

Draft Proposal for Generate Modifications in 1364-2005

Version 1.4

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This document contains the following sections:

1. Grammar Modifications

Changes to the BNF, mostly for clarification of generates. Some minor language changes.

2. General Modifications

Changes that need to be made throughout the document: new terminology, clarifications, corrections.

3. New LRM section 12.4

Text for a new LRM section 12.4 to replace the current 12.1.3

1. Grammar Modifications

The grammar for generate statements is the basis of the understanding of what they are. I believe that much of the difficulty we are having in coming up with language to convey this understanding is due to the way the grammar was constructed. By slightly altering this structure and the terms used in the BNF, I believe we can create a stronger basis from which a description of generates will flow much more naturally. This grammar describes the same language as was described by the original grammar, with only slight intentional modifications: the generate / endgenerate keywords are now optional, generate blocks can no longer exist on their own without an *if*, *case* or *for* construct, for-generate blocks no longer require an explicit name, and localparams can be declared inside generate blocks. Some justification and explanation for my changes follows:

The use of the word "statement" in the BNF for the generate constructs is misleading. Until now, that word was used only for behavioral statements. We should keep it that way. Generate constructs look like their behavioral counterparts, but we should avoid confusing the two. A better word is "construct", which is currently used for always and initial blocks.

Although generate constructs are very much a new concept in Verilog, we should try to demystify them as much as we can. To this end, we should treat them grammatically as peers of the other items that can appear at the same places in a module. For this reason, I have put them into the module_or_generate_item production alongside always blocks, initial blocks, module instantiations, etc. By doing this, the requirement that generate/endgenerate keywords surround all generate constructs is removed, but the language is not changed in any other way, and it is much clearer from the grammar where generate constructs can appear.

A single BNF production, called generate_block, is the thing which is brought into existence by any of the generate constructs. This gives us one specific term, "generate block", to describe that which is generated. Generate blocks may or may not be named, and they may even consist of only one item that is not surrounded by begin/end keywords. But still calling it a generate block should simplify the wording of our descriptions tremendously. It also has the advantage of conveying the sense that it constitutes a separate scope, which we have proposed as a necessary interpretation.

I have grouped the if-generate and case-generate constructs together under the heading of "conditional generate". These two types of generate both select at most one generate block from a choice of blocks, and both check a condition to determine which block to select. Also, grouping them under one heading will make writing the descriptive paragraphs easier.

The original grammar required generate/endgenerate keywords to surround all generate constructs, but it also allowed for any other module item to appear inside them. We have discussed making these keywords optional since they have no real semantic purpose. My grammar uses the term "generate_region" instead of "generated_instance" for this. The word "instance" has other implications that do not quite apply here. By using the word "region", I hope to make it easier to explain the minor role that these keywords serve. Also, unlike the original grammar, my grammar makes it clear that any module or generate item can appear inside them.

I have removed the ability to have a generate block exist on its own without any conditional or looping construct around it. It has been speculated that this was an unintended artifact of the original grammar and it serves no real purpose.

I have changed the production name "genvar_case_item" to "case_generate_item". It has nothing to do with genvars.

I have removed "genvar_identifier" from the constant_primary production. In this proposal, the expressions within the control structure of a for-generate loop, which include genvar identifiers, are covered by a new genvar_primary production. References to the genvar in constant expressions inside the loop generate block are actually references to an implicit localparam within the block. See my Sect. 12.4 for details.

