

XST User Guide for Virtex-4, Virtex-5, Spartan-3, and Newer CPLD Devices

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This document applies to the following software versions: ISE Design Suite 14.5 through 14.7



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About This Guide

This chapter includes:

- [Guide Overview](#)
- [Supported Devices](#)
- [Additional Resources](#)
- [Conventions](#)

Guide Overview

This Guide:

- Applies *only* to the devices listed in Supported Devices.
- Describes Xilinx Synthesis Technology (XST) support for:
 - Hardware Description Language (HDL) designs
 - Supported Xilinx® devices
 - Design constraints for the Xilinx ISE® Design Suite software
- Discusses optimization and coding techniques when creating designs for use with XST.
- Explains how to run XST from the:
 - ISE Design Suite **Process** window
 - Command line

Supported Devices

This Guide applies to the following Xilinx® devices *only*:

- FPGA Devices
 - Virtex®-4
 - Virtex-5
 - Spartan®-3 device family, including:
 - ◆ Spartan-3
 - ◆ Spartan-3A
 - ◆ Spartan-3A DSP
 - ◆ Spartan-3AN
 - ◆ Spartan-3E
 - ◆ Spartan-3L
- CPLD Devices
 - CoolRunner™ XPLA3
 - CoolRunner-II
 - XC9500
 - XC9500XL

Introduction to Xilinx Synthesis Technology (XST)

This chapter includes:

- [About XST](#)
- [Setting XST Options](#)

About XST

Xilinx Synthesis Technology (XST) is a Xilinx® application that synthesizes Hardware Description Language (HDL) designs to create Xilinx specific netlist files called NGC files.

The NGC file:

- Is a netlist that contains both logical design data and constraints.
- Takes the place of both Electronic Data Interchange Format (EDIF) and Netlist Constraints File (NCF) files.

For more information, see:

[Xilinx Synthesis Technology \(XST\) - Frequently Asked Questions \(FAQ\)](#)

Search for keyword *XST FAQ*.

Setting XST Options

Before synthesizing your design, you can set a variety of options for XST.

Designs are usually made up of:

- Combinatorial logic
- Macros such as flip-flops, adders, subtractors, counters, FSMs, and RAMs

Macros greatly improve performance of the synthesized designs. It is important to use coding techniques to model the macros so they are optimally processed by XST.

XST first tries to recognize (infer) as many macros as possible. These macros are then passed to the Low Level Optimization step. In order to obtain better optimization results, the macros are either preserved as separate blocks, or merged with surrounded logic. This filtering depends on the type and size of a macro. For example, by default, 2-to-1 multiplexers are not preserved by the optimization engine. Synthesis constraints control the processing of inferred macros.

For more information, see:

- [ISE® Design Suite Help](#)
- [XST Design Constraints](#)
- [XST Command Line Mode](#)

XST HDL Coding Techniques

This chapter discusses XST HDL Coding Techniques, and includes:

- [Signed and Unsigned Support in XST](#)
- [Registers HDL Coding Techniques](#)
- [Latches HDL Coding Techniques](#)
- [Tristates HDL Coding Techniques](#)
- [Counters HDL Coding Techniques](#)
- [Accumulators HDL Coding Techniques](#)
- [Shift Registers HDL Coding Techniques](#)
- [Dynamic Shift Registers HDL Coding Techniques](#)
- [Multiplexers HDL Coding Techniques](#)
- [Decoders HDL Coding Techniques](#)
- [Priority Encoders HDL Coding Techniques](#)
- [Logical Shifters HDL Coding Techniques](#)
- [Arithmetic Operators HDL Coding Techniques](#)
- [Adders, Subtractors, and Adders/Subtractors HDL Coding Techniques](#)
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- [Sequential Complex Multipliers HDL Coding Techniques](#)
- [Pipelined Multipliers HDL Coding Techniques](#)
- [Multiply Adder/Subtractors HDL Coding Techniques](#)
- [Multiply Accumulate HDL Coding Techniques](#)
- [Dividers HDL Coding Techniques](#)
- [Resource Sharing HDL Coding Techniques](#)
- [RAMs and ROMs HDL Coding Techniques](#)
- [ROMs Using Block RAM Resources HDL Coding Techniques](#)
- [Pipelined Distributed RAM HDL Coding Techniques](#)
- [FSM HDL Coding Techniques](#)
- [Black Boxes HDL Coding Techniques](#)

For more information, see:

- [XST FPGA Optimization](#)
- [XST CPLD Optimization](#)

For information on accessing the synthesis templates from ISE® Design Suite, see the ISE Design Suite Help.

Signed and Unsigned Support in XST

When using Verilog or VHDL in XST, some macros, such as adders or counters, can be implemented for signed and unsigned values.

To enable support for signed and unsigned values in Verilog, enable Verilog-2001 as follows:

- ISE® Design Suite
Select **Verilog 2001** as instructed in the *Synthesis Options* topic of ISE Design Suite Help
- XST Command Line
Set **-verilog2001** to **yes**.

For VHDL, depending on the operation and type of the operands, you must include additional packages in your code. For example, to create an unsigned adder, use the arithmetic packages and types that operate on unsigned values shown in the following table.

Unsigned Adders

| PACKAGE | TYPE |
|--------------------|------------------|
| numeric_std | unsigned |
| std_logic_arith | unsigned |
| std_logic_unsigned | std_logic_vector |

To create a signed adder, use the arithmetic packages and types that operate on signed values shown in the following table.

Signed Adders

| PACKAGE | TYPE |
|------------------|------------------|
| numeric_std | signed |
| std_logic_arith | signed |
| std_logic_signed | std_logic_vector |

For more information about available types, see the *IEEE VHDL Manual*.

Registers HDL Coding Techniques

This section discusses Registers HDL Coding Techniques, and includes:

- [About Registers](#)
- [Registers Log File](#)
- [Registers Related Constraints](#)
- [Registers Coding Examples](#)

About Registers

XST recognizes flip-flops with the following control signals:

- Asynchronous Set/Reset
- Synchronous Set/Reset
- Clock Enable

For more information, see:

[Specifying INIT and RLOC](#)

Registers Log File

The XST log file reports the type and size of recognized flip-flops during the Macro Recognition step.

With device families such as the Virtex®-4 device family, XST may optimize different slices of the same register in different ways. For example, XST may push a part of a register into a DSP48 block, while another part may be implemented on slices, or even become a part of a shift register. XST reports the total number of FF bits in the design in the HDL Synthesis Report after the Advanced HDL Synthesis step.

Registers Log File Example

```

...
=====
*                               HDL Synthesis                               *
=====

Synthesizing Unit <registers_5>.
  Related source file is "registers_5.vhd".
  Found 4-bit register for signal <Q>.
  Summary:
    inferred    4 D-type flip-flop(s).
Unit <registers_5> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Registers                               : 1
  4-bit register                           : 1

=====
*                               Advanced HDL Synthesis                       *
=====

Advanced HDL Synthesis Report

```

```

Macro Statistics
# Registers                               : 4
  Flip-Flops/Latches                       : 4

```

```

=====
...

```

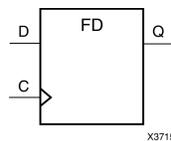
Registers Related Constraints

- [Pack I/O Registers Into IOBs \(IOB\)](#)
- [Register Duplication \(REGISTER_DUPLICATION\)](#)
- [Equivalent Register Removal \(EQUIVALENT_REGISTER_REMOVAL\)](#)
- [Register Balancing \(REGISTER_BALANCING\)](#)

Registers Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Flip-Flop With Positive-Edge Clock Diagram



Flip-Flop With Positive-Edge Clock Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| D | Data Input |
| C | Positive-Edge Clock |
| Q | Data Output |

Flip-Flop With Positive Edge Clock VHDL Coding Example

```

--
-- Flip-Flop with Positive-Edge Clock
--
library ieee;
use ieee.std_logic_1164.all;

entity registers_1 is
    port(C, D : in std_logic;
         Q   : out std_logic);
end registers_1;

architecture archi of registers_1 is
begin

    process (C)
    begin
        if (C'event and C='1') then
            Q <= D;
        end if;
    end process;
end archi;

```

```
        end process;  
end archi;
```

When using VHDL for a positive-edge clock, instead of using:

```
if (C'event and C='1') then  
you can also use:
```

```
if (rising_edge(C)) then
```

Flip-Flop With Positive-Edge Clock Verilog Coding Example

```
//  
// Flip-Flop with Positive-Edge Clock  
//  
module v_registers_1 (C, D, Q);  
    input  C, D;  
    output Q;  
    reg    Q;  
  
    always @(posedge C)  
    begin  
        Q <= D;  
    end  
  
endmodule
```

Flip-Flop With Positive Edge Clock with INITSTATE of the Flop Set Verilog Coding Example

```
module test(d, C, q);  
    input d;  
    input C;  
    output q;  
  
    reg qtemp = 'b1 ;  
  
    always @ (posedge C)  
    begin  
        qtemp = d;  
    end  
  
    assign q = qtemp;  
endmodule
```

Flip-Flop With Positive Edge Clock with INITSTATE of the Flop Set VHDL Coding Example

```

library ieee;
use ieee.std_logic_1164.all;

entity registers_1 is
  port(C, D : in std_logic;
       Q : out std_logic);
end registers_1;

architecture archi of registers_1 is
  signal qtemp : std_logic := '1';

begin

  process (C)

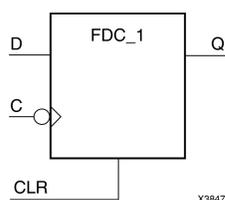
    begin
      if (C'event and C='1') then
        qtemp <= D;

      end if;
      Q <= Qtemp;
    end process;

end archi;

```

Flip-Flop With Negative-Edge Clock and Asynchronous Reset Diagram



Flip-Flop With Negative-Edge Clock and Asynchronous Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| D | Data Input |
| C | Negative-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| Q | Data Output |

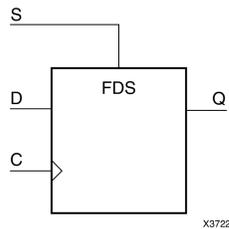
Flip-Flop With Negative-Edge Clock and Asynchronous Reset VHDL Coding Example

```
--  
-- Flip-Flop with Negative-Edge Clock and Asynchronous Reset  
--  
  
library ieee;  
use ieee.std_logic_1164.all;  
  
entity registers_2 is  
    port(C, D, CLR : in  std_logic;  
         Q       : out std_logic);  
end registers_2;  
  
architecture archi of registers_2 is  
begin  
  
    process (C, CLR)  
    begin  
        if (CLR = '1')then  
            Q <= '0';  
        elsif (C'event and C='0')then  
            Q <= D;  
        end if;  
    end process;  
  
end archi;
```

Flip-Flop With Negative-Edge Clock and Asynchronous Reset Verilog Coding Example

```
//  
// Flip-Flop with Negative-Edge Clock and Asynchronous Reset  
//  
  
module v_registers_2 (C, D, CLR, Q);  
    input  C, D, CLR;  
    output Q;  
    reg    Q;  
  
    always @(negedge C or posedge CLR)  
    begin  
        if (CLR)  
            Q <= 1'b0;  
        else  
            Q <= D;  
        end  
    end  
  
endmodule
```

Flip-Flop With Positive-Edge Clock and Synchronous Set Diagram



Flip-Flop With Positive-Edge Clock and Synchronous Set Pin Descriptions

| IO Pins | Description |
|---------|-------------------------------|
| D | Data Input |
| C | Positive-Edge Clock |
| S | Synchronous Set (active-High) |
| Q | Data Output |

Flip-Flop With Positive-Edge Clock and Synchronous Set VHDL Coding Example

```
--
-- Flip-Flop with Positive-Edge Clock and Synchronous Set
--
library ieee;
use ieee.std_logic_1164.all;
entity registers_3 is
  port(C, D, S : in std_logic;
        Q : out std_logic);
end registers_3;

architecture archi of registers_3 is
begin

  process (C)
  begin
    if (C'event and C='1') then
      if (S='1') then
        Q <= '1';
      else
        Q <= D;
      end if;
    end if;
  end process;

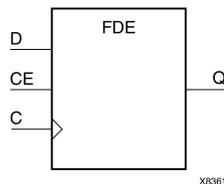
end archi;
```

Flip-Flop With Positive-Edge Clock and Synchronous Set Verilog Coding Example

```
//
// Flip-Flop with Positive-Edge Clock and Synchronous Set
//
module v_registers_3 (C, D, S, Q);
  input C, D, S;
  output Q;
  reg Q;

  always @(posedge C)
  begin
    if (S)
      Q <= 1'b1;
    else
      Q <= D;
    end
endmodule
```

Flip-Flop With Positive-Edge Clock and Clock Enable Diagram



Flip-Flop With Positive-Edge Clock and Clock Enable Pin Descriptions

| IO Pins | Description |
|---------|----------------------------|
| D | Data Input |
| C | Positive-Edge Clock |
| CE | Clock Enable (active-High) |
| Q | Data Output |

Flip-Flop With Positive-Edge Clock and Clock Enable VHDL Coding Example

```
--
-- Flip-Flop with Positive-Edge Clock and Clock Enable
--
library ieee;
use ieee.std_logic_1164.all;

entity registers_4 is
  port(C, D, CE : in std_logic;
        Q       : out std_logic);
end registers_4;

architecture archi of registers_4 is
begin
```

```

process (C)
begin
    if (C'event and C='1') then
        if (CE='1') then
            Q <= D;
        end if;
    end if;
end process;

end archi;

```

Flip-Flop With Positive-Edge Clock and Clock Enable Verilog Coding Example

```

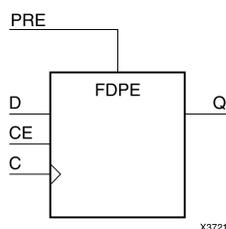
//
// Flip-Flop with Positive-Edge Clock and Clock Enable
//

module v_registers_4 (C, D, CE, Q);
    input C, D, CE;
    output Q;
    reg Q;

    always @(posedge C)
    begin
        if (CE)
            Q <= D;
    end
endmodule

```

4-Bit Register With Positive-Edge Clock, Asynchronous Set, and Clock Enable Diagram



4-Bit Register With Positive-Edge Clock, Asynchronous Set, and Clock Enable Pin Descriptions

| IO Pins | Description |
|---------|--------------------------------|
| D | Data Input |
| C | Positive-Edge Clock |
| PRE | Asynchronous Set (active-High) |
| CE | Clock Enable (active-High) |
| Q | Data Output |

4-Bit Register With Positive-Edge Clock, Asynchronous Set, and Clock Enable VHDL Coding Example

```
--  
-- 4-bit Register with Positive-Edge Clock,  
-- Asynchronous Set and Clock Enable  
--  
  
library ieee;  
use ieee.std_logic_1164.all;  
  
entity registers_5 is  
    port(C, CE, PRE : in std_logic;  
         D           : in std_logic_vector (3 downto 0);  
         Q           : out std_logic_vector (3 downto 0));  
end registers_5;  
  
architecture archi of registers_5 is  
begin  
  
    process (C, PRE)  
    begin  
        if (PRE='1') then  
            Q <= "1111";  
        elsif (C'event and C='1') then  
            if (CE='1') then  
                Q <= D;  
            end if;  
        end if;  
    end process;  
  
end archi;
```

4-Bit Register With Positive-Edge Clock, Asynchronous Set, and Clock Enable Verilog Coding Example

```
//  
// 4-bit Register with Positive-Edge Clock,  
// Asynchronous Set and Clock Enable  
//  
module v_registers_5 (C, D, CE, PRE, Q);  
    input  C, CE, PRE;  
    input  [3:0] D;  
    output [3:0] Q;  
    reg    [3:0] Q;  
  
    always @(posedge C or posedge PRE)  
    begin  
        if (PRE)  
            Q <= 4'b1111;  
        else  
            if (CE)  
                Q <= D;  
        end  
    end  
  
endmodule
```

Latches HDL Coding Techniques

This section includes:

- [About Latches](#)
- [Latches Log File](#)
- [Latches Related Constraints](#)
- [Latches Coding Examples](#)

About Latches

XST can recognize latches with asynchronous set/reset control signals. Latches can be described using:

- Process (VHDL)
- Always block (Verilog)
- Concurrent state assignment

XST does not support **wait** statements (VHDL) for latch descriptions.

Latches Log File

The XST log file reports the type and size of recognized latches during the Macro Recognition step.

Latches Log File Example

```
...
Synthesizing Unit <latch>.
  Related source file is latch_1.vhd.
WARNING:Xst:737 - Found 1-bit latch for signal <q>.
  Summary:
    inferred    1 Latch(s).
Unit <latch> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Latches                : 1
  1-bit latch            : 1
=====
...
```

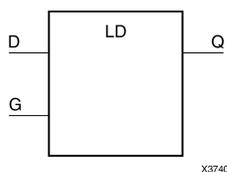
Latches Related Constraints

[Pack I/O Registers Into IOBs \(IOB\)](#)

Latches Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Latch With Positive Gate Diagram



Latch With Positive Gate Pin Descriptions

| IO Pins | Description |
|---------|---------------|
| D | Data Input |
| G | Positive Gate |
| Q | Data Output |

Latch With Positive Gate VHDL Coding Example

```
--
-- Latch with Positive Gate
--
library ieee;
use ieee.std_logic_1164.all;
entity latches_1 is
  port(G, D : in std_logic;
        Q : out std_logic);
end latches_1;

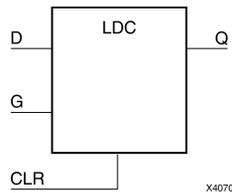
architecture archi of latches_1 is
begin
  process (G, D)
  begin
    if (G='1') then
      Q <= D;
    end if;
  end process;
end archi;
```

Latch With Positive Gate Verilog Coding Example

```
//
// Latch with Positive Gate
//
module v_latches_1 (G, D, Q);
  input G, D;
  output Q;
  reg Q;

  always @(G or D)
  begin
    if (G)
      Q = D;
    end
endmodule
```

Latch With Positive Gate and Asynchronous Reset Diagram



Latch With Positive Gate and Asynchronous Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| D | Data Input |
| G | Positive Gate |
| CLR | Asynchronous Reset (active-High) |
| Q | Data Output |

Latch With Positive Gate and Asynchronous Reset VHDL Coding Example

```
--
-- Latch with Positive Gate and Asynchronous Reset
--

library ieee;
use ieee.std_logic_1164.all;

entity latches_2 is
    port(G, D, CLR : in std_logic;
         Q : out std_logic);
end latches_2;

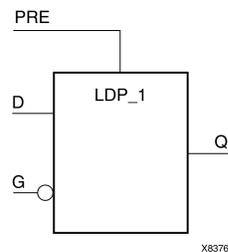
architecture archi of latches_2 is
begin
    process (CLR, D, G)
    begin
        if (CLR='1') then
            Q <= '0';
        elsif (G='1') then
            Q <= D;
        end if;
    end process;
end archi;
```

Latch With Positive Gate and Asynchronous Reset Verilog Coding Example

```
//
// Latch with Positive Gate and Asynchronous Reset
//

module v_latches_2 (G, D, CLR, Q);
    input G, D, CLR;
    output Q;
    reg Q;

    always @(G or D or CLR)
    begin
        if (CLR)
            Q = 1'b0;
        else if (G)
            Q = D;
    end
endmodule
```

4-Bit Latch With Inverted Gate and Asynchronous Set Diagram**4-Bit Latch With Inverted Gate and Asynchronous Set Pin Descriptions**

| IO Pins | Description |
|---------|-----------------------------------|
| D | Data Input |
| G | Inverted Gate |
| PRE | Asynchronous Preset (active-High) |
| Q | Data Output |

4-Bit Latch With Inverted Gate and Asynchronous Set VHDL Coding Example

```
--
-- 4-bit Latch with Inverted Gate and Asynchronous Set
--

library ieee;
use ieee.std_logic_1164.all;

entity latches_3 is
    port(D      : in std_logic_vector(3 downto 0);
         G, PRE : in std_logic;
         Q      : out std_logic_vector(3 downto 0));
end latches_3;
```

```
architecture archi of latches_3 is
begin
    process (PRE, G, D)
    begin
        if (PRE='1') then
            Q <= "1111";
        elsif (G='0') then
            Q <= D;
        end if;
    end process;
end archi;
```

4-Bit Latch With Inverted Gate and Asynchronous Set Verilog Coding Example

```
//
// 4-bit Latch with Inverted Gate and Asynchronous Set
//

module v_latches_3 (G, D, PRE, Q);
    input G, PRE;
    input [3:0] D;
    output [3:0] Q;
    reg [3:0] Q;

    always @(G or D or PRE)
    begin
        if (PRE)
            Q = 4'b1111;
        else if (~G)
            Q = D;
    end
endmodule
```

Tristates HDL Coding Techniques

This section discusses Tristates HDL Coding Techniques, and includes:

- [About Tristates](#)
- [Tristates Log File](#)
- [Tristates Related Constraints](#)
- [Tristates Coding Examples](#)

About Tristates

Tristate elements can be described using:

- Combinatorial process (VHDL)
- Always block (Verilog)
- Concurrent assignment

In the [Tristates Coding Examples](#), comparing to **0** instead of **1** infers a BUFT primitive instead of a BUFE macro. The BUFE macro has an inverter on the **E** pin.

Tristates Log File

The XST log file reports the type and size of recognized tristates during the Macro Recognition step.

Tristates Log File Example

```
...
Synthesizing Unit <three_st>.
  Related source file is tristates_1.vhd.
  Found 1-bit tristate buffer for signal <o>.
  Summary:
    inferred    1 Tristate(s).
  Unit <three_st> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Tristates                : 1
  1-bit tristate buffer    : 1
=====
...
```

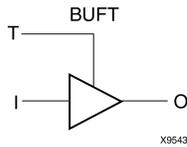
Tristates Related Constraints

[Convert Tristates to Logic \(TRISTATE2LOGIC\)](#)

Tristates Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Tristate Description Using Combinatorial Process and Always Block Diagram



Tristate Description Using Combinatorial Process and Always Block Pin Descriptions

| IO Pins | Description |
|---------|----------------------------|
| I | Data Input |
| T | Output Enable (active-Low) |
| O | Data Output |

Tristate Description Using Combinatorial Process VHDL Coding Example

```
--
-- Tristate Description Using Combinatorial Process
--

library ieee;
use ieee.std_logic_1164.all;

entity three_st_1 is
    port(T : in  std_logic;
         I : in  std_logic;
         O : out std_logic);
end three_st_1;

architecture archi of three_st_1 is
begin

    process (I, T)
    begin
        if (T='0') then
            O <= I;
        else
            O <= 'Z';
        end if;
    end process;

end archi;
```

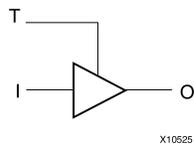
Tristate Description Using Combinatorial Always Block Verilog Coding Example

```
//
// Tristate Description Using Combinatorial Always Block
//

module v_three_st_1 (T, I, O);
    input  T, I;
    output O;
    reg    O;

    always @(T or I)
    begin
        if (~T)
            O = I;
        else
            O = 1'bZ;
        end
    endmodule
```

Tristate Description Using Concurrent Assignment Diagram



Tristate Description Using Concurrent Assignment Pin Descriptions

| IO Pins | Description |
|---------|----------------------------|
| I | Data Input |
| T | Output Enable (active-Low) |
| O | Data Output |

Tristate Description Using Concurrent Assignment VHDL Coding Example

```
--
-- Tristate Description Using Concurrent Assignment
--

library ieee;
use ieee.std_logic_1164.all;

entity three_st_2 is
    port(T : in  std_logic;
         I : in  std_logic;
         O : out std_logic);
end three_st_2;

architecture archi of three_st_2 is
begin
    O <= I when (T='0') else 'Z';
end archi;
```

```
end archi;
```

Tristate Description Using Concurrent Assignment Verilog Coding Example

```
//  
// Tristate Description Using Concurrent Assignment  
//  
module v_three_st_2 (T, I, O);  
    input  T, I;  
    output O;  
  
    assign O = (~T) ? I: 1'bZ;  
  
endmodule
```

Counters HDL Coding Techniques

This section discusses Counters HDL Coding Techniques, and includes:

- [About Counters](#)
- [Counters Log File](#)
- [Counters Related Constraints](#)
- [Counters Coding Examples](#)

About Counters

XST recognizes counters with the following control signals:

- Asynchronous Set/Reset
- Synchronous Set/Reset
- Asynchronous/Synchronous Load (signal or constant or both)
- Clock Enable
- Modes (Up, Down, Up/Down)
- Mixture of all of the above

Hardware Description Language (HDL) coding styles for the following control signals are equivalent to those described in [Registers HDL Coding Techniques](#).

- Clock
- Asynchronous Set/Reset
- Synchronous Set/Reset

XST supports both unsigned and signed counters.

Counters Log File

The XST log file reports the type and size of recognized counters during the Macro Recognition step.

Counters Log File Example

```

...
Synthesizing Unit <counter>.
  Related source file is counters_1.vhd.
  Found 4-bit up counter for signal <tmp>.
  Summary:
    inferred    1 Counter(s).
  Unit <counter> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Counters                : 1
  4-bit up counter        : 1
=====
...

```

Counters Related Constraints

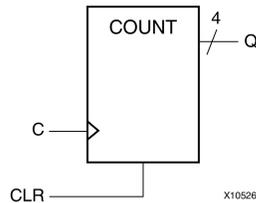
- Use DSP48 (USE_DSP48)
- DSP Utilization Ratio (DSP_UTILIZATION_RATIO)
- Keep (KEEP)

Counters Coding Examples

Coding examples can be downloaded in text format from

http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

4-Bit Unsigned Up Counter With Asynchronous Reset Diagram



4-Bit Unsigned Up Counter With Asynchronous Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| C | Positive-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| Q | Data Output |

4-Bit Unsigned Up Counter With Asynchronous Reset VHDL Coding Example

```
--
-- 4-bit unsigned up counter with an asynchronous reset.
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counters_1 is
    port(C, CLR : in std_logic;
         Q : out std_logic_vector(3 downto 0));
end counters_1;

architecture archi of counters_1 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C, CLR)
    begin
        if (CLR='1') then
            tmp <= "0000";
        elsif (C'event and C='1') then
            tmp <= tmp + 1;
        end if;
    end process;
end archi;
```

```

    Q <= tmp;
end archi;

```

4-Bit Unsigned Up Counter With Asynchronous Reset Verilog Coding Example

```

//
// 4-bit unsigned up counter with an asynchronous reset.
//

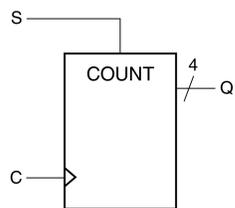
module v_counters_1 (C, CLR, Q);
    input C, CLR;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C or posedge CLR)
    begin
        if (CLR)
            tmp <= 4'b0000;
        else
            tmp <= tmp + 1'b1;
        end

    assign Q = tmp;
endmodule

```

4-Bit Unsigned Down Counter With Synchronous Set Diagram



X10527

4-Bit Unsigned Down Counter With Synchronous Set Pin Descriptions

| IO Pins | Description |
|---------|-------------------------------|
| C | Positive-Edge Clock |
| S | Synchronous Set (active-High) |
| Q | Data Output |

4-Bit Unsigned Down Counter With Synchronous Set VHDL Coding Example

```
--
-- 4-bit unsigned down counter with a synchronous set.
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counters_2 is
    port(C, S : in std_logic;
         Q : out std_logic_vector(3 downto 0));
end counters_2;

architecture archi of counters_2 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C)
    begin
        if (C'event and C='1') then
            if (S='1') then
                tmp <= "1111";
            else
                tmp <= tmp - 1;
            end if;
        end if;
    end process;

    Q <= tmp;

end archi;
```

4-Bit Unsigned Down Counter With Synchronous Set Verilog Coding Example

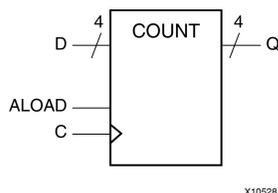
```
//
// 4-bit unsigned down counter with a synchronous set.
//

module v_counters_2 (C, S, Q);
    input C, S;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C)
    begin
        if (S)
            tmp <= 4'b1111;
        else
            tmp <= tmp - 1'b1;
        end

        assign Q = tmp;
    endmodule
```

4-Bit Unsigned Up Counter With Asynchronous Load From Primary Input Diagram



4-Bit Unsigned Up Counter With Asynchronous Load From Primary Input Pin Descriptions

| IO Pins | Description |
|---------|---------------------------------|
| C | Positive-Edge Clock |
| ALOAD | Asynchronous Load (active-High) |
| D | Data Input |
| Q | Data Output |

4-Bit Unsigned Up Counter With Asynchronous Load From Primary Input VHDL Coding Example

```
--
-- 4-bit Unsigned Up Counter with Asynchronous Load
-- from Primary Input
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counters_3 is
    port(C, ALOAD : in std_logic;
         D : in std_logic_vector(3 downto 0);
         Q : out std_logic_vector(3 downto 0));
end counters_3;

architecture archi of counters_3 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C, ALOAD, D)
    begin
        if (ALOAD='1') then
            tmp <= D;
        elsif (C'event and C='1') then
            tmp <= tmp + 1;
        end if;
    end process;

    Q <= tmp;

end archi;
```

4-Bit Unsigned Up Counter With Asynchronous Load From Primary Input Verilog Coding Example

```
//
// 4-bit Unsigned Up Counter with Asynchronous Load
// from Primary Input
//

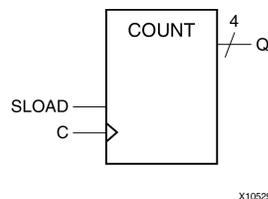
module v_counters_3 (C, ALOAD, D, Q);
    input C, ALOAD;
    input [3:0] D;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C or posedge ALOAD)
    begin
        if (ALOAD)
            tmp <= D;
        else
            tmp <= tmp + 1'b1;
        end

    assign Q = tmp;

endmodule
```

4-Bit Unsigned Up Counter With Synchronous Load With Constant Diagram



X10529

4-Bit Unsigned Up Counter With Synchronous Load With Constant Pin Descriptions

| IO Pins | Description |
|---------|--------------------------------|
| C | Positive-Edge Clock |
| SLOAD | Synchronous Load (active-High) |
| Q | Data Output |

4-Bit Unsigned Up Counter With Synchronous Load With Constant VHDL Coding Example

```
--
-- 4-bit Unsigned Up Counter with Synchronous Load
-- with a Constant
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counters_4 is
    port(C, SLOAD : in std_logic;
         Q : out std_logic_vector(3 downto 0));
end counters_4;

architecture archi of counters_4 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C)
    begin
        if (C'event and C='1') then
            if (SLOAD='1') then
                tmp <= "1010";
            else
                tmp <= tmp + 1;
            end if;
        end if;
    end process;

    Q <= tmp;

end archi;
```

4-Bit Unsigned Up Counter With Synchronous Load With Constant Verilog Coding Example

