



Unified Coverage Data Base (UCDB) API Reference

Software Version 10.1

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Chapter 1

Introduction

UCDB API is an application programming interface for the Unified Coverage Database included in the Questa SV/AFV and ModelSim SE products. The UCDB and its API are completely independent of Questa and ModelSim, however UCDBs are easily created with these tools. In this document, the term *Questa* refers to both the Questa and the ModelSim SE systems.

Questa software uses the UCDB API for saving, reading, reporting on and merging UCDB format databases. The Questa GUI features are based on the UCDB API as are the command-line interface features in the *coverage view mode*:

```
shell prompt> vsim -viewcov ucdb_file
```

Questa UCDB format databases are created with the *coverage save* command and UCDBs can be externally processed with the *vcover* commands (see the Questa User Guide and Reference manuals). For simple tasks such as generating a coverage report or merging coverage data, use the corresponding Questa tool features. Use the UCDB API for more complex tasks such as:

- Importing data into a UCDB or Questa database from another source.
- Exporting data to a database that has a format not supported by Questa (for example, an SQL database or a graphing package).
- Analyzing coverage data in a way not supported by any tool.
- Loading coverage data into a UCDB from a VPI application linked with Questa (that will be saved by Questa).

UCDBs can be read from, and written to, using the C-based UCDB API. A UCDB can be created with the API; data can be added to an existing UCDB; and a UCDB can be traversed and analyzed with the read API. The UCDB API library supports both memory efficient modes (read/write streaming modes) and a fully-populated data model (in-memory mode).

The UCDB API library is in *mti_install_dir/questasim/platform/libucdb.a* (UNIX) and *ucdb.lib* (Windows). The annotated header file is *mti_install_dir/questasim/include/ucdb.h*. Examples illustrating how to compile various UCDB API applications are in *mti_install_dir/questasim/examples/ucdb*.

Terminology

- Child — node that is a descendant of another, where “decent” means nesting in a design hierarchy, in a coverage hierarchy or as a subset of data categorized with the parent.
- Coverage scope — scope that represents a coverage grouping of some kind.
- Coveritem — leaf node in a UCDB (i.e., a node not capable of having child nodes) used to store a coverage count.
- Design hierarchy — part of the UCDB data model representing the design, testbench, and coverage.
- Design unit — scope that represents a Verilog (or SystemVerilog) module or a VHDL entity-architecture.
- Design unit list — set of all design units in a UCDB.
- History node — generalized test data record that captures information about the database merges and test plan imports used to create the UCDB.
- Instance — scope that represents a component instance (for example, a module instantiation) in the design hierarchy.
- Node — general term for a scope or coveritem.
- Parent — ancestor node (of a child), which represents a higher level of design hierarchy, a higher level of coverage hierarchy or a grouping.
- Scope — hierarchical object in a UCDB (i.e., a node capable of having child nodes).
- Tag — name associated with a scope—typically used to link test plan scopes with instance, coverage, or design unit scopes—similar to a user-defined attribute with a name but not a value.
- Test plan hierarchy — data model structure (whose nodes are linked to coverage, instance or design unit data structures) used to analyze coverage in the context of a test plan.
- Test plan scope (or test plan section) — scope that represents part of a test plan.
- Test data record — data model structure that stores information about the test and the tool from which the UCDB was created.
- User-defined attribute — name-value pair (explicitly added by the user) that is not part of the UCDB primary data model.

Chapter 2

UCDB Basics

The UCDB is a general-purpose database for storing verification data. Most of this is of a coverage nature, therefore the name “Unified Coverage Database”. But the UCDB can store more types of data:

- Code coverage data — statement, branch, expression, condition, toggle, and FSM.
- Functional coverage data — from SystemVerilog covergroups, and SVA or PSL “cover” statements.
- Assertion data — from SVA or PSL “assert” statements.
- History data — information about any number of test runs, merges, or imports that produced data in the UCDB.
- User-defined data.
- Design hierarchy — so that coverage and assertion data appear in the proper design or testbench context.
- Design units — needed to represent design hierarchy fully; these can correspond to Verilog modules or VHDL entity/architecture pairs.
- Test plan hierarchy — so that coverage items can be related to a test plan, and verification data can be analyzed in terms of the test plan rather than in isolation.

UCDB Data Hierarchy

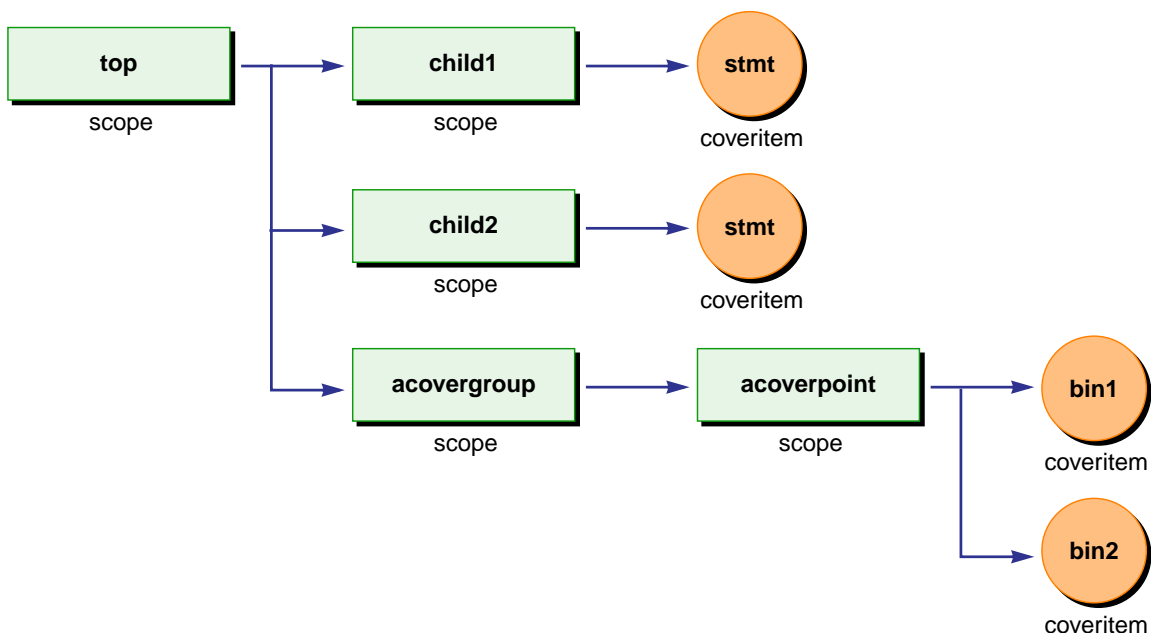
Scopes and Coveritems

Designs and testbenches are hierarchically organized. Design units (Verilog modules or VHDL entity/architectures) can be hierarchical, though they are not always. Test plans can be hierarchical. Even coverage data (of which the SystemVerilog covergroup is the best example) can be hierarchical. Therefore, the UCDB needs some general way to store hierarchical structures.

The UCDB has *scopes* (also referred to as *hierarchical nodes*), which store hierarchical structures (i.e., elements of a database that can have children). Coverage data and assertion data are stored as *counters*, which indicate how many times something happened in the design. For example, they count how many times a sequence completed, how many times a bin incremented or how many times a statement executed.. In UCDB terminology, these types of counters and some associated data are called *coveritems*. These counters are database *leaf nodes*, which cannot have children.

Tree models of hierarchical organization are central to the UCDB. [Figure 2-1](#) is an illustration of a simple hierarchy.

Figure 2-1. Basic Design/Coverage Hierarchy



Design Unit Scopes

For representing an HDL design, a simple hierarchy as shown above is not sufficient. For example, take this SystemVerilog code that corresponds to the tree in [Figure 2-1](#):

```
module top;
  int i;
  covergroup acovergroup;
    acoverpoint: coverpoint i {
      bins bin1 = { 0 };
      bins bin2 = { 1 };
    }
  endgroup
  acovergroup acovervar = new;
  submodule child1();
  submodule child2();
endmodule
module submodule;
  initial $display("hello from %m");
endmodule
```

The scopes *top*, *child1*, and *child2* represent the module instances of this design hierarchy. The design units (SystemVerilog modules) need to be represented also.

In a UCDB created by Questa with code coverage, there will be code coverage associated with the design unit. This is the *union* of code coverage from the instances of the design unit. This is calculated by the kernel, and because it is available immediately from the kernel, it is stored directly in the UCDB. This requires that the UCDB store another scope to correspond to the design unit.

Questa also stores source file information with the design unit. (This is not a requirement of a UCDB, but happens to be the case when one is created from Questa.)

From each module instance scope, its corresponding design unit may be accessed; in fact, the design unit must exist prior to creating the instance.

UCDB Scope Types

Because the UCDB needs to distinguish between module instances, design units, and even other scopes like those for covergroups and coverpoints, the UCDB has a *scope type* associated with every scope. This scope type is the C type *ucdbScopeTypeT*.

Scope types are in these categories (found in the *ucdb.h*):

- HDL scope — these are the basic building blocks of the design hierarchy, or named scopes (in the true HDL sense, rather than the UCDB sense) in the design.
- Design unit scope — these must be provided for those HDL scopes which have corresponding design units.

- Cover scope — these are used to introduce hierarchy in coverage objects, essentially to group them together.
- Group scope — these are used to maintain bus structures for supporting part selects and supporting a general bus data model.
- Test plan scope — a scope to represent part of a test plan hierarchy; this is unique because it can only have children that are other test plan scopes.

These relationships must exist between HDL scopes *that are instances* of a given design unit scope:

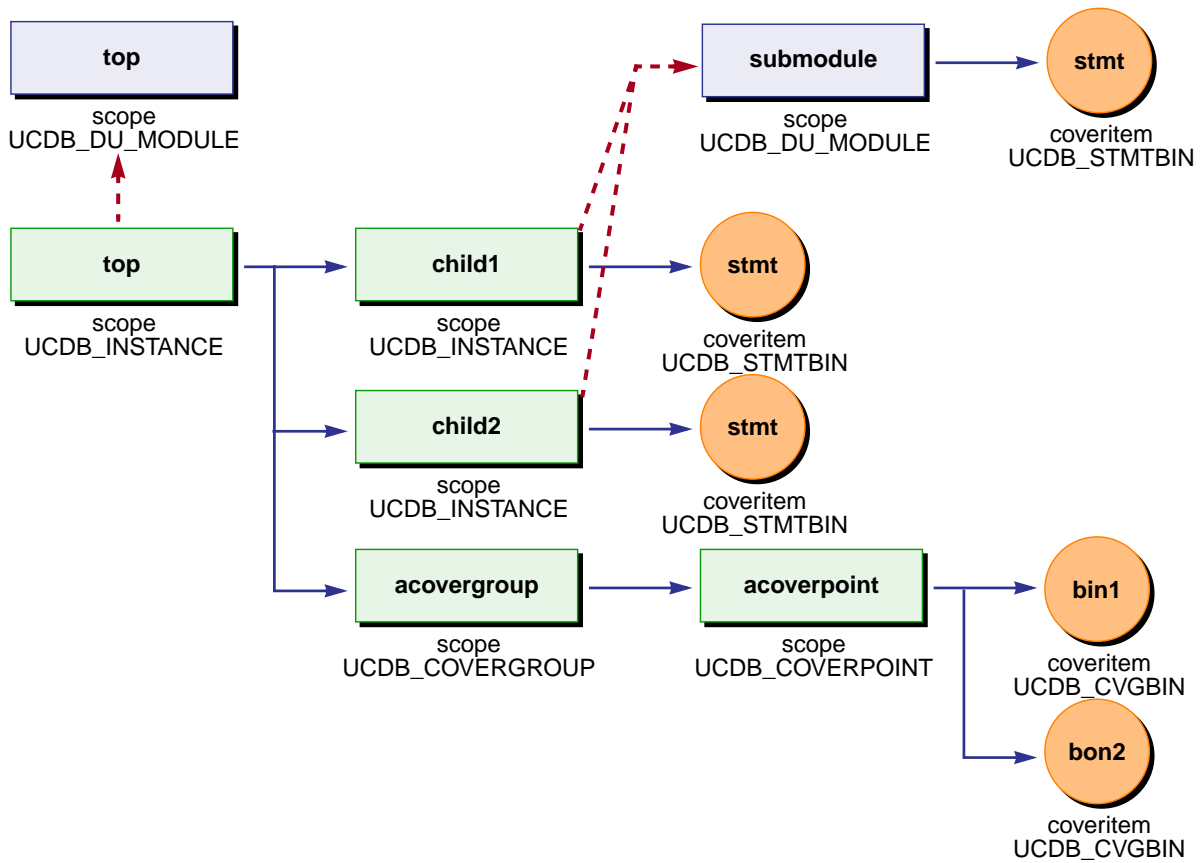
- UCDB_INSTANCE has a corresponding UCDB_DU_MODULE or UCDB_DU_ARCH scope as its design unit.
- UCDB_PROGRAM has a corresponding UCDB_DU_PROGRAM scope as its design unit.
- UCDB_PACKAGE has a corresponding UCDB_DU_PACKAGE scope as its design unit. Note that, though VHDL and SystemVerilog do not have actual instances of packages in the language, tools like Questa do represent a package twice: the UCDB_PACKAGE corresponds to the top-level node in the instance tree, and UCDB_DU_PACKAGE to the definition of the package.
- UCDB_INTERFACE has a corresponding UCDB_DU_INTERFACE scope as its design unit.

Figure 2-2 revisits the hierarchy of Figure 2-1 and shows how design unit scopes exist to represent the SystemVerilog code given above. The `ucdbScopeTypeT` values for the scopes are given, as well as coveritem types which have not yet been discussed. Links from the HDL scopes to the design unit scopes are indicated as red dashed lines.

Note that the design unit scopes (UCDB_DU_MODULE in this case) have no special relationships among them; they are not really part of design hierarchy, though they represent a crucial part of the design.

In this example, the statement coverage coveritem (UCDB_STMTBIN) exists in both module instances (/top/child1 and top/child2) as well as the design unit scope (submodule). This shows one of the uses of the design unit scope: not only does it allow us to determine that child1 and child2 are instances of the same module, but any design-unit-wide data can reside “inside” the design unit scope.

Figure 2-2. Design/Coverage Hierarchy with Design Units



UCDB Data Models

The UCDB API is a very general one that creates certain objects – such as scopes, coveritems, test data records – with certain names, types, and attributes. This allows creation of many different potential data models.

The data models are important because they capture assumptions about how Questa creates a UCDB data structure for a given kind of coverage. Other tools might be able to read and make sense of different data structures, but Questa will not.

This is only to say that the UCDB API itself is more general than Questa: many different kinds of coverage hierarchies could be created through the API, but only a small subset of those will be valid input to Questa.

Over time, the Questa assumptions will be refined and fewer assumptions made. This document sets out to describe the minimum set of assumptions so that a UCDB can be read by Questa.

Code Coverage Roll-Ups in Design Units and Instances

In releases prior to 6.4, Questa created code coverage underneath both design units and instances. The coverage under the design unit was the union of coverage under all instances. This was done primarily to make coverage analysis by design unit faster.

From 6.4 onward, the code coverage roll-up – as it is called, the aggregation of design-unit-based coverage from instances of those design units – is done implicitly (or “on-the-fly”) when the database is loaded into memory. However, when accessed using *read streaming mode*, the nature of the storage cannot be hidden, since read streaming mode reflects exactly what is laid out on disk. In that case, coverage never appears underneath design units.

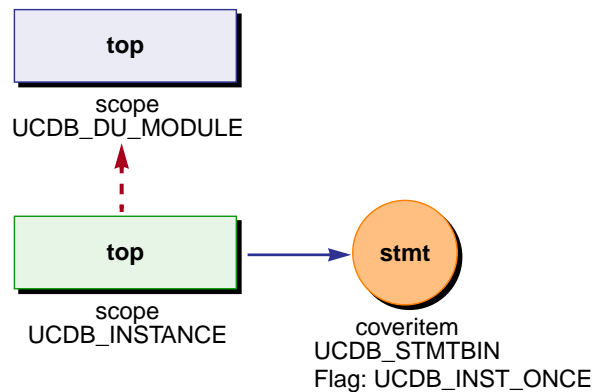
In releases prior to 6.4, the design unit roll-up was skipped (not stored) when there was only a single instance of the design unit – because in that case, the roll-up would be identical to the instance. This was an optimization, though one that is necessarily exposed to the user in read streaming mode.

Statement Coverage

Statement coverage data is created simply as a coveritem, with no hierarchy.

Verilog Example (“statement”):

```
module top;
  initial $display("hello world");
endmodule
```

Figure 2-3. Data Model for Verilog Statements

Note how in [Figure 2-3](#) the statement bin does not appear with the design unit also; this is because of the UCDB_INST_ONCE optimization described in the section [Design Units](#).

Statement Coverage with Generates

Verilog Example (“statement-generate”):

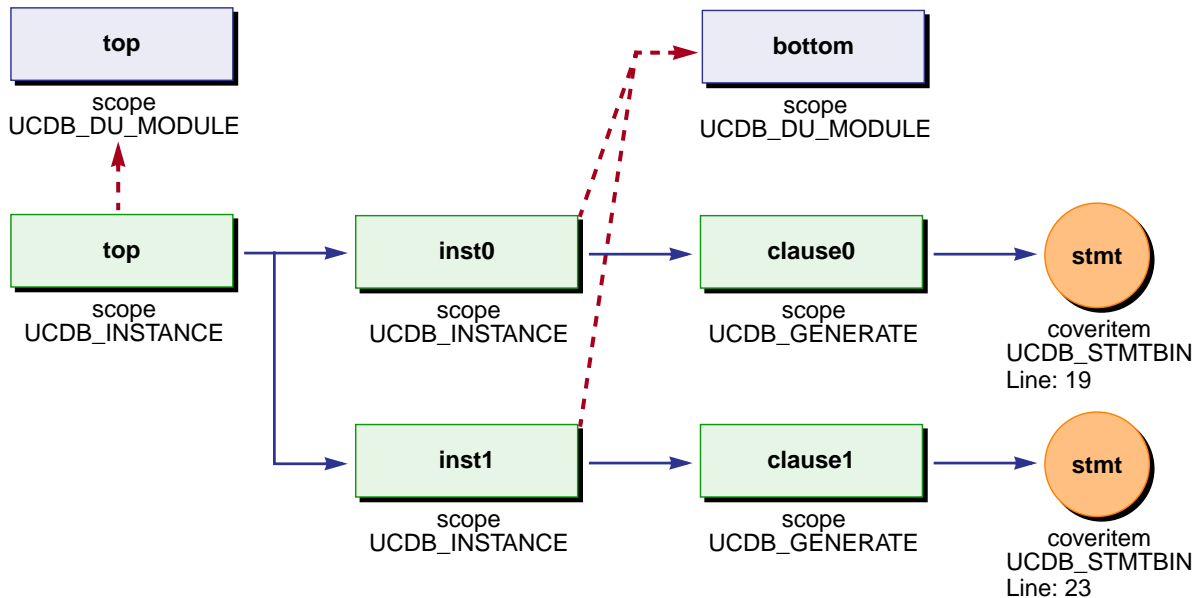
```
module top;
  bottom #0 inst0();
  bottom #1 inst1();
endmodule
module bottom;
  parameter clause = 0;
  if (clause == 0)
  begin: clause0
    initial $display("hello from %m");
  end
  else
  begin: clause1
    initial $display ("hello from %m");
  end
endmodule
```

There are a number of interesting things to note here:

- UCDB_GENERATE scopes are created for the generate blocks. These must be created even if the generate block does not have a name generated by the user (the “begin: label” constructs in the example). Having different generate blocks for different scopes would handle the case of the for-generate where different blocks correspond to the same line of source.
- The statements appear inside the generate scopes as well as the design unit scopes. In [Figure 2-4](#), the line number associated with the statement is shown to distinguish between the two statements.
- While the code coverage from generate blocks could be merged into the instance – for example, having another set of merged statement coveritems as children of the

UCDB_INSTANCE scopes in this example – that is not a requirement of the data model. Questa does this aggregation on the fly, so never stores any redundant data with the instances themselves. (Yes, this philosophy is inconsistent with design units, where redundant data *is* stored.)

Figure 2-4. Data Model for Verilog Statements in Generate Blocks



Branch Coverage

Branch coverage falls into 3 special cases:

1. Verilog if-else — in which case a single UCDB_BRANCH scope has 2 coveritems, one each for the if and else branches.
2. VHDL if-elsif-else — in which case there are as many coveritems as the if-cascade has clauses.
3. Verilog and VHDL case statements — in which case there is one coveritem per value in the case statement.

Additionally, branch coverage has extra information in the scope:

- BCOUNT attribute — total number of times the test was executed. This is useful if the branch does not have an “else” clause.
- BTYPE attribute — to distinguish between branch and if-else
- BHASELSE attribute — to distinguish between if-else branches having an else and those which do not.

Branch Coverage of Verilog if-else

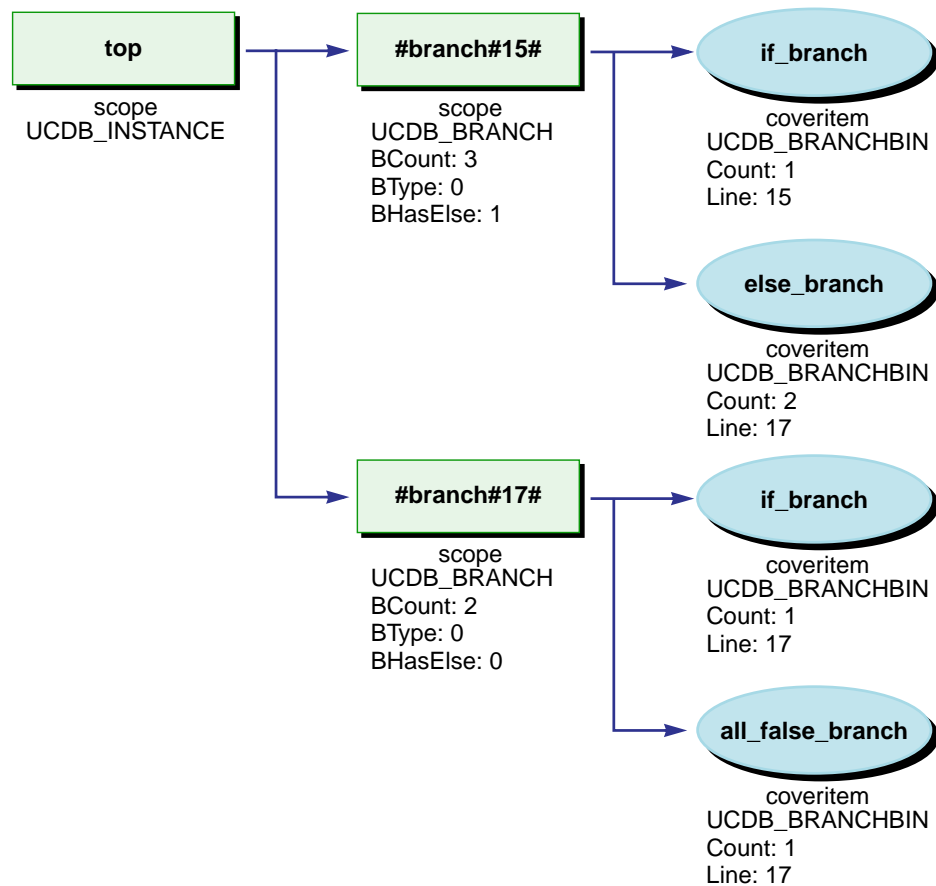
SystemVerilog Example (“branch-vlog-if”):

```
module top;
    bit x = 0;
    bit y = 0;
    always @(x or y) begin
        if (x)
            $display("x is true");
        else if (y)
            $display("y is true");
    end
    initial begin
        #1; x = 1;
        #1; x = 0;
        #1; y = 1;
    end
endmodule
```

In [Figure 2-5](#), the design unit is omitted. This is the first data model drawing where coverage counts are indicated. Some data is redundant, but this describes the basic components of the data model:

- UCDB_BRANCH scopes are named according to type of coverage and line number. (Note: in Questa 6.3, these scopes are named “dummy_coverage_scope”, the naming according to line number is new to 6.4.)
- BCOUNT is the sum of if and else counts (even if the “else” is lacking, as in the line 7 branch.)
- BTYPE is 0 for these cases to indicate an “if” as opposed to a “case” statement.
- BHASELSE is 0 for the line 7 branch to indicate that it does not have an else clause.
- “if_branch” is the coveritem name for the true clause of the branch.
- “else_branch” is the coveritem name for the false clause of the branch if it has an explicit “else”.
- “all_false_branch” is the coveritem name for the missing else.

Figure 2-5. Data Model for a Verilog if-else-if



Branch Coverage of VHDL if-elsif-else

VHDL Example (“branch-vhdl-if”):

```

library IEEE;
use IEEE.STD_LOGIC_1164.all;
use std.textio.all;
entity top is end;
architecture arch of top is
  signal x : std_logic := '0';
  signal y: std_logic := '0';
  begin
    branch: process
      variable myoutput : line;
    begin
      wait until x'event or y'event;
      if (x = '1') then
        write(myoutput,string'("x is true"));
        writeline(output,myoutput);
      elsif (y = '1') then
        write(myoutput,string'("y is true"));
        writeline(output,myoutput);
      end if;
    end process branch;
  end

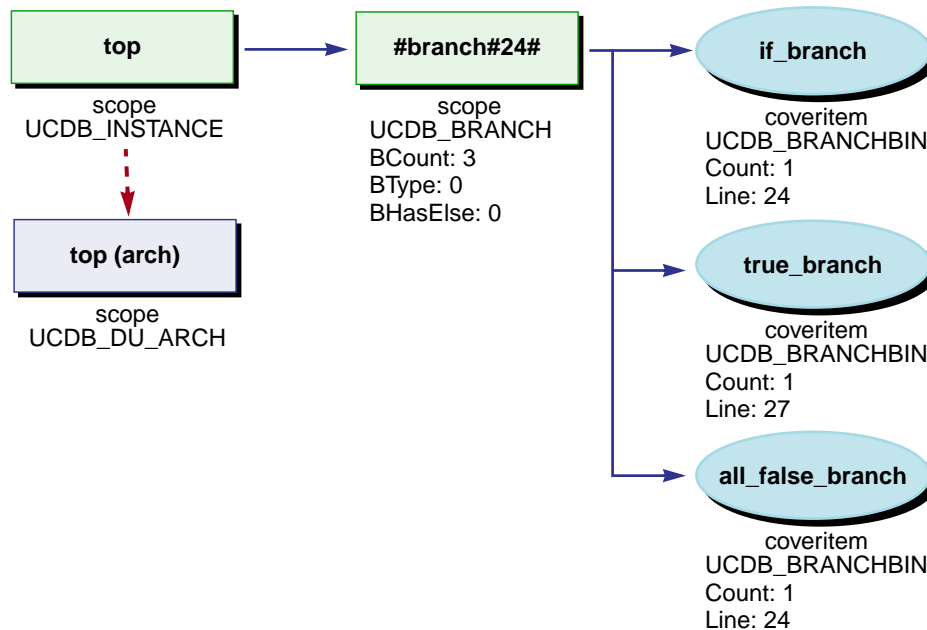
```

```

drive: process
begin
    wait for 10 ns;
    x <= '1';
    wait for 10 ns;
    x <= '0';
    wait for 10 ns;
    y <= '1';
    wait;
end process drive;
end architecture;

```

Figure 2-6. Data Model for a VHDL if-elsif



This is the VHDL branch to correspond to the previous Verilog one. In this case, the design unit is shown to illustrate the difference between VHDL and Verilog design units: the scope type is different, and the architecture name follows the entity name in parenthesis. (These diagrams omit the work library name, which varies depending how the module or architecture was compiled. Technically that is part of the design unit name in the UCDB, too.)

The most obvious difference is that there is a single UCDB_BRANCH scope rather than multiple ones. This is because VHDL has the “elsif” syntax that allows a branch to have multiple paths rather than just 2 paths. Some things are in common:

- The first branch coveritem is called “if_branch”.
- The last coveritem is called “all_false_branch” if there is no explicit “else”.
- If there were an explicit “else”, the last coveritem would be called “else_branch”.
- The attributes with the UCDB_BRANCH scope carry the same meanings.

And some things are different:

- Coveritems to correspond to “elsif” branches are called “true_branch”.
- The UCDB_BRANCH scope may have arbitrarily many coveritem children to correspond to all the “elsif” branches in the VHDL if construct.

Case Statements

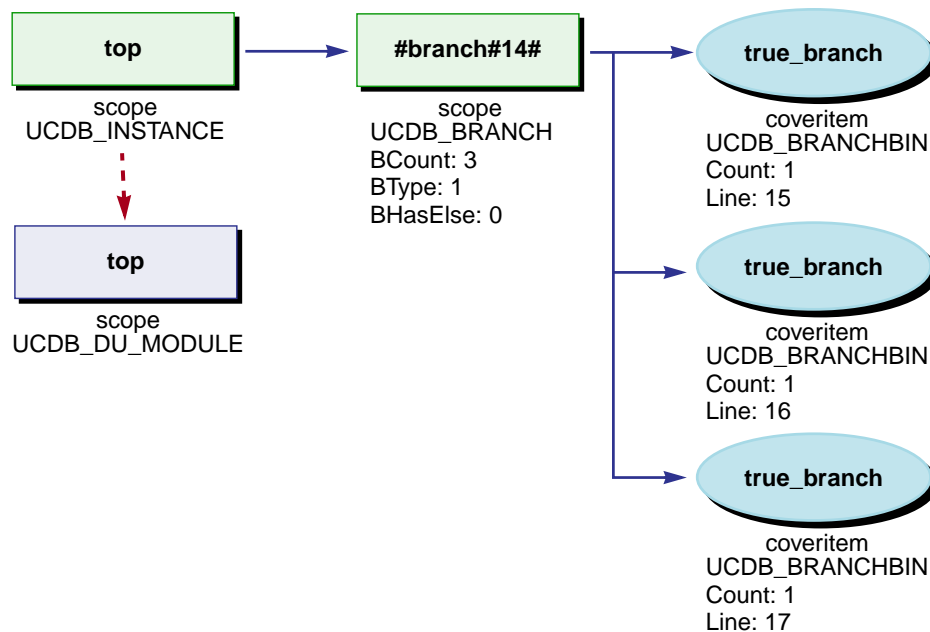
SystemVerilog Example (“branch-case”):

```
module top;
  int x = 0;
  always @(x)
    case (x)
      1:          $display("x is 1");
      2:          $display("x is 2");
      default:    $display("x is neither 1 nor 2");
    endcase
  initial begin
    #1; x = 1;
    #1; x = 2;
    #1; x = 3;
  end
endmodule
```

This is very similar to the if-elsif construct. The key difference is that the “BTYPE” attribute has value 1, and that all the coveritems are named “true_branch”.

Note how there is no way in the data model to distinguish between the explicit values in the case statement and the default value. (There are differences in the line numbers stored with the coveritems, so the difference could be determined from source if available.)

Figure 2-7. Data Model for a case Statement



Expression and Condition Coverage

Expression coverage is defined to be the truth table coverage for an expression used to drive a continuous assignment. *Condition coverage* is defined to be the truth table coverage for an expression in a branch.

SystemVerilog Example (“expr-cond”):

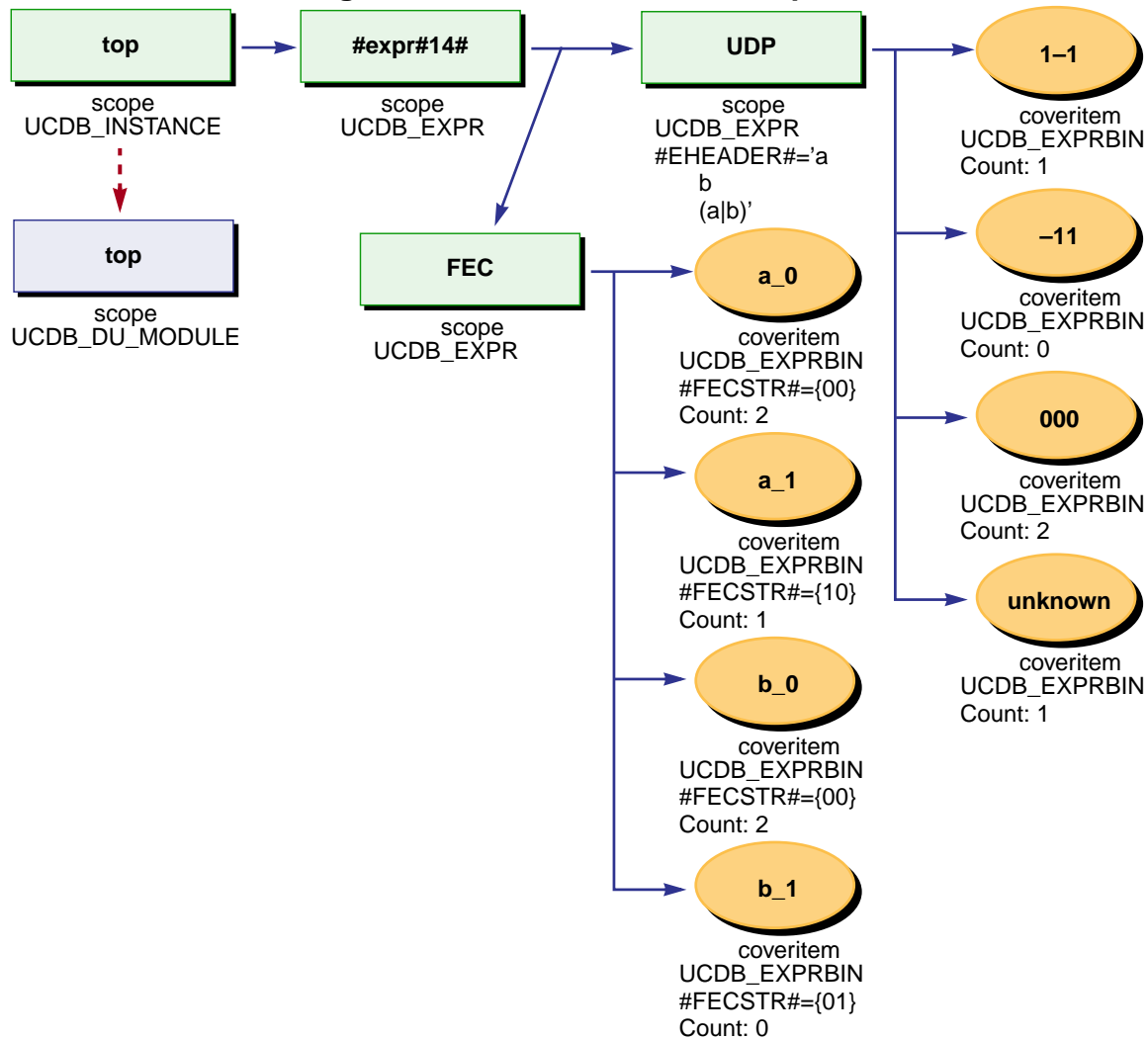
```

module top;
  logic a = 0;
  logic b = 0;
  assign c = (a|b);
  always @(c)
    if (a || b)
      $display("a or b");
  initial begin
    #1; a = 1;
    #1; a = 0;
    #1; a = 1'bx;
  end
endmodule

```

Note the example is configured by default for expression coverage only. It can be configured for either expression coverage, condition coverage, or both. Expression coverage is for line 14; condition coverage is for line 16.

Figure 2-8. Data Model for an Expression



The data model for expression/condition coverage is split into two styles, each represented simultaneously by default. (There is a way to turn off FEC-style coverage, with the `-nocoverfec` switch to `vopt`, for example.) The UDP-style coverage is underneath the node named “UDP”. UDP stands for “user-defined primitive” which really means “truth table.” Verilog UDPs use a truth table syntax in their specification and the names of the UDP-style coverage bins are similar to Verilog UDP row specifications.

FEC-style coverage is also a truth-table-based coverage, but of a different kind of truth table. FEC stands for “focused expression coverage”. While a UDP-style truth table is somewhat arbitrarily generated to have a minimal number of rows, the FEC-style truth table considers each input independently, where each row in the truth table corresponds to a change in a particular input, where that input affects the output. Complete coverage in FEC guarantees that each input changed. FEC is also sometimes called MCDC (modified condition decision coverage).

If this test case were configured for condition coverage instead, the differences would be:

- UCDB_COND scope type instead of UCDB_EXPR.
- UCDB_CONDBIN coveritem type instead of UCDB_EXPRBIN.
- EHEADER would be the same except for the last line: “(a || b)”.
- Difference in line numbers, of course.
- Difference in the coverage enabled flags in the design unit: see more on design units, below.

UDP-Style Expression and Condition Coverage

Probably the easiest illustration of how the “UDP” sub-tree data model corresponds to UDP-style expression coverage is to show the report generated by Questa:

```

Line      4 Stmt      1      assign c = (a|b);
Expression totals: 2 hits of 3 rows = 66.7%
Truth Table:
              a
              |b
      hits   ||(a | b)
Row   1:      1 1-1
Row   2:    ***0*** -11
Row   3:      2 000
unknown:      1

```

The columns of the truth table are stored with the EHEADER attribute with the expression scope. This is a newline-separated string. The coveritem names correspond literally to the rows of the truth table: “1-1”, “-11”, “000”, and “unknown”. Note that the “unknown” coveritem does not contribute to coverage; its presence is necessary for the report only.

FEC-Style Expression Condition Coverage

The *FEC* sub-tree data model is likewise explained by the Focused Expression View portion of the report:

```

Line      14 Item      1      assign c = (a|b);
Expression totals: 3 hits of 4 rows = 75.0%
  Rows:      hits      Fec Targets      Matching input patterns
-----
Row   1:      2      a_0      { 00 }
Row   2:      1      a_1      { 10 }
Row   3:      2      b_0      { 00 }
Row   4:    ***0***      b_1      { 01 }

```

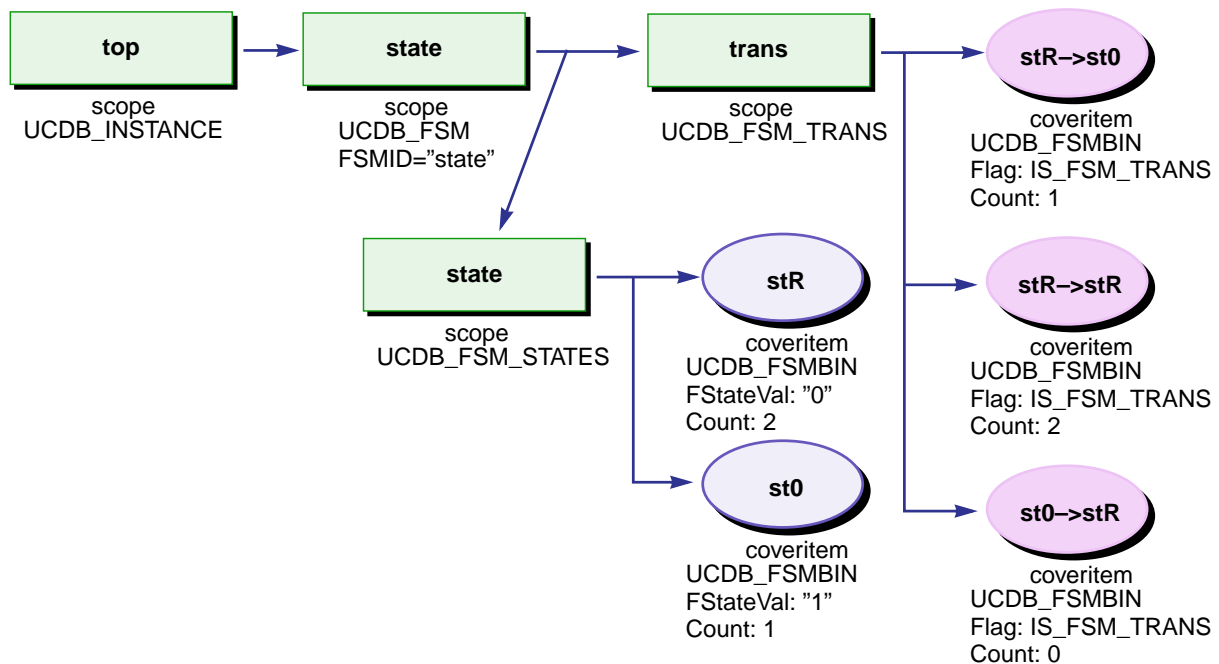
This is very similar to the UDP style data model, except that the bin names are “Fec Targets” – meaning, the specific input transition represented by the row. With the “-fecanalysis” option, the report shows matching input patterns, which are associated as the attribute “#FECSTR#” with each bin.

Finite State Machine (FSM) Coverage

SystemVerilog Example (“fsm”):

```
module top;
  bit clk = 0;
  bit i = 0;
  bit reset = 1;
  enum { stR, st0 } state;
  always @(posedge clk or posedge reset)
  begin
    if (reset)
      state = stR;
    else
      case(state)
        stR: if (i==0) state = st0;
      endcase
  end
  always #10 clk = ~clk;
  always @(state) $display(state);
  initial begin
    $display(state);
    @(negedge clk);
    @(negedge clk) reset = 0;
    @(negedge clk);
    $stop;
  end
endmodule
```

Figure 2-9. Data Model for a Finite State Machine



The finite state machine is represented as a two-level hierarchy of coverage scopes: the topmost one for the state machine itself (whose “FSMID” is identified as an attribute) and two child scopes: one for states and one for transitions. These are distinguished by name and scope type. The state machine scope itself (of type UCDB_FSM) is identified by the name of the state variable if possible – note this does mean that it can take the same name as a toggle coverage scope for exactly the same variable in HDL source. Refer to [Toggle Coverage](#) for more information.

The state coveritems are named according to the state name. An integer form of the state name is held in the attribute FSTATEVAL and used in the report.

The transition coveritems are named according to the transition. The flag IS_FSM_TRAN is used to distinguish a coveritem of type UCDB_FSMBIN when it is an FSM transition bin.

Toggle Coverage

There are six basic types of toggle coverage:

- Integer toggles (VHDL only with Questa) — some unique number of integer values are maintained up to a configurable tool limit (with Questa.) The toggle is covered if the toggle is assigned any value.

Note



In Questa, Verilog or SystemVerilog integer types are broken into constituent bits, so become net or register toggles.

- Enum toggles — The toggle is covered if all the enum values have been assigned.
- Register toggles, 2 transition — Covered if toggled from 0->1 and 1->0.
- Net toggles, 2 transition — Covered if toggled from 0->1 and 1->0. Net (or wire) toggles must be reported without redundancy: in other words, connected nets are reported only once, by the top-most or canonical name. This checking for redundancy is sometimes called “unaliasing” because two connected nets in different levels of hierarchy are really aliases of each other. The top-most net is usually considered to have the canonical name for all connected nets.
- Extended register toggles, with 6 transitions — Adds Z transitions. Covered if it toggles from 1->0 and 0->1 without any z transitions, otherwise it must show all transitions: 0->1, 1->0, 0->Z, Z->0, 1->Z, and Z->1.
- Extended net toggles, with 6 transitions — Adds Z transitions, with coverage rules similar to register toggles. Unaliasing or elimination of redundancy among connected nets also occurs.

VHDL Integer Toggles

VHDL example (“toggle-int”):

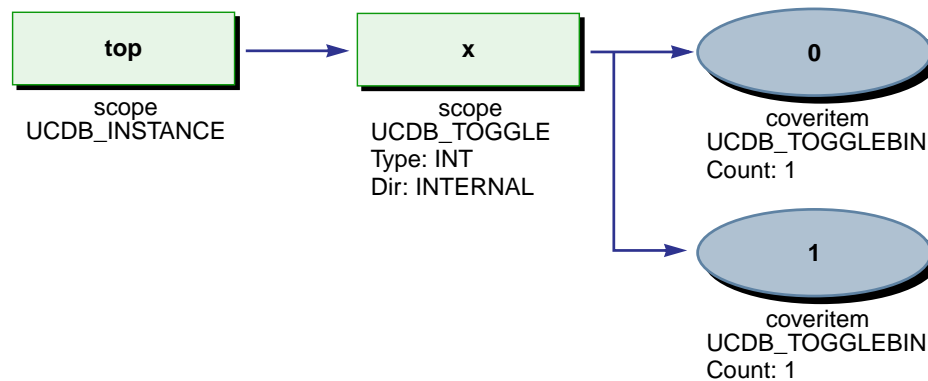
```
library IEEE;
use IEEE.STD_LOGIC_1164.all;
use std.textio.all;
entity top is
end;
architecture arch of top is
    signal x : integer := 0;
    begin
        branch: process
            variable myoutput : line;
        begin
            wait until x'event;
            write(myoutput,x);
            writeline(output,myoutput);
        end process branch;
        drive: process
        begin
            wait for 10 ns;
            x <= 1;
            wait;
        end process drive;
    end architecture;
```

The UCDB_TOGGLE scope is named the same as the variable or signal being covered; if it were also a finite state machine variable, the name would thus appear twice in the database.

The scope has specific information relevant to toggles, two fields of which are visible in [Figure 2-10](#):

- **Type** — These types are the ucdbToggleTypeT enum values that correspond to the six types of toggles.
- **Dir (Direction)** — The ucdbToggleDirT enum values: INTERNAL, IN, OUT, and INOUT. These are used by the report software to restrict the subset of toggles being reported upon.
- **Canonical Name** — The canonical name of the toggle node if it is a wire and is not the top-most node. This is not shown in the example because it is NULL.

Figure 2-10. Data Model for a VHDL Integer Toggle



The integer toggle has bins for both of the values it assumes: “0” and “1”. The bins are named according to the integer value of the signal.

Note

If there were no data changes (no events) on the integer signal, there would be no bins for the toggle scope in the UCDB. However, because the default integer value is counted as a bin value, it is not possible to have only one bin for the integer toggle; it has at least the default value plus some set of other values to which it was assigned (up to a configurable tool limit with the **ToggleMaxIntValues** variable in the *modelsim.ini* file.)

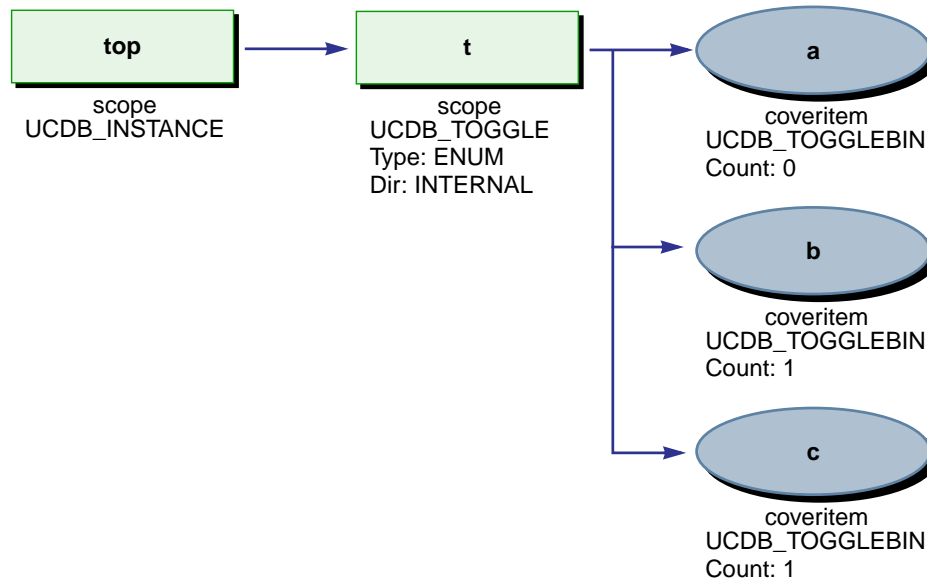
Enum Toggles

SystemVerilog Example (“toggle-enum”):

```
module top;
  enum { a, b, c } t = a;
  initial begin
    #1; t = c;
    #1; t = b;
  end
endmodule
```

This is very similar to the [VHDL Integer Toggles](#), except with the toggle type equal to ENUM. The coveritems are named according to enum values. In this case, the default value is explicitly not covered, to distinguish between an explicit and implicit assignment to that value. In this particular simulation, “b” and “c” are covered while “a” is not, so the toggle “/top/t” itself is uncovered.