Note: These BNF productions need to be changed wherever they appear in the LRM.

non_port_module_item ::=

```
    module_or_generate_item
    | specify_block
    | generate_region
    | { attribute_instance } parameter_declaration ;
    | { attribute_instance } specparam_declaration
```

module_or_generate_item ::=

```
    { attribute_instance } module_or_generate_item_declaration
    | { attribute_instance } local_parameter_declaration ;
    | { attribute_instance } parameter_override
    | { attribute_instance } continuous_assign
    | { attribute_instance } gate_instantiation
    | { attribute_instance } udp_instantiation
    | { attribute_instance } module_instantiation
    | { attribute_instance } initial_construct
    | { attribute_instance } always_construct
    | { attribute_instance } loop_generate_construct
    | { attribute_instance } conditional_generate_construct
```

module_or_generate_item_declaration ::=

```
    net_declaration
    | reg_declaration
    | integer_declaration
    | real_declaration
    | time_declaration
    | realtime_declaration
    | event_declaration
    | genvar_declaration
    | task_declaration
    | function_declaration
```

generate_region ::=

```
    generate { module_or_generate_item } endgenerate
```

loop_generate_construct ::=

```
    for ( genvar_initialization ; genvar_expression ; genvar_iteration )
        generate_block
```

genvar_initialization ::=

```

    genvar_identifier = constant_expression

genvar_iteration ::=
    genvar_identifier = genvar_expression

genvar_expression ::=
    genvar_primary
    | unary_operator { attribute_instance } genvar_primary
    | genvar_expression binary_operator { attribute_instance } genvar_expression
    | genvar_expression ? { attribute_instance } genvar_expression : genvar_expression
    | string

genvar_primary ::=
    constant_primary
    | genvar_identifier

conditional_generate_construct ::=
    if_generate_construct
    | case_generate_construct

if_generate_construct ::=
    if ( constant_expression ) generate_block_or_null
    [ else generate_block_or_null ]

case_generate_construct ::=
    case ( constant_expression )
    case_generate_item { case_generate_item } endcase

case_generate_item ::=
    constant_expression { , constant_expression } :
    generate_block_or_null
    | default [ : ] generate_block_or_null

generate_block_or_null ::=
    generate_block
    | ;

generate_block ::=
    module_or_generate_item
    | begin [ : generate_block_identifier ] { module_or_generate_item } end

constant_primary ::=
    constant_concatenation
    | constant_function_call
    | ( constant_mintypmax_expression )
    | constant_multiple_concatenation
    | number
    | parameter_identifier
    | specparam_identifier

```

2. General Modifications

Delete Sect. 2.7.2 "Generated Identifiers".

In Sect. 3.5, in the second of the three rules, change “**explicitly declared previously in one of the declaration statements of the instantiating module**” to “**declared previously in the scope where the instantiation appears or in any scope whose declarations can be directly referenced from that scope (See 12.7)**”

In Sect 3.5, in the third of the three rules, change “**declared previously**” to “**declared previously in the scope where the assignment statement appears or in any scope whose declarations can be directly referenced from that scope (See 12.7)**”.

Add the following paragraph to the end of Sect. 3.5

Note that the implicit net declaration belongs to the scope in which the net reference appears. For example, if the implicit net is declared by a reference in a generate block, then the net is implicitly declared only in that generate block. Subsequent references to the net from outside the generate block or in another generate block within the same module would either be illegal or would create another implicit declaration of a different net (depending on whether the reference meets the above criteria). See 12.4 for information about generate blocks.

Change Sect. 3.10.1 to:

Elements of net arrays can be used in the same fashion as a scalar or vector net. They are useful for connecting to ports of module instances inside loop generate constructs (See 12.4.1).

In Sect. 3.12:

In the first sentence of the first paragraph, change “**seven**” to “**several**” and change “**five**” to “**the rest**”

In the third paragraph, change “**There are five local name spaces:**” to “**The local name spaces are:**”.

Also in the third paragraph, change the two occurrences of “block, module, port, specify block,” to “block, module, port, generate block, specify block,”

In the “module name space” paragraph, add “genvars” to the list of declarations allowed in the name space after “named events”, and change “instance names” to “module instances, generate blocks”.

Add a new paragraph after the “module name space” paragraph as follows:

The *generate block name space* is introduced by generate constructs (see 12.4). It unifies the definition of functions, tasks, named blocks, module instances, generate

blocks, local parameters, named events, genvars, net type of declaration, and variable type of declaration.