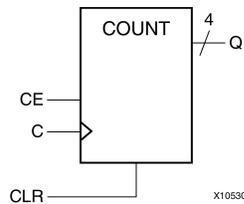
```
//
// 4-bit Unsigned Up Counter with Synchronous Load
// with a Constant
//

module v_counters_4 (C, SLOAD, Q);
    input C, SLOAD;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C)
    begin
        if (SLOAD)
            tmp <= 4'b1010;
        else
            tmp <= tmp + 1'b1;
        end

        assign Q = tmp;
    endmodule
```

4-Bit Unsigned Up Counter With Asynchronous Reset and Clock Enable Diagram



4-Bit Unsigned Up Counter With Asynchronous Reset and Clock Enable Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| C | Positive-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| CE | Clock Enable |
| Q | Data Output |

4-Bit Unsigned Up Counter With Asynchronous Reset and Clock Enable VHDL Coding Example

```
--
-- 4-bit Unsigned Up Counter with Asynchronous Reset
-- and Clock Enable
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counters_5 is
    port(C, CLR, CE : in std_logic;
         Q : out std_logic_vector(3 downto 0));
end counters_5;

architecture archi of counters_5 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C, CLR)
    begin
        if (CLR='1') then
            tmp <= "0000";
        elsif (C'event and C='1') then
            if (CE='1') then
                tmp <= tmp + 1;
            end if;
        end if;
    end process;

    Q <= tmp;

end archi;
```

4-Bit Unsigned Up Counter With Asynchronous Reset and Clock Enable Verilog Coding Example

```
//
// 4-bit Unsigned Up Counter with Asynchronous Reset
// and Clock Enable
//

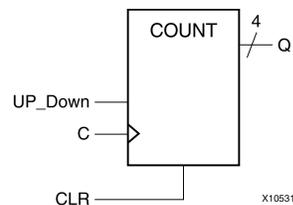
module v_counters_5 (C, CLR, CE, Q);
    input C, CLR, CE;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C or posedge CLR)
    begin
        if (CLR)
            tmp <= 4'b0000;
        else if (CE)
            tmp <= tmp + 1'b1;
        end

    assign Q = tmp;

endmodule
```

4-Bit Unsigned Up/Down Counter With Asynchronous Reset Diagram



4-Bit Unsigned Up/Down Counter With Asynchronous Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| C | Positive-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| UP_DOWN | Up/Down Count Mode Selector |
| Q | Data Output |

4-Bit Unsigned Up/Down Counter With Asynchronous Reset VHDL Coding Example

```
--
-- 4-bit Unsigned Up/Down counter
-- with Asynchronous Reset
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity counters_6 is
    port(C, CLR, UP_DOWN : in std_logic;
         Q : out std_logic_vector(3 downto 0));
end counters_6;

architecture archi of counters_6 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C, CLR)
    begin
        if (CLR='1') then
            tmp <= "0000";
        elsif (C'event and C='1') then
            if (UP_DOWN='1') then
                tmp <= tmp + 1;
            else
                tmp <= tmp - 1;
            end if;
        end if;
    end process;

    Q <= tmp;

end archi;
```

4-Bit Unsigned Up/Down Counter With Asynchronous Reset Verilog Coding Example

```
//
// 4-bit Unsigned Up/Down counter
// with Asynchronous Reset
//

module v_counters_6 (C, CLR, UP_DOWN, Q);
    input C, CLR, UP_DOWN;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C or posedge CLR)
    begin
        if (CLR)
            tmp <= 4'b0000;
        else if (UP_DOWN)
            tmp <= tmp + 1'b1;
        else
            tmp <= tmp - 1'b1;
    end
endmodule
```

```

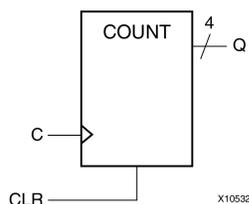
end

assign Q = tmp;

endmodule

```

4-Bit Signed Up Counter With Asynchronous Reset Diagram



4-Bit Signed Up Counter With Asynchronous Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| C | Positive-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| Q | Data Output |

4-Bit Signed Up Counter With Asynchronous Reset VHDL Coding Example

```

--
-- 4-bit Signed Up Counter with Asynchronous Reset
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_signed.all;

entity counters_7 is
    port(C, CLR : in std_logic;
         Q : out std_logic_vector(3 downto 0));
end counters_7;

architecture archi of counters_7 is
    signal tmp: std_logic_vector(3 downto 0);
begin
    process (C, CLR)
    begin
        if (CLR='1') then
            tmp <= "0000";
        elsif (C'event and C='1') then
            tmp <= tmp + 1;
        end if;
    end process;

    Q <= tmp;

end archi;

```

4-Bit Signed Up Counter With Asynchronous Reset Verilog Coding Example

```
//
// 4-bit Signed Up Counter with Asynchronous Reset
//

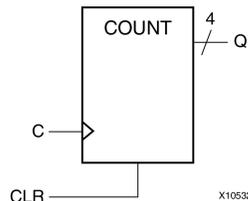
module v_counters_7 (C, CLR, Q);
    input C, CLR;
    output signed [3:0] Q;
    reg signed [3:0] tmp;

    always @ (posedge C or posedge CLR)
    begin
        if (CLR)
            tmp <= 4'b0000;
        else
            tmp <= tmp + 1'b1;
        end

    assign Q = tmp;

endmodule
```

4-Bit Signed Up Counter With Asynchronous Reset and Modulo Maximum Diagram



4-Bit Signed Up Counter With Asynchronous Reset and Modulo Maximum Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| C | Positive-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| Q | Data Output |

4-Bit Signed Up Counter With Asynchronous Reset and Modulo Maximum VHDL Coding Example

```
--
-- 4-bit Signed Up Counter with Asynchronous Reset
-- and Modulo Maximum
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_arith.all;

entity counters_8 is
```

```

        generic (MAX : integer := 16);
        port(C, CLR : in std_logic;
             Q : out integer range 0 to MAX-1);
    end counters_8;

    architecture archi of counters_8 is
        signal cnt : integer range 0 to MAX-1;
    begin
        process (C, CLR)
        begin
            if (CLR='1') then
                cnt <= 0;
            elsif (rising_edge(C)) then
                cnt <= (cnt + 1) mod MAX ;
            end if;
        end process;

        Q <= cnt;
    end archi;

```

4-Bit Signed Up Counter With Asynchronous Reset and Modulo Maximum Verilog Coding Example

```

//
// 4-bit Signed Up Counter with Asynchronous Reset
// and Modulo Maximum
//

module v_counters_8 (C, CLR, Q);
    parameter
        MAX_SQRT = 4,
        MAX = (MAX_SQRT*MAX_SQRT);

    input  C, CLR;
    output [MAX_SQRT-1:0] Q;
    reg    [MAX_SQRT-1:0] cnt;

    always @ (posedge C or posedge CLR)
    begin
        if (CLR)
            cnt <= 0;
        else
            cnt <= (cnt + 1) %MAX;
        end

        assign Q = cnt;
    endmodule

```

Accumulators HDL Coding Techniques

This section discusses Accumulators HDL Coding Techniques, and includes:

- [About Accumulators](#)
- [Accumulators in Virtex®-4 Devices and Virtex-5 Device](#)
- [Accumulators Log File](#)
- [Accumulators Related Constraints](#)
- [Accumulators Coding Examples](#)

About Accumulators

An *accumulator* differs from a *counter* in the nature of the operands of the **add** and **subtract** operation.

- In a *counter*:
 - The destination and first operand is a signal or variable
 - The second operand is a constant equal to 1:

$$A \leq A + 1$$

- In an *accumulator*:
 - The destination and first operand is a signal or variable
 - The second operand is either:

- ◆ A signal or variable:

$$A \leq A + B$$

- ◆ A constant not equal to 1:

$$A \leq A + \text{Constant}$$

An inferred accumulator can be **up**, **down**, or **updown**. For an **updown** accumulator, the accumulated data may differ between the **up** and **down** mode:

```
...
if updown = '1' then
  a <= a + b;
else
  a <= a - c;
...
```

XST can infer an accumulator with the same set of control signals available for counters.

For more information, see:

[Counters HDL Coding Techniques](#)

Accumulators in Virtex-4 Devices and Virtex-5 Devices

This section discusses Accumulators in Virtex®-4 Devices and Virtex-5 Devices, and includes:

- [About Accumulators in Virtex-4 Devices and Virtex-5 Devices](#)
- [Macro Implementation on DSP48 Resources](#)
- [Maximum Macro Configuration](#)
- [Reporting of Inferred Accumulators](#)

About Accumulators in Virtex-4 Devices and Virtex-5 Devices

Virtex-4 devices and Virtex-5 devices enable accumulators to be implemented on DSP48 resources. XST can push up to two levels of input registers into DSP48 blocks.

XST can implement an accumulator in a DSP48 block if its implementation requires only a single DSP48 resource. If an accumulator macro does not fit in a single DSP48, XST implements the entire macro using slice logic.

Macro Implementation on DSP48 Resources

Macro implementation on DSP48 resources is controlled by [Use DSP48 \(USE_DSP48\)](#), with a default value of **auto**. In **auto** mode, XST implements accumulators taking into account DSP48 resources on the device.

Use [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#) in **auto** mode to control DSP48 resources for synthesis. By default, XST tries to utilize all DSP48 resources.

For more information, see:

[DSP48 Block Resources](#)

Maximum Macro Configuration

To deliver the best performance, XST by default tries to infer and implement the maximum macro configuration, including as many registers as possible in the DSP48. Use [Keep \(KEEP\)](#) to shape a macro in a specific way. For example, to exclude the first register stage from the DSP48, place [Keep \(KEEP\)](#) constraints on the outputs of these registers.

Reporting of Inferred Accumulators

XST reports the details of inferred accumulators at the HDL Synthesis step. Because accumulators are implemented within the MAC implementation mechanism, they are no longer visible in the Final Synthesis Report.

Accumulators Log File

The XST log file reports the type and size of recognized accumulators during the Macro Recognition step.

Accumulators Log File Example

```
...
Synthesizing Unit <accum>.
  Related source file is accumulators_1.vhd.
  Found 4-bit up accumulator for signal <tmp>.
  Summary:
    inferred    1 Accumulator(s).
  Unit <accum> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Accumulators           : 1
  4-bit up accumulator   : 1
=====
...

```

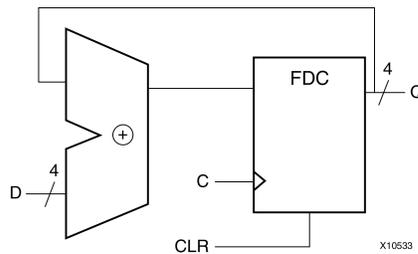
Accumulators Related Constraints

- Use DSP48 (USE_DSP48)
- DSP Utilization Ratio (DSP_UTILIZATION_RATIO)
- Keep (KEEP)

Accumulators Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

4-Bit Unsigned Up Accumulator With Asynchronous Reset Diagram



4-Bit Unsigned Up Accumulator With Asynchronous Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| C | Positive-Edge Clock |
| CLR | Asynchronous Reset (active-High) |
| D | Data Input |
| Q | Data Output |

4-Bit Unsigned Up Accumulator With Asynchronous Reset VHDL Coding Example

```
--
-- 4-bit Unsigned Up Accumulator with Asynchronous Reset
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity accumulators_1 is
    port(C, CLR : in std_logic;
         D : in std_logic_vector(3 downto 0);
         Q : out std_logic_vector(3 downto 0));
end accumulators_1;

architecture archi of accumulators_1 is
    signal tmp: std_logic_vector(3 downto 0);
begin
```

```
process (C, CLR)
begin
    if (CLR='1') then
        tmp <= "0000";
    elsif (C'event and C='1') then
        tmp <= tmp + D;
    end if;
end process;

Q <= tmp;

end archi;
```

4-Bit Unsigned Up Accumulator With Asynchronous Reset Verilog Coding Example

```
//
// 4-bit Unsigned Up Accumulator with Asynchronous Reset
//

module v_accumulators_1 (C, CLR, D, Q);

    input C, CLR;
    input [3:0] D;
    output [3:0] Q;
    reg [3:0] tmp;

    always @(posedge C or posedge CLR)
    begin
        if (CLR)
            tmp = 4'b0000;
        else
            tmp = tmp + D;
        end
    assign Q = tmp;
endmodule
```

Shift Registers HDL Coding Techniques

This section discusses Shift Registers HDL Coding Techniques, and includes:

- [About Shift Registers](#)
- [Shift Registers Log File](#)
- [Shift Registers Related Constraints](#)
- [Shift Registers Coding Examples](#)

About Shift Registers

This section discusses About Shift Registers, and includes:

- [Shift Register Definition](#)
- [Static Shift Register Components](#)
- [Additional Functionality](#)
- [Describing Shift Registers](#)
- [Implementing Shift Registers](#)

Shift Register Definition

A shift register is a chain of flip-flops allowing propagation of data across a fixed (static) number of latency stages. In [Dynamic Shift Registers HDL Coding Techniques](#), the length of the propagation chain dynamically varies during circuit operation.

Static Shift Register Components

A static shift register usually involves:

- A clock
- An optional clock enable
- A serial data input
- A serial data output

Additional Functionality

You can include additional functionality, such as reset, set, or parallel load logic. In this case however, XST may not always be able to take advantage of dedicated SRL-type primitives for reduced device utilization and optimized performance. Xilinx® recommends removing such logic, and loading the desired contents serially instead.

Describing Shift Registers

Ways to describe shift registers in VHDL include:

- Concatenation operator

```
shreg <= shreg (6 downto 0) & SI;
```
- For loop construct

```
for i in 0 to 6 loop
  shreg(i+1) <= shreg(i);
end loop;
shreg(0) <= SI;
```
- Predefined shift operators (for example, SLL or SRL)

For more information, see your VHDL and Verilog language reference manuals.

Implementing Shift Registers

Inferred shift registers are implemented on SRL-type resources. The resources shown in the following table are leveraged.

| Devices | SRL16 | SRL16E | SRLC16 | SRLC16E | SRLC32E |
|------------|-------|--------|--------|---------|---------|
| Spartan®-3 | Yes | Yes | Yes | Yes | No |
| Spartan-3E | | | | | |
| Spartan-3A | | | | | |
| Virtex®-4 | Yes | Yes | Yes | Yes | No |
| Virtex-5 | Yes | Yes | Yes | Yes | Yes |

Shift Registers Log File

XST recognizes shift registers in the Low Level Optimization step. The XST log file reports the size of recognized shift registers.

Shift Registers Log File Example

```

...
=====
*                      HDL Synthesis                      *
=====

Synthesizing Unit <shift_registers_1>.
  Related source file is "shift_registers_1.vhd".
  Found 8-bit register for signal <tmp>.
  Summary:
    inferred    8 D-type flip-flop(s).
Unit <shift_registers_1> synthesized.

=====
*                      Advanced HDL Synthesis              *
=====
Advanced HDL Synthesis Report
Macro Statistics
# Registers : 8
  Flip-Flops : 8
=====
*                      Low Level Synthesis                *
=====
Processing Unit <shift_registers_1> :
  Found 8-bit shift register for signal <tmp_7>.
Unit <shift_registers_1> processed.
=====
Final Register Report
Macro Statistics
# Shift Registers : 1
  8-bit shift register : 1
=====

```

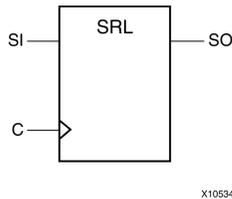
Shift Registers Related Constraints

[Shift Register Extraction \(SHREG_EXTRACT\)](#)

Shift Registers Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

8-Bit Shift-Left Register With Positive-Edge Clock, Serial In and Serial Out Diagram



8-Bit Shift-Left Register With Positive-Edge Clock, Serial In and Serial Out Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| C | Positive-Edge Clock |
| SI | Serial In |
| SO | Serial Output |

8-Bit Shift-Left Register With Positive-Edge Clock, Serial In and Serial Out VHDL Coding Example

```
--
-- 8-bit Shift-Left Register with Positive-Edge Clock,
-- Serial In, and Serial Out
--

library ieee;
use ieee.std_logic_1164.all;

entity shift_registers_1 is
    port(C, SI : in std_logic;
         SO : out std_logic);
end shift_registers_1;

architecture archi of shift_registers_1 is
    signal tmp: std_logic_vector(7 downto 0);
begin

    process (C)
    begin
        if (C'event and C='1') then
            for i in 0 to 6 loop
                tmp(i+1) <= tmp(i);
            end loop;
            tmp(0) <= SI;
        end if;
    end process;

    SO <= tmp(7);

end archi;
```

8-Bit Shift-Left Register With Positive-Edge Clock, Serial In and Serial Out Verilog Coding Example

```
//
// 8-bit Shift-Left Register with Positive-Edge Clock,
// Serial In, and Serial Out
//

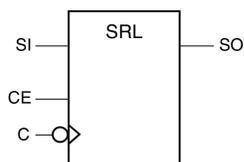
module v_shift_registers_1 (C, SI, SO);
    input C,SI;
    output SO;
    reg [7:0] tmp;

    always @(posedge C)
    begin
        tmp = {tmp[6:0], SI};
    end

    assign SO = tmp[7];

endmodule
```

8-Bit Shift-Left Register With Negative-Edge Clock, Clock Enable, Serial In and Serial Out Diagram



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8-Bit Shift-Left Register With Negative-Edge Clock, Clock Enable, Serial In and Serial Out Pin Descriptions

| IO Pins | Description |
|---------|----------------------------|
| C | Negative-Edge Clock |
| SI | Serial In |
| CE | Clock Enable (active-High) |
| SO | Serial Output |

8-Bit Shift-Left Register With Negative-Edge Clock, Clock Enable, Serial In and Serial Out VHDL Coding Example

```
--
-- 8-bit Shift-Left Register with Negative-Edge Clock,
-- Clock Enable, Serial In, and Serial Out
--
library ieee;
use ieee.std_logic_1164.all;

entity shift_registers_2 is
    port(C, SI, CE : in std_logic;
         SO : out std_logic);
end shift_registers_2;

architecture archi of shift_registers_2 is
    signal tmp: std_logic_vector(7 downto 0);
begin

    process (C)
    begin
        if (C'event and C='0') then
            if (CE='1') then
                for i in 0 to 6 loop
                    tmp(i+1) <= tmp(i);
                end loop;
                tmp(0) <= SI;
            end if;
        end if;
    end process;

    SO <= tmp(7);

end archi;
```

8-Bit Shift-Left Register With Negative-Edge Clock, Clock Enable, Serial In and Serial Out Verilog Coding Example

```
//  
// 8-bit Shift-Left Register with Negative-Edge Clock,  
// Clock Enable, Serial In, and Serial Out  
//  
  
module v_shift_registers_2 (C, CE, SI, SO);  
    input C,SI, CE;  
    output SO;  
    reg [7:0] tmp;  
  
    always @(negedge C)  
    begin  
        if (CE)  
        begin  
            tmp = {tmp[6:0], SI};  
        end  
    end  
  
    assign SO = tmp[7];  
  
endmodule
```

Dynamic Shift Registers HDL Coding Techniques

This section discusses Dynamic Shift Registers HDL Coding Techniques, and includes:

- [About Dynamic Shift Registers](#)
- [Dynamic Shift Registers Log File](#)
- [Dynamic Shift Registers Related Constraints](#)
- [Dynamic Shift Registers Coding Examples](#)

About Dynamic Shift Registers

XST can infer Dynamic Shift Registers. Once a Dynamic Shift Register has been identified, its characteristics are handed to the XST macro generator for optimal implementation using the primitives shown in the following table.

| Devices | SRL16 | SRL16E | SRLC16 | SRLC16E | SRLC32E |
|------------|-------|--------|--------|---------|---------|
| Spartan®-3 | Yes | Yes | Yes | Yes | No |
| Spartan-3E | | | | | |
| Spartan-3A | | | | | |
| Virtex®-4 | Yes | Yes | Yes | Yes | No |
| Virtex-5 | Yes | Yes | Yes | Yes | Yes |

Dynamic Shift Registers Log File

Dynamic shift registers are recognized in the Advanced HDL Synthesis step. The XST log file reports the size of recognized dynamic shift registers during the Macro Recognition step.

Dynamic Shift Registers Log File Example

```

...
=====
*                HDL Synthesis                *
=====

Synthesizing Unit <dynamic_shift_registers_1>.
  Related source file is "dynamic_shift_registers_1.vhd".
  Found 1-bit 16-to-1 multiplexer for signal <Q>.
  Found 16-bit register for signal <SRL_SIG>.
  Summary:
    inferred 16 D-type flip-flop(s).
    inferred 1 Multiplexer(s).
Unit <dynamic_shift_registers_1> synthesized.

=====
*                Advanced HDL Synthesis        *
=====
...
Synthesizing (advanced) Unit <dynamic_shift_registers_1>.
  Found 16-bit dynamic shift register for signal <Q>.
Unit <dynamic_shift_registers_1> synthesized (advanced).

=====
HDL Synthesis Report

```

```

Macro Statistics
# Shift Registers                : 1
  16-bit dynamic shift register  : 1

=====
...

```

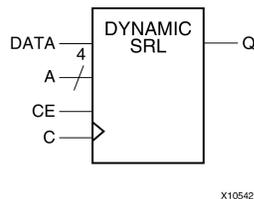
Dynamic Shift Registers Related Constraints

Shift Register Extraction (SHREG_EXTRACT)

Dynamic Shift Registers Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

16-Bit Dynamic Shift Register With Positive-Edge Clock, Serial In and Serial Out Diagram



The following table shows pin descriptions for a dynamic register. The register can:

- Be either serial or parallel
- Be left or right
- Have a synchronous or asynchronous reset
- Have a depth up to 16 bits.

16-Bit Dynamic Shift Register With Positive-Edge Clock, Serial In and Serial Out Pin Descriptions

| IO Pins | Description |
|---------------|---|
| C | Positive-Edge Clock |
| SI | Serial In |
| AClr | Asynchronous Reset |
| SClr | Synchronous Reset |
| SLoad | Synchronous Parallel Load |
| Data | Parallel Data Input Port |
| ClkEn | Clock Enable |
| LeftRight | Direction selection |
| SerialInRight | Serial Input Right for Bidirectional Shift Register |
| PSO | Serial or Parallel Output |

16-Bit Dynamic Shift Register With Positive-Edge Clock, Serial In and Serial Out VHDL Coding Example

```
--
-- 16-bit dynamic shift register.
--

library IEEE;
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;

entity dynamic_shift_registers_1 is
    port(CLK : in std_logic;
         DATA : in std_logic;
         CE : in std_logic;
         A : in std_logic_vector(3 downto 0);
         Q : out std_logic);
end dynamic_shift_registers_1;

architecture rtl of dynamic_shift_registers_1 is
    constant DEPTH_WIDTH : integer := 16;

    type SRL_ARRAY is array (0 to DEPTH_WIDTH-1) of std_logic;
    -- The type SRL_ARRAY can be array
    -- (0 to DEPTH_WIDTH-1) of
    -- std_logic_vector(BUS_WIDTH downto 0)
    -- or array (DEPTH_WIDTH-1 downto 0) of
    -- std_logic_vector(BUS_WIDTH downto 0)
    -- (the subtype is forward (see below))
    signal SRL_SIG : SRL_ARRAY;

begin
    PROC_SRL16 : process (CLK)
    begin
        if (CLK'event and CLK = '1') then
            if (CE = '1') then
                SRL_SIG <= DATA & SRL_SIG(0 to DEPTH_WIDTH-2);
            end if;
        end if;
    end process;

    Q <= SRL_SIG(conv_integer(A));

end rtl;
```

16-Bit Dynamic Shift Register With Positive-Edge Clock, Serial In and Serial Out Verilog Coding Example

```
//  
// 16-bit dynamic shift register.  
//  
module v_dynamic_shift_registers_1 (Q,CE,CLK,D,A);  
    input CLK, D, CE;  
    input [3:0] A;  
    output Q;  
    reg [15:0] data;  
  
    assign Q = data[A];  
  
    always @(posedge CLK)  
    begin  
        if (CE == 1'b1)  
            data <= {data[14:0], D};  
    end  
  
endmodule
```

Multiplexers HDL Coding Techniques

This section discusses Multiplexers HDL Coding Techniques, and includes:

- [About Multiplexers](#)
- [Multiplexers Log File](#)
- [Multiplexers Related Constraints](#)
- [Multiplexers Coding Examples](#)

About Multiplexers

This section discusses About Multiplexers, and includes:

- [Multiplexers Description Styles](#)
- [Verilog Case Statements](#)
- [Verilog Case Statement Resources](#)
- [Case Implementation Style Parameter](#)
- [Multiplexers Case Statements](#)

Multiplexers Description Styles

XST supports different description styles for multiplexers (MUX), such as:

- **if-then-else**
- **case**

If you describe a MUX using a **case** statement, and you do not specify all values of the selector, the result may be latches instead of a multiplexer. When writing a MUX, you can use **dont care** to describe selector values.

XST decides whether to infer the MUX during the Macro Inference step. If the MUX has several inputs that are the same, XST can decide not to infer it. Use [MUX_EXTRACT](#) to force XST to infer the MUX.

Verilog Case Statements

Verilog **case** statements can be:

- **full** or **not full**
- **parallel** or **not parallel**

A Verilog **case** statement is:

- **full** if all possible branches are specified
- **parallel** if it does not contain branches that can be executed simultaneously

Verilog Case Statement Resources

Verilog Case Statement Resources indicates the *resources* used to synthesize the Multiplexers Case Statement Examples using the four Case Implementation Styles. The term *resources* means the functionality.

For example, if you code the **case** statement neither **full** nor **parallel** with [Case Implementation Style](#) set to **none**, from the functionality point of view, XST implements a priority encoder + latch. But it does not inevitably mean that XST *infers* the priority encoder during the Macro Recognition step.

| Parameter Value | Case Implementation | | |
|-----------------|---------------------|----------|---------------------------|
| | Full | Not Full | Neither Full nor Parallel |
| none | MUX | Latch | Priority Encoder + Latch |
| parallel | MUX | Latch | Latch |
| full | MUX | MUX | Priority Encoder |
| full-parallel | MUX | MUX | MUX |

Specifying **full**, **parallel** or **full-parallel** may result in an implementation with a behavior that may differ from the behavior of the initial model.

Case Implementation Style Parameter

This characterization of the **case** statements can be guided or modified by using [Case Implementation Style](#). Accepted values for this parameter are:

- **none**
- **full**
- **parallel**
- **full-parallel**

| Value | XST Behavior |
|--------------------------|---|
| none (default) | Implements the exact behavior of the case statements |
| full | Considers that case statements are complete and avoids latch creation |
| parallel | Considers that the branches cannot occur in parallel and does not use a priority encoder |
| full-parallel | Considers that case statements are complete and that the branches cannot occur in parallel, therefore saving latches and priority encoders |

For more information, see:

[XST Design Constraints](#)

Multiplexers Case Statements

Following are three examples of Case statements:

- [Full and Parallel Case Statement](#)
- [Not Full But Parallel Case Statement](#)
- [Neither Full Nor Parallel Case Statement](#)

Full and Parallel Case Statement

```
module full (sel, i1, i2, i3, i4, o1);
input [1:0] sel;
input [1:0] i1, i2, i3, i4;
output [1:0] o1;

reg [1:0] o1;

always @(sel or i1 or i2 or i3 or i4)
begin
case (sel)
2'b00: o1 = i1;
2'b01: o1 = i2;
2'b10: o1 = i3;
2'b11: o1 = i4;
endcase
end
endmodule
```

Not Full But Parallel Case Statement

```
module notfull (sel, i1, i2, i3, o1);
input [1:0] sel;
input [1:0] i1, i2, i3;
output [1:0] o1;

reg [1:0] o1;

always @(sel or i1 or i2 or i3)
begin
case (sel)
2'b00: o1 = i1;
2'b01: o1 = i2;
2'b10: o1 = i3;
endcase
end
endmodule
```

Neither Full Nor Parallel Case Statement

```
module notfull_notparallel (sel1, sel2, i1, i2, o1);
input [1:0] sel1, sel2;
input [1:0] i1, i2;
output [1:0] o1;

reg [1:0] o1;

always @(sel1 or sel2)
begin
case (2'b00)
sel1: o1 = i1;
sel2: o1 = i2;
endcase
end
endmodule
```

XST automatically determines the characteristics of the **case** statements and generates logic using multiplexers, priority encoders, and latches that best implement the exact behavior of the **case** statement.

Multiplexers Log File

The XST log file reports the type and size of recognized multiplexers (MUX) during the Macro Recognition step.

Multiplexers Log File Example

```
...
Synthesizing Unit <mux>.
    Related source file is multiplexers_1.vhd.
    Found 1-bit 4-to-1 multiplexer for signal <o>.
    Summary:
        inferred    1 Multiplexer(s).
    Unit <mux> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Multiplexers                : 1
  1-bit 4-to-1 multiplexer    : 1
=====
...

```

Explicit inference and reporting of multiplexers may vary depending on the targeted device families. The following coding examples are limited to 4-to-1 multiplexers. They are reported as shown above only if the target is a LUT4-based device family. For Virtex®-5 devices, multiplexers are explicitly inferred only for sizes of 8-to-1 and above.