Figure 2-11. Data Model for an Enum Toggle



Extended Register Toggle

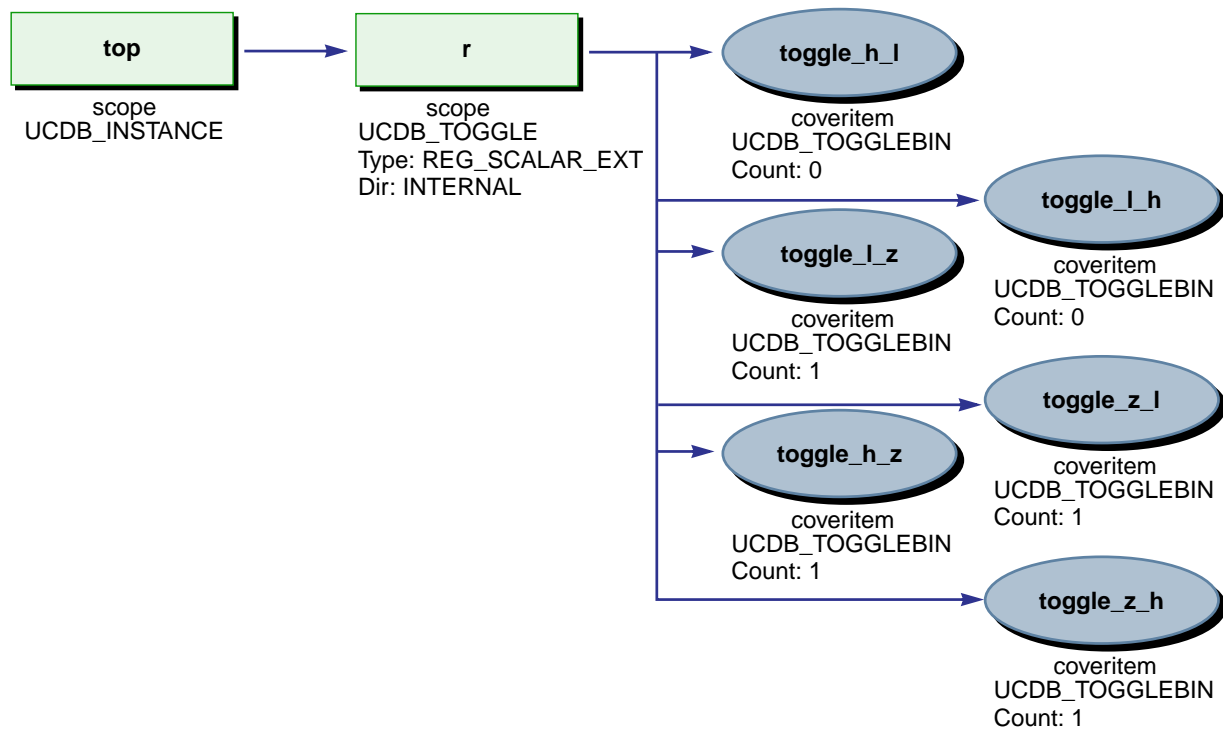
This shows an example of the extended (6-transition) toggle for a register only. Extended toggle coverage can be used for nets, too, but this document will not illustrate it; the data structure will be identical except for the toggle type.

SystemVerilog Example (“toggle-reg-ext”):

```

module top;
  logic r = 1'bx;
  initial begin
    #1; r = 1'b0;
    #1; r = 1'b1;
    #1; r = 1'bz;
    #1; r = 1'b0;
    #1; r = 1'b1;
    #1; r = 1'b0;
  end
endmodule
  
```

The type of the toggle scope shows that this is a register extended toggle. The 6 bins are named according to the possible transitions among 0, 1, and z. If this were a 2-transition toggle, it would be covered based on “toggle_h_l” and “toggle_l_h” bins. However, since it has some z transitions with non-zero count, it would have to have all bins with non-zero count in order for the “/top/r” register toggle to be covered.

Figure 2-12. Data Model for an Extended Register Toggle

Net Toggle with Connected Net

Note that this example – because of its contrived and trivial nature – requires turning off the optimizer in Questa to allow the “bottom” module to survive elaboration.

SystemVerilog Example (“toggle-net”):

```

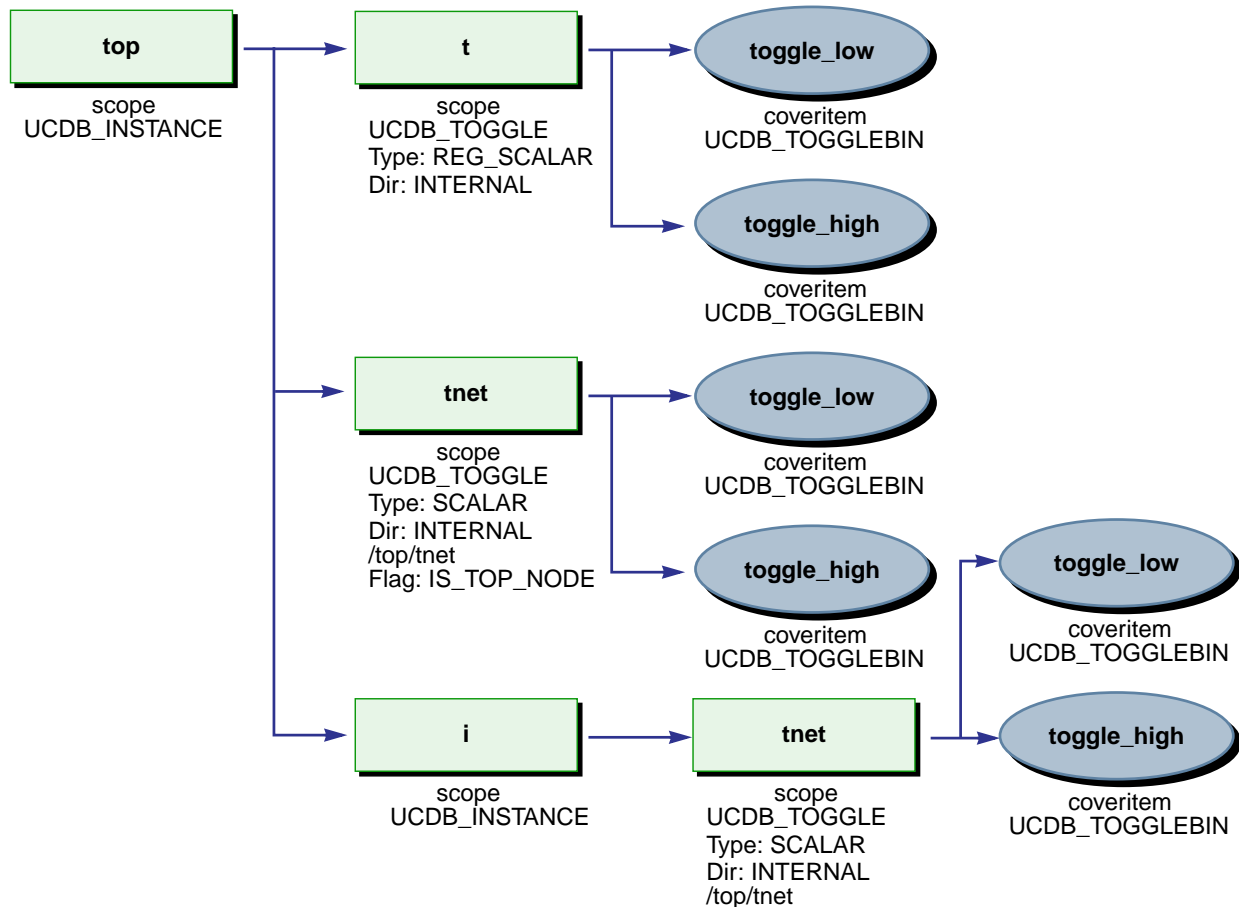
module top;
  bit t = 0;
  wire tnet;
  assign tnet = t;
  initial begin
    #1; t = 1;
    #1; t = 0;
  end
  end
  bottom i(tnet);
endmodule
module bottom(input wire tnet);
  always @(tnet)
    $display(tnet);
endmodule

```

Since the UCDB does not represent connectivity, it must indicate the connectedness of two nets (“tnet” in this example) in a different way. These two data attributes are used:

- The top node has a flag – UCDB_IS_TOP_NODE – set for the toggle scope. This is useful when traversing the entire database to restrict the report or other analysis to top-level (canonical) nodes only. However, it does not suffice for analyzing a subset of the database. Note that hierarchical references as well as port connections can create connected nets.
- The canonical name is stored for all net toggles. This is accessed with the `ucdb_GetToggleInfo()` function, which also returns toggle type and toggle direction. Note in this example how `/top/tnet` and `/top/i/tnet` both have the same canonical name: “/top/tnet”.

Figure 2-13. Data Model for a Connected Net Toggle



Groups

SystemVerilog Example (“top/outer_struct.nested_struct.multiD_array[1][5][3]”):

```
module top;

    typedef struct {
        reg[0:4] multiD_array [1:0] [2:5];
        bit simple_struct_elem_b;
        bit simple_struct_elem_c;
    } ST1;

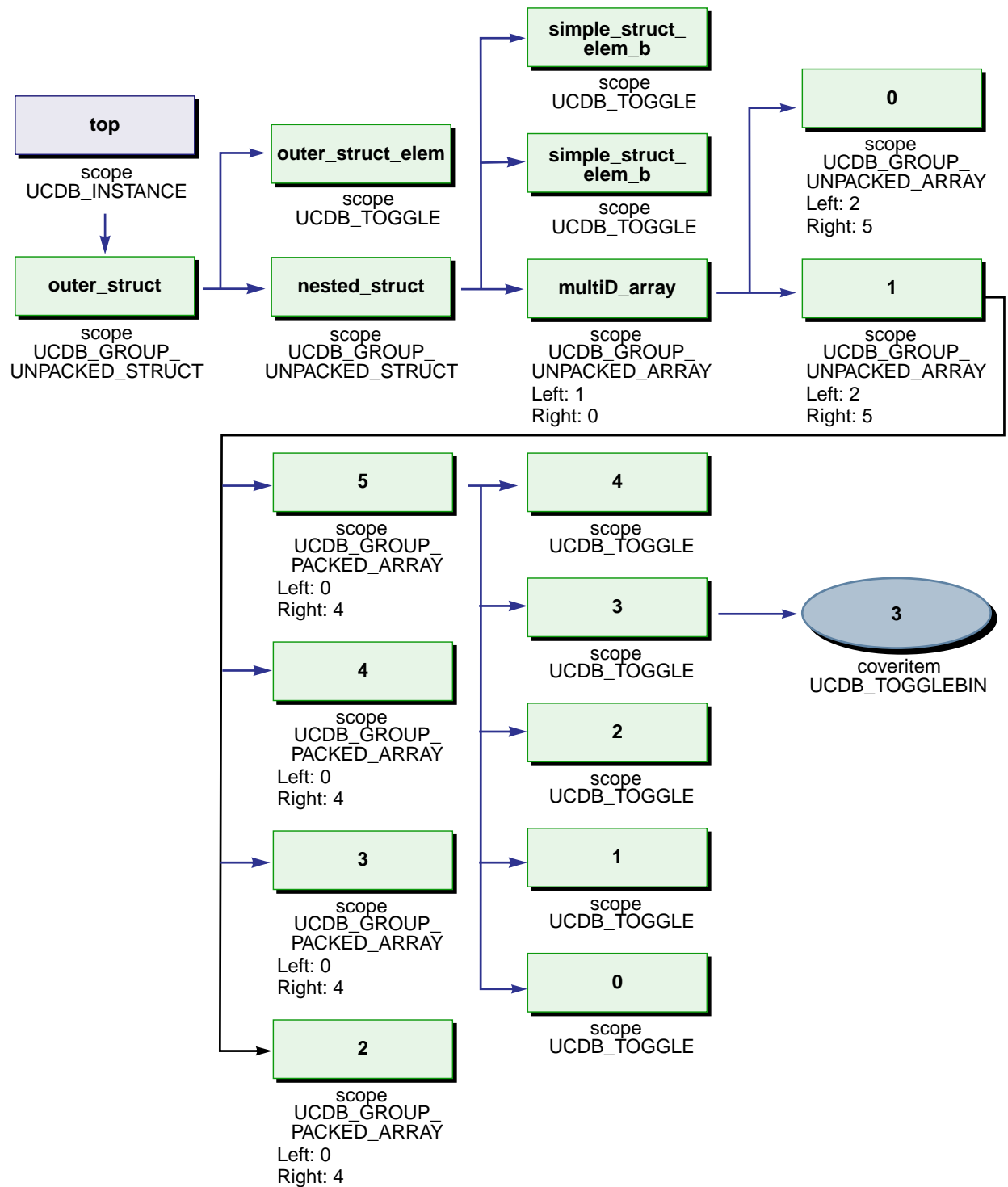
    typedef struct {
        bit outer_struct_elem;
        ST1 nested_struct;
    } ST2;

    ST2 outer_struct;

    initial begin
        outer_struct.nested_struct.multiD_array[1][5][3]= 1'b0;
    end

endmodule
```

Figure 2-14. Data Model for a Group



SVA and PSL Covers

Cover directives in PSL or cover statements in SystemVerilog Assertions language are exactly the same in Questa. (Both are referred to as “cover directives” in Questa.)

SystemVerilog Example (“cover”):

```
module top;
  bit a = 0, b = 0, clk = 0;
  always #10 clk = ~clk;
  initial begin
    @(negedge clk);      b = 1;
    @(negedge clk); a = 1; b = 0;
    @(negedge clk); a = 0;
    @(negedge clk); $stop;
  end
  // psl default clock = rose(clk);
  // psl pslcover: cover {b;a};
  sequence a_after_b;
    @(posedge clk) b ##1 a;
  endsequence
  svacover: cover property(a_after_b);
endmodule
```

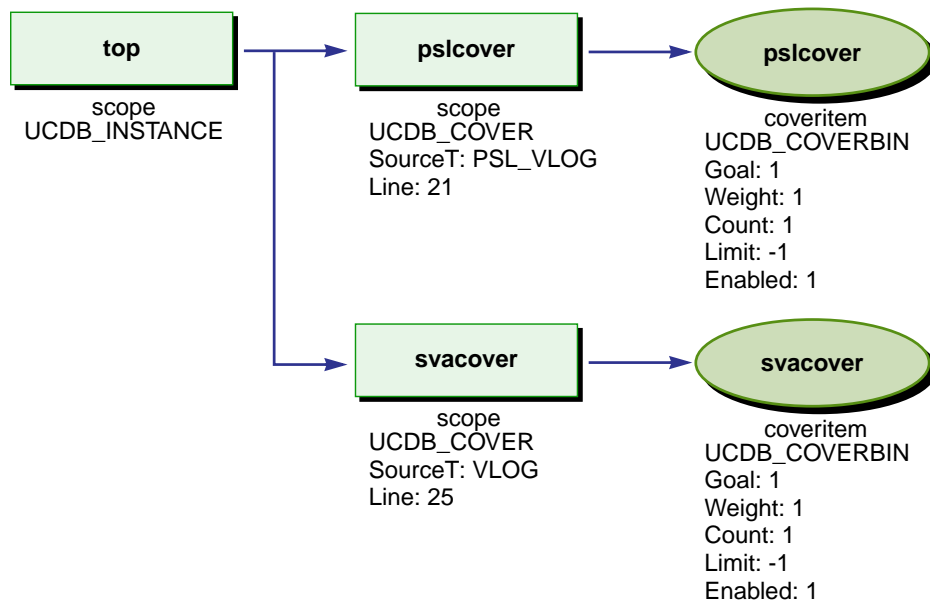
Except for name, the two cover directives are identical. The differences are:

- Line number — accessed with source information.
- Scope source type (accessed with `ucdb_GetScopeSourceType()`) — PSL_VLOG for the Verilog PSL, VLOG for the native SVA cover. The value PSL_VHDL is used for VHDL PSL.

There are additional data – accessed with `ucdb_GetCoverData()` – available for cover directives:

- Goal — A tool feature in Questa, the “at_least” value for a cover directive, set with the `fcover` configure command.
- Weight — An individual weight for this cover directive, another tool feature. The weight is set at the coveritem level as well as the UCDB_COVER scope level.
- Limit — Questa has a tool feature for disabling a cover after reaching a certain count. If -1, this is unlimited.
- Enabled — Questa has a tool feature for disabling a cover directive. This feature is disabled when the *enabled* bit is set to FALSE.
- Count — The pass count for the cover directive. In the future multiple counts may be maintained. Failure counts are implied in the SystemVerilog LRM for sequences; vacuous passes and attempts for properties. These have not yet been implemented in Questa.

Figure 2-15. Data Model for SVA and PSL Cover Directives



Assertion Data

Assertions have different counts maintained in different circumstances. There are three cases:

- The immediate or concurrent assertion with a fail count only.
- The concurrent assertion with a full complement of 7 counts (assert debug mode).
- The immediate assertion with both fail count and pass count (assert debug mode).

Assertions with Fail Counts Only

Example, compiled by default with optimizations (“assert”):

```

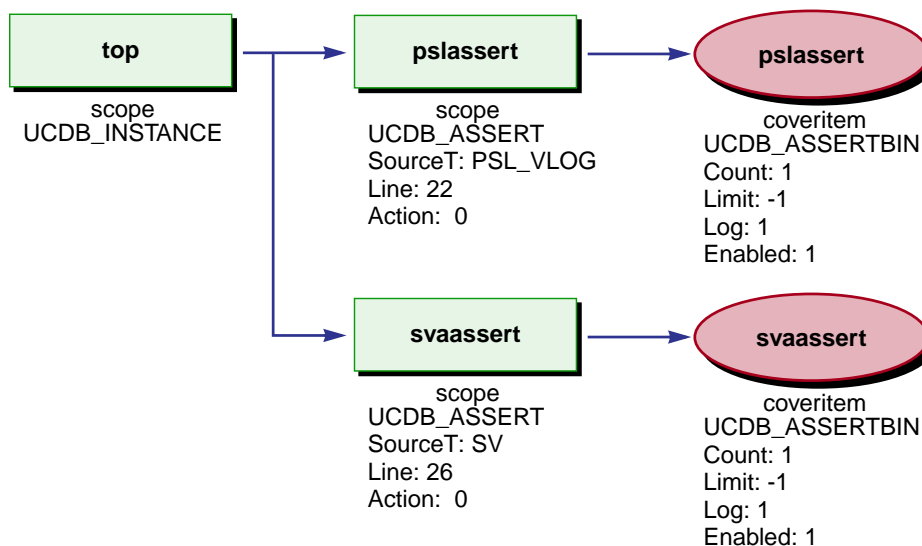
module top;
  bit a = 0, b = 0, clk = 0;
  always #10 clk = ~clk;
  initial begin
    @(negedge clk);      b = 1;
    @(negedge clk); a = 1; b = 0;
    @(negedge clk); a = 0; b = 1;
    @(negedge clk);      b = 0;
    @(negedge clk); $stop;
  end
  // psl default clock = rose(clk);
  // psl pslassert: assert always {b} | => {a};
  property a_after_b;
    @(posedge clk) b | => a;
  endproperty
  svaassert: assert property(a_after_b);
endmodule
  
```

The UCDB_ASSERTBIN is the fail count for the assertion. Other aspects of the data model include:

- The “ACTION” attribute on the UCDB_ASSERT scope. This is an integer attribute whose values indicate how the simulator should react to an assertion failure:
 - 0 — continue after failure.
 - 1 — break after failure.
 - 2 — exit after failure
- Log (the flag UCDB_LOG_ON) — this is a bit to indicate that the assertion failure messages appear in the simulator transcript.

Other aspects of the data model are in common with the cover directives.

Figure 2-16. Data Model for Assertions (with Fail Count Only)



Assertion with All Counts Using -assertdebug

This requires both the -assertdebug option and full visibility for all assertions. The example is compiled with -assertdebug -novopt to turn off the optimizer completely, but the -voptargs="+acc=a" flag could be used instead or could be used selectively to enable visibility for some regions and not others.

SystemVerilog Example (“assert-debug”):

```

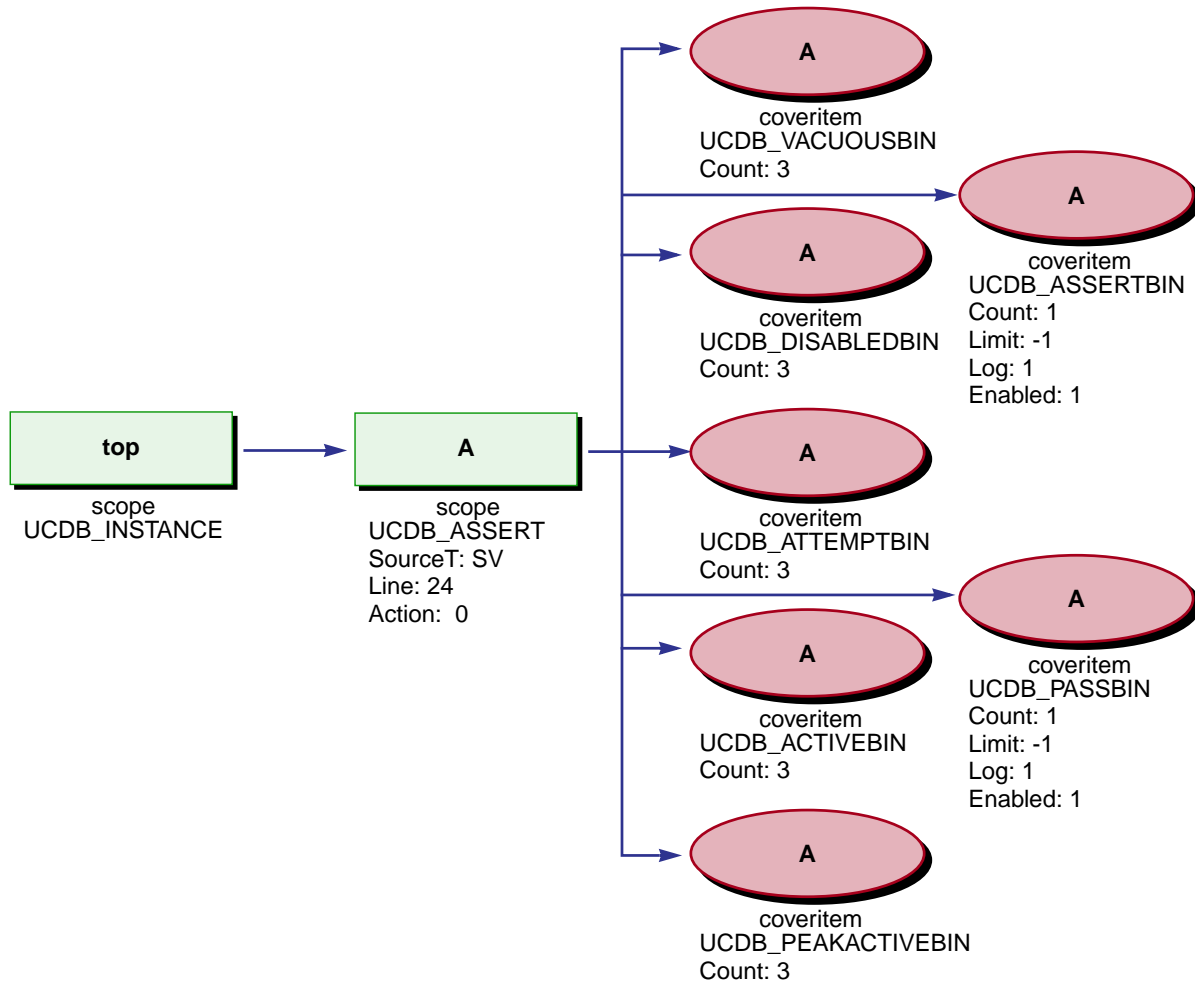
module top;
  bit a = 0, b = 0, clk = 0;
  always #10 clk = ~clk;
  initial begin
    @(negedge clk);      b = 1;
    @(negedge clk);      a = 1; b = 0;
    @(negedge clk);      a = 0; b = 1;
  end
endmodule
  
```

```

    @(negedge clk);      b = 0;
    @(negedge clk); $stop;
end
property a_after_b;
    @(posedge clk) b | => a;
endproperty
A: assert property(a_after_b);
endmodule

```

Figure 2-17. Data Model for an Assertion (with All Counts)



This currently represents 7 bins with the following meanings:

- **ASSERTBIN** — The assertion failure count. Has data values for limit, log, etc., as previously discussed.
- **PASSBIN** — The assertion non-vacuous pass (success) count. Similar to the ASSERTBIN in which flags and data fields it offers. This is useful to determine if an assertion has been fully exercised during simulation. Coverage metrics derived from an assertion use this metric if available.

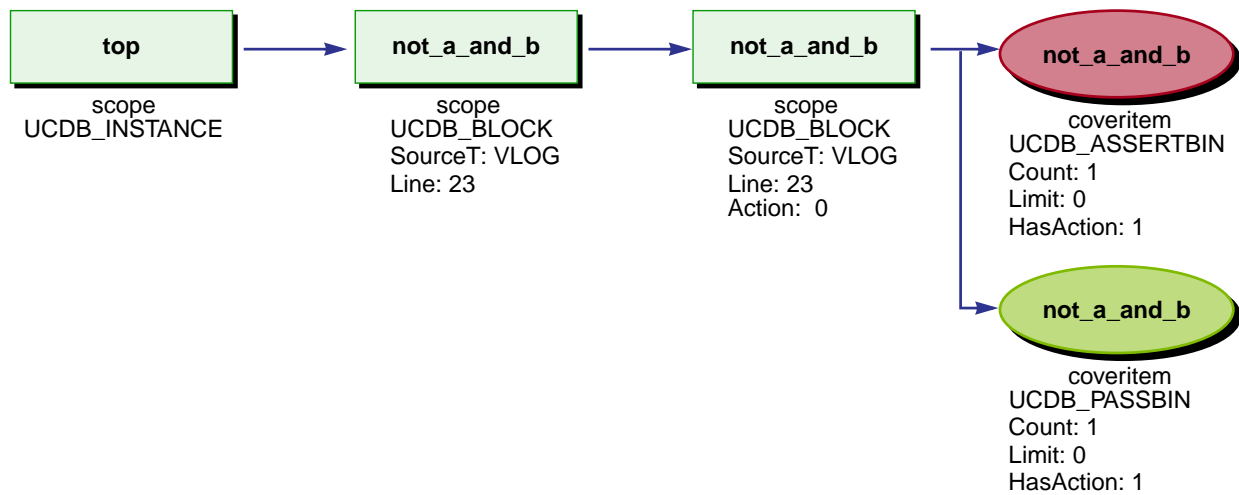
- **VACUOUSBIN** — The vacuous pass (success) count. This is for implications whose left-hand-side is false.
- **DISABLEDBIN** — Counts the number of cycles for which the assertion was explicitly disabled through the SystemVerilog “disable iff” construct. This is essentially the number of attempts missed because the assertion was disabled.
- **ATTEMPTBIN** — The number of times the assertion was attempted: the number of times its clocking expression triggered.
- **ACTIVEBIN** — The number of threads left active (in-progress) at the end of simulation for this assertion.
- **PEAKACTIVEBIN** — The maximum number of threads ever created for this assertion at any given point in time.

Immediate Assert with Pass/Fail

Example, compiled with -assertdebug and without the optimizer (“immed-assert”):

```
module top;
  bit a = 0, b = 0, clk = 0;
  always #10 clk = ~clk;
  initial begin
    @(negedge clk);      b = 1;
    @(negedge clk); a = 1; b = 0;
    @(negedge clk); a = 1; b = 1;
    @(negedge clk);      b = 0;
    @(negedge clk); $stop;
  end
  end
  always @(posedge clk)
    not_a_and_b: assert (!(a && b)) else $error("a and b both true!");
endmodule
```

Figure 2-18. Data Model for an Immediate Assertion with Pass/Fail Counts



SystemVerilog Covergroup Coverage

Covergroup with a Cross

SystemVerilog example (“covergroup”):

```
module top;
  int a = 0, b = 0;
  covergroup cg;
    type_option.comment = "Example";
    option.at_least = 2;
    cvpa: coverpoint a { bins a = { 0 }; }
    cvpb: coverpoint b { bins b = { 1 }; }
    axb: cross cvpa, cvpb { type_option.weight = 2; }
  endgroup
  cg cv = new;
  initial begin
    #1; a = 0; b = 1; cv.sample();
    #1; a = 1; b = 1; cv.sample();
    #1; $display($get_coverage());
  end
endmodule
```

The covergroup type roll-up is part of the subtree rooted at the “cg” (UCDB_COVERGROUP) node – specifically, the subtree containing the UCDB_COVERPOINT and UCDB_CROSS children. The covergroup instance is the subtree rooted at the UCDB_COVERINSTANCE node. It is a mirror of the type subtree.

Note



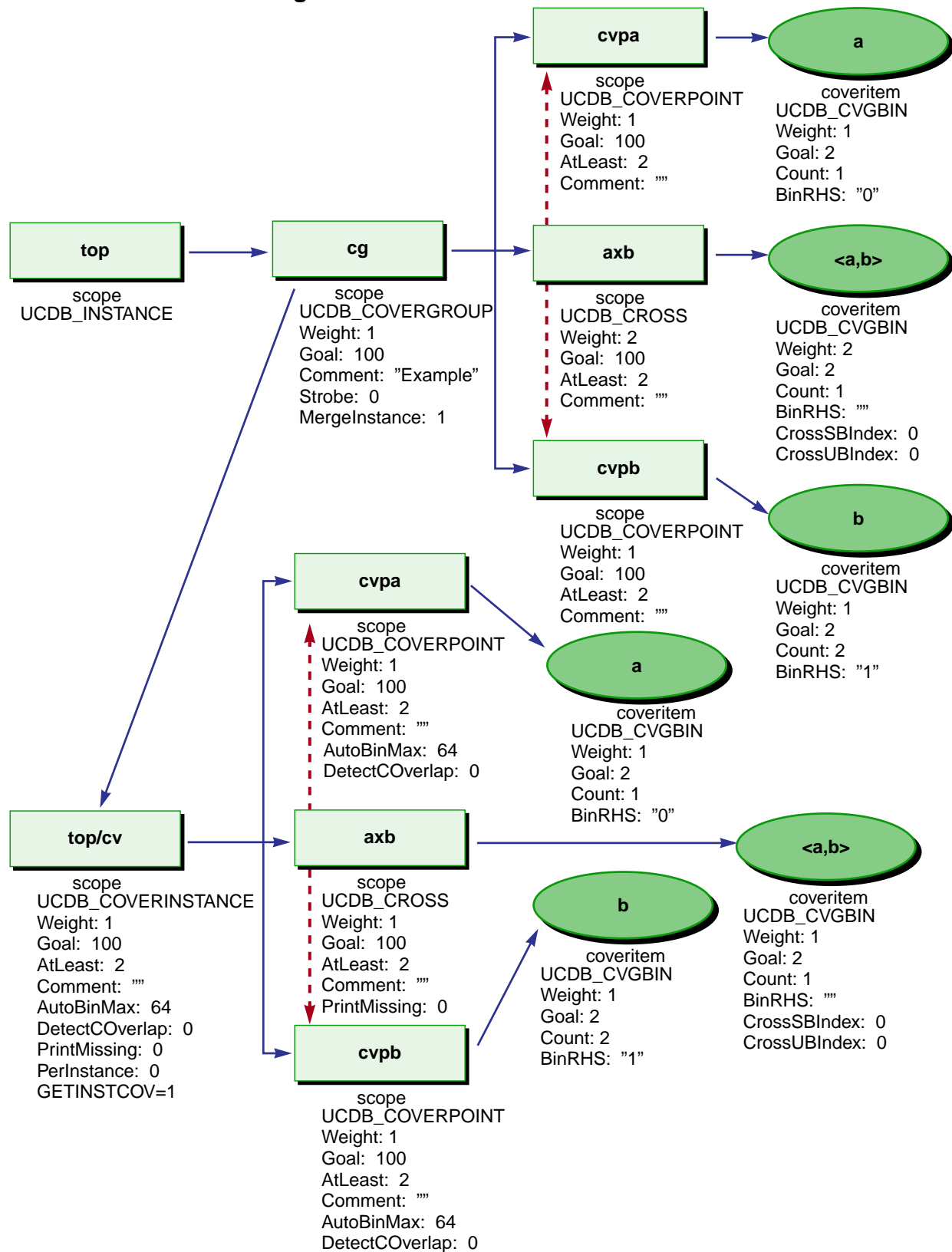
When there are multiple instances, the number of coverpoint and cross children must be the same among all instances, but the numbers of bins can be different.

In this case, it is true, the instance data is largely redundant, but since `option.per_instance` is effectively ignored by Questa, the instance data serves the purpose of storing instance-specific options and is also used when the data is reloaded with `$load_coverage_db()`.

Some interesting things to note here are:

- Weight is a primary data component of a UCDB scope – accessed with `ucdb_GetScopeWeight()`. Note how the cross weight is reflected in the weight for the *axb* cross scope. It is also reflected in the weight associated with the coveritem itself, (but this is less useful).
- The goal for the scope – `ucdb_GetScopeGoal()` – is the goal established by the covergroup `type_option.goal` or `option.goal`. In this example, all scopes – covergroup, coverinstance, coverpoint, and cross – have a default of 100. This is a percentage. The attribute name is “#GOAL#” to adhere to a convention whereby attributes with “#” in the name do not appear in the command-line and graphical user interface.

Figure 2-19. Data Model for a Cross



- Goal associated with the coveritem is really the “at_least” value for the covergroup. This allows a simple algorithm for determining if a coveritem is covered: if its count is greater than or equal to its goal.
- Other attributes reflect the type_option or option values associated with the covergroup, coverpoint or cross:
 - COMMENT — for the type_option.comment in all scopes in the type subtree, or the option.comment in all scopes in the instance subtree.
 - STROBE — for the type_option.strobe for the covergroup scope.
 - AUTOBINMAX — for the option.auto_bin_max in covergroup and coverpoint scopes.
 - DETECTOVERLAP — for the option.detect_overlap in covergroup and coverpoint scopes.
 - PRINTMISSING — for the option.cross_num_print_missing in covergroup and cross scopes.
 - GETINSTCOV — for the option.get_inst_cov.
- There are some additional attributes used for internal purposes:
 - BINRHS — the set of sampled values that could potentially cause the bin to increment. These are referred to as the “bin right-hand-side values” because they are derived from the right-hand-side of the “=” declaration for the bin. Note that BINRHS is not set for the cross bin because the bin depends only on the coverpoint bins, which are referenced as part of the bin name (“<a,b>”) in this case. If the cross bin were explicitly declared (with the cross select expression syntax), then there would be a meaningful BINRHS attribute for the cross bin.
 - CROSSBINIDX and CROSSUBINIDX — these are used to implement the SystemVerilog call \$load_coverage_db(). In this example the values are not very interesting. The section [Sparse Cross Bin Representation](#) explains them in more detail.
- There is an association between the cross and its component coverpoints, indicated by the red dashed lines in [Figure 2-12](#). These associations are accessed with the following functions:
 - ucdb_GetNumCrossedCvps()
 - ucdb_GetIthCrossedCvp()
 - ucdb_GetIthCrossedCvpName()

Sparse Cross Bin Representation

If you create a UCDB with Questa, you will see that only cross bins with non-zero coverage counts are in the database. This was an optimization introduced to make saving crosses more efficient.

Unfortunately, much of this infrastructure relies on a private API. (If you are a customer and you'd like to use it, please request it.) The software will still accept UCDBs with fully enumerated crosses, i.e., all cross bins stored explicitly in the database, and there is a trick for allowing the API to traverse all bins whether they are stored or not. So to some degree the sparse implementation is optional.

The trick to allow the API to traverse all bins, whether stored or not, is to use this function:

```
void
ucdb_SetIterateAllCrossAutoBins(
    ucdbT db,
    int yesno);
```

If this is called as `ucdb_SetIterateAllCrossAutoBins(db,1)`, then the API will create a bin object during traversal whether it was really stored or not.

Other relevant bits of information for sparse crosses:

- The 0x10000000 bit is set in the cross scope flags value if it is sparsely implemented.
- The attribute “#CROSSNUMBINS#” shows the total number of coverage bins in the cross, useful for computing total coverage.

The mechanism for storing crosses sparsely closely follows the *cross select expression* syntax and semantic in SystemVerilog. There is an expression API that can be used with the cross, essentially to store and retrieve the cross select expression with which the cross was specified in SystemVerilog source.

CROSSBINIDX and CROSSUBINIDX

These user-defined attributes are associated with cross bins to implement the SystemVerilog predefined system task `$load_coverage_db()`. For Questa, the `$load_coverage_db()` predefined system task cannot work unless these attributes are correctly set.

Consider this more complex covergroup with a cross.

SystemVerilog example (“covergroup-cross3x3”):

```
covergroup cg;
  cvpa: coverpoint a { bins azero = { 0 }; bins anonzero[] = { [1:2] }; }
  cvpb: coverpoint b { bins bzero = { 0 }; bins bnonzero[] = { [1:2] }; }
  axb: cross cvpa, cvpb;
endgroup
```

The “cross bin index” attributes are best illustrated as such:

Bin Name	CROSSUBINIDX	CROSSSBINIDX
<azero,bzero>	0	0
<anonzero[1],bzero>	1	0
<anonzero[2],bzero>	1	1
<azero,bnonzero[1]>	2	0
<azero,bnonzero[2]>	2	1
<anonzero[1],bnonzero[1]>	3	0
<anonzero[2],bnonzero[1]>	3	1
<anonzero[1],bnonzero[2]>	3	2
<anonzero[2],bnonzero[2]>	3	3

- CROSSUBINIDX is mnemonically “cross user bin index” -- using an internal terminology by which a “bin declaration” is a “user bin”. This is the syntactic bin declaration with a bin name and terminated by a semicolon.
- CROSSSBINIDX is mnemonically “cross sub-bin index” -- using an internal terminology by which a “bin” is a “sub-bin”. This is the actual bin or coveritem object with an individual count, which may map 1-to-1 with the declaration or many-to-1.

The secret here is to look at the coverpoint bin declarations in isolation. Although there are 3 bins in each coverpoint and thus 9 in the cross, there are 2 bin declarations in each coverpoint. The cross is thus organized into 4 groups of crosses of bin declarations:

- <azero,bzero>
- <anonzero[*],bzero>
- <azero,bnonzero[*]>
- <anonzero[*],bnonzero[*]>

The CROSSUBINIDX is an index value corresponding to these groups. Note the bin declarations in the left-most crossed coverpoint (“a” in this case) are “less significant” in the sense that they change more rapidly as the cross bins are enumerated. This is implementation specific and is reflected in the order of bins in the report.

The CROSSSBINIDX is a given bin's index within one of these groups.

Note: if you or your customer does not care about using \$load_coverage_db(), then these user-defined attribute values could be ignored. They are created automatically by Questa but might take some work to reproduce independently. Note that \$load_coverage_db() requires a corresponding SystemVerilog covergroup to have been created in simulation, otherwise the

load will fail anyway. This implies that if the covergroup is being ported from third-party data, there is still the requirement to create a corresponding SystemVerilog covergroup into which the data could be reloaded in simulation with `$load_coverage_db()`.

Covergroup in Package with Multiple Instances

SystemVerilog example (“covergroup-perinstance”):

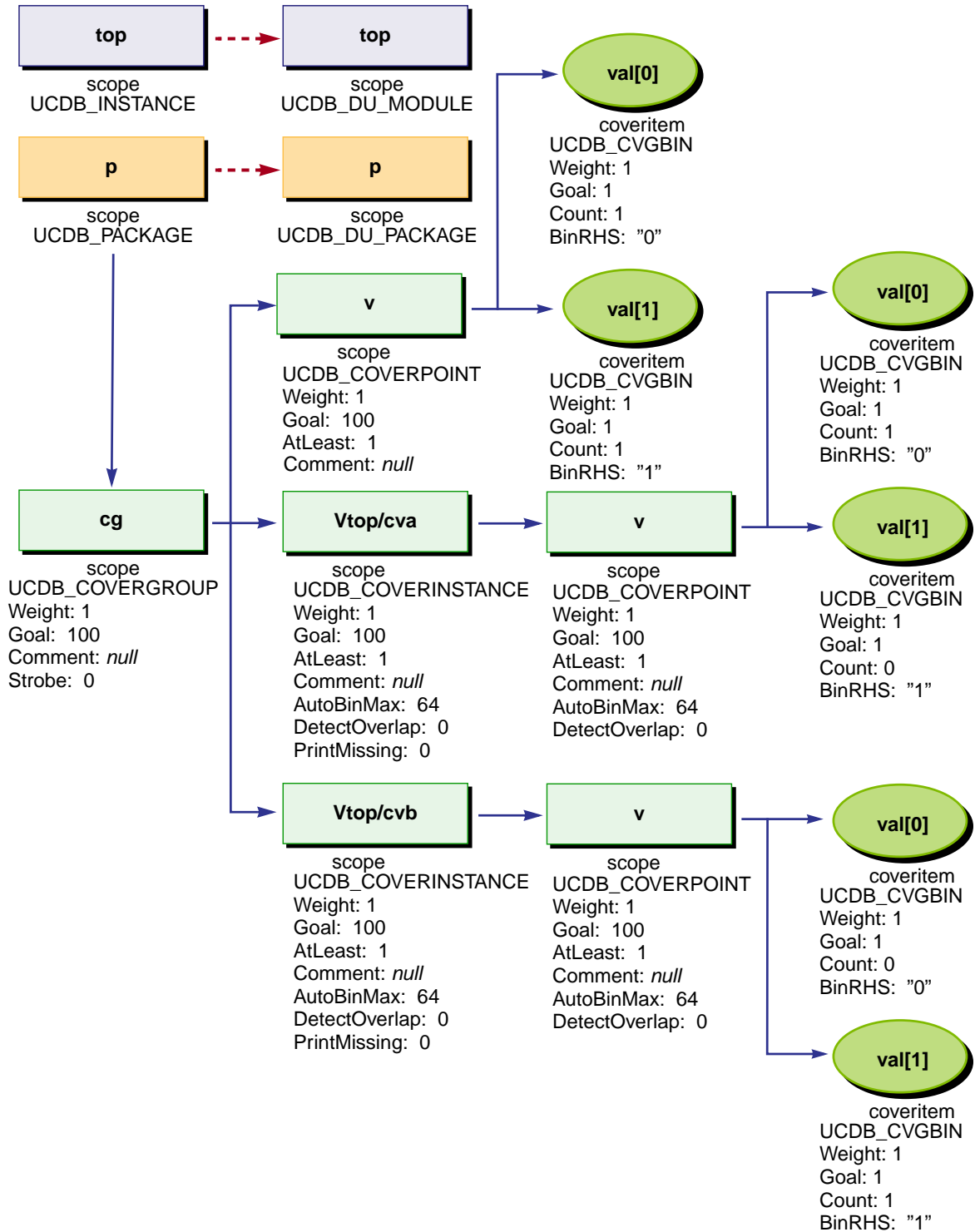
```
package p;
  covergroup cg (ref int v);
    option.per_instance = 1;
    coverpoint v { bins val[] = { [0:1] }; }
  endgroup
endpackage
module top;
  int a, b;
  p::cg cva = new(a);
  p::cg cvb = new(b);
  initial begin
    #1; a = 0; cva.sample();
    #1; b = 1; cvb.sample();
    #1; $display("cva=%.2f cvb=%.2f cva+cvb=%.2f",
                cva.get_inst_coverage(),
                cvb.get_inst_coverage(),
                p::cg::get_coverage());
  end
endmodule
```

This illustrates two interesting cases together: the covergroup with per-instance coverage (`option.per_instance` assigned to 1), and the covergroup in a package. [Figure 2-20](#) shows the design unit scopes. This is to show the different scope types for a package: the package has an instance type `UCDB_PACKAGE`, and a design unit type `UCDB_DU_PACKAGE`.

Note how the module instance “top” has nothing in it. The covergroup *variables* are in the module top, but covergroup variables are nothing more than references to a previously created covergroup object. The object might exist with no reference (because coverage must persist, covergroup objects are not garbage collected); there could be more than one reference to a given object; or the same reference might refer to different objects at different points in time. So the covergroup variable is not very relevant to the covergroup objects themselves. Consequently, the covergroup instances in the UCDB are stored underneath the covergroup type (`UCDB_COVERGROUP` scope) as a different UCDB scope type: `UCDB_COVERINSTANCE`.

Covergroup instances are identified by name. The name could be assigned explicitly by you – by assigning `option.name` or using the `set_inst_name()` built-in method. If not assigned explicitly, Questa automatically assigns the covergroup instance name using the path to the variable used to construct the covergroup object. This path is quoted as an extended identifier so that references to paths within the UCDB work easily. The middle coverpoint scope in [Figure 2-20](#) would be referenced as “/p/cg/top/cva /v”. Note the space after “cva” to terminate the extended identifier.

Figure 2-20. Data Model for a Covergroup (with Per-Instance Coverage)



The UCDB_COVERINSTANCE scopes and their child scopes have some attributes to convey the option values for those scopes:

- ATLEAST — the option.at_least value.
- COMMENT — the option.comment for the corresponding scopes.
- AUTOBINMAX — the option.auto_bin_max setting.
- DETECTOVERLAP — this is option.detect_overlap.
- PRINTMISSING: the option.cross_num_print_missing.

Note how option.per_instance itself is implied by the presence of the UCDB_COVERINSTANCE in the data model.

Finally, this example illustrates another interesting point. The get_inst_coverage() for /top/cva or /top/cvb could be calculated from the UCDB_COVERINSTANCE scopes. The get_coverage() for covergroup “cg” could be calculated from the UCDB_COVERPOINT scope “/p/cg/v”, i.e., the coverpoint that is an immediate child of the UCDB_COVERGROUP scope. This represents, as in the previous example, the type coverage for the covergroup. Note how the covergroup coverage is the merging together of the coverage from the two instances. The IEEE Std 1800-2005 says “It is important to understand that the cumulative coverage considers the union of all significant bins; thus, it includes the contribution of all bins (including overlapping bins) of all instances.”

