success events, only the attempt time field is valid
c. on a failure event, the attempt time and detail.failExpr are valid
d. on a step callback, the attempt time and detail.step elements are valid.

On a step callback, the detail describes the set of expressions matched in satisfying a step along the assertion, together with the corresponding source references. In addition the step also identifies source and destination “states” to uniquely identify the path being taken through the assertion. State ids are just integers, with 0 identifying the origin state, 1 identifying an accepting state, and any other number representing some intermediate point in the assertion. It is possible for the number of expressions in a step to be 0, in which case this represents an unconditional transition. In the case of a failing transition, the information provided is just as for a successful transition, but the last expression in the array will represent the expression at which the transition failed. Note that in a failing transition there will always be at least one element in the expression array.
Note that placing a step callback will result in the same callback function being invoked for both success and failure steps.

5 Control Functions

5.1 Assertion System control

Use vpi_control(), with one of the following operators and no other arguments:

1. vpiPropertySysReset
   discard all attempts in progress for all assertions and restore the entire assertion system to its initial state.
2. vpiPropertySysStop
   consider all attempts in progress as unterminated and disable any further assertions from being started.

3. vpiPropertySysStart
   restart the property system after it was stopped (eg due to vpiPropertySysStop). Once started, attempts will resume on all properties.
4. vpiPropertySysEnd
   discard all attempts in progress and disable any further assertions from starting.

5.2 Assertion control

Use vpi_control() with one of the following operators:

1. For all the following, the second argument must be a valid property handle.
   a. vpiPropertyReset
      discards all current attempts in progress for this assertion and resets this assertion to its initial state
   b. vpiPropertyDisable
      disables the starting of any new attempts for this assertion. Has no effect on any existing attempts. No effect if assertion already disabled. Note that by default all assertions are enabled.
   c. vpiPropertyEnable
      Enables starting new attempts for this assertion. No effect if assertion already enabled. No effect on any existing attempts.
2. For all the following, the second argument must be a valid property handle and the third argument must be an attempt start time (as a pointer to a correctly initialized s_vpi_time structure)
   a. vpiPropertyKill
      Discards the given attempts but leaves assertion enabled and does not reset any state used by this assertion (eg past() sampling)
   b. vpiPropertyDisableStep
      Disables step callbacks for this assertion. No effect if stepping not enabled or already disabled
3. For the following, the second argument must be a valid property handle, the third argument must be an attempt start time (as a pointer to a correctly initialized s_vpi_time structure) and the fourth argument must be a "step control" constant. **Note** that in this release, the only step control constant available is vpiPropertyClockSteps, indicating callbacks on a per assertion/clock-tick basis[7].
   a. vpiPropertyEnableStep
      Enables step callbacks to occur for this property attempt. Note that by default stepping is disabled for all assertions. This call has no effect if stepping already enabled for this property+attempt, other than possibly changing the stepping mode for the attempt iff the attempt has not occurred yet. The stepping mode of any particular attempt cannot be modified after the assertion attempt in question has started.

[7] The property clock is the event expression supplied as the clocking expression to the temporal property declaration. The property will "advance" whenever this event occurs, and when stepping is enabled such events will also cause step callbacks to occur.