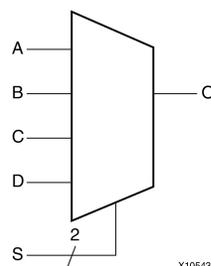
Multiplexers Related Constraints

- [Mux Extraction \(MUX_EXTRACT\)](#)
- [Mux Style \(MUX_STYLE\)](#)
- [Enumerated Encoding \(ENUM_ENCODING\)](#)

Multiplexers Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

4-to-1 1-Bit MUX Using IF Statement Diagram



4-to-1 1-Bit MUX Using IF Statement Pin Descriptions

| IO Pins | Description |
|------------|--------------|
| a, b, c, d | Data Inputs |
| s | MUX Selector |
| o | Data Output |

4-to-1 1-Bit MUX Using IF Statement VHDL Coding Example

```
--
-- 4-to-1 1-bit MUX using an If statement.
--

library ieee;
use ieee.std_logic_1164.all;

entity multiplexers_1 is
    port (a, b, c, d : in std_logic;
          s : in std_logic_vector (1 downto 0);
          o : out std_logic);
end multiplexers_1;

architecture archi of multiplexers_1 is
begin
    process (a, b, c, d, s)
    begin
        if (s = "00") then o <= a;
        elsif (s = "01") then o <= b;
        elsif (s = "10") then o <= c;
        else o <= d;
        end if;
    end process;
end archi;
```

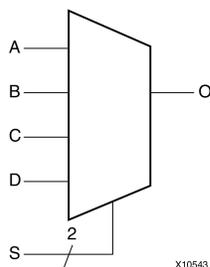
4-to-1 1-Bit MUX Using IF Statement Verilog Coding Example

```
//
// 4-to-1 1-bit MUX using an If statement.
//

module v_multiplexers_1 (a, b, c, d, s, o);
    input a,b,c,d;
    input [1:0] s;
    output o;
    reg o;

    always @(a or b or c or d or s)
    begin
        if (s == 2'b00) o = a;
        else if (s == 2'b01) o = b;
        else if (s == 2'b10) o = c;
        else o = d;
    end
endmodule
```

4-to-1 1-Bit MUX Using Case Statement Diagram



4-to-1 1-Bit MUX Using Case Statement Pin Descriptions

| IO Pins | Description |
|------------|--------------|
| a, b, c, d | Data Inputs |
| s | MUX Selector |
| o | Data Output |

4-to-1 1-Bit MUX Using Case Statement VHDL Coding Example

```
--
-- 4-to-1 1-bit MUX using a Case statement.
--

library ieee;
use ieee.std_logic_1164.all;

entity multiplexers_2 is
    port (a, b, c, d : in std_logic;
          s : in std_logic_vector (1 downto 0);
          o : out std_logic);
end multiplexers_2;

architecture archi of multiplexers_2 is
begin
    process (a, b, c, d, s)
    begin
        case s is
            when "00" => o <= a;
            when "01" => o <= b;
            when "10" => o <= c;
            when others => o <= d;
        end case;
    end process;
end archi;
```

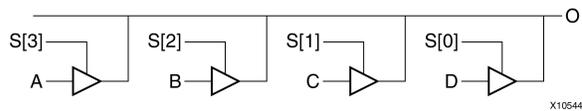
4-to-1 1-Bit MUX Using Case Statement Verilog Coding Example

```
//
// 4-to-1 1-bit MUX using a Case statement.
//

module v_multiplexers_2 (a, b, c, d, s, o);
    input a,b,c,d;
    input [1:0] s;
    output o;
    reg o;

    always @(a or b or c or d or s)
    begin
        case (s)
            2'b00 : o = a;
            2'b01 : o = b;
            2'b10 : o = c;
            default : o = d;
        endcase
    end
endmodule
```

4-to-1 1-Bit MUX Using Tristate Buffers Diagram



4-to-1 1-Bit MUX Using Tristate Buffers Pin Descriptions

| IO Pins | Description |
|------------|--------------|
| a, b, c, d | Data Inputs |
| s | MUX Selector |
| o | Data Output |

4-to-1 1-Bit MUX Using Tristate Buffers VHDL Coding Example

```
--
-- 4-to-1 1-bit MUX using tristate buffers.
--

library ieee;
use ieee.std_logic_1164.all;

entity multiplexers_3 is
    port (a, b, c, d : in std_logic;
          s : in std_logic_vector (3 downto 0);
          o : out std_logic);
end multiplexers_3;

architecture archi of multiplexers_3 is
begin
    o <= a when (s(0)='0') else 'Z';
    o <= b when (s(1)='0') else 'Z';
    o <= c when (s(2)='0') else 'Z';
end archi;
```

```
    o <= d when (s(3)='0') else 'Z';
end archi;
```

4-to-1 1-Bit MUX Using Tristate Buffers Verilog Coding Example

```
//
// 4-to-1 1-bit MUX using tristate buffers.
//

module v_multiplexers_3 (a, b, c, d, s, o);
    input a,b,c,d;
    input [3:0] s;
    output o;

    assign o = s[3] ? a :1'bz;
    assign o = s[2] ? b :1'bz;
    assign o = s[1] ? c :1'bz;
    assign o = s[0] ? d :1'bz;
endmodule
```

VHDL Coding Example of a Missing Else Statement Leading to a Latch Inference

The following coding examples illustrate how XST infers a latch when no **else** statement is described at the end of an **if/elsif** construct. Since the **else** statement is missing, XST assumes that, for the **s=11** case, **o** retains its old value, and that a memory element is needed. XST issues the following warning message.

```
WARNING:Xst:737 - Found 1-bit latch for signal <o1>.  INFO:Xst
- HDL ADVISOR - Logic functions respectively driving the data
and gate enable inputs of this latch share common terms.  This
situation will potentially lead to setup/hold violations and,
as a result, to simulation problems.  This situation may come
from an incomplete case statement (all selector values are
not covered).  You should carefully review if it was in your
intentions to describe such a latch.
```

Unless you actually intended to describe such a latch, add the missing **else** statement.

Caution! Leaving out an **else** statement may result in errors during simulation.

```
--
-- 3-to-1 1-bit MUX with a 1-bit latch.
--

library ieee;
use ieee.std_logic_1164.all;

entity multiplexers_4 is
    port (a, b, c: in std_logic;
          s : in std_logic_vector (1 downto 0);
          o : out std_logic);
end multiplexers_4;

architecture archi of multiplexers_4 is
begin
    process (a, b, c, s)
    begin
        if (s = "00") then o <= a;
        elsif (s = "01") then o <= b;
        elsif (s = "10") then o <= c;
        end if;
    end process;
end archi;
```

Verilog Coding Example of a Missing Else Statement Leading to a Latch Inference

```
//
// 3-to-1 1-bit MUX with a 1-bit latch.
//
module v_multiplexers_4 (a, b, c, s, o);
    input a,b,c;
    input [1:0] s;
    output o;
    reg o;

    always @(a or b or c or s)
    begin
        if (s == 2'b00) o = a;
        else if (s == 2'b01) o = b;
        else if (s == 2'b10) o = c;
    end
endmodule
```

Decoders HDL Coding Techniques

This section includes:

- [About Decoders](#)
- [Decoders Log File](#)
- [Decoders Related Constraints](#)
- [Decoders Coding Examples](#)

About Decoders

A decoder is a multiplexer the inputs of which are all constant with distinct one-hot (or one-cold) coded values.

For more information, see:

[Multiplexers HDL Coding Techniques](#)

Decoders Log File

The XST log file reports the type and size of recognized decoders during the Macro Recognition step.

Decoders Log File Example

```
Synthesizing Unit <dec>.
  Related source file is decoders_1.vhd.
  Found 1-of-8 decoder for signal <res>.
  Summary:
    inferred    1 Decoder(s).
  Unit <dec> synthesized.
=====
HDL Synthesis Report

Macro Statistics
# Decoders           : 1
  1-of-8 decoder     : 1
=====
...
```

Decoders Related Constraints

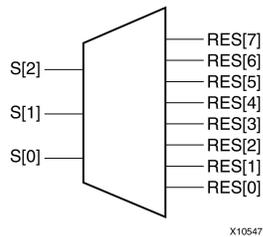
[Decoder Extraction \(DECODER_EXTRACT\)](#)

Decoders Coding Examples

Coding examples can be downloaded in text format from

http://www.xilinx.com/tpatches/pub/documentation/misc/xstug_examples.zip

1-of-8 Decoder (One-Hot) Diagram



1-of-8 Decoders (One-Hot) Pin Descriptions

| IO Pins | Description |
|---------|-------------|
| s | Selector |
| res | Data Output |

1-of-8 Decoder (One-Hot) VHDL Coding Example

```
--
-- 1-of-8 decoder (One-Hot)
--

library ieee;
use ieee.std_logic_1164.all;

entity decoders_1 is
    port (sel: in std_logic_vector (2 downto 0);
          res: out std_logic_vector (7 downto 0));
end decoders_1;

architecture archi of decoders_1 is
begin
    res <= "00000001" when sel = "000" else
           "00000010" when sel = "001" else
           "00000100" when sel = "010" else
           "00001000" when sel = "011" else
           "00010000" when sel = "100" else
           "00100000" when sel = "101" else
           "01000000" when sel = "110" else
           "10000000";
end archi;
```

1-of-8 decoder (One-Hot) Verilog Coding Example

```
//
// 1-of-8 decoder (One-Hot)
//

module v_decoders_1 (sel, res);
    input [2:0] sel;
    output [7:0] res;
    reg [7:0] res;

    always @(sel or res)
    begin
        case (sel)

```

```

        3'b000 : res = 8'b00000001;
        3'b001 : res = 8'b00000010;
        3'b010 : res = 8'b00000100;
        3'b011 : res = 8'b00001000;
        3'b100 : res = 8'b00010000;
        3'b101 : res = 8'b00100000;
        3'b110 : res = 8'b01000000;
        default : res = 8'b10000000;
    endcase
end
endmodule

```

1-of-8 Decoder (One-Cold) Pin Descriptions

| IO Pins | Description |
|---------|-------------|
| s | Selector |
| res | Data Output |

1-of-8 decoder (One-Cold) VHDL Coding Example

```

--
-- 1-of-8 decoder (One-Cold)
--

library ieee;
use ieee.std_logic_1164.all;

entity decoders_2 is
    port (sel: in std_logic_vector (2 downto 0);
          res: out std_logic_vector (7 downto 0));
end decoders_2;

architecture archi of decoders_2 is
begin
    res <= "11111110" when sel = "000" else
           "11111101" when sel = "001" else
           "11111011" when sel = "010" else
           "11110111" when sel = "011" else
           "11101111" when sel = "100" else
           "11011111" when sel = "101" else
           "10111111" when sel = "110" else
           "01111111";
end archi;

```

1-of-8 Decoder (One-Cold) Verilog Coding Example

```
//
// 1-of-8 decoder (One-Cold)
//

module v_decoders_2 (sel, res);
    input [2:0] sel;
    output [7:0] res;
    reg [7:0] res;

    always @(sel)
    begin
        case (sel)
            3'b000 : res = 8'b11111110;
            3'b001 : res = 8'b11111101;
            3'b010 : res = 8'b11111011;
            3'b011 : res = 8'b11110111;
            3'b100 : res = 8'b11101111;
            3'b101 : res = 8'b11011111;
            3'b110 : res = 8'b10111111;
            default : res = 8'b01111111;
        endcase
    end
endmodule
```

Decoder With Unselected Outputs Pin Descriptions

| IO Pins | Description |
|---------|-------------|
| s | Selector |
| res | Data Output |

No Decoder Inference (Unused Decoder Output) VHDL Coding Example

```
--
-- No Decoder Inference (unused decoder output)
--

library ieee;
use ieee.std_logic_1164.all;

entity decoders_3 is
    port (sel: in std_logic_vector (2 downto 0);
          res: out std_logic_vector (7 downto 0));
end decoders_3;

architecture archi of decoders_3 is
begin
    res <= "00000001" when sel = "000" else
        -- unused decoder output
        "XXXXXXXX" when sel = "001" else
        "00000100" when sel = "010" else
        "00001000" when sel = "011" else
        "00010000" when sel = "100" else
        "00100000" when sel = "101" else
        "01000000" when sel = "110" else
        "10000000";
```

```
end archi;
```

No Decoder Inference (Unused Decoder Output) Verilog Coding Example

```
//
// No Decoder Inference (unused decoder output)
//

module v_decoders_3 (sel, res);
    input [2:0] sel;
    output [7:0] res;
    reg [7:0] res;

    always @(sel)
    begin
        case (sel)
            3'b000 : res = 8'b00000001;
            // unused decoder output
            3'b001 : res = 8'bxxxxxxxx;
            3'b010 : res = 8'b00000100;
            3'b011 : res = 8'b00001000;
            3'b100 : res = 8'b00010000;
            3'b101 : res = 8'b00100000;
            3'b110 : res = 8'b01000000;
            default : res = 8'b10000000;
        endcase
    end
endmodule
```

No Decoder Inference (Some Selector Values Unused) VHDL Coding Example

```
--
-- No Decoder Inference (some selector values are unused)
--

library ieee;
use ieee.std_logic_1164.all;

entity decoders_4 is
    port (sel: in std_logic_vector (2 downto 0);
          res: out std_logic_vector (7 downto 0));
end decoders_4;

architecture archi of decoders_4 is
begin
    res <= "00000001" when sel = "000" else
           "00000010" when sel = "001" else
           "00000100" when sel = "010" else
           "00001000" when sel = "011" else
           "00010000" when sel = "100" else
           "00100000" when sel = "101" else
           -- 110 and 111 selector values are unused
           "XXXXXXXX";
end archi;
```

No Decoder Inference (Some Selector Values Unused) Verilog Coding Example

```
//  
// No Decoder Inference (some selector values are unused)  
//  
module v_decoders_4 (sel, res);  
    input [2:0] sel;  
    output [7:0] res;  
    reg [7:0] res;  
  
    always @(sel or res)  
    begin  
        case (sel)  
            3'b000 : res = 8'b00000001;  
            3'b001 : res = 8'b00000010;  
            3'b010 : res = 8'b00000100;  
            3'b011 : res = 8'b00001000;  
            3'b100 : res = 8'b00010000;  
            3'b101 : res = 8'b00100000;  
            // 110 and 111 selector values are unused  
            default : res = 8'bxxxxxxxx;  
        endcase  
    end  
endmodule
```

Priority Encoders HDL Coding Techniques

This section discusses Priority Encoders HDL Coding Techniques, and includes:

- [About Priority Encoders](#)
- [Priority Encoders Log File](#)
- [Priority Encoders Related Constraints](#)
- [Priority Encoders Coding Examples](#)

About Priority Encoders

XST can recognize a priority encoder, but in most cases XST does not infer it. To force priority encoder inference, use [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#) with the value **force**.

Xilinx® recommends that you use [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#) on a signal-by-signal basis. Otherwise, [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#) may give less than optimal results.

Priority Encoders Log File

The XST log file reports the type and size of recognized priority encoders during the Macro Recognition step.

Priority Encoders Log File Example

```
...
Synthesizing Unit <priority>.
    Related source file is priority_encoders_1.vhd.
    Found 3-bit 1-of-9 priority encoder for signal <code>.
    Summary:
        inferred    3 Priority encoder(s).
    Unit <priority> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Priority Encoders           : 1
  3-bit 1-of-9 priority encoder : 1
=====
...
```

Priority Encoders Related Constraints

[Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#)

Priority Encoders Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

For this example XST may infer a priority encoder. Use [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#) with a value of **force** to force its inference.

3-Bit 1-of-9 Priority Encoder Pin Descriptions

| IO Pins | Description |
|---------|--------------------|
| sel | Selector |
| code | Encoded Output Bus |

3-Bit 1-of-9 Priority Encoder VHDL Coding Example

```
--
-- 3-Bit 1-of-9 Priority Encoder
--

library ieee;
use ieee.std_logic_1164.all;

entity priority_encoder_1 is
    port ( sel : in std_logic_vector (7 downto 0);
          code :out std_logic_vector (2 downto 0));

    attribute priority_extract: string;
    attribute priority_extract of priority_encoder_1: entity is "force";
end priority_encoder_1;

architecture archi of priority_encoder_1 is
begin

    code <= "000" when sel(0) = '1' else
            "001" when sel(1) = '1' else
            "010" when sel(2) = '1' else
            "011" when sel(3) = '1' else
            "100" when sel(4) = '1' else
            "101" when sel(5) = '1' else
            "110" when sel(6) = '1' else
            "111" when sel(7) = '1' else
            "---";

end archi;
```

3-Bit 1-of-9 Priority Encoder Verilog Coding Example

```
//
// 3-Bit 1-of-9 Priority Encoder
//

(* priority_extract="force" *)
module v_priority_encoder_1 (sel, code);
    input  [7:0] sel;
    output [2:0] code;
    reg     [2:0] code;

    always @(sel)
    begin
        if      (sel[0]) code = 3'b000;
        else if (sel[1]) code = 3'b001;
        else if (sel[2]) code = 3'b010;
        else if (sel[3]) code = 3'b011;
        else if (sel[4]) code = 3'b100;
        else if (sel[5]) code = 3'b101;
        else if (sel[6]) code = 3'b110;
        else if (sel[7]) code = 3'b111;
        else      code = 3'bxxx;
    end
end
```

```
endmodule
```

Logical Shifters HDL Coding Techniques

This section discusses Logical Shifters HDL Coding Techniques, and includes:

- [About Logical Shifters](#)
- [Logical Shifters Log File](#)
- [Logical Shifters Related Constraints](#)
- [Logical Shifters Coding Examples](#)

About Logical Shifters

Xilinx® defines a logical shifter as a combinatorial circuit with 2 inputs and 1 output:

- The first input is a data input that is shifted.
- The second input is a selector whose binary value defines the shift distance.
- The output is the result of the shift operation.

All of these I/Os are mandatory. Otherwise, XST does *not* infer a logical shifter.

When writing your Hardware Description Language (HDL) code:

- Use only logical, arithmetic, and rotate shift operators. Shift operations that fill vacated positions with values from another signal are not recognized.
- For VHDL, you can use predefined shift (for example, SLL, SRL, ROL) or concatenation operations only. For more information on predefined shift operations, see the IEEE VHDL reference manual.
- Use only one type of shift operation.
- The n value in the shift operation must be incremented or decremented only by 1 for each consequent binary value of the selector.
- The n value can be positive only.
- All values of the selector must be presented.

Logical Shifters Log File

The XST log file reports the type and size of a recognized logical shifter during the Macro Recognition step.

Logical Shifters Log File Example

```

...
Synthesizing Unit <lshift>.
  Related source file is Logical_Shifters_1.vhd.
  Found 8-bit shifter logical left for signal <so>.
  Summary:
    inferred 1 Combinational logic shifter(s).
  Unit <lshift> synthesized.
...
=====
HDL Synthesis Report

Macro Statistics
# Logic shifters                : 1
  8-bit shifter logical left    : 1
=====
...

```

Logical Shifters Related Constraints

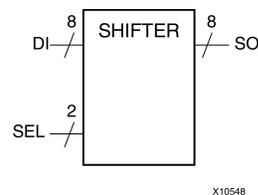
[Logical Shifter Extraction \(SHIFT_EXTRACT\)](#)

Logical Shifters Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

The minimal size for XST to explicitly infer logical shifter macros may vary depending on the targeted device family. The following coding examples have been validated on LUT4-based device families such as Virtex®-4 devices. For Virtex-5 devices, logical shifters are explicitly inferred only when the selector size is at least 3.

Logical Shifter One Diagram



Logical Shifter One Pin Descriptions

| IO Pins | Description |
|---------|-------------------------|
| DI | Data Input |
| SEL | Shift Distance Selector |
| SO | Data Output |

Logical Shifter One VHDL Coding Example

```
--
-- Following is the VHDL code for a logical shifter.
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity logical_shifters_1 is
    port(DI : in unsigned(7 downto 0);
         SEL : in unsigned(1 downto 0);
         SO : out unsigned(7 downto 0));
end logical_shifters_1;

architecture archi of logical_shifters_1 is
begin
    with SEL select
        SO <= DI when "00",
        DI sll 1 when "01",
        DI sll 2 when "10",
        DI sll 3 when others;
end archi;
```

Logical Shifter One Verilog Coding Example

```
//
// Following is the Verilog code for a logical shifter.
//

module v_logical_shifters_1 (DI, SEL, SO);
    input [7:0] DI;
    input [1:0] SEL;
    output [7:0] SO;
    reg [7:0] SO;

    always @(DI or SEL)
    begin
        case (SEL)
            2'b00 : SO = DI;
            2'b01 : SO = DI << 1;
            2'b10 : SO = DI << 2;
            default : SO = DI << 3;
        endcase
    end
endmodule
```

Logical Shifter Two Pin Descriptions

| IO Pins | Description |
|---------|-------------------------|
| DI | Data Input |
| SEL | Shift Distance Selector |
| SO | Data Output |

Logical Shifter Two VHDL Coding Example

XST does *not* infer a logical shifter for Logical Shifter Two, since not all selector values are presented.

```
--
-- XST does not infer a logical shifter for this example,
-- as not all of the selector values are presented.
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity logical_shifters_2 is
    port(DI : in unsigned(7 downto 0);
         SEL : in unsigned(1 downto 0);
         SO : out unsigned(7 downto 0));
end logical_shifters_2;

architecture archi of logical_shifters_2 is
begin
    with SEL select
        SO <= DI when "00",
        DI sll 1 when "01",
        DI sll 2 when others;
end archi;
```

Logical Shifter Two Verilog Coding Example

```
//
// XST does not infer a logical shifter for this example,
// as not all of the selector values are presented.
//

module v_logical_shifters_2 (DI, SEL, SO);
    input [7:0] DI;
    input [1:0] SEL;
    output [7:0] SO;
    reg [7:0] SO;

    always @(DI or SEL)
    begin
        case (SEL)
            2'b00 : SO = DI;
            2'b01 : SO = DI << 1;
            default : SO = DI << 2;
        endcase
    end
endmodule
```

Logical Shifter Three Pin Descriptions

| IO Pins | Description |
|---------|-------------------------|
| DI | Data Input |
| SEL | Shift Distance Selector |
| SO | Data Output |

Logical Shifter Three VHDL Coding Example

XST does *not* infer a logical shifter for this example, as the value is not incremented by 1 for each consequent binary value of the selector.

```
--
-- XST does not infer a logical shifter for this example,
-- as the value is not incremented by 1 for each consequent
-- binary value of the selector.
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity logical_shifters_3 is
    port(DI : in unsigned(7 downto 0);
         SEL : in unsigned(1 downto 0);
         SO : out unsigned(7 downto 0));
end logical_shifters_3;

architecture archi of logical_shifters_3 is
begin
    with SEL select
        SO <= DI when "00",
        DI sll 1 when "01",
        DI sll 3 when "10",
```

```
        DI sll 2 when others;
end archi;
```

Logical Shifter Three Verilog Coding Example

```
//
// XST does not infer a logical shifter for this example,
// as the value is not incremented by 1 for each consequent
// binary value of the selector.
//

module v_logical_shifters_3 (DI, SEL, SO);
    input [7:0] DI;
    input [1:0] SEL;
    output [7:0] SO;
    reg[7:0] SO;

    always @(DI or SEL)
    begin
        case (SEL)
            2'b00 : SO = DI;
            2'b01 : SO = DI << 1;
            2'b10 : SO = DI << 3;
            default : SO = DI << 2;
        endcase
    end
endmodule
```

Arithmetic Operators HDL Coding Techniques

This section and includes:

- [About Arithmetic Operators](#)
- [Arithmetic Operators Log File](#)
- [Arithmetic Operators Related Constraints](#)
- [Arithmetic Operators Coding Examples](#)

About Arithmetic Operators

This section discusses Arithmetic Operators, and includes:

- [Supported Arithmetic Operators](#)
- [Signed and Unsigned Operators](#)
- [Resource Sharing](#)

Supported Arithmetic Operators

XST supports the following arithmetic operators:

- Adders with:
 - Carry In
 - Carry Out
 - Carry In/Out
- Subtractors
- Adders/Subtractors
- Comparators:
 - =
 - /=
 - <
 - <=
 - >
 - >=
- Multipliers
- Dividers

Signed and Unsigned Operators

XST supports the following for signed and unsigned operators:

- Adders
- Subtractors
- Comparators
- Multipliers

For more information on signed and unsigned operators support in VHDL, see:

[Registers HDL Coding Techniques](#)

Resource Sharing

XST performs resource sharing for:

- Adders
- Subtractors
- Adders/subtractors
- Multipliers

Arithmetic Operators Log File

The XST log file reports the type and size of recognized adder, subtractor and adder/subtractor during the Macro Recognition step.

Arithmetic Operators Log File Example

```
...
Synthesizing Unit <adder>.
  Related source file is arithmetic_operations_1.vhd.
  Found 8-bit adder for signal <sum>.
  Summary:
    inferred    1 Adder/Subtractor(s).
  Unit <adder> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Adders/Subtractors           : 1
  8-bit adder                   : 1
=====
```

Arithmetic Operators Related Constraints

- [Use DSP48 \(USE_DSP48\)](#)
- [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#)
- [Keep \(KEEP\)](#)

Arithmetic Operators Coding Examples

None

Adders, Subtractors, and Adders/Subtractors HDL Coding Techniques

This section includes:

- [About Adders, Subtractors, and Adders/Subtractors](#)
- [Adders, Subtractors, and Adders/Subtractors Log File](#)
- [Adders, Subtractors, and Adders/Subtractors Related Constraints](#)
- [Adders, Subtractors, and Adders/Subtractors Coding Examples](#)

About Adders, Subtractors, and Adders/Subtractors

This section includes:

- [Supported Device Families](#)
- [XST DSP48 Block Support](#)
- [Macro Implementation on DSP48 Blocks](#)
- [Automatic DSP48 Resource Control](#)
- [Maximum Macro Configuration](#)

Supported Device Families

The following device families allow adders and subtractors to be implemented on DSP48 resources:

- Virtex®-4
- Virtex-5
- Spartan®-3A DSP

XST DSP48 Block Support

XST supports the one level of output registers into DSP48 blocks. If the Carry In or Add/Sub operation selectors are registered, XST pushes these registers into the DSP48 as well.

XST can implement an adder/subtractor in a DSP48 block if its implementation requires only a single DSP48 resource. If an adder/subtractor macro does not fit in a single DSP48, XST implements the entire macro using slice logic.

Macro Implementation on DSP48 Blocks

Macro implementation on DSP48 blocks is controlled by [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#) with a default value of **auto**. In **auto** mode, if an adder/subtractor is a part of a more complex macro such as a filter, XST automatically places it on the DSP block. Otherwise, XST implements adders/subtractors using LUTs.

Set the value of [Use DSP48 \(USE_DSP48\)](#) to **yes** in order to force XST to push these macros into a DSP48. When placing an Adder/Subtractor on a DSP block, XST checks to see if it is connected to other DSP chains. If so, XST tries to take advantage of fast DSP connections, and connects this adder/subtractor to the DSP chain using these fast connections.

Automatic DSP48 Resource Control

When implementing adders/subtractors on DSP48 blocks, XST performs automatic DSP48 resource control.

Maximum Macro Configuration

To deliver the best performance, XST by default tries to infer and implement the maximum macro configuration, including as many registers in the DSP48 as possible. Use [Keep \(KEEP\)](#) to shape a macro in a specific way. For example, to exclude the first register stage from the DSP48, place [Keep \(KEEP\)](#) constraints on the outputs of these registers.

Adders, Subtractors, and Adders/Subtractors Log File

In the log file, XST reports the details of inferred multipliers, adders, subtractors, and registers at the HDL Synthesis step. XST reports about inferred MACs during the Advanced HDL Synthesis Step where the MAC implementation mechanism takes place.

Adders, Subtractors, and Adders/Subtractors Log File Example

```
Synthesizing Unit <v_adders_4>.
  Related source file is "v_adders_4.v".
  Found 8-bit adder carry in/out for signal <$addsub0000>.
  Summary:
  inferred 1 Adder/Subtractor(s).
  Unit <v_adders_4> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Adders/Subtractors           : 1
 8-bit adder carry in/out      : 1
=====
```

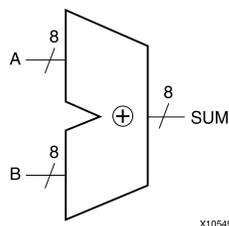
Adders, Subtractors, and Adders/Subtractors Related Constraints

- [Use DSP48 \(USE_DSP48\)](#)
- [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#)
- [Keep \(KEEP\)](#)

Adders, Subtractors, and Adders/Subtractors Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Unsigned 8-Bit Adder Diagram



Unsigned 8-Bit Adder Pin Descriptions IO Pins

| IO Pins | Description |
|---------|--------------|
| A, B | Add Operands |
| SUM | Add Result |

Unsigned 8-Bit Adder VHDL Coding Example

```
--
-- Unsigned 8-bit Adder
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity adders_1 is
  port(A,B : in std_logic_vector(7 downto 0);
        SUM : out std_logic_vector(7 downto 0));
end adders_1;

architecture archi of adders_1 is
begin

  SUM <= A + B;

end archi;
```

Unsigned 8-Bit Adder Verilog Coding Example

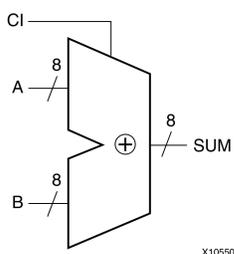
```
//
// Unsigned 8-bit Adder
//

module v_adders_1(A, B, SUM);
  input [7:0] A;
  input [7:0] B;
  output [7:0] SUM;

  assign SUM = A + B;

endmodule
```

Unsigned 8-Bit Adder With Carry In Diagram



Unsigned 8-Bit Adder With Carry In Pin Descriptions IO Pins

| IO Pins | Description |
|---------|--------------|
| A, B | Add Operands |
| CI | Carry In |
| SUM | Add Result |

Unsigned 8-Bit Adder With Carry In VHDL Coding Example

```
--
-- Unsigned 8-bit Adder with Carry In
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity adders_2 is
  port(A,B : in std_logic_vector(7 downto 0);
        CI : in std_logic;
        SUM : out std_logic_vector(7 downto 0));
end adders_2;

architecture archi of adders_2 is
begin

  SUM <= A + B + CI;

end archi;
```

Unsigned 8-Bit Adder With Carry In Verilog Coding Example

```
//
// Unsigned 8-bit Adder with Carry In
//

module v_adders_2(A, B, CI, SUM);
  input [7:0] A;
  input [7:0] B;
  input CI;
  output [7:0] SUM;

  assign SUM = A + B + CI;

endmodule
```

Unsigned 8-Bit Adder With Carry Out

Before writing a + (plus) operation with carry out in VHDL, read the arithmetic package you plan to use. For example, `std_logic_unsigned` does not allow you to write + (plus) in the following form to obtain Carry Out:

$$\text{Res(9-bit)} = \text{A(8-bit)} + \text{B(8-bit)}$$

The reason is that the size of the result for + (plus) in this package is equal to the size of the longest argument (8 bits).

One solution for the example is to adjust the size of operands **A** and **B** to 9 bits using concatenation.

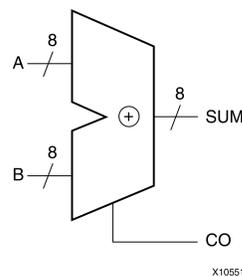
```
Res <= ("0" & A) + ("0" & B);
```

In this case, XST recognizes that this 9-bit adder can be implemented as an 8-bit adder with carry out.