In other words, the /top/cva instance covers bin val[0], while the /top/cvb instance covers bin val[1]. Therefore each instance has 50% coverage, but the type is covered 100% because each bin is covered in the union contributed from all instances. This is reflected in the simulation output of the \$display in the example:

```
# cva=50.00 cvb=50.00 cva+cvb=100.00
```

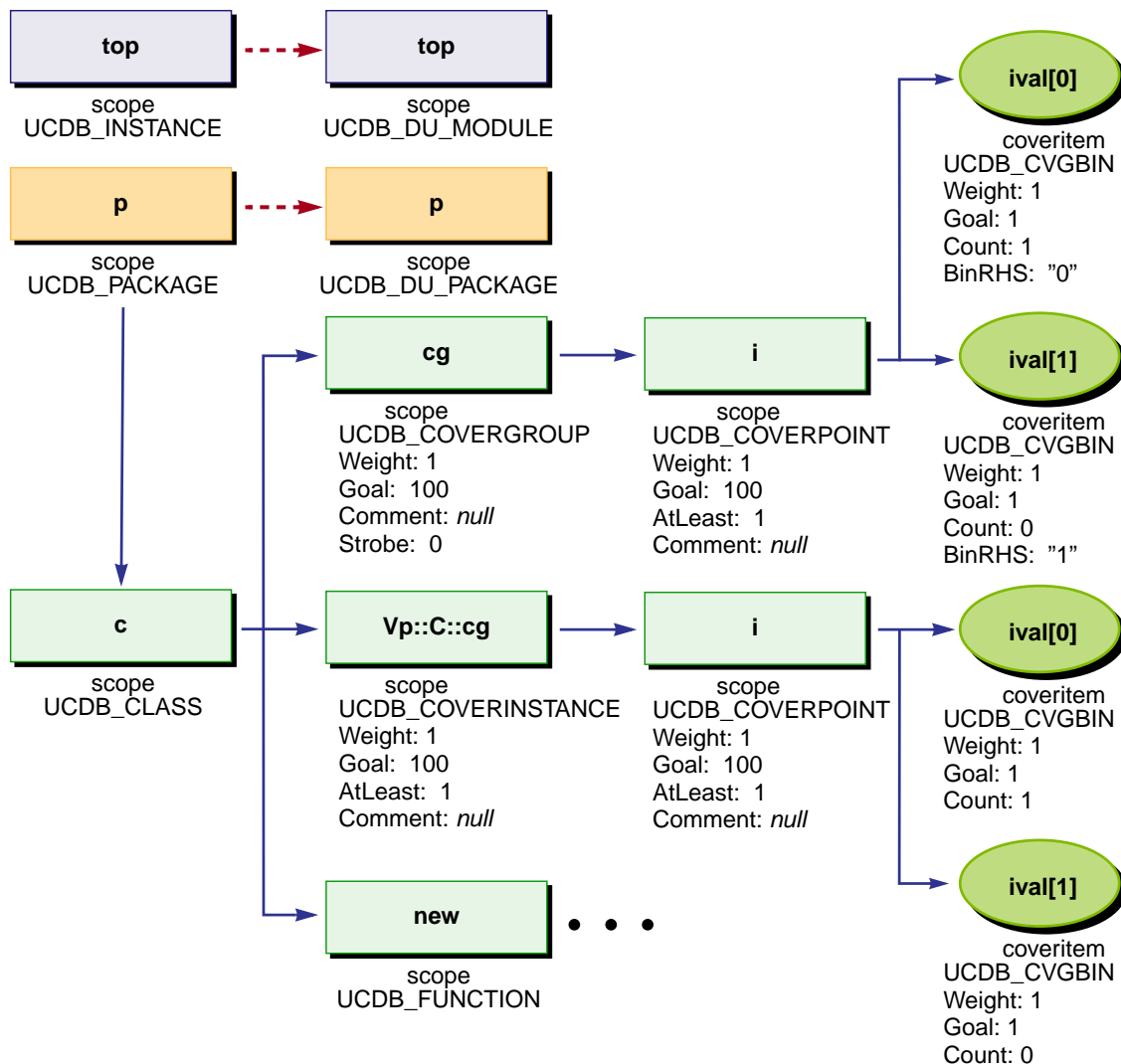
Covergroup in a Class (Embedded Covergroup)

SystemVerilog example (“covergroup-embedded”):

```
package p;
class c;
    int i;
    covergroup cg;
        coverpoint i { bins ival[] = { [0:1] }; }
    endgroup
    function new();
        cg = new;
    endfunction
    function void sample(int val);
        i = val;
        cg.sample();
    endfunction
endclass
```

```
endpackage
module top;
  p::c cv = new;
  initial begin
    cv.sample(0);
    $display($get_coverage());
  end
endmodule
```

Figure 2-21. Data Model for an Embedded Covergroup



This is very similar to the previous data models, with two interesting points.

First, the covergroup type name is stored as the declaration name “cg”. Technically this is incorrect: IEEE Std 1800-2008 specifies that the embedded covergroup declaration creates a covergroup of anonymous type. In Questa this is really “#cg#” and invisible to the user. However, because UCDB scope names must be visible during coverage analysis, Questa transforms the anonymous name to the visible covergroup variable name. This is allowable

because the embedded covergroup has other restrictions that result in a 1-to-1 mapping between the covergroup type and the covergroup variable.

The example dump output shows clearly how other unexpected scopes – such as, “new”, “post_randomize” – are created in the UCDB. This is because scopes are saved in the UCDB prior to determining whether or not they contain coverage.

The presence of these scopes does illustrate how the UCDB captures the complete “context tree” of the elaborated design.

Design Units

The output of `ucdbdump` shows some of the interesting data associated with a design unit. This is taken from the “fsm” example:

```
----- DESIGN UNIT -----
Name       : work.top
Type       : UCDB_DU_MODULE
Source type : VERILOG
File info  : name = test.sv line = 0
Flags      : 0x00000121
Attribute: name = DUSIGNATURE string = ogR[Jb^m9kQbO9nX]eoj;l
```

The important points are:

- Name — the name is composed as *library.name* for Verilog and *library.entity(architecture)* for VHDL. In Verilog, the architecture notation may be used for variants created by parameterization or optimization; however, these are merged together to create a single design unit. The reason is that these variants may be created arbitrarily by the optimizer; they could be artifacts not intended by the user. This does have the consequence that the context tree in the UCDB will differ from the context tree visible in Questa in simulation. The same is true for VHDL design units which are sometimes denoted *library.entity(architecture)#index*. The different index versions are merged together to reflect the “canonical” design unit.
- Flags
 - UCDB_ENABLED_STMT (0x00000002) through UCDB_ENABLED_TOGGLEEEXT (0x00000080) are required for code coverage to appear in Questa's reports. There is an open enhancement to invert the sense of these flags and by default to have code coverage appear if present; this would be less surprising to third parties creating UCDB design units from scratch. But in the current release of the UCDB, these flags are required in order for code coverage to appear in the reports; these flags are created correctly by Questa itself.
 - UCDB_SCOPE_UNDER_DU is an internal flag to mark the scopes under the design unit, if any, as well as the design unit itself.

- UCDB_INST_ONCE flag indicates that there was only one instance of the design unit so there is no code coverage roll-up stored under the design unit. This optimization is less apparent when the UCDB is loaded into memory.
- DUSIGNATURE attribute — this is a crucial attribute used to determine that the code content of the design unit has not changed, so that line number mappings used in all code coverage (except FSM and toggle) is still valid.

Test Data Records and History Nodes

In earlier versions of the database and API, there were only “test data records” which were designed to record information about the test run which produced the UCDB. It is not possible to create a UCDB without a test data record.

Later, test data records were extended, so that they became a special case of the “history node”. The history node records information about any process that creates a UCDB. In Questa, there are three ways to create a UCDB:

- By running the simulator — The simulator will create a “test data record” with various information about the simulation run.
- By XML test plan import — This creates a “testplan history node”.
- By merging — This creates a “merge history node”.

Because of the merging process, whereby UCDBs may be combined in various ways to create other UCDBs, history nodes are arranged in a tree. The test data records and testplan history nodes must be leaves of the tree. But a merge must have child nodes, which are the inputs to the merge. The topology of the tree, in other words, allows each merge to be reproduced with its original inputs.

The motivation of the history nodes, besides recording interesting information about each test, merge, or test plan, is to allow each of these operations to be reproduced automatically by the tool.

Any of these nodes may have user-defined attributes. Presently user-defined attributes are heavily used with test data records, but they could be used in the other cases, too.

Test Plan Hierarchy and Tags

The UCDB has the facility for representing a test plan hierarchy. Ordinarily a test plan is created as a spreadsheet, Word document, or other file – and there is some symbolic convention in the tool to link between sections of the test plan and coverage objects in the design. This could be through fields in the document, through the covergroup comment, through Verilog-2001 attributes, or any other mechanism.

The association in the UCDB is made through a specialized data attribute called a “tag”. This is nothing other than a string that is associated with a scope; there may be multiple tags per scope. Any scope or test data record can be “tagged”. A test plan section is represented by a UCDB scope of type UCDB_TESTPLAN. If it shares a tag with any other scope not of type UCDB_TESTPLAN, the coverage associated with that non-testplan scope is considered linked to the section represented by the testplan scope. After that it is a tool feature to calculate coverage in some way that is meaningful based on the test plan and the coverage linked to it.

Note that *any* UCDB scope could be linked with the test plan, not just coverage scopes. However, coveritems may not be linked with the test plan because the tag API does not apply to coveritems.

The “testplan” example shows a trivial test plan with two sections linked to two trivial coverpoints. Creating a test plan is ordinarily a tool feature, but this example shows how to create one with the API, since this is the API User Guide; this is the first example to introduce the API itself rather than the data model. In this case it is not possible to create the data model in the simplest possible way without using the API as well as HDL source. Hopefully the following example is intelligible without knowing the API – which is introduced in the next Chapter.

C Example (“testplan”):

```
ucdbT db = ucdb_Open(ucdbfile);
ucdbScopeT testplan, section1, section2, cvpi, cvpj;
if (db==0) return;

/* Create test plan scopes: */
testplan = ucdb_CreateScope(db,NULL,"testplan",NULL,1,UCDB_NONE,
                             UCDB_TESTPLAN,0);
section1 = ucdb_CreateScope(db,testplan,"section1",NULL,1,UCDB_NONE,
                             UCDB_TESTPLAN,0);
section2 = ucdb_CreateScope(db,testplan,"section2",NULL,1,UCDB_NONE,
                             UCDB_TESTPLAN,0);

/* Look up coverpoint scopes: */
cvpi = ucdb_MatchScopeByPath(db,"/top/cg/i");
cvpj = ucdb_MatchScopeByPath(db,"/top/cg/j");

/* Tag to link test plan scopes to coverpoint scopes */
ucdb_AddObjTag(db,section1,"1");
ucdb_AddObjTag(db,cvpi,"1");
ucdb_AddObjTag(db,section2,"2");
ucdb_AddObjTag(db,cvpj,"2");

/* Write everything back to the same file */
ucdb_Write(db,ucdbfile,NULL,1,-1);
ucdb_Close(db);
```

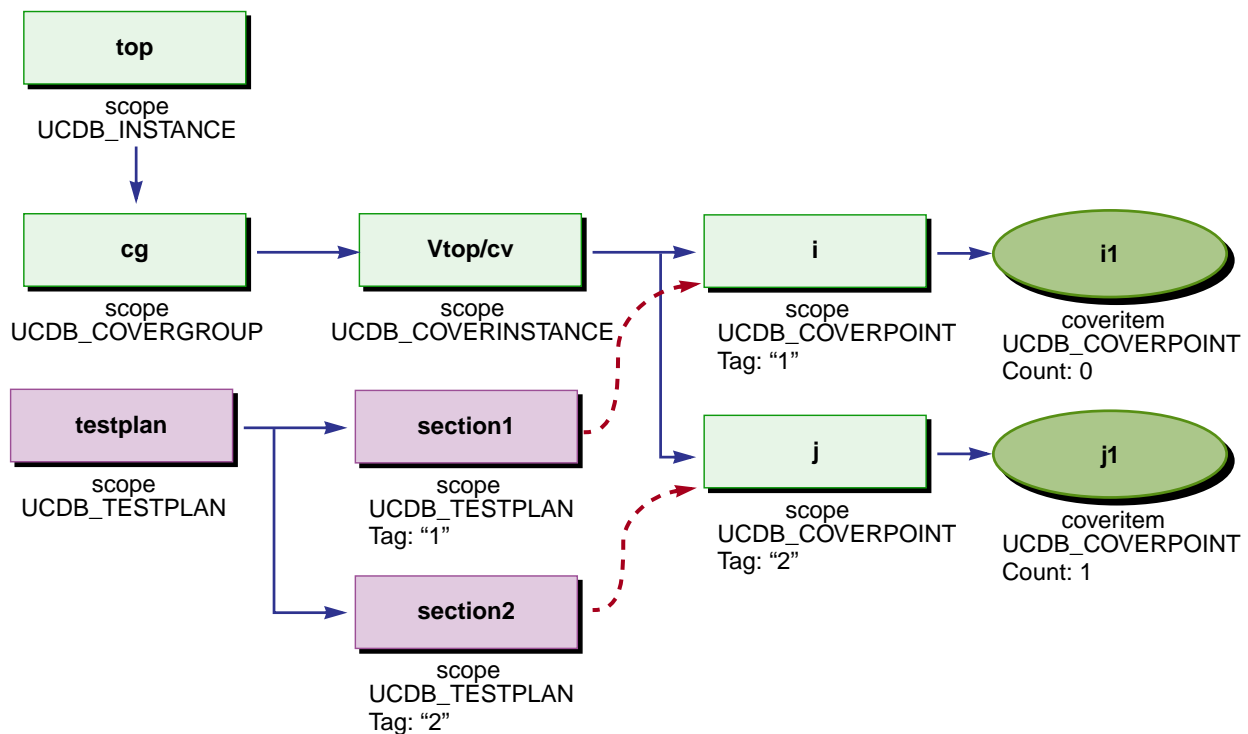
This example executes the following sections of code:

- Open the UCDB file, loading its contents into memory.

- Create the three test plan scopes. Note that the first one, “testplan”, is used subsequently as the parent of “section1” and “section2” (the second argument to `ucdb_CreateScope()` is the parent node). This creates the parent-child relationship and thus the hierarchical structure of the test plan.
- Look up the coverpoint scopes by path. Paths in the UCDB use the path separator “/” by default and otherwise concatenate the names of the scope on a downward traversal through hierarchy. In this case “top” is the module instance, “cg” the covergroup underneath the instance, and “i” and “j” the coverpoints underneath the covergroup.
- Give section1 the same tag as `/top/cg/i`, and section2 the same tag as `/top/cg/j`. This is all that is necessary to make the test plan association with coverage.
- Write the UCDB data in memory back to the same file from which it was read, and close the UCDB handle in order to de-allocate its memory.

This results in the following data model:

Figure 2-22. Data Model for a Test Plan with Linked Coverage



In this case, the shared tag names imply the red dashed-line links from UCDB_TESTPLAN scopes to the UCDB_COVERPOINT scopes. Refer to the section [Using Tags to Traverse from Test Plan to Coverage Data](#) for more information.

This is nearly the simplest possible data model for a test plan. Note that in Questa there is a “SECTION” attribute used in the report, tags are composed in a more sophisticated way, tags are automatically applied by **vcov merge** according to yet other attributes attached to test plans, and test plan scopes may have user-defined attributes added from the test plan document

– so that a test plan data structure created by Questa is more complex than the one shown here. But the basic tree relationships will be of the same nature.

Memory Statistics

There is a facility in the UCDB API for *memory statistics*. These are available in constant time when a UCDB is loaded, so are designed for fast access.

The API calls are `ucdb_GetMemoryStats()` and `ucdb_SetMemoryStats()`. These use the `ucdbAttrValueT` attribute value structure, but otherwise rely on two enumerators to create, in effect, a 2-dimensional array of attributes. The enumerators are `ucdbMemStatsEnumT` and `ucdbMemStatsTypeEnumT`, which are essentially a category and type, respectively.

The memory statistics API is used internally by Questa.

UCDB Use Cases

Understanding the [UCDB Data Models](#) is a prerequisite to using the API. The API is more general than the specific data models used to represent specific kinds of coverage. This section discusses how to use the API. It makes some assumptions about the data model. It also describes specific use scenarios.

UCDB Access Modes

You can open a UCDB file in the following ways:

- In-memory — open the UCDB file so that the entire UCDB data model lies in memory. This is the most general of the use models: all functions related to data access and modification should work in this mode.
- Read-streaming — given a file name, the file is opened and closed within an API function, but the user specifies a callback that is called for each data record in the database. Effectively this maintains a narrow “window” of data visibility as the database is traversed, so its data access is limited. Some types of data are maintained globally, but the goal of this mode is to minimize the memory profile of the reading application.
- Write-streaming — open a database handle that must be used to write data in a narrowly prescribed manner. This is the most difficult mode to perfect, because to successfully write the file, data must be created in requisite order with a precise sequence of API calls – but it has the advantage that the data is streamed to disk without maintaining substantial UCDB data structures, and so minimizes the memory profile of the writing application.
- Summary read — this is a *constant-time read* of a coverage summary stored within the file. This allows overall statistics from the database to be read without traversing the entire database. The disadvantage is that the summary coverage calculations are fixed and cannot be customized in any way by the user.

Of these modes, the first one to discuss is the easiest: in-memory mode. Others will be discussed in separate sections.

The database handle type of the UCDB is `ucdbT` which is a `void*` pointing to a hidden structure type of implementation-specific data associated with the database. This handle must be used with nearly all API calls. Opening a database in-memory is trivially easy:

```
ucdbT db = ucdb_Open(filename);
```

If the database handle is non-NULL, the open succeeded and the database handle can be used to access all data in the database. Note the database is not tied in any way to the file on the file system. The database exists entirely in memory, and may be re-written to the same file or a different file after it is changed.

Writing the database to a file is simple if the database has been previously opened in-memory. The write call can write subsets of the database – characterized by instance sub-sets or instance tree sub-sets or by coverage type sub-sets. Without worrying about sub-sets of the database, the basic write call is this one:

```
ucdb_Write(db,filename,NULL,1,-1);
```

The “NULL” means write the entire database, “1” is a recursive indicator that is irrelevant if “NULL” is given, and “-1” indicates that all coverage types should be written (it is a coverage scope type mask.)

Finally, the database in memory is de-allocated with this call:

```
ucdb_Close(db);
```

Error Handling

Most API calls return status or invalid values in case of error. However, these error return cases give no extra information about error circumstances. It is recommended that all standalone applications install their own UCDB error handler. If the API application is linked with Questa, installation of an error handler will not be allowed because Questa already is linked with one.

The basic error handler looks something like this. All examples for this manual will have one.

```
void
error_handler(void *data,
              ucdbErrorT *errorInfo)
{
    fprintf(stderr, "%s\n", errorInfo->msgstr);
    if (errorInfo->severity == UCDB_MSG_ERROR)
        exit(1);
}
```

The error-handler is installed as follows:

```
ucdb_RegisterErrorHandler(error_handler, NULL);
```

If there is any user-specific data to be passed to the error-handler, a pointer to it would be provided instead of NULL and that value would be passed as the void* first argument to the callback.

Traverse a UCDB in Memory

This illustrates a callback-based traversal, showing all UCDB scope types. The `ucdb_CallBack()` function is a versatile function that is only available in-memory: given a scope pointer (NULL in this case, meaning traverse the entire database) it traverses everything recursively. The callback function, called “callback” in this case, is called for every scope, every test record, and every coveritem in the part of the database being traversed. Design units

and test data records are only traversed when the entire database is being traversed, as in this case.

C Example (“traverse-scopes”):

```
ucdbCBReturnT
callback(
    void*          userdata,
    ucdbCBDataT*   cbdata)
{
    ucdbScopeT scope;
    switch (cbdata->reason) {
    case UCDB_REASON_DU:
    case UCDB_REASON_SCOPE:
        scope = (ucdbScopeT)(cbdata->obj);
        printf("%s\n", ucdb_GetScopeHierName(cbdata->db, scope));
        break;
    default: break;
    }
    return UCDB_SCAN_CONTINUE;
}

void
example_code(const char* ucdbfile)
{
    ucdbT db = ucdb_Open(ucdbfile);
    if (db==NULL)
        return;
    ucdb_CallBack(db, NULL, callback, NULL);
    ucdb_Close(db);
}
```

The `ucdbCBDataT*` argument to the callback function gives information about the database object for which the callback is executed. The “reason” element tells what kind of object it is. There are also reasons for end-of-scope (useful for maintaining stacks, so that the callback can know how many levels deep in the design or coverage tree is the current object), the test data records, and coveritems themselves.

For the scope callbacks, `REASON_DU` and `REASON_SCOPE`, the “obj” element of `ucdbCBDataT` is identical to a `ucdbScopeT`, which is a handle to the current scope. In this example, for stylistic reasons, the “obj” is type-cast explicitly into the “scope” variable.

The function `ucdb_GetScopeHierName()` returns a hierarchically composed name for the given scope handle.

Read Coverage Data

This example illustrates how to read coverage counts for all coveritems in all instances of a database. This is also based upon the `ucdb_CallBack()` function for traversing the entire database in memory.

C example (“read-coverage”):

```
/* Callback to report coveritem count */
ucdbCBReturnT
callback(
    void*          userdata,
    ucdbCBDataT*   cbdata)
{
    ucdbScopeT scope = (ucdbScopeT)(cbdata->obj);
    ucdbT db = cbdata->db;
    char* name;
    ucdbCoverDataT coverdata;
    ucdbSourceInfoT sourceinfo;

    switch (cbdata->reason) {
    case UCDB_REASON_DU:
        /* Don't traverse data under a DU: see read-coverage2 */
        return UCDB_SCAN_PRUNE;
    case UCDB_REASON_CVBIN:
        scope = (ucdbScopeT)(cbdata->obj);
        /* Get coveritem data from scope and coverindex passed in: */
        ucdb_GetCoverData(db,scope,cbdata->coverindex,
                           &name,&coverdata,&sourceinfo);
        if (name!=NULL && name[0]!='\0') {
            /* Coveritem has a name, use it: */
            printf("%s%c%s: ",ucdb_GetScopeHierName(db,scope),
                  ucdb_GetPathSeparator(db),name);
        } else {
            /* Coveritem has no name, use [file:line] instead: */
            printf("%s [%s:%d]: ",ucdb_GetScopeHierName(db,scope),
                  ucdb_GetFileName(db,&sourceinfo.filehandle),
                  sourceinfo.line);
        }
        print_coverage_count(&coverdata);
        printf("\n");
        break;
    default: break;
    }
    return UCDB_SCAN_CONTINUE;
}
```

This example skips the code coverage stored under a design unit – see the “read-coverage2” example for that, discussed below. If a design unit scope is encountered in the callback, the UCDB_SCAN_PRUNE return value instructs the callback generator to skip further callbacks for data structures underneath the design unit.

The callback prints something for the UCDB_REASON_CVBIN callback. This is for coveritems in the data model. The cbdata->obj value is set to the parent scope of the coveritem, and cbdata->coverindex is the index that can be used to access the cover item. Data for the coveritem is accessed with ucdb_GetCoverData(). This retrieves the name, coverage data, and source information for the coveritem. The source information is essential sometimes because some coverage objects – specifically, statement coveritems – do not have names: they can only be identified by the source file, line, and token with which they are associated. More information is available below on how source files are stored in the UCDB.

The coverage data itself is printed in this function:

```
void
print_coverage_count(ucdbCoverDataT* coverdata)
{
    if (coverdata->flags & UCDB_IS_32BIT) {
        /* 32-bit count: */
        printf("%d", coverdata->data.int32);
    } else if (coverdata->flags & UCDB_IS_64BIT) {
        /* 64-bit count: */
        printf("%lld", coverdata->data.int64);
    } else if (coverdata->flags & UCDB_IS_VECTOR) {
        /* bit vector coveritem: */
        int bytelen = coverdata->bitlen/8 + (coverdata->bitlen%8)?1:0;
        int i;
        for ( i=0; i<bytelen; i++ ) {
            if (i) printf(" ");
            printf("%02x",coverdata->data.bytevector[i]);
        }
    }
}
```

This comprehensively shows how the coverage count must be printed. There are not currently any source inputs or tools that create the UCDB_IS_VECTOR type of coverage data, but 32-bit and 64-bit platforms each create counts of their respective integer sizes, and those must be handled gracefully.

read-coverage2 Example

What happens if you try to traverse the code coverage data underneath a design unit? The “read-coverage2” example shows a way of handling it.

The problem is the UCDB_INST_ONCE optimization where coverage data for a single-instance design unit is stored only in the instance. For a per-design-unit coverage roll-up, it is convenient to access data through the UCDB design unit scope – and indeed the UCDB API allows that. However, the problem comes when printing the path to those scopes that were accessed underneath the design unit. Because the data is actually stored underneath the instance, the path prints the same whether it was accessed through the design unit or not. Extra code must be written to determine how the data was accessed: via the design unit or through the instance tree.

Partial C Callback Example (from “read-coverage2”):

```
struct dustate* du = (struct dustate*)userdata;

switch (cbdata->reason) {
/*
 * The DU/SCOPE/ENDSCOPE logic distinguishes those objects which
occur
 * underneath a design unit. Because of the INST_ONCE optimization,
it is
 * otherwise impossible to distinguish those objects by name.
 */
case UCDB_REASON_DU:
    du->underneath = 1; du->subscope_counter = 0; break;
case UCDB_REASON_SCOPE:
    if (du->underneath) {
        du->subscope_counter++;
    }
    break;
case UCDB_REASON_ENDSCOPE:
    if (du->underneath) {
        if (du->subscope_counter)
            du->subscope_counter--;
        else
            du->underneath = 0;
    }
    break;
```

This requires some user data established for the callback function. The “du” user data pointer has “underneath” which is a flag that is 1 while underneath a design unit, and a “subscope_counter” for subscopes underneath the design unit. (FSM coverage, for example, will create subscopes underneath a design unit.) Then if du->underneath is true, the application can print something distinctive to indicate when a coveritem was really found through the design unit rather than the instance:

```
read_coverage ../../data-models/toggle-enum/test.ucdb
/top/t/a: 0 (FROM DU)
/top/t/b: 1 (FROM DU)
/top/t/c: 1 (FROM DU)
/top/t/a: 0
/top/t/b: 1
/top/t/c: 1
```

Find Objects in a UCDB

C Example (“find-object”):

```
ucdbCBReturnT
callback(
    void*          userdata,
    ucdbCBDataT*   cbdata)
{
    switch (cbdata->reason) {
    case UCDB_REASON_SCOPE:
        print_scope(cbdata->db, (ucdbScopeT)(cbdata->obj));
        break;
    case UCDB_REASON_CVBIN:
        print_coveritem(cbdata->db, (ucdbScopeT)(cbdata->obj),
                        cbdata->coverindex);
        break;
    default: break;
    }
    return UCDB_SCAN_CONTINUE;
}

void
example_code(const char* ucdbfile, const char* path)
{
    ucdbT db = ucdb_Open(ucdbfile);
    if (db==NULL)
        return;
    ucdb_PathCallBack(db,
        0, /* don't recurse from found object */
        path,
        NULL, /* design unit name does not apply */
        UCDB_NONTESTPLAN_SCOPE, /* tree root type */
        -1, /* match any scope type */
        -1, /* match any coveritem type */
        callback, NULL);
    ucdb_Close(db);
}
```

The easiest way in the UCDB API to find particular objects by name in the database is this `ucdb_PathCallBack()` function. It has the added advantage of handling wildcards '*' (for multiple characters) and '?' (for a single character) in individual path component names.

The arguments to `ucdb_PathCallBack()`, in order, are:

- A database handle which must be opened with `ucdb_Open()`.
- A recursion flag. In this case, since we are interested in finding scopes and not everything underneath them, therefore the recursion is false.
- The path passed in from the command line of the example.
- The design unit name is NULL because it doesn't apply to the intent here. Paths *could* be design-unit-relative. In that case, the design unit name must be given.

- The tree root type must be given to distinguish between the two basic types of trees available in the UCDB: the test plan tree or the design instance tree.
- The scope mask restricts the search to particular scope types; -1 in this case means all scope types.
- The cover mask restricts the search to particular coveritem types; -1 in this case means all coveritem types. An alternative is to set this value to 0, in which case only scopes would be matched and not coveritems at all.
- The callback function.
- The private data for the callback function.

The `print_scope()` and `print_coveritem()` functions use scope or coveritem names, types, and line numbers to display data about the object found in the database. Note that statement coveritems will never be found by this API because they have no names at all. Only a linear search by filename, line number, and token number could find a particular statement coveritem.

The “sink” design supplied with `examples/ucdb/ucdbcrawl` has many different types of coverage in it. This illustrates using the *find_object* example with a pattern that is known to have multiple matches:

```
./find_object ../../../../ucdbcrawl/sink.ucdb '/top/mach/state/*'  
Found scope '/top/mach/state/states': type=20000000 line=33  
Found scope '/top/mach/state/trans': type=40000000 line=33  
Found cover '/top/mach/state/st0': types=00000001/00000200 line=0  
Found cover '/top/mach/state/st1': types=00000001/00000200 line=0  
Found cover '/top/mach/state/st2': types=00000001/00000200 line=0  
Found cover '/top/mach/state/st3': types=00000001/00000200 line=0
```

In this case, “/top/mach/state” is both an FSM scope and a toggle scope. When matching all children with “*”, this matches the transition and state child scopes of the FSM scope, and the enum toggle bins. Source information for toggles is stored at the scope level (not at the bin level). Therefore, the output for the toggle bins shows *line=0*.

Increment Coverage

C Example (“increment-cover”):

```
ucdbCBReturnT  
callback(  
    void*          userdata,  
    ucdbCBDataT*   cbdata)  
{  
    switch (cbdata->reason) {  
    case UCDB_REASON_CVBIN:  
        ucdb_IncrementCover(cbdata->db, (ucdbScopeT)(cbdata->obj),  
                             cbdata->coverindex, 1);  
        return UCDB_SCAN_STOP;  
        break;  
    default: break;  
    }
```

```
    }
    return UCDB_SCAN_CONTINUE;
}

void
example_code(const char* ucdbfile, const char* path)
{
    ucdbT db = ucdb_Open(ucdbfile);
    if (db==NULL)
        return;
    ucdb_PathCallBack(db,
                      0, /* don't recurse from found object */
                      path,
                      NULL, /* design unit name does not apply */
                      UCDB_NONTESTPLAN_SCOPE, /* tree root type */
                      -1, /* match any scope type */
                      -1, /* match any coveritem type */
                      callback, NULL);
    ucdb_Write(db,ucdbfile,
               NULL, /* save entire database */
               1, /* recurse: not necessary with NULL */
               -1); /* save all scope types */
    ucdb_Close(db);
}
```

Incrementing a coveritem is simple: there is a function to do it. Again, the `ucdb_PathCallBack()` approach has the disadvantage that it only recognizes named items, which excludes statement coveritems. But `ucdb_IncrementCover` could be applied to statement coveritems if their parent scopes are identified. To increment a coveritem multiple times, it is recommended that a scope pointer and coverindex be saved for later use.

The callback in this case uses the `UCDB_SCAN_STOP` return code to avoid iterating over the entire database: the iteration is halted after recognizing the coveritem to increment.

The `example_code()` function illustrates saving the UCDB back to its original file. The original file is closed by the operating system after `ucdb_Open()` completes, so there is really no link between the open UCDB handle “db” and the original file. The UCDB can be changed and written back to the same file or any other file.

The `ucdb_Save()` arguments “db” and “ucdbfile” are obvious, the others less so:

- Third argument (NULL) — a scope from which to execute the save; if NULL, save the entire database.
- Fourth argument (1) — a recursion flag, really only needed if the scope handle in the previous argument is non-NULL.
- Fifth argument (-1) — a scope mask, to indicate which scopes to save to the database. This can be used, for example, to create a database with functional coverage only, or code coverage only.

Remove Data from a UCDB

C example (“remove-data”):

```
ucdbCBReturnT
callback(
    void*          userdata,
    ucdbCBDataT*   cbdata)
{
    int rc;
    ucdbScopeT scope = (ucdbScopeT)(cbdata->obj);
    ucdbT db = cbdata->db;
    char* name;
    switch (cbdata->reason) {
    case UCDB_REASON_SCOPE:
        printf("Removing scope %s\n",ucdb_GetScopeHierName(db,scope));
        ucdb_RemoveScope(db,scope);
        return UCDB_SCAN_PRUNE;
    case UCDB_REASON_CVBIN:
        ucdb_GetCoverData(db,scope,cbdata->coverindex,&name,NULL,NULL);
        printf(
            Removing cover %s/%s\n",ucdb_GetScopeHierName(db,scope),name);
        rc = ucdb_RemoveCover(db,scope,cbdata->coverindex);
        if (rc!=0) {
            printf("Unable to remove cover %s/%s\n",
                ucdb_GetScopeHierName(db,scope), name);
        }
        break;
    default: break;
    }
    return UCDB_SCAN_CONTINUE;
}

void
example_code(const char* ucdbfile, const char* path)
{
    ucdbT db = ucdb_Open(ucdbfile);
    int matches;
    if (db==NULL)
        return;
    matches = ucdb_PathCallBack(
        db,
        0, /* don't recurse from found object */
        path,
        NULL, /* design unit name does not apply */
        UCDB_NONTESTPLAN_SCOPE, /* tree root type */
        -1, /* match any scope type */
        -1, /* match any coveritem type */
        callback, NULL);

    if (matches==0)
        printf("No matches for path\n");
    else
        ucdb_Write(db,ucdbfile,
            NULL, /* save entire database */
            1, /* recurse: not necessary with NULL */
            -1); /* save all scope types */

    ucdb_Close(db);
}
```

Note



This example does not work with wildcards.

The `ucdb_RemoveScope()` and `ucdb_RemoveCover()` functions are used to delete objects from the database. There is a limitation on `ucdb_RemoveCover()` in that it cannot delete toggle bins for the most common types: the 2-state and 3-state wires and registers – this is because toggle bins are optimized and don't really exist in isolation. The toggle scope can be deleted, but not individual bins in that case. Because of this, the error handler in this example does not call `exit()` but allows the code to continue; otherwise there is an internal API error generated for trying to remove a toggle scope of these kinds. Also, the return code from `ucdb_RemoveCover()` is checked to be able to give an error message with a specific path to the object whose removal failed.

When a scope is removed, all its children are removed, too.

This example also checks the return code from `ucdb_PathCallBack()` to indicate when no objects were matched by the given path. Otherwise, the application would remain silent.

This is one of those API applications whose use may be a little dangerous: for example, it would be possible to delete an FSM transition scope, leaving a set of transitions which could be inconsistent with the state values for the same FSM.

User-Defined Attributes and Tags in the UCDB

Tags are names that are associated with scopes and/or test data records in the database. These names could be used for general purpose grouping in the database. There may be an enhancement in the future that allows a tag to reference another tag: that would pave ground for hierarchical groups of otherwise unrelated objects.

Tags in the UCDB

In Questa, tags are used for making test traceability associations. This is explained in more detail below.

C Example to print tags (“print-attrtags”):

```
void
print_tags(ucdbT db, ucdbScopeT scope)
{
    int i, ntags = ucdb_GetObjNumTags(db, (ucdbObjT)scope);
    const char* tagname;
    printf("Tags for %s:\n", ucdb_GetScopeHierName(db, scope));
    if (ntags > 0) {
        for ( i=0; i<ntags; i++ ) {
            ucdb_GetObjIthTag(db, (ucdbObjT)scope, i, &tagname);
            printf("%s ", tagname);
        }
    }
}
```

```
    }  
    printf("\n");  
}  
}
```

This uses an integer-based iterator. First the number of tags are acquired with `ucdb_GetObjNumTags`, then the function `ucdb_GetObjIthTag()` is used to acquire the tag name for the *i*-th tag. Because these functions operate on both scopes (`ucdbScopeT`) and test data records (`ucdbTestT`), there is a so-called polymorphic type `ucdbObjT` that can stand for both. Some functions – queries as to object type or kind, queries about tags, and queries about attributes – take these object handles rather than scope or test data record handles. However, because this is C and not C++, all these types are really `void*`, so they are interchangeable and type unsafe. In this example the cast with “(`ucdbObjT`)” is used for readability; it is not strictly necessary.

User-Defined Attributes in the UCDB

User-defined attributes are also names that can be associated with a UCDB object, but are more powerful than tags in what they can represent:

- They can appear with any type of object in the database: test data records, scopes, and coveritems.
- There is a class of attributes – where `NULL` is given as the `ucdbObjT` handle to the API calls – that are called “global” or “UCDB” attributes. These are not associated with any particular object in the database but instead are associated with the database itself. There are a few of these used by Questa.
- User-defined attributes have values as well as names. The names are the so-called “key” for the values. In other words, you can look up a value by name.
- Attribute values can be of five different types:
 - 32-bit integer
 - 32-bit floating point (float).
 - 64-bit floating point (double).
 - Null-terminated string.
 - A byte stream of any number of bytes with any values. This is useful for storing unprintable characters or binary values that might contain 0 (and thus cannot be stored as a null-terminated string.)

C example to print attributes (“read-attrtags”):

```
void  
print_attrs(ucdbT db, ucdbScopeT scope, int coverindex)  
{  
    const char* attrname;
```

```
ucdbAttrValueT* attrvalue;
char* covername;
printf("Attributes for %s",ucdb_GetScopeHierName(db,scope));
if (coverindex>=0) {
    ucdb_GetCoverData(db,scope,coverindex,&covername,NULL,NULL);
    printf("%c%s:\n",ucdb_GetPathSeparator(db),covername);
} else {
    printf(":\n");
}
attrname = NULL;
while ((attrname = ucdb_AttrNext(db,(ucdbObjT)scope,coverindex,
                                attrname,&attrvalue))) {
    printf("\t%s: ", attrname);
    switch (attrvalue->type)
    {
    case UCDB_ATTR_INT:
        printf("int = %d\n", attrvalue->u.ivalue);
        break;
    case UCDB_ATTR_FLOAT:
        printf("float = %f\n", attrvalue->u.fvalue);
        break;
    case UCDB_ATTR_DOUBLE:
        printf("double = %lf\n", attrvalue->u.dvalue);
        break;
    case UCDB_ATTR_STRING:
        printf("string = '%s'\n",
              attrvalue->u.svalue ? attrvalue->u.svalue : "(null)");
        break;
    case UCDB_ATTR_MEMBLK:
        printf("binary, size = %d ", attrvalue->u.mvalue.size);
        if (attrvalue->u.mvalue.size > 0) {
            int i;
            printf("value = ");
            for ( i=0; i<attrvalue->u.mvalue.size; i++ )
                printf("%02x ", attrvalue->u.mvalue.data[i]);
        }
        printf("\n");
        break;
    default:
        printf("ERROR! UNKNOWN ATTRIBUTE TYPE (%d)\n",
              attrvalue->type);
    } /* end switch (attrvalue->type) */
} /* end while (ucdb_AttrNext(...)) */
}
```

The first thing you might notice is that the iterator convention is different. Why is that? The simple answer is that there might not be a good reason. Because backward compatibility is a design goal, other design decisions – good and bad – are enshrined for posterity because we make the commitment not to abandon an API in the future. Once having an API in a certain form, it seems better to leave it as-is than change it for purely cosmetic reasons.

This iterator requires a loop like this:

```
attrname = NULL;
while ((attrname = ucdb_AttrNext(db, (ucdbObjT)scope, coverindex,
                                attrname, &attrvalue))) {
```

The assignment of attrname to NULL is crucial; it starts the iteration. (A common bug in this case is to leave the attrname variable uninitialized. If it happens to be 0, the loop may execute, otherwise it will behave unpredictably, either crashing or doing nothing.)

If the attribute is for a scope, coveritem==(-1). If the attribute is for a test data record, the second (ucdbObjT) argument must be a ucdbTestT handle. If the attribute is for the UCDB as a whole, the second argument must be NULL.

The same attribute name as was returned by ucdb_AttrNext() must be passed to the function for the next iteration. The ucdbAttrValueT* variable must be declared by the user and is set by ucdb_AttrNext(). This variable is changed to point to memory owned by the API.

The code, as illustrated above, must switch on attrvalue->type to print something appropriate for the attribute value of the given type.

Some of the examples for adding data to a UCDB below show how to write user-defined attributes. There is no special trick to writing them, just that you must create your own memory for the attribute value(s); this memory is copied for the API's purposes to store with the UCDB.

Predefined Attribute Names in the UCDB

One thing you will notice in the ucdb.h header is #defines of this form:

```
#define UCDBKEY_SIMTIME          "SIMTIME"
```

Any of these macros starting with “UCDBKEY” are predefined attribute names. You may re-use these attribute names in different scopes, but it is inadvisable to re-use these attribute names in the same scopes in which Questa itself creates them. More precisely, if you do, please know what you are doing.

These attribute names and values are declared in ucdb.h so that you can be aware of them.

For the most part, the built-in attributes created by Questa must be read or written with the same API has for any user-defined attribute. For test data records only, built-in attributes may also be read or written with the API functions ucdb_GetTestData() and ucdb_AddTest().

Create a Test Plan in a UCDB

The data model example discussed in the section “[Test Plan Hierarchy and Tags](#)” shows how to create a trivially simple test plan from scratch. Some things to remark for the test plans created by Questa:

- Tag names for test plan sections in Questa are a concatenation of the test plan root name and the section number. This guarantees that test plans can be merged together from different files.
- The Questa tag CLI (viewcov mode command-line interface) is actually embedded as a user-defined attribute in the test plan scope, with UCDBKEY_TAGCMD as the name. The value is a string of semicolon-separated list of arguments to the coverage tag commands; these commands are automatically executed by vcover merge.
- Test plan sections have the UCDBKEY_SECTION attribute set to the literal section number that must appear in the report.
- The XML import for test plans can create any arbitrary user-defined attributes from the test plan source. For example, if you want an attribute named “Responsible” whose value is the name of the person responsible for the section of the test plan, that can be set up. These attributes then appear in the GUI and can be used as search criteria with the CLI or GUI.

Using Tags to Traverse from Test Plan to Coverage Data

This illustrates a hand-coded recursive traversal of test plan scopes only, and for each test plan scope, pursuing the linked objects that share the same tag. The fact is, `ucdb_PathCallBack()` does this automatically; it considers the linked object to be a “virtual child” of the test plan scope.

C Example (“traverse-testplan”):

```
void
recurse_testplan(int level, ucdbT db, ucdbScopeT scope)
{
    int t, numtags;
    const char* tagname;
    ucdbScopeT subscope;

    /* Print test plan scope name and recurse child test plan sections */
    indent(level);
    printf("%s\n",ucdb_GetScopeName(db,scope));
    subscope=NULL;
    while ((subscope=ucdb_NextSubScope(db,scope,subscope,UCDB_TESTPLAN)))
    {
        recurse_testplan(level+1,db,subscope);
    }

    /* from ucdb.h: traverse non-testplan objects with the same tag name */
    numtags = ucdb_GetObjNumTags(db,(ucdbObjT)scope);
    for ( t=0; t<numtags; t++ ) {
        int found;
        ucdbObjT taggedobj;
        ucdb_GetObjIthTag(db,(ucdbObjT)scope,t,&tagname);
        for ( found=ucdb_BeginTaggedObj(db,tagname,&taggedobj);
              found; found=ucdb_NextTaggedObj(db,&taggedobj) ) {
            if (ucdb_ObjKind(db,taggedobj)==UCDB_OBJ_SCOPE
```

```

        &&
        ucdb_GetScopeType(db, (ucdbScopeT) taggedobj) == UCDB_TESTPLAN)
        continue;
    /* tagged object is not a test plan scope: */
    indent(level+1);
    if (ucdb_ObjKind(db, taggedobj) == UCDB_OBJ_SCOPE)
        printf("%s\n", ucdb_GetScopeHierName(db, (ucdbScopeT) taggedobj));
    else if (ucdb_ObjKind(db, taggedobj) == UCDB_OBJ_TESTDATA)
        printf("%s\n", ucdb_GetTestName(db, (ucdbTestT) taggedobj));
    }
}

void
example_code(const char* ucdbfile)
{
    ucdbScopeT subscope;
    ucdbT db = ucdb_Open(ucdbfile);
    if (db == NULL)
        return;
    subscope = NULL;
    while ((subscope = ucdb_NextSubScope(db, NULL, subscope, UCDB_TESTPLAN)) != NULL) {
        recurse_testplan(0, db, subscope);
    }
    ucdb_Close(db);
}

```

The `ucdb_NextSubScope` function is an iterator that must start with a NULL pointer. One common mistake with this iterator is to confuse the “scope” and “subscope”. The traversal in `example_code()` is a traversal of roots, because NULL is given as the scope. The sub-scopes are returned, but these are root scopes with no parent. Note that the last argument to `ucdb_NextSubScope` – the UCDB_TESTPLAN value – is a scope mask. This is one of those cases where the scope type is used as a mask, justifying the implementation where each scope type occupies one and only one bit. In this case, the iterator will return only test plan scopes.

The `recurse_testplan()` scope prints the test plan scope name with indentation and recurses into test plan sub-scopes.

The complex second loop in `recurse_testplan()` is taken from an example in the `ucdb.h` header. This acquires each tag from the test plan. (Even though Questa creates test plan sections with one and only one tag, the UCDB has no such restriction in its data model.) The `ucdb_BeginTaggedObj()` and `ucdb_NextTaggedObj()` use the tag name to return the list of objects that share the tag. Note that tagged objects may be either scopes – test plan scopes, module instance scopes, coverage scopes, design unit scopes, etc. – or test data records. The `ucdb_GetScopeType()` function may only be used with scopes, so `ucdb_ObjKind()` is used first to guarantee that the object is a scope.

If the loop drops through the `continue` statement, we are guaranteed that the current object (`taggedobj`) shares a tag with the current test plan scope and is not itself a test plan scope. The names are printed in two different fashions: one for other scopes and one for test data records.

The end result is a simpler version of the “coverage analyze -plan / -r” command that can be used in viewcov mode in Questa. This is essentially the logic followed by the coverage analyze command. Note, however, that “coverage analyze” really relies on `ucdb_PathCallback()` which has the traversal logic built-in.

File Representation in the UCDB

File representation in the UCDB is designed to be efficient and capable. For efficiency, inside most objects in the database source file information is stored as a triple: file number, line number, and token number. File numbers need to relate to a file table. The UCDB has various ways to create a file table, implicitly or explicitly. With Questa itself, file tables are stored with design units. The file number is then the index into the file table of the design unit to which the object belongs. However, in general, file handles may be mixed and matched among different file tables. The example for this section (“filehandles”) uses both the design-unit file table created by Questa and a global one created implicitly through the API.

For capability, a file is specified as two parts: the directory to which the file belongs and the relative path to the file itself. This allows a heuristic algorithm to try to find the file even if the UCDB has been moved. A “heuristic” is not guaranteed to work. The heuristic includes possible use of a Questa-specific environment variable (“MGC_WD”) that can be used explicitly to point to source if the original directory no longer exists. Additionally, there is the `MGC_LOCATION_MAP` feature which allows mapping of directory prefixes between different networks so that Questa files can be portable between different file systems. The UCDB implementation will make use of `MGC_LOCATION_MAP` features if present.

The example for this document is a simple one that does not illustrate all of the subtleties of the UCDB file representation, but shows some simple scenarios.

Creating a File Handle From a File Name

In this case, Questa itself manages the file table. This has the disadvantage that each time a file handle is created by name, there is a string-based look-up to ensure that the file table contains only unique names.

C Example (“filehandles/create_filehandles.c”):

```
void
create_statement_with_filehandle(ucdbT db,
                                ucdbScopeT parent,
                                ucdbFileHandleT filehandle,
                                int line,
                                int count)
{
    ucdbCoverDataT coverdata;
    ucdbSourceInfoT srcinfo;
    ucdbAttrValueT attrvalue;
    int coverindex;
    coverdata.type = UCDB_STMTBIN;
```



```
coverdata.flags = UCDB_IS_32BIT;    /* data type flag */
coverdata.data.int32 = count;        /* must be set for 32 bit flag */
srcinfo.filehandle = filehandle;
srcinfo.line = line;
srcinfo.token = 0;                  /* fake token # */
coverindex = ucdb_CreateNextCover(db,parent,
                                   NULL, /* name: statements have none */
                                   &coverdata,
                                   &srcinfo);
...
}
example_code(const char* ucdbfile)
{
...
/* Let UCDB API create a global file table for each unique filename: */
ucdb_CreateSrcFileHandleByName(db,&filehandle,
                               NULL, /* let API create file table */
                               "test.sv",
                               pwd);
create_statement_with_filehandle(db,instance,filehandle,3,1);
...
}
```

This shows two excerpts from the example. The `ucdb_CreateSrcFileHandleByName()` takes these arguments:

- Database
- File handle to be filled in.
- Path to scope in which file table is to reside. If `NULL`, that means a global file table. Note, a global file is most efficient, but Questa does not use this since it does per-design-unit compilation and much of its source information is oriented around the design unit.
- Name of file.
- Directory in which the file is found. This example relies on a “PWD” environment.