In Sect. 10.3.5, first paragraph, remove the cross reference to 12.1.3 for elaboration info. [*When/if a section 12.8 on elaboration is added, make this a cross reference to that section*):

In Sect. 12.1.1, change "**are not instantiated**" to "**do not appear in any module instantiation statement**". Add the sentence, "**Note that this applies even if the module instantiation appears in a generate block that is not itself instantiated (see 12.4). A model shall contain at least one top-level module**".

Delete Sect. 12.1.3, rename Sect. 12.4, 12.5 and 12.6 to be 12.5, 12.6 and 12.7 respectively, and insert Sect. 12.4 (Generate constructs) as provided in the file Sect12.4.txt. Update all cross references appropriately.

In Sect. 12.5 (formerly 12.4, Hierarchical Names):

First paragraph, change "**generated instance**" to "**generate block instance**".

In the second paragraph, remove the first sentence and add in its place:

A design description contains one or more top-level modules (see 12.1.1). Each such module forms the top of a name hierarchy.

Second paragraph, remove "**or generated**" from the parenthetical phrase, and add "**, generate block instance**" just after the closing parenthesis.

Second paragraph, add the following sentence to the end after ETF #325 is applied:

Unnamed generate blocks are also exceptions. They create branches that are visible only from within the block and within any hierarchy instantiated by the block. See 12.4.3 for a discussion of unnamed generate blocks.

Fourth paragraph, first sentence, add "**generate blocks**" to the list of the types of names that can be in a hierarchical name, after "**module instance names**".

Fourth paragraph, add the following sentence to the end after ETF #325 is applied:

Objects declared in unnamed generate blocks are also exceptions. They can be referenced by hierarchical names only from within the block and within any hierarchy instantiated by the block.

Add new paragraph:

Names in a hierarchical path name that refer to instance arrays or loop generate blocks may be followed immediately by a constant expression in square brackets. This expression selects a particular instance of the array and is therefore called an *instance select*. The expression shall evaluate to one of the legal index values of the

array. If the array name is not the last path element in the hierarchical name, the instance select expression is required.

In Sect. 12.6 (formerly 12.5, Upwards name referencing):

First paragraph, change "For tasks, functions and named blocks," to "For tasks, functions, named blocks and generate blocks".

Change all occurrences of "module_instance_name" to "scope_name".

Prior to "A name of this form shall be resolved as follows", add "where scope_name is either a module instance name or a generate block name."

Replace rules a) and b) with:

- a) **Look in the current scope for a scope named `scope_name`. If not found and the current scope is not the module scope, look for the name in the enclosing scope, repeating as necessary until the name is found or the module scope is reached. If still not found, proceed to b). Otherwise this name reference shall be treated as a downward reference from the scope in which the name is found.**
- b) **Look in the parent module's outermost scope for a scope named `scope_name`. If found, the item name shall be resolved from that scope.**

After rules a), b) and c), insert the following paragraphs:

There is an exception to these rules for hierarchical names on the left hand side of `defparam` statements. See section 12.2.1 for details. *(when/if these restrictions are moved to section 12.8, this reference will change to 12.8.)*

In Sect. 12.7 (formerly 12.6, Scope rules):

Change "The following four elements" to "The following elements".

Add "Generate blocks" to the list of items between the first and second paragraphs.

Second paragraph, add the following sentence to the end:

For generate blocks, this rule applies whether or not the generate block is instantiated. An exception to this is made for generate blocks in a conditional generate construct. See Sect. 12.4.3 for a discussion of naming conditional generate blocks.

Third paragraph, replace each occurrence of "task, function or named block" with "task, function, named block or generate block". Replace "module, task or named block" with "module, task, function, named block or generate block". Replace "named block, task, and function boundaries" with "generate block, named block, task and function boundaries".

Fourth paragraph, replace "or named block" with "named block or named generate block".

In Sect. 13.1, last paragraph, change “, **which is not instantiated elsewhere in the design**” to “**(See Sect. 12.1.1)**”.