Another solution is:

- Convert **A** and **B** to integers
- Convert the result back to the `std_logic` vector
- Specify the size of the vector equal to 9

Unsigned 8-Bit Adder With Carry Out Diagram



Unsigned 8-Bit Adder With Carry Out Pin Descriptions IO Pins

| IO Pins | Description |
|---------|--------------|
| A, B | Add Operands |
| SUM | Add Result |
| CO | Carry Out |

Unsigned 8-Bit Adder With Carry Out VHDL Coding Example

```
--
-- Unsigned 8-bit Adder with Carry Out
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_arith.all;
use ieee.std_logic_unsigned.all;

entity adders_3 is
  port(A,B : in std_logic_vector(7 downto 0);
        SUM : out std_logic_vector(7 downto 0);
        CO : out std_logic);
end adders_3;

architecture archi of adders_3 is
  signal tmp: std_logic_vector(8 downto 0);
begin

  tmp <= conv_std_logic_vector((conv_integer(A) + conv_integer(B)),9);
  SUM <= tmp(7 downto 0);
  CO <= tmp(8);

end archi;
```

The preceding example uses two arithmetic packages:

- **std_logic_arith**
Contains the integer to **std_logic** conversion function (**conv_std_logic_vector**)
- **std_logic_unsigned**
Contains the unsigned + (plus) operation

Unsigned 8-Bit Adder With Carry Out Verilog Coding Example

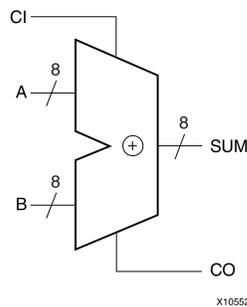
```
//
// Unsigned 8-bit Adder with Carry Out
//

module v_adders_3(A, B, SUM, CO);
  input [7:0] A;
  input [7:0] B;
  output [7:0] SUM;
  output CO;
  wire [8:0] tmp;

  assign tmp = A + B;
  assign SUM = tmp [7:0];
  assign CO = tmp [8];

endmodule
```

Unsigned 8-Bit Adder With Carry In and Carry Out Diagram



Unsigned 8-Bit Adder With Carry In and Carry Out Pin Descriptions IO Pins

| IO Pins | Description |
|---------|--------------|
| A, B | Add Operands |
| CI | Carry In |
| SUM | Add Result |
| CO | Carry Out |

Unsigned 8-Bit Adder With Carry In and Carry Out VHDL Coding Example

```
--
-- Unsigned 8-bit Adder with Carry In and Carry Out
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_arith.all;
use ieee.std_logic_unsigned.all;

entity adders_4 is
  port(A,B : in std_logic_vector(7 downto 0);
       CI : in std_logic;
       SUM : out std_logic_vector(7 downto 0);
       CO : out std_logic);
end adders_4;

architecture archi of adders_4 is
  signal tmp: std_logic_vector(8 downto 0);
begin

  tmp <= conv_std_logic_vector((conv_integer(A) + conv_integer(B) + conv_integer(CI)),9);
  SUM <= tmp(7 downto 0);
  CO <= tmp(8);

end archi;
```

Unsigned 8-Bit Adder With Carry In and Carry Out Verilog Coding Example

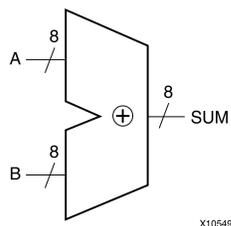
```
//
// Unsigned 8-bit Adder with Carry In and Carry Out
//

module v_adders_4(A, B, CI, SUM, CO);
  input CI;
  input [7:0] A;
  input [7:0] B;
  output [7:0] SUM;
  output CO;
  wire [8:0] tmp;

  assign tmp = A + B + CI;
  assign SUM = tmp [7:0];
  assign CO = tmp [8];

endmodule
```

Signed 8-Bit Adder Diagram



Signed 8-Bit Adder Pin Descriptions IO Pins

| IO Pins | Description |
|---------|--------------|
| A, B | Add Operands |
| SUM | Add Result |

Signed 8-Bit Adder VHDL Coding Example

```
--
-- Signed 8-bit Adder
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_signed.all;

entity adders_5 is
  port(A,B : in std_logic_vector(7 downto 0);
        SUM : out std_logic_vector(7 downto 0));
end adders_5;

architecture archi of adders_5 is
begin

  SUM <= A + B;

end archi;
```

Signed 8-Bit Adder Verilog Coding Example

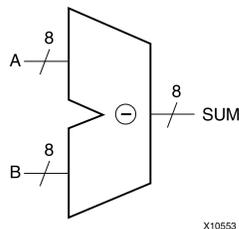
```
//
// Signed 8-bit Adder
//

module v_adders_5 (A,B,SUM);
  input signed [7:0] A;
  input signed [7:0] B;
  output signed [7:0] SUM;
  wire signed [7:0] SUM;

  assign SUM = A + B;

endmodule
```

Unsigned 8-Bit Subtractor Diagram



Unsigned 8-Bit Subtractor Pin Descriptions

| IO Pins | Description |
|---------|--------------|
| A, B | Sub Operands |
| RES | Sub Result |

Unsigned 8-Bit Subtractor VHDL Coding Example

```
--
-- Unsigned 8-bit Subtractor
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity adders_6 is
  port(A,B : in std_logic_vector(7 downto 0);
       RES : out std_logic_vector(7 downto 0));
end adders_6;

architecture archi of adders_6 is
begin

  RES <= A - B;

end archi;
```

Unsigned 8-Bit Subtractor Verilog Coding Example

```
//
// Unsigned 8-bit Subtractor
//

module v_adders_6(A, B, RES);
  input [7:0] A;
  input [7:0] B;
  output [7:0] RES;

  assign RES = A - B;

endmodule
```

Unsigned 8-Bit Subtractor With Borrow In Pin Descriptions

| IO Pins | Description |
|---------|--------------|
| A, B | Sub Operands |
| BI | Borrow In |
| RES | Sub Result |

Unsigned 8-Bit Subtractor With Borrow In VHDL Coding Example

```
--
-- Unsigned 8-bit Subtractor with Borrow In
--

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity adders_8 is
  port(A,B : in std_logic_vector(7 downto 0);
       BI : in std_logic;
       RES : out std_logic_vector(7 downto 0));
end adders_8;

architecture archi of adders_8 is

begin

  RES  <= A - B - BI;

end archi;
```

Unsigned 8-Bit Subtractor With Borrow In Verilog Coding Example

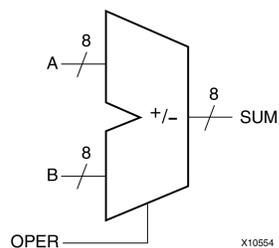
```
//
// Unsigned 8-bit Subtractor with Borrow In
//

module v_adders_8(A, B, BI, RES);
  input [7:0] A;
  input [7:0] B;
  input BI;
  output [7:0] RES;

  assign RES = A - B - BI;

endmodule
```

Unsigned 8-Bit Adder/Subtractor Diagram



Unsigned 8-Bit Adder/Subtractor Pin Descriptions

| IO Pins | Description |
|---------|------------------|
| A, B | Add/Sub Operands |
| OPER | Add/Sub Select |
| SUM | Add/Sub Result |

Unsigned 8-Bit Adder/Subtractor VHDL Coding Example

```
--
-- Unsigned 8-bit Adder/Subtractor
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity adders_7 is
port(A,B : in std_logic_vector(7 downto 0);
     OPER: in std_logic;
     RES : out std_logic_vector(7 downto 0));
end adders_7;

architecture archi of adders_7 is
begin

    RES <= A + B when OPER='0'
          else A - B;

end archi;
```

Unsigned 8-Bit Adder/Subtractor Verilog Coding Example

```
//
// Unsigned 8-bit Adder/Subtractor
//

module v_adders_7(A, B, OPER, RES);
    input OPER;
    input [7:0] A;
    input [7:0] B;
    output [7:0] RES;
    reg [7:0] RES;

    always @(A or B or OPER)
    begin
        if (OPER==1'b0) RES = A + B;
        else RES = A - B;
    end

endmodule
```

Comparators HDL Coding Techniques

This section discusses Comparators HDL Coding Techniques, and includes:

- [About Comparators](#)
- [Comparators Log File](#)
- [Comparators Related Constraints](#)
- [Comparators Coding Examples](#)

About Comparators

Not applicable.

Comparators Log File

The XST log file reports the type and size of recognized comparators during the Macro Recognition step.

Comparators Log File Example

```

...
Synthesizing Unit <compar>.
  Related source file is comparators_1.vhd.
  Found 8-bit comparator greatequal for signal <$n0000> created at line 10.
  Summary:
    inferred    1 Comparator(s).
  Unit <compar> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Comparators           : 1
 8-bit comparator greatequal : 1
=====
...

```

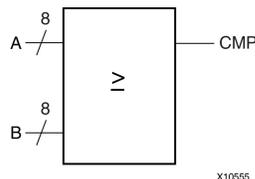
Comparators Related Constraints

None

Comparators Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Unsigned 8-Bit Greater or Equal Comparator Diagram



Unsigned 8-Bit Greater or Equal Comparator Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| A, B | Comparison Operands |
| CMP | Comparison Result |

Unsigned 8-Bit Greater or Equal Comparator VHDL Coding Example

```
--  
-- Unsigned 8-bit Greater or Equal Comparator  
--  
  
library ieee;  
use ieee.std_logic_1164.all;  
use ieee.std_logic_unsigned.all;  
  
entity comparator_1 is  
    port(A,B : in  std_logic_vector(7 downto 0);  
         CMP : out std_logic);  
end comparator_1;  
  
architecture archi of comparator_1 is  
begin  
  
    CMP <= '1' when A >= B else '0';  
  
end archi;
```

Unsigned 8-Bit Greater or Equal Comparator Verilog Coding Example

```
//  
// Unsigned 8-bit Greater or Equal Comparator  
//  
  
module v_comparator_1 (A, B, CMP);  
    input  [7:0] A;  
    input  [7:0] B;  
    output CMP;  
  
    assign CMP = (A >= B) ? 1'b1 : 1'b0;  
endmodule
```

Multipliers HDL Coding Techniques

This section discusses Multipliers HDL Coding Techniques, and includes:

- [About Multipliers](#)
- [Multipliers \(Virtex®-4, Virtex-5, and Spartan®-3A DSP Devices\)](#)
- [Multipliers Log File](#)
- [Multipliers Related Constraints](#)
- [Multipliers Coding Examples](#)

About Multipliers

This section discusses Multipliers, and includes:

- [Implementing a Multiplier](#)
- [Registered Multipliers](#)
- [Multiplication with Constant](#)

Implementing a Multiplier

When implementing a multiplier, the size of the resulting signal is equal to the sum of two operand lengths. For example, if you multiply **A** (8-bit signal) by **B** (4-bit signal), the size of the result must be declared as a 12-bit signal.

Registered Multipliers

In instances where a multiplier would have a registered output, XST infers a unique registered multiplier for the following devices:

- Virtex®-4
- Virtex-5

This registered multiplier is **18x18** bits.

Under the following conditions, a registered multiplier is *not* used, and a multiplier + register is used instead.

- Output from the multiplier goes to any component other than the register.
- The [Multiplier Style \(MULT_STYLE\)](#) constraint is set to:
lut
- The multiplier is asynchronous.
- The multiplier has control signals other than synchronous reset or clock enable.
- The multiplier does not fit in a single 18x18 bit block multiplier.

The following pins are optional for a registered multiplier:

- Clock enable port
- Synchronous and asynchronous reset, and load ports

Multiplication with Constant

When one of the arguments is a constant, XST can create efficient dedicated implementations of a multiplier with a constant using two methods:

- Constant Coefficient Multiplier (KCM)
- Canonical Signed Digit (CSD)

Dedicated implementations do not always provide the best results for multiplication with constants. XST can automatically choose between KCM or standard multiplier implementation. The CSD method cannot be automatically chosen. Use [Mux Style \(MUX_STYLE\)](#) to force CSD implementation.

XST does not support KCM or CSD implementation for signed numbers.

If either of the arguments is larger than 32 bits, XST does not use KCM or CSD implementation, even if it is specified with [Multiplier Style \(MULT_STYLE\)](#).

Multipliers (Virtex-4, Virtex-5, and Spartan-3A DSP Devices)

Note This section applies to Virtex®-4 devices, Virtex-5 devices, and Spartan®-3A DSP devices only.

This section discusses Multipliers (Virtex-4, Virtex-5, and Spartan-3A DSP Devices), and includes:

- [Implementing Multipliers on DSP48 Resources](#)
- [Multiple DSP48 Resources](#)
- [Macro Implementation on DSP48 Blocks](#)
- [Recognizing the Multiplier Style Constraint](#)
- [Maximum Macro Configuration](#)

Implementing Multipliers on DSP48 Resources

Virtex-4 devices, Virtex-5 devices, and Spartan-3A DSP devices allow multipliers to be implemented on DSP48 resources. XST supports the registered version of these macros and can push up to 2 levels of input registers and 2 levels of output registers into DSP48 blocks.

Multiple DSP48 Resources

If a multiplier implementation requires multiple DSP48 resources, XST automatically decomposes it onto multiple DSP48 blocks. Depending on the operand size, and to obtain the best performance, XST may implement most of a multiplier using DSP48 blocks, and use slice logic for the rest of the macro. For example, it is not sufficient to use a single DSP48 to implement an 18x18 unsigned multiplier. In this case, XST implements most of the logic in one DSP48, and the rest in LUTs.

For Virtex-4 devices, Virtex-5 devices, and Spartan-3A DSP devices, XST can infer pipelined multipliers, not only for the LUT implementation, but for the DSP48 implementation as well.

Macro Implementation on DSP48 Blocks

Macro implementation on DSP48 blocks is controlled by the [Use DSP48 \(USE_DSP48\)](#) constraint or command line option, with a default value of **auto**. In this mode, XST implements multipliers taking into account available DSP48 resources in the device.

In **auto** mode, use [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#) to control DSP48 resources for synthesis. By default, XST tries to utilize all DSP48 resources.

For more information, see:

[DSP48 Block Resources](#).

Recognizing the Multiplier Style Constraint

XST can automatically recognize the [Multiplier Style \(MULT_STYLE\)](#) constraint with values **lut** and **block** and then convert it to [Use DSP48 \(USE_DSP48\)](#).

Xilinx® recommends:

- Use [Use DSP48 \(USE_DSP48\)](#) for Virtex-4 devices and Virtex-5 devices to define FPGA resources used for multiplier implementation.
- Use [Multiplier Style \(MULT_STYLE\)](#) to define the multiplier implementation method on the selected FPGA resources.

The following rules apply:

- If [Use DSP48 \(USE_DSP48\)](#) is set to **auto** or **yes**, you may use **mult_style=pipe_block** to pipeline the DSP48 implementation if the multiplier implementation requires multiple DSP48 blocks.
- If [Use DSP48 \(USE_DSP48\)](#) is set to **no**, use **mult_style=pipe_lut|KCM|CSD** to define the multiplier implementation method on LUTs.

Maximum Macro Configuration

To deliver the best performance, XST by default tries to infer and implement the maximum macro configuration, including as many registers in the DSP48 as possible. Use [Keep \(KEEP\)](#) to shape a macro in a specific way. For example, to exclude the first register stage from the DSP48, place [Keep \(KEEP\)](#) constraints on the outputs of these registers.

Multipliers Log File

The XST log file reports the type and size of recognized multipliers during the Macro Recognition step.

Multipliers Log File Example

```
...
Synthesizing Unit <mux>.
    Related source file is multiplexers_1.vhd.
    Found 1-bit 4-to-1 multiplexer for signal <o>.
    Summary:
        inferred    1 Multiplexer(s).
    Unit <mux> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Multiplexers           : 1
  1-bit 4-to-1 multiplexer : 1
=====
...

```

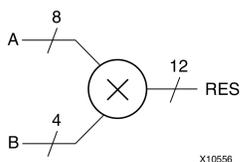
Multipliers Related Constraints

- [Multiplier Style \(MULT_STYLE\)](#)
- [Use DSP48 \(USE_DSP48\)](#)
- [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#)
- [Keep \(KEEP\)](#)

Multipliers Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Unsigned 8x4-Bit Multiplier Diagram



Unsigned 8x4-Bit Multiplier Pin Descriptions

| IO Pins | Description |
|---------|---------------|
| A, B | MULT Operands |
| RES | MULT Result |

Unsigned 8x4-Bit Multiplier VHDL Coding Example

```
--
-- Unsigned 8x4-bit Multiplier
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity multipliers_1 is
    port(A : in std_logic_vector(7 downto 0);
         B : in std_logic_vector(3 downto 0);
         RES : out std_logic_vector(11 downto 0));
end multipliers_1;

architecture beh of multipliers_1 is
begin
    RES <= A * B;
end beh;
```

Unsigned 8x4-Bit Multiplier Verilog Coding Example

```
//
// Unsigned 8x4-bit Multiplier
//

module v_multipliers_1(A, B, RES);
    input [7:0] A;
    input [3:0] B;
    output [11:0] RES;

    assign RES = A * B;
endmodule
```

Sequential Complex Multipliers HDL Coding Techniques

This section discusses Sequential Complex Multipliers HDL Coding Techniques, and includes:

- [About Sequential Complex Multipliers](#)
- [Sequential Complex Multipliers Log File](#)
- [Sequential Complex Multipliers Related Constraints](#)
- [Sequential Complex Multipliers Coding Examples](#)

About Sequential Complex Multipliers

A sequential complex multiplier requires:

- Four cycles to make a complete multiplication by accumulating intermediate results.
- One DSP block for implementation.

Multiplying two complex numbers A and B requires four cycles.

The first two first cycles compute:

$$\text{Res_real} = \text{A_real} * \text{B_real} - \text{A_imag} * \text{B_imag}$$

The second two cycles compute:

$$\text{Res_imag} = \text{A_real} * \text{B_imag} + \text{A_imag} * \text{B_real}$$

While several templates could be used to describe the above functionality, XST does not support using **enum** or **integer** types to describe the different DSP modes and store the **enum** values. Instead, Xilinx® recommends a very regular template to ease XST inferencing. This general accumulator template allows XST to inference a single DSP to perform the following operations:

- **Load:** $P \leftarrow \text{Value}$
- **Load:** $P \leftarrow -\text{Value}$
- **Accumulate:** $P \leftarrow P + \text{Value}$
- **Accumulate:** $P \leftarrow P - \text{Value}$

This template works with the following two control signals that perform the above four operations when combined:

- **load**
- **addsub**

Sequential Complex Multipliers Log File

None

Sequential Complex Multipliers Related Constraints

None

Sequential Complex Multipliers Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Signed 18x18-bit Sequential Complex Multiplier Pin Descriptions

| IO Pins | Description |
|------------------------|--|
| CLK | Clock Signal |
| Oper_Load, Oper_AddSub | Control Signals controlling Load and AddSub Operations |
| A, B | MULT Operands |
| RES | MULT Result |

Signed 18x18-bit Sequential Complex Multiplier VHDL Coding Example

```
--
-- Sequential Complex Multiplier
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity multipliers_8 is
  generic(A_WIDTH:      positive:=18;
         B_WIDTH:      positive:=18;
         RES_WIDTH:    positive:=48);
  port(
    CLK:               in  std_logic;
    A:                 in  signed(A_WIDTH-1 downto 0);
    B:                 in  signed(B_WIDTH-1 downto 0);

    Oper_Load:        in  std_logic;
    Oper_AddSub:      in  std_logic;
    -- Oper_Load Oper_AddSub Operation
    -- 0          0          R= +A*B
    -- 0          1          R= -A*B
    -- 1          0          R=R+A*B
    -- 1          1          R=R-A*B

    RES:              out signed(RES_WIDTH-1 downto 0)
  );
end multipliers_8;

architecture beh of multipliers_8 is

  constant P_WIDTH: integer:=A_WIDTH+B_WIDTH;

  signal oper_load0: std_logic:='0';
  signal oper_addsub0: std_logic:='0';

  signal p1: signed(P_WIDTH-1 downto 0):=(others=>'0');
  signal oper_load1: std_logic:='0';
  signal oper_addsub1: std_logic:='0';

  signal res0: signed(RES_WIDTH-1 downto 0);
begin

  process (clk)
    variable acc: signed(RES_WIDTH-1 downto 0);
  begin
    if rising_edge(clk) then
```

```
oper_load0    <= Oper_Load;
oper_addsub0  <= Oper_AddSub;

p1 <= A*B;
oper_load1    <= oper_load0;
oper_addsub1  <= oper_addsub0;

if (oper_load1='1') then
    acc := res0;
else
    acc := (others=>'0');
end if;

if (oper_addsub1='1') then
    res0 <= acc-p1;
else
    res0 <= acc+p1;
end if;

end if;
end process;

RES <= res0;

end architecture;
```

Signed 18x18-bit Sequential Complex Multiplier Verilog Coding Example

```

module v_multipliers_8(CLK,A,B,Oper_Load,Oper_AddSub, RES);
  parameter A_WIDTH    = 18;
  parameter B_WIDTH    = 18;
  parameter RES_WIDTH  = 48;
  parameter P_WIDTH    = A_WIDTH+B_WIDTH;

  input  CLK;
  input  signed [A_WIDTH-1:0] A, B;

  input  Oper_Load, Oper_AddSub;
  // Oper_Load Oper_AddSub Operation
  // 0         0           R= +A*B
  // 0         1           R= -A*B
  // 1         0           R=R+A*B
  // 1         1           R=R-A*B

  output [RES_WIDTH-1:0] RES;

  reg oper_load0    = 0;
  reg oper_addsub0 = 0;

  reg signed [P_WIDTH-1:0] p1 = 0;
  reg oper_load1    = 0;
  reg oper_addsub1 = 0;

  reg signed [RES_WIDTH-1:0] res0 = 0;
  reg signed [RES_WIDTH-1:0] acc;

  always @(posedge CLK)
  begin
    oper_load0    <= Oper_Load;
    oper_addsub0 <= Oper_AddSub;

    p1 <= A*B;
    oper_load1    <= oper_load0;
    oper_addsub1 <= oper_addsub0;

    if (oper_load1==1'b1)
      acc = res0;
    else
      acc = 0;

    if (oper_addsub1==1'b1)
      res0 <= acc-p1;
    else
      res0 <= acc+p1;

  end

  assign RES = res0;
endmodule

```

Pipelined Multipliers HDL Coding Techniques

This section discusses Pipelined Multipliers HDL Coding Techniques, and includes:

- [About Pipelined Multipliers](#)
- [Pipelined Multipliers Log File](#)
- [Pipelined Multipliers Related Constraints](#)
- [Pipelined Multipliers Coding Examples](#)

About Pipelined Multipliers

This section discusses About Pipelined Multipliers, and includes:

- [Inferring Pipelined Multipliers](#)
- [Maximizing Performance](#)
- [Implementing Unused Stages](#)
- [XST Limitations](#)

Inferring Pipelined Multipliers

In order to increase the speed of designs with large multipliers, XST can infer pipelined multipliers. By interspersing registers between the stages of large multipliers, pipelining can significantly increase the overall frequency of your design. The effect of pipelining is similar to [Flip-Flop Retiming](#).

To insert pipeline stages:

1. Describe the necessary registers in your HDL code
2. Place them after any multipliers
3. Set [Multiplier Style \(MULT_STYLE\)](#) to:

pipe_lut

XST can also pipeline an implementation when:

- The target is a Virtex®-4 device or a Virtex-5 device, and
- Implementation of a multiplier requires multiple DSP48 blocks

Set [Multiplier Style \(MULT_STYLE\)](#) in this instance to:

pipe_block

Maximizing Performance

In order to reach the maximum multiplier speed, XST uses the maximum number of available registers when:

- XST detects valid registers for pipelining, and
- [Multiplier Style \(MULT_STYLE\)](#) is set to:

pipe_lut or **pipe_block**

In order to obtain the best frequency, XST automatically calculates the maximum number of registers for each multiplier .

During the Advanced HDL Synthesis step, the XST HDL Advisor advises you to specify the optimum number of register stages if:

- You have not specified sufficient register stages, and
- [Multiplier Style \(MULT_STYLE\)](#) is coded directly on a signal,

Implementing Unused Stages

XST implements the unused stages as shift registers if:

- The number of registers placed after the multiplier exceeds the maximum required, and
- Shift register extraction is activated

XST Limitations

XST has the following limitations:

- XST cannot pipeline hardware Multipliers (implementation using MULT18X18S resource)
- XST cannot pipeline Multipliers if registers contain async set/reset or sync reset signals. XST *can* pipeline if registers contain sync reset signals.

Pipelined Multipliers Log File

Following is a Pipelined Multipliers Log File Example.

Pipelined Multipliers Log File Example

```

=====
*                               HDL Synthesis                               *
=====

Synthesizing Unit <multipliers_2>.
  Related source file is "multipliers_2.vhd".
  Found 36-bit register for signal <MULT>.
  Found 18-bit register for signal <a_in>.
  Found 18-bit register for signal <b_in>.
  Found 18x18-bit multiplier for signal <mult_res>.
  Found 36-bit register for signal <pipe_1>.
  Found 36-bit register for signal <pipe_2>.
  Found 36-bit register for signal <pipe_3>.
  Summary:
    inferred 180 D-type flip-flop(s).
    inferred   1 Multiplier(s).
Unit <multipliers_2> synthesized.
...
=====
*                               Advanced HDL Synthesis                       *
=====

Synthesizing (advanced) Unit <multipliers_2>.
Found pipelined multiplier on signal <mult_res>:
- 4 pipeline level(s) found in a register connected to the
multiplier macro output.
Pushing register(s) into the multiplier macro.
INFO:Xst - HDL ADVISOR - You can improve the performance of the
multiplier Mmult_mult_res by adding 1 register level(s).
Unit <multipliers_2> synthesized (advanced).

=====
HDL Synthesis Report

Macro Statistics
# Multipliers                : 1
18x18-bit registered multiplier : 1
=====

```

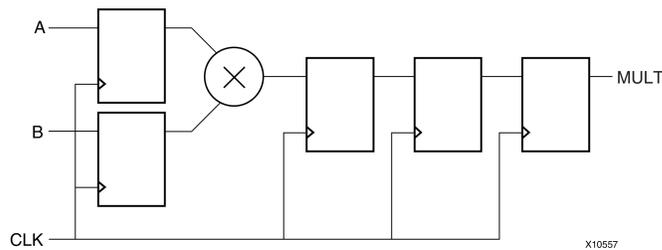
Pipelined Multipliers Related Constraints

- Use DSP48 (USE_DSP48)
- DSP Utilization Ratio (DSP_UTILIZATION_RATIO)
- Keep (KEEP)
- Multiplier Style (MULT_STYLE)

Pipelined Multipliers Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Pipelined Multiplier (Outside, Single) Diagram



Pipelined Multiplier (Outside, Single) Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| A, B | MULT Operands |
| MULT | MULT Result |

Pipelined Multiplier (Outside, Single) VHDL Coding Example

```
--
-- Pipelined multiplier
-- The multiplication operation placed outside the
-- process block and the pipeline stages represented
-- as single registers.
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity multipliers_2 is
  generic(A_port_size : integer := 18;
         B_port_size : integer := 18);
  port(clk : in std_logic;
       A : in unsigned (A_port_size-1 downto 0);
       B : in unsigned (B_port_size-1 downto 0);
       MULT : out unsigned ( (A_port_size+B_port_size-1) downto 0));

  attribute mult_style: string;
  attribute mult_style of multipliers_2: entity is "pipe_lut";

end multipliers_2;

architecture beh of multipliers_2 is
  signal a_in, b_in : unsigned (A_port_size-1 downto 0);
  signal mult_res : unsigned ( (A_port_size+B_port_size-1) downto 0);
  signal pipe_1,
         pipe_2,
```

```

        pipe_3 : unsigned ((A_port_size+B_port_size-1) downto 0);
begin
    mult_res <= a_in * b_in;

    process (clk)
    begin
        if (clk'event and clk='1') then
            a_in <= A; b_in <= B;
            pipe_1 <= mult_res;
            pipe_2 <= pipe_1;
            pipe_3 <= pipe_2;
            MULT <= pipe_3;
        end if;
    end process;
end beh;

```

Pipelined Multiplier (Outside, Single) Verilog Coding Example

```

//
// Pipelined multiplier
//   The multiplication operation placed outside the
//   always block and the pipeline stages represented
//   as single registers.
//

(*mult_style="pipe_lut"*)
module v_multipliers_2(clk, A, B, MULT);

    input clk;
    input [17:0] A;
    input [17:0] B;
    output [35:0] MULT;
    reg [35:0] MULT;
    reg [17:0] a_in, b_in;
    wire [35:0] mult_res;
    reg [35:0] pipe_1, pipe_2, pipe_3;

    assign mult_res = a_in * b_in;

    always @(posedge clk)
    begin
        a_in <= A; b_in <= B;
        pipe_1 <= mult_res;
        pipe_2 <= pipe_1;
        pipe_3 <= pipe_2;
        MULT <= pipe_3;
    end
endmodule

```

Pipelined Multiplier (Inside, Single) Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| A, B | MULT Operands |
| MULT | MULT Result |

Pipelined Multiplier (Inside, Single) VHDL Coding Example

```
--
-- Pipelined multiplier
-- The multiplication operation placed inside the
-- process block and the pipeline stages represented
-- as single registers.
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity multipliers_3 is
  generic(A_port_size: integer := 18;
         B_port_size: integer := 18);
  port(clk : in std_logic;
       A : in unsigned (A_port_size-1 downto 0);
       B : in unsigned (B_port_size-1 downto 0);
       MULT : out unsigned ((A_port_size+B_port_size-1) downto 0));

  attribute mult_style: string;
  attribute mult_style of multipliers_3: entity is "pipe_lut";

end multipliers_3;

architecture beh of multipliers_3 is
  signal a_in, b_in : unsigned (A_port_size-1 downto 0);
  signal mult_res : unsigned ((A_port_size+B_port_size-1) downto 0);
  signal pipe_2,
         pipe_3 : unsigned ((A_port_size+B_port_size-1) downto 0);

begin
  process (clk)
  begin
    if (clk'event and clk='1') then
      a_in <= A; b_in <= B;
      mult_res <= a_in * b_in;
      pipe_2 <= mult_res;
      pipe_3 <= pipe_2;
      MULT <= pipe_3;
    end if;
  end process;
end beh;
```

Pipelined Multiplier (Inside, Single) Verilog Coding Example

```
//
// Pipelined multiplier
// The multiplication operation placed inside the
// process block and the pipeline stages are represented
// as single registers.
//

(*mult_style="pipe_lut"*)
module v_multipliers_3(clk, A, B, MULT);

  input clk;
  input [17:0] A;
  input [17:0] B;
  output [35:0] MULT;
  reg [35:0] MULT;
  reg [17:0] a_in, b_in;
  reg [35:0] mult_res;
  reg [35:0] pipe_2, pipe_3;

  always @(posedge clk)
```

```

begin
    a_in <= A; b_in <= B;
    mult_res <= a_in * b_in;
    pipe_2 <= mult_res;
    pipe_3 <= pipe_2;
    MULT <= pipe_3;
end
endmodule

```

Pipelined Multiplier (Outside, Shift) Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| A, B | MULT Operands |
| MULT | MULT Result |

Pipelined Multiplier (Outside, Shift) VHDL Coding Example

```

--
-- Pipelined multiplier
-- The multiplication operation placed outside the
-- process block and the pipeline stages represented
-- as shift registers.
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity multipliers_4 is
    generic(A_port_size: integer := 18;
           B_port_size: integer := 18);
    port(clk : in std_logic;
         A : in unsigned (A_port_size-1 downto 0);
         B : in unsigned (B_port_size-1 downto 0);
         MULT : out unsigned ( (A_port_size+B_port_size-1) downto 0));

    attribute mult_style: string;
    attribute mult_style of multipliers_4: entity is "pipe_lut";
end multipliers_4;

architecture beh of multipliers_4 is
    signal a_in, b_in : unsigned (A_port_size-1 downto 0);
    signal mult_res : unsigned ((A_port_size+B_port_size-1) downto 0);

    type pipe_reg_type is array (2 downto 0) of unsigned ((A_port_size+B_port_size-1) downto 0);
    signal pipe_regs : pipe_reg_type;
begin

    mult_res <= a_in * b_in;

    process (clk)
    begin
        if (clk'event and clk='1') then
            a_in <= A; b_in <= B;
            pipe_regs <= mult_res & pipe_regs(2 downto 1);
            MULT <= pipe_regs(0);
        end if;
    end process;
end beh;

```

Pipelined Multiplier (Outside, Shift) Verilog Coding Example

```
//  
// Pipelined multiplier  
//   The multiplication operation placed outside the  
//   always block and the pipeline stages represented  
//   as shift registers.  
//  
  
(*mult_style="pipe_lut"*)  
module v_multipliers_4(clk, A, B, MULT);  
  
    input clk;  
    input [17:0] A;  
    input [17:0] B;  
    output [35:0] MULT;  
    reg [35:0] MULT;  
    reg [17:0] a_in, b_in;  
    wire [35:0] mult_res;  
    reg [35:0] pipe_regs [2:0];  
    integer i;  
  
    assign mult_res = a_in * b_in;  
  
    always @(posedge clk)  
    begin  
        a_in <= A; b_in <= B;  
  
        pipe_regs[2] <= mult_res;  
        for (i=0; i<=1; i=i+1) pipe_regs[i] <= pipe_regs[i+1];  
  
        MULT <= pipe_regs[0];  
    end  
  
endmodule
```

Multiply Adder/Subtractors HDL Coding Techniques

This section discusses Multiply Adder/Subtractors HDL Coding Techniques, and includes:

- [About Multiply Adder/Subtractors](#)
- [Multiply Adder/Subtractors in Virtex-4 Devices and Virtex-5 Devices](#)
- [Multiply Adder/Subtractors Log File](#)
- [Multiply Adder/Subtractors Related Constraints](#)
- [Multiply Adder/Subtractors Coding Examples](#)

About Multiply Adder/Subtractors

The Multiply Adder/Subtractor macro is a complex macro consisting of several basic macros such as:

- Multipliers
- Adder/subtractors
- Registers

The recognition of this complex macro enables XST to implement it on dedicated DSP48 resources in the following devices:

- Virtex®-4
- Virtex-5

Multiply Adder/Subtractors in Virtex-4 Devices and Virtex-5 Devices

This section discusses Multiply Adder/Subtractors in Virtex®-4 Devices and Virtex-5 Devices, and includes:

- [XST Registered Macro Support](#)
- [XST DSP48 Block Support](#)
- [Macro Implementation on DSP48 Blocks](#)
- [Maximum Macro Configuration](#)

XST Registered Macro Support

XST supports the registered version of this macro and can push up to:

- Two levels of input registers on multiplier inputs
- One register level on the Adder/Subtractor input
- One level of output register into the DSP48 block

If the Carry In or Add/Sub operation selectors are registered, XST pushes these registers into the DSP48. In addition, the multiplication operation could be registered as well.