The file handle is assigned to the `ucdbSourceInfoT` structure. The structure contains other information for line number and token number. This structure is passed to API functions like `ucdb_CreateNextCover()` and `ucdb_CreateScope()` and `ucdb_CreateInstance()` which create new objects in the database. The section [Add New Data to a UCDB](#) discusses creation of new objects in more detail.

The token number is difficult to use unless you have access to a tokenizer (lexical analyzer) for each source language of interest.

Creating a File Handle From an Existing File Table

In this “filehandles” example, Questa is invoked on these source files:

Example (“filehandles/test.sv”):

```
module top;
```

```
        initial begin
            // $display("hello");
            // $display("there");
            `include "test2.sv"
        end
    endmodule
```

Example (“filehandles/test2.sv”):

```
    // $display "world";
```

Even though these source files have commented-out statements, the compiler did parse the code, and Questa did create a file table inside the “work.top” design unit that has two entries. The first entry is “test.sv” and the second entry is “test2.sv”. Consequently, this code can be used to create statements that use file handles from the existing design unit file table:

C Example (“filehandles/create_filehandles.c”):

```
void
create_statement_with_filenumber(ucdbT db,
                                ucdbScopeT parent,
                                ucdbScopeT filetable_scope,
                                int filenum,
                                int line,
                                int count)
{
    ucdbCoverDataT coverdata;
    ucdbSourceInfoT srcinfo;
    ucdbFileHandleT filehandle;
    ucdbAttrValueT attrvalue;
    int coverindex;

    ucdb_CreateFileHandleByNum(db,&filehandle,filetable_scope,filenum);
    coverdata.type = UCDB_STMTBIN;
    coverdata.flags = UCDB_IS_32BIT;    /* data type flag */
    coverdata.data.int32 = count;      /* must be set for 32 bit flag */
    srcinfo.filehandle = filehandle;
    srcinfo.line = line;
    srcinfo.token = 0;                 /* fake token # */
    coverindex = ucdb_CreateNextCover(db,parent,
                                     NULL, /* name: statements have none */
                                     &coverdata,
                                     &srcinfo);

    ...
    /* Re-use file table from DU: */
    create_statement_with_filenumber(db,instance,du,0,4,1);
    create_statement_with_filenumber(db,instance,du,1,1,1);
    ...
}
```

This is the more efficient approach to creating a file handle. It requires a handle to the scope containing the file table (or NULL if using a global file table). The function `ucdb_CreateFileHandleByNum()` is used to create a file handle from the given file table.

This creates two statements:

- First statement from file 0 (“test.sv”) from du's file table, at line 4, with count 1.
- Second statement from file 1 (“test2.sv”) from du's file table, at line 1, with count 1.

There are other ways to create file handles, as well. For example, the `ucdb_CloneFileHandle()` function can be used if you don't have access to the scope containing the file table, but only have access to a valid file handle. You can clone the file handle, which means to use the same file table, but with a different file number, such as a different offset into the table.

This example also did not illustrate how to create the file table in the first place (since that was already done by Questa for the design unit.) That is very easy: use `ucdb_SrcFileTableAppend()` for each successive file.

Dumping File Tables

Accessing a file name from a file table is trivially easy: use `ucdb_GetFileName()`. That has already been used in the “read-coverage” example as a way to identify a statement bin, since statement bins have no names.

This example shows how to dump file tables throughout a database:

C Example (“filehandles/dump_filehandles.c”):

```
void
dump_filetable(ucdbT db, ucdbScopeT scope)
{
    int file;
    for ( file=0; file<ucdb_FileTableSize(db,scope); file++ ) {
        if (file==0) {
            if (scope)
                printf("File Table for '%s':\n",
                    ucdb_GetScopeHierName(db,scope));
            else
                printf("Global File Table:\n");
        }
        printf("\t%s\n", ucdb_FileTableName(db,scope,file));
    }
}

ucdbCBReturnT
callback(
    void*          userdata,
    ucdbCBDataT*   cbdata)
{
    switch (cbdata->reason) {
        case UCDB_REASON_DU:
        case UCDB_REASON_SCOPE:
            dump_filetable(cbdata->db, (ucdbScopeT)(cbdata->obj));
            break;
        default: break;
    }
    return UCDB_SCAN_CONTINUE;
}
```

```
void
example_code(const char* ucdbfile)
{
    ucdbT db = ucdb_Open(ucdbfile);
    printf("Dumping file tables for '%s' ...\n", ucdbfile);
    dump_filetable(db, NULL);
    ucdb_CallBack(db, NULL, callback, NULL);
    ucdb_Close(db);
}
```

First, the global file table is dumped, with `scope==NULL`. Technically any scope can have a file table – except for toggle scopes, which have limited capability for space efficiency (because there are potentially many toggles.) There are some limitations on where a file handle may be used for a given file table. Basically, the scope with the file table must be an ancestor in the UCDB hierarchy relative to the object that refers to it with a file handle.

There is a function for dumping the file name directly from the table, `ucdb_FileTableName()`. The same name could be acquired indirectly by using `ucdb_CreateFileHandleByNum()` to get a file handle from the table and then `ucdb_GetFileName()` to get a name from the file handle. The `ucdb_FileTableName()` does the same thing in a single step.

In the example, there are only two file tables: the one created by Questa in the design unit, and the global one created by “create_filehandles” that partially overlaps the design unit table:

```
Dumping file tables for 'test.ucdb' ...
Global File Table:
    test.sv
File Table for 'work.top':
    test.sv
    test2.sv
```

Add New Data to a UCDB

The single complex example “create-ucdb/create_ucdb.c” creates a hardcoded UCDB from scratch. The code that it uses could be adapted – with variations – to add objects to an existing UCDB. After all, even in the “create_ucdb.c” example, the database exists: it just starts out empty and is added to with each call. The subsections below discuss each type of object in turn.

The example is not exhaustive. Statements, an enum toggle, and a covergroup are created as an illustration. To create other types of objects, the user should refer to the chapter “[UCDB Data Models](#)”. It also may help to reverse-engineer UCDB data created by Questa using the `ucdbdump` example from *examples/ucdb/ucdbdump*.

Remember that the UCDB is more general than Questa. It is one thing to put data into a UCDB, another thing to get that data to display in Questa.

Add Design Unit to a UCDB

C Example (“create-ucdb”):

```
ucdbScopeT
create_design_unit(ucdbT db,
                  const char* duname,
                  ucdbFileHandleT file,
                  int line)
{
    ucdbScopeT duscope;
    ucdbSourceInfoT srcinfo;
    ucdbAttrValueT attrvalue;
    srcinfo.filehandle = file;
    srcinfo.line = line;
    srcinfo.token = 0;
    duscope = ucdb_CreateScope(db,
                              NULL,
                              duname,
                              &srcinfo,
                              1,
                              UCDB_VLOG,
                              UCDB_DU_MODULE,
                              /* flags: */
                              UCDB_ENABLED_STMT | UCDB_ENABLED_BRANCH |
                              UCDB_ENABLED_COND | UCDB_ENABLED_EXPR |
                              UCDB_ENABLED_FSM | UCDB_ENABLED_TOGGLE |
                              UCDB_INST_ONCE | UCDB_SCOPE_UNDER_DU);
    attrvalue.type = UCDB_ATTR_STRING;
    attrvalue.u.svalue = "FAKE DU SIGNATURE";
    ucdb_AttrAdd(db,duscope,-1,UCDBKEY_DUSIGNATURE,&attrvalue);
    return duscope;
}
```

One cardinal rule is that design units must be created before their corresponding instances. Design units come in five types:

- UCDB_DU_MODULE: a Verilog or SystemVerilog module.
- UCDB_DU_ARCH: a VHDL architecture.
- UCDB_DU_PACKAGE: a Verilog, SystemVerilog or VHDL package.
- UCDB_DU_PROGRAM: a SystemVerilog program block.
- UCDB_DU_INTERFACE: a SystemVerilog interface.

One crucial fact about all these, except packages, is that differently parameterized versions of the same design unit are merged together by Questa when saving a UCDB. This is because different parameterizations may be created arbitrarily and capriciously by the optimizer. The Structure window in Questa shows these parameterizations, but when a UCDB is loaded into the coverage view mode GUI, the Structure window shows only the canonical module, architecture, and so forth.

One peculiarity of Questa is that it does not use the UCDB_SV language type except for types of objects peculiar to SystemVerilog (such as interfaces.) A module will always have the UCDB_VLOG language type.

The flags for the design unit have the requirement – in order for Questa's report to work correctly – that flags be turned on to correspond to the different types of code coverage having been compiled for the design unit. If these flags are not present, the report will not recognize the corresponding code coverage type.

The UCDB_INST_ONCE flag is hardcoded in this case, but the user is responsible for maintaining it. If you add an instance to a design unit that already has a single instance, the flag must be cleared. In this example, it is known a priori that the design unit will only ever have a single instance.

The flag UCDB_SCOPE_UNDER_DU is required for certain coverage CLI commands and summary data to work correctly: it supplies the implementation for `ucdb_ScopeIsUnderDU()` and has implications for `ucdb_CalcCoverageSummary()`. If the flag is not set, some design-unit-oriented coverage may be mistaken as being per-instance.

The UCDBKEY_DUSIGNATURE attribute is required to detect source code changes for the files associated with the design unit.

Note that the Questa implementation of the signature is not available as a public API. If a valid signature is not computed by the API user, it has implications for the merge. If UCDBs from the same design source are merged together, there will be no problem – but the potential problem of merging files from different source would not be detected. (Merging from different source is a problem for the UCDB because most code coverage objects, with the exception of FSMs and toggles, are identified by source code only, i.e., by some combination of file, line, and token number.)

The weight of a design unit has relevance to Questa's “coverage analyze” command and the “Test Tracking GUI”.

Add Module Instance to a UCDB

There is little more to this than to use an API call. C Example (“create-ucdb”):

```
ucdb_CreateInstance(db,parent,instname,
    NULL,           /* source info: not used in Questa */
    1,             /* weight */
    UCDB_VLOG,      /* source language */
    UCDB_INSTANCE, /* instance of module/architecture */
    duscope,        /* reference to design unit */
    UCDB_INST_ONCE); /* flags */
```

Because the UCDB is a hierarchical data structure, the parent must be given. (If NULL, that creates the instance at the top-level, i.e., creates it as root.) This implicitly adds the new instance underneath the parent.

The instance name (instname) will become part of the path to identify the instance in the UCDB hierarchy. If the name contains odd characters, it is good practice to turn it into an escaped (or extended) identifier to allow path searching in Questa to work properly. The escaped identifier syntax will be VHDL style for instances under a VHDL parent, Verilog style for instances under a Verilog parent.

Source information may be given.

The weight may be relevant to the coverage analyze command and the Test Tracking GUI.

The scope type (UCDB_INSTANCE in this case) must map correctly to the given design unit type:

- UCDB_INSTANCE for design unit type of UCDB_DU_MODULE or UCDB_DU_ARCH.
- UCDB_PACKAGE for design unit type of UCDB_DU_PACKAGE.
- UCDB_INTERFACE for design unit type of UCDB_DU_INTERFACE.
- UCDB_PROGRAM for design unit type of UCDB_DU_PROGRAM.

The UCDB_INST_ONCE flag is set only for the case of the single instance of a given design unit. If adding an additional instance, the flag must be cleared explicitly by the user. Here is an example:

```
ucdb_SetScopeFlag(db, scope, UCDB_INST_ONCE, 0);
```

Add Statement to a UCDB

This has already been illustrated in the “filehandles” example. Here is a full discussion.

C Example (“create-ucdb”):

```
void
create_statement(ucdbT db,
                ucdbScopeT parent,
                ucdbFileHandleT filehandle,
                int line,
                int count)
{
    ucdbCoverDataT coverdata;
    ucdbSourceInfoT srcinfo;
    ucdbAttrValueT attrvalue;
    int coverindex;
    coverdata.type = UCDB_STMTBIN;
    coverdata.flags = UCDB_IS_32BIT;      /* data type flag */
    coverdata.data.int32 = count;         /* must be set for 32 bit flag */
    srcinfo.filehandle = filehandle;
    srcinfo.line = line;
    srcinfo.token = 0;                   /* fake token # */
    coverindex = ucdb_CreateNextCover(db, parent,
```

```
NULL, /* name: statements have none */
    &coverdata,
    &srcinfo);
/* SINDEXT attribute is used internally by Questa: */
attrvalue.type = UCDB_ATTR_INT;
attrvalue.u.ivalue = 1;

ucdb_AttrAdd(db,parent,coverindex,UCDBKEY_STATEMENT_INDEX,&attrvalue);
}
```

Like any object to be created in the design or test bench or test plan hierarchy, this requires a parent. The third argument to `ucdb_CreateNextCover()` is the name of the object. Note that statements do not have a name as created by Questa. (You can provide one, naturally, but Questa does not and will ignore it.)

The `&coverdata` argument is a pointer to the `ucdbCoverDataT` structure. This structure contains all the data associated with the bin except for the name and source information. The “data” field is a union containing the coverage count: `int32` for 32-bit platforms or `int64` for 64-bit platforms. In this example, it is hard-coded to 32-bits, which requires setting both the appropriate field of the union and the corresponding flag. Other data fields are optionally enabled based on the flags field of `ucdbCoverDataT`. Statements require only the data field (the coverage count).

The “SINDEXT” user-defined attribute is used to determine the ordering of the statement on a line. If the statement is the only one to appear on the line, “SINDEXT” is always 1. The second statement on a line would have value 2, etc. Yes, this is redundant with the token number. Perhaps it is an acknowledgement that the token number is unreliable, as previously discussed. If this “SINDEXT” attribute is not given, the “ItemNo” column of Questa's statement coverage details report (*vcov report -code s -byfile -details ucdb*) will not be correct.

Add Toggle to a UCDB

Toggles have special data characteristics which require they be created with a special API call.

C Example (“create-ucdb”):

```
void
create_enum_toggle(ucdbT db,ucdbScopeT parent)
{
    ucdbCoverDataT coverdata;
    ucdbScopeT toggle;
    toggle = ucdb_CreateToggle(db,parent,
        "t", /* toggle name */
        NULL, /* canonical name */
        0, /* exclusions flags */
        UCDB_TOGGLE_ENUM, /* toggle type */
        UCDB_TOGGLE_INTERNAL); /* toggle "direction" */
    coverdata.type = UCDB_TOGGLEEBIN;
    coverdata.flags = UCDB_IS_32BIT; /* data type flag */
    coverdata.data.int32 = 0; /* must be set for 32 bit flag */
    ucdb_CreateNextCover(db,toggle,
```



```
        "a",                                /* enum name */
        &coverdata,                          /* source data */
        NULL);                              /* must be set for 32 bit flag */
coverdata.data.int32 = 1;
ucdb_CreateNextCover(db,toggle,
    "b",                                    /* enum name */
    &coverdata,                            /* source data */
    NULL);
}
```

This corresponds to a source toggle declared like so in SystemVerilog:

```
enum { a, b } t;
```

Note that the toggle has only name and no source information (so NULL values are passed to `ucdb_CreateNextCover()`). Source info could be added later using `ucdb_SetScopeSourceInfo()` on toggle scopes.

The canonical name is used for wire (net) toggles, as described in the section [Net Toggle with Connected Net](#). The exclusions flags may apply to the toggle, so those can be given, too.

Finally, the toggle type and directionality (input, output, inout, or internal) are given. Directionality really only applies to net toggles, but is set to internal for others.

Recall that an enum toggle has bins whose names correspond to the enum values in the source language. If creating bins for other types of toggles, use the appropriate `UCDBBIN_TOGGLE_#define` value as declared in `ucdb.h`.

Add Covergroup to a UCDB

The covergroup is created in various stages. The covergroup for the “create-ucdb” example looks like this:

```
enum { a, b } t;
covergroup cg;
    coverpoint t;
endgroup
```

This requires creating a hierarchy like this:

1. cg
 - a. t
 - i. a
 - ii. b

The top level code is this:

C Example (“create-ucdb”):

```
cvlg = create_covergroup(db,instance,"cg",filehandle,3);
cvp = create_coverpoint(db, cvlg, "t", filehandle, 4);
create_coverpoint_bin(db, cvp, "auto[a]", filehandle, 4, 1, 0, "a");
create_coverpoint_bin(db, cvp, "auto[b]", filehandle, 4, 1, 1, "b");
```

The hierarchy is implied by the use of the parent pointers, second argument to each of these functions. The parent of “cg” is the instance whose scope handle is “instance”; this is loaded into the “cvlg” handle. The “cvlg” handle is used as the parent to create the “cvp” handle for the coverpoint named “t”. The “cvp” handle is then used as the parent of the bins.

The creation of the covergroup is this example:

C Example (“create-ucdb”):

```
ucdbScopeT
create_covergroup(ucdbT db,
                  ucdbScopeT parent,
                  const char* name,
                  ucdbFileHandleT filehandle,
                  int line)
{
    ucdbScopeT cvlg;
    ucdbSourceInfoT srcinfo;
    ucdbAttrValueT attrvalue;
    srcinfo.filehandle = filehandle;
    srcinfo.line = line;
    srcinfo.token = 0; /* fake token # */
    cvlg = ucdb_CreateScope(db, parent, name,
                           &srcinfo,
                           1, /* from type_option.weight */
                           UCDB_VLOG, /* source language type */
                           UCDB_COVERGROUP,
                           0); /* flags */
    /* Hardcoding attribute values to defaults for type_options: */
    attrvalue.type = UCDB_ATTR_INT;
    attrvalue.u.ivalue = 100;
    ucdb_AttrAdd(db, cvlg, -1, UCDBKEY_GOAL, &attrvalue);
    attrvalue.u.ivalue = 0;
    ucdb_AttrAdd(db, cvlg, -1, UCDBKEY_STROBE, &attrvalue);
    attrvalue.type = UCDB_ATTR_STRING;
    attrvalue.u.svalue = "";
    ucdb_AttrAdd(db, cvlg, -1, UCDBKEY_COMMENT, &attrvalue);
    return cvlg;
}
```

Much of the ucdb_CreateScope() usage has been discussed before. The only interesting thing to note is the scope type (UCDB_COVERGROUP) and the fact that the source type is UCDB_VLOG. The source type could reasonably be UCDB_SV as well, but Questa does not create it that way. In fact, Questa does not really draw a fine distinction between SystemVerilog and Verilog.

The attributes are required to have full report capability for the covergroup. Because this covergroup has option.per_instance the default of 0, the example creates type_option values

only. Note that `type_option.weight` is provided directly as an argument to `ucdb_CreateScope()`. The option `per_instance` influences the topology of the covergroup tree itself; if there are no covergroup objects with `option.per_instance==1`, then there will be no UCDB_COVERINSTANCE scopes in the covergroup subtree.

Following is the creation of the coverpoint.

C Example (“create-ucdb”):

```
ucdbScopeT
create_coverpoint(ucdbT db,
                  ucdbScopeT parent,
                  const char* name,
                  ucdbFileHandleT filehandle,
                  int line)
{
    ucdbScopeT cvp;
    ucdbSourceInfoT srcinfo;
    ucdbAttrValueT attrvalue;
    srcinfo.filehandle = filehandle;
    srcinfo.line = line;
    srcinfo.token = 0; /* fake token # */
    cvp = ucdb_CreateScope(db, parent, name,
                           &srcinfo,
                           1, /* from type_option.weight */
                           UCDB_VLOG, /* source language type */
                           UCDB_COVERPOINT,
                           0); /* flags */
    /* Hardcoding attribute values to defaults for type_options: */
    attrvalue.type = UCDB_ATTR_INT;
    attrvalue.u.ivalue = 100;
    ucdb_AttrAdd(db, cvp, -1, UCDBKEY_GOAL, &attrvalue);
    attrvalue.u.ivalue = 1;
    ucdb_AttrAdd(db, cvp, -1, UCDBKEY_ATLEAST, &attrvalue);
    attrvalue.type = UCDB_ATTR_STRING;
    attrvalue.u.svalue = "";
    ucdb_AttrAdd(db, cvp, -1, UCDBKEY_COMMENT, &attrvalue);
    return cvp;
}
```

This is very similar to the covergroup creation, except for the scope type, the parent (which is the previously created covergroup), and the options – including the weight given to `ucdbCreateScope()` -- which derive from the default values for the `type_option` structure in coverpoint scope.

Finally, the bins are created as children of the coverpoint.

C Example (“create-ucdb”):

```
void
create_coverpoint_bin(ucdbT db,
                     ucdbScopeT parent,
                     const char* name,
                     ucdbFileHandleT filehandle,
```

```
        int line,
        int at_least,
        int count,
        const char* binrhs)    /* right-hand-side value */
{
    ucdbSourceInfoT srcinfo;
    ucdbCoverDataT coverdata;
    ucdbAttrValueT attrvalue;
    int coverindex;
    coverdata.type = UCDB_CVGBIN;
    coverdata.flags = UCDB_IS_32BIT | UCDB_HAS_GOAL | UCDB_HAS_WEIGHT;
    coverdata.goal = at_least;
    coverdata.weight = 1;
    coverdata.data.int32 = count;
    srcinfo.filehandle = filehandle;
    srcinfo.line = line;
    srcinfo.token = 0;                                /* fake token # */
    coverindex = ucdb_CreateNextCover(db,parent,name,
                                     &coverdata,&srcinfo);

    attrvalue.type = UCDB_ATTR_STRING;
    attrvalue.u.svalue = binrhs;
    ucdb_AttrAdd(db,parent,coverindex,UCDBKEY_BINRHSVALUE,&attrvalue);
}
```

This is similar to previous examples, except for these data:

- UCDB_HAS_GOAL indicates that the “goal” field of ucdbCoverDataT should be used. This corresponds to the “at_least” value for the coverpoint: the threshold at which the bin is considered to be 100% covered.
- UCDB_HAS_WEIGHT indicates that the “weight” field of the ucdbCoverDataT is valid. This weight is identical to the weight for the parent coverpoint, but is also set here in case coverage is computed on a bin basis rather than for the coverpoint as a whole. The field is useful for coveritems with no explicit parent (e.g., statement bins.)
- The BINRHSVALUE attribute is one added by Questa that depends on knowledge of how the coverpoint is declared. This should be reverse-engineered from covergroup bin declarations and using *ucdbdump*. The “bin rhs value” is the sampled value(s), on the right-hand-side of the “=” in the bin declaration, that potentially cause(s) a bin to increment. In the LRM these are described as “associated” values or transitions. These values vary depending on whether the bin has a single value or multiple, whether it is a transition bin or not. It can be an enum value (as in the case illustrated above, if you look back at the top-level C code) or it can be another type of integral value, or transitions among those values.

Currently in Questa, the BINRHSVALUE is accessible only through the UCDB API.

Test Data Records

C Example (“create-ucdb”):

```
void
```

```
create_testdata(ucdbT db,
                const char* ucdbfile)
{
    ucdb_AddTest(db,
        ucdbfile,
        "test", /* test name */
        UCDB_TESTSTATUS_OK, /* test status */
        0.0, /* simulation time */
        "ns", /* simulation time units */
        0.0, /* CPU time */
        "0", /* random seed */
        NULL, /* test script: not used by Questa */
        NULL, /* simulator arguments: */
        "-coverage -do 'run -all; coverage save test.ucdb; quit' -c top ",
        NULL, /* comment */
        0, /* compulsory */
        "20070824143300", /* fake date */
        "userid" /* fake userid */
    );
}
```

This is an example of creating test data that is “faked” to be nearly identical to that created automatically by Questa for the “create-ucdb” example. The differences are in the date and userid, which cannot be reproduced since those will vary according to who runs the example when.

All of the test data attributes (arguments to the function above) correspond to attributes names that can be accessed using the UCDB attribute API. One of the chief uses of the attribute data is to add user-defined attributes that can be added for any reason. In Questa, these will appear in the UCDB Browser or the Test Tracking GUI if the test data record is linked as a directed test in a test plan.

Any of these test data attributes can be created or accessed in Quest with the coverage attribute command. They can be accessed with vcover attribute as well.

The format of the date is strict, the UCDB API Reference Manual describes how it can be created (from a POSIX-compliant C library call, `strftime()`.) The virtue of this format is that it can be sorted alphabetically.

The “test script” argument to `ucdb_AddTest()` is not used, though it could be. The simulator arguments are created automatically and can be used to re-run the test. The simulator arguments should be quoted such that the arguments could be passed to a shell for running with the simulator (*vsim* in this case.)

The comment is typically not used, but of course can be set within the tool. This is a general-purpose comment that can be used for anything.

Create a UCDB from Scratch in Memory

C Example (“create-ucdb”):

```
void
example_code(const char* ucdbfile)
{
    ucdbFileHandleT filehandle;
    ucdbScopeT instance, du, cvg, cvp;
    ucdbT db = ucdb_Open(NULL);
    create_testdata(db,ucdbfile);
    filehandle = create_filehandle(db,"test.sv");
    du = create_design_unit(db,"work.top",filehandle,0);
    instance = create_instance(db,"top",NULL,du);
    create_statement(db,instance,filehandle,6,1);
    create_statement(db,instance,filehandle,8,1);
    create_statement(db,instance,filehandle,9,1);
    create_enum_toggle(db,instance);
    cvg = create_covergroup(db,instance,"cg",filehandle,3);
    cvp = create_coverpoint(db,cvg,"t",filehandle,4);
    create_coverpoint_bin(db,cvp,"auto[a]",filehandle,4,1,0,"a");
    create_coverpoint_bin(db,cvp,"auto[b]",filehandle,4,1,1,"b");
    printf("Writing UCDB file '%s'\n", ucdbfile);
    ucdb_Write(db,ucdbfile,NULL,1,-1);
    ucdb_Close(db);
}
```

This is the top-level code that calls all the functions previously described in the section “[Add New Data to a UCDB](#)”. This reproduces – with a few exceptions described in the header comment of `create_ucdb.c` – the UCDB created by Questa from this source:

SystemVerilog Example (“create-ucdb”):

```
module top;
    enum { a, b } t;
    covergroup cg;
        coverpoint t;
    endgroup
    cg cv = new;
    initial begin
        t = b;
        cv.sample();
    end
endmodule
```

Many of the details have been discussed elsewhere. The only notable thing is the call to `ucdb_Open()` with a `NULL` argument: this creates a completely empty UCDB in memory, to which any data can be added. Note that because of tool requirements, it is not permissible to create a UCDB without a test data record; the `ucdb_Write()` will not succeed if there is no test data record.

The final `ucdb_Close(db)` is not strictly necessary because the memory used by the database handle will be freed when the process finishes, but it is good practice to explicitly free the memory associated with the database handle.

Read Streaming Mode

Read-streaming mode is a call-back based traversal of a UCDB as laid out on disk. It has the advantage of reducing memory overhead, as the UCDB is never fully loaded into memory.

The layout on disk is broadly thus:

- Header with database version and other header information.
- Global UCDB attributes can appear at any time at the top-level, but are ordinarily written as early as possible.
- Test data records.
- Design units are written before instances of them.
- Scopes (design units, instances, or any coverage scope) are written in a nested fashion: meaning that the start of the scope is distinct from the end of the scope. Scopes that start and end within another's start and end are children scopes. This is how the parent-child relationships are recorded: the start of the parent is always written before the children. The termination of the parent scope “pops” the current scope back to its parent.
- Coveritems are written immediately after the parent scope.
- Attributes and tags are written after the initial header for the scope or coveritem.
- Tail with summary data.

The presence of the tail is in some sense an implementation detail: the tail is loaded at the same time as the header. This allows `ucdb_GetCoverageSummary()` to work.

The rules for read streaming mode are relatively simple. In general, available data follows the order in which data is laid out on disk. The attributes, flags, etc., are complete with the read object. *There is no access to child scopes or coveritems at the time a scope is read.* The implementation maintains the following data at all times:

- All ancestors of a given scope or coveritem.
- All design units.
- All global UCDB attributes and other data global to the UCDB.
- All test data records.
- The summary data used by `ucdb_GetCoverage()`, `ucdb_GetStatistics()` and various other functions described in the API Reference as pertaining to global coverage statistics.

However, the inaccessibility of children means that any descendant nodes, or any descendants of ancestors (what you might informally call “cousin nodes” or “uncle nodes”) are not available.

The intuitive way to think of this is as read streaming mode maintaining a relatively small “window” into the data, that progresses through the file, with some global data available generally.

There are some other limitations, all of which relate to the fact that children are not available except exactly when they are encountered within the streaming “window”:

- Since the test plan tree is implemented with tags, there is no way to know when reading a test plan node what are the other nodes sharing the same tag. Test plan trees are essentially unusable in read-streaming mode, though if you wished to build the associations yourself, you could.
- The functions like `ucdb_PathCallback()` which require searching the database cannot work.
- The functions like `ucdb_CalcCoverageSummary()` which require traversing some subset of the database cannot work.

The following shows a simple example adapted from one of the previously discussed in-memory examples:

C Example (“read-streaming”):

```
ucdbCBReturnT
callback(
    void*          userdata,
    ucdbCBDataT*   cbdata)
{
    ucdbScopeT scope;
    switch (cbdata->reason) {
    case UCDB_REASON_DU:
    case UCDB_REASON_SCOPE:
        scope = (ucdbScopeT)(cbdata->obj);
        printf("%s\n", ucdb_GetScopeHierName(cbdata->db, scope));
        break;
    default: break;
    }
    return UCDB_SCAN_CONTINUE;
}

void
example_code(const char* ucdbfile)
{
    ucdb_OpenReadStream(ucdbfile, callback, NULL);
}
```

The read streaming mode is based on the same callback type functions as `ucdb_Callback()`. This example should look familiar: it is the “traverse-scopes” example. The “example_code” function is different. The database handle is only available through the callback. The path to the UCDB file is given to the open call, and this calls the callback for each object in the database.

The big example **examples/ucdb/ucdbdump** is a read streaming mode application. It is a thorough example of how to use the mode.

Write Streaming Mode

Write streaming mode is a way of *writing* a UCDB with optimally low memory overhead. This is the hardest of all use cases of the UCDB API. In general, it should be avoided unless you fall into one of the following circumstances:

- You are a professional tool developer for whom memory overhead is a crucial concern.
- You are linked with the Questa kernel – as through PLI, VPI, or FLI – and want to contribute your own data “on the fly” to a UCDB being saved with Questa's coverage save command executed from vsim. This is discussed in the section [“Using the mti_AddUCDBSaveCB FLI Callback”](#).

It is much easier to create a UCDB from scratch in memory, as described earlier in the section [“Create a UCDB from Scratch in Memory”](#).

The “write-streaming” example among the “userguide” examples shows the “create-ucdb” example adapted to write streaming mode. There is also the **examples/ucdb/writestream** example which was released earlier with Questa. This contains extensive comments on using the mode. This document will restrict itself to relatively simple observations and the key differences between the “write-streaming” example and the “create-ucdb” example.

C Example (“create-ucdb”) top-level code:

```
void
example_code(const char* ucdbfile)
{
    ucdbFileHandleT filehandle;
    ucdbT db = ucdb_OpenWriteStream(ucdbfile);
    create_testdata(db,ucdbfile);
    filehandle = create_filehandle(db,"test.sv");
    create_design_unit(db,"work.top",filehandle,0);
    create_instance(db,"top","work.top");
    create_statement(db,filehandle,6,1);
    create_statement(db,filehandle,8,1);
    create_statement(db,filehandle,9,1);
    create_enum_toggle(db);
    create_covergroup(db,"cg",filehandle,3);
    create_coverpoint(db,"t",filehandle,4);
    create_coverpoint_bin(db,"auto[a]",filehandle,4,1,0,"a");
    create_coverpoint_bin(db,"auto[b]",filehandle,4,1,1,"b");
    ucdb_WriteStreamScope(db);          /* terminate coverpoint */
    ucdb_WriteStreamScope(db);          /* terminate covergroup */
    ucdb_WriteStreamScope(db);          /* terminate instance */
    printf("Writing UCDB file '%s'\n", ucdbfile);
    ucdb_Close(db);
}
```

The differences required to convert the in-memory creation of data to a write-streaming creation of data are as follows:

- The open call is `ucdb_OpenWriteStream()`, which gives the name of the output file. The concept of write streaming is that it writes to the file “as it goes along”. So you have to create objects in the same order as was previously explained for read-streaming mode. This imposes order-of-creation rules that must be clearly understood. The API is designed to emit errors in case functions are used in the wrong order, but this has not yet been exposed to third-party developers for beta testing.
- The parent pointers for all creation API calls must be NULL. This emphasizes that the level of hierarchy for creating the current object relies on the current context. This will be explained more deeply below. Because no parent pointers are used, the functions in the example are all of type void – except for the `create_filehandle()` routine, because file handles must be used when needed. (In this case, because the file handle is global, it can be used with any object.
- The `ucdb_WriteStream(db)` call is used to terminate the creation of the current object. For scopes, this terminates the creation of the *beginning* of the scope. Literally, this creates the scope as a context, writes the name of the scope and other information to the file, so that subsequent objects are known to be created as children of that scope. Note that the API is actually relatively forgiving about use of `ucdb_WriteStream(db)`. It is really like a “flush” to disk. You can do the experiment of removing `ucdb_WriteStream(db)` from this example entirely, by placing this line after the include of `ucdb.h`:

```
#define ucdb_WriteStream(db) ;
```

This will still work exactly the same. The reason is that the API will flush the current object before writing the next one if you call any `ucdb_Create...` API function; it calls `ucdb_WriteStream()` implicitly. The utility of having the explicit “flush” capability of `ucdb_WriteStream()` is for cases where you are re-using string storage (as in creating objects from a loop). If you need to set up string storage in advance of calling `ucdb_CreateNextCover()`, for example, then you must flush the current object *before* calling `ucdb_CreateNextCover()`. Because the API is designed for efficiency, it does not always copy string storage; it makes use of the string value when you call `ucdb_Writestream()`, and after that you may change the value.

- The `ucdb_CreateInstanceByName()` function must be used to create the instance. This is name-based for the design unit rather than using a `ucdbScopeT` handle.
- The `ucdb_WriteStreamScope(db)` call must be used to terminate the scope. More on this in a moment.
- The `ucdb_Close(db)` function terminates the write to the file as well as freeing the database handle. This writes the summary information which has been calculated as you were writing the contents of the file.

The crucial fact of write streaming mode, besides various fairly arbitrary order-of-creation rules, is that the nesting of calls creates the design and test bench hierarchy. This means that `ucdb_WriteStreamScope(db)` is not optional. It terminates a scope. Think of write streaming mode as maintaining a “current scope”. (In fact it does.) When you create a new scope, it is added under the current scope, then it itself becomes the current scope in turn. When a coveritem is added, it is added to the current scope. When the current scope is terminated, the current scope becomes the parent of that scope (or none if that scope was itself at the top-level.) The three calls to `ucdb_WriteStreamScope(db)` in the example are thus commented with the type of the scope they terminate. If you wanted to write another coverpoint to the covergroup in the write streaming example, you would have to create it after the line commented with “// terminate coverpoint” but before the line commented with “// terminate covergroup”.

Because write streaming mode has crucial and sometimes peculiar dependencies on order of creation, it is a difficult mode to use. But it is necessary to use when you want the most seamless mode of integration with Questa, when you have code linked into Questa through an interface like VPI.

UCDB in Questa and ModelSim

This section is aimed at the (most likely professional) third-party developer who wants the most transparent integration of coverage data with Questa. This is for cases where you have a model linked with the simulation kernel through PLI, VPI, or FLI, and you want to take advantage of the coverage save command of Questa. There is a facility for installing a callback through FLI, which is the Questa/ModelSim-proprietary simulator interface. Whenever Questa executes “coverage save”, it calls your callback, whereupon you may use write-streaming mode to contribute your own data to the UCDB being saved. This requires some elementary understanding of the role the UCDB plays in the Questa architecture.

UCDB in the Tool Architecture

One common misconception about the UCDB is whether it exists as a memory image in simulation. It does not. Coverage data in simulation is intricately linked into the simulation context tree (hierarchical name-based data structure), and is only extracted on demand and written – using a wrapper around the UCDB API's write streaming mode – to disk. The UCDB only exists in memory in so-called “viewcov” mode, where there is no current facility for linking in third-party C or C++ code. So if you want to participate in the UCDB in simulation, your only choice is to install the FLI callback described in the next section and write your data in write streaming mode.

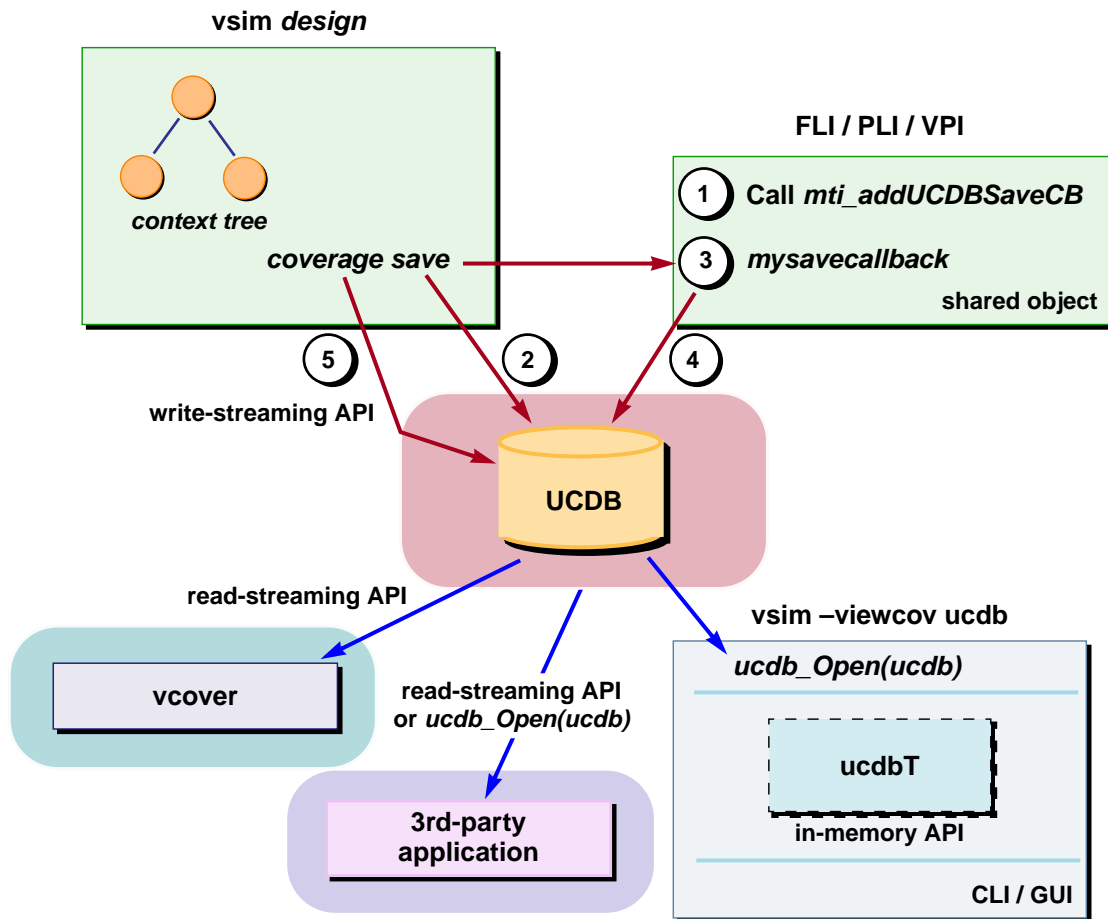
[Figure 2-23](#) illustrates the tool architecture and the callback to be discussed. In the upper left is vsim in simulation mode, i.e., invoked on a design. When coverage save is invoked, the data from the context tree is written to the UCDB using the UCDB write streaming API.

If a shared object is attached to the simulator, the UCDB save FLI callback operates in this order:

1. The callback (*mysavecallback* in this case) is installed.
2. Vsim code underlying coverage save initiates the save of the UCDB.
3. In contexts for which the callback is installed, vsim calls the callback function specified by the user.
4. The user's callback makes write streaming API calls to write data into the same UCDB.
5. The vsim code underlying *coverage save* continues to save to the UCDB file.

Steps 3 through 5 may repeat arbitrarily many times.

Figure 2-23. Questa and the UCDB Save FLI Callback



The diagram further illustrates some important facts:

- In general, the only Questa tool where a UCDB image exists in memory (illustrated here at the dashed box around “ucdbT” or a UCDB handle) is vsim in “viewcov mode” where it is invoked on a UCDB file. The file is opened in memory, and the CLI and GUI have full in-memory facilities upon which to operate on the data.
- In general, the vcover utility processes all its inputs using the read-streaming API. (There are some exceptions to this, but the most commonly used applications, report and merge, are exclusively read-streaming. Note that merge maintains its *output* in memory, but its inputs are always read-streaming.)
- A third-party application may be either read-streaming or in-memory, as the developer of the application chooses.

Using the mti_AddUCDBSaveCB FLI Callback

The example *save-callback* demonstrates use of the callback to create the 2-bin covergroup from the write-streaming example. The write-streaming code is not the interesting part of this example; that is just copied from the previous example. The interesting part is use of the callback and the interoperation of VPI and FLI (the Mentor Graphics proprietary Foreign Language Interface.)

Note that the callback is designed to work on one and only one “region” (or scope: a module instance in the example.) This means that if you have data in multiple scopes, you must install the callback multiple times. However, this means that you only need install the callback for as many scopes as you have coverage data to contribute.

The callback, as described above, is executed when the UCDB save is, either automatically at end of simulation or when the CLI is used. The example uses the CLI. (Note that if the Verilog code uses \$finish, which returns control to the operating system, the save must be set up in advance in one of various ways.)

C Example (“save-callback”):

```
/*
 * Register mymodel with simulator
 */
void register_mymodel()
{
    s_vpi_systf_data systf_data;
    systf_data.type = vpiSysFunc;
    systf_data.sysfunctype = vpiSysFuncSized;
    systf_data.tfname = "$mymodel";
    systf_data.calltf = mymodel;
    systf_data.compiletf = mymodel_setup;
    systf_data.sizetf = NULL;
    vpi_register_systf(&systf_data);
}
...
/*
 * UCDB Save Callback
 */
void
mymodel_ucdb_save(ucdbT db,
                  mtiRegionIdT region,
                  void* unused)
{
    vpi_printf("Saving UCDB data from VPI model ...\n");
    write_ucdb_data(db);
}

/*
 * Register UCDB Save Callback
 */
int mymodel_setup(char* unused)
{
    vpiHandle systf_handle, scope_handle;
```

```
char* scope_name;
mtiRegionIdT FLI_scope_handle;

/* Get name of enclosing scope through VPI */
systf_handle = vpi_handle(vpiSysTfCall,NULL);
scope_handle = vpi_handle(vpiScope,systf_handle);
scope_name = vpi_get_str(vpiFullName,scope_handle);

/* Convert to FLI region id type */
FLI_scope_handle = mti_FindRegion(scope_name);
scope_name = mti_GetRegionFullName(FLI_scope_handle);

/* Install UCDB save callback */
vpi_printf("Installing UCDB Save Callback for %s ...\n",scope_name);
mti_AddUCDBSaveCB(FLI_scope_handle,mymodel_ucdb_save,NULL);
return 0;
}
```

Note that the callback uses FLI, while the model uses VPI. Somehow an FLI scope handle (region ID) must be derived from a VPI handle. The only way to do this is by name – specifically, “full name” which is a full path to the scope. In the example, “scope_name” is “top.inst” as returned from VPI but “/top/inst” as returned from FLI. Fortunately, the two different conventions for regarding the full name are interchangeable, and the FLI scope handle is directly acquired.

The FLI scope handle (region ID) is passed to the callback “mymodel_ucdb_save” but unused in this example. There is also private data that could be used as well, though unused here. The implementation of “write_ucdb_data” should look familiar:

C Example (“save-callback”):

```
void
write_ucdb_data(ucdbT db)
{
    ucdbFileHandleT filehandle;
    filehandle = create_filehandle(db,"test.sv");
    create_covergroup(db,"cg",filehandle,3);
    create_coverpoint(db,"t",filehandle,4);
    create_coverpoint_bin(db,"auto[a]",filehandle,4,1,0,"a");
    create_coverpoint_bin(db,"auto[b]",filehandle,4,1,1,"b");
    ucdb_WriteStreamScope(db);          /* terminate coverpoint */
    ucdb_WriteStreamScope(db);          /* terminate covergroup */
}
```

This is part of the top-level code from the “write-streaming” example. The code is *exactly the same*, and the functions called are exactly the same. The most important thing to realize is that the enclosing scope – for the module instance “/top/inst” in this case – has already been started or initialized by the UCDB save code from Questa, and will be terminated by Questa, too. The context, in other words, is already assured. Any write-streaming mode UCDB API code may be used in the callback. Questa should emit errors for mis-use of the API, and those should appear in the transcript. It is not allowed to install your own UCDB API error handler with VPI, FLI, or DPI code, because the Questa kernel has already installed its own.

Questa Compatibility

These compatibility commitments are made by Questa and its implementation of the UCDB API:

- Questa release 6.2b is the base release for the UCDB and API.
- The UCDB API will load any UCDB created from the base release onward.
- The header maintains strict backward compatibility from the base release onward. This means that applications compiled against the base release will continue to compile and continue to link.
- From Questa 6.3 onward, the UCDB API is *forward link compatible*. This means that an application can be compiled with an earlier version of the `ucdb.h` and still link with a later version of the library archive or shared object (or DLL on Windows.) This allows some flexibility in dynamically linking to the UCDB API by a third-party tool whose releases may not be predictably synchronized with Questa's.
- Questa does not commit to backward compatibility with respect to data models. This means that some applications may require changes when significant portions of the data model change. Examples include the change to the covergroup data model with 6.4, or the addition of an additional level of expression and condition hierarchy to capture UDP vs. FEC coverage in 6.4.

This last is an important point. Complete backward compatibility of the API is not the same as complete backward compatibility of the data model. API compatibility means that an earlier application will continue to compile and link. However, if it makes critical assumptions about the data model that are no longer met, the application will not continue to work as expected.

This allows some flexibility to change data models in the tool. It also reflects the reality that it is difficult to know what assumptions an application might make. Some applications may be sufficiently general that they always continue to work; others may not. Until data models are standardized and can be verified to conform to the standard, the UCDB API developer should be prepared to make occasional changes to an application when data models change. This is expected to be a relatively uncommon case, but it has already happened in the transition from Questa 6.3 to 6.4.

Chapter 3

UCDB API Functions

The UCDB API functions are defined in the following function groups:

- [Source Files](#)
- [Error Handler](#)
- [Tests](#)
- [Databases and Database Files](#)
- [User-specified Attributes](#)
- [Scopes](#)
- [Coverage and Statistics Summaries](#)
- [Coveritems](#)
- [Toggles](#)
- [Groups](#)
- [Tags](#)
- [Formal Data](#)
- [Test Traceability](#)

Source Files

Every UCDB object can potentially have a source file name stored with it. Different applications have different requirements for how these are stored. Consequently, the UCDB contains an object called a "file handle", which provides a way of storing indirect references to file names.