3. Section 12.4 Generate constructs

12.4 Generate constructs

Generate constructs are used to either conditionally or multiply instantiate generate blocks into a model. A generate block is a collection of one or more module items. A generate block may not contain port declarations, parameter declarations, specify blocks and specparam declarations. All other module items, including other generate constructs, are allowed in a generate block. Generate constructs provide the ability for parameter values to affect the structure of the model. They also allow for modules with repetitive structure to be described more concisely, and they make recursive module instantiation possible.

There are two kinds of generate constructs: loops and conditionals. Loop generate constructs allow a single generate block to be instantiated into a model multiple times. Conditional generates, which include if-generate and case-generate constructs, instantiate at most one generate block from a set of alternative generate blocks. The term *generate scheme* refers to the method for determining which or how many generate blocks are instantiated. It includes the conditional expressions, case alternatives and loop control statements that appear in a generate construct.

Generate schemes are evaluated during elaboration of the model. Elaboration occurs after parsing the HDL and before simulation, and involves expanding module instantiations, computing parameter values, resolving hierarchical names (see 12.5), establishing net connectivity and in general preparing the model for simulation. Although generate schemes use syntax that is similar to behavioral statements, it is important to note that they do not execute at simulation time. They are evaluated at elaboration time and the result is determined before simulation begins. Therefore, all expressions in generate schemes must be constant expressions, deterministic at elaboration time. [For more details on elaboration, see 12.8. - *if a section on elaboration is added*]

The elaboration of a generate construct results in zero or more instances of a generate block. An instance of a generate block is similar in some ways to an instance of a module. It creates a new level of hierarchy. It brings the objects, behavioral constructs and module instances within the block into existence. These constructs act the same as they would if they were in a module brought into existence with a module instantiation, except that object declarations from the enclosing scope can be referenced directly (see 12.7). Names in instantiated named generate blocks can be referenced hierarchically as described in 12.5.

The keywords generate and endgenerate may be used in a module to define a *generate region*. A generate region is a textual span in the module description where generate constructs may appear. Use of generate regions is optional. There is no semantic difference in the module when a generate region is used. A parser may choose to take note of the generate region to produce different error messages for misused generate construct keywords. Generate regions do not nest and they may only occur directly within a module. If the generate keyword is used, it must be matched by an endgenerate keyword.

The syntax for generate constructs is given in Syntax 12-3.

[Insert new grammar here, with the caption: Syntax 12-3 Syntax for generate constructs]

12.4.1 Loop generate construct

A loop generate construct permits a generate block to be instantiated multiple times using syntax that is similar to a for-loop statement. The loop index variable must be declared in a genvar declaration prior to its use in a loop generate scheme.

The syntax for genvar declarations is given in Syntax 12-4.

[Caption should be: Syntax 12-4 Syntax for genvar declarations]

The genvar is used as an integer during elaboration to evaluate the generate loop and create instances of the generate block, but it does not exist at simulation time. A genvar shall not be referenced anywhere other than in a loop generate scheme.

Both the initialization and iteration assignments in the loop generate scheme shall assign to the same genvar. The initialization assignment shall not reference the loop index variable on the right hand side.

Within the generate block of a loop generate construct, there is an implicit localparam declaration. This is an integer parameter that has the same name as the loop index variable, and its value within each instance of the generate block is the value of the index variable at the time the instance was elaborated. This parameter can be used anywhere within the generate block that a normal parameter with an integer value can be used. It can be referenced with a hierarchical name.

Because this implicit localparam has the same name as the genvar, any reference to this name inside the loop generate block will be a reference to the localparam, not to the genvar. As a consequence, it is not possible to have two nested loop generate constructs that use the same genvar.

Generate blocks in loop generate constructs can be named or unnamed, and they can consist of only one item which need not be surrounded by begin/end keywords. Even if the begin/end keywords are absent, it is still a generate block which, like all generate blocks, comprises a separate scope and a new level of hierarchy when it is instantiated.