XST DSP48 Block Support

XST can implement a multiply adder/subtractor in a DSP48 block if its implementation requires only a single DSP48 resource. If the macro exceeds the limits of a single DSP48, XST processes it as two separate Multiplier and Adder/Subtractor macros, making independent decisions on each macro.

For more information, see:

- [Multipliers Hardware Description Language \(HDL\) Coding Techniques](#)
- [Adders, Subtractors, and Adders/Subtractors Hardware Description Language \(HDL\) Coding Techniques](#)

Macro Implementation on DSP48 Blocks

Macro implementation on DSP48 blocks is controlled by [Use DSP48 \(USE_DSP48\)](#) with a default value of **auto**. In this mode, XST implements multiply adder/subtractors taking into account DSP48 resources in the device.

In **auto** mode, use [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#) to control DSP48 resources for the synthesis. By default, XST tries to utilize all available DSP48 resources.

For more information, see:

[DSP48 Block Resources](#)

Maximum Macro Configuration

To deliver the best performance, XST by default tries to infer and implement the maximum macro configuration, including as many registers in the DSP48 as possible. Use [Keep \(KEEP\)](#) to shape a macro in a specific way. For example, to exclude the first register stage from the DSP48, place [Keep \(KEEP\)](#) constraints on the outputs of these registers.

Multiply Adder/Subtractors Log File

In the log file, XST reports the details of inferred multipliers, adder/subtractors and registers at the HDL Synthesis step. The composition of multiply adder/subtractor macros happens at the Advanced HDL Synthesis step. XST reports information about inferred MACs, because they are implemented within the MAC implementation mechanism.

Multiply Adder/Subtractors Log File Example

```

=====
*                               HDL Synthesis                               *
=====

Synthesizing Unit <multipliers_6>.
  Related source file is "multipliers_6.vhd".
  Found 8-bit register for signal <A_reg1>.
  Found 8-bit register for signal <A_reg2>.
  Found 8-bit register for signal <B_reg1>.
  Found 8-bit register for signal <B_reg2>.
  Found 8x8-bit multiplier for signal <mult>.
  Found 16-bit addsub for signal <multaddsub>.
  Summary:
    inferred  32 D-type flip-flop(s).
    inferred   1 Adder/Subtractor(s).
    inferred   1 Multiplier(s).
Unit <multipliers_6> synthesized.
...
=====
*                               Advanced HDL Synthesis                       *
=====
...
Synthesizing (advanced) Unit <Mmult_mult>.
  Multiplier <Mmult_mult> in block <multipliers_6> and adder/subtractor
  <Maddsub_multaddsub> in block <multipliers_6> are combined into a
  MAC<Mmac_Maddsub_multaddsub>.
  The following registers are also absorbed by the MAC: <A_reg2> in block
  <multipliers_6>, <A_reg1> in block <multipliers_6>, <B_reg2> in
  block <multipliers_6>, <B_reg1> in block <multipliers_6>.
Unit <Mmult_mult> synthesized (advanced).

=====
HDL Synthesis Report

Macro Statistics
# MACs                               : 1
 8x8-to-16-bit MAC                   : 1

```

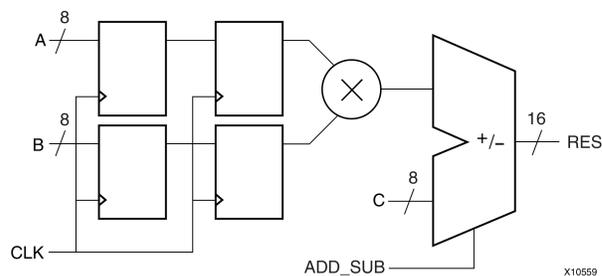
Multiply Adder/Subtractors Related Constraints

- Use DSP48 (USE_DSP48)
- DSP Utilization Ratio (DSP_UTILIZATION_RATIO)
- Keep (KEEP)

Multiply Adder/Subtractors Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Multiplier Adder With 2 Register Levels on Multiplier Inputs Diagram



Multiplier Adder With 2 Register Levels on Multiplier Inputs Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| A, B, C | MULT-Add Operands |
| RES | MULT-Add Result |

Multiplier Adder With 2 Register Levels on Multiplier Inputs VHDL Coding Example

```
--
-- Multiplier Adder with 2 Register Levels on Multiplier Inputs
--

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity multipliers_5 is
    generic (p_width: integer:=8);
    port (clk : in std_logic;
          A, B, C : in std_logic_vector(p_width-1 downto 0);
          RES : out std_logic_vector(p_width*2-1 downto 0));
end multipliers_5;

architecture beh of multipliers_5 is
    signal A_reg1, A_reg2,
           B_reg1, B_reg2 : std_logic_vector(p_width-1 downto 0);
```

```

    signal multaddsub : std_logic_vector(p_width*2-1 downto 0);
begin

    multaddsub <= A_reg2 * B_reg2 + C;

    process (clk)
    begin
        if (clk'event and clk='1') then
            A_reg1 <= A; A_reg2 <= A_reg1;
            B_reg1 <= B; B_reg2 <= B_reg1;
        end if;
    end process;

    RES <= multaddsub;

end beh;

```

Multiplier Adder With 2 Register Levels on Multiplier Inputs Verilog Coding Example

```

//
// Multiplier Adder with 2 Register Levels on Multiplier Inputs
//

module v_multipliers_5 (clk, A, B, C, RES);

    input  clk;
    input  [7:0] A;
    input  [7:0] B;
    input  [7:0] C;
    output [15:0] RES;
    reg    [7:0] A_reg1, A_reg2, B_reg1, B_reg2;
    wire   [15:0] multaddsub;

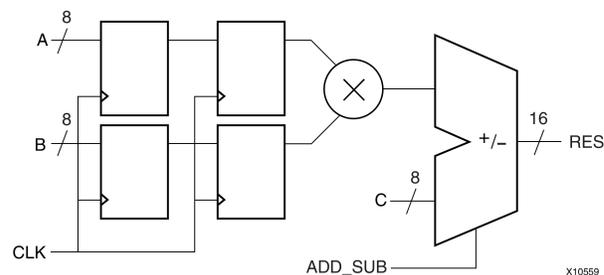
    always @(posedge clk)
    begin
        A_reg1 <= A; A_reg2 <= A_reg1;
        B_reg1 <= B; B_reg2 <= B_reg1;
    end

    assign multaddsub = A_reg2 * B_reg2 + C;
    assign RES = multaddsub;

endmodule

```

Multiplier Adder/Subtractor With 2 Register Levels On Multiplier Inputs Diagram



Multiplier Adder/Subtractor With 2 Register Levels On Multiplier Inputs Pin Descriptions

| IO Pins | Description |
|---------|----------------------|
| clk | Positive-Edge Clock |
| add_sub | AddSub Selector |
| A, B, C | MULT-AddSub Operands |
| RES | MULT-AddSub Result |

Multiplier Adder/Subtractor With 2 Register Levels On Multiplier Inputs VHDL Coding Example

```
--
-- Multiplier Adder/Subtractor with
-- 2 Register Levels on Multiplier Inputs
--

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity multipliers_6 is
    generic (p_width: integer:=8);
    port (clk,add_sub: in std_logic;
          A, B, C: in std_logic_vector(p_width-1 downto 0);
          RES: out std_logic_vector(p_width*2-1 downto 0));
end multipliers_6;

architecture beh of multipliers_6 is
    signal A_reg1, A_reg2,
           B_reg1, B_reg2 : std_logic_vector(p_width-1 downto 0);
    signal mult, multaddsub : std_logic_vector(p_width*2-1 downto 0);
begin

    mult <= A_reg2 * B_reg2;
    multaddsub <= C + mult when add_sub = '1' else C - mult;

    process (clk)
    begin
        if (clk'event and clk='1') then
            A_reg1 <= A; A_reg2 <= A_reg1;
            B_reg1 <= B; B_reg2 <= B_reg1;
        end if;
    end process;

    RES <= multaddsub;

end beh;
```

Multiplier Adder/Subtractor With 2 Register Levels On Multiplier Inputs Verilog Coding Example

```
//
// Multiplier Adder/Subtractor with
// 2 Register Levels on Multiplier Inputs
//

module v_multipliers_6 (clk, add_sub, A, B, C, RES);

    input  clk,add_sub;
    input  [7:0] A;
    input  [7:0] B;
    input  [7:0] C;
```

```
output [15:0] RES;
reg     [7:0] A_reg1, A_reg2, B_reg1, B_reg2;
wire    [15:0] mult, multaddsub;

always @(posedge clk)
begin
    A_reg1 <= A; A_reg2 <= A_reg1;
    B_reg1 <= B; B_reg2 <= B_reg1;
end

assign mult = A_reg2 * B_reg2;
assign multaddsub = add_sub ? C + mult : C - mult;
assign RES = multaddsub;

endmodule
```

Multiply Accumulate HDL Coding Techniques

This section discusses Multiply Accumulate HDL Coding Techniques, and includes:

- [About Multiply Accumulate](#)
- [Multiply Accumulate in Virtex-4 Devices and Virtex-5 Devices](#)
- [Multiply Accumulate Log File](#)
- [Multiply Accumulate Related Constraints](#)
- [Multiply Accumulate Coding Examples](#)

About Multiply Accumulate

The Multiply Accumulate macro is a complex macro consisting of several basic macros such as:

- Multipliers
- Accumulators
- Registers

The recognition of this complex macro enables XST to implement it on dedicated DSP48 resources in the following devices:

- Virtex®-4
- Virtex-5

Multiply Accumulate in Virtex-4 Devices and Virtex-5 Devices

This section discusses Multiply Accumulate in Virtex®-4 Devices and Virtex-5 Devices, and includes:

- [XST Registered Macro Support](#)
- [XST DSP48 Block Support](#)
- [Macro Implementation on DSP48 Blocks](#)
- [Maximum Macro Configuration](#)

For more information, see:

- [Multipliers HDL Coding Techniques](#)
- [Accumulators HDL Coding Techniques](#)

XST Registered Macro Support

XST supports the registered version of this macro, and can push up to 2 levels of input registers into the DSP48 block. If Adder/Subtractor operation selectors are registered, XST pushes these registers into the DSP48. In addition, the multiplication operation could be registered as well.

XST DSP48 Block Support

XST can implement a multiply accumulate in a DSP48 block if its implementation requires only a single DSP48 resource. If the macro exceeds the limits of a single DSP48, XST processes it as two separate Multiplier and Accumulate macros, making independent decisions on each macro.

Macro Implementation on DSP48 Blocks

Macro implementation on DSP48 blocks is controlled by the [Use DSP48 \(USE_DSP48\)](#) constraint or command line option, with a default value of **auto**. In **auto** mode, XST implements multiply accumulate taking into account available DSP48 resources in the device.

In **auto** mode, use [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#) to control DSP48 resources. XST tries to utilize as many DSP48 resources as possible. For more information, see [DSP48 Block Resources](#).

Maximum Macro Configuration

To deliver the best performance, XST by default tries to infer and implement the maximum macro configuration, including as many registers in the DSP48 as possible. To shape a macro in a specific way, use the [Keep \(KEEP\)](#) constraint. For example, to exclude the first register stage from the DSP48, place [Keep \(KEEP\)](#) constraints on the outputs of these registers.

Multiply Accumulate Log File

XST reports the following information in the Multiply Accumulate Log File.

| Step | Report |
|------------------------|---|
| HDL Synthesis | Details of inferred multipliers, accumulators and registers |
| Advanced HDL Synthesis | Composition of multiply accumulate macros |

Multiply Accumulate Log File Example

```

=====
*                               HDL Synthesis                               *
=====
...
Synthesizing Unit <multipliers_7a>.
  Related source file is "multipliers_7a.vhd".
  Found 8x8-bit multiplier for signal <$n0002> created at line 28.
  Found 16-bit up accumulator for signal <accum>.
  Found 16-bit register for signal <mult>.
  Summary:
    inferred   1 Accumulator(s).
    inferred  16 D-type flip-flop(s).
    inferred   1 Multiplier(s).
Unit <multipliers_7a> synthesized...
=====
*                               Advanced HDL Synthesis                       *
=====
...
Synthesizing (advanced) Unit <Mmult__n0002>.
  Multiplier <Mmult__n0002> in block <multipliers_7a> and accumulator
  <accum> in block <multipliers_7a> are combined into a MAC<Mmac_accum>.
  The following registers are also absorbed by the MAC: <mult> in block
  <multipliers_7a>. Unit <Mmult__n0002> synthesized (advanced).

=====
HDL Synthesis Report

Macro Statistics
# MACs                               : 1
8x8-to-16-bit MAC                     : 1
=====

```

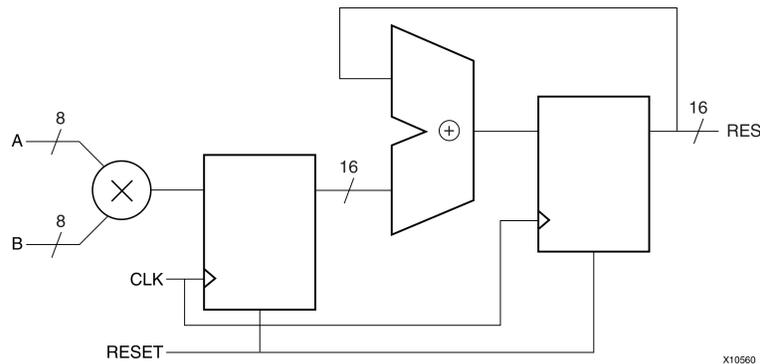
Multiply Accumulate Related Constraints

- Use DSP48 (USE_DSP48)
- DSP Utilization Ratio (DSP_UTILIZATION_RATIO)
- Keep (KEEP)

Multiply Accumulate Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/tpatches/pub/documentation/misc/xstug_examples.zip

Multiplier Up Accumulate With Register After Multiplication Diagram



Multiplier Up Accumulate With Register After Multiplication Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| reset | Synchronous Reset |
| A, B | MAC Operands |
| RES | MAC Result |

Multiplier Up Accumulate With Register After Multiplication VHDL Coding Example

```
--
-- Multiplier Up Accumulate with Register After Multiplication
--
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity multipliers_7a is
  generic (p_width: integer:=8);
  port (clk, reset: in std_logic;
        A, B: in std_logic_vector(p_width-1 downto 0);
        RES: out std_logic_vector(p_width*2-1 downto 0));
end multipliers_7a;

architecture beh of multipliers_7a is
  signal mult, accum: std_logic_vector(p_width*2-1 downto 0);
```

```
begin

    process (clk)
    begin
        if (clk'event and clk='1') then
            if (reset = '1') then
                accum <= (others => '0');
                mult <= (others => '0');
            else
                accum <= accum + mult;
                mult <= A * B;
            end if;
        end if;
    end process;

    RES <= accum;

end beh;
```

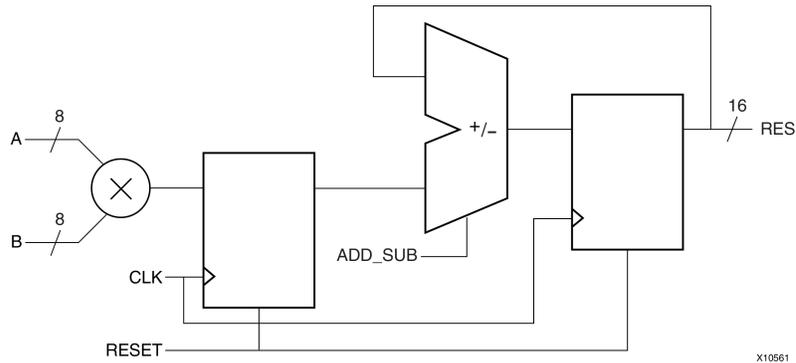
Multiplier Up Accumulate With Register After Multiplication Verilog Coding Example

```
//
// Multiplier Up Accumulate with Register After Multiplication
//
module v_multipliers_7a (clk, reset, A, B, RES);
    input clk, reset;
    input [7:0] A;
    input [7:0] B;
    output [15:0] RES;
    reg [15:0] mult, accum;

    always @(posedge clk)
    begin
        if (reset)
            mult <= 16'b0000000000000000;
        else
            mult <= A * B;
        end

    always @(posedge clk)
    begin
        if (reset)
            accum <= 16'b0000000000000000;
        else
            accum <= accum + mult;
        end
        assign RES = accum;
    endmodule
```

Multiplier Up/Down Accumulate With Register After Multiplication Diagram



Multiplier Up/Down Accumulate With Register After Multiplication Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| reset | Synchronous Reset |
| add_sub | AddSub Selector |
| A, B | MAC Operands |
| RES | MAC Result |

Multiplier Up/Down Accumulate With Register After Multiplication VHDL Coding Example

```
--
-- Multiplier Up/Down Accumulate with Register
-- After Multiplication
--

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;
entity multipliers_7b is
    generic (p_width: integer:=8);
    port (clk, reset, add_sub: in std_logic;
          A, B: in std_logic_vector(p_width-1 downto 0);
          RES: out std_logic_vector(p_width*2-1 downto 0));
end multipliers_7b;

architecture beh of multipliers_7b is
    signal mult, accum: std_logic_vector(p_width*2-1 downto 0);
begin

    process (clk)
    begin
        if (clk'event and clk='1') then
            if (reset = '1') then
                accum <= (others => '0');
                mult <= (others => '0');
            else

```

```

        if (add_sub = '1') then
            accum <= accum + mult;
        else
            accum <= accum - mult;
        end if;

        mult <= A * B;
    end if;
end if;
end process;

RES <= accum;

end beh;

```

Multiplier Up/Down Accumulate With Register After Multiplication Verilog Coding Example

```

//
// Multiplier Up/Down Accumulate with Register
// After Multiplication
//

module v_multipliers_7b (clk, reset, add_sub, A, B, RES);

    input  clk, reset, add_sub;
    input  [7:0] A;
    input  [7:0] B;
    output [15:0] RES;
    reg    [15:0] mult, accum;

    always @(posedge clk)
    begin
        if (reset)
            mult <= 16'b0000000000000000;
        else
            mult <= A * B;
        end

    always @(posedge clk)
    begin
        if (reset)
            accum <= 16'b0000000000000000;
        else
            if (add_sub)
                accum <= accum + mult;
            else
                accum <= accum - mult;
            end

        assign RES = accum;
    end

endmodule

```

Dividers HDL Coding Techniques

This section discusses Dividers HDL Coding Techniques, and includes:

- [About Dividers](#)
- [Dividers Log File](#)
- [Dividers Related Constraints](#)
- [Dividers Coding Examples](#)

About Dividers

Dividers are supported only when the divisor is a constant and is a power of 2. In that case, the operator is implemented as a shifter. Otherwise, XST issues an error message.

Dividers Log File

When you implement a divider with a constant with the power of 2, XST does not issue any message during the Macro Recognition step. If the divider does not correspond to the case supported by XST, then XST issues the following error message:

```
...
ERROR:Xst:719 - file1.vhd (Line 172).
Operator is not supported yet : 'DIVIDE'
...
```

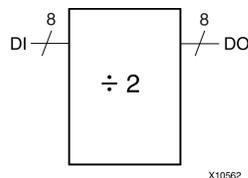
Dividers Related Constraints

None

Dividers Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/tpatches/pub/documentation/misc/xstug_examples.zip

Division by Constant 2 Divider Diagram



Division by Constant 2 Divider Pin Descriptions

| IO Pins | Description |
|---------|-------------------|
| DI | Division Operands |
| DO | Division Result |

Division by Constant 2 Divider VHDL Coding Example

```
--  
-- Division By Constant 2  
--  
  
library ieee;  
use ieee.std_logic_1164.all;  
use ieee.numeric_std.all;  
  
entity divider_1 is  
    port(DI : in  unsigned(7 downto 0);  
         DO : out unsigned(7 downto 0));  
end divider_1;  
  
architecture archi of divider_1 is  
begin  
  
    DO <= DI / 2;  
  
end archi;
```

Division by Constant 2 Divider Verilog Coding Example

```
//  
// Division By Constant 2  
//  
  
module v_divider_1 (DI, DO);  
    input  [7:0] DI;  
    output [7:0] DO;  
  
    assign DO = DI / 2;  
  
endmodule
```

Resource Sharing HDL Coding Techniques

This section discusses Resource Sharing HDL Coding Techniques, and includes:

- [About Resource Sharing](#)
- [Resource Sharing Log File](#)
- [Resource Sharing Related Constraints](#)
- [Resource Sharing Coding Examples](#)

About Resource Sharing

The goal of resource sharing (also known as *folding*) is to minimize the number of operators and the subsequent logic in the synthesized design. This optimization is based on the principle that two similar arithmetic resources may be implemented as one single arithmetic operator if they are never used at the same time. XST performs both resource sharing and, if required, reduces the number of multiplexers.

XST supports resource sharing for:

- Adders
- Subtractors
- Adders/subtractors
- Multipliers

If the optimization goal is speed, disabling resource sharing may give better results. To improve clock frequency, Xilinx® recommends deactivating resource sharing at the Advanced HDL Synthesis step.

Resource Sharing Log File

The XST log file reports the type and size of recognized arithmetic blocks and multiplexers during the Macro Recognition step.

Resource Sharing Log File Example

```

...
Synthesizing Unit <addsub>.
  Related source file is resource_sharing_1.vhd.
  Found 8-bit addsub for signal <res>.
  Found 8 1-bit 2-to-1 multiplexers.
  Summary:
    inferred   1 Adder/Subtractor(s).
    inferred   8 Multiplexer(s).
  Unit <addsub> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# Multiplexers           : 1
  2-to-1 multiplexer     : 1
# Adders/Subtractors     : 1
  8-bit addsub           : 1
=====
...
*                          Advanced HDL Synthesis                          *
=====

INFO:Xst - HDL ADVISOR - Resource sharing has identified that some
arithmetic operations in this design can share the same physical resources
for reduced device utilization. For improved clock frequency you may
try to disable resource sharing.
...

```

Resource Sharing Related Constraints

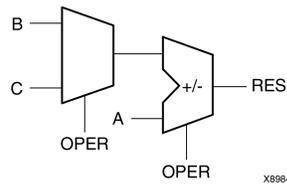
Resource Sharing (RESOURCE_SHARING)

Resource Sharing Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/tpatches/pub/documentation/misc/xstug_examples.zip

For the following VHDL and Verilog examples, XST gives the following solution.

Resource Sharing Diagram



Resource Sharing Pin Descriptions

| IO Pins | Description |
|---------|--------------------|
| A, B, C | Operands |
| OPER | Operation Selector |
| RES | Data Output |

Resource Sharing VHDL Coding Example

```
--
-- Resource Sharing
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity resource_sharing_1 is
    port(A,B,C : in std_logic_vector(7 downto 0);
         OPER : in std_logic;
         RES  : out std_logic_vector(7 downto 0));
end resource_sharing_1;

architecture archi of resource_sharing_1 is
begin

    RES <= A + B when OPER='0' else A - C;

end archi;
```

Resource Sharing Verilog Coding Example

```
//  
// Resource Sharing  
//  
  
module v_resource_sharing_1 (A, B, C, OPER, RES);  
    input  [7:0] A, B, C;  
    input  OPER;  
    output [7:0] RES;  
    wire   [7:0] RES;  
  
    assign RES = !OPER ? A + B : A - C;  
  
endmodule
```

RAMs and ROMs HDL Coding Techniques

This section discusses RAMs and ROMs HDL Coding Techniques, and includes:

- [About RAMs and ROMs](#)
- [RAMs and ROMs Log File](#)
- [RAMs and ROMs Related Constraints](#)
- [RAMs and ROMs Coding Examples](#)
- [Initializing RAM Coding Examples](#)
- [Initializing RAM From an External File Coding Examples](#)

About RAMs and ROMs

This section discusses About RAMs and ROMs, and includes:

- [Automatic RAM Recognition](#)
- [RAMs and ROMs with Negative Addresses](#)
- [Types of Inferred RAM](#)
- [Block and Distributed RAM](#)
- [Unsupported Block RAM Features](#)
- [Speed-Oriented Implementation](#)
- [Additional XST Capabilities](#)
- [Automatic BRAM Resource Control](#)
- [Small RAMs and ROMs](#)
- [Available BRAM Resources](#)

Automatic RAM Recognition

If you do not want to instantiate RAM primitives to keep your Hardware Description Language (HDL) code architecture independent, use XST automatic RAM recognition. XST can infer distributed as well as block RAM. It covers the following characteristics, offered by these RAM types:

- Synchronous write
- Write enable
- RAM enable
- Asynchronous or synchronous read
- Reset of the data output latches
- Data output reset
- Single, dual, or multiple-port read
- Single-port and dual-port write
- Parity bits
- Block Ram with Byte-Wide Write Enable
- Simple dual-port BRAM

RAMs and ROMs with Negative Addresses

XST does not support RAMs and ROMs with negative addresses.

Types of Inferred RAM

The type of Inferred RAM depends on its description.

- RAM descriptions with an *asynchronous* read generate a distributed RAM macro.
- RAM descriptions with a *synchronous* read generate a block RAM macro. In some cases, a block RAM macro can actually be implemented with distributed RAM. The decision on the actual RAM implementation is done by the macro generator.

Block and Distributed RAM

If a given template can be implemented using Block and Distributed RAM, XST implements BLOCK ones. Use the [RAM Style \(RAM_STYLE\)](#) constraint to control RAM implementation and select a desirable RAM type.

For more information, see:

[XST Design Constraints](#)

Unsupported Block RAM Features

The following block RAM features are *not* supported:

- Parity bits
- Different aspect ratios on each port
- Simple dual-port distributed RAMs
- Quad-port distributed RAMs

Speed-Oriented Implementation

XST uses speed-oriented implementation to implement RAMs on BRAM resources. This gives good results for speed, but may require more BRAM resources than area-oriented implementation. XST does not support area-oriented BRAM implementation. Xilinx® recommends the CORE Generator™ software for area-oriented implementation.

For more information, see:

[XST FPGA Optimization](#)

Additional XST Capabilities

XST can:

- Implement Finite State Machine (FSM) components.

For more information, see:

[Finite State Machine \(FSM\) HDL Coding Techniques](#).

- Map general logic onto block RAMs

For more information, see:

[Mapping Logic Onto Block RAM](#)

Automatic BRAM Resource Control

XST automatically controls BRAM resources on the target device. [BRAM Utilization Ratio \(BRAM_UTILIZATION_RATIO\)](#) allows you to specify the number of BRAM blocks that XST must not exceed during synthesis.

Small RAMs and ROMs

Use [RAM Style \(RAM_STYLE\)](#) and [ROM Style \(ROM_STYLE\)](#) to force implementation of small RAMs and ROMs on BRAM resources.

To achieve better design speed, XST implements small RAMs and ROMs using distributed resources. RAMs and ROMs are considered *small* if their sizes follow the rules shown in the following table.

| Devices | Size (bits) * Width (bits) |
|-----------|----------------------------|
| Virtex®-4 | <= 512 |
| Virtex-5 | <= 512 |

Available BRAM Resources

XST calculates the available BRAM resources for inference using the following formula:

Total_Number_of_Available_BRAMs - Number_of_Reserved_BRAMs

where

Total_Number_of_Available_BRAMs is the number of BRAMs specified by the [BRAM Utilization Ratio \(BRAM_UTILIZATION_RATIO\)](#) constraint. By default it is 100%.

The **Number of Reserved_BRAMs** encapsulates:

- The number of instantiated BRAMs in the Hardware Description Language (HDL) code from the UNISIM library
- The number of RAM which were forced to be implemented as BRAMs by the [RAM Style \(RAM_STYLE\)](#) and [ROM Style \(ROM_STYLE\)](#) constraints
- The number of BRAMs generated using BRAM mapping optimizations (BRAM_MAP).

Where there are available BRAM resources, XST implements the largest inferred RAMs and ROMs using BRAM, and the smallest on distributed resources.

If the **Number_of_Reserved_BRAMs** exceeds available resources, XST implements them as block RAMs, and all inferred RAMs are implemented on distributed memory.