Simple Use Models

If you don't care about file names and line numbers at all, you can create objects with NULL for the `ucdbSourceInfoT` argument, e.g.:

```
mycover = ucdb_CreateNextCover(db,parent,name,&coverdata,NULL);
```

Alternatively, you can create a file and store it with the object.

```
ucdbSourceInfoT sourceinfo;
status = ucdb_CreateSrcFileHandleByName(
    db,
    &source_info.filehandle,
    NULL,
    filename,
    fileworkdir);
source_info.line = myline;
source_info.token = mytoken;
(void) ucdb_CreateNextCover(db,parent,name,&coverdata,&sourceinfo);
```

This method creates a single global look-up table for file names within the UCDB. File names are stored efficiently for each object within the UCDB, and each unique file name string is stored only once. Whichever means are used to store file names, you can always access the file name, for example:

```
ucdbSourceInfoT sourceinfo;
ucdb_GetCoverData(db,parent,i,&name,&coverdata,&sourceinfo);
if (sourceinfo.filehandle != NULL) {
    printf("File name is %s\n",
        ucdb_GetFileName(db,&sourceinfo.filehandle));
}
```

Scope Handle

```
typedef void* ucdbScopeT;
```

Scope handle.

Object Handle

```
typedef void* ucdbObjT;
```

Either `ucdbScopeT` or `ucdbTestT`.

File Handle

```
typedef void* ucdbFileHandleT;
```

File handle.

Source Information Type

```
typedef struct {
    ucdbFileHandleT    filehandle;
    int                line;
    int                token;
} ucdbSourceInfoT;
```

Source information for database objects

ucdb_CreateSrcFileHandleByName

```
int ucdb_CreateSrcFileHandleByName(
    ucdbT          db,
    ucdbFileHandleT* filehandle,
    ucdbScopeT     scope,
    const char*    filename,
    const char*    fileworkdir);
```

db	Database.
filehandle	Filehandle returned.
scope	File table scope, or NULL for the global table.
filename	Absolute or relative file name to look up in table.
fileworkdir	Work directory for the file when filename is a path relative to fileworkdir. Ignored if filename is an absolute path.

Creates a file handle for the specified file, from the file table associated with the given scope. If filename is not found, it is added to the file table for the given scope. Returns 0 if successful, or -1 if error and ucdb_IsValidFileHandle(returnvalue) == 0 if error.

ucdb_CreateFileHandleByNum

```
int ucdb_CreateFileHandleByNum(
    ucdbT          db,
    ucdbFileHandleT* filehandle,
    ucdbScopeT     scope,
    int            filenum);
```

db	Database.
filehandle	Filehandle returned.
scope	File table scope, or NULL for the global table.

filenum Offset of the file in the file table.

Creates a file handle for the specified offset into the file table of the specified scope. Returns 0 if successful, or -1 if error (for example, if filenum is out of bounds or no file table exists for the scope) and `ucdb_IsValidFileHandle(returnvalue) == 0` if error.

ucdb_CloneFileHandle

```
int ucdb_CloneFileHandle(
    ucdbT          db,
    ucdbFileHandleT* filehandle,
    ucdbFileHandleT* origfilehandle,
    int            filenum);
```

db	Database.
filehandle	Filehandle returned.
origfilehandle	Filehandle to clone.
filenum	Offset to the new file in the file table.

Creates a file handle cloned from the specified file handle, at the specified offset, in the same table as the cloned file. The file number (offset) must be in bounds for the file table. Returns 0 if successful, or -1 if error.

ucdb_CreateNullFileHandle

```
int ucdb_CreateNullFileHandle(
    ucdbFileHandleT* filehandle);
```

filehandle	Null filehandle returned.
------------	---------------------------

Creates a new file handle. Returns 0 if successful, or -1 if error and `ucdb_IsValidFileHandle(filehandle) == 0`.

ucdb_IsValidFileHandle

```
int ucdb_IsValidFileHandle(
    ucdbT          db,
    ucdbFileHandleT* filehandle);
```

db	Database.
filehandle	Filehandle to test.

Checks whether or not the specified filehandle returned by a UCDB function is valid. Use this function for non-callback-based error-checking. Returns 1 if file handle is valid, or 0 if invalid.

ucdb_GetFileName

```
const char* ucdb_GetFileName(
    ucdbT          db,
    ucdbFileHandleT* filehandle);
```

db	Database.
filehandle	File handle.

Returns the file name of the file specified by filehandle, or NULL if error. This function tries to reconstruct a valid file path from the file handle and the directory stored with it and the UCDB. In the following algorithm, *filename* and *fileworkdir* refer to the corresponding arguments of `ucdb_CreateSrcFileHandleByName()` or `ucdb_SrcFileTableAppend()`:

```
if (filename is an absolute path) return the path name
else (filename is a relative path)
    if (filename exists at the relative path)
        return filename
    else if (filename exists relative to fileworkdir)
        return workdir/fileworkdir
    else if (filename exists relative to the the value of the environment
        variable MGC_WD)
        return $MGC_WD/filename
    else if (filename exists relative to the directory from which the
        UCDB file was opened -- i.e., the directory extracted from the
        file given to ucdb_Open() or equivalent)
        return that dir/filename
    else if (filename exists relative to the directory extracted from the
        ORIGFILENAME attribute of the first test record -- i.e.,
        representing the file into which the UCDB was originally saved)
        return that dir/filename
    else return filename.
```

If the filename was created as an absolute path, it must be correct. Otherwise only the last case indicates that the file was not found, and the original filename is returned for lack of anything better.

ucdb_GetFileNum

```
int ucdb_GetFileNum(
    ucdbT          db,
    ucdbFileHandleT* filehandle);
```

db	Database.
filehandle	File handle.

Returns the file number of the file specified by filehandle, or -1 if error.

ucdb_GetFileTableScope

```
ucdbScopeT ucdb_GetFileTableScope(  
    ucdbT          db,  
    ucdbFileHandleT* filehandle);
```

db	Database.
filehandle	File handle.

Returns the scope of the table of the file specified by filehandle. Returns NULL if the specified file handle is not valid or if the table is the global file table. Also calls an error handler (if installed) when the file handle is not valid.

ucdb_SrcFileTableAppend

```
int ucdb_SrcFileTableAppend(  
    ucdbT          db,  
    ucdbFileHandleT* filehandle,  
    ucdbScopeT     scope,  
    const char*     filename,  
    const char*     fileworkdir);
```

db	Database.
filehandle	Filehandle returned.
scope	File table scope, or NULL for the global table.
filename	Absolute or relative file name to look up in table.
fileworkdir	Work directory for the file when filename is a path relative to fileworkdir. Ignored if filename is an absolute path.

Creates a file handle for the specified file, from the file table associated with the given scope. The filename is added to the file table for the given scope, so the filename is assumed to be unique. To check for duplicate file names, use ucdb_CreateSrcFileHandleByName. Returns 0 if successful, or -1 if error and ucdb_IsValidFileHandle(returnvalue) == 0 if error.

ucdb_FileTableSize

```
int ucdb_FileTableSize(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
scope	File table scope, or NULL for the global table.

Returns the number of files in the file table associated with the specified scope, or -1 if error.

ucdb_FileTableName

```
const char* ucdb_FileTableName(  
    ucdbT          db,  
    ucdbScopeT     scope  
    int            index);
```

db	Database.
scope	File table scope, or NULL for the global table.
index	File table index of the file.

Returns the name of the file with the specified index in the file table for the specified scope, or NULL if error.

ucdb_FileTableRemove

```
int ucdb_FileTableRemove(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    const char*     filename);
```

db	Database.
scope	File table scope, or NULL for the global table.
filename	File to remove from the table, or NULL for the whole table.

No effect in streaming modes. Removes the specified file from the file table for the specified scope (or the entire table if filename is NULL). Returns 0 if successful, or -1 if error.

ucdb_FileInfoToString

```
const char* ucdb_FileInfoToString(  
    ucdbT          db,  
    ucdbSourceInfoT* source_info);
```

db	Database.
file_info	Source file information handle.

Returns a string representation of the file handle in the specified ucdbSourceInfoT item, or NULL if error. This is equivalent to calling:

```
ucdb_GetFileName(db, &source_info->filehandle)
```

The returned string only remains valid until the next call of this routine. To be used, the user must copy the returned string before the next call to this function.

Error Handler

The most convenient error-handling mode is to use `ucdb_RegisterErrorHandler()` before any UCDB calls. The user's error callback, a function pointer of type `ucdb_ErrorHandler`, is called for any error produced by the system.

Alternatively, function return values can be checked. In general, functions that return a handle return NULL (or invalid handle) on error (they return the handle otherwise). Functions that return an int return non-zero on error (0 otherwise).

Message Severity Type

```
typedef enum {  
    UCDB_MSG_INFO,  
    UCDB_MSG_WARNING,  
    UCDB_MSG_ERROR  
} ucdbMsgSeverityT;
```

Error Type

```
typedef struct ucdbErr_s {  
    int msgno; /* Message identifier */  
    ucdbMsgSeverityT severity; /* Message severity */  
    const char* msgstr; /* Raw message string */  
} ucdbErrorT;
```

Error Handler

```
typedef void (*ucdb_ErrorHandler) (void* userdata, ucdbErrorT* errdata);
```

ucdb_RegisterErrorHandler

```
void ucdb_RegisterErrorHandler(  
    ucdb_ErrorHandler errHandle,  
    void* userdata);
```

<code>errHandle</code>	Error handler handle.
<code>userdata</code>	User-specified data for the error handler.

Registers the specified error handler that is called whenever an API error occurs.

ucdb_IsModified

```
int ucdb_IsModified(  
    ucdbT db);
```

<code>db</code>	Database.
-----------------	-----------

Returns 1 if the database was modified after it was loaded into memory, or 0 if error.

ucdb_ModifiedSinceSim

```
int ucdb_ModifiedSinceSim(  
    ucdbT      db);
```

db Database.

Returns 1 if the database was modified after it was saved from the simulation, or 0 if error. For merged databases, if all the input databases are unmodified, the merged output is unmodified. Otherwise if any file is modified, the output database is modified.

ucdb_SuppressModified

```
int ucdb_SuppressModified(  
    ucdbT      db  
    int        yes);
```

db Database.

If yes is 1, additional changes to the specified database *do not* “modify” the database. If yes is 0, changes to the specified database *do* “modify” the database. This function suppresses both the in-memory-modified flag and the modified-since-simulation flag, so both the functions `ucdb_IsModified()` and `ucdb_ModifiedSinceSim()` return 0 if a change is made while the modify flags are suppressed.

Tests

If a UC database was created as a result of a single test run, the database has a single test data record associated with it. If it was created as a result of a test merge operation, the UC database should have multiple sets of test data. The functions defined in this section can be used to create sets of test data. Each test data record should be associated with the name of the UC database file in which the database was first stored.

For efficiency, history nodes (`ucdbHistoryNodeT`) and associated functions use different test records for different situations (like merging) (rather than creating the same or similar test record for each database operation). Test data record nodes (`ucdbTestStatusT`) are a subset of history nodes.

Test Type

```
typedef ucdbHistoryNodeT ucdbTestT;
```

Test Status Type

```
typedef enum {
    UCDB_TESTSTATUS_OK,
    UCDB_TESTSTATUS_WARNING,          /* test warning ($warning called) */
    UCDB_TESTSTATUS_ERROR,           /* test error ($error called) */
    UCDB_TESTSTATUS_FATAL,           /* fatal test error ($fatal called) */
    UCDB_TESTSTATUS_MISSING,         /* test not run yet */
    UCDB_TESTSTATUS_MERGE_ERROR      /* testdata record was merged with
                                     inconsistent data values */
} ucdbTestStatusT;
```

History Node Types

```
typedef void* ucdbHistoryNodeT;
```

History Node Kind Types

```
typedef enum {
    UCDB_HISTORYNODE_NONE,           /* no node or error */
    UCDB_HISTORYNODE_MERGE,          /* interior merge node */
    UCDB_HISTORYNODE_TEST,           /* test leaf node */
    UCDB_HISTORYNODE_TESTPLAN,       /* test plan leaf node */
} ucdbHistoryNodeKindEnumT;
```

ucdb_AddTest

```
ucdbTestT ucdb_AddTest(
    ucdbT          db,
    const char*    filename,          /* ORIGFILENAME    */
    const char*    testname,          /* TESTNAME        */
    ucdbTestStatusT test_status,      /* TESTSTATUS      */
    double         simtime,           /* SIMTIME         */
    const char*    simtime_units,     /* TIMEUNIT        */
    double         realtime,          /* CPUTIME         */
    const char*    seed,              /* SEED            */
    const char*    command,           /* TESTCMD         */
    const char*    simargs,           /* VSIMARGS        */
    const char*    comment,           /* TESTCOMMENT     */
    int            compulsory,        /* COMPULSORY      */
    const char*    date,              /* DATE            */
    const char*    userid);           /* USERNAME        */
```

db	Database to hold the test.
filename	Name of UCDB file to which the database was saved.
testname	Test name. Must be unique for each test run.
test_status	Test status.
simtime	Simulation run time of test (in simtime_units).
simtime_units	Simulation time units.
realtime	CPU run time of test.
seed	Randomization seed used for the test.
command	Test script arguments.
simargs	Simulator arguments.
comment	User-specified comment.
compulsory	1 if a required test, or 0 if not.
date	Time of start of simulation, specified as a string. Output of <i>strftime</i> with format "%Y%m%d%H%M%S", for example, 4:00:30 PM January 5, 2008 is coded as "20080105160030".
userid	ID of the user who created the file.

Adds the specified test data to the database. Used to capture a single set of data from a test's coverage results saved to a UCDB from simulation. The filename must be the name of the file that later will be saved. The filename is given explicitly to aid in copying test data records. Returns a new test handle, or NULL if error.

ucdb_AddPotentialTest

```
ucdbTestT ucdb_AddPotentialTest(
    ucdbT      db,
    const char* testname);
```

db	Database to hold the test.
testname	Test name. Must be unique for each test run.

Adds a test data record with the specified test name and test_status of UCDB_TESTSTATUS_MISSING. All other fields have invalid values. Used to tag a test data record for tests not yet run. Returns a new test handle, or NULL if error.

ucdb_GetTestData

```
int ucdb_GetTestData(
    ucdbT      db,
    ucdbTestT  test,
    const char** filename,      /* ORIGFILENAME */
    const char** testname,      /* TESTNAME */
    ucdbTestStatusT* test_status, /* TESTSTATUS */
    double*     simtime,        /* SIMTIME */
    const char** simtime_units, /* TIMEUNIT */
    double*     cputime,        /* CPUTIME */
    const char** seed,          /* SEED */
    const char** command,       /* TESTCMD */
    const char** simargs,       /* VSIMARGS */
    const char** comment,       /* TESTCOMMENT */
    int*        compulsory,     /* COMPULSORY */
    const char** date,          /* DATE */
    const char** userid);       /* USERNAME */
```

db	Database.
test	Test.
filename	Name of UCDB file first associated with the test.
testname	Test name.
test_status	Test status.
simtime	Simulation run time of test (in simtime_units).
simtime_units	Simulation time units.
realtime	CPU run time of test.
seed	Randomization seed used for the test.
command	Test script arguments.
simargs	Simulator arguments.
comment	User-specified comment.

compulsory	1 if a required test, or 0 if not.
date	Time of start of simulation, specified as a string. Output of <i>strftime</i> with format "%Y%m%d%H%M%S", for example, 4:00:30 PM January 5, 2008 is coded as "20080105160030".
userid	ID of the user who created the file.

Gets the data for the specified test in the specified database. Allocated values (strings, date and attributes) must be copied if the user wants them to persist. Returns 0 if successful, or non-zero if error.

ucdb_GetTestName

```
const char* ucdb_GetTestName(  
    ucdbT      db,  
    ucdbTestT  test);
```

db	Database.
test	Test.

Returns the test name for the specified test handle from the specified opened database, or NULL if error.

ucdb_NextTest

```
ucdbTestT ucdb_NextTest(  
    ucdbT      db,  
    ucdbTestT  test);
```

db	Database.
test	Test or NULL for first test handle.

Returns the next (or first) test handle from the specified opened database, or NULL if error.

ucdb_CloneTest

```
ucdbTestT ucdb_CloneTest(  
    ucdbT      targetdb,  
    ucdbTestT  test,  
    ucdbSelectFlagsT cloneflags);
```

targetdb	Target database for the cloned test.
test	Source test.
cloneflags	UCDB_CLONE_ATTRS (to clone attributes) or 0 (to omit attributes).

No effect if targetdb is in streaming mode. Creates an exact copy of the specified test record. Returns handle to the cloned test, or NULL if error.

ucdb_RemoveTest

```
int ucdb_RemoveTest(  
    ucdbT          db,  
    ucdbTestT      test);
```

db	Database.
test	Test.

No effect if db is in streaming mode. Removes the specified test from the database. Returns 0 if successful, or -1 if error.

ucdb_NumTests

```
int ucdb_NumTests(  
    ucdbT          db);
```

db	Database.
----	-----------

Reliable with in-memory mode but only works in streaming mode after all test records are read or written. Returns the number of tests associated with the specified database, or -1 if error (for example, if the value cannot be calculated yet in streaming mode).

ucdb_CreateHistoryNode

```
ucdbHistoryNodeT ucdb_CreateHistoryNode(  
    ucdbT          db,  
    char*          path,  
    ucdbHistoryNodeKindEnumT kind);
```

db	Database.
path	Testplan path. Must be a valid pathname (cannot be NULL). Set to merge file pathname if kind is UCDB_HISTORYNODE_MERGE, otherwise, set to file pathname.
kind	History node kind.

Creates a history node of the specified kind in the specified database. History node has default values of path for FILENAME and the current execution directory for RUNCWD. Returns handle to the created history node, or NULL if error or if node already exists. Returned node is owned by the routine and should not be freed by the caller.

ucdb_AddHistoryNodeChild

```
int ucdb_AddHistoryNodeChild(  
    ucdbT db,  
    ucdbHistoryNodeT parent,  
    ucdbHistoryNodeT child);
```

db	Database.
parent	Parent history node.
child	Child history node.

Sets the specified node to be a child node of the specified parent node. Each history node appears exactly once in the history trees. In particular, every child can have at most one parent; once `ucdb_AddHistoryNodeChild` assigns a parent to a child, the child cannot be reassigned to a different parent; and a child node cannot be (directly or indirectly) its own parent. Returns non-zero if successful, or 0 if error.

ucdb_NextHistoryNode

```
ucdbHistoryNodeT ucdb_NextHistoryNode(  
    ucdbT db,  
    ucdbHistoryNodeT historynode,  
    ucdbHistoryNodeKindEnumT kind);
```

db	Database.
historynode	History node or NULL.
kind	History node kind.

Returns the next history node of the same kind as the specified history node, or if historynode is NULL, returns the first history node of the specified kind. Returns NULL if error or if node does not exist. History node “order” is vendor specific. Returned node is owned by the routine and should not be freed by the caller.

ucdb_HistoryRoot

```
ucdbHistoryNodeT ucdb_HistoryRoot(  
    ucdbT db);
```

db	Database.
----	-----------

Returns the unique history node that has no parent, or NULL if error or if multiple roots exist. Returned node is owned by the routine and should not be freed by the caller. This routine assumes that only one history node is defined.

ucdb_NextHistoryRoot

```
ucdbHistoryNodeT ucdb_NextHistoryRoot(  
    ucdbT db,  
    ucdbHistoryNodeT historynode,  
    ucdbHistoryNodeKindEnumT kind);
```

db	Database.
historynode	History node or NULL.
kind	History node kind.

Returns the next orphan (parentless) history node of the same kind as the specified history node, or if historynode is NULL, returns the first orphan history node of the specified kind. Returns NULL if node does not exist. History node “order” is vendor specific. Returned node is owned by the routine and should not be freed by the caller. This routine assumes multiple history roots are possible (i.e., a collection subtree orphans).

ucdb_NextHistoryLookup

```
ucdbHistoryNodeT ucdb_NextHistoryLookup(  
    ucdbT db,  
    ucdbHistoryNodeT historynode,  
    const char* attributekey,  
    const char* attributevalue,  
    ucdbHistoryNodeKindEnumT kind);
```

db	Database.
historynode	History node or NULL.
attributekey	UCDB_ATTR_STRING attribute key.
attributevalue	Attribute value.
kind	History node kind.

Returns the next history node of the same kind as the specified history node that has an attribute matching the specified key/value pair, or if historynode is NULL, returns the first history node of the specified kind that has an attribute matching the specified key/value pair. Returns NULL if error or if node does not exist. History node “order” is vendor specific. Returned node is owned by the routine and should not be freed by the caller.

ucdb_GetHistoryNodeParent

```
ucdbHistoryNodeT ucdb_GetHistoryNodeParent(  
    ucdbT          db,  
    ucdbHistoryNodeT child);
```

db	Database.
----	-----------

child	History node.
-------	---------------

Returns the parent of the specified history node, or NULL if error or if specified node is a root node. Returned node is owned by the routine and should not be freed by the caller.

ucdb_GetNextHistoryNodeChild

```
ucdbHistoryNodeT ucdb_GetNextHistoryNodeChild(  
    ucdbT          db,  
    ucdbHistoryNodeT parent,  
    ucdbHistoryNodeT child);
```

db	Database.
----	-----------

parent	Parent history node.
--------	----------------------

child	Child history node or NULL.
-------	-----------------------------

Returns the next history node after the specified child history node, or if child is NULL, returns the first history node of the specified parent history node. Returns NULL if error or if next node does not exist. History node “order” is vendor specific. Returned node is owned by the routine and should not be freed by the caller.

ucdb_CloneHistoryNode

```
ucdbHistoryNodeT ucdb_CloneHistoryNode(  
    ucdbT          targetdb,  
    ucdbT          sourcedb,  
    ucdbHistoryNodeT historynode);
```

targetdb	Target database for the copied node.
----------	--------------------------------------

sourcedb	Source database containing the node to copy.
----------	--

historynode	History node to copy.
-------------	-----------------------

Creates an exact copy (including attributes) of the specified history node. Returns the history node for the copy, or NULL if error or if the target history node exists.

ucdb_GetHistoryKind

```
ucdbScopeTypeT ucdb_GetHistoryKind(  
    ucdbT          db,  
    ucdbScopeT     object);
```

db	Database.
----	-----------

object	Object.
--------	---------

Polymorphic function (aliased to `ucdb_GetObjType`) for acquiring an object type. Returns `UCDB_HISTORYNODE_TEST` (object is a test data record), `UCDB_HISTORYNODE_TESTPLAN` (object is a test plan record), `UCDB_HISTORYNODE_MERGE` (object is a merge record), scope type `ucdbScopeTypeT` (object is not of these), or `UCDB_SCOPE_ERROR` if error. This function can return a value with multiple bits set (for history data objects). Return value *must not be used* as a mask.

ucdb_CalculateHistorySignature

```
char* ucdb_CalculateHistorySignature(  
    ucdbT          db,  
    char*          file);
```

db	Database.
----	-----------

file	File.
------	-------

Returns a history signature of the specified file, or NULL if error. The returned string is owned by the routine and must not be freed by the caller. If a file's contents remain unmodified, recalculating the file's history signature produces the same results. Conversely, when the file is modified, the resulting signature will also be changed. Use this mechanism to check whether or not a file has become "dirty".

Databases and Database Files

A UCDB database exists in two forms: an in-memory image accessible with a database handle, and a persistent form on the file system. There are *read streaming* and *write streaming* modes that minimize the memory usage in the current process. These streaming modes keep only a small “window” of data in memory; and once you have moved onward in reading or writing, you cannot revisit earlier parts of the database. Random access is not possible.

You use the functions defined in this section to run the following operations:

- Opening a file and creating an in-memory image.

Reading from a persistent database and creating an in-memory image are combined in the same function: `ucdb_Open()`, which always creates a valid database handle. If a filename is given to `ucdb_Open()`, the in-memory image is populated from the persistent database in the named file.

Some parts of the data model can be accessed without fully populating the in-memory data image, if and only if no other calls have been made since `ucdb_Open()` that require accessing the in-memory image. In particular, the following data can be accessed in constant time regardless of the size of the UCDB:

- `ucdb_CalcCoverageSummary` (`scope==NULL` and `test_mask==NULL`)
- `ucdb_GetCoverage`
- `ucdb_GetStatistics`
- `ucdb_GetMemoryStats`
- Writing to a file from an in-memory image.

This operation can be performed at any time with the `ucdb_Write()` function. This function transfers all of (or a subset of) the in-memory image to the named persistent database file, overwriting the file if it previously existed.

- Deleting the in-memory image.

This operation is done with the `ucdb_Close()` function. After this call, the database handle is no longer valid.

- Using write streaming mode.

To create a UCDB with minimal memory overhead, use `ucdb_OpenWriteStream()` to create a UCDB handle whose use is restricted. In particular, objects must be created in the following prescribed order:

- a. Create UCDB attributes first. Creating UCDB attributes at the beginning of the file is not enforced to allow the case of UCDB attributes created at the end of the output (which might be necessary for attributes whose values must be computed as a result of traversing the data during write).

- b. Create TestData.
- c. Create scopes. Creating DU scopes before corresponding instance scopes. If a scope contains coverage items, create those first. If a scope contains child scopes, create those after coveritems.

There are other restrictions as well; see comments for individual functions. For example, accessing immediate ancestors is OK, but accessing siblings is not (nor is it OK to access an ancestor's siblings).

The function `ucdb_WriteStream()` must be used in write streaming mode to finish writing a particular object. The function `ucdb_WriteStreamScope()` must be used to finish writing a scope and to resume writing the parent scope. In write streaming mode, the `ucdb_Close()` function must be used to finish the file being written to and to free any temporary memory used for the database handle.

- Using read streaming mode

The read streaming mode operates with callbacks. The persistent database is opened with a `ucdb_OpenReadStream()` call that passes control to the UCDB system which then initiates callbacks to the given callback function. Each callback function returns a "reason" that identifies the data valid for the callback and enough information to access the data. Note the following information on read streaming mode callback order:

- a. INITDB is always the first callback.
- b. UCDB attributes created first in write streaming mode are available, as are UCDB attributes created with in-memory mode.
- c. All TEST callbacks follow; after the next non-TEST callback there will be no more TEST callbacks.
- d. DU callbacks must precede their first associated instance SCOPE callbacks, but need not immediately precede them.
- e. SCOPE, DU and CVBIN callbacks can occur in any order, except for the DU before first instance rule—although nesting level is implied by the order of callbacks.
- f. ENDSCOPE callbacks correspond to SCOPE and DU callbacks and imply a "pop" in the nesting of scopes and design units.
- g. ENDDDB callbacks can be used to access UCDB attributes written at the end of the file, if created in write streaming modes.

- Opening UCDB in streaming mode to read data through callbacks without creating an in-memory database.

Use the `ucdb_OpenReadStream()` read API to open a UCDB in stream mode with a callback function of type `ucdb_CBFuncT` along with user data (which can be NULL). The callback function is called for all UCDB objects present in the database, with an object of type `ucdbCBDataT` with the user data.

Callback Reason Type

```
typedef enum {
    UCDB_REASON_INITDB,          /* Start of the database,
                                apply initial settings */
    UCDB_REASON_DU,             /* Start of a design unit scope */
    UCDB_REASON_TEST,           /* Testplan object */
    UCDB_REASON_SCOPE,          /* Start of a scope object */
    UCDB_REASON_CVBIN,          /* Cover item */
    UCDB_REASON_ENDSCOPE        /* End of a scope,
                                including design units */
    UCDB_REASON_ENDDDB,         /* End of database (database handle
                                still valid) */
    UCDB_REASON_PLANHISTORY,     /* Testplan history object */
    UCDB_REASON_MERGEHISTORY     /* Merge history object */
} ucdbCBReasonT;
```

Callback Return Type

```
typedef enum {
    UCDB_SCAN_CONTINUE = -1,    /* Continue to scan ucdb file */
    UCDB_SCAN_STOP = -2,        /* Stop scanning ucdb file */
    UCDB_SCAN_PRUNE = -3        /* Prune the scanning of the ucdb file at
                                this node. Scanning continues but
                                ignores processing of this node's
                                children. NOTE: This enum value is
                                currently disallowed in read
                                streaming mode. */
} ucdbCBReturnT;
```

Read Callback Data Type

```
typedef struct ucdbCBDataS {
    ucdbCBReasonT reason;        /* Reason for this callback */
    ucdbT db;                   /* Database handle, to use in APIs */
    ucdbObjT obj;               /* ucdbScopeT or ucdbTestT */
    int coverindex;             /* If UCDB_REASON_CVBIN, index of
                                coveritem */
} ucdbCBDataT;
```

Function Type for Use with ucdb_OpenReadStream()

```
typedef ucdbCBReturnT (*ucdb_CBFuncT) \
    (void* userdata, ucdbCBDataT* cbdata);
```

ucdb_Open

```
ucdbT ucdb_Open(
    const char* name);
```

name	File system path.
------	-------------------

Creates an in-memory database, optionally populating it from the specified file. Returns a database handle if successful, or NULL if error.

ucdb_OpenReadStream

```
int ucdb_OpenReadStream(  
    const char*   name,  
    ucdb_CBFuncT cbfunc,  
    void*         userdata);
```

name	File system path.
cbfunc	User-supplied callback function.
userdata	User-supplied function data.

Opens a database for streaming read mode from the specified file. Returns 0 if successful, or -1 if error.

ucdb_OpenWriteStream

```
ucdbT ucdb_OpenWriteStream(  
    const char* name);
```

name	File system path (write permission must exist for the file).
------	--

Opens data in write streaming mode, overwriting the specified file. Returns a restricted database handle if successful, or NULL if error.

ucdb_WriteStream

```
int ucdb_WriteStream(  
    ucdbT db);
```

db	Database.
----	-----------

Finishes a write of current object to the persistent database file in write streaming mode. This operation is like a *flush*, which completes the write of whatever was most recently created in write streaming mode. Multiple `ucdb_WriteStream()` calls cause no harm because if the current object has already been written, it is not be written again. The specified database handle must have been previously opened with `ucdb_OpenWriteStream()`. Returns 0 if successful, or -1 if error.

ucdb_WriteStreamScope

```
int ucdb_WriteStreamScope(  
    ucdbT db);
```

db	Database.
----	-----------

Finishes a write of the current scope (similar to the *flush* operation of `ucdb_WriteStream`) and *pops* the stream to the parent scope. (i.e., terminates the current scope and reverts to its parent). Objects created after this belong to the parent scope of the scope just ended. Unlike `ucdb_WriteStream`, this function cannot be called benignly multiple times as it always causes a

reversion to the parent scope. This process is the write streaming analogue of the UCDB_REASON_ENDSCOPE callback in read streaming mode. The specified database handle must have been previously opened with `ucdb_OpenWriteStream()`. Returns 0 if successful, or -1 if error.

ucdb_Write

```
int ucdb_Write(
    ucdbT      db,
    const char* file,
    ucdbScopeT scope,
    int        recurse,
    int        covertype);
```

db	Database. The database handle "db" cannot have been opened for one of the streaming modes.
file	File name (write permission must exist for the file).
scope	Scope or NULL if all objects.
recurse	Non-recursive if 0. If non-zero, recurse from specified scope or ignored if scope==NULL.
covertype	Cover types (see “Cover Types” on page 158) to save or -1 for everything.

Copies the entire in-memory database or the specified subset of the in-memory database to a persistent form stored in the specified file, overwriting the specified file. Returns 0 if successful, or -1 if error.

ucdb_Close

```
int ucdb_Close(
    ucdbT      db);
```

db	Database.
----	-----------

Invalidates the specified database handle and frees all memory associated with the handle, including the in-memory image of the database, if not in one of the streaming modes. If db was opened with `ucdb_OpenWriteStream()`, this functional call has the side-effect of closing the output file. Returns 0 if successful, or non-zero if error.

ucdb_DBVersion

```
int ucdb_DBVersion(
    ucdbT      db);
```

db	Database.
----	-----------

Returns integer version of the API library, or a negative value if error. If the database handle was created from a file (i.e., `ucdb_Open` with non-NULL file name or `ucdb_OpenReadStream`) this call returns the version of the database file itself. That is, the version of the API that originally created the file. Otherwise, (i.e., `ucdb_Open` with NULL filename or `ucdb_OpenWriteStream`), this function is the same as `ucdb_APIVersion()`.

ucdb_APIVersion

```
int ucdb_APIVersion();
```

Returns the current integer version of the API library. For a file to be readable:

```
ucdb_APIVersion() @>= ucdb_DBVersion(db)
```

ucdb_SetPathSeparator

```
int ucdb_SetPathSeparator(  
    ucdbT      db,  
    char        separator);
```

db Database.

separator Path separator.

Sets the path separator for the specified database. See “[ucdb_GetScopeHierName](#)” on page 140, “[ucdb_MatchCallBack](#)” on page 148, “[ucdb_MatchCallBack](#)” on page 148 and “[ucdb_MatchCallBack](#)” on page 148. The path separator is stored with the persistent form of the database. Returns 0 if successful, or -1 if error.

ucdb_GetPathSeparator

```
char ucdb_GetPathSeparator(  
    ucdbT      db);
```

db Database.

Returns the path separator for the specified database, or “0” if error.

ucdb_Filename

```
const char* ucdb_Filename(  
    ucdbT      db);
```

db Database.

Returns the file name from which the specified database was read or the most recent file name written, or NULL if none.

User-specified Attributes

User-defined attributes are associated with objects in the database—scopes, coveritems, or tests—or with the database itself (global attributes). They are key-value pairs that can be traversed or looked up by key. Key/value string storage is maintained by the API. With *set* routines (which add key/value pairs), passed-in strings are copied to storage maintained by the API. You must not de-allocate individual strings returned by the API. On reading from or writing to memory, values returned are always owned by the API. They are good until the next call. The memory for keys is always good.

For attributes of coveritems, the coveritems are identified by a combination of the parent scope handle (pointer) and an integer index for the coveritem. To use the attribute functions for a scope only, the integer index must be set to -1. For history node objects, the index must always be -1. If a function is given an attribute handle, if that handle is of type UCDB_ATTR_ARRAY, then the index must be a value from 0 to *array size - 1*. The array size may be queried using the `ucdb_AttrArraySize()` function. If the attribute handle is of type UCDB_ATTR_HANDLE, then the index must be -1.

Attribute Type

```
typedef enum {
    UCDB_ATTR_INT,
    UCDB_ATTR_FLOAT,
    UCDB_ATTR_DOUBLE,
    UCDB_ATTR_STRING,
    UCDB_ATTR_MEMBLK,
    UCDB_ATTR_INT64,
    UCDB_ATTR_HANDLE, /* Refers to other attributes: for nesting */
    UCDB_ATTR_ARRAY   /* Handle used to refer to an attribute array */
} ucdbAttrTypeT;
```

Attribute Value Type

```
typedef struct {
    ucdbAttrTypeT type; /* Value type */
    union {
        int64_t i64value /* 64-bit integer value */
        int ivalue; /* Integer value */
        float fvalue; /* Float value */
        double dvalue; /* Double value */
        const char* svalue; /* String value */
        struct {
            int size; /* Size of memory block, number of bytes */
            unsigned char* data; /* Starting address of memory block */
        } mvalue;
        ucdbAttrHandleT attrhandle; /* for HANDLE and ARRAY */
    } u;
} ucdbAttrValueT;
```

ucdb_AttrGetNext

```
const char* ucdb_AttrGetNext(  
    ucdbT          db,  
    ucdbObjT       obj,  
    int            coverindex,  
    const char*    key,  
    ucdbAttrValueT** value);
```

db	Database.
obj	Object type: ucdbScopeT, ucdbHistoryNodeT, or NULL (for global attribute).
coverindex	Index of coveritem. If obj is ucdbScopeT, specify -1 for scope.
key	Previous key or NULL to get the first attribute.
value	Attribute value returned.

Returns the next attribute key and gets the corresponding attribute value from the specified database object, or returns NULL when done traversing attributes. Do not use free or strdup on keys. Memory for the returned key is owned by the API. To preserve the old key, just use another char* variable for it. For example, to traverse the list of attributes for a scope:

```
const char* key = NULL;  
ucdbAttrValueT* value;  
while (key = ucdb_AttrGetNext(db,obj,-1,key,&value)) {  
    printf("Attribute '%s' is ", key);  
    print_attrvalue(value);  
}
```

ucdb_AttrAdd

```
int ucdb_AttrAdd(  
    ucdbT          db,  
    ucdbObjT       obj,  
    int            coverindex,  
    const char*    key,  
    ucdbAttrValueT* value);
```

db	Database.
obj	Object type: ucdbScopeT, ucdbTestT, or NULL (for global attribute).
coverindex	Index of coveritem. If obj is ucdbScopeT, specify -1 for scope.
key	Attribute key.
value	Attribute value.

Adds the specified attribute (key/value) to the specified database object or global attribute list. The attribute value is copied to the system. Returns 0 if successful, or -1 if error.

ucdb_AttrRemove

```
int ucdb_AttrRemove(  
    ucdbT      db,  
    ucdbObjT   obj,  
    int        coverindex,  
    const char* key);
```

db	Database.
obj	Object type: ucdbScopeT, ucdbTestT, or NULL (for global attribute).
coverindex	Index of coveritem. If obj is ucdbScopeT, specify -1 for scope.
key	Key or NULL to remove the first attribute.

Removes the attribute that has the specified key from the specified database object or global attribute list. Returns 0 if successful, or -1 if error.

ucdb_AttrGet

```
int ucdb_AttrGet(  
    ucdbT      db,  
    ucdbObjT   obj,  
    int        coverindex,  
    const char* key,  
    ucdbAttrValueT* value);
```

db	Database.
obj	Object type: ucdbScopeT, ucdbHistoryNodeT, or NULL (for global attribute).
coverindex	Index. If obj is ucdbScopeT, specify -1 for scope. Valid index for coveritem is ucdbAttrHandleT: <ul style="list-style-type: none">• array index (if type is UCDB_ATTR_ARRAY)• -1 (if type is UCDB_ATTR_HANDLE)
key	Not necessary if obj is ucdbAttrHandleT and its type is UCDB_ATTR_ARRAY.
value	Attribute value returned.

Gets the attribute value for the specified object/key or global attribute value if obj is NULL. Returns 1 if a match is found, or 0 if error.

ucdb_AttrArraySize

```
int ucdb_AttrArraySize(  
    ucdbT          db,  
    ucdbAttrHandleT arrayhandle);
```

db	Database.
arrayhandle	Attribute array handle.

Returns the size (*max index* + 1) of the attribute array, or -1 if error (i.e., type is not UCDB_ATTR_ARRAY).

Scopes

Scopes functions manage the design hierarchy and coverage scopes. The UCDB database is organized hierarchically in parallel with the the design database, which consists of a tree of module instances, each of a given module type.

Note the following about scopes functions:

- hierarchical identifiers
 - If a scope type is Verilog or SystemVerilog, Verilog escaped identifiers syntax is assumed for a path within that scope.
 - If a scope type is VHDL, VHDL extended identifiers are assumed. The escaped identifier syntax is sensitive to the scope type so that escaped identifiers can appear in the user's accustomed syntax. If a scope type is VHDL, the entity, architecture and library can be encoded in the name.
- attributes
 - char* attributes can be omitted with a NULL value.
 - int attributes can be omitted with a negative value.

Scope Type

```
typedef unsigned int ucdbScopeTypeT;

#define UCDB_TOGGLE          INT64_LITERAL(0x0000000000000001)
/* cover scope: toggle coverage scope */
#define UCDB_BRANCH          INT64_LITERAL(0x0000000000000002)
/* cover scope: branch coverage scope */
#define UCDB_EXPR            INT64_LITERAL(0x0000000000000004)
/* cover scope: expression coverage scope */
#define UCDB_COND            INT64_LITERAL(0x0000000000000008)
/* cover scope: condition coverage scope */
#define UCDB_INSTANCE        INT64_LITERAL(0x0000000000000010)
/* HDL scope: Design hierarchy instance */
#define UCDB_PROCESS         INT64_LITERAL(0x0000000000000020)
/* HDL scope: process */
#define UCDB_BLOCK           INT64_LITERAL(0x0000000000000040)
/* HDL scope: vhdl block, vlog begin-end */
#define UCDB_FUNCTION        INT64_LITERAL(0x0000000000000080)
/* HDL scope: function */
#define UCDB_FORKJOIN        INT64_LITERAL(0x0000000000000100)
/* HDL scope: Verilog fork-join block */
#define UCDB_GENERATE         INT64_LITERAL(0x0000000000000200)
/* HDL scope: generate block */
#define UCDB_GENERIC         INT64_LITERAL(0x0000000000000400)
/* cover scope: generic scope type */
#define UCDB_CLASS           INT64_LITERAL(0x0000000000000800)
/* HDL scope: class type scope */
#define UCDB_COVERGROUP      INT64_LITERAL(0x0000000000001000)
/* cover scope: covergroup type scope */
```

```
#define UCDB_COVERINSTANCE    INT64_LITERAL(0x00000000000002000)
/* cover scope: covergroup instance scope */
#define UCDB_COVERPOINT      INT64_LITERAL(0x00000000000004000)
/* cover scope: coverpoint scope */
#define UCDB_CROSS           INT64_LITERAL(0x00000000000008000)
/* cover scope: cross scope */
#define UCDB_COVER           INT64_LITERAL(0x00000000000010000)
/* cover scope: directive (SVA/PSL) cover */
#define UCDB_ASSERT          INT64_LITERAL(0x00000000000020000)
/* cover scope: directive (SVA/PSL) assert */
#define UCDB_PROGRAM         INT64_LITERAL(0x00000000000040000)
/* HDL scope: SV program instance */
#define UCDB_PACKAGE         INT64_LITERAL(0x00000000000080000)
/* HDL scope: package instance */
#define UCDB_TASK            INT64_LITERAL(0x00000000000100000)
/* HDL scope: task */
#define UCDB_INTERFACE       INT64_LITERAL(0x00000000000200000)
/* HDL scope: SV interface instance */
#define UCDB_FSM             INT64_LITERAL(0x00000000000400000)
/* cover scope: FSM coverage scope */
#define UCDB_TESTPLAN        INT64_LITERAL(0x00000000000800000)
/* test scope: for test plan item */
#define UCDB_DU_MODULE       INT64_LITERAL(0x000000000001000000)
/* design unit: for instance type */
#define UCDB_DU_ARCH         INT64_LITERAL(0x000000000002000000)
/* design unit: for instance type */
#define UCDB_DU_PACKAGE      INT64_LITERAL(0x000000000004000000)
/* design unit: for instance type */
#define UCDB_DU_PROGRAM      INT64_LITERAL(0x000000000008000000)
/* design unit: for instance type */
#define UCDB_DU_INTERFACE    INT64_LITERAL(0x000000000010000000)
/* design unit: for instance type */
#define UCDB_FSM_STATES      INT64_LITERAL(0x000000000020000000)
/* cover scope: FSM states coverage scope */
#define UCDB_FSM_TRANS       INT64_LITERAL(0x000000000040000000)
/* cover scope: FSM transitions
   coverage scope*/
#define UCDB_GROUP           INT64_LITERAL(0x000000000080000000)
/* group scope */
#define UCDB_TRANSITION      INT64_LITERAL(0x000000001000000000)
/* cover scope: covergroup transition scope */
#define UCDB_RESERVED_SCOPE  INT64_LITERAL(0xFF000000000000000)
/* RESERVED scope type */
#define UCDB_SCOPE_ERRORUCDB_SCOPE_ERROR
   INT64_LITERAL(0x00000000000000000) /* error return code */
#define UCDB_FSM_SCOPE ((ucdbScopeMaskTypeT) \
   (UCDB_FSM | UCDB_FSM_STATES | UCDB_FSM_TRANS))
#define UCDB_CODE_COV_SCOPE ((ucdbScopeMaskTypeT) \
   (UCDB_BRANCH | UCDB_EXPR | UCDB_COND | UCDB_TOGGLE | UCDB_FSM_SCOPE | \
   UCDB_BLOCK))
#define UCDB_DU_ANY ((ucdbScopeMaskTypeT) \
   (UCDB_DU_MODULE | UCDB_DU_ARCH | UCDB_DU_PACKAGE | \
   UCDB_DU_PROGRAM | UCDB_DU_INTERFACE))
#define UCDB_CVG_SCOPE ((ucdbScopeMaskTypeT) \
   (UCDB_COVERGROUP | UCDB_COVERINSTANCE | UCDB_COVERPOINT | UCDB_CROSS))
#define UCDB_FUNC_COV_SCOPE ((ucdbScopeMaskTypeT) \
   (UCDB_CVG_SCOPE | UCDB_COVER))
#define UCDB_COV_SCOPE ((ucdbScopeMaskTypeT) \
```

```

    (UCDB_CODE_COV_SCOPE | UCDB_FUNC_COV_SCOPE)\
#define UCDB_VERIF_SCOPE ((ucdbScopeMaskTypeT) \
    (UCDB_COV_SCOPE | UCDB_ASSERT | UCDB_GENERIC))
#define UCDB_HDL_SUBSCOPE ((ucdbScopeMaskTypeT) \
    (UCDB_PROCESS | UCDB_BLOCK | UCDB_FUNCTION | UCDB_FORKJOIN | \
    UCDB_GENERATE | UCDB_CLASS | UCDB_TASK))
#define UCDB_HDL_INST_SCOPE ((ucdbScopeMaskTypeT) \
    (UCDB_INSTANCE | UCDB_PROGRAM | UCDB_PACKAGE | UCDB_INTERFACE))
#define UCDB_HDL_DU_SCOPE ((ucdbScopeMaskTypeT) (UCDB_DU_ANY))
#define UCDB_HDL_SCOPE ((ucdbScopeMaskTypeT) \
    (UCDB_HDL_SUBSCOPE | UCDB_HDL_INST_SCOPE | UCDB_HDL_DU_SCOPE))
#define UCDB_NONTESTPLAN_SCOPE ((ucdbScopeMaskTypeT) (~UCDB_TESTPLAN))
#define UCDB_NO_SCOPES ((ucdbScopeMaskTypeT) INT64_ZERO)
#define UCDB_ALL_SCOPES ((ucdbScopeMaskTypeT) INT64_NEG1)

```

Source Type

Enumerated type to encode the source type of a scope, if needed. Note that scope type can have an effect on how the system regards escaped identifiers within the design hierarchy.