If the generate block is named, it is a declaration of an array of generate block instances. The index values in this array are the values assumed by the genvar during elaboration. Note that this can be a sparse array since the genvar values do not have to form a contiguous range of integers. The array is considered to be declared even if the loop generate scheme resulted in no instances of the generate block. If the generate block is not named, the declarations within it cannot be referenced using hierarchical names other than from within the hierarchy instantiated by the generate block itself.

It shall be an error if the name of the array conflicts with any other declaration, including any other generate block instance array. It shall be an error if the loop generate scheme does not terminate. It shall be an error if a genvar value is repeated during the evaluation of the loop generate scheme. It shall be an error if any bit of the genvar is set to x or z during the evaluation of the loop generate scheme.

Examples:

Example 1:

```

module mod_a;
genvar i;

// Note that "generate", "endgenerate" keywords are not required

for (i=0; i<5; i=i+1) begin:a
  for (i=0; i<5; i=i+1) begin:b
    ... // error -- using "i" as loop index for
    ... // two nested generate loops
  end
end

endmodule

-----

module mod_b;
genvar i;
reg a;

for (i=1; i<0; i=i+1) begin: a
  ... // error -- "a" conflicts with name of reg "a"
end

endmodule

-----

module mod_c;
genvar i;

for (i=1; i<5; i=i+1) begin: a
  ...
end

for (i=10; i<15; i=i+1) begin: a
  ... // error -- "a" conflicts with name of previous
  ... // loop even though indices are unique
end

endmodule

```

[Keep the other examples currently in the corresponding section of the LRM, but remove from the code comments and their descriptive paragraphs all references to generated names. Replace these with comments showing the hierarchical names to the items in the generate blocks. Put generate and endgenerate keywords on a separate line and eliminate them altogether in half the examples. Eliminate Example 2, as it is too similar to Example 1.]

12.4.2 Conditional generate constructs

The conditional generate constructs, if-generate and case-generate, select at most one generate block from a set of alternative generate blocks based on constant expressions evaluated during elaboration. The selected generate block, if any, is instantiated into the model.

Generate blocks in conditional generate constructs can be named or unnamed, and they can consist of only one item which need not be surrounded by begin/end keywords. Even if the begin/end keywords are absent, it is still a generate block which, like all generate blocks, comprises a separate scope and a new level of hierarchy when it is instantiated.

Because at most one of the alternative generate blocks is instantiated, it is permissible for there to be more than one block with the same name within a single conditional generate construct. It is not permissible for any of the named generate blocks to have the same name as generate blocks in any other conditional or loop generate construct in the same scope, even if the blocks with the same name are not selected for instantiation. It is not permissible for any of the named generate blocks to have the same name as any other declaration in the same scope, even if that block is not selected for instantiation.

If the generate block selected for instantiation is named, then this name declares a generate block instance and is the name for the scope it creates. Normal rules for hierarchical naming apply. If the generate block selected for instantiation is not named, it still creates a scope, but the declarations within it cannot be referenced using hierarchical names other than from within the hierarchy instantiated by the generate block itself.

If a generate block in a conditional generate construct consists of only one item which is itself a conditional generate construct, and if that item is not surrounded by begin/end keywords, then this generate block is not treated as a separate scope. The generate construct within this block is said to be directly nested. The generate blocks of the directly nested construct are treated as if they belong to the outer construct, and therefore can have the same name as the generate blocks of the outer construct. This allows complex conditional generate schemes to be expressed without creating unnecessary levels of generate block hierarchy. The most common use of this would be to create an if-else-if generate scheme with any number of else-if clauses, all of which can have generate blocks with the same name because only one will be selected for instantiation. It is permissible to combine if-generate and case-generate constructs in the same complex generate scheme. Note that direct nesting applies only to conditional generate constructs nested in conditional generate constructs. It does not apply in any way to loop generate constructs.