As soon as this process is completed, XST can automatically pack two small single-port BRAMs in a single BRAM primitive. This optimization is controlled by [Automatic BRAM Packing \(AUTO_BRAM_PACKING\)](#). It is disabled by default.

For more information, see:

- [BRAM Utilization Ratio \(BRAM_UTILIZATION_RATIO\)](#)
- [Automatic BRAM Packing \(AUTO_BRAM_PACKING\)](#)

RAMs and ROMs Log File

The XST RAMs and ROMs log file reports the following:

- Type and size of recognized RAM
- Complete information on its I/O ports

Steps in RAM Recognition

| Step | XST Behavior |
|------------------------|--|
| HDL Synthesis | Recognizes the presence of the memory structure in the Hardware Description Language (HDL) code |
| Advanced HDL Synthesis | Decides how to implement a specific memory (that is, whether to use Block or Distributed memory resources) |

RAMs and ROMs Log File Example

```

=====
* HDL Synthesis *
=====

Synthesizing Unit <rams_16>.
Related source file is "rams_16.vhd".
Found 64x16-bit dual-port RAM <Mram_RAM> for signal <RAM>.
Found 16-bit register for signal <doa>.
Found 16-bit register for signal <dob>.
Summary:
inferred 1 RAM(s).
inferred32 D-type flip-flop(s).
Unit <rams_16> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# RAMs : 1
 64x16-bit dual-port RAM : 1
# Registers: 2
 16-bit register : 2

=====

* Advanced HDL Synthesis*
=====

Synthesizing (advanced) Unit <rams_16>.
INFO:Xst - The RAM <Mram_RAM> will be implemented as a BLOCK RAM, absorbing
the following register(s): <doa> <dob>

-----
| ram_type          | Block          |           |
-----
| Port A           |               |           |
|   aspect ratio   | 64-word x 16-bit |           |
|   mode           | write-first     |           |
|   clkA           | connected to signal <clka> | rise |
|   enA            | connected to signal <ena> | high |
|   weA            | connected to internal <wea> | high |
|   addrA          | connected to signal <addra> |           |
|   diA            | connected to internal <dia> |           |
|   doA            | connected to signal <doa> |           |
-----
| optimization     | speed          |           |
-----

-----
| ram_type          | Block          |           |
-----
| Port B           |               |           |
|   aspect ratio   | 64-word x 16-bit |           |
|   mode           | write-first     |           |
|   clkB           | connected to signal <clkb> | rise |
|   enB            | connected to signal <enb> | high |
|   weB            | connected to internal <web> | high |
|   addrB          | connected to signal <addrb> |           |
|   diB            | connected to internal <dib> |           |
|   doB            | connected to signal <dob> |           |
-----
| optimization     | speed          |           |
-----

Unit <rams_16> synthesized (advanced).

=====
Advanced HDL Synthesis Report

```

```
Macro Statistics
# RAMs : 1
 64x16-bit dual-port block RAM : 1
```

=====

RAMs and ROMs Related Constraints

- [BRAM Utilization Ratio \(BRAM_UTILIZATION_RATIO\)](#)
- [Automatic BRAM Packing \(AUTO_BRAM_PACKING\)](#)
- [RAM Extraction \(RAM_EXTRACT\)](#)
- [RAM Style \(RAM_STYLE\)](#)
- [ROM Extraction \(ROM_EXTRACT\)](#)
- [ROM Style \(ROM_STYLE\)](#)

XST accepts [LOC](#) and [RLOC](#) constraints on inferred RAMs that can be implemented in a single block RAM primitive. The [LOC](#) and [RLOC](#) constraints are propagated to the NGC netlist.

RAMs and ROMs Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/tpatches/pub/documentation/misc/xstug_examples.zip

See Also:

[Initializing RAM Coding Examples](#)

[Initializing RAM From an External File Coding Examples](#)

About RAMs and ROMs Coding Examples

Block RAM resources in the following devices offer different read/write synchronization modes:

- Virtex®-4
- Virtex-5
- Spartan®-3
- Spartan-3E
- Spartan-3A

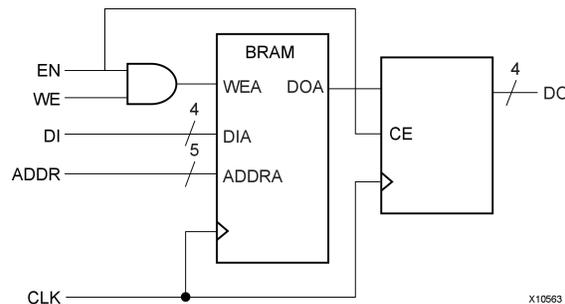
The following coding examples describe a single-port block RAM. You can deduce descriptions of dual-port block RAMs from these examples. Dual-port block RAMs can be configured with a different read/write mode on each port. Inference supports this capability.

This table summarizes support for read/write modes according to the targeted devices and how XST handles it.

Support For Read/Write Modes

| Devices | Inferred Modes | Behavior |
|------------|----------------|---|
| Spartan-3 | write-first | Macro inference and generation |
| Spartan-3E | read-first | Attach adequate WRITE_MODE, WRITE_MODE_A, WRITE_MODE_B constraints to generated block RAMs in NCF |
| Spartan-3A | no-change | |
| Virtex-4 | | |
| Virtex-5 | | |
| CPLD | none | RAM inference completely disabled |

Single-Port RAM in Read-First Mode Diagram



Single-Port RAM in Read-First Mode Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| en | Clock Enable |
| addr | Read/Write Address |
| di | Data Input |
| do | Data Output |

Single-Port RAM in Read-First Mode VHDL Coding Example One

```
--
-- Read-First Mode
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;
entity rams_01 is
    port (clk : in std_logic;
          we  : in std_logic;
          en  : in std_logic;
          addr : in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          do  : out std_logic_vector(15 downto 0));
end rams_01;

architecture syn of rams_01 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM: ram_type;
begin

    process (clk)

```


Single-Port RAM in Write-First Mode Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| en | Clock Enable |
| addr | Read/Write Address |
| di | Data Input |
| do | Data Output |

Single-Port RAM in Write-First Mode VHDL Coding Example One

```
--
-- Write-First Mode (template 1)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_02a is
    port (clk : in std_logic;
          we  : in std_logic;
          en  : in std_logic;
          addr: in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          do  : out std_logic_vector(15 downto 0));
end rams_02a;

architecture syn of rams_02a is
    type ram_type is array (63 downto 0)
        of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
begin

    process (clk)
    begin
        if clk'event and clk = '1' then
            if en = '1' then
                if we = '1' then
                    RAM(conv_integer(addr)) <= di;
                    do <= di;
                else
                    do <= RAM( conv_integer(addr));
                end if;
            end if;
        end if;
    end process;

end syn;
```

Single-Port RAM in Write-First Mode VHDL Coding Example Two

```
--
-- Write-First Mode (template 2)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_02b is
port (clk : in std_logic;
      we : in std_logic;
      en : in std_logic;
      addr : in std_logic_vector(5 downto 0);
      di : in std_logic_vector(15 downto 0);
      do : out std_logic_vector(15 downto 0));
end rams_02b;

architecture syn of rams_02b is
  type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
  signal RAM : ram_type;
  signal read_addr: std_logic_vector(5 downto 0);
begin

  process (clk)
  begin
    if clk'event and clk = '1' then
      if en = '1' then
        if we = '1' then
          ram(conv_integer(addr)) <= di;
        end if;
        read_addr <= addr;
      end if;
    end if;
  end process;

  do <= ram(conv_integer(read_addr));

end syn;
```

Single-Port RAM In Write-First Mode Verilog Coding Example One

```
//
// Write-First Mode (template 1)
//

module v_rams_02a (clk, we, en, addr, di, do);

  input  clk;
  input  we;
  input  en;
  input  [5:0] addr;
  input  [15:0] di;
  output [15:0] do;
  reg    [15:0] RAM [63:0];
  reg    [15:0] do;

  always @(posedge clk)
  begin
    if (en)
    begin
      if (we)
      begin
        RAM[addr] <= di;
      end
    end
  end
endmodule
```

```

        do <= di;
    end
    else
        do <= RAM[addr];
    end
end
end
endmodule

```

Single-Port RAM In Write-First Mode Verilog Coding Example Two

```

//
// Write-First Mode (template 2)
//

module v_rams_02b (clk, we, en, addr, di, do);

    input  clk;
    input  we;
    input  en;
    input  [5:0] addr;
    input  [15:0] di;
    output [15:0] do;
    reg    [15:0] RAM [63:0];
    reg    [5:0] read_addr;

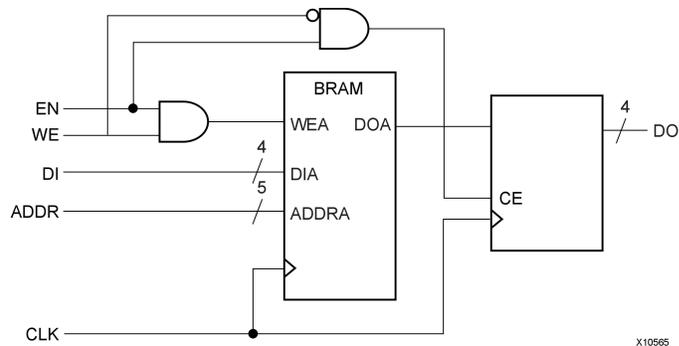
    always @(posedge clk)
    begin
        if (en)
        begin
            if (we)
                RAM[addr] <= di;
                read_addr <= addr;
            end
        end

        assign do = RAM[read_addr];
    end

endmodule

```

Single-Port RAM In No-Change Mode Diagram



Single-Port RAM In No-Change Mode Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| en | Clock Enable |
| addr | Read/Write Address |
| di | Data Input |
| do | Data Output |

Single-Port RAM In No-Change Mode VHDL Coding Example Two

```
--
-- No-Change Mode (template 1)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_03 is
    port (clk : in std_logic;
          we  : in std_logic;
          en  : in std_logic;
          addr : in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          do  : out std_logic_vector(15 downto 0));
end rams_03;

architecture syn of rams_03 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
begin

    process (clk)
    begin
        if clk'event and clk = '1' then
            if en = '1' then
                if we = '1' then
                    RAM(conv_integer(addr)) <= di;
                else
                    do <= RAM( conv_integer(addr));
                end if;
            end if;
        end if;
    end process;

end syn;
```

Single-Port RAM In No-Change Mode Verilog Coding Example Two

```
//
// No-Change Mode (template 1)
//

module v_rams_03 (clk, we, en, addr, di, do);

    input  clk;
    input  we;
    input  en;
    input  [5:0] addr;
    input  [15:0] di;
    output [15:0] do;
```

```

reg    [15:0] RAM [63:0];
reg    [15:0] do;

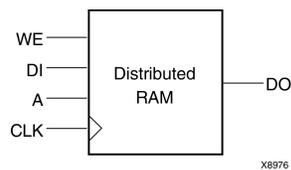
always @(posedge clk)
begin
    if (en)
    begin
        if (we)
            RAM[addr] <= di;
        else
            do <= RAM[addr];
        end
    end
end

endmodule

```

The following descriptions are directly mappable onto *distributed RAM only*.

Single-Port RAM With Asynchronous Read Diagram



Single-Port RAM With Asynchronous Read Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| a | Read/Write Address |
| di | Data Input |
| do | Data Output |

Single-Port RAM With Asynchronous Read VHDL Coding Example

```

--
-- Single-Port RAM with Asynchronous Read
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_04 is
    port (clk : in std_logic;
          we  : in std_logic;
          a   : in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          do  : out std_logic_vector(15 downto 0));
end rams_04;

architecture syn of rams_04 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
begin

    process (clk)

```

```

begin
  if (clk'event and clk = '1') then
    if (we = '1') then
      RAM(conv_integer(a)) <= di;
    end if;
  end if;
end process;

do <= RAM(conv_integer(a));

end syn;

```

Single-Port RAM With Asynchronous Read Verilog Coding Example

```

//
// Single-Port RAM with Asynchronous Read
//

module v_rams_04 (clk, we, a, di, do);

  input  clk;
  input  we;
  input  [5:0] a;
  input  [15:0] di;
  output [15:0] do;
  reg    [15:0] ram [63:0];

  always @(posedge clk) begin
    if (we)
      ram[a] <= di;
  end

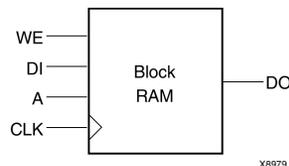
  assign do = ram[a];

endmodule

```

The following description implements a true synchronous read. A true synchronous read is the synchronization mechanism in Virtex device block RAMs, where the read address is registered on the RAM clock edge. Such descriptions are *directly mappable onto block RAM*, as shown in the diagram below. The same descriptions can also be mapped onto *Distributed RAM*.

Single-Port RAM With Synchronous Read (Read Through) Diagram



Single-Port RAM With Synchronous Read (Read Through) Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| a | Read/Write Address |
| di | Data Input |
| do | Data Output |

Single-Port RAM With Synchronous Read (Read Through) VHDL Coding Example

```
--
-- Single-Port RAM with Synchronous Read (Read Through)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_07 is
    port (clk : in std_logic;
          we  : in std_logic;
          a   : in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          do  : out std_logic_vector(15 downto 0));
end rams_07;

architecture syn of rams_07 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
    signal read_a : std_logic_vector(5 downto 0);
begin

    process (clk)
    begin
        if (clk'event and clk = '1') then
            if (we = '1') then
                RAM(conv_integer(a)) <= di;
            end if;
            read_a <= a;
        end if;
    end process;

    do <= RAM(conv_integer(read_a));

end syn;
```

Single-Port RAM With Synchronous Read (Read Through) Verilog Coding Example

```
//
// Single-Port RAM with Synchronous Read (Read Through)
//

module v_rams_07 (clk, we, a, di, do);

    input  clk;
    input  we;
    input  [5:0] a;
    input  [15:0] di;
    output [15:0] do;
```

```

reg    [15:0] ram [63:0];
reg    [5:0] read_a;

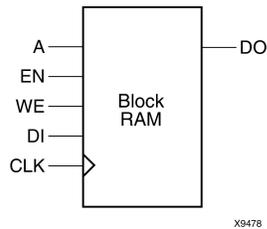
always @(posedge clk) begin
    if (we)
        ram[a] <= di;
        read_a <= a;
    end

assign do = ram[read_a];

endmodule

```

Single-Port RAM With Enable Diagram



Single-Port RAM With Enable Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| en | Global Enable |
| we | Synchronous Write Enable (active-High) |
| a | Read/Write Address |
| di | Data Input |
| do | Data Output |

Single-Port RAM With Enable VHDL Coding Example

```

--
-- Single-Port RAM with Enable
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_08 is
    port (clk : in std_logic;
          en  : in std_logic;
          we  : in std_logic;
          a   : in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          do  : out std_logic_vector(15 downto 0));
end rams_08;

architecture syn of rams_08 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
    signal read_a : std_logic_vector(5 downto 0);
begin

    process (clk)

```

```

begin
  if (clk'event and clk = '1') then
    if (en = '1') then
      if (we = '1') then
        RAM(conv_integer(a)) <= di;
      end if;
      read_a <= a;
    end if;
  end if;
end process;

do <= RAM(conv_integer(read_a));

end syn;

```

Single-Port RAM With Enable Verilog Coding Example

```

//
// Single-Port RAM with Enable
//

module v_rams_08 (clk, en, we, a, di, do);

    input  clk;
    input  en;
    input  we;
    input  [5:0] a;
    input  [15:0] di;
    output [15:0] do;
    reg    [15:0] ram [63:0];
    reg    [5:0] read_a;

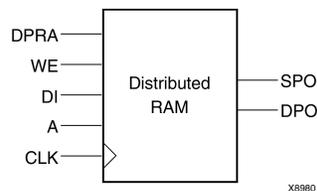
    always @(posedge clk) begin
        if (en)
            begin
                if (we)
                    ram[a] <= di;
                read_a <= a;
            end
        end

        assign do = ram[read_a];
    endmodule

```

The following diagram shows where the two output ports are used. It is directly mappable onto *Distributed RAM only*.

Dual-Port RAM With Asynchronous Read Diagram



Dual-Port RAM With Asynchronous Read Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| a | Write Address/Primary Read Address |
| dpra | Dual Read Address |
| di | Data Input |
| spo | Primary Output Port |
| dpo | Dual Output Port |

Dual-Port RAM With Asynchronous Read VHDL Coding Example

```
--
-- Dual-Port RAM with Asynchronous Read
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_09 is
  port (clk : in std_logic;
        we : in std_logic;
        a : in std_logic_vector(5 downto 0);
        dpra : in std_logic_vector(5 downto 0);
        di : in std_logic_vector(15 downto 0);
        spo : out std_logic_vector(15 downto 0);
        dpo : out std_logic_vector(15 downto 0));
end rams_09;

architecture syn of rams_09 is
  type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
  signal RAM : ram_type;
begin

  process (clk)
  begin
    if (clk'event and clk = '1') then
      if (we = '1') then
        RAM(conv_integer(a)) <= di;
      end if;
    end if;
  end process;

  spo <= RAM(conv_integer(a));
  dpo <= RAM(conv_integer(dpra));

end syn;
```

Dual-Port RAM With Asynchronous Read Verilog Coding Example

```
//
// Dual-Port RAM with Asynchronous Read
//

module v_rams_09 (clk, we, a, dpra, di, spo, dpo);

    input  clk;
    input  we;
    input  [5:0] a;
    input  [5:0] dpra;
    input  [15:0] di;
    output [15:0] spo;
    output [15:0] dpo;
    reg    [15:0] ram [63:0];

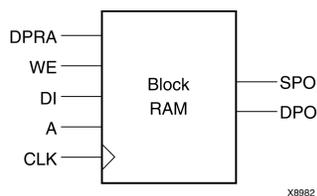
    always @(posedge clk) begin
        if (we)
            ram[a] <= di;
    end

    assign spo = ram[a];
    assign dpo = ram[dpra];

endmodule
```

The following descriptions are directly mappable onto block RAM, as shown in the diagram below. They may also be implemented with Distributed RAM.

Dual-Port RAM With Synchronous Read (Read Through) Diagram



Dual-Port RAM With Synchronous Read (Read Through) Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| a | Write Address/Primary Read Address |
| dpra | Dual Read Address |
| di | Data Input |
| spo | Primary Output Port |
| dpo | Dual Output Port |

Dual-Port RAM With Synchronous Read (Read Through) VHDL Coding Example

```
--
-- Dual-Port RAM with Synchronous Read (Read Through)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_11 is
    port (clk : in std_logic;
          we  : in std_logic;
          a   : in std_logic_vector(5 downto 0);
          dpra : in std_logic_vector(5 downto 0);
          di  : in std_logic_vector(15 downto 0);
          spo : out std_logic_vector(15 downto 0);
          dpo : out std_logic_vector(15 downto 0));
end rams_11;

architecture syn of rams_11 is
    type ram_type is array (63 downto 0)
        of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
    signal read_a : std_logic_vector(5 downto 0);
    signal read_dpra : std_logic_vector(5 downto 0);
begin

    process (clk)
    begin
        if (clk'event and clk = '1') then
            if (we = '1') then
                RAM(conv_integer(a)) <= di;
            end if;
            read_a <= a;
            read_dpra <= dpra;
        end if;
    end process;

    spo <= RAM(conv_integer(read_a));
    dpo <= RAM(conv_integer(read_dpra));

end syn;
```

Dual-Port RAM With Synchronous Read (Read Through) Verilog Coding Example

```
//
// Dual-Port RAM with Synchronous Read (Read Through)
//

module v_rams_11 (clk, we, a, dpra, di, spo, dpo);

    input  clk;
    input  we;
    input  [5:0] a;
    input  [5:0] dpra;
```

```

input  [15:0] di;
output [15:0] spo;
output [15:0] dpo;
reg    [15:0] ram [63:0];
reg    [5:0] read_a;
reg    [5:0] read_dpra;

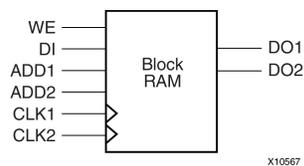
always @(posedge clk) begin
    if (we)
        ram[a] <= di;
    read_a <= a;
    read_dpra <= dpra;
end

assign spo = ram[read_a];
assign dpo = ram[read_dpra];

endmodule

```

Dual-Port RAM With Synchronous Read (Read Through) and Two Clocks Diagram



Dual-Port RAM With Synchronous Read (Read Through) and Two Clocks Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk1 | Positive-Edge Write/Primary Read Clock |
| clk2 | Positive-Edge Dual Read Clock |
| we | Synchronous Write Enable (active-High) |
| add1 | Write/Primary Read Address |
| add2 | Dual Read Address |
| di | Data Input |
| do1 | Primary Output Port |
| do2 | Dual Output Port |

Dual-Port RAM With Synchronous Read (Read Through) and Two Clocks VHDL Coding Example

```
--
-- Dual-Port RAM with Synchronous Read (Read Through)
-- using More than One Clock
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_12 is
    port (clk1 : in std_logic;
          clk2 : in std_logic;
          we   : in std_logic;
          add1 : in std_logic_vector(5 downto 0);
          add2 : in std_logic_vector(5 downto 0);
          di   : in std_logic_vector(15 downto 0);
          do1  : out std_logic_vector(15 downto 0);
          do2  : out std_logic_vector(15 downto 0));
end rams_12;

architecture syn of rams_12 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
    signal read_add1 : std_logic_vector(5 downto 0);
    signal read_add2 : std_logic_vector(5 downto 0);
begin

    process (clk1)
    begin
        if (clk1'event and clk1 = '1') then
            if (we = '1') then
                RAM(conv_integer(add1)) <= di;
            end if;
            read_add1 <= add1;
        end if;
    end process;

    do1 <= RAM(conv_integer(read_add1));

    process (clk2)
    begin
        if (clk2'event and clk2 = '1') then
            read_add2 <= add2;
        end if;
    end process;

    do2 <= RAM(conv_integer(read_add2));

end syn;
```

Dual-Port RAM With Synchronous Read (Read Through) and Two Clocks Verilog Coding Example

```
//
// Dual-Port RAM with Synchronous Read (Read Through)
// using More than One Clock
//

module v_rams_12 (clk1, clk2, we, add1, add2, di, do1, do2);

    input  clk1;
    input  clk2;
    input  we;
    input  [5:0] add1;
    input  [5:0] add2;
```

```

input  [15:0] di;
output [15:0] do1;
output [15:0] do2;
reg    [15:0] ram [63:0];
reg    [5:0] read_add1;
reg    [5:0] read_add2;

always @(posedge clk1) begin
    if (we)
        ram[add1] <= di;
        read_add1 <= add1;
    end

assign do1 = ram[read_add1];

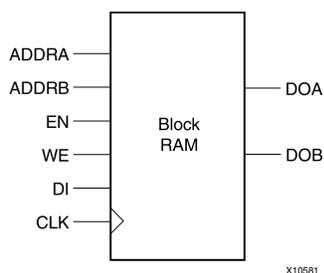
always @(posedge clk2) begin
    read_add2 <= add2;
end

assign do2 = ram[read_add2];

endmodule

```

Dual-Port RAM With One Enable Controlling Both Ports Diagram



Dual-Port RAM With One Enable Controlling Both Ports Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| en | Primary Global Enable (active-High) |
| we | Primary Synchronous Write Enable (active-High) |
| addra | Write Address/Primary Read Address |
| addrb | Dual Read Address |
| di | Primary Data Input |
| doa | Primary Output Port |
| dob | Dual Output Port |

Dual-Port RAM With One Enable Controlling Both Ports VHDL Coding Example

```
--
-- Dual-Port RAM with One Enable Controlling Both Ports
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_13 is
    port (clk      : in std_logic;
          en       : in std_logic;
          we       : in std_logic;
          addra    : in std_logic_vector(5 downto 0);
          addrb    : in std_logic_vector(5 downto 0);
          di       : in std_logic_vector(15 downto 0);
          doa      : out std_logic_vector(15 downto 0);
          dob      : out std_logic_vector(15 downto 0));
end rams_13;

architecture syn of rams_13 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
    signal read_addra : std_logic_vector(5 downto 0);
    signal read_addrb : std_logic_vector(5 downto 0);
begin

    process (clk)
    begin
        if (clk'event and clk = '1') then
            if (en = '1') then
                if (we = '1') then
                    RAM(conv_integer(addra)) <= di;
                end if;

                read_addra <= addra;
                read_addrb <= addrb;

            end if;
        end if;
    end process;

    doa <= RAM(conv_integer(read_addra));
    dob <= RAM(conv_integer(read_addrb));

end syn;
```

Dual-Port RAM With One Enable Controlling Both Ports Verilog Coding Example

```
//
// Dual-Port RAM with One Enable Controlling Both Ports
//

module v_rams_13 (clk, en, we, addra, addrb, di, doa, dob);

    input  clk;
    input  en;
    input  we;
    input  [5:0] addra;
    input  [5:0] addrb;
    input  [15:0] di;
    output [15:0] doa;
    output [15:0] dob;
    reg    [15:0] ram [63:0];
    reg    [5:0] read_addra;
```

```

reg    [5:0] read_addrb;

always @(posedge clk) begin
    if (en)
        begin
            if (we)
                ram[addra] <= di;
            read_addra <= addra;
            read_addrb <= addrb;
        end
    end

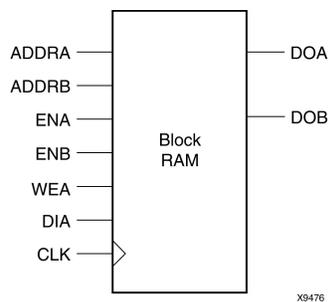
assign doa = ram[read_addra];
assign dob = ram[read_addrb];

endmodule

```

The following descriptions are directly mappable onto block RAM, as shown in the diagram.

Dual Port RAM With Enable on Each Port Diagram



Dual Port RAM With Enable on Each Port Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| ena | Primary Global Enable (active-High) |
| enb | Dual Global Enable (active-High) |
| wea | Primary Synchronous Write Enable (active-High) |
| addra | Write Address/Primary Read Address |
| addrb | Dual Read Address |
| dia | Primary Data Input |
| doa | Primary Output Port |
| dob | Dual Output Port |

Dual Port RAM With Enable on Each Port VHDL Coding Example

```
--
-- Dual-Port RAM with Enable on Each Port
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_14 is
    port (clk      : in std_logic;
          ena      : in std_logic;
          enb      : in std_logic;
          wea      : in std_logic;
          addra    : in std_logic_vector(5 downto 0);
          addrb    : in std_logic_vector(5 downto 0);
          dia      : in std_logic_vector(15 downto 0);
          doa      : out std_logic_vector(15 downto 0);
          dob      : out std_logic_vector(15 downto 0));
end rams_14;

architecture syn of rams_14 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal RAM : ram_type;
    signal read_addra : std_logic_vector(5 downto 0);
    signal read_addrb : std_logic_vector(5 downto 0);
begin

    process (clk)
    begin
        if (clk'event and clk = '1') then

            if (ena = '1') then
                if (wea = '1') then
                    RAM(conv_integer(addra)) <= dia;
                end if;
                read_addra <= addra;
            end if;

            if (enb = '1') then
                read_addrb <= addrb;
            end if;

        end if;
    end process;

    doa <= RAM(conv_integer(read_addra));
    dob <= RAM(conv_integer(read_addrb));

end syn;
```

Dual Port RAM With Enable on Each Port Verilog Coding Example

```
//
// Dual-Port RAM with Enable on Each Port
//

module v_rams_14 (clk,ena,enb,wea,addra,addrb,dia,doa,dob);

    input  clk;
    input  ena;
    input  enb;
    input  wea;
    input  [5:0] addra;
    input  [5:0] addrb;
    input  [15:0] dia;
    output [15:0] doa;
    output [15:0] dob;
```

```

reg    [15:0] ram [63:0];
reg    [5:0] read_addra;
reg    [5:0] read_addrb;

always @(posedge clk) begin
    if (ena)
        begin
            if (wea)
                ram[addr_a] <= dia;
            read_addra <= addr_a;
        end

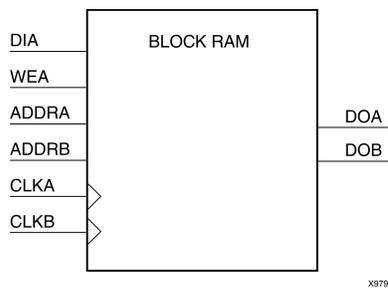
    if (enb)
        read_addrb <= addrb;
end

assign doa = ram[read_addra];
assign dob = ram[read_addrb];

endmodule

```

Dual-Port Block RAM With Different Clocks Diagram



Dual-Port Block RAM With Different Clock Pin Descriptions

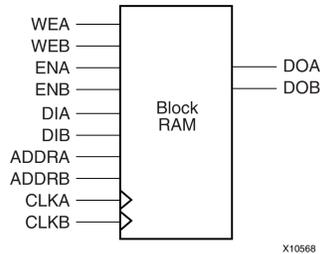
| IO Pins | Description |
|---------|--|
| clka | Positive-Edge Clock |
| clkb | Positive-Edge Clock |
| wea | Primary Synchronous Write Enable (active-High) |
| addr_a | Write Address/Primary Read Address |
| addr_b | Dual Read Address |
| dia | Primary Data Input |
| doa | Primary Output Port |
| dob | Dual Output Port |

XST supports dual-port block RAMs with two write ports for VHDL and Verilog.

The concept of dual-write ports implies not only distinct data ports, but the possibility of distinct write clocks and write enables as well. Distinct write clocks also mean distinct read clocks, since the dual-port block RAM offers two clocks, one shared by the primary read and write port, the other shared by the secondary read and write port.

In VHDL, the description of this type of block RAM is based on the usage of shared variables. The XST VHDL analyzer accepts shared variables, but errors out in the HDL Synthesis step if a shared variable does not describe a valid RAM macro.