```

typedef enum {
    UCDB_VHDL,
    UCDB_VLOG,           /* Verilog */
    UCDB_SV,             /* SystemVerilog */
    UCDB_SYSTEMC,
    UCDB_PSL_VHDL,       /* assert/cover in PSL VHDL */
    UCDB_PSL_VLOG,       /* assert/cover in PSL Verilog */
    UCDB_PSL_SV,         /* assert/cover in PSL SystemVerilog */
    UCDB_PSL_SYSTEMC,    /* assert/cover in PSL SystemC */
    UCDB_E,
    UCDB_VERA,
    UCDB_NONE,           /* not important */
    UCDB_OTHER,          /* user-defined attribute */
    UCDB_VLOG_AMS,       /* Verilog Analog Mixed Signal */
    UCDB_VHDL_AMS,       /* VHDL Analog Mixed Signal */
    UCDB_SPICE,
    UCDB_MATLAB,
    UCDB_C,
    UCDB_CPP,
    UCDB_SOURCE_ERROR = -1 /* for error cases */
} ucdbSourceT;

```

Flags Type

```

typedef unsigned int ucdbFlagsT;

/* Flags for scope data */
#define UCDB_INST_ONCE 0x00000001 /* Instance is instantiated only
                                   once; code coverage is stored only
                                   in the instance. */

/* Flags that indicate whether the scope was compiled with the
/* corresponding type of code coverage enabled.
#define UCDB_ENABLED_STMT 0x00000002 /* statement coverage
#define UCDB_ENABLED_BRANCH 0x00000004 /* branch coverage
#define UCDB_ENABLED_COND 0x00000008 /* condition coverage

```

```

#define UCDB_ENABLED_EXPR      0x00000010    /* expression coverage */
#define UCDB_ENABLED_FSM      0x00000020    /* FSM coverage */
#define UCDB_ENABLED_TOGGLE    0x00000040    /* toggle coverage */
#define UCDB_ENABLED_TOGGLEEXT 0x00000080    /* extended (3-state)
                                           toggle */
#define UCDB_SCOPE_UNDER_DU    0x00000100    /* whether or not scope is
                                           under a design unit */

#define UCDB_SCOPE_EXCLUDED    0x00000200
#define UCDB_SCOPE_PRAGMA_EXCLUDED 0x00000400
#define UCDB_SCOPE_PRAGMA_CLEARED 0x00000800
#define UCDB_SCOPE_GOAL_SPECIFIED 0x00001000
#define UCDB_SCOPE_AUTO_EXCLUDED 0x00002000
#define UCDB_IS_TOP_NODE      0x00008000 /*for top-level toggle node*/
#define UCDB_IS_IMMEDIATE_ASSERT 0x00010000 /*for SV immediate asserts*/
/* Reuse these two flag values for covergroup scopes */
#define UCDB_IS_E_PER_INST     0x00008000 /* for covergroup */
#define UCDB_IS_E_PER_TYPE     0x00010000 /* instance scopes */

/* For Zero Information in "flags" */
#define UCDB_SCOPE_IFF_EXISTS   0x00100000
#define UCDB_SCOPE_SAMPLE_TRUE 0x00200000 /* No bin under the scope
                                           is sampled */

/* Two-bit Expression/Condition short circuit information flags applicable
to UCDB_EXPR and UCDB_COND scopes only. Two bits are overloaded by
re-using UCDB_SCOPE_IFF_EXISTS and UCDB_SCOPE_SAMPLE_TRUE flags which
are applicable to the covergroup scopes only. The two bits carry
meaningful information only when used together:
    00: Short circuit enabled
    01: Short circuit partially enabled
    10: Short circuit disallowed
    11: Short circuit disabled (Same as flag UCDB_SCOPE_SAMPLE_TRUE)

/* Flags that specify whether the short circuit is enabled or disabled at
the Design Unit level. */
#define UCDB_SCOPE_SCKT_PART_ENABLED 0x00100000
#define UCDB_SCOPE_SCKT_DISALLOWED   0x00200000
#define UCDB_SCOPE_SCKT_DISABLED     0x00300000

/* Flag for checking if DU had short circuiting disabled for coverage */
#define UCDB_DISABLED_SHORTCKT       0x00400000

/* Flag for checking if a DU had UDP coverage enabled for expr/cond
coverage */
#define UCDB_EXPRCOND_UDP            0x00800000

/*Flag for checking if it is a PA coverage scope */
#define UCDB_PACOVERAGE              0x02000000

/* Flag used only on bimodal expressions to trigger Extended FEC
Analysis */
#define UCDB_EXPRCOND_EXT_FEC        0x01000000

/* Flag set on last row of Extended FEC table */
#define UCDB_EXPRCOND_LAST_FEC_ROW 0x00080000
#define UCDB_SCOPEFLAG_MARK         0x08000000 /* flag for temporary mark */
#define UCDB_SCOPE_INTERNAL         0xF0000000 /* flags for internal use */
#define UCDB_SCOPEFLAG_MARK         0x08000000 /* flag for temporary mark */
#define UCDB_SCOPE_INTERNAL         0xF0000000 /* flags for internal use */

```


ucdb_CreateScope

```
ucdbScopeT ucdb_CreateScope(
    ucdbT          db,
    ucdbScopeT     parent,
    const char*     name,
    ucdbSourceInfoT* srcinfo,
    int            weight,
    ucdbSourceT     source,
    ucdbScopeTypeT type,
    ucdbFlagsT      flags);
```

db	Database.
parent	Parent scope. If NULL, creates the root scope.
name	Name to assign to scope.
srcinfo	
weight	Weight to assign to the scope. Negative indicates no weight.
source	Source of scope.
type	Type of scope to create.
flags	Flags for the scope.

Creates the specified scope beneath the parent scope. Returns the scope handle if successful, or NULL if error. In write streaming mode, "name" is not copied, so it should be kept unchanged until the next ucdb_WriteStream* call or the next ucdb_Create* call.

Use ucdb_CreateInstance for UCDB_INSTANCE or UCDB_COVERINSTANCE scopes.

ucdb_ComposeDUName

```
const char*
ucdb_ComposeDUName(
    const char*     library_name,
    const char*     primary_name,
    const char*     secondary_name);
```

library_name	Library name.
primary_name	Primary name.
secondary_name	Secondary name.

Composes as design unit scope name for specified design unit. Returns handle to the parsed design unit scope name for the specified component names, or -1 if error. The ucdb_ComposeDUName and ucdb_ParseDUName utilities use a static dynamic string (one for the "Compose" function, one for the "Parse" function), so values are only valid until the next call to the respective function. To hold a name across separate calls, the user must copy it.

ucdb_ParseDUName

```
void ucdb_ParseDUName(  
    const char*      du_name,  
    const char**     library_name,  
    const char**     primary_name,  
    const char**     secondary_name);
```

du_name	Design unit name to parse.
library_name	Library name returned by the call.
primary_name	Primary name returned by the call.
secondary_name	Secondary name returned by the call.

Gets the library name, primary name, and secondary name for the design unit specified by du_name. Design unit scope name has the form:

library_name.primary_name(secondary_name)

The ucdb_ComposeDUName and ucdb_ParseDUName utilities use a static dynamic string (one for the "Compose" function, one for the "Parse" function), so values are only valid until the next call to the respective function. To hold a name across separate calls, the user must copy it.

ucdb_CreateInstance

```
ucdbScopeT ucdb_CreateInstance(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    const char*     name,  
    ucdbSourceInfoT* fileinfo,  
    int            weight,  
    ucdbSourceT     source,  
    ucdbScopeTypeT type,  
    ucdbScopeT     du_scope,  
    int            flags);
```

db	Database.
parent	Parent of instance scope. If NULL, creates a new root scope.
name	Name to assign to scope.
fileinfo	
weight	Weight to assign to the scope. Negative indicates no weight.
source	Source of instance.
type	Type of scope to create: UCDB_INSTANCE or UCDB_COVERINSTANCE.

du_scope	Previously-created scope that is usually the design unit. If type is UCDB_INSTANCE, then du_scope has type UCDB_DU_*. If type is UCDB_COVERINSTANCE, then du_scope has type UCDB_COVERGROUP to capture the instance -> type of the instance relationship for the covergroup instance.
flags	Flags for the scope.

Creates an instance scope of the specified design unit type under the specified parent. Not supported in streaming modes; use `ucdb_CreateInstanceByName()` in write streaming mode. Returns a scope handle, or NULL if error.

ucdb_CreateInstanceByName

```
ucdbScopeT ucdb_CreateInstanceByName(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    const char*     name,  
    ucdbSourceInfoT* fileinfo,  
    int             weight,  
    ucdbSourceT     source,  
    ucdbScopeTypeT type,  
    char*           du_name,  
    int             flags);
```

db	Database.
parent	Parent of instance scope. In write streaming mode, should be NULL. For other modes, NULL creates a root scope.
name	Name to assign to scope.
fileinfo	
weight	Weight to assign to the scope. Negative indicates no weight.
source	Source of instance.
type	Type of scope to create: UCDB_INSTANCE or UCDB_COVERINSTANCE.
du_name	Name of previously-created scope of the instance's design unit or the coverinstance's covergroup type.
flags	Flags for the scope.

Creates an instance of the specified named design unit under the specified parent scope. Returns a scope handle, or NULL if error.

ucdb_CreateCross

```
ucdbScopeT ucdb_CreateCross(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    const char*     name,  
    ucdbSourceInfoT* fileinfo,  
    int             weight,  
    ucdbSourceT     source,  
    int             num_points,  
    ucdbScopeT*     points);
```

db	Database.
parent	Parent scope: UCDB_COVERGROUP or UCDB_COVERINSTANCE.
name	Name to assign to cross scope.
fileinfo	
weight	Weight to assign to the scope. Negative indicates no weight.
source	Source of cross.
num_points	Number of crossed coverpoints.
points	Array of scopes of the coverpoints that comprise the cross scope. These coverpoints must already exist in the parent.

Creates the specified cross scope under the specified parent (covergroup or cover instance) scope. Returns a scope handle for the cross, or NULL if error.

ucdb_CreateCrossByName

```
ucdbScopeT ucdb_CreateCrossByName(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    const char*     name,  
    ucdbSourceInfoT* fileinfo,  
    int             weight,  
    ucdbSourceT     source,  
    int             num_points,  
    char**          point_names);
```

db	Database.
parent	Parent scope: UCDB_COVERGROUP or UCDB_COVERINSTANCE.
name	Name to assign to cross scope.
fileinfo	Associated source information. Can be NULL.
weight	Weight to assign to the scope. Negative indicates no weight.
source	Source of cross.

<code>num_points</code>	Number of crossed coverpoints.
<code>point_names</code>	Array of names of the coverpoints that comprise the cross scope. These coverpoints must already exist in the parent.

Creates the specified cross scope under the specified parent (covergroup or cover instance) scope. Returns a scope handle for the cross, or NULL if error.

ucdb_CreateTransition

```
ucdbScopeT ucdb_CreateTransition(
    ucdbT          db,
    ucdbScopeT     parent,
    const char*     name,
    ucdbSourceInfoT* fileinfo,
    int            weight,
    ucdbSourceT     source,
    ucdbScopeT     item);
```

<code>db</code>	Database.
<code>parent</code>	Parent scope: UCDB_COVERGROUP or UCDB_COVERINSTANCE.
<code>name</code>	Name of coveritem. Can be NULL.
<code>fileinfo</code>	Associated source information. Can be NULL.
<code>weight</code>	Weight to assign to the scope. Negative indicates no weight.
<code>source</code>	Source of the transition.
<code>item</code>	Array of coverpoint scopes: must exist in the <i>parent</i> .

Creates a transition scope under the given parent. In write-streaming mode, *name* is not copied; it should be preserved unchanged until the next *ucdb_WriteStream** call or the next *ucdb_Create** call. Returns the scope pointer, or NULL if error.

ucdb_CreateTransitionByName

```
ucdbScopeT ucdb_CreateTransitionbyName(
    ucdbT          db,
    ucdbScopeT     parent,
    const char*     name,
    ucdbSourceInfoT* fileinfo,
    int            weight,
    ucdbSourceT     source,
    char*           item_name);
```

<code>db</code>	Database.
<code>parent</code>	Parent scope: UCDB_COVERGROUP or UCDB_COVERINSTANCE.

name	Name of coveritem. Can be NULL.
fileinfo	Associated source information. Can be NULL.
weight	Weight to assign to the scope. Negative indicates no weight. Not applicable to toggles.
source	Source of the transition.
item_name	Transition item: must exist in the <i>parent</i> .

Creates a transition scope under the given parent. In write-streaming mode, *name* is not copied; it should be preserved unchanged until the next *ucdb_WriteStream** call or the next *ucdb_Create** call. Returns the scope pointer, or NULL if error.

ucdb_InstanceSetDU

```
int ucdb_InstanceSetDU(
    ucdbT          db,
    ucdbScopeT     instance,
    ucdbScopeT     du_scope);
```

db	Database (must contain instance and du_scope).
instance	Scope of the instance.
du_scope	Previously-created scope that is usually the design unit. If type is UCDB_INSTANCE, then du_scope has type UCDB_DU_*. If type is UCDB_COVERINSTANCE, then du_scope has type UCDB_COVERGROUP to capture the instance -> type of the instance relationship for the covergroup instance.

Sets the specified design unit scope handle in the specified instance. Returns 0 if successful, or -1 if error.

ucdb_CloneScope

```
ucdbScopeT ucdb_CloneScope(
    ucdbT          targetdb,
    ucdbScopeT     targetparent,
    ucdbT          sourcedb,
    ucdbScopeT     scope,
    ucdbSelectFlagsT cloneflags,
    int            is_recursive);
```

targetdb	Database context for clone.
targetparent	Parent scope of clone.
sourcedb	Source database.
scope	Source scope to clone.
cloneflags	Flags specifying what to copy.

`is_recursive` If non-zero, recursively clones subscopes. If 0, only clones the specified scope.

Has no effect when `targetdb` is in streaming mode. Creates a copy of the specified scope under the specified destination scope (`targetparent`). Predefined attributes are created by default. Returns the scope handle of the cloned scope, or -1 if error.

ucdb_RemoveScope

```
int ucdb_RemoveScope(  
    ucdbT          db,  
    ucdbScopeT     scope );
```

`db` Database.

`scope` Scope to remove.

Has no effect when `db` is in streaming mode. Removes the specified scope from its parent scope, along with all its subscopes and coveritems. When a scope is removed, that scope handle immediately becomes invalid along with all of its subscope handles. Those handles cannot be used in any API routines. Returns 0 if successful, or -1 if error.

ucdb_ScopeParent

```
ucdbScopeT ucdb_ScopeParent(  
    ucdbT          db,  
    ucdbScopeT     scope );
```

`db` Database.

`scope` Scope.

Returns the parent scope handle of the specified scope, or NULL if none or error.

ucdb_ScopeGetTop

```
ucdbScopeT ucdb_ScopeGetTop(  
    ucdbT          db,  
    ucdbScopeT     scope );
```

`db` Database.

`scope` Scope.

Returns the top-level scope (i.e., the scope with no parent) above the specified scope, or NULL if error.

ucdb_GetScopeName

```
const char* ucdb_GetScopeName(  
    ucdbT          db,  
    ucdbScopeT     scope ) ;
```

db	Database.
scope	Scope.

Returns the non-hierarchical string name of the specified scope, or NULL if error.

ucdb_SetScopeName

```
int ucdb_SetScopeName(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    const char*     name ) ;
```

db	Database.
scope	Scope.
name	Name to assign to scope.

Sets the name of the specified scope. Returns -1 if error.

ucdb_GetScopeType

```
ucdbScopeTypeT ucdb_GetScopeType(  
    ucdbT          db,  
    ucdbScopeT     scope ) ;
```

db	Database.
scope	Scope.

Returns the scope type of the specified scope, or UCDB_SCOPE_ERROR if error.

ucdb_GetScopeSourceType

```
ucdbSourceT ucdb_GetScopeSourceType(  
    ucdbT          db,  
    ucdbScopeT     scope ) ;
```

db	Database.
scope	Scope.

Returns the source of the specified scope, or UCDB_SOURCE_ERROR if error.

ucdb_GetScopeFlags

```
ucdbFlagsT ucdb_GetScopeFlags(  
    ucdbT      db,  
    ucdbScopeT scope);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

Returns the scope flags of the specified scope, or -1 if error.

ucdb_SetScopeFlags

```
void ucdb_SetScopeFlags(  
    ucdbT      db,  
    ucdbScopeT scope,  
    ucdbFlagsT flags);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

flags	Flags to assign to scope.
-------	---------------------------

Sets the flags of the specified scope.

ucdb_GetScopeFlag

```
int ucdb_GetScopeFlag(  
    ucdbT      db,  
    ucdbScopeT scope,  
    ucdbFlagsT mask);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

mask	Flag bit to match with scope flags.
------	-------------------------------------

Returns 1 if the scope's flag bit matches the specified mask, otherwise, no match.

ucdb_SetScopeFlag

```
void ucdb_SetScopeFlag(  
    ucdbT      db,  
    ucdbScopeT scope,  
    ucdbFlagsT mask,  
    int         bitvalue);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

mask	Flag bits to set.
bitvalue	Value (0 or 1) to set mask bits.

Sets bits in the scope's flags fields corresponding to the mask to the specified bit value (0 or 1).

ucdb_GetScopeSourceInfo

```
int ucdb_GetScopeSourceInfo(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    ucdbSourceInfoT* sourceinfo);
```

db	Database.
scope	Scope.
sourceinfo	Returned source information (file/line/token). Memory for source information string is allocated by the system and must not be de-allocated by the user.

Gets the source information for the specified scope. Returns 0 if successful, or non-zero if error.

ucdb_SetScopeSourceInfo

```
int ucdb_SetScopeSourceInfo(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    ucdbSourceInfoT* sourceinfo);
```

db	Database.
scope	Scope.
sourceinfo	Source information (file/line/token) to store for the specified scope.

Sets the source information for the specified scope. Returns 0 if successful, or non-zero if error.

ucdb_SetScopeFileHandle

```
int ucdb_SetScopeFileHandle(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    ucdbFileHandleT* filehandle);
```

db	Database.
scope	Scope.
filehandle	File handle to set for the scope.

Sets the file handle for the specified scope. Does not apply to toggle nodes. API maintains the file handle string storage—do not free. Returns 0 if successful, or non-zero if error.

ucdb_GetScopeWeight

```
int ucdb_GetScopeWeight(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

Returns the weight for the specified scope, or -1 if error. Note that toggle nodes have no weight and always return 1.

ucdb_SetScopeWeight

```
int ucdb_SetScopeWeight(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            weight);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

weight	Weight to assign to scope.
--------	----------------------------

Sets the weight for the specified scope. Returns 0 if successful, or -1 if error. Not applicable to toggle nodes.

ucdb_GetScopeGoal

```
int ucdb_GetScopeGoal(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    float*         goal);
```

db	Database.
----	-----------

scope	Scope.
-------	--------

goal	Goal returned.
------	----------------

Gets the goal for the specified scope. For UCDB_CVG_SCOPE type, converts from the integer value (see [ucdb_SetScopeGoal](#)). Returns 1 if found, or 0 if not found. Not applicable to toggle nodes.

ucdb_SetScopeGoal

```
int ucdb_SetScopeGoal(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    float           goal);
```

db	Database.
scope	Scope.
goal	Goal value.

Sets the goal for the specified scope. For UCDB_CVG_SCOPE types, converts to the integer value (in the SystemVerilog LRM, option.goal and type_option.goal are defined as integers). Returns 0 if successful, or -1 if error. Not applicable to toggle nodes.

ucdb_GetScopeHierName

```
const char* ucdb_GetScopeHierName(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
scope	Scope.

Returns pointer to hierarchical name of scope, or NULL if error. Hierarchical path separator is as set for the current database (see [“hierarchical identifiers”](#) on page 125).

ucdb_GetInstanceDU

```
ucdbScopeT ucdb_GetInstanceDU(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
scope	Instance scope (i.e., scope type is UCDB_INSTANCE).

Returns the handle of the design unit scope of the specified instance scope, or NULL if error. Note: this call can return the UCDB_COVERGROUP scope for a UCDB_COVERINSTANCE as well.

ucdb_GetInstanceDUName

```
char* ucdb_GetInstanceDUName(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
scope	Instance scope (i.e., scope type is UCDB_INSTANCE).

Returns the handle of the design unit scope name of the specified instance scope, or NULL if error. Note: this call can return the UCDB_COVERGROUP scope name for a UCDB_COVERINSTANCE as well. Handle must not to be de-allocated or saved in streaming modes. If not in in-memory mode, handle must be copied.

ucdb_GetNumCrossedCvps

```
int ucdb_GetNumCrossedCvps(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int*           num_points);
```

db	Database.
scope	Cross scope.
num_points	Number of coverpoints returned.

Gets the number of crossed coverpoints of the specified cross scope. Returns 0 if successful, or non-zero if error.

ucdb_GetIthCrossedCvp

```
int ucdb_GetIthCrossedCvp(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            index,  
    ucdbScopeT*    point_scope);
```

db	Database.
scope	Cross scope.
index	Coverpoint index in the cross scope.
point_scope	Crossed coverpoint scope returned.

Gets the crossed coverpoint of the scope specified by the coverpoint index in the specified cross scope. Returns 0 if successful, or non-zero if error.

ucdb_GetIthCrossedCvpName

```
char* ucdb_GetIthCrossedCvpName(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            index);
```

db	Database.
scope	Cross scope.
index	Coverpoint index in the cross scope.

Returns the handle of the name of the crossed coverpoint of the scope specified by the coverpoint index in the specified cross scope, or NULL if error.

ucdb_GetTransitionItem

```
ucdbScopeT ucdb_GetTransitionItem(  
    ucdbT          db,  
    ucdbScopeT     scope) ;
```

db	Database.
----	-----------

scope	Transition scope.
-------	-------------------

Returns the transition item scope, or NULL if error (for example, scope is not a transition scope).

ucdb_GetTransitionItemName

```
char* ucdb_GetTransitionItemName(  
    ucdbT          db,  
    ucdbScopeT     scope) ;
```

db	Database.
----	-----------

scope	Transition scope.
-------	-------------------

Returns the transition item scope name, or NULL if error (for example, scope is not a transition scope).

ucdb_NextPackage

```
ucdbScopeT ucdb_NextPackage(  
    ucdbT          db,  
    ucdbScopeT     package) ;
```

db	Database.
----	-----------

package	Package or NULL to return the first package.
---------	--

Returns the next package following the specified package in the database, NULL if package is the last package, or UCDB_SCOPE_ERROR if error.

ucdb_NextDU

```
ucdbScopeT ucdb_NextDU(  
    ucdbT      db,  
    ucdbScopeT du);
```

db	Database.
----	-----------

du	Design unit or NULL to return the first design unit.
----	--

Returns the next design unit following the specified design unit in the database, NULL if package is the last package, or UCDB_SCOPE_ERROR if error.

ucdb_MatchDU

```
ucdbScopeT ucdb_MatchDU(  
    ucdbT      db,  
    const char* name);
```

db	Database.
----	-----------

name	Design unit name to match.
------	----------------------------

Returns the design unit scope with the specified name, or NULL if no match is found.

ucdb_NextSubScope

```
ucdbScopeT ucdb_NextSubScope(  
    ucdbT      db,  
    ucdbScopeT parent,  
    ucdbScopeT scope,  
    ucdbScopeMaskTypeT scopemask);
```

db	Database.
----	-----------

parent	Parent scope or NULL for top-level modules.
--------	---

scope	Previous child scope or NULL to start traversal.
-------	--

scopemask	Scope type mask.
-----------	------------------

Returns the next child scope in the iteration that has a scope type that matches the specified scope mask, or NULL if last element or error. Setting scope == NULL starts the traversal; replacing scope with the previous returned scope runs the next iteration; a return value of NULL indicates the call is the last iteration. If parent scope is NULL, the iteration is through the top-level modules in the design.

ucdb_NextScopeInDB

```
ucdbScopeT ucdb_NextScopeInDB(
    ucdbT      db,
    ucdbScopeT scope,
    ucdbScopeMaskTypeT scopemask);
```

db	Database.
scope	Previous child scope or NULL to start traversal.
scopemask	Scope type mask.

Returns the next child scope in the iteration that has a scope type that matches the specified scope mask, or NULL if last element or error. Setting scope == NULL starts the traversal; replacing scope with the previous returned scope runs the next iteration; a return value of NULL indicates the call is the last iteration. Traversal starts with the first top level scope in the database and iterates through all matching scopes.

ucdb_NextInstOfDU

```
ucdbScopeT ucdb_NextInstOfDU(
    ucdbT      db,
    ucdbScopeT instance,
    ucdbScopeT du);
```

db	Database.
instance	Previous instance or NULL to start traversal.
du	Design unit scope (i.e., UCDB_DU_*).

Returns the next instance in the iteration, or NULL if last element or error. Setting instance == NULL starts the traversal; replacing instance with the previous returned instance runs the next iteration; a return value of NULL indicates the call is the last iteration.

ucdb_ScopesUnderDU

```
int ucdb_ScopeIsUnderDU(
    ucdbT      db,
    ucdbScopeT scope);
```

db	Database.
scope	Scope.

Returns 1 if scope is under a design unit (scope type is in UCDB_HDL_DU_SCOPE), 0 if not, or -1 if error. Does not work currently for scopes beneath single-instance design units, because of UCDB_INST_ONCE optimization (where the node is under the instance).

ucdb_ScopesUnderCoverInstance

```
int ucdb_ScopeIsUnderCoverInstance(
    ucdbT          db,
    ucdbScopeT     scope);
```

db Database.

scope Scope.

Returns 1 if scope is under a UCDB_COVERINSTANCE scope (scope type must be UCDB_COVERPOINT or UCDB_CROSS), 0 if not, or -1 if error.

ucdb_CallBack

```
int ucdb_CallBack(
    ucdbT          db,
    ucdbScopeT     start,
    ucdb_CBFuncT   cbfunc,
    void*          userdata);
```

db Database.

start Starting scope or NULL to traverse entire database.

cbfunc User-supplied callback function.

userdata User-supplied function data.

In-memory mode only. Traverses the part of the database rooted at and below the specified starting scope, issuing calls to cbfunc along the way. Returns 0 if successful, or -1 with error.

ucdb_PathCallBack

```
int ucdb_PathCallBack(
    ucdbT          db,
    int            recurse,
    const char*    path,
    const char*    du_name,
    ucdbScopeMaskTypeT root_mask,
    ucdbScopeMaskTypeT scope_mask,
    ucdbScopeMaskTypeT cover_mask,
    ucdb_CBFuncT   cbfunc,
    void*          userdata);
```

db Database.

recurse Non-recursive if 0. If non-zero, recurse from matched du_name or scopes specified by path. Note that scope_mask and cover_mask are applied AFTER recursion. Recursion proceeds from all scopes matching the (possibly wildcarded) path, after which callbacks are generated only for scopes and covers (including those specified by the path itself) that share a bit with the scope or cover mask.

path	<p>Path interpreted as follows:</p> <ul style="list-style-type: none"> • if du_name==NULL: absolute path. • if du_name!=NULL: path is relative to design units matching du_name. <p>If path is "/" it is treated as "*", which matches all roots or all paths under a design unit. Wildcards can be given to match multiple results. Uses UCDB path separator ("hierarchical identifiers" on page 125) and escaped identifier rules in a context-sensitive fashion. Current wildcard symbols:</p> <ul style="list-style-type: none"> * — matches any substring within a level of hierarchy ? — preceding character is optional [int:int] — matches any integer index in range {int *} to {int *} — matches any integer index in range {int *} downto {int *} — matches any integer index in range <p>To match wildcard characters literally, use the appropriate escaped identifier syntax.</p>
du_name	<p>Design unit name. Name is specified in the form:</p> <p style="text-align: center;"><i>library.primary(secondary)</i></p> <p>where <i>secondary</i> matches for VHDL only. Multiple matches are possible if <i>library</i> or <i>secondary</i> is absent (even for Verilog design units, if the simulator created an artificial secondary). If path is also specified, then path is relative to all matching design units.</p>
root_mask	<p>If set, matches start from a root that satisfies 1 bit of this mask. Ignored if du_name specified as this field applies to the top level only. Typically set to UCDB_TESTPLAN or UCDB_NON-TESTPLAN_SCOPE to choose a testplan tree or non-testplan tree.</p>
scope_mask	Only match scopes that satisfy 1 bit of this mask.
cover_mask	Only match coveritems that satisfy 1 bit of this mask.
cbfunc	User-supplied callback function. Only these callback reasons (ucdbCBReasonT) are generated: UCDB_REASON_DU, UCDB_REASON_SCOPE, UCDB_REASON_CVBIN, and UCDB_REASON_ENDSCOPE.
userdata	User-supplied function data.

In-memory mode only. This callback mechanism is more flexible than ucdb_CallBack (it implements wildcarded paths, filtering according to type, and so on). Traverses the database as specified, issuing calls to cbfunc as specified along the way. Returns number (0 or more) of matches, or -1 if error. When recursing through a test plan scope, the scope has as "virtual children" the design or coverage scopes with which it is linked through common tags, which reflects the fact that these scopes contribute to the test plan scope's coverage. The same notion applies to matching "*" children of a test plan scope, which matches both real test plan children as well as scopes linked to the test plan scope with tags.

Examples:

```
ucdb_PathCallBack(db,0,"/top/a*",NULL,UCDB_NONTESTPLAN_SCOPE,\
    UCDB_HDL_INST_SCOPE,0,f,d);
```

Call back for all HDL instance scopes that start with "/top/a".

```
ucdb_PathCallBack(db,0,NULL,"duname",-1,-1,0,f,d);
```

Call back for all design units with the name "duname". This may match multiple architectures or library implementations of the design unit.

```
ucdb_PathCallBack(db,0,"myvec*", "work.duname(myarch)", \
    -1,UCDB_TOGGLE,0,f,d);
```

Within the VHDL architecture "work.duname(myarch)", call back for all toggle scopes whose names start with "myvec".

```
ucdb_PathCallBack(db,1,"/top/a",NULL,UCDB_NONTESTPLAN_SCOPE, \
    UCDB_COVERGROUP|UCDB_COVERPOINT|UCDB_CROSS,0,f,d);
```

Call back for all covergroup, cross, and coverpoint scopes that lie under "/top/a". Only if "/top/a" is a covergroup scope will "/top/a" itself be a callback.

```
ucdb_PathCallBack(db,1,"/top/a",NULL,UCDB_NONTESTPLAN_SCOPE, \
    UCDB_COVERGROUP|UCDB_COVERPOINT|UCDB_CROSS,UCDB_CVGBIN,f,d);
```

Same callback as above, but includes bin callbacks as well.

ucdb_MatchTests

```
int ucdb_MatchTests(
    ucdbT      db,
    const char* testname,
    ucdb_CBFuncT cbfunc,
    void*      userdata);
```

db	Database.
testname	Test name pattern. Current wildcard symbols: * — matches any substring within a level of hierarchy ? — preceding character is optional To match wildcard characters literally, the appropriate escaped identifier syntax must be used.
cbfunc	User-supplied callback function. Only UCDB_REASON_TEST callback reasons (ucdbCBReasonT) are generated.
userdata	User-supplied function data.

In-memory mode only. Generates callbacks for tests whose testname attribute matches the specified testname pattern. Returns number (0 or more) of matches, or -1 if error.

ucdb_MatchCallback

```
int ucdb_MatchCallback(
    ucdbT          db,
    const char*     pattern,
    const char*     du_name,
    ucdbScopeMaskTypeT root_mask,
    ucdbScopeMaskTypeT scope_mask,
    ucdbScopeMaskTypeT cover_mask,
    ucdb_CBFuncT    cbfunc,
    void*           userdata);
```

db	Database.
pattern	<p>Name pattern. Current wildcard symbols:</p> <ul style="list-style-type: none"> * — matches any substring within a level of hierarchy ? — preceding character is optional [int:int] — matches any integer index in range {int *} to {int *} — matches any integer index in range {int *} downto {int *} — matches any integer index in range <p>To match wildcard characters literally, use the appropriate escaped identifier syntax.</p>
du_name	<p>Design unit name. Name is specified in the form:</p> <p style="text-align: center;"><i>library.primary(secondary)</i></p> <p>where <i>secondary</i> matches for VHDL only. Multiple matches are possible if <i>library</i> or <i>secondary</i> is absent (even for Verilog design units, if the simulator created an artificial secondary).</p>
root_mask	If set, matches start from a root that satisfies 1 bit of this mask.
scope_mask	Only match scopes that satisfy 1 bit of this mask.
cover_mask	Only match coveritems that satisfy 1 bit of this mask.
cbfunc	User-supplied callback function.
userdata	User-supplied function data.

In-memory mode only. Matches the specified name pattern for any name in the entire instance tree or within specified design units. Recursively searches the subtree and generates callbacks for all named objects matching the pattern. Returns number (0 or more) of matches, or -1 if error.

Coverage and Statistics Summaries

Summary coverage statistics interface allows quick access to aggregated coverage and statistics for different kinds of coverage, and some overall statistics for the database.

Summary Coverage Data Type

Summary data type (ucdbSummaryEnumT) has the following nomenclature conventions:

- *_DU

Coverage numbers that accumulate per-design-unit aggregations. Coverage from all instances of a design unit are merged into, and stored with the design unit itself. The summaries are then computed by traversing design units (not design instances). In our UCDB, this occurs for code coverage only.

- *_INST

Values that accumulate all results from the entire instance tree. Design instances (not design units) are traversed. Note that UCDB_CVG_INST coverage refers to covergroup instances, not design instances, which is coverage for exactly those covergroup objects that have option.per_instance set to 1 in the SystemVerilog source (weighted by option.weight). If no such covergroup objects exist, UCDB_CVG_INST coverage is 0.

```
/* For backward compatibility in enum literal names. */
#define UCDB_EXPR_INST    UCDB_UDP_EXPR_INST
#define UCDB_EXPR_DU     UCDB_UDP_EXPR_DU
#define UCDB_COND_INST   UCDB_UDP_COND_INST
#define UCDB_COND_DU     UCDB_UDP_COND_DU

typedef enum {
    UCDB_CVG_TYPE,      /* 0 Covergroup type coverage == $get_coverage()
                        value */
    UCDB_CVG_INST,      /* 1 Covergroup instances (option.per_instance==1) ,
                        if any, weighted average */
    UCDB_COVER_INST,    /* 2 Cover directive, weighted average, per design
                        instance */
    UCDB_SC_INST,       /* 3 SystemC functional coverage, per design
                        instance */
    UCDB_ZIN_INST,      /* 4 0-In checkerware coverage, per design
                        instance */
    UCDB_STMT_INST,     /* 5 statement coverage, per design instance */
    UCDB_STMT_DU,       /* 6 statement coverage, per design unit */
    UCDB_BRANCH_INST,   /* 7 branch coverage, per design instance */
    UCDB_BRANCH_DU,     /* 8 branch coverage, per design unit */
    UCDB_UDP_EXPR_INST, /* 9 UDP expression coverage, per design instance */
    UCDB_UDP_EXPR_DU,   /* 10 UDP expression coverage, per design unit */
    UCDB_UDP_COND_INST, /* 11 UDP condition coverage, per design instance */
    UCDB_UDP_COND_DU,   /* 12 UDP condition coverage, per design unit */
    UCDB_TOGGLE_INST,   /* 13 toggle coverage, per design instance */
    UCDB_TOGGLE_DU,     /* 14 toggle coverage, per design unit */
    UCDB_FSM_ST_INST,   /* 15 FSM state coverage, per design instance */
    UCDB_FSM_ST_DU,     /* 16 FSM state coverage, per design unit */
    UCDB_FSM_TR_INST,   /* 17 FSM transition coverage, per design inst */
}
```

```

UCDB_FSM_TR_DU,      /* 18 FSM transition coverage, per design unit */
UCDB_USER_INST,      /* 19 user-defined coverage, per design instance */
UCDB_ASSERT_PASS_INST, /* 20 Assertion directive passes, per design
                        instance */
UCDB_ASSERT_FAIL_INST, /* 21 Assertion directive failures, per
                        design instance */
UCDB_ASSERT_VPASS_INST, /* 22 Assertion directive vacuous passes,
                        per design instance */
UCDB_ASSERT_DISABLED_INST, /* 23 Assertion directive disabled, per
                        design instance */
UCDB_ASSERT_ATTEMPTED_INST, /* 24 Assertion directive attempted, per
                        design instance */
UCDB_ASSERT_ACTIVE_INST, /* 25 Assertion directive active, per
                        design instance */
UCDB_CVP_INST,        /* 26 Coverpoint/cross weighted average, all
                        coverpoint and cross declarations */
UCDB_DIRECTED_TESTS,  /* 27 Reserved */
UCDB_FEC_EXPR_INST,   /* 28 Focused expression coverage, per
                        design instance */
UCDB_FEC_EXPR_DU,     /* 29 Focused expression coverage, per
                        design unit */
UCDB_FEC_COND_INST,   /* 30 Focused condition coverage, per
                        design instance */
UCDB_FEC_COND_DU,     /* 31 Focused condition coverage, per
                        design unit */
UCDB_ASSERT_SUCCESS_INST, /* 32 Assertion directives that succeeded:
                        never failed, passed at least once (if
                        pass counts available.) */
UCDB_EXPRESSION_INST, /* 33 Expression coverage, per design
                        instance */
UCDB_EXPRESSION_DU,   /* 34 Expression coverage, per design unit */
UCDB_CONDITION_INST,  /* 35 Condition coverage, per design inst */
UCDB_CONDITION_DU,    /* 36 Condition coverage, per design unit */
UCDB_FSM_INST,        /* 37 FSM state coverage, per design instance */
UCDB_FSM_DU,          /* 38 FSM state coverage, per design unit */
UCDB_TP_COVERAGE     /* 39 Testplan coverage for merged files
                        with testplans */
UCDB_N_SUMMARY_ENUM_T /* 40 Can be used for array bounds */
} ucdbSummaryEnumT;

```

Coverage Structure

Stores values for a particular enumerator.

```

typedef struct {
    float    coverage_pct; /* floating point coverage value, percentage */
    float    goal_pct;     /* floating point goal, percentage */
    int      num_coveritems; /* total number of coveritems (bins) */
    int      num_covered;   /* number of coveritems (bins) covered */
} ucdbCoverageT;

```

Values for num_coveritems depend on the type of coverage:

Enumerator	Type	Number of:
CVG*	SV covergroup	bins

COVER	SVA or PSL cover	cover directives or statements
STMT*	statement	statements
BRANCH*	branch	branches (including implicit elses)
EXPR*	expression	known-value truth table rows
COND*	condition	known-value truth table rows
TOGGLE*	toggle	toggles (scopes in UCDB)
FSM_ST*	FSM state	FSM states
FSM_TR*	FSM transition	FSM transitions
ASSERT*	SVA or PSL assert	assert directives or statements This value is almost always the number of coveritems covered, except for ASSERT_PASS* (number of assertion passes) and ASSERT_FAIL* (number of assertion failures).
BLOCK*	Block	blocks

Coverage Summary Structure

Stores all statistics returned by `ucdb_GetCoverageSummary()`.

```
typedef enum {
    /* Bit 0 set implies "merge -totals" file */
    /* Bit 1 set implies "merge -testassociated" file */
    UCDB_SUMMARY_FLAG_none = 0,
    UCDB_SUMMARY_FLAG_is_merge_totals = 1,
    UCDB_SUMMARY_FLAG_is_merge_testassociated = 2,
    UCDB_SUMMARY_FLAG_is_merge = 3
} ucdbSummaryFlagsEnumT;

typedef struct {
    int          num_instances; /* number of design instances */
    int          num_coverpoints; /* number of SV coverpoint and */
                                /* cross types */
    int          num_covergroups; /* number of SV covergroup types */
    int          num_dus; /* number of design units */
    ucdbSummaryFlagsEnumT flags;
    ucdbCoverageT coverage[UCDB_N_SUMMARY_ENUM_T];
} ucdbCoverageSummaryT;
```

Memory Statistics Types

Memory statistics are summary statistics for simulator memory usage. For merged data, the merged output is the maximum of the merged inputs.

The following type is an enumerator for the category of statistics merged.

```
typedef enum {
```

```

    UCDB_MEMSTATS_COVERGROUP, /* covergroup          */
    UCDB_MEMSTATS_ASSERT,    /* assertion            */
    UCDB_MEMSTATS_CONSTRAINT, /* constraint solver     */
    UCDB_MEMSTATS_CLASS,     /* classes               */
    UCDB_MEMSTATS_DYNAMIC,   /* dynamic objects       */
    UCDB_MEMSTATS_OTHER,     /* other categories      */
    UCDB_MEMSTATS_ENDCATEGORY /* marker past last value */
} ucdbMemStatsEnumT;

```

The following type is an enumerator for the type of statistic.

```

typedef enum {
    UCDB_MEMSTATS_MAXMEM, /* All categories: maximum memory usage
                           high water mark) -- bytes */
    UCDB_MEMSTATS_PEAKTIME, /* All categories: peak memory time */
    UCDB_MEMSTATS_CURRMEM, /* All categories: current memory
                           usage (in bytes) at time of saving
                           the UCDB file */
    UCDB_MEMSTATS_NUMOBJECTS, /* All categories: number of objects */
    UCDB_MEMSTATS_ENDTYPE /* marker past last value */
} ucdbMemStatsTypeEnumT;

```

ucdb_SetGoal

```

int ucdb_SetGoal(
    ucdbT          db,
    ucdbSummaryEnumT type,
    float          percentage);

```

db	Database.
type	Summary coverage type.
percentage	Goal to set for the coverage type. Aggregated coverage is compared to this percentage to determine whether the goal is satisfied.

Sets the goal percentage for the specified type of aggregated coverage. Returns 0 if successful, or non-zero if error.

ucdb_GetGoal

```

float ucdb_GetGoal(
    ucdbT          db,
    ucdbSummaryEnumT type);

```

db	Database.
type	Summary coverage type.

Returns the goal for the specified type of aggregated coverage. The goal is a percentage, 0.0 to 100.0. Returns non-negative goal value if successful, or -1.0 if error.

ucdb_SetWeightPerType

```
int ucdb_SetWeightPerType(
    ucdbT      db,
    ucdbSummaryEnumT type,
    int        weight);
```

db	Database.
type	Summary coverage type.
weight	Weight to set for the coverage type. Weights are non-negative integers, used to compute total coverage numbers as in <code>ucdb_GetTotalCoverage</code> .

Sets the weight for the specified type of aggregated coverage. Returns 0 if successful, or non-zero if error.

ucdb_GetWeightPerType

```
int ucdb_GetWeightPerType(
    ucdbT      db,
    ucdbSummaryEnumT type);
```

db	Database.
type	Summary coverage type.

Returns the weight for the specified type of aggregated coverage. Returns non-negative value if successful, or -1.0 if error.

ucdb_GetCoverageSummary

```
int ucdb_GetCoverageSummary(
    const char* name,
    ucdbCoverageSummaryT* data);
```

name	File system path.
data	Coverage summary returned.

Gets coverage summary statistics. The specified file is opened, seeked to the location of previously computed summary statistics, and immediately closed. See [“Opening a file and creating an in-memory image.”](#) on page 115 for the “efficient” read option. Returns 0 if successful, or non-zero if error.

ucdb_GetCoverage

```
float ucdb_GetCoverage(
    ucdbT          db,
    ucdbSummaryEnumT type,
    int*           num_covered_bins,
    int*           num_total_bins);
```

db	Database.
type	Summary coverage type.
num_covered_bins	Number of covered bins for the coverage type, or NULL if not set.
num_total_bins	Total number of bins for the coverage type, or NULL if not set.

Returns the aggregated coverage of the specified type. The returned value might not equal:

$$\text{num_covered_bins} / \text{num_total_bins}$$

for cases where coveritems can be weighted differently and for SystemVerilog covergroups (for which coverage is not only weighted but is calculated hierarchically). A return value of -1.0 indicates the coverage is not applicable (i.e., no coveritems of the implied type are in the database, so num_total_bins is 0). Other negative return values indicate error.

Note



If any significant data has changed since the last call, this call forces an expensive recalculation using the entire database. The aggregated coverage is automatically recalculated with ucdb_Close, if necessary. However, if no significant data changes were made since the file was opened or the last call to ucdb_GetCoverage, this call remains an efficient operation—it is maintained as summary data in the database, for fast retrieval.

ucdb_GetStatistics

```
int ucdb_GetStatistics(
    ucdbT          db,
    int*           num_covergroups,
    int*           num_coverpoints,
    int*           num_instances,
    int*           num_dus);
```

db	Database.
num_covergroups	Number of covergroup types.
num_coverpoints	Number of covergroup coverpoints.
num_instances	Number of design instances.
num_dus	Number of design units.

Gets overall statistics for the database. Returns 0 if successful, or non-zero if error.

Note: if any significant data has changed since the last call, this call forces an expensive recalculation using the entire database. The statistics are automatically recalculated with `ucdb_Close`, if necessary. However, if no significant data changes were made since the last call to `ucdb_GetStatistics`, this call remains an efficient operation—it is maintained as summary data in the database, for fast retrieval.

ucdb_CalcCoverageSummary

```
int ucdb_CalcCoverageSummary(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            recurse_instances,  
    ucdbCoverageSummaryT* data,  
    ucdbBitVectorT* test_mask);
```

db	Database.
scope	Scope. Entire database if NULL.
recurse_instances	Recursion instances flag. <ul style="list-style-type: none">• For non-testplan scopes, this flag causes a recursion into subscores of types matching the mask UCDB_HDL_INST_SCOPE.• For testplan scopes, this causes recursion into scopes of type UCDB_TESTPLAN. One type of recursion always occurs with testplan scopes: following non-testplan scopes that share a tag with the "scope" given to this routine.
data	Coverage summary data.
test mask	Optional test mask. If set, the database must have been created with all coveritems containing a cover test mask (i.e., as a result of running a "test-associated merge"). Only coveritems matching the test mask are considered covered in the calculation, which is prone to some error and can be improved with additional data in the future. Setting test_mask to NULL will calculate coverage based on current bin values only.

In-memory mode only. Calculates coverage summary statistics, the same data as above, on a subset of an opened database. When called on an instance, function reports by-DU coverage only for the case where UCDB_INST_ONCE is set for the instance. Here, by-DU coverage and instance coverage are identical. When called on the entire database, coverage from all DUs and all instances are counted.

Note



If called with a NULL scope and NULL test_mask, this call can be made on an open database handle without fully populating the in-memory data image, see [“Opening a file and creating an in-memory image.”](#) on page 115.

ucdb_GetTotalCoverage

```
int ucdb_GetTotalCoverage(
    ucdbT          db,
    ucdbObjT       obj,
    float*         total_coverage,
    ucdbBitVectorT* test_mask);
```

db	Database.
obj	Object type (ucdbScopeT or ucdbTestT). All roots if NULL.
total_coverage	<p>Total coverage.</p> <ul style="list-style-type: none"> • For a coverage scope, this is the total coverage calculated in a way similar to ucdb_CalcCoverageSummary(). • The mode set with ucdb_SetExprCondMode() selects focused expressions/conditions or UDP expression/conditions to contribute to total coverage. • For a design instance, this is the weighted average of coverage per type, for all types found in the design subtree rooted at that instance. This coverage uses weights as set from ucdb_SetWeightPerType() and retrieved by ucdb_GetWeightPerType(). • For a leaf testplan scope, coverage is the weighted average of all design instance or coverage scopes sharing the same tag. • For a non-leaf testplan scope, coverage is the weighted average of coverage of all children. If the non-leaf testplan scope shares a tag with design or coverage scopes, those collectively are equally weighted as one child testplan instance, as if a virtual child testplan scope shared a tag with all the other design and coverage scopes. • Test data records with status attribute values UCDB_TESTSTATUS_OK and UCDB_TESTSTATUS_WARNING count as 100%; other test data records count as 0%. <p>Assertion results are included in the form of "% non-vacuously passed", which is the percentage of assertions that non-vacuously passed at least once (i.e, non-zero non-vacuous pass count).</p>
test mask	<p>Optional test mask. If set, the database must have been created with all coveritems containing a cover test mask (i.e., as a result of running a "test-associated merge"). Only coveritems matching the test mask are considered covered in the calculation, which is prone to some error and can be improved with additional data in the future. Setting test_mask to NULL will calculate coverage based on current bin values only.</p>

This calculates a single coverage number (as a percentage, 0.0-100.0) for a scope in the database. Returns 1 if the scope had any coverage data. Returns 0 if none were found and sets total_coverage to -1.0. Returns -1 if error.

ucdb_GetMemoryStats

```
int ucdb_GetMemoryStats(  
    ucdbT          db,  
    ucdbMemStatsEnumT category,  
    ucdbMemStatsTypeEnumT type,  
    ucdbAttrValueT** value);
```

db	Database.
category	Memory statistics category.
type	Statistics type for the memory statistics category.
value	Memory statistics value returned.