Example 6:

```
module test;
parameter p = 0, q = 0;
wire a, b, c;

//-----
// Code to either generate a u1.g1 instance or no instance.
// The u1.g1 instance of one of the following gates:
// (and, or, xor, xnor) is generated if
// {p,q} == {1,0}, {1,2}, {2,0}, {2,1}, {2,2}, {2, default}
//-----

if (p == 1)
  if (q == 0)
    begin : u1          // If p==1 and q==0, then instantiate
      and g1(a, b, c); // AND with hierarchical name test.u1.g1
    end
  else if (q == 2)
    begin : u1          // If p==1 and q==2, then instantiate
      or g1(a, b, c); // OR with hierarchical name test.u1.g1
    end
end
```

```

// "else" added to end "if (q == 2)" statement
// If p==1 and q!=0 or 2, then no instantiation
else ;
else if (p == 2)
  case (q)
    0, 1, 2:
      begin : u1          // If p==2 and q==0,1, or 2, then instantiate
        xor g1(a, b, c); // XOR with hierarchical name test.u1.g1
      end
    default:
      begin : u1          // If p==2 and q!=0,1, or 2, then instantiate
        xnor g1(a, b, c); // XNOR with hierarchical name test.u1.g1
      end
  endcase
endmodule

```

Depending on the values of parameters p and q , this generate construct will select at most one of the generate blocks named `u1`. The hierarchical name of the gate instantiation in that block would be `test.u1.g1`. Note that when nesting if-generate constructs there can be ambiguity as to which "if" construct an "else" belongs to. The "else" always belongs to the nearest "if" construct. As in the example above, an "else" with a null generate block can be inserted to make a subsequent "else" belong to an outer "if" construct. Begin/end keywords can also be used to disambiguate, but this would violate the criteria for direct nesting and an extra level of generate block hierarchy would be created.

Conditional generate constructs make it possible for a module to contain an instantiation of itself. The same can be said of loop generate constructs, but it is more easily done with conditional generates. With proper use of parameters, the resulting recursion can be made to terminate, resulting in a legitimate model hierarchy. Note that because of the rules for determining top-level modules, a module containing an instantiation of itself will not be a top-level module.

[Keep examples 6 and 7, modify them in the same ways that the loop generate examples were modified].

12.4.3 External names for unnamed generate blocks

Although an unnamed generate block has no name that can be used in a hierarchical name, it needs to have a name by which external interfaces can refer to it. A name will be assigned for this purpose to each unnamed generate block as follows.

Each generate construct in a given scope is assigned a number. The number will be 1 for the construct that appears textually first in that scope, and will increase by 1 for each subsequent generate construct in that scope. All unnamed generate blocks will be given the name "genblk<n>" where <n> is the number assigned to its enclosing generate construct. If such a name would conflict with an explicitly declared name, then leading zeroes are added in front of the number until the name does not conflict.

Note that each generate construct is assigned its number as described above even if it does not contain any unnamed generate blocks.

Example 10:

```
module top;

    parameter genblk2 = 0;
    genvar i;

    // The following generate scope is implicitly named genblk1

    if (genblk2) reg a; // top.genblk1.a
    else        reg b; // top.genblk1.b

    // The following generate scope is implicitly named genblk02
    // as genblk2 is already a declared identifier

    if (genblk2) reg a; // top.genblk02.a
    else        reg b; // top.genblk02.b

    // The following generate scope would have been named genblk3
    // but is explicitly named g1

    for (i = 0; i < 1; i = i + 1) begin : g1 // block name
        // The following generate scope is implicitly named genblk1
        // as the first nested scope inside of g1
        if (1)    reg a; // top.g1[0].genblk1.a
    end

    // The following generate scope is implicitly named genblk4 since
    // it belongs to the fourth generate construct in scope "top".
    // Note that the previous generate construct would have been
    // named genblk3 if it had not been explicitly named g1

    for (i = 0; i < 1; i = i + 1)
        // The following generate scope is implicitly named genblk1
        // as the first nested scope of genblk4
        if (1)    reg a; // top.genblk4[0].genblk1.a

    // The following generate scope is implicitly named genblk5
    if (1)        reg a; // top.genblk5.a

endmodule
```