Dual-Port Block RAM With Two Write Ports Diagram



Dual-Port Block RAM With Two Write Ports Pin Descriptions

| IO Pins | Description |
|------------|--|
| clka, clkb | Positive-Edge Clock |
| ena | Primary Global Enable (active-High) |
| enb | Dual Global Enable (active-High) |
| wea, web | Primary Synchronous Write Enable (active-High) |
| addr a | Write Address/Primary Read Address |
| addr b | Dual Read Address |
| dia | Primary Data Input |
| dib | Dual Data Input |
| doa | Primary Output Port |
| dob | Dual Output Port |

Dual-Port Block RAM With Two Write Ports VHDL Coding Example

This is the most general example. It has different clocks, enables, and write enables.

```
--
-- Dual-Port Block RAM with Two Write Ports
--

library IEEE;
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;

entity rams_16 is
    port(clka : in std_logic;
         clkb : in std_logic;
         ena : in std_logic;
         enb : in std_logic;
         wea : in std_logic;
         web : in std_logic;
         addr a : in std_logic_vector(5 downto 0);
         addr b : in std_logic_vector(5 downto 0);
         dia : in std_logic_vector(15 downto 0);
         dib : in std_logic_vector(15 downto 0);
         doa : out std_logic_vector(15 downto 0);
         dob : out std_logic_vector(15 downto 0));
end rams_16;

architecture syn of rams_16 is
```

```

type ram_type is array (63 downto 0) of std_logic_vector(15 downto 0);
shared variable RAM : ram_type;
begin

  process (CLKA)
  begin
    if CLKA'event and CLKA = '1' then
      if ENA = '1' then
        if WEA = '1' then
          RAM(conv_integer(ADDRA)) := DIA;
        end if;
        DOA <= RAM(conv_integer(ADDRA));
      end if;
    end if;
  end process;

  process (CLKB)
  begin
    if CLKB'event and CLKB = '1' then
      if ENB = '1' then
        if WEB = '1' then
          RAM(conv_integer(ADDRB)) := DIB;
        end if;
        DOB <= RAM(conv_integer(ADDRB));
      end if;
    end if;
  end process;
end syn;

```

Because of the shared variable, the description of the different read/write synchronizations may be different from coding examples recommended for single-write RAMs. The order of appearance of the different lines of code is significant.

Dual-Port Block RAM With Two Write Ports Verilog Coding Example

This is the most general example. It has different clocks, enables, and write enables.

```

//
// Dual-Port Block RAM with Two Write Ports
//

module v_rams_16 (clka,clkb,ena,enb,wea,web,addra,addrb,dia,dib,doa,dob);

  input  clka,clkb,ena,enb,wea,web;
  input  [5:0]  addra,addrb;
  input  [15:0] dia,dib;
  output [15:0] doa,dob;
  reg    [15:0] ram [63:0];
  reg    [15:0] doa,dob;

  always @(posedge clka) begin
    if (ena)
      begin
        if (wea)
          ram[addra] <= dia;
          doa <= ram[addra];
        end
      end
  end

  always @(posedge clkb) begin
    if (enb)
      begin
        if (web)
          ram[addrb] <= dib;
          dob <= ram[addrb];
        end
      end
  end
endmodule

```

Write-First Synchronization Coding Example One

```
process (CLKA)
begin
  if CLKA'event and CLKA = '1' then
    if WEA = '1' then
      RAM(conv_integer(ADDRA)) := DIA;
      DOA <= DIA;
    else
      DOA <= RAM(conv_integer(ADDRA));
    end if;
  end if;
end process;
```

Write-First Synchronization Coding Example Two

In this example, the read statement necessarily comes after the write statement.

```
process (CLKA)
begin
  if CLKA'event and CLKA = '1' then
    if WEA = '1' then
      RAM(conv_integer(ADDRA)) := DIA;
    end if;
    DOA <= RAM(conv_integer(ADDRA)); -- The read statement must come
                                     -- AFTER the write statement
  end if;
end process;
```

Although they may look the same except for the signal/variable difference, it is also important to understand the functional difference between this template and the following well known template which describes a read-first synchronization in a single-write RAM.

```
signal RAM : RAMtype;

process (CLKA)
begin
  if CLKA'event and CLKA = '1' then
    if WEA = '1' then
      RAM(conv_integer(ADDRA)) <= DIA;
    end if;
    DOA <= RAM(conv_integer(ADDRA));
  end if;
end process;
```

Read-First Synchronization Coding Example

A read-first synchronization is described as follows, where the read statement must come BEFORE the write statement.

```
process (CLKA)
begin
  if CLKA'event and CLKA = '1' then
    DOA <= RAM(conv_integer(ADDRA)); -- The read statement must come
                                     -- BEFORE the write statement

    if WEA = '1' then
      RAM(conv_integer(ADDRA)) := DIA;
    end if;
  end if;
end process;
```

No-Change Synchronization Coding Example

```

process (CLKA)
begin
  if CLKA'event and CLKA = '1' then
    if WEA = '1' then
      RAM(conv_integer(ADDR)) := DIA;
    else
      DOA <= RAM(conv_integer(ADDR));
    end if;
  end if;
end process;

```

Single and Dual-Port Block RAM with Byte-Wide Write Enable

XST supports single and dual-port block RAM with Byte-wide Write Enable for VHDL and Verilog. The RAM can be seen as a collection of equal size columns. During a write cycle, you separately control writing into each of these columns.

- Multiple Write Statement

There is one separate write access statement, including the description of the related write enable, for each column.

- Single Write Statement

Allows you to describe only one write access statement. The write enables are described separately outside the main sequential process. XST currently supports this method only.

The two methods for describing column-based RAM writes are shown in the following coding examples.

Multiple Write Statement VHDL Coding Example

```

type ram_type is array (SIZE-1 downto 0)
  of std_logic_vector (2*WIDTH-1 downto 0);
signal RAM : ram_type;

(...)

process(clk)
begin
  if posedge(clk) then
    if we(1) = '1' then
      RAM(conv_integer(addr))(2*WIDTH-1 downto WIDTH) <= di(2*WIDTH-1 downto WIDTH);
    end if;
    if we(0) = '1' then
      RAM(conv_integer(addr))(WIDTH-1 downto 0) <= di(WIDTH-1 downto 0);
    end if;

    do <= RAM(conv_integer(addr));
  end if;
end process;

```

Multiple Write Statement Verilog Coding Example

```

reg      [2*DI_WIDTH-1:0] RAM [SIZE-1:0];

always @(posedge clk)
begin
    if (we[1]) then
        RAM[addr][2*WIDTH-1:WIDTH] <= di[2*WIDTH-1:WIDTH];
    end if;
    if (we[0]) then
        RAM[addr][WIDTH-1:0] <= di[WIDTH-1:0];
    end if;

    do <= RAM[addr];
end

```

Single Write Statement VHDL Coding Example

```

type ram_type is array (SIZE-1 downto 0)
    of std_logic_vector (2*WIDTH-1 downto 0);
signal RAM : ram_type;
signal di0, di1 : std_logic_vector (WIDTH-1 downto 0);

(...)

-- Write enables described outside main sequential process
process(we, di, addr)
begin
    if we(1) = '1' then
        di1 <= di(2*WIDTH-1 downto WIDTH);
    else
        di1 <= RAM(conv_integer(addr))(2*WIDTH-1 downto WIDTH);
    end if;

    if we(0) = '1' then
        di0 <= di(WIDTH-1 downto 0);
    else
        di0 <= RAM(conv_integer(addr))(WIDTH-1 downto 0);
    end if;

end process;

process(clk)
begin
    if posedge(clk) then
        if en = '1' then
            RAM(conv_integer(addr)) <= di1 & di0; -- single write access statement
            do <= RAM(conv_integer(addr));
        end if;
    end if;
end process;

```

Single Write Statement Verilog Coding Example

```

reg      [2*DI_WIDTH-1:0] RAM [SIZE-1:0];
reg      [DI_WIDTH-1:0]   di0, di1;

always @(we or di or addr)
begin
    if (we[1])
        di1 = di[2*DI_WIDTH-1:1*DI_WIDTH];
    else
        di1 = RAM[addr][2*DI_WIDTH-1:1*DI_WIDTH];

    if (we[0])
        di0 = di[DI_WIDTH-1:0];

```

```

        else
            di0 = RAM[addr][DI_WIDTH-1:0];
        end

always @(posedge clk)
begin
    RAM[addr]<={di1,di0};
    do <= RAM[addr];
end

```

To simplify the understanding of byte-wide write enable templates, the following coding examples use single-port block RAMs. XST supports dual-port Block RAM, as well as byte-wide write enable.

Read-First Mode: Single-Port BRAM with Byte-wide Write Enable (2 Bytes) Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| clk | Positive-Edge Clock |
| we | Write Enable |
| addr | Write/Read Address |
| di | Data Input |
| do | RAM Output Port |

Read-First Mode: Single-Port BRAM With Byte-Wide Write Enable (2 Bytes) VHDL Coding Example

```

--
-- Single-Port BRAM with Byte-wide Write Enable (2 bytes) in Read-First Mode
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_24 is
    generic (SIZE          : integer := 512;
            ADDR_WIDTH    : integer := 9;
            DI_WIDTH      : integer := 8);

    port (clk : in  std_logic;
          we  : in  std_logic_vector(1 downto 0);
          addr : in  std_logic_vector(ADDR_WIDTH-1 downto 0);
          di   : in  std_logic_vector(2*DI_WIDTH-1 downto 0);
          do   : out std_logic_vector(2*DI_WIDTH-1 downto 0));
end rams_24;

architecture syn of rams_24 is

    type ram_type is array (SIZE-1 downto 0) of std_logic_vector (2*DI_WIDTH-1 downto 0);
    signal RAM : ram_type;

    signal di0, di1 : std_logic_vector (DI_WIDTH-1 downto 0);
begin

    process(we, di)
    begin
        if we(1) = '1' then
            di1 <= di(2*DI_WIDTH-1 downto 1*DI_WIDTH);
        else
            di1 <= RAM(conv_integer(addr))(2*DI_WIDTH-1 downto 1*DI_WIDTH);
        end if;
    end process;
end architecture syn;

```

```

        if we(0) = '1' then
            di0 <= di(DI_WIDTH-1 downto 0);
        else
            di0 <= RAM(conv_integer(addr))(DI_WIDTH-1 downto 0);
        end if;
    end process;

    process(clk)
    begin
        if (clk'event and clk = '1') then
            RAM(conv_integer(addr)) <= di1 & di0;
            do <= RAM(conv_integer(addr));
        end if;
    end process;

end syn;

```

Read-First Mode: Single-Port BRAM With Byte-wide Write Enable (2 Bytes) Verilog Coding Example

```

//
// Single-Port BRAM with Byte-wide Write Enable (2 bytes) in Read-First Mode
//
module v_rams_24 (clk, we, addr, di, do);

    parameter SIZE      = 512;
    parameter ADDR_WIDTH = 9;
    parameter DI_WIDTH  = 8;

    input  clk;
    input  [1:0] we;
    input  [ADDR_WIDTH-1:0] addr;
    input  [2*DI_WIDTH-1:0] di;
    output [2*DI_WIDTH-1:0] do;
    reg    [2*DI_WIDTH-1:0] RAM [SIZE-1:0];
    reg    [2*DI_WIDTH-1:0] do;

    reg    [DI_WIDTH-1:0] di0, di1;

    always @(we or di)
    begin
        if (we[1])
            di1 = di[2*DI_WIDTH-1:1*DI_WIDTH];
        else
            di1 = RAM[addr][2*DI_WIDTH-1:1*DI_WIDTH];

        if (we[0])
            di0 = di[DI_WIDTH-1:0];
        else
            di0 = RAM[addr][DI_WIDTH-1:0];
    end

    always @(posedge clk)
    begin
        RAM[addr] <= {di1, di0};
        do <= RAM[addr];
    end

endmodule

```

Write-First Mode: Single-Port BRAM with Byte-wide Write Enable (2 Bytes) Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| Clk | Positive-Edge Clock |
| We | Write Enable |
| Addr | Write/Read Address |
| Di | Data Input |
| Do | RAM Output Port |

Write-First Mode: Single-Port BRAM with Byte-Wide Write Enable (2 Bytes) VHDL Coding Example

```
--
-- Single-Port BRAM with Byte-wide Write Enable (2 bytes) in Write-First Mode
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_25 is
    generic (SIZE      : integer := 512;
            ADDR_WIDTH : integer := 9;
            DI_WIDTH   : integer := 8);

    port (clk : in  std_logic;
          we  : in  std_logic_vector(1 downto 0);
          addr : in  std_logic_vector(ADDR_WIDTH-1 downto 0);
          di   : in  std_logic_vector(2*DI_WIDTH-1 downto 0);
          do   : out std_logic_vector(2*DI_WIDTH-1 downto 0));
end rams_25;

architecture syn of rams_25 is
    type ram_type is array (SIZE-1 downto 0) of std_logic_vector (2*DI_WIDTH-1 downto 0);
    signal RAM : ram_type;

    signal di0, di1 : std_logic_vector (DI_WIDTH-1 downto 0);
    signal do0, do1 : std_logic_vector (DI_WIDTH-1 downto 0);
begin

    process(we, di)
    begin
        if we(1) = '1' then
            di1 <= di(2*DI_WIDTH-1 downto 1*DI_WIDTH);
            do1 <= di(2*DI_WIDTH-1 downto 1*DI_WIDTH);
        else
            di1 <= RAM(conv_integer(addr))(2*DI_WIDTH-1 downto 1*DI_WIDTH);
            do1 <= RAM(conv_integer(addr))(2*DI_WIDTH-1 downto 1*DI_WIDTH);
        end if;

        if we(0) = '1' then
            di0 <= di(DI_WIDTH-1 downto 0);
            do0 <= di(DI_WIDTH-1 downto 0);
        else
            di0 <= RAM(conv_integer(addr))(DI_WIDTH-1 downto 0);
            do0 <= RAM(conv_integer(addr))(DI_WIDTH-1 downto 0);
        end if;
    end process;

    process(clk)
    begin
        if (clk'event and clk = '1') then
            RAM(conv_integer(addr)) <= di1 & di0;
            do <= do1 & do0;
        end if;
    end process;
end process;
```

```
end syn;
```

Write-First Mode: Single-Port BRAM with Byte-Wide Write Enable (2 Bytes) Verilog Coding Example

```
//
// Single-Port BRAM with Byte-wide Write Enable
// (2 bytes) in Write-First Mode
//

module v_rams_25 (clk, we, addr, di, do);

    parameter SIZE      = 512;
    parameter ADDR_WIDTH = 9;
    parameter DI_WIDTH  = 8;

    input  clk;
    input  [1:0] we;
    input  [ADDR_WIDTH-1:0] addr;
    input  [2*DI_WIDTH-1:0] di;
    output [2*DI_WIDTH-1:0] do;
    reg    [2*DI_WIDTH-1:0] RAM [SIZE-1:0];
    reg    [2*DI_WIDTH-1:0] do;

    reg    [DI_WIDTH-1:0]  di0, di1;
    reg    [DI_WIDTH-1:0]  do0, do1;

    always @(we or di)
    begin
        if (we[1])
            begin
                di1 = di[2*DI_WIDTH-1:1*DI_WIDTH];
                do1 = di[2*DI_WIDTH-1:1*DI_WIDTH];
            end
        else
            begin
                di1 = RAM[addr][2*DI_WIDTH-1:1*DI_WIDTH];
                do1 = RAM[addr][2*DI_WIDTH-1:1*DI_WIDTH];
            end

        if (we[0])
            begin
                di0 <= di[DI_WIDTH-1:0];
                do0 <= di[DI_WIDTH-1:0];
            end
        else
            begin
                di0 <= RAM[addr][DI_WIDTH-1:0];
                do0 <= RAM[addr][DI_WIDTH-1:0];
            end
        end

    end

    always @(posedge clk)
    begin
        RAM[addr] <= {di1, di0};
        do <= {do1, do0};
    end
end
```

```
endmodule
```

No-Change Mode: Single-Port BRAM with Byte-Wide Write Enable (2 Bytes) Pin Descriptions

| IO Pins | Description |
|---------|---------------------|
| Clk | Positive-Edge Clock |
| We | Write Enable |
| Addr | Write/Read Address |
| Di | Data Input |
| Do | RAM Output Port |

XST infers latches for `do1` and `do0` signals during the basic HDL Synthesis. These latches are absorbed by BRAM during the Advanced HDL Synthesis step.

No-Change Mode: Single-Port BRAM with Byte-Wide Write Enable (2 Bytes) VHDL Coding Example

```
--
-- Single-Port BRAM with Byte-wide Write Enable (2 bytes) in No-Change Mode
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_26 is
  generic (SIZE      : integer := 512;
          ADDR_WIDTH : integer := 9;
          DI_WIDTH   : integer := 8);

  port (clk : in std_logic;
        we  : in std_logic_vector(1 downto 0);
        addr : in std_logic_vector(ADDR_WIDTH-1 downto 0);
        di   : in std_logic_vector(2*DI_WIDTH-1 downto 0);
        do   : out std_logic_vector(2*DI_WIDTH-1 downto 0));
end rams_26;

architecture syn of rams_26 is
  type ram_type is array (SIZE-1 downto 0) of std_logic_vector (2*DI_WIDTH-1 downto 0);
  signal RAM : ram_type;

  signal di0, di1 : std_logic_vector (DI_WIDTH-1 downto 0);
  signal do0, do1 : std_logic_vector (DI_WIDTH-1 downto 0);
begin

  process(we, di)
  begin
    if we(1) = '1' then
      di1 <= di(2*DI_WIDTH-1 downto 1*DI_WIDTH);
    else
      di1 <= RAM(conv_integer(addr))(2*DI_WIDTH-1 downto 1*DI_WIDTH);
      do1 <= RAM(conv_integer(addr))(2*DI_WIDTH-1 downto 1*DI_WIDTH);
    end if;

    if we(0) = '1' then
      di0 <= di(DI_WIDTH-1 downto 0);
    else
      di0 <= RAM(conv_integer(addr))(DI_WIDTH-1 downto 0);
      do0 <= RAM(conv_integer(addr))(DI_WIDTH-1 downto 0);
    end if;
  end process;

  process(clk)
```

```

begin
  if (clk'event and clk = '1') then
    RAM(conv_integer(addr)) <= di1 & di0;
    do <= do1 & do0;
  end if;
end process;

end syn;

```

No-Change Mode: Single-Port BRAM with Byte-Wide Write Enable (2 Bytes) in Verilog Coding Example

```

//
// Single-Port BRAM with Byte-wide Write Enable
// (2 bytes) in No-Change Mode
//

module v_rams_26 (clk, we, addr, di, do);

    parameter SIZE      = 512;
    parameter ADDR_WIDTH = 9;
    parameter DI_WIDTH  = 8;

    input  clk;
    input  [1:0] we;
    input  [ADDR_WIDTH-1:0] addr;
    input  [2*DI_WIDTH-1:0] di;
    output [2*DI_WIDTH-1:0] do;
    reg    [2*DI_WIDTH-1:0] RAM [SIZE-1:0];
    reg    [2*DI_WIDTH-1:0] do;

    reg    [DI_WIDTH-1:0] di0, di1;
    reg    [DI_WIDTH-1:0] do0, do1;

    always @(we or di)
    begin
        if (we[1])
            di1 = di[2*DI_WIDTH-1:1*DI_WIDTH];
        else
            begin
                di1 = RAM[addr][2*DI_WIDTH-1:1*DI_WIDTH];
                do1 = RAM[addr][2*DI_WIDTH-1:1*DI_WIDTH];
            end

            if (we[0])
                di0 <= di[DI_WIDTH-1:0];
            else
                begin
                    di0 <= RAM[addr][DI_WIDTH-1:0];
                    do0 <= RAM[addr][DI_WIDTH-1:0];
                end
            end

        end

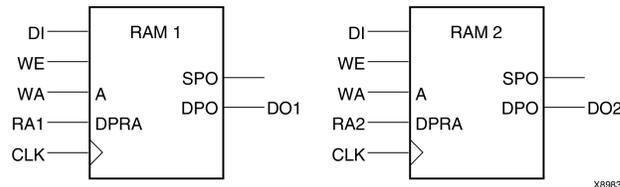
    always @(posedge clk)
    begin
        RAM[addr] <= {di1, di0};
        do <= {do1, do0};
    end
end

```

```
endmodule
```

XST can identify RAM descriptions with two or more read ports that access the RAM contents at addresses different from the write address. However, there can only be one write port. XST implements the following descriptions by replicating the RAM contents for each output port, as shown in the following figure.

Multiple-Port RAM Descriptions Diagram



Multiple-Port RAM Descriptions Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| wa | Write Address |
| ra1 | Read Address of the First RAM |
| ra2 | Read Address of the Second RAM |
| di | Data Input |
| do1 | First RAM Output Port |
| do2 | Second RAM Output Port |

Multiple-Port RAM Descriptions VHDL Coding Example

```
--
-- Multiple-Port RAM Descriptions
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_17 is
  port (clk : in std_logic;
        we  : in std_logic;
        wa  : in std_logic_vector(5 downto 0);
        ra1 : in std_logic_vector(5 downto 0);
        ra2 : in std_logic_vector(5 downto 0);
        di  : in std_logic_vector(15 downto 0);
        do1 : out std_logic_vector(15 downto 0);
        do2 : out std_logic_vector(15 downto 0));
end rams_17;

architecture syn of rams_17 is
  type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
  signal RAM : ram_type;
begin

  process (clk)
  begin
    if (clk'event and clk = '1') then
      if (we = '1') then
        RAM(conv_integer(wa)) <= di;
      end if;
    end if;
  end process;
end architecture;
```

```
        end if;
    end if;
end process;

do1 <= RAM(conv_integer(ra1));
do2 <= RAM(conv_integer(ra2));

end syn;
```

Multiple-Port RAM Descriptions Verilog Coding Example

```
//
// Multiple-Port RAM Descriptions
//

module v_rams_17 (clk, we, wa, ra1, ra2, di, do1, do2);

    input  clk;
    input  we;
    input  [5:0] wa;
    input  [5:0] ra1;
    input  [5:0] ra2;
    input  [15:0] di;
    output [15:0] do1;
    output [15:0] do2;
    reg    [15:0] ram [63:0];

    always @(posedge clk)
    begin
        if (we)
            ram[wa] <= di;
    end

    assign do1 = ram[ra1];
    assign do2 = ram[ra2];

endmodule
```

Block RAM with Reset on the Data Outputs

XST supports block RAM with reset on the data outputs, as offered with Virtex-4 devices, Virtex-5 devices, and related block RAM resources. Optionally, you can include a synchronously controlled initialization of the RAM data outputs.

Block RAM with the following synchronization modes can have re-settable data ports.

- Read-First Block RAM with Reset
- Write-First Block RAM with Reset
- No-Change Block RAM with Reset
- Registered ROM with Reset
- Supported Dual-Port Templates

Because XST does not support block RAMs with dual-write in a dual-read block RAM description, both data outputs may be reset, but the various read-write synchronizations are allowed for the primary data output only. The dual output may be used in Read-First Mode only.

Block RAM With Reset Pin Descriptions

| IO Pins | Description |
|---------|----------------------------|
| clk | Positive-Edge Clock |
| en | Global Enable |
| we | Write Enable (active-High) |
| addr | Read/Write Address |
| rst | Reset for data output |
| di | Data Input |
| do | RAM Output Port |

Block RAM With Reset VHDL Coding Example

```
--
-- Block RAM with Reset
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_18 is
  port (clk : in std_logic;
        en  : in std_logic;
        we  : in std_logic;
        rst : in std_logic;
        addr: in std_logic_vector(5 downto 0);
        di  : in std_logic_vector(15 downto 0);
        do  : out std_logic_vector(15 downto 0));
end rams_18;

architecture syn of rams_18 is
  type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
  signal ram : ram_type;
begin

  process (clk)
  begin
    if clk'event and clk = '1' then
      if en = '1' then -- optional enable

        if we = '1' then -- write enable
          ram(conv_integer(addr)) <= di;
        end if;

        if rst = '1' then -- optional reset
          do <= (others => '0');
        else
          do <= ram(conv_integer(addr)) ;
        end if;

      end if;
    end if;
  end process;

end syn;
```

Block RAM With Reset Verilog Coding Example

```
//
// Block RAM with Reset
//

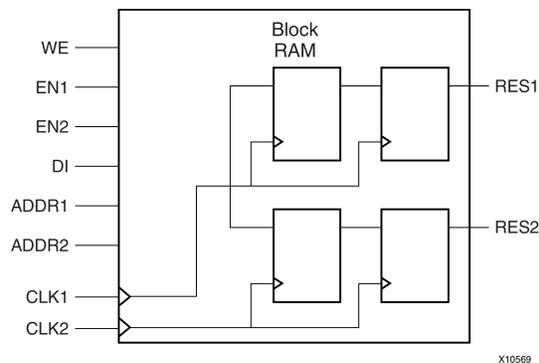
module v_rams_18 (clk, en, we, rst, addr, di, do);

    input  clk;
    input  en;
    input  we;
    input  rst;
    input  [5:0] addr;
    input  [15:0] di;
    output [15:0] do;
    reg    [15:0] ram [63:0];
    reg    [15:0] do;

    always @(posedge clk)
    begin
        if (en) // optional enable
        begin
            if (we) // write enable
                ram[addr] <= di;

            if (rst) // optional reset
                do <= 16'h0000;
            else
                do <= ram[addr];
        end
    end
endmodule
```

Block RAM With Optional Output Registers Diagram



Block RAM With Optional Output Registers Pin Descriptions

| IO Pins | Description |
|------------|----------------------------|
| clk1, clk2 | Positive-Edge Clock |
| we | Write Enable |
| en1, en2 | Clock Enable (active-High) |
| addr1 | Primary Read Address |
| addr2 | Dual Read Address |
| di | Data Input |
| res1 | Primary Output Port |
| res2 | Dual Output Port |

Block RAM With Optional Output Registers VHDL Coding Example

```
--
-- Block RAM with Optional Output Registers
--

library IEEE;
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;

entity rams_19 is
    port (clk1, clk2    : in std_logic;
          we, en1, en2 : in std_logic;
          addr1         : in std_logic_vector(5 downto 0);
          addr2         : in std_logic_vector(5 downto 0);
          di            : in std_logic_vector(15 downto 0);
          res1          : out std_logic_vector(15 downto 0);
          res2          : out std_logic_vector(15 downto 0));
end rams_19;

architecture beh of rams_19 is
    type ram_type is array (63 downto 0) of std_logic_vector (15 downto 0);
    signal ram : ram_type;
    signal do1 : std_logic_vector(15 downto 0);
    signal do2 : std_logic_vector(15 downto 0);
begin

    process (clk1)
    begin
        if rising_edge(clk1) then
            if we = '1' then
                ram(conv_integer(addr1)) <= di;
            end if;
            do1 <= ram(conv_integer(addr1));
        end if;
    end process;

    process (clk2)
    begin
        if rising_edge(clk2) then
            do2 <= ram(conv_integer(addr2));
        end if;
    end process;

    process (clk1)
    begin
        if rising_edge(clk1) then
            if en1 = '1' then
                res1 <= do1;
            end if;
        end if;
    end process;
end process;
```

```

process (clk2)
begin
    if rising_edge(clk2) then
        if en2 = '1' then
            res2 <= do2;
        end if;
    end if;
end process;

end beh;

```

Block RAM With Optional Output Registers Verilog Coding Example

```

//
// Block RAM with Optional Output Registers
//

module v_rams_19 (clk1, clk2, we, en1, en2, addr1, addr2, di, res1, res2);

    input  clk1;
    input  clk2;
    input  we, en1, en2;
    input  [5:0] addr1;
    input  [5:0] addr2;
    input  [15:0] di;
    output [15:0] res1;
    output [15:0] res2;
    reg    [15:0] res1;
    reg    [15:0] res2;
    reg    [15:0] RAM [63:0];
    reg    [15:0] do1;
    reg    [15:0] do2;

    always @(posedge clk1)
    begin
        if (we == 1'b1)
            RAM[addr1] <= di;
        do1 <= RAM[addr1];
    end

    always @(posedge clk2)
    begin
        do2 <= RAM[addr2];
    end

    always @(posedge clk1)
    begin
        if (en1 == 1'b1)
            res1 <= do1;
    end

    always @(posedge clk2)
    begin
        if (en2 == 1'b1)
            res2 <= do2;
    end

endmodule

```

Initializing RAM Coding Examples

Coding examples can be downloaded in text format from

http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Block and distributed RAM initial contents can be specified by initialization of the signal describing the memory array in your HDL code. Do this directly in your HDL code, or specify a file containing the initialization data.

XST supports RAM initialization in both VHDL and Verilog.

The following coding examples show how to initialize RAM directly in Hardware Description Language (HDL) code.