Gets memory usage statistics for the specified statistics type for the specified statistics category. Returns 0 if successful, 1 if the statistic does not apply, or -1 if error.

ucdb_SetMemoryStats

```
int ucdb_SetMemoryStats(  
    ucdbT          db,  
    ucdbMemStatsEnumT category,  
    ucdbMemStatsTypeEnumT type,  
    ucdbAttrValueT** value);
```

db	Database.
category	Memory statistics category.
type	Statistics type for the memory statistics category.
value	Memory statistics value to set.

Sets memory usage statistics for the specified statistics type for the specified statistics category. Returns 0 if successful, or non-zero if error.

Coveritems

Cover Types

```
typedef unsigned int ucdbCoverTypeT;

/* Bits for ucdbCoverTypeT: */
#define UCDB_CVGBIN          INT64_LITERAL(0x0000000000000001)
/* For SV Covergroups */
#define UCDB_COVERBIN        INT64_LITERAL(0x0000000000000002)
/* For cover directives: pass */
#define UCDB_ASSERTBIN       INT64_LITERAL(0x0000000000000004)
/* For assert directives: fail */
#define UCDB_SCBIN           INT64_LITERAL(0x0000000000000008)
/* For SystemC transactions */
#define UCDB_ZINBIN          INT64_LITERAL(0x0000000000000010)
/* For 0-in Checkerware */
#define UCDB_STMTBIN         INT64_LITERAL(0x0000000000000020)
/* For Code coverage(Statement) */
#define UCDB_BRANCHBIN       INT64_LITERAL(0x0000000000000040)
/* For Code coverage(Branch) */
#define UCDB_EXPRBIN         INT64_LITERAL(0x0000000000000080)
/* For Code coverage(Expression) */
#define UCDB_CONDBIN         INT64_LITERAL(0x0000000000000100)
/* For Code coverage(Condition) */
#define UCDB_TOGGLEBIN       INT64_LITERAL(0x0000000000000200)
/* For Code coverage(Toggle) */
#define UCDB_PASSBIN         INT64_LITERAL(0x0000000000000400)
/* For assert directives: pass count */
#define UCDB_FSMBIN          INT64_LITERAL(0x0000000000000800)
/* For FSM coverage */
#define UCDB_USERBIN         INT64_LITERAL(0x0000000000001000)
/* User-defined coverage */
#define UCDB_GENERICBIN      UCDB_USERBIN
#define UCDB_COUNT           INT64_LITERAL(0x0000000000002000)
/* user-defined count, not in coverage*/
#define UCDB_FAILBIN         INT64_LITERAL(0x0000000000004000)
/* For cover directives: fail count */
#define UCDB_VACUOUSBIN      INT64_LITERAL(0x0000000000008000)
/* For assert: vacuous pass count */
#define UCDB_DISABLEDBIN     INT64_LITERAL(0x0000000000010000)
/* For assert: disabled count */
#define UCDB_ATTEMPTBIN      INT64_LITERAL(0x0000000000020000)
/* For assert: attempt count */
#define UCDB_ACTIVEBIN       INT64_LITERAL(0x0000000000040000)
/* For assert: active thread count */
#define UCDB_IGNOREBIN       INT64_LITERAL(0x0000000000080000)
/* For SV Covergroups */
#define UCDB_ILLEGALBIN      INT64_LITERAL(0x00000000000100000)
/* For SV Covergroups */
#define UCDB_DEFAULTBIN      INT64_LITERAL(0x00000000000200000)
/* For SV Covergroups */
#define UCDB_PEAKACTIVEBIN   INT64_LITERAL(0x00000000000400000)
/* For assert: max active thread count*/
```

```
#define UCDB_RESERVED          INT64_LITERAL(0x000000000008000000)
/* For other API use */
#define UCDB_CROSSPRODUCTBIN  INT64_LITERAL(0x000000000001000000)
/* For SV cross products */
#define UCDB_BLOCKBIN          INT64_LITERAL(0x000000000002000000)
/* For code (block) coverage */
#define UCDB_USERBITS          INT64_LITERAL(0x0000000000FC000000)
/* For user-defined coverage */
#define UCDB_RESERVEDBIN      INT64_LITERAL(0xFC0000000000000000)
/* Reserved */
```

Coveritem Types

```
#define UCDB_COVERGROUPBINS ((ucdbCoverMaskTypeT)\
    (UCDB_CVGBIN | UCDB_IGNOREBIN | UCDB_ILLEGALBIN | UCDB_DEFAULTBIN))
#define UCDB_FUNC_COV ((ucdbCoverMaskTypeT)\
    (UCDB_COVERGROUPBINS | UCDB_COVERBIN | UCDB_SCBIN))
#define UCDB_CODE_COV ((ucdbCoverMaskTypeT)\
    (UCDB_STMTBIN | UCDB_BRANCHBIN | UCDB_EXPRBIN | UCDB_CONDBIN \
    | UCDB_TOGGLEBIN | UCDB_FSMBIN))
#define UCDB_ASSERTIONBINS ((ucdbCoverMaskTypeT)\
    (UCDB_ASSERTBIN | UCDB_PASSBIN | UCDB_VACUOUSBIN | UCDB_DISABLEDIN \
    | UCDB_ATTEMPTBIN | UCDB_ACTIVEBIN | UCDB_PEAKACTIVEBIN))
#define UCDB_NO_BINS ((ucdbCoverMaskTypeT)INT64_ZERO)
#define UCDB_ALL_BINS ((ucdbCoverMaskTypeT)INT64_NEG1)
```

Flags for Coveritem Data

```
#define UCDB_IS_32BIT          0x00000001 /* data is 32 bits */
#define UCDB_IS_64BIT          0x00000002 /* data is 64 bits */
#define UCDB_IS_VECTOR         0x00000004 /* data is actually a vector */
#define UCDB_HAS_GOAL          0x00000008 /* goal included */
#define UCDB_HAS_WEIGHT        0x00000010 /* weight included */
#define UCDB_EXCLUDE_PRAGMA    0x00000020 /* excluded by pragma */
#define UCDB_EXCLUDE_FILE      0x00000040 /* excluded by file; does not
count in total coverage */
#define UCDB_LOG_ON            0x00000080 /* for cover/assert directives:
controls simulator output */
#define UCDB_ENABLED           0x00000100 /* generic enabled flag; if
disabled, still counts in total
coverage */
#define UCDB_HAS_LIMIT         0x00000200 /* for limiting counts */
#define UCDB_HAS_ACTION        0x00000400 /* for assert directives, refer
to "ACTION" in attributes */
#define UCDB_IS_FSM_RESET      0x00000400 /* For fsm reset states */
#define UCDB_IS_ASSERT_DEBUG   0x00000800 /* for assert directives, if
true, has 4 counts */
#define UCDB_IS_TLW_ENABLED    0x00001000 /* for assert directives */
#define UCDB_IS_FSM_TRAN       0x00002000 /* for FSM coveritems, is a
transition bin */
#define UCDB_IS_BR_ELSE        0x00004000 /* for branch ELSE coveritems */
#define UCDB_CLEAR_PRAGMA      0x00008000
#define UCDB_IS_EOS_NOTE       0x00010000 /* for directives active at end
of simulation */
#define UCDB_EXCLUDE_INST      0x00020000 /* for instance-specific
exclusions */
#define UCDB_EXCLUDE_AUTO      0x00040000 /* for automatic exclusions */
```

```
#define UCDB_IS_CROSSAUTO    0x00400000    /* covergroup auto cross bin */

/* For Zero Information in "flags" */
#define UCDB_BIN_IFF_EXISTS  0x00100000    /* covergroup bin has no iff */
#define UCDB_BIN_SAMPLE_TRUE 0x00200000    /* covergroup bin is
                                           not sampled */
#define UCDB_IS_CROSSAUTO    0x00400000    /* covergroup auto cross bin */
#define UCDB_COVERFLAG_MARK  0x00800000    /* flag for temporary mark */
#define UCDB_USERFLAGS       0xFF000000    /* reserved for user flags */
#define UCDB_FLAG_MASK       0xFFFFFFFF
#define UCDB_EXCLUDED        ( UCDB_EXCLUDE_FILE | UCDB_EXCLUDE_PRAGMA \
                               | UCDB_EXCLUDE_INST | UCDB_EXCLUDE_AUTO)
```

Coveritem Data Type

```
typedef union {
    uint64_t          int64;      /* if UCDB_IS_32BIT */
    uint32_t          int32;      /* if UCDB_IS_64BIT */
    unsigned char*    bytevector; /* if UCDB_IS_VECTOR */
} ucdbCoverDataValueT;

typedef struct {
    ucdbCoverTypeT    type;      /* type of coveritem */
    ucdbFlagsT        flags;     /* as above, validity of fields below */
    ucdbCoverDataValueT data;
    int               goal;      /* if UCDB_HAS_GOAL; determines whether
                                or not a bin is covered; (like
                                at_least in covergroup) */
    int               weight;     /* if UCDB_HAS_WEIGHT */
    int               limit;      /* if UCDB_HAS_LIMIT */
    int               bitlen;     /* length of data.bytevector in bits,
                                extra bits are lower order bits of
                                the last byte in the byte vector */
} ucdbCoverDataT;
```

ucdb_CreateNextCover

```
int ucdb_CreateNextCover(
    ucdbT          db,
    ucdbScopeT     parent,
    const char*    name,
    ucdbCoverDataT* data,
    ucdbSourceInfoT* sourceinfo);
```

db	Database.
parent	Scope in which to create the coveritem.
name	Name to give the coveritem. Can be NULL.
data	Associated data for coverage.
sourceinfo	Associated source information.

Creates the next coveritem in the given scope. Returns the index number of the created coveritem, -1 if error.

ucdb_CloneCover

```

int ucdb_CloneCover(
    ucdbT          targetdb,
    ucdbScopeT     targetparent,
    ucdbT          sourcedb,
    ucdbScopeT     sourceparent,
    int            coverindex,
    ucdbSelectFlagsT cloneflags);

```

targetdb	Database context for clone.
targetparent	Parent scope of clone.
db	Source database.
parent	Source scope.
coverindex	Source coverindex.
cloneflags	UCDB_CLONE_ATTRS or 0.

Has no effect when targetdb is in streaming mode. Creates a copy of the specified coveritem in the specified scope (targetparent). Predefined attributes are created by default. Returns the coverindex if successful, or -1 if error.

ucdb_RemoveCover

```

int ucdb_RemoveCover(
    ucdbT          db,
    ucdbScopeT     parent,
    int            coverindex);

```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem to remove.

Has no effect when db is in streaming mode. Removes the specified coveritem from its parent. Returns 0 if successful, or -1 if error. Coveritems cannot be removed from scopes of type UCDB_ASSERT (instead, remove the whole scope). Similarly, coveritems from scopes of type UCDB_TOGGLE with toggle kind UCDB_TOGGLE_SCALAR, UCDB_TOGGLE_SCALAR_EXT, UCDB_TOGGLE_REG_SCALAR, or UCDB_TOGGLE_REG_SCALAR_EXT cannot be removed (instead, remove the whole scope).

ucdb_MatchCoverInScope

```
int ucdb_MatchCoverInScope(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    const char*     name);
```

db	Database.
parent	Parent scope of coveritem.
name	Coveritem name to match.

Gets coveritem from database if it exists in the specified scope. Returns coveritem index, or -1 if error.

ucdb_IncrementCover

```
int ucdb_IncrementCover(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int             coverindex,  
    int64_t         increment);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
increment	Increment count to add to current count.

Increments the data count for the coveritem, if not a vector item. Returns 0 if successful, or -1 if error.

ucdb_GetCoverFlags

```
ucdb_FlagsT ucdb_GetCoverFlags(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int             coverindex);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.

Returns the flags for the specified coveritem, or NULL if error.

ucdb_GetCoverFlag

```
int ucdb_GetCoverFlag(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    ucdbFlagsT     mask);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
mask	Flag mask to match.

Returns 1 if coveritem's flag bit matches the specified mask, 0 if the coveritem has flag bits not matching the specified mask, or -1 if the coveritem does not have any flag bits.

ucdb_SetCoverFlag

```
void ucdb_SetCoverFlag(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    ucdbFlagsT     mask,  
    int            bitvalue);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
mask	Flag mask.
bitvalue	Value to set: 0 or 1.

Sets bits in the coveritem's flag field with respect to the given mask.

ucdb_GetCoverType

```
ucdbCoverTypeT ucdb_GetCoverType(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.

Returns the cover type of the specified coveritem. or 0 if error.

ucdb_GetCoverData

```
int ucdb_GetCoverData(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    char**         name,  
    ucdbCoverDataT* data,  
    ucdbSourceInfoT* sourceinfo);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
name	Name returned (<i>failbin</i> , <i>passbin</i> , <i>vacuousbin</i> , <i>disabledbin</i> , <i>attemptbin</i> , <i>activebin</i> or <i>peakactivebin</i>).
data	Data returned.
sourceinfo	Source information returned.

Gets name, data and source information for the specified coveritem. Returns 0 if successful, or non-zero if error. The user must save the returned data as the next call to this function can invalidate the returned data. Note: any of the data arguments can be NULL (i.e., that data is not retrieved).

ucdb_SetCoverData

```
int ucdb_SetCoverData(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    ucdbCoverDataT* data);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
data	Data to set.

Sets data for the specified coveritem. Returns 0 if successful, or non-zero if error. The user must ensure the data fields are valid.

ucdb_SetCoverCount

```
int ucdb_SetCoverCount(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    int64_t         count);
```

db	Database.
----	-----------

parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
count	Cover count value to set.

Sets the count for the specified coveritem. Returns 0 if successful, or non-zero if error.

ucdb_SetCoverGoal

```
int ucdb_SetCoverGoal(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    int            goal);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
goal	Cover goal value to set.

Sets the goal for the specified coveritem. Returns 0 if successful, or non-zero if error.

ucdb_SetCoverLimit

```
int ucdb_SetCoverLimit(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    int            limit);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Coverindex of coveritem in parent scope.
limit	Cover limit value to set.

Sets the limit for the specified coveritem. Returns 0 if successful, or non-zero if error.

ucdb_SetCoverWeight

```
int ucdb_SetCoverWeight(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            coverindex,  
    int            weight);
```

db	Database.
parent	Parent scope of coveritem.

coverindex	Coverindex of coveritem in parent scope.
weight	Cover weight value to set.

Sets the weight for the specified coveritem. Returns 0 if successful, or non-zero if error.

ucdb_GetScopeNumCovers

```
int ucdb_GetScopeNumCovers(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
scope	Scope.

Returns the number of coveritems in the specified scope (which can be 0), or -1 if error.

ucdb_GetECCoverNumHeaders

```
int ucdb_GetECCoverNumHeaders(  
    ucdbT          db,  
    ucdbScopeT     scope);
```

db	Database.
scope	Scope.

Returns the number of UDP header columns for Expression and Condition coverage in the specified scope (which can be 0), or -1 if error. For example, to get all the header columns:

```
num_columns = ucdb_GetECCoverNumHeaders(db, cvitem);  
for (i = 0; i < num_columns; i++) {  
    char* header;  
    status = ucdb_GetECCoverHeader(db, cvitem, i, &header);  
}
```

ucdb_GetECCoverHeader

```
int ucdb_GetECCoverHeader(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            index,  
    char**         header);
```

db	Database.
scope	Scope.
index	Index.
header	Header string returned.

Gets the indexed UDP header string of Expression and Condition coverage. Returns 0 if successful, or 1 if error.

ucdb_NextCoverInScope

```
int ucdb_NextCoverInScope(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int*           coverindex,  
    ucdbCoverMaskTypeT covermask);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Index of coveritem in parent.
covermask	Mask for type of coveritem.

Given a coveritem and cover type mask, gets the next coveritem from the scope. Start with a coverindex == -1 to return the first coveritem in the scope. Returns 0 at end of traversal, -1 if error.

ucdb_NextCoverInDB

```
int ucdb_NextCoverInDB(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int*           coverindex,  
    ucdbCoverMaskTypeT covermask);
```

db	Database.
parent	Parent scope of coveritem.
coverindex	Index of coveritem in parent.
covermask	Mask for type of coveritem.

Given a coveritem and cover type mask, gets the next coveritem from the scope. Start with a coverindex == -1 and parent == NULL to return the first coveritem in the database. Returns 0 at end of traversal, -1 if error.

Toggles

Toggles are the most common type of object in a typical code coverage database. Therefore, they have a specific interface in the API which can be restricted for optimization purposes. Net toggles can be duplicated throughout the database through port connections. They can be reported once rather than in as many different local scopes as they appear (this requires a net id).

```
typedef enum {
    UCDB_TOGGLE_ENUM,          /* Enum type object */
    UCDB_TOGGLE_INT,           /* Integer type object */
    UCDB_TOGGLE_REG_SCALAR=4,  /* Scalar, one bit reg */
    UCDB_TOGGLE_REG_SCALAR_EXT, /* Extended toggle of scalar reg */
    UCDB_TOGGLE_SCALAR,        /* Scalar net or std_logic_bit */
    UCDB_TOGGLE_SCALAR_EXT     /* Ext toggle of scalar net or
                                std_logic_bit */
    UCDB_TOGGLE_REAL           /* Real type object */
} ucdbToggleTypeT;

typedef enum {
    UCDB_TOGGLE_INTERNAL,      /* non-port: internal wire or variable */
    UCDB_TOGGLE_IN,            /* input port */
    UCDB_TOGGLE_OUT,           /* output port */
    UCDB_TOGGLE_INOUT          /* inout port */
} ucdbToggleDirT;
```

ucdb_CreateToggle

```
ucdbScopeT ucdb_CreateToggle(
    ucdbT      db,
    ucdbScopeT parent,
    const char* name,
    const char* canonical_name,
    ucdbFlagsT flags,
    ucdbToggleTypeT toggle_type,
    ucdbToggleDirT toggle_dir);
```

db	Database.
parent	Scope in which to create the toggle.
name	Name to give the toggle object.
canonical_name	Canonical name for the toggle object. Identifies unique toggles. Toggles with the same canonical_name must count once when traversed for a report or coverage summary.
flags	Exclusion flags.
toggle_type	Toggle type.
toggle_dir	Toggle direction.

Creates the specified toggle scope beneath the given parent scope. Returns a handle to the created scope (type UCDB_TOGGLE), or NULL if error.

ucdb_GetToggleInfo

```
int ucdb_GetToggleInfo(  
    ucdbT          db,  
    ucdbScopeT     toggle,  
    const char**   canonical_name,  
    ucdbToggleTypeT* toggle_type,  
    ucdbToggleDirT* toggle_dir);
```

db	Database.
toggle	Toggle scope containing the information..
canonical_name	Canonical name for the toggle object. May be NULL for unconnected nets, enum, int, and reg type toggles. Memory for canonical_name is allocated by the system and must not be de-allocated by the user.
toggle_type	Toggle type.
toggle_dir	Toggle direction.

Returns toggle-specific information associated with the specified toggle scope. Returns 0 if successful, -1 if error.

ucdb_GetToggleCovered

```
int ucdb_GetToggleCovered(  
    ucdbT          db,  
    ucdbScopeT     toggle);
```

db	Database.
toggle	Toggle scope containing the information..

Returns 1 if toggle is covered, 0 if toggle is uncovered and -1 if an error.

ucdb_GetBCoverInfo

```
int ucdb_GetBCoverInfo(  
    ucdbT          db,  
    ucdbScopeT     coveritem,  
    int*           has_else,  
    int*           iscase,  
    int*           num_elmts);
```

db	Database.
coveritem	Coveritem.
has_else	1 if branch has else clause; 0 otherwise.
iscase	1 if branch is a CASE statement; 0 otherwise.
num_elmts	Number of elements in branch. 1 if a CASE branch.

Returns 1 if branch is a CASE statement; 0 otherwise (IF statement).

Groups

Groups are used to maintain bus structures in the database. They provide additional support for part-select toggle nodes, particularly with the support for wildcard ranges provided by group scopes.

Group Kind Type

```
#define UCDB_GROUP_MASK_PACKED    0x1000
#define UCDB_GROUP_MASK_ORDERED  0x2000
typedef enum {
    UCDB_GROUP_BASIC                = 0x0001,
    UCDB_GROUP_UNPACKED_STRUCT     = 0x0002,
    UCDB_GROUP_UNPACKED_UNION      = 0x0003,
    UCDB_GROUP_UNPACKED_ARRAY      = (0x0004 | UCDB_GROUP_MASK_ORDERED),
    UCDB_GROUP_ASSOC_ARRAY         = 0x0005,
    UCDB_GROUP_PACKED_STRUCT       =
        (UCDB_GROUP_UNPACKED_STRUCT | UCDB_GROUP_MASK_PACKED),
    UCDB_GROUP_PACKED_UNION        =
        (UCDB_GROUP_UNPACKED_UNION | UCDB_GROUP_MASK_PACKED),
    UCDB_GROUP_PACKED_ARRAY        =
        (UCDB_GROUP_UNPACKED_ARRAY | UCDB_GROUP_MASK_PACKED)
} ucdbGroupKind;
```

Wildcard Matching

General wildcard matching supports:

- * Matches one or more characters. Only spans one scope, so * matches [2], but does not match [2][4].
- ? Matches a single character.

The following range pattern searches require group scopes:

- (*number*)
- [*number*]
- [*number:number*]
- (*number* to *number*)
- (*number* downto *number*)

ucdb_CreateGroupScope

```
ucdbScopeT ucdb_CreateGroupScope(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    ucdbGroupKind  kind,  
    char*          name,  
    ucdbFlagsT     flags,  
    int            numberOfRangePairs,  
    int*           rangePairs);
```

db	Database.
parent	Parent scope.
kind	Group kind.
name	Name to assign to the group scope.
flags	Flags.
numberOfRangePairs	Number of range pairs. Only used for ordered groups.
rangePairs	Range pairs. Only used for ordered groups.

Creates the specified group scope beneath the parent scope. Returns the scope handle if successful, or NULL if error. In write streaming mode, *name* and *rangePairs* are not copied, so they should be kept unchanged until the next `ucdb_WriteStream*` call or the next `ucdb_Create*` call.

ucdb_GetGroupInfo

```
int ucdb_GetGroupInfo(  
    ucdbT          db,  
    ucdbScopeT     group,  
    ucdbGroupKind* kind,  
    const char**   name,  
    int*           numberOfRangePairs,  
    int**          rangePairs);
```

db	Database.
group	Group scope.
kind	Group kind.
name	Name of the group scope.
numberOfRangePairs	Number of range pairs. Only used for ordered groups.
rangePairs	Range pairs. Only used for ordered groups.

Gets the group-specific information (*kind*, *name*, *numberOfRangePairs* and *rangePairs*) for the specified group scope. Returns 0 if successful, or -1 if error.

ucdb_ExpandOrderedGroupRangeList

```
int ucdb_ExpandOrderedGroupRangeList(  
    ucdbT          db,  
    ucdbScopeT     group,  
    int            numberOfRangePairs,  
    int*           rangePairs);
```

db	Database.
group	Group scope. Must be UCDB_GROUP_PACKED_ARRAY or UCDB_GROUP_UNPACKED_ARRAY type.
numberOfRangePairs	Number of range pairs.
rangePairs	Range pairs.

Expands the range pairs for the specified group with the specified list of range pairs according to the following rules:

- A range that does not overlap an existing range is added to the range list.
- A range that encloses one or more existing ranges replaces the enclosed ranges.
- A range that (partially) overlaps an existing range expands that range.
- A range completely enclosed in an existing range is ignored.

Returns 0 if successful, -1 if error.

ucdb_GetOrderedGroupElementByIndex

```
ucdbScopeT ucdb_GetOrderedGroupElementByIndex(  
    ucdbT          db,  
    ucdbScopeT     parent,  
    int            index);
```

db	Database.
group	Parent ordered group scope. Must be UCDB_GROUP_PACKED_ARRAY or UCDB_GROUP_UNPACKED_ARRAY type.
index	Index of the child.

Returns the handle of the child element of the specified ordered group scope that has the specified index, or NULL if error or if no element corresponds to the index. For example, for the ordered group corresponding to *bus[3:0]*:

- *index = 1* returns the right-most range number (0)
- *index = 4* returns the left-most range number (3)

Function is used in memory mode only.

Tags

A tag is a group of strings associated with a scope. Scopes can have associated tags for grouping: when items share a tag they are associated together. In particular, when UCDB_TESTPLAN scopes share tags with coverage scopes that contain coveritems, the association can be used to do traceability analysis tests. The following example traverses all non-testplan scopes that share a tag with a given testplan scope:

```
if ( ucdb_ObjKind(db,obj)==UCDB_OBJ_SCOPE &&
    ucdb_GetScopeType(db,(ucdbScopeT)obj)==UCDB_TESTPLAN ) {
    int t, numtags = ucdb_GetScopeNumTags(db,scope);
    const char* tagname;
    for ( t=0; t<numtags; t++ ) {
        int found;
        ucdbObjT taggedobj;
        ucdb_GetScopeIthTag(db,scope,t,&tagname);
        for ( found=ucdb_BeginTaggedObj(db,tagname,&taggedobj);
              found; found=ucdb_NextTaggedObj(db,&taggedobj) ) {
            if ( ucdb_ObjKind(db,taggedobj)==UCDB_OBJ_SCOPE &&
                ucdb_GetScopeType(db,(ucdbScopeT)taggedobj)==UCDB_TESTPLAN
            ) continue;
            /* Now taggedobj is a non-testplan obj sharing a tag with */
            /* obj -- put your code here */
        }
    }
}
```

Here is an example of traversing all scopes for all tags in a UCDB file:

```
ucdbT db = ucdb_Open(filename);
const char* tagname = NULL;
while (tagname = ucdb_NextTag(db,tagname)) {
    int found;
    ucdbScopeT scope;
    for ( found=ucdb_BeginTagged(db,tagname,&scope);
          found; found=ucdb_NextTagged(db,&scope) ) {
        /* Put your code here */
    }
}
```

Important: This traversal cannot nest. Code inside this loop cannot re-use the *BeginTagged/NextTagged* functions.

Object Mask Type

```
typedef enum {
    UCDB_OBJ_ERROR = 0,      /* Start of the db, apply initial settings */
    UCDB_OBJ_TESTDATA = 1,  /* Testdata object */
    UCDB_OBJ_SCOPE = 2,     /* Scope object */
    UCDB_OBJ_COVER = 4,     /* Cover object */
    UCDB_OBJ_ANY = -1       /* ucdbScopeT or ucdbHistoryNodeT */
} ucdbObjMaskT;
```

Enum type for different object kinds. This is a bit mask for the different kinds of objects that are tagged. Mask values can be ANDed and ORed together.

ucdb_ObjKind

```
ucdbObjMaskT ucdb_ObjKind(
    ucdbT      db,
    ucdbObjT    obj);
```

db Database.

obj Obj.

Returns object type (ucdbScopeT or ucdbTestT) for the specified object, or UCDB_OBJ_ERROR if error.

ucdb_GetObjType

```
ucdbObjTypeT ucdb_GetObjType(
    ucdbT      db,
    ucdbScopeT object);
```

db Database.

object Object.

Polymorphic function (aliased to ucdb_GetHistoryKind) for acquiring an object type. Returns UCDB_HISTORYNODE_TEST (object is a test data record), UCDB_HISTORYNODE_TESTPLAN (object is a test plan record), UCDB_HISTORYNODE_MERGE (object is a merge record), scope type ucdbScopeTypeT (object is not of these), or UCDB_SCOPE_ERROR if error. This function can return a value with multiple bits set (for history data objects). Return value *must not be used* as a mask.

ucdb_AddObjTag

```
int ucdb_AddObjTag(
    ucdbT      db,
    ucdbObjT    obj,
    const char* tag);
```

db Database.

obj Object (ucdbScopeT or ucdbTestT).

tag Tag.

Adds a tag to a given object. Returns 0 if successful, or non-zero if error. Error includes null tag or tag with '\n' character.

ucdb_RemoveObjTag

```
int ucdb_RemoveObjTag(  
    ucdbT          db,  
    ucdbObjT       obj,  
    const char*    tag);
```

db	Database.
obj	Object (ucdbScopeT or ucdbTestT).
tag	Tag.

Removes the given tag from the object. Returns 0 if successful, or non-zero if error.

ucdb_GetObjNumTags

```
int ucdb_GetObjNumTags(  
    ucdbT          db,  
    ucdbObjT       obj);
```

db	Database.
obj	Object (ucdbScopeT or ucdbTestT).

Gets the number of tags from a given object. Returns number of tags, or 0 if error or no tags.

ucdb_GetObjIthTag

```
int ucdb_GetObjIthTag(  
    ucdbT          db,  
    ucdbObjT       obj,  
    int            index,  
    const char**   tag);
```

db	Database.
obj	Object (ucdbScopeT or ucdbTestT).
index	Tag index.
tag	Tag.

Gets an indexed tag from a given object. Returns 0 if successful, or non-zero if error.

ucdb_SetObjTags

```
int ucdb_SetObjTags(  
    ucdbT          db,  
    ucdbObjT       obj,  
    int            numtags,  
    const char**   tag_array);
```

db	Database.
----	-----------

Tags

obj	Object (ucdbScopeT or ucdbTestT).
numtags	Size of tag_array, 0 to clear all flags.
tag_array	Array of string handles.

Sets all tags for a given a object (replaces previous tags). Returns 0 if successful, or non-zero if error.

ucdb_BeginTaggedObj

```
int ucdb_BeginTaggedObj(
    ucdbT          db,
    const char*    tagname,
    ucdbObjT*      p_obj);
```

db	Database.
tagname	Tag to match.
p_obj	Object (ucdbScopeT or ucdbTestT).

In-memory mode only. Gets the first object that exists with the given tag. Returns 1 if the tag exists in the database, or 0 if not. When the function returns 1, *p_obj is non-NULL.

ucdb_NextTaggedObj

```
int ucdb_NextTaggedObj(
    ucdbT          db,
    ucdbObjT*      p_obj);
```

db	Database.
p_obj	Object (ucdbScopeT or ucdbTestT).

In-memory mode only and must be called immediately after ucdb_BeginTaggedObj—the function re-uses tag from the previous call. Gets the next obj that exists with the given tag. Returns 1 if the next object exists in the database, or 0 if not. When it returns 1, *p_obj is non-NULL.

ucdb_NextTag

```
int ucdb_NextTag(
    ucdbT          db,
    const char*    tagname);
```

db	Database.
tagname	Tag name.

In-memory mode only. Iterator function for returning the set of all tags in the UCDB file. Returns NULL when traversal is done or -1 with error.

Formal Data

A UCDB test is the result of functional verification analysis performed by a simulator or a formal verification tool. A *formal test* is a `ucdbTestT` object that is also associated with special information that describes a particular formal analysis session (`ucdb_AssocFormalInfoTest`).

This information (see [Formal Tool Info Type](#)) describes:

- how, when and where the formal test ran
- scope of the formal analysis
- location of detailed results
- environment assumptions

Formal analysis gives two types of results:

- assertion information

Formal analysis of an assertion results in an indication of the formal status of the assertion under the test assumptions for the scope of the assertion. For example: the assertion is proven; a counterexample exists that makes the assertion fail; or the formal analysis is inconclusive (among other possible statuses, see [Formal Status Enum](#)).

- coverage information

Formal analysis of a cover statement or an assertion returns coverage information such as cover statement coverage, line coverage, stimulus coverage and assertion witnesses that the assertions can be exercised. You model this functionality using the same scopes and coverage items as for simulation, in conjunction with additional facilities for formal verification.

A UCDB formal environment attribute (see [Formal Coverage Context](#)) indicates the context for interpreting the coverage data obtained from a formal analysis session. Coverage “contexts” support various formal coverage use models, for example:

- “Coverage reachability” is the primary objective of the formal analysis session or it is an ancillary by-product of the formal analysis session.
- “Coverage” describes the controllability of the design based on the formal assumptions or it indicates the design logic observable by assertions.

Formal coverage context shows how different types of coverage information (see [Cover Types](#)) were obtained and how you should interpret them.

Note



In general, all arguments returned by the formal routines are only valid as long as the *db* database remains open. Once the *db* database is closed, these arguments are invalid and should not be accessed in any way. If a caller of the formal routines needs access to the returned values beyond the lifetime of the *db* database, it must make copies of them.

Formal Status Enum

```
typedef enum {
    UCDB_FORMAL_NONE,           /* No formal info (default) */
    UCDB_FORMAL_FAILURE,       /* Fails */
    UCDB_FORMAL_PROOF,         /* Proven to never fail */
    UCDB_FORMAL_VACUOUS,       /* Assertion is vacuous as defined by the
                                assertion language */
    UCDB_FORMAL_INCONCLUSIVE,   /* Proof failed to complete */
    UCDB_FORMAL_ASSUMPTION,     /* Assertion is an assume */
    UCDB_FORMAL_CONFLICT       /* Data merge conflict */
} ucdbFormalStatusT;
```

Formal test result for a particular asserted or assumed property.

Formal Environment Type

```
typedef void* ucdbFormalEnvT;
```

Formal Tool Info Type

```
typedef struct ucdbFormalToolInfoS {
    char* formal_tool;          /* tool name */
    char* formal_tool_version;  /* tool version */
    char* formal_tool_setup;    /* setup file (text) */
    char* formal_tool_db;       /* database file (binary) */
    char* formal_tool_rpt;      /* report file (text) */
    char* formal_tool_log;      /* log file (text) */
} ucdbFormalToolInfoT;
```

Structure identifying the test as a formal test and indicating tool-specific information about the formal analysis run.

Formal Coverage Context

```
#define UCDB_FORMAL_COVERAGE_CONTEXT_STIMULUS \
    "UCDB_FORMAL_COVERAGE_CONTEXT_STIMULUS"
#define UCDB_FORMAL_COVERAGE_CONTEXT_RESPONSE \
    "UCDB_FORMAL_COVERAGE_CONTEXT_REPONSE"
#define UCDB_FORMAL_COVERAGE_CONTEXT_TARGETED \
    "UCDB_FORMAL_COVERAGE_CONTEXT_TARGETED"
#define UCDB_FORMAL_COVERAGE_CONTEXT_ANCILLARY \
    "UCDB_FORMAL_COVERAGE_CONTEXT_ANCILLARY"
#define UCDB_FORMAL_COVERAGE_CONTEXT_INCONCLUSIVE_ANALYSIS \
    "UCDB_FORMAL_COVERAGE_CONTEXT_INCONCLUSIVE_ANALYSIS"
```

Formal coverage context is a string that indicates the context for interpreting formal coverage information. This string can be one of the following predefined UCDB formal context attribute values, a user-defined string specific to the tool/application, or NULL (i.e., no formal coverage context specified).

- **UCDB_FORMAL_COVERAGE_CONTEXT_STIMULUS**

Coverage information associated with the test approximates the set of legal stimuli permitted within the constraints of the formal verification run. For example, for this formal coverage context, you can check that the test's formal assumptions do not over- or under-constrain the formal analysis.

- **UCDB_FORMAL_COVERAGE_CONTEXT_RESPONSE**

Coverage information associated with the test identifies the structures under observation by the assertions. For example, knowing the logic verified by formal analysis helps you determine the “completeness” of the assertion instrumentation of the design.

- **UCDB_FORMAL_COVERAGE_CONTEXT_TARGETED**

Coverage information associated with the test is used for comprehensive coverage analysis. For example, one purpose might be to identify the controllable elements of the design. Another might be to evaluate the particular assumptions applied.

- **UCDB_FORMAL_COVERAGE_CONTEXT Ancillary**

Coverage information associated with the test is a by-product of formal analysis and is not the primary objective for the formal test. Results provide coverage information helpful in understanding what was exercised, but that information is not necessarily comprehensive. For example the main objective of the formal verification test might be to prove assertions and find counterexamples. Here, parts of the design not in the fanin of the formal properties are typically ignored by the formal tool. So, coverage is a side effect of the formal analysis.

- **UCDB_FORMAL_COVERAGE_CONTEXT_INCONCLUSIVE_ANALYSIS**

Coverage information associated with the test helps you analyze assertions with inconclusive formal analysis results (i.e., assertions with UCDB_FORMAL_INCONCLUSIVE status).

ucdb_SetFormalStatus

```
int ucdb_SetFormalStatus(  
    ucdbT          db,  
    ucdbTestT      test,  
    ucdbScopeT     assertscope,  
    ucdbFormalStatusT formal_status);
```

db	Database.
test	UCDB test object.
assertscope	Scope of the assertion.
formal_status	Assert formal status.

Sets the formal status of the specified assertion with respect to the specified test. Not supported in read streaming mode. This is a routine that sets a value, so in write streaming mode this routine can only be called while the scope of the assertion is actively being written. Returns 0 if successful, or non-zero if error (and formal status is unchanged). Returns an error if any argument is NULL.

ucdb_GetFormalStatus

```
int ucdb_GetFormalStatus(  
    ucdbT          db,  
    ucdbTestT      test,  
    ucdbScopeT     assertscope,  
    ucdbFormalStatusT* formal_status);
```

db	Database.
test	UCDB test object.
assertscope	Scope of the assertion.
formal_status	Assert formal status returned.

Gets the formal status of the specified assertion with respect to the specified test. Not supported in write streaming mode. This is a routine that gets a value, so in read streaming mode this routine can only be called while the scope of the assertion is actively being read. Neither iteration of *assertscopes* paired with a given test nor iteration of *test* with a given assertscope is supported. Returns 0 if successful, or non-zero if error (and formal status is not returned). Returns an error if any argument is NULL.

ucdb_SetFormalRadius

```
int ucdb_SetFormalRadius(  
    ucdbT          db,  
    ucdbTestT      test,  
    ucdbScopeT     assertscope,  
    int            radius,  
    char*          clock);
```

db	Database.
----	-----------

<code>test</code>	UCDB test object.
<code>assertscope</code>	Scope of the assertion.
<code>radius</code>	Radius expressed in <i>clock</i> cycles. Exact meaning depends on the assertion's status: <ul style="list-style-type: none"> • <code>UCDB_FORMAL_INCONCLUSIVE</code> Proof radius (if a bounded proof is reported) or -1 (if no bounded proof is reported). • <code>UCDB_FORMAL_FAILURE</code> Counterexample depth.
<code>clock</code>	Assertion clock specified as a hierarchical name string. Can be NULL.

Sets the formal radius (proof radius or counterexample depth) for the specified assertion with respect to the specified test. Not supported in read streaming mode. This is a routine that sets a value, so in write streaming mode this routine can only be called while the scope of the assertion is actively being written. Returns 0 if successful, or non-zero if error (and formal radius is unchanged). Returns an error if any argument except *clock* is NULL.

ucdb_GetFormalRadius

```
int ucdb_GetFormalRadius(
    ucdbT          db,
    ucdbTestT      test,
    ucdbScopeT     assertscope,
    int*           radius,
    char**         clock);
```

<code>db</code>	Database.
<code>test</code>	UCDB test object.
<code>assertscope</code>	Scope of the assertion.
<code>radius</code>	Radius returned (expressed in <i>clock</i> cycles). Exact meaning depends on the assertion's status: <ul style="list-style-type: none"> • <code>UCDB_FORMAL_INCONCLUSIVE</code> Proof radius (if a bounded proof is reported) or -1 (if no bounded proof is reported). • <code>UCDB_FORMAL_FAILURE</code> Counterexample depth.
<code>clock</code>	Assertion clock returned (specified as a hierarchical name string). If NULL, the clock is NULL or the formal radius was not set.

Gets the formal radius for the specified assertion with respect to the specified test and gets the associated clock for the radius. Not supported in write streaming mode. This is a routine that gets values, so in read streaming mode this routine can only be called while the scope of the assertion is actively being read. Neither iteration of *assertscopes* paired with a given test nor iteration of *test* with a given assertscope is supported. Returns 0 if successful, or non-zero if error (and *radius/clock* are not returned). Returns an error if any argument is NULL.

ucdb_SetFormalWitness

```
int ucdb_SetFormalWitness(  
    ucdbT          db,  
    ucdbTestT      test,  
    ucdbScopeT     assertscope,  
    char*          witness_file_or_dir);
```

db	Database.
test	UCDB test object.
assertscope	Scope of the assertion.
witness_file_or_dir	Path to a waveform file or directory containing waveform files, expressed as a string. Waveform files can be in any standard or widely-used format.

Sets witness waveforms for the specified assertion with respect to the specified test. A witness is a counterexample (for a failed property) or a sanity waveform (for a proven property). Not supported in read streaming mode. This is a routine that sets a value, so in write streaming mode this routine can only be called while the scope of the assertion is actively being written. Returns 0 if successful, or non-zero if error (and witness waveform information is unchanged). Returns an error if any argument is NULL.

ucdb_GetFormalWitness

```
int ucdb_GetFormalWitness(  
    ucdbT          db,  
    ucdbTestT      test,  
    ucdbScopeT     assertscope,  
    char**         witness_file_or_dir);
```

db	Database.
test	UCDB test object.
assertscope	Scope of the assertion.
witness_file_or_dir	Witness string returned. String is the path to a witness waveform file or a directory containing witness waveform files (expressed in a standard or widely-used format).

Gets witness waveforms for the specified assertion with respect to the specified test. A witness is a counterexample (for a failed property) or a sanity waveform (for a proven property). Not supported in write streaming mode. This is a routine that gets a value, so in read streaming mode this routine can only be called while the scope of the assertion is actively being read. Neither iteration of *assertscopes* paired with a given test nor iteration of *test* with a given assertscope is supported. Returns 0 if successful, or non-zero if error (and *witness_file_or_dir* is not returned). Returns an error if any argument is NULL.

ucdb_SetFormallyUnreachableCoverTest

```
int ucdb_SetFormallyUnreachableCoverTest(
    ucdbT          db,
    ucdbTestT      test,
    ucdbScopeT     coverscope,
    int            coverindex);
```

db	Database.
test	UCDB test object.
coverscope	Scope of the cover item.
coverindex	Index of the cover item in the cover scope.

Sets the formally-unreachable status flag for the specified cover item with respect to the specified test. Use this function in conjunction with [ucdb_AssocCoverTest](#), which indicates whether or not the coverage item is reachable with respect to the test. With these two flags, you can indicate the status of the cover item with respect to a formal test: covered by formal, proven unreachable, or unknown coverage status (i.e., if both flags are clear).

Not supported in read streaming mode. This is a routine that sets a value, so in write streaming mode this routine can only be called while the scope of the cover item is actively being written. Returns 0 if successful, or non-zero if error (and formally-unreachable status flag is unchanged). Returns an error if any argument is NULL.

ucdb_ClearFormallyUnreachableCoverTest

```
int ucdb_ClearFormallyUnreachableCoverTest(
    ucdbT          db,
    ucdbTestT      test,
    ucdbScopeT     coverscope,
    int            coverindex);
```

db	Database.
test	UCDB test object.
coverscope	Scope of the cover item.
coverindex	Index of the cover item in the cover scope.

Clears the formally-unreachable status flag (see [ucdb_SetFormallyUnreachableCoverTest](#)) for the specified cover item with respect to the specified test. Not supported in read streaming mode. This is a routine that sets a value, so in write streaming mode this routine can only be called while the scope of the cover item is actively being written. Returns 0 if successful, or non-zero if error (and formally-unreachable status flag is unchanged). Returns an error if any argument is NULL.

ucdb_GetFormallyUnreachableCoverTest

```
int ucdb_GetFormallyUnreachableCoverTest(
    ucdbT          db,
    ucdbTestT      test,
    ucdbScopeT     coverscope,
    int            coverindex,
    int*           unreachable_flag);
```

db	Database.
test	UCDB test object.
coverscope	Scope of the cover item.
coverindex	Index of the cover item in the cover scope.
unreachable_flag	Flag value returned: <ul style="list-style-type: none"> • 0 — coverage item possibly reachable • 1 — coverage item formally unreachable

Gets the formally-unreachable status flag for the specified cover item with respect to the specified test. Not supported in write streaming mode. This is a routine that gets a value, so in read streaming mode this routine can only be called while the scope of the cover item is actively being read. Neither iteration of *coverscopes* paired with a given test nor iteration of *test* with a given coverscope is supported. Returns 0 if successful, or non-zero if error (and formally-unreachable status flag is not returned). Returns an error if any argument is NULL.

ucdb_AddFormalEnv

```
ucdbFormalEnvT ucdb_AddFormalEnv(
    ucdbT          db,
    const char*    name,
    ucdbScopeT     scope);
```

db	Database.
name	Environment name.
scope	Scope indicating the part of the design analyzed by formal verification.

Creates a new formal environment object. A formal environment describes the scope of a formal test and the environmental assumptions used to perform the formal analysis. Returns the handle for the new environment (if successful); returns the handle for an existing environment (if *name* and *scope* match those of an existing formal environment); or returns NULL if error. Names of formal environments must be unique, so it is an error if *name* matches an existing formal environment's name, but the two *scopes* do not match. Not supported in read streaming mode. This is a routine that writes information, so in write streaming mode this routine can only be called while the scope of the environment is actively being written.

Once a formal environment is created, use [ucdb_AssocAssumptionFormalEnv](#) repeatedly to associate assumption scopes with the environment. Then, use [ucdb_AssocFormalInfoTest](#) to associate the formal environment with formal tests run under those environmental constraints.

ucdb_AssocAssumptionFormalEnv

```
int ucdb_AssocAssumptionFormalEnv(
    ucdbT          db,
    ucdbFormalEnvT formal_env,
    ucdbScopeT     assumption_scope);
```

db	Database.
formal_env	UCDB formal environment.
assumption_scope	Scope of an assumption.

Adds the specified assumption to the specified formal environment (created with [ucdb_AddFormalEnv](#)). Not supported in read streaming mode. This is a routine that writes a value, so in write streaming mode this routine can only be called while the scope of the assumption is actively being written. Returns 0 if successful, or non-zero if error (and assumption is not added to the environment).

ucdb_AssocFormalInfoTest

```
int ucdb_AssocFormalInfoTest(
    ucdbT          db,
    ucdbTestT      test,
    ucdbFormalToolInfoT* formal_tool_info,
    ucdbFormalEnvT formal_env,
    char*          formal_cov_context);
```

db	Database.
test	UCDB test object.
formal_tool_info	Formal tool information (see Formal Tool Info Type).
formal_env	UCDB formal environment.
formal_cov_context	Formal coverage context (see Formal Coverage Context).

Adds a formal environment, tool-specific information and a formal coverage context to the information for a test, which in effect makes *test* a formal test. Returns 0 if successful, or non-zero if error (and the formal information is not added to the test).

ucdb_NextFormalEnv

```
ucdbFormalEnvT ucdb_NextFormalEnv(
    ucdbT          db,
    ucdbFormalEnvT formal_env);
```

db	Database.
formal_env	UCDB formal environment (or NULL, to return the first formal environment).

Returns the handle for the first formal environment (if *formal_env* is NULL), or the next formal environment after *formal_env*, or NULL (if *formal_env* is the last environment added by [ucdb_AddFormalEnv](#) or if error).

ucdb_NextFormalEnvAssumption

```
ucdbScopeT ucdb_AssocAssumptionFormalEnv(  
    ucdbT          db,  
    ucdbFormalEnvT formal_env,  
    ucdbScopeT     assumption_scope);
```

db	Database.
formal_env	UCDB formal environment.
assumption_scope	Scope of an assumption added to <i>formal_env</i> using ucdb_AssocAssumptionFormalEnv or NULL.

Returns the handle for the first assumption added to *formal_env* (if *assumption_scope* is NULL), or the next formal environment after *formal_env*, or NULL (if *assumption_scope* is the last assumption added to *formal_env* or if error). Not supported in streaming mode (only supported in memory mode).

ucdb_FormalEnvGetData

```
int ucdb_FormalEnvGetData(  
    ucdbT          db,  
    ucdbFormalEnvT formal_env,  
    const char**    name,  
    ucdbScopeT*     scope);
```

db	Database.
formal_env	UCDB formal environment.
name	Environment name returned.
scope	Scope returned indicating the part of the design analyzed by formal verification.

Gets the name and scope of the specified formal environment. Not supported in streaming mode (only supported in memory mode). Returns 0 if successful, or non-zero if error (and the formal environment information is not updated).

ucdb_FormalTestGetInfo

```
int ucdb_FormalTestGetInfo(  
    ucdbT          db,  
    ucdbTestT      test,  
    ucdbFormalToolInfoT** formal_tool_info,  
    ucdbFormalEnvT* formal_env,  
    char**         formal_cov_context);
```

db	Database.
test	UCDB test object.
formal_tool_info	Formal tool information returned.
formal_env	UCDB formal environment returned.
formal_cov_context	Formal coverage context returned.

Gets the formal environment, tool information and formal coverage context for the specified formal test (from data created by [ucdb_AssocFormalInfoTest](#)). This function allocates and owns the memory for the returned values *formal_tool_info* and *formal_cov_context*, so the calling code should not “free” the memory these arguments point to. Returns 0 if successful, or non-zero if error (and the formal test information is not returned).

Test Traceability

API for associating tests and coverage objects. Coveritems or scopes may be associated with one of the ucdbTestT records in the database through this API.

NOTE on the tests and coverage object association: For compactness, this is implemented as a bit vector associated with each coverage object, where each bit corresponds to a test in the list of test data records in the database. Consequently, this is dependent on the ordering of test data records being stable. If test data records are removed (with ucdb_RemoveTest()), all test-coverage associations can be invalidated.

Some test traceability support functions use the ucdbBitVectorT structure, which contains a vector whose bits correspond to the test data records in the database.

```
typedef struct {
    unsigned char*    bitvector;        /* LSBs are filled first */
    int               bitlength;        /* length in bits */
    int               bytelength;      /* length in bytes */
} ucdbBitVectorT;
```

This structure is used for efficient implementation. When using ucdb_SetCoverTestMask() or other functions reading the bit vector, bitlength takes priority over bytelength, either will be ignored if set to -1. Both may not be set to -1. Setting length to 0 will erase the attribute.

The following optional defines enforce the conventions for bitlength vs. bytelength in ucdbBitVectorT structures:

```
#define ucdb_SetBitVectorLengthBits(bitvector,numbits) \
    { (bitvector).bitlength = (numbits); \
      (bitvector).bytelength = (((bitvector).bitlength)/8) \
                               + (((bitvector).bitlength)%8) ? 1 : 0);}

#define ucdb_SetBitVectorLengthBytes(bitvector,numbytes) \
    { (bitvector).bytelength = (numbytes); \
      (bitvector).bitlength = ((bitvector).bytelength) * 8 ;}

#define ucdb_GetBitVectorLengthBytes(bitvector) \
    ((bitvector).bitlength >= 0 ? \
     (((bitvector).bitlength/8) + (((bitvector).bitlength%8) ? 1 : 0)) \
     : (bitvector).bytelength)

#define ucdb_GetBitVectorLengthBits(bitvector) \
    ((bitvector).bitlength >= 0 ? \
     (bitvector).bitlength \
     : (bitvector).bytelength * 8)
```

ucdb_AssocCoverTest

```
int ucdb_AssocCoverTest(  
    ucdbT          db,  
    ucdbTestT      testdata,  
    ucdbScopeT     scope,  
    int            coverindex);
```

db	Database.
testdata	Test data record.
scope	Scope.
coverindex	Index of coveritem. If -1, associate scope.

Associates a scope or coveritem with the given test data record. This may be done for any purpose, but is most logically done to indicate that the given test incremented or covered the bin; in-memory mode only. Returns 0 if successful, -1 for failure (e.g., coverindex out-of-bounds.)

ucdb_NextCoverTest

```
ucdbTestT ucdb_NextCoverTest(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            coverindex,  
    ucdbTestT      test);
```

db	Database.
scope	Scope.
coverindex	Index of coveritem. If -1, scope only.
test	Test.

In-memory mode only. Gets the next test record associated with the given scope or coveritem. Returns the first record with NULL as input, or returns NULL when list is exhausted.

ucdb_GetCoverTestMask

```
int ucdb_GetCoverTestMask(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            coverindex,  
    ucdbBitVectorT* mask);
```

db	Database.
scope	Scope.
coverindex	Index of coveritem. If -1, scope only.
mask	Database bit vector.

Gets a bit vector whose bits correspond to the associated test data records in the database. First bit (mask.bitvector[0]&0x01) corresponds to first test retrieved by `ucdb_NextTest()`, subsequent bits correspond in order to subsequent test data records. If tests are saved in an array, this allows quick retrieval of all associated tests in a single call. Returns 0 if successful, or -1 if error. mask.bitvector == NULL if none, lengths == 0.

This function always sets both bitlength and bytelength on the bitvector. Note: bitvector storage is not to be de-allocated by the user.

ucdb_SetCoverTestMask

```
int ucdb_SetCoverTestMask(  
    ucdbT          db,  
    ucdbScopeT     scope,  
    int            coverindex,  
    ucdbBitVectorT* mask);
```

db	Database.
scope	Scope.
coverindex	Index of coveritem. If -1, scope only.
mask	Database bit vector.

Writes a bit vector whose bits correspond to the associated test data records in the database. This is for write-streaming versions of the API and is not as foolproof as `ucdb_AssocCoverTest()`. See details for read function above. Returns 0 if successful, or -1 if error.

When initializing a mask, be careful with the rules for setting bitlength and bytelength, (see above). Note: bitvector storage is copied by this routine.

ucdb_OrCoverTestMask

```
int ucdb_OrCoverTestMask(  
    ucdbT          db,  
    ucdbBitVectorT* mask,  
    ucdbTestT       test);
```

db	Database.
mask	Database bit vector.
test	Test.

ORs the required bit for the given test data record. Returns 0 if successful, non-zero if error.

Appendix A

UCDB Organization

A UCDB file is organized into two sections:

- Test section.
- Coverage section.

Test Section

The *test section* of a UC database contains information about the test or set of tests that were used to generate the coverage data. If the file was created by merging multiple databases, the database contains multiple test records. When creating a database, first define information about the test from which coverage data is acquired (see “[ucdb_AddTest](#)” on page 107). In addition to a fixed list of fields ([Table A-1](#)), any of which may be NULL or unused, there are user-defined attributes.

Table A-1. Fields of a Test Record

Field	Value	Description
testname	string	Name of the coverage test.
simtime	double	Simulation time of completion of the test.
simtime_units	string	Units for simulation time: "fs", "ps", "ns", "us", "ms", "sec", "min", "hr".
realtime	double	CPU time for completion of the test.
seed	string	Randomization seed for the test. (Same as the seed value provided by the "-sv_seed" vsim option.)
command	string	Test script arguments. Used to capture "knob settings" for parameterizable tests, as well as the name of the test script.
date	string	Time file was saved. For example, this might be a string like "20060105160030", which represents 4:00:30 PM January 5, 2006 (output of strftime with the format "%Y%m%d%H%M%S").
simargs	string	Simulator command line arguments.
userid	string	User ID of user who ran the test.
compulsory	boolean	Whether (1) or not (0) this test should be considered compulsory (i.e., a “must-run” test).

Table A-1. Fields of a Test Record

Field	Value	Description
comment	string	String (description) saved by the user associated with the test
test_status	int	Status of test: fatal error (\$fatal was called), error (\$error was called), warning (\$warning was called) or OK.
filename	string	Name of the original file, to which the test was first written.

Test records are a subset of history nodes, which have the attributes shown in [Table A-2](#)

Table A-2. Attributes of a History Node

Attribute	Value	Description
filename	string	Pathname of the merged file (UCDB_HISTORYNODE_MERGE), test file (UCDB_HISTORYNODE_TEST), or testplan file (UCDB_HISTORYNODE_TESTPLAN).
cmdline	string	Command line used to create resulting UCDB file associated with filename.
runcwd	string	Working directory where cmdline was executed.
cputime	double	(Optional) CPU time for the execution of cmdline.
histcomment	string	(Optional) String used as a general-purpose comment.
path	string	(UCDB_HISTORYNODE_TESTPLAN only) Testplan path.
xmlsource	string	(UCDB_HISTORYNODE_TESTPLAN only) XML file pathname.
signature	string	(UCDB_HISTORYNODE_TESTPLAN only, optional) Source-based signature used to determine if the xmlsource file is stale.
numtests	integer	(UCDB_HISTORYNODE_MERGE only) Number of tests merged.

Coverage Section

The *coverage section* of a UC database contains the coverage data, organized in a hierarchy of scopes related to the design, testbench, and test plan.

Scope Nodes

Coverage data in the database form a tree of nodes, called *scopes*, generally corresponding to the design hierarchy. All nodes except the root node have a pointer to their parent. If the design hierarchy is not relevant to coverage, it need not be represented in the UCDB.

Nodes can have children: other scope nodes or coverage items. Design units (for example, Verilog modules or VHDL architectures) also are represented as scopes, because sometimes coverage for a design unit is often represented as a union of the coverage of all instances of the design unit. Typically, only code coverage is represented under the design unit. Note that a design unit with a single instance a higher-level design are not stored (only the instance is stored).

Scope nodes can represent:

- Design hierarchy: instances of modules, function scope, packages, and so on.
- Hierarchy for coverage counts. For example:
 - Scopes to contain different counts for expression rows in expression coverage.
 - Scopes to represent SystemVerilog covergroups.

If there is no coverage hierarchy (e.g., with statement coverage) none is used.

- Test plan items.

These are optional, but are required for some use models of test traceability analysis. In particular, if you want the UCDB to represent associations between test plan items and coverage items using built-in "tags" (see [“Tags”](#) on page 173), then a test plan item scope should exist in the database.

Coveritems

Coveritems (coverage items) are always children of parent scopes and each coverage item is only accessible through its parent scope. This property of a UCDB allows optimizations related to efficiently storing a sets of coverage items that always lie in certain scopes.

A coveritem is a single count or vector of bits, generally used to compute coverage, represented in the database. In some coverage models (for example, SystemVerilog covergroups) coveritems these represent "bins"—the UCDB architecture is expanded to represent more types of coverage data.

A coveritem is only accessed through a handle to its parent scope and an index uniquely identifying it within the scope. The user can query a scope for how many coveritems it contains.

Nesting Rules

The UCDB does some light enforcement of HDL nesting rules, but strictly enforces nesting rules for coverage scopes, coveritems and testplan scopes. The "covergroup" scopes are for generic use. For clarity, different types of coverage (assertion, statement, FSM, and so on) are given separate scopes, although the UCDB coverage hierarchy could have been built using only "covergroup" scopes only (COVERGROUP, COVERINSTANCE, COVERPOINT, and CROSS).

Table A-3 shows the netlisting rules enforced by the UCDB.

Table A-3. Nesting Rules Enforced by UCDB

Hierarchical Object	Rules
HDL SCOPE	Can contain any of: HDL SCOPE, COVER SCOPE and STANDALONE COVERITEM. Is one of the following scope types: UCDB_INSTANCE, UCDB_PACKAGE, UCDB_PROGRAM, UCDB_PACKAGE, UCDB_INTERFACE, UCDB_PROCESS, UCDB_GENERATE, UCDB_TASK, UCDB_FUNCTION, UCDB_FORKJOIN, UCDB_BLOCK, UCDB_CLASS, or UCDB_GENERIC
UCDB_INSTANCE	Contains a "DU" (design unit) or a "type" pointer to one of: UCDB_DU_MODULE or UCDB_DU_ARCH.
UCDB_PACKAGE	Contains a "DU" (design unit) or a "type" pointer to a UCDB_DU_PACKAGE.
UCDB_PROGRAM	Contains a "DU" (design unit) or a "type" pointer to a UCDB_DU_PROGRAM.
UCDB_INTERFACE	Contains a "DU" (design unit) or a "type" pointer to a UCDB_DU_INTERFACE.
DU SCOPE (i.e., UCDB_DU_*)	Can contain: code coverage coveritems.
COVER SCOPE	Is one of the following scope types: UCDB_COVERGROUP, UCDB_COVERINSTANCE, UCDB_COVERPOINT, UCDB_CROSS, UCDB_BRANCH, UCDB_EXPR, UCDB_COND, UCDB_TOGGLE, UCDB_FSM, UCDB_ASSERT, UCDB_COVER, UCDB_BLOCK, UCDB_CVGBINSCOPE, UCDB_ILLEGALBINSCOPE, UCDB_IGNOREBINSCOPE, UCDB_CROSSPRODUCT, UCDB_CROSSPRODUCT_ITEM.

Table A-3. Nesting Rules Enforced by UCDB

Hierarchical Object	Rules
STANDALONE COVERITEM	Is one of the following coveritem types: UCDB_STMTBIN, UCDB_USERBIN, UCDB_COUNT.
UCDB_TESTPLAN	Can contain only a UCDB_TESTPLAN scope.
UCDB_COVERGROUP	Can contain only the following scope types: UCDB_COVERINSTANCE, UCDB_COVERPOINT, UCDB_CROSS.
UCDB_CROSS	Must refer to at least two scopes of type UCDB_COVERPOINT, which must have the same parent as the UCDB_CROSS. UCDB_CROSS scope can contain only: <ul style="list-style-type: none"> • UCDB_CVGBINSCOPE scopes • UCDB_ILLEGALBINSCOPE scopes • UCDB_IGNOREBINSCOPE scopes • UCDB_CVGBIN coveritems • UCDB_ILLEGALBIN coveritems • UCDB_IGNOREBIN coveritems • UCDB_DEFAULT coveritems
UCDB_COVERPOINT	UCDB_COVERPOINT scope can contain only: <ul style="list-style-type: none"> • UCDB_CVGBINSCOPE scopes • UCDB_ILLEGALBINSCOPE scopes • UCDB_IGNOREBINSCOPE scopes • UCDB_CVGBIN coveritems • UCDB_ILLEGALBIN coveritems • UCDB_IGNOREBIN coveritems • UCDB_DEFAULT coveritems (can be ORed with each of the other bin types to indicate a default bin of the given type).
UCDB_CVGBINSCOPE	UCDB_CVGBINSCOPE scope can contain only: <ul style="list-style-type: none"> • UCDB_CVGBIN coveritems • UCDB_ILLEGALBIN coveritems • UCDB_IGNOREBIN coveritems • UCDB_DEFAULT coveritems
UCDB_ILLEGALBINSCOPE	UCDB_ILLEGALBINSCOPE scope can contain only: <ul style="list-style-type: none"> • UCDB_CVGBIN coveritems • UCDB_ILLEGALBIN coveritems • UCDB_IGNOREBIN coveritems • UCDB_DEFAULT coveritems
UCDB_IGNOREBINSCOPE	UCDB_IGNOREBINSCOPE scope can contain only: <ul style="list-style-type: none"> • UCDB_CVGBIN coveritems • UCDB_ILLEGALBIN coveritems • UCDB_IGNOREBIN coveritems • UCDB_DEFAULT coveritems

Table A-3. Nesting Rules Enforced by UCDB

Hierarchical Object	Rules
UCDB_COVERINSTANCE	Can contain the only the following scope types: UCDB_COVERPOINT and UCDB_CROSS.
UCDB_ASSERT	Must contain UCDB_ASSERTBIN and can contain any of the following coveritems: UCDB_VACUOUSBIN, UCDB_DISABLEDBIN, UCDB_ATTEMPTSBIN, UCDB_ACTIVEBIN, UCDB_PEAKACTIVEBIN or UCDB_PASSBIN. No coveritem type can be represented more than once. Note: UCDB_ASSERTBIN indicates assertion failures. UCDB_PASSBIN contributes toward aggregated coverage.
UCDB_ASSERTBIN	Contains assert-fail count or boolean. Can be a direct descendant of the enclosing instance scope.
UCDB_COVER	Must contain exactly one UCDB_COVERBIN (indicating non-vacuous coverage passes or successes).
UCDB_COVERBIN	Contains non-vacuous cover pass count or boolean. Can be a direct descendant of the enclosing instance scope.
UCDB_STMTBIN	Can appear in any HDL scope.
UCDB_BRANCH	Must contain only UCDB_BRANCHBIN coveritems.
UCDB_EXPR	Used in a 3-level hierarchy: <ul style="list-style-type: none"> • UCDB_EXPR top node contains name and source info. • UCDB_EXPR second-level nodes are named "FEC" and "UDP" for different representations of expression coverage UCDB_EXPRBIN coveritems. The coveritem name is a description of the expression truth table row. Can appear in any HDL scope or another UCDB_EXPR scope. Must contain only UCDB_EXPR scopes and UCDB_EXPR coveritems.
UCDB_COND	Used in a 3-level hierarchy: <ul style="list-style-type: none"> • UCDB_COND top node contains name and source info. • UCDB_COND second-level nodes are named "FEC" and "UDP" for different representations of condition coverage UCDB_CONDBIN coveritems. The coveritem name is a description of the expression truth table row. Can appear in any HDL scope or another UCDB_COND scope. Must contain only UCDB_COND scopes and UCDB_COND coveritems.
UCDB_TOGGLE	Must contain only UCDB_TOGGLEBIN coveritems (coveritem name is the name of toggle transition). For extended toggles: coveritems 0 and 1 are the low->high and high->low transitions, and coveritems 2-5 are the Z transitions. Toggle nodes, because of their abundance, are lighter-weight structures than all other types in the database, lacking some data that other scopes have.

Table A-3. Nesting Rules Enforced by UCDB

Hierarchical Object	Rules
UCDB_FSM	Must contain the two subsopes UCDB_FSM_STATES and UCDB_FSM_TRANS.
UCDB_FSM_STATES	Must contain UCDB_FSMBIN coveritems.
UCDB_FSM_TRANS	Must contain UCDB_FSMBIN coveritems.
UCDB_BLOCK	Can appear in any HDL scope or another UCDB_BLOCK scope. Must contain only UCDB_BLOCK scopes, UCDB_BLOCKBIN coveritems and UCDB_STMTBIN.
UCDB_HIERARCHY	Light-weight hierarchy node that can have any other scope nodes as parents or children. Supports the user-defined attribute mechanism but not other attributes (such as design unit, source references, and so on). Useful for representing hierarchies that can be merged. The following functions cannot use the UCDB_HIERARCHY scope: ucdb_*File*, ucdb_InstanceSetDU, ucdb_*ScopeFlags, ucdb_*ScopeSourceType, ucdb_*ScopeSourceInfo, ucdb_*ScopeWeight, ucdb_*ScopeGoal, ucdb_GetInstanceDU*, ucdb_*Tag*.

Attributes

UCDB attributes provide a faster access mechanism for some frequently accessed attributes, compared to user-defined attributes. [Table A-3](#) shows the UCDB predefined attributes.

Table A-4. UCDB Defined Attributes

Attribute	Type	Macro	Definition
Test Attributes			
SIMTIME	string	UCDBKEY_SIMTIME	Simulation time.
TIMEUNIT	string	UCDBKEY_TIMEUNIT	Time unit for SIMTIME.
CPUTIME	string	UCDBKEY_CPUTIME	CPU time.
DATE	string	UCDBKEY_DATE	Time at which the UCDB save was initiated.
VSIMARGS	string	UCDBKEY_SIMARGS	Simulator command line arguments.
USERNAME	string	UCDBKEY_USERNAME	Name of the user who ran the test.
TESTSTATUS	ucdbTest-StatusT	UCDBKEY_TESTSTATUS	Status of the simulation run.
TESTNAME	string	UCDBKEY_TESTNAME	Name of the test.
ORIGFILE-NAME	string	UCDBKEY_FILENAME	Database filename that the test was originally written to.

Table A-4. UCDB Defined Attributes

Attribute	Type	Macro	Definition
SEED	string	UCDBKEY_SEED	0 or the seed provided by the -sv_seed vsim option.
TESTCMD	string	UCDBKEY_TESTCMD	String provided by the user intended for test arguments.
TESTCOMMENT	string	UCDBKEY_TESTCOMMENT	General-purpose comment provided with the test.
COMPULSORY	int (0 1)	UCDBKEY_COMPULSORY	Whether (1) or not (0) the test is compulsory.
RUNCWD	string	UCDBKEY_RUNCWD	When this attribute exists, it holds the working directory of the simulation from which the UCDB was saved.

Code Coverage Attributes

#SINDEX#	int (>0)	UCDBKEY_STATEMENT_INDEX	Statement number of a statement or expression in a design unit, starting at 1.
#BCOUNT#	int	UCDBKEY_BRANCH_COUNT	Total count of a branch scope (sum of true counts of individual branch cover items plus the count of the <i>else</i> branch).
#BTYPE#	int (0 1)	UCDBKEY_BRANCH_ISCASE	Branch type: <i>if-else</i> (0) or <i>case</i> (1).
#BHASELSE#	int (0 1)	UCDBKEY_BRANCH_HASELSE	Whether (1) or not (0) branch has an <i>else</i> clause.
#EHEADER#	string	UCDBKEY_EXPR_HEADERS	Header strings for each column of the table separated by ';'. Used on expression or condition scopes.
#FSMID#	string	UCDBKEY_FSM_ID	Symbolic name for an FSM state, usually derived from the state variable. Used with FSM coverages
#FSTATEVAL#	int	UCDBKEY_FSM_STATEVAL	Value of an FSM state. Used on FSM coverage state coveritems.

SystemVerilog covergroups Attributes

BINRHS	string	UCDBKEY_BINRHSVALUE	RHS value of a bin, a string that describes the sampled values that potentially could cause the particular bin to increment. Used on SV coverpoint coveritems (bins).
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Table A-4. UCDB Defined Attributes

Attribute	Type	Macro	Definition
#GOAL#	int	UCDBKEY_GOAL	The option.goal or type_option.goal of the object. Used on SV covergroup, coverpoint or cross scopes.
#GOAL#	float	UCDBKEY_GOAL	Arbitrary goal that can have an effect (as for TESTPLAN scopes) in GUIs or reports. Used on other types of scopes.
ATLEAST	int	UCDBKEY_ATLEAST	The option.at_least or type_option.at_least of the object. Used on SV covergroup, coverpoint or cross scopes.
COMMENT	string	UCDBKEY_COMMENT	The option.comment or type_option.comment of the object. Used on SV covergroup, coverpoint or cross scopes.
AUTOBINMAX	int	UCDBKEY_AUTOBINMAX	The option.auto_bin_max of the object. Used on SV covergroup or coverpoint scopes.
DETECT-OVERLAP	int (0 1)	UCDBKEY_DETECTOVERLAP	The option.detect_overlap of the object. Used on SV covergroup or coverpoint scopes.
PRINT-MISSING	int	UCDBKEY_NUMPRINTMISSING	The option.cross_num_print_missing of the object. Used on SV covergroup or cross scopes.
STROBE	int (0 1)	UCDBKEY_STROBE	The type_option.strobe of the object. Used on SV covergroup scopes.
#CROSSERR#	int (0 1)	UCDBKEY_CROSSERROR	When 1, indicates a cross type coverage calculation not supported by the simulator (i.e., when crossed coverpoints are parameterized with different numbers of bins in different covergroup instances). Used on SV covergroup scopes.
NUMSAMPLED	int	UCDBKEY_NUMSAMPLED	Optional sample count for covergroups
#SAMPLES#		UCDBKEY_SAMPLES	Array of sample counts, for level 2 merge
Cover and Assertion Memory Profile Attributes			
MEM_ASSERT		UCDBKEY_MEM_ASRTCURR	Current memory.

Table A-4. UCDB Defined Attributes

Attribute	Type	Macro	Definition
MEM_ASSERT		UCDBKEY_MEM_ASRTPEAK	Peak memory.
CMLTTHREADS_ASRT		UCDBKEY_CMLTTHREADS_ASRT	Cumulative threads.
TIME_PEAKMEM		UCDBKEY_MEM_PEAKTIME	Time of peak.
Covergroup Memory Profile Attributes			
PERSISTMEM_CVG		UCDBKEY_MEM_CVGPERSIST	Persistent memory.
TRANSMEM_CVG		UCDBKEY_MEM_CVGTRANS	Transient memory.
TRANSPEAK_CVG		UCDBKEY_MEM_CVGTRANS_PEAK	Transient peak.
UCDBKEY_MEM_PEAKTIME		UCDBKEY_MEM_CVGTRANS_PEAKTIME	Time of peak.
Assertion Directive Attributes			
#ACTION#	int (0 1 2)	UCDBKEY_ASSERT_ACTION	Simulator action performed when the assertion fails: continue (0), break (1) or exit (2). Used on assertion objects.
PROOFRADIUS	int	UCDBKEY_ASSERT_PROOFRADIUS	Proof radius from formal analysis of the assertion.
SEVERITY		UCDBKEY_ASSERT_SEVERITY	Severity metric for the assertion.
General Attributes			
#	binary: bit vector	UCDBKEY_TESTVECTOR	Indicates which tests caused the object to be covered. Used on bins and UCDB_TOGGLE coverage scope.
MERGED		UCDBKEY_TESTDATA_MERGED	
TAGCMD	string	UCDBKEY_TAGCMD	Semicolon-separated arguments to "coverage tag" command. This supports implicit tagging during merge, so as to associate test plans with coverage for test traceability. Used for UCDB_TESTPLAN scopes.
#SECTION#	string	UCDBKEY_SECTION	Section number within test plan. Used for UCDB_TESTPLAN scopes.
#DUSIG-NATURE#	string	UCDBKEY_DUSIGNATURE	MD5 signature string of a source design unit.

Table A-4. UCDB Defined Attributes

Attribute	Type	Macro	Definition
#COV#	float	UCDBKEY_COV	Used by coverage analysis to cache a computed total coverage number. Used for any scope.
MERGELEVEL	int (1 2)	UCDBKEY_MERGELEVEL	Used with merge files. <ol style="list-style-type: none"> 1. Default merge, test data is merged, the union of bins are merged, with integer counts incremented and vector counts ORed. 2. Tests are associated with most bins as a bit vector indicating what test caused them to be covered. For vector bins, this means non-zero. For UCDB_COVER scopes, this means cover count > at_least; for UCDB_ASSERT scopes, this means fail count > 0; for UCDB_TOGGLE scopes, this means all bins covered (>0) except for UCDB_TOGGLE_ENUM types, where individual bins >0. Also: NUMSAMPLED attributes for UCDB_COVERGROUP and UCDB_COVERINSTANCE scopes are combined into a binary attribute called "SAMPLED" that is an array of as many integers as there are tests.

Table A-5. UCDB Defined Objects

Attribute	Macro	Definition
Some UCDB bin names are predefined to identify which count value is for a particular coveritem. These names are the names of coveritems, where applicable.		
true_branch	UCDBBIN_BRANCH_T	Branch true bins.
false_branch	UCDBBIN_BRANCH_F	Branch true bins.
else_branch	UCDBBIN_BRANCH_E	<i>else</i> count
all_false_branch	UCDBBIN_BRANCH_AF	All false count when there is no <i>else</i> part.
toggle_low	UCDBBIN_TOGGLE_L	2-state toggle bins
toggle_high	UCDBBIN_TOGGLE_H	2-state toggle bins
toggle_h_l	UCDBBIN_TOGGLE_EXT_H_L	3-state (extended) toggles

Table A-5. UCDB Defined Objects

Attribute	Macro	Definition
toggle_l_h	UCDBBIN_TOGGLE_EXT_L_H	3-state (extended) toggles
toggle_z_l	UCDBBIN_TOGGLE_EXT_Z_L	3-state (extended) toggles
toggle_l_z	UCDBBIN_TOGGLE_EXT_L_Z	3-state (extended) toggles
toggle_h_z	UCDBBIN_TOGGLE_EXT_H_Z	3-state (extended) toggles
toggle_z_h	UCDBBIN_TOGGLE_EXT_Z_H	3-state (extended) toggles
unknown	UCDBBIN_EXPRCOND_UNKNOWN	Unknown value row.

Some of the UCDB scope names are hard coded to distinguish between different natures of scopes.

FEC	UCDBSCOPE_FEC	Name of FEC scope.
UDP	UCDBSCOPE_UDP	Name of UDP scope.

UCDB select flags used to specify different objects types in various routines, such as making clones, printing objects, and so on.

0x0001	UCDB_SELECT_TAGS	Select scope tags.
0x0002	UCDB_SELECT_ATTRS	Select user defined attributes.
0x0004	UCDB_SELECT_COVERS	Select covers (does not work with copy in streaming modes).
0x0008	UCDB_SELECT_FILETABS	Select file tables.
0x0010	UCDB_SELECT_SOURCEINFO	Select source information (print only).
0xffffffff	UCDB_SELECT_ALL	Select all flags above.

Generic UCDB Handle

```
#ifndef DEFINE_UCDBT
#define DEFINE_UCDBT
typedef void* ucdbT;          /* generic handle to a UCDB */
#endif
```

Size-critical Types

```
#if defined (__MSC_VER)
typedef unsigned __int64 uint64_t;
typedef signed __int64 int64_t;
typedef unsigned __int32 uint32_t;
#elif defined (__MINGW32__)
#include <stdint.h>
#elif defined (__linux)
#include <inttypes.h>
#else
```

```
#include <sys/types.h>
#if defined(__STRICT_ANSI__)
#ifdef _LP64
typedef long int64_t;
typedef unsigned long uint64_t;
#else
typedef long long int64_t;
typedef unsigned long long uint64_t;
#endif
#endif
#ifdef WIN32
#define INT64_LITERAL(val) ((int64_t)val)
#define INT64_ZERO ((int64_t)0)
#define INT64_ONE ((int64_t)1)
#define INT64_NEG1 ((int64_t)-1)
#else
#define INT64_LITERAL(val) (val##LL)
#define INT64_ZERO (0LL)
#define INT64_ONE (1LL)
#define INT64_NEG1 (-1LL)
#endif

typedef uint64_t ucdbCoverTypeT;           // typedef for one of these
typedef uint64_t ucdbCoverMaskTypeT;      // typedef for a set of these.
```


Appendix B: UCDB Diff BNF

any_diff_line ::= *diff_line* | *diff_comment* | *summary_line*

diff_comment ::= -- *comment_text* --

summary_line ::= SS *tbd_format*

diff_line ::= *diff_file_location* *diff_text*

diff_file_location ::= <> | << | >>

diff_text ::= *ucdb_structural_type* *primary_key* *diff_aspect* [*diff_details*]

ucdb_structural_type ::= Scope | Bin | Historynode | UCDBRoot

primary_key ::= *scope_key* | *bin_key* | *historynode_key*

scope_key ::= *ucdb_scope_type_string* "ucdb_hiername"

bin_key ::= *ucdb_bin_type_string* "ucdb_hiername" "coveritemname"

ucdb_scope_type_string ::= Branch | Toggle | Covergroup | ...

ucdb_bin_type_string ::= BranchBin | ToggleBin | StatementBin | ...

historynode_key ::= "historynode_logical_name"

diff_aspect ::= Structural | Attribute | Flag | Flagfield | Tag | DU | Source | Count | Goal
| Weight | Limit | Bitlen | Kind | Sourceinfo | Version

diff_value ::= *attribute_diff_value* | *integer integer* | *float float* | *first_value second_value*

attribute_diff_value ::=
"attribute_name" *attribute_type* [*attribute_type*] "attribute_value" ["attribute_value"]

attribute_type ::= Int | Float | Double | String | Memblk | Long | Handle | Array

attribute_value ::= *numeric_value* | *string* | *memblk_representation*

memblk_representation ::= *num_bytes*bytes:MEMBLK | *num_bytes*bytes:hex_byte_list

historynode_type_string ::= Test | Merge | Testplan

num_bytes ::= *integer*

hex_byte_list ::= *xx[_xx]*

x ::= *hex_digit*

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- 4.3. Customer agrees to maintain Beta Code in confidence and shall restrict access to the Beta Code, including the methods and concepts utilized therein, solely to those employees and Customer location(s) authorized by Mentor Graphics to perform beta testing. Customer agrees that any written evaluations and all inventions, product improvements, modifications or developments that Mentor Graphics conceived or made during or subsequent to this Agreement, including those based partly or wholly on Customer's feedback, will be the exclusive property of Mentor Graphics. Mentor Graphics will have exclusive rights, title and interest in all such property. The provisions of this Subsection 4.3 shall survive termination of this Agreement.

5. **RESTRICTIONS ON USE.**

- 5.1. Customer may copy Software only as reasonably necessary to support the authorized use. Each copy must include all notices and legends embedded in Software and affixed to its medium and container as received from Mentor Graphics. All copies shall remain the property of Mentor Graphics or its licensors. Customer shall maintain a record of the number and primary location of all copies of Software, including copies merged with other software, and shall make those records available to Mentor Graphics upon request. Customer shall not make Products available in any form to any person other than Customer's employees and on-site contractors, excluding Mentor Graphics competitors, whose job performance requires access and who are under obligations of confidentiality. Customer shall take appropriate action to protect the confidentiality of Products and ensure that any person permitted access does not disclose or use it except as permitted by this Agreement. Customer shall give Mentor Graphics written notice of any unauthorized disclosure or use of the Products as soon as Customer learns or becomes aware of such unauthorized disclosure or use. Except as otherwise permitted for purposes of interoperability as specified by applicable and mandatory local law, Customer shall not reverse-assemble, reverse-compile, reverse-engineer or in any way derive any source code from Software. Log files, data files, rule files and script files generated by or for the Software (collectively "Files"), including without limitation files containing Standard Verification Rule Format ("SVRF") and Tcl Verification Format ("TVF") which are Mentor Graphics' proprietary syntaxes for expressing process rules, constitute or include confidential information of Mentor Graphics. Customer may share Files with third parties, excluding Mentor Graphics competitors, provided that the confidentiality of such Files is protected by written agreement at least as well as Customer protects other information of a similar nature or importance, but in any case with at least reasonable care. Customer may use Files containing SVRF or TVF only with Mentor Graphics products. Under no circumstances shall Customer use Software or Files or allow their use for the purpose of developing, enhancing or marketing any product that is in any way competitive with Software, or disclose to any third party the results of, or information pertaining to, any benchmark.
- 5.2. If any Software or portions thereof are provided in source code form, Customer will use the source code only to correct software errors and enhance or modify the Software for the authorized use. Customer shall not disclose or permit disclosure of source code, in whole or in part, including any of its methods or concepts, to anyone except Customer's employees or contractors, excluding Mentor Graphics competitors, with a need to know. Customer shall not copy or compile source code in any manner except to support this authorized use.
- 5.3. Customer may not assign this Agreement or the rights and duties under it, or relocate, sublicense or otherwise transfer the Products, whether by operation of law or otherwise ("Attempted Transfer"), without Mentor Graphics' prior written consent and payment of Mentor Graphics' then-current applicable relocation and/or transfer fees. Any Attempted Transfer without Mentor Graphics' prior written consent shall be a material breach of this Agreement and may, at Mentor Graphics' option, result in the immediate termination of the Agreement and/or the licenses granted under this Agreement. The terms

of this Agreement, including without limitation the licensing and assignment provisions, shall be binding upon Customer's permitted successors in interest and assigns.

5.4. The provisions of this Section 5 shall survive the termination of this Agreement.

6. **SUPPORT SERVICES.** To the extent Customer purchases support services, Mentor Graphics will provide Customer updates and technical support for the Products, at the Customer site(s) for which support is purchased, in accordance with Mentor Graphics' then current End-User Support Terms located at <http://supportnet.mentor.com/about/legal/>.

7. **AUTOMATIC CHECK FOR UPDATES; PRIVACY.** Technological measures in Software may communicate with servers of Mentor Graphics or its contractors for the purpose of checking for and notifying the user of updates and to ensure that the Software in use is licensed in compliance with this Agreement. Mentor Graphics will not collect any personally identifiable data in this process and will not disclose any data collected to any third party without the prior written consent of Customer, except to Mentor Graphics' outside attorneys or as may be required by a court of competent jurisdiction.

8. **LIMITED WARRANTY.**

8.1. Mentor Graphics warrants that during the warranty period its standard, generally supported Products, when properly installed, will substantially conform to the functional specifications set forth in the applicable user manual. Mentor Graphics does not warrant that Products will meet Customer's requirements or that operation of Products will be uninterrupted or error free. The warranty period is 90 days starting on the 15th day after delivery or upon installation, whichever first occurs. Customer must notify Mentor Graphics in writing of any nonconformity within the warranty period. For the avoidance of doubt, this warranty applies only to the initial shipment of Software under an Order and does not renew or reset, for example, with the delivery of (a) Software updates or (b) authorization codes or alternate Software under a transaction involving Software re-mix. This warranty shall not be valid if Products have been subject to misuse, unauthorized modification or improper installation. MENTOR GRAPHICS' ENTIRE LIABILITY AND CUSTOMER'S EXCLUSIVE REMEDY SHALL BE, AT MENTOR GRAPHICS' OPTION, EITHER (A) REFUND OF THE PRICE PAID UPON RETURN OF THE PRODUCTS TO MENTOR GRAPHICS OR (B) MODIFICATION OR REPLACEMENT OF THE PRODUCTS THAT DO NOT MEET THIS LIMITED WARRANTY, PROVIDED CUSTOMER HAS OTHERWISE COMPLIED WITH THIS AGREEMENT. MENTOR GRAPHICS MAKES NO WARRANTIES WITH RESPECT TO: (A) SERVICES; (B) PRODUCTS PROVIDED AT NO CHARGE; OR (C) BETA CODE; ALL OF WHICH ARE PROVIDED "AS IS."

8.2. THE WARRANTIES SET FORTH IN THIS SECTION 8 ARE EXCLUSIVE. NEITHER MENTOR GRAPHICS NOR ITS LICENSORS MAKE ANY OTHER WARRANTIES EXPRESS, IMPLIED OR STATUTORY, WITH RESPECT TO PRODUCTS PROVIDED UNDER THIS AGREEMENT. MENTOR GRAPHICS AND ITS LICENSORS SPECIFICALLY DISCLAIM ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY.

9. **LIMITATION OF LIABILITY.** EXCEPT WHERE THIS EXCLUSION OR RESTRICTION OF LIABILITY WOULD BE VOID OR INEFFECTIVE UNDER APPLICABLE LAW, IN NO EVENT SHALL MENTOR GRAPHICS OR ITS LICENSORS BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS OR SAVINGS) WHETHER BASED ON CONTRACT, TORT OR ANY OTHER LEGAL THEORY, EVEN IF MENTOR GRAPHICS OR ITS LICENSORS HAVE BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL MENTOR GRAPHICS' OR ITS LICENSORS' LIABILITY UNDER THIS AGREEMENT EXCEED THE AMOUNT RECEIVED FROM CUSTOMER FOR THE HARDWARE, SOFTWARE LICENSE OR SERVICE GIVING RISE TO THE CLAIM. IN THE CASE WHERE NO AMOUNT WAS PAID, MENTOR GRAPHICS AND ITS LICENSORS SHALL HAVE NO LIABILITY FOR ANY DAMAGES WHATSOEVER. THE PROVISIONS OF THIS SECTION 9 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

10. **HAZARDOUS APPLICATIONS.** CUSTOMER ACKNOWLEDGES IT IS SOLELY RESPONSIBLE FOR TESTING ITS PRODUCTS USED IN APPLICATIONS WHERE THE FAILURE OR INACCURACY OF ITS PRODUCTS MIGHT RESULT IN DEATH OR PERSONAL INJURY ("HAZARDOUS APPLICATIONS"). NEITHER MENTOR GRAPHICS NOR ITS LICENSORS SHALL BE LIABLE FOR ANY DAMAGES RESULTING FROM OR IN CONNECTION WITH THE USE OF MENTOR GRAPHICS PRODUCTS IN OR FOR HAZARDOUS APPLICATIONS. THE PROVISIONS OF THIS SECTION 10 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

11. **INDEMNIFICATION.** CUSTOMER AGREES TO INDEMNIFY AND HOLD HARMLESS MENTOR GRAPHICS AND ITS LICENSORS FROM ANY CLAIMS, LOSS, COST, DAMAGE, EXPENSE OR LIABILITY, INCLUDING ATTORNEYS' FEES, ARISING OUT OF OR IN CONNECTION WITH THE USE OF PRODUCTS AS DESCRIBED IN SECTION 10. THE PROVISIONS OF THIS SECTION 11 SHALL SURVIVE THE TERMINATION OF THIS AGREEMENT.

12. **INFRINGEMENT.**

12.1. Mentor Graphics will defend or settle, at its option and expense, any action brought against Customer in the United States, Canada, Japan, or member state of the European Union which alleges that any standard, generally supported Product acquired by Customer hereunder infringes a patent or copyright or misappropriates a trade secret in such jurisdiction. Mentor Graphics will pay costs and damages finally awarded against Customer that are attributable to the action. Customer understands and agrees that as conditions to Mentor Graphics' obligations under this section Customer must: (a) notify Mentor Graphics promptly in writing of the action; (b) provide Mentor Graphics all reasonable information and assistance

to settle or defend the action; and (c) grant Mentor Graphics sole authority and control of the defense or settlement of the action.

12.2. If a claim is made under Subsection 12.1 Mentor Graphics may, at its option and expense, (a) replace or modify the Product so that it becomes noninfringing; (b) procure for Customer the right to continue using the Product; or (c) require the return of the Product and refund to Customer any purchase price or license fee paid, less a reasonable allowance for use.

12.3. Mentor Graphics has no liability to Customer if the action is based upon: (a) the combination of Software or hardware with any product not furnished by Mentor Graphics; (b) the modification of the Product other than by Mentor Graphics; (c) the use of other than a current unaltered release of Software; (d) the use of the Product as part of an infringing process; (e) a product that Customer makes, uses, or sells; (f) any Beta Code or Product provided at no charge; (g) any software provided by Mentor Graphics' licensors who do not provide such indemnification to Mentor Graphics' customers; or (h) infringement by Customer that is deemed willful. In the case of (h), Customer shall reimburse Mentor Graphics for its reasonable attorney fees and other costs related to the action.

12.4. THIS SECTION 12 IS SUBJECT TO SECTION 9 ABOVE AND STATES THE ENTIRE LIABILITY OF MENTOR GRAPHICS AND ITS LICENSORS FOR DEFENSE, SETTLEMENT AND DAMAGES, AND CUSTOMER'S SOLE AND EXCLUSIVE REMEDY, WITH RESPECT TO ANY ALLEGED PATENT OR COPYRIGHT INFRINGEMENT OR TRADE SECRET MISAPPROPRIATION BY ANY PRODUCT PROVIDED UNDER THIS AGREEMENT.

13. **TERMINATION AND EFFECT OF TERMINATION.** If a Software license was provided for limited term use, such license will automatically terminate at the end of the authorized term.

13.1. Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement immediately upon written notice if Customer: (a) exceeds the scope of the license or otherwise fails to comply with the licensing or confidentiality provisions of this Agreement, or (b) becomes insolvent, files a bankruptcy petition, institutes proceedings for liquidation or winding up or enters into an agreement to assign its assets for the benefit of creditors. For any other material breach of any provision of this Agreement, Mentor Graphics may terminate this Agreement and/or any license granted under this Agreement upon 30 days written notice if Customer fails to cure the breach within the 30 day notice period. Termination of this Agreement or any license granted hereunder will not affect Customer's obligation to pay for Products shipped or licenses granted prior to the termination, which amounts shall be payable immediately upon the date of termination.

13.2. Upon termination of this Agreement, the rights and obligations of the parties shall cease except as expressly set forth in this Agreement. Upon termination, Customer shall ensure that all use of the affected Products ceases, and shall return hardware and either return to Mentor Graphics or destroy Software in Customer's possession, including all copies and documentation, and certify in writing to Mentor Graphics within ten business days of the termination date that Customer no longer possesses any of the affected Products or copies of Software in any form.

14. **EXPORT.** The Products provided hereunder are subject to regulation by local laws and United States government agencies, which prohibit export or diversion of certain products and information about the products to certain countries and certain persons. Customer agrees that it will not export Products in any manner without first obtaining all necessary approval from appropriate local and United States government agencies.

15. **U.S. GOVERNMENT LICENSE RIGHTS.** Software was developed entirely at private expense. All Software is commercial computer software within the meaning of the applicable acquisition regulations. Accordingly, pursuant to US FAR 48 CFR 12.212 and DFAR 48 CFR 227.7202, use, duplication and disclosure of the Software by or for the U.S. Government or a U.S. Government subcontractor is subject solely to the terms and conditions set forth in this Agreement, except for provisions which are contrary to applicable mandatory federal laws.

16. **THIRD PARTY BENEFICIARY.** Mentor Graphics Corporation, Mentor Graphics (Ireland) Limited, Microsoft Corporation and other licensors may be third party beneficiaries of this Agreement with the right to enforce the obligations set forth herein.

17. **REVIEW OF LICENSE USAGE.** Customer will monitor the access to and use of Software. With prior written notice and during Customer's normal business hours, Mentor Graphics may engage an internationally recognized accounting firm to review Customer's software monitoring system and records deemed relevant by the internationally recognized accounting firm to confirm Customer's compliance with the terms of this Agreement or U.S. or other local export laws. Such review may include FLEXIm or FLEXnet (or successor product) report log files that Customer shall capture and provide at Mentor Graphics' request. Customer shall make records available in electronic format and shall fully cooperate with data gathering to support the license review. Mentor Graphics shall bear the expense of any such review unless a material non-compliance is revealed. Mentor Graphics shall treat as confidential information all information gained as a result of any request or review and shall only use or disclose such information as required by law or to enforce its rights under this Agreement. The provisions of this Section 17 shall survive the termination of this Agreement.

18. **CONTROLLING LAW, JURISDICTION AND DISPUTE RESOLUTION.** The owners of certain Mentor Graphics intellectual property licensed under this Agreement are located in Ireland and the United States. To promote consistency around the world, disputes shall be resolved as follows: excluding conflict of laws rules, this Agreement shall be governed by and construed under the laws of the State of Oregon, USA, if Customer is located in North or South America, and the laws of Ireland if Customer is located outside of North or South America. All disputes arising out of or in relation to this Agreement shall be submitted to the exclusive jurisdiction of the courts of Portland, Oregon when the laws of Oregon apply, or Dublin, Ireland when the laws of Ireland apply. Notwithstanding the foregoing, all disputes in Asia arising out of or in relation to this Agreement shall be resolved by arbitration in Singapore before a single arbitrator to be appointed by the chairman of the Singapore International

Arbitration Centre (“SIAC”) to be conducted in the English language, in accordance with the Arbitration Rules of the SIAC in effect at the time of the dispute, which rules are deemed to be incorporated by reference in this section. This section shall not restrict Mentor Graphics’ right to bring an action against Customer in the jurisdiction where Customer’s place of business is located. The United Nations Convention on Contracts for the International Sale of Goods does not apply to this Agreement.

19. **SEVERABILITY.** If any provision of this Agreement is held by a court of competent jurisdiction to be void, invalid, unenforceable or illegal, such provision shall be severed from this Agreement and the remaining provisions will remain in full force and effect.
20. **MISCELLANEOUS.** This Agreement contains the parties’ entire understanding relating to its subject matter and supersedes all prior or contemporaneous agreements, including but not limited to any purchase order terms and conditions. Some Software may contain code distributed under a third party license agreement that may provide additional rights to Customer. Please see the applicable Software documentation for details. This Agreement may only be modified in writing by authorized representatives of the parties. Waiver of terms or excuse of breach must be in writing and shall not constitute subsequent consent, waiver or excuse.

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