RAM Initial Contents VHDL Coding Example (Hexadecimal)

To specify RAM initial contents, initialize the signal describing the memory array in the VHDL code as shown in the following coding example.

```
...
type ram_type is array (0 to 63) of std_logic_vector(19 downto 0);
signal RAM : ram_type :=
(
  X"0200A", X"00300", X"08101", X"04000", X"08601", X"0233A",
  X"00300", X"08602", X"02310", X"0203B", X"08300", X"04002",
  X"08201", X"00500", X"04001", X"02500", X"00340", X"00241",
  X"04002", X"08300", X"08201", X"00500", X"08101", X"00602",
  X"04003", X"0241E", X"00301", X"00102", X"02122", X"02021",
  X"00301", X"00102", X"02222", X"04001", X"00342", X"0232B",
  X"00900", X"00302", X"00102", X"04002", X"00900", X"08201",
  X"02023", X"00303", X"02433", X"00301", X"04004", X"00301",
  X"00102", X"02137", X"02036", X"00301", X"00102", X"02237",
  X"04004", X"00304", X"04040", X"02500", X"02500", X"02500",
  X"0030D", X"02341", X"08201", X"0400D");
...
process (clk)
begin
  if rising_edge(clk) then
    if we = '1' then
      RAM(conv_integer(a)) <= di;
    end if;
    ra <= a;
  end if;
end process;
...
do <= RAM(conv_integer(ra));
```

Initializing Block RAM Verilog Coding Example (Hexadecimal)

To specify RAM initial contents, initialize the signal describing the memory array in your Verilog code using initial statements as shown in the following coding example.

```
...
reg [19:0] ram [63:0];
initial begin
  ram[63] = 20'h0200A; ram[62] = 20'h00300; ram[61] = 20'h08101;
  ram[60] = 20'h04000; ram[59] = 20'h08601; ram[58] = 20'h0233A;
  ...
  ram[2] = 20'h02341; ram[1] = 20'h08201; ram[0] = 20'h0400D;
end
...
always @(posedge clk)
begin
  if (we)
    ram[addr] <= di;
  do <= ram[addr];
end
```

RAM Initial Contents VHDL Coding Example (Binary)

RAM initial contents can be specified in hexadecimal, as shown in *RAM Initial Contents VHDL Coding Example (Hexadecimal)*, or in binary as shown in the following coding example.

```
...
type ram_type is array (0 to SIZE-1) of std_logic_vector(15 downto 0);
signal RAM : ram_type :=
(
  "0111100100000101",
  "0000010110111101",
  "1100001101010000",
  ...
  "0000100101110011");
```

Initializing Block RAM Verilog Coding Example (Binary)

RAM initial contents can be specified in hexadecimal, as shown in *Initializing Block RAM Verilog Coding Example (Hexadecimal)*, or in binary as shown in the following coding example.

```
...
reg [15:0] ram [63:0];
initial begin
  ram[63] = 16'b0111100100000101;
  ram[62] = 16'b0000010110111101;
  ram[61] = 16'b1100001101010000;
  ...
  ram[0] = 16'b0000100101110011;
end
...
```

Single-Port BRAM Initial Contents VHDL Coding Example

```
--
-- Initializing Block RAM (Single-Port BRAM)
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_20a is
    port (clk : in std_logic;
          we : in std_logic;
          addr : in std_logic_vector(5 downto 0);
          di : in std_logic_vector(19 downto 0);
          do : out std_logic_vector(19 downto 0));
end rams_20a;

architecture syn of rams_20a is

    type ram_type is array (63 downto 0) of std_logic_vector (19 downto 0);
    signal RAM : ram_type:= (X"0200A", X"00300", X"08101", X"04000", X"08601", X"0233A",
                             X"00300", X"08602", X"02310", X"0203B", X"08300", X"04002",
                             X"08201", X"00500", X"04001", X"02500", X"00340", X"00241",
                             X"04002", X"08300", X"08201", X"00500", X"08101", X"00602",
                             X"04003", X"0241E", X"00301", X"00102", X"02122", X"02021",
                             X"00301", X"00102", X"02222", X"04001", X"00342", X"0232B",
                             X"00900", X"00302", X"00102", X"04002", X"00900", X"08201",
                             X"02023", X"00303", X"02433", X"00301", X"04004", X"00301",
                             X"00102", X"02137", X"02036", X"00301", X"00102", X"02237",
                             X"04004", X"00304", X"04040", X"02500", X"02500", X"02500",
                             X"0030D", X"02341", X"08201", X"0400D");

begin

    process (clk)
    begin
        if rising_edge(clk) then
            if we = '1' then
                RAM(conv_integer(addr)) <= di;
            end if;
            do <= RAM(conv_integer(addr));
        end if;
    end process;

end syn;
```

Single-Port BRAM Initial Contents Verilog Coding Example

```
//  
// Initializing Block RAM (Single-Port BRAM)  
//  
module v_rams_20a (clk, we, addr, di, do);  
    input clk;  
    input we;  
    input [5:0] addr;  
    input [19:0] di;  
    output [19:0] do;  
    reg [19:0] ram [63:0];  
    reg [19:0] do;  
  
    initial begin  
        ram[63] = 20'h0200A; ram[62] = 20'h00300; ram[61] = 20'h08101;  
        ram[60] = 20'h04000; ram[59] = 20'h08601; ram[58] = 20'h0233A;  
        ram[57] = 20'h00300; ram[56] = 20'h08602; ram[55] = 20'h02310;  
        ram[54] = 20'h0203B; ram[53] = 20'h08300; ram[52] = 20'h04002;  
        ram[51] = 20'h08201; ram[50] = 20'h00500; ram[49] = 20'h04001;  
        ram[48] = 20'h02500; ram[47] = 20'h00340; ram[46] = 20'h00241;  
        ram[45] = 20'h04002; ram[44] = 20'h08300; ram[43] = 20'h08201;  
        ram[42] = 20'h00500; ram[41] = 20'h08101; ram[40] = 20'h00602;  
        ram[39] = 20'h04003; ram[38] = 20'h0241E; ram[37] = 20'h00301;  
        ram[36] = 20'h00102; ram[35] = 20'h02122; ram[34] = 20'h02021;  
        ram[33] = 20'h00301; ram[32] = 20'h00102; ram[31] = 20'h02222;  
  
        ram[30] = 20'h04001; ram[29] = 20'h00342; ram[28] = 20'h0232B;  
        ram[27] = 20'h00900; ram[26] = 20'h00302; ram[25] = 20'h00102;  
        ram[24] = 20'h04002; ram[23] = 20'h00900; ram[22] = 20'h08201;  
        ram[21] = 20'h02023; ram[20] = 20'h00303; ram[19] = 20'h02433;  
        ram[18] = 20'h00301; ram[17] = 20'h04004; ram[16] = 20'h00301;  
        ram[15] = 20'h00102; ram[14] = 20'h02137; ram[13] = 20'h02036;  
        ram[12] = 20'h00301; ram[11] = 20'h00102; ram[10] = 20'h02237;  
        ram[9] = 20'h04004; ram[8] = 20'h00304; ram[7] = 20'h04040;  
        ram[6] = 20'h02500; ram[5] = 20'h02500; ram[4] = 20'h02500;  
        ram[3] = 20'h0030D; ram[2] = 20'h02341; ram[1] = 20'h08201;  
        ram[0] = 20'h0400D;  
    end  
  
    always @(posedge clk)  
    begin  
        if (we)  
            ram[addr] <= di;  
        do <= ram[addr];  
    end  
  
endmodule
```

Dual-Port RAM Initial Contents VHDL Coding Example

```
--
-- Initializing Block RAM (Dual-Port BRAM)
--
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_20b is
  port (clk1 : in std_logic;
        clk2 : in std_logic;
        we : in std_logic;
        addr1 : in std_logic_vector(7 downto 0);
        addr2 : in std_logic_vector(7 downto 0);
        di : in std_logic_vector(15 downto 0);
        do1 : out std_logic_vector(15 downto 0);
        do2 : out std_logic_vector(15 downto 0));
end rams_20b;

architecture syn of rams_20b is

  type ram_type is array (255 downto 0) of std_logic_vector (15 downto 0);
  signal RAM : ram_type:= (255 downto 100 => X"B8B8", 99 downto 0 => X"8282");

begin

  process (clk1)
  begin
    if rising_edge(clk1) then
      if we = '1' then
        RAM(conv_integer(addr1)) <= di;
      end if;
      do1 <= RAM(conv_integer(addr1));
    end if;
  end process;

  process (clk2)
  begin
    if rising_edge(clk2) then
      do2 <= RAM(conv_integer(addr2));
    end if;
  end process;

end syn;
```

Dual-Port RAM Initial Contents Verilog Coding Example

```
//
// Initializing Block RAM (Dual-Port BRAM)
//
module v_rams_20b (clk1, clk2, we, addr1, addr2, di, do1, do2);
  input clk1, clk2;
  input we;
  input [7:0] addr1, addr2;
  input [15:0] di;
  output [15:0] do1, do2;

  reg [15:0] ram [255:0];
  reg [15:0] do1, do2;
  integer index;

  initial begin
    for (index = 0 ; index <= 99 ; index = index + 1) begin
      ram[index] = 16'h8282;
    end

    for (index= 100 ; index <= 255 ; index = index + 1) begin
      ram[index] = 16'h8B8B;
    end
  end

  always @(posedge clk1)
  begin
    if (we)
      ram[addr1] <= di;
      do1 <= ram[addr1];
  end

  always @(posedge clk2)
  begin
    do2 <= ram[addr2];
  end
endmodule
```

Initializing RAM From an External File Coding Examples

The following coding examples show how to initialize RAM from an external file.

To initialize RAM from values contained in an external file, use a read function in the VHDL code.

For more information, see:

[VHDL File Type Support.](#)

Set up the initialization file as follows.

- Use each line of the initialization file to represent the initial contents of a given row in the RAM.
- RAM contents can be represented in binary or hexadecimal.
- There should be as many lines in the file as there are rows in the RAM array.

Following is an example of the contents of a file initializing an 8 x 32-bit RAM with binary values:

```
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
11111101010000011100010000100100
00001111000011110000111100001111
```

```
01001010001000001100000010000100
00000000001111100000000001000001
1111101010000011100010000100100
```

Initializing Block RAM (External Data File)

RAM initial values may be stored in an external data file that is accessed from within the HDL code. The data file must be pure binary or hexadecimal content with no comments or other information.

Following is an example of the contents of a file initializing an 8 x 32-bit RAM with binary values. For both examples, the data file referenced is called `rams_20c.data`.

```
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
1111101010000011100010000100100
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
1111101010000011100010000100100
```

Initializing Block RAM (External Data File) VHDL Coding Example

In the following coding example, the loop that generates the initial value is controlled by testing that we are in the RAM address range. The following coding examples show initializing Block RAM from an external data file.

```
--
-- Initializing Block RAM from external data file
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;
use std.textio.all;

entity rams_20c is
  port(clk : in std_logic;
       we : in std_logic;
       addr : in std_logic_vector(5 downto 0);
       din : in std_logic_vector(31 downto 0);
       dout : out std_logic_vector(31 downto 0));
end rams_20c;

architecture syn of rams_20c is

  type RamType is array(0 to 63) of bit_vector(31 downto 0);

  impure function InitRamFromFile (RamFileName : in string) return RamType is
    FILE RamFile : text is in RamFileName;
    variable RamFileLine : line;
    variable RAM : RamType;
  begin
    for I in RamType'range loop
      readline (RamFile, RamFileLine);
      read (RamFileLine, RAM(I));
    end loop;
    return RAM;
  end function;

  signal RAM : RamType := InitRamFromFile("rams_20c.data");

begin

  process (clk)
  begin
    if clk'event and clk = '1' then
      if we = '1' then
        RAM(conv_integer(addr)) <= to_bitvector(din);
      end if;
      dout <= to_stdlogicvector(RAM(conv_integer(addr)));
    end if;
  end process;

end syn;
```

If there are not enough lines in the external data file, XST issues the following message.
 ERROR:Xst - raminitfile1.vhd line 40: Line <RamFileLine has not enough elements for target <RAM<63>>.

Initializing Block RAM (External Data File) Verilog Coding Example

To initialize RAM from values contained in an external file, use a `$readmemb` or `$readmemh` system task in your Verilog code.

For more information, see:

[XST Behavioral Verilog Language Support](#)

Set up the initialization file as follows.

- Arrange each line of the initialization file to represent the initial contents of a given row in the RAM
- RAM contents can be represented in binary or hexadecimal.
- Use `$readmemb` for binary and `$readmemh` for hexadecimal representation. To avoid the possible difference between XST and simulator behavior, Xilinx® recommends that you use index parameters in these system tasks. See the following coding example.

```
$readmemb("rams_20c.data", ram, 0, 7);
```

Create as many lines in the file as there are rows in the RAM array.

```
//  
// Initializing Block RAM from external data file  
//  
module v_rams_20c (clk, we, addr, din, dout);  
  input clk;  
  input we;  
  input [5:0] addr;  
  input [31:0] din;  
  output [31:0] dout;  
  
  reg [31:0] ram [0:63];  
  reg [31:0] dout;  
  
  initial  
  begin  
    $readmemb("rams_20c.data", ram, 0, 63);  
  end  
  
  always @(posedge clk)  
  begin  
    if (we)  
      ram[addr] <= din;  
      dout <= ram[addr];  
  end  
  
endmodule
```

Initializing RAM From an External File Coding Examples

The following coding examples show how to initialize RAM from an external file.

To initialize RAM from values contained in an external file, use a read function in the VHDL code.

For more information, see:

[VHDL File Type Support](#).

Set up the initialization file as follows.

- Use each line of the initialization file to represent the initial contents of a given row in the RAM.
- RAM contents can be represented in binary or hexadecimal.
- There should be as many lines in the file as there are rows in the RAM array.

Following is an example of the contents of a file initializing an 8 x 32-bit RAM with binary values:

```
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
11111101010000011100010000100100
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
11111101010000011100010000100100
```

Initializing Block RAM (External Data File)

RAM initial values may be stored in an external data file that is accessed from within the HDL code. The data file must be pure binary or hexadecimal content with no comments or other information.

Following is an example of the contents of a file initializing an 8 x 32-bit RAM with binary values. For both examples, the data file referenced is called `rams_20c.data`.

```
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
11111101010000011100010000100100
00001111000011110000111100001111
01001010001000001100000010000100
00000000001111100000000001000001
11111101010000011100010000100100
```

Initializing Block RAM (External Data File) VHDL Coding Example

In the following coding example, the loop that generates the initial value is controlled by testing that we are in the RAM address range. The following coding examples show initializing Block RAM from an external data file.

```
--
-- Initializing Block RAM from external data file
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;
use std.textio.all;

entity rams_20c is
  port(clk : in std_logic;
       we : in std_logic;
       addr : in std_logic_vector(5 downto 0);
       din : in std_logic_vector(31 downto 0);
       dout : out std_logic_vector(31 downto 0));
end rams_20c;

architecture syn of rams_20c is

  type RamType is array(0 to 63) of bit_vector(31 downto 0);

  impure function InitRamFromFile (RamFileName : in string) return RamType is
    FILE RamFile : text is in RamFileName;
    variable RamFileLine : line;
    variable RAM : RamType;
  begin
    for I in RamType'range loop
      readline (RamFile, RamFileLine);
      read (RamFileLine, RAM(I));
    end loop;
    return RAM;
  end function;

  signal RAM : RamType := InitRamFromFile("rams_20c.data");

begin

  process (clk)
  begin
    if clk'event and clk = '1' then
      if we = '1' then
        RAM(conv_integer(addr)) <= to_bitvector(din);
      end if;
      dout <= to_stdlogicvector(RAM(conv_integer(addr)));
    end if;
  end process;

end syn;
```

If there are not enough lines in the external data file, XST issues the following message.
 ERROR:Xst - raminitfile1.vhd line 40: Line <RamFileLine has not enough elements for target <RAM<63>>.

Initializing Block RAM (External Data File) Verilog Coding Example

To initialize RAM from values contained in an external file, use a `$readmemb` or `$readmemh` system task in your Verilog code.

For more information, see:

[XST Behavioral Verilog Language Support](#)

Set up the initialization file as follows.

- Arrange each line of the initialization file to represent the initial contents of a given row in the RAM
- RAM contents can be represented in binary or hexadecimal.
- Use `$readmemb` for binary and `$readmembh` for hexadecimal representation. To avoid the possible difference between XST and simulator behavior, Xilinx® recommends that you use index parameters in these system tasks. See the following coding example.

```
$readmemb("rams_20c.data", ram, 0, 7);
```

Create as many lines in the file as there are rows in the RAM array.

```
//  
// Initializing Block RAM from external data file  
//  
module v_rams_20c (clk, we, addr, din, dout);  
  input clk;  
  input we;  
  input [5:0] addr;  
  input [31:0] din;  
  output [31:0] dout;  
  
  reg [31:0] ram [0:63];  
  reg [31:0] dout;  
  
  initial  
  begin  
    $readmemb("rams_20c.data", ram, 0, 63);  
  end  
  
  always @(posedge clk)  
  begin  
    if (we)  
      ram[addr] <= din;  
      dout <= ram[addr];  
  end  
  
endmodule
```

ROMs Using Block RAM Resources HDL Coding Techniques

This section discusses ROMs Using Block RAM Resources HDL Coding Techniques, and includes:

- [About ROMs Using Block RAM Resources](#)
- [ROMs Using Block RAM Resources Log File](#)
- [ROMs Using Block RAM Resources Related Constraints](#)
- [ROMs Using Block RAM Resources Coding Examples](#)

About ROMs Using Block RAM Resources

XST can use block RAM resources to implement ROMs with synchronous outputs or address inputs. These ROMs are implemented as single-port or dual-port block RAMs depending on the HDL description.

XST can infer block ROM across hierarchies if [Keep Hierarchy \(KEEP_HIERARCHY\)](#) is set to **no**. In this case, ROM and the data output or address register can be described in separate hierarchy blocks. This inference is performed during Advanced HDL Synthesis.

Using block RAM resources to implement ROMs is controlled by the [ROM Style \(ROM_STYLE\)](#) constraint.

For more information about [ROM Style \(ROM_STYLE\)](#), see:

[XST Design Constraints](#)

For more information about ROM implementation, see:

[XST FPGA Optimization](#)

ROMs Using Block RAM Resources Log File

Following is a ROMs Using Block RAM Resources Log File Example.

ROMs Using Block RAM Resources Log File Example

```

=====
*                               HDL Synthesis                               *
=====
Synthesizing Unit <rams_21a>.
  Related source file is "rams_21a.vhd".
  Found 64x20-bit ROM for signal <$varindex0000> created at line 38.
  Found 20-bit register for signal <data>.
  Summary:
    inferred   1 ROM(s).
    inferred  20 D-type flip-flop(s).
Unit <rams_21a> synthesized.
=====
HDL Synthesis Report
Macro Statistics
# ROMs                : 1
 64x20-bit ROM       : 1
# Registers           : 1
 20-bit register     : 1
=====
*                               Advanced HDL Synthesis                       *
=====
INFO:Xst - Unit <rams_21a> : The ROM <Mrom_varindex0000> will be implemented
as a read-only BLOCK RAM, absorbing the register: <data>.

-----
| ram_type           | Block                               |
-----
| Port A             |                                     |
|   aspect ratio    | 64-word x 20-bit (6.9%)           |
|   mode             | write-first                         |
-----

```

| | | |
|-------|----------------------------|------|
| clkA | connected to signal <clk> | rise |
| enA | connected to signal <en> | high |
| weA | connected to internal node | high |
| addrA | connected to signal <addr> | |
| diA | connected to internal node | |
| doA | connected to signal <data> | |

=====
 Advanced HDL Synthesis Report
 Macro Statistics

```
# RAMs                : 1
 64x20-bit single-port block RAM : 1
```

=====

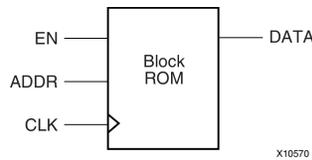
ROMs Using Block RAM Resources Related Constraints

[ROM Style \(ROM_STYLE\)](#)

ROMs Using Block RAM Resources Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

ROM With Registered Output Diagram



ROM With Registered Output Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| clk | Positive-Edge Clock |
| en | Synchronous Enable (active-High) |
| addr | Read Address |
| data | Data Output |

ROM With Registered Output VHDL Coding Example One

```
--
-- ROMs Using Block RAM Resources.
-- VHDL code for a ROM with registered output (template 1)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_21a is
  port (clk : in std_logic;
        en  : in std_logic;
        addr : in std_logic_vector(5 downto 0);
        data : out std_logic_vector(19 downto 0));
end rams_21a;

architecture syn of rams_21a is

  type rom_type is array (63 downto 0) of std_logic_vector (19 downto 0);
  signal ROM : rom_type:= (X"0200A", X"00300", X"08101", X"04000", X"08601", X"0233A",
                          X"00300", X"08602", X"02310", X"0203B", X"08300", X"04002",
```

```

        X"08201", X"00500", X"04001", X"02500", X"00340", X"00241",
        X"04002", X"08300", X"08201", X"00500", X"08101", X"00602",
        X"04003", X"0241E", X"00301", X"00102", X"02122", X"02021",
        X"00301", X"00102", X"02222", X"04001", X"00342", X"0232B",
        X"00900", X"00302", X"00102", X"04002", X"00900", X"08201",
        X"02023", X"00303", X"02433", X"00301", X"04004", X"00301",
        X"00102", X"02137", X"02036", X"00301", X"00102", X"02237",
        X"04004", X"00304", X"04040", X"02500", X"02500", X"02500",
        X"0030D", X"02341", X"08201", X"0400D");

begin

    process (clk)
    begin
        if (clk'event and clk = '1') then
            if (en = '1') then
                data <= ROM(conv_integer(addr));
            end if;
        end if;
    end process;

end syn;

```

ROM With Registered Output VHDL Coding Example Two

```

--
-- ROMs Using Block RAM Resources.
-- VHDL code for a ROM with registered output (template 2)
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_21b is
port (clk : in std_logic;
      en : in std_logic;
      addr : in std_logic_vector(5 downto 0);
      data : out std_logic_vector(19 downto 0));
end rams_21b;

architecture syn of rams_21b is
    type rom_type is array (63 downto 0) of std_logic_vector (19 downto 0);
    signal ROM : rom_type:= (X"0200A", X"00300", X"08101", X"04000", X"08601", X"0233A",
        X"00300", X"08602", X"02310", X"0203B", X"08300", X"04002",
        X"08201", X"00500", X"04001", X"02500", X"00340", X"00241",
        X"04002", X"08300", X"08201", X"00500", X"08101", X"00602",
        X"04003", X"0241E", X"00301", X"00102", X"02122", X"02021",
        X"00301", X"00102", X"02222", X"04001", X"00342", X"0232B",
        X"00900", X"00302", X"00102", X"04002", X"00900", X"08201",
        X"02023", X"00303", X"02433", X"00301", X"04004", X"00301",
        X"00102", X"02137", X"02036", X"00301", X"00102", X"02237",
        X"04004", X"00304", X"04040", X"02500", X"02500", X"02500",
        X"0030D", X"02341", X"08201", X"0400D");

    signal rdata : std_logic_vector(19 downto 0);
begin

    rdata <= ROM(conv_integer(addr));

    process (clk)
    begin
        if (clk'event and clk = '1') then
            if (en = '1') then
                data <= rdata;
            end if;
        end if;
    end process;

end syn;

```

ROM With Registered Output Verilog Coding Example One

```
//
// ROMs Using Block RAM Resources.
// Verilog code for a ROM with registered output (template 1)
//

module v_rams_21a (clk, en, addr, data);

    input    clk;
    input    en;
    input    [5:0] addr;
    output reg [19:0] data;

    always @(posedge clk) begin
        if (en)
            case(addr)
                6'b000000: data <= 20'h0200A;    6'b100000: data <= 20'h02222;
                6'b000001: data <= 20'h00300;    6'b100001: data <= 20'h04001;
                6'b000010: data <= 20'h08101;    6'b100010: data <= 20'h00342;
                6'b000011: data <= 20'h04000;    6'b100011: data <= 20'h0232B;
                6'b000100: data <= 20'h08601;    6'b100100: data <= 20'h00900;
                6'b000101: data <= 20'h0233A;    6'b100101: data <= 20'h00302;
                6'b000110: data <= 20'h00300;    6'b100110: data <= 20'h00102;
                6'b000111: data <= 20'h08602;    6'b100111: data <= 20'h04002;
                6'b001000: data <= 20'h02310;    6'b101000: data <= 20'h00900;
                6'b001001: data <= 20'h0203B;    6'b101001: data <= 20'h08201;
                6'b001010: data <= 20'h08300;    6'b101010: data <= 20'h02023;
                6'b001011: data <= 20'h04002;    6'b101011: data <= 20'h00303;
                6'b001100: data <= 20'h08201;    6'b101100: data <= 20'h02433;
                6'b001101: data <= 20'h00500;    6'b101101: data <= 20'h00301;
                6'b001110: data <= 20'h04001;    6'b101110: data <= 20'h04004;
                6'b001111: data <= 20'h02500;    6'b101111: data <= 20'h00301;
                6'b010000: data <= 20'h00340;    6'b110000: data <= 20'h00102;
                6'b010001: data <= 20'h00241;    6'b110001: data <= 20'h02137;
                6'b010010: data <= 20'h04002;    6'b110010: data <= 20'h02036;
                6'b010011: data <= 20'h08300;    6'b110011: data <= 20'h00301;
                6'b010100: data <= 20'h08201;    6'b110100: data <= 20'h00102;
                6'b010101: data <= 20'h00500;    6'b110101: data <= 20'h02237;
                6'b010110: data <= 20'h08101;    6'b110110: data <= 20'h04004;
                6'b010111: data <= 20'h00602;    6'b110111: data <= 20'h00304;
                6'b011000: data <= 20'h04003;    6'b111000: data <= 20'h04040;
                6'b011001: data <= 20'h0241E;    6'b111001: data <= 20'h02500;
                6'b011010: data <= 20'h00301;    6'b111010: data <= 20'h02500;
                6'b011011: data <= 20'h00102;    6'b111011: data <= 20'h02500;
                6'b011100: data <= 20'h02122;    6'b111100: data <= 20'h0030D;
                6'b011101: data <= 20'h02021;    6'b111101: data <= 20'h02341;
                6'b011110: data <= 20'h00301;    6'b111110: data <= 20'h08201;
                6'b011111: data <= 20'h00102;    6'b111111: data <= 20'h0400D;
            endcase
        end
    end
endmodule
```

ROM With Registered Output Verilog Coding Example Two

```
//
// ROMs Using Block RAM Resources.
// Verilog code for a ROM with registered output (template 2)
//

module v_rams_21b (clk, en, addr, data);

    input    clk;
    input    en;
    input    [5:0] addr;
    output reg [19:0] data;
    reg      [19:0] rdata;

    always @(addr) begin
        case(addr)

```

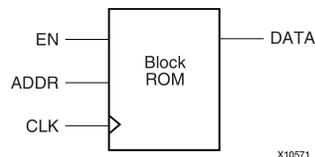
```

6'b000000: rdata <= 20'h0200A; 6'b100000: rdata <= 20'h02222;
6'b000001: rdata <= 20'h00300; 6'b100001: rdata <= 20'h04001;
6'b000010: rdata <= 20'h08101; 6'b100010: rdata <= 20'h00342;
6'b000011: rdata <= 20'h04000; 6'b100011: rdata <= 20'h0232B;
6'b000100: rdata <= 20'h08601; 6'b100100: rdata <= 20'h00900;
6'b000101: rdata <= 20'h0233A; 6'b100101: rdata <= 20'h00302;
6'b000110: rdata <= 20'h00300; 6'b100110: rdata <= 20'h00102;
6'b000111: rdata <= 20'h08602; 6'b100111: rdata <= 20'h04002;
6'b001000: rdata <= 20'h02310; 6'b101000: rdata <= 20'h00900;
6'b001001: rdata <= 20'h0203B; 6'b101001: rdata <= 20'h08201;
6'b001010: rdata <= 20'h08300; 6'b101010: rdata <= 20'h02023;
6'b001011: rdata <= 20'h04002; 6'b101011: rdata <= 20'h00303;
6'b001100: rdata <= 20'h08201; 6'b101100: rdata <= 20'h02433;
6'b001101: rdata <= 20'h00500; 6'b101101: rdata <= 20'h00301;
6'b001110: rdata <= 20'h04001; 6'b101110: rdata <= 20'h04004;
6'b001111: rdata <= 20'h02500; 6'b101111: rdata <= 20'h00301;
6'b010000: rdata <= 20'h00340; 6'b110000: rdata <= 20'h00102;
6'b010001: rdata <= 20'h00241; 6'b110001: rdata <= 20'h02137;
6'b010010: rdata <= 20'h04002; 6'b110010: rdata <= 20'h02036;
6'b010011: rdata <= 20'h08300; 6'b110011: rdata <= 20'h00301;
6'b010100: rdata <= 20'h08201; 6'b110100: rdata <= 20'h00102;
6'b010101: rdata <= 20'h00500; 6'b110101: rdata <= 20'h02237;
6'b010110: rdata <= 20'h08101; 6'b110110: rdata <= 20'h04004;
6'b010111: rdata <= 20'h00602; 6'b110111: rdata <= 20'h00304;
6'b011000: rdata <= 20'h04003; 6'b111000: rdata <= 20'h04040;
6'b011001: rdata <= 20'h0241E; 6'b111001: rdata <= 20'h02500;
6'b011010: rdata <= 20'h00301; 6'b111010: rdata <= 20'h02500;
6'b011011: rdata <= 20'h00102; 6'b111011: rdata <= 20'h02500;
6'b011100: rdata <= 20'h02122; 6'b111100: rdata <= 20'h0030D;
6'b011101: rdata <= 20'h02021; 6'b111101: rdata <= 20'h02341;
6'b011110: rdata <= 20'h00301; 6'b111110: rdata <= 20'h08201;
6'b011111: rdata <= 20'h00102; 6'b111111: rdata <= 20'h0400D;
endcase
end

always @(posedge clk) begin
  if (en)
    data <= rdata;
end
endmodule

```

ROM With Registered Address Diagram



ROM With Registered Address Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| clk | Positive-Edge Clock |
| en | Synchronous Enable (active-High) |
| addr | Read Address |
| data | Data Output |
| clk | Positive-Edge Clock |

ROM With Registered Address VHDL Coding Example

```
--
-- ROMs Using Block RAM Resources.
-- VHDL code for a ROM with registered address
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_21c is
port (clk : in std_logic;
      en : in std_logic;
      addr : in std_logic_vector(5 downto 0);
      data : out std_logic_vector(19 downto 0));
end rams_21c;

architecture syn of rams_21c is
  type rom_type is array (63 downto 0) of std_logic_vector (19 downto 0);
  signal ROM : rom_type:= (X"0200A", X"00300", X"08101", X"04000", X"08601", X"0233A",
    X"00300", X"08602", X"02310", X"0203B", X"08300", X"04002",
    X"08201", X"00500", X"04001", X"02500", X"00340", X"00241",
    X"04002", X"08300", X"08201", X"00500", X"08101", X"00602",
    X"04003", X"0241E", X"00301", X"00102", X"02122", X"02021",
    X"00301", X"00102", X"02222", X"04001", X"00342", X"0232B",
    X"00900", X"00302", X"00102", X"04002", X"00900", X"08201",
    X"02023", X"00303", X"02433", X"00301", X"04004", X"00301",
    X"00102", X"02137", X"02036", X"00301", X"00102", X"02237",
    X"04004", X"00304", X"04040", X"02500", X"02500", X"02500",
    X"0030D", X"02341", X"08201", X"0400D");

  signal raddr : std_logic_vector(5 downto 0);
begin

  process (clk)
  begin
    if (clk'event and clk = '1') then
      if (en = '1') then
        raddr <= addr;
      end if;
    end if;
  end process;

  data <= ROM(conv_integer(raddr));
end syn;
```

ROM With Registered Address Verilog Coding Example

```
//
// ROMs Using Block RAM Resources.
// Verilog code for a ROM with registered address
//

module v_rams_2lc (clk, en, addr, data);

    input    clk;
    input    en;
    input    [5:0] addr;
    output reg [19:0] data;
    reg      [5:0] raddr;

    always @(posedge clk) begin
        if (en)
            raddr <= addr;
    end

    always @(raddr) begin
        case(raddr)
            6'b000000: data <= 20'h0200A;    6'b100000: data <= 20'h02222;
            6'b000001: data <= 20'h00300;    6'b100001: data <= 20'h04001;
            6'b000010: data <= 20'h08101;    6'b100010: data <= 20'h00342;
            6'b000011: data <= 20'h04000;    6'b100011: data <= 20'h0232B;
            6'b000100: data <= 20'h08601;    6'b100100: data <= 20'h00900;
            6'b000101: data <= 20'h0233A;    6'b100101: data <= 20'h00302;
            6'b000110: data <= 20'h00300;    6'b100110: data <= 20'h00102;
            6'b000111: data <= 20'h08602;    6'b100111: data <= 20'h04002;
            6'b001000: data <= 20'h02310;    6'b101000: data <= 20'h00900;
            6'b001001: data <= 20'h0203B;    6'b101001: data <= 20'h08201;
            6'b001010: data <= 20'h08300;    6'b101010: data <= 20'h02023;
            6'b001011: data <= 20'h04002;    6'b101011: data <= 20'h00303;
            6'b001100: data <= 20'h08201;    6'b101100: data <= 20'h02433;
            6'b001101: data <= 20'h00500;    6'b101101: data <= 20'h00301;
            6'b001110: data <= 20'h04001;    6'b101110: data <= 20'h04004;
            6'b001111: data <= 20'h02500;    6'b101111: data <= 20'h00301;
            6'b010000: data <= 20'h00340;    6'b110000: data <= 20'h00102;
            6'b010001: data <= 20'h00241;    6'b110001: data <= 20'h02137;
            6'b010010: data <= 20'h04002;    6'b110010: data <= 20'h02036;
            6'b010011: data <= 20'h08300;    6'b110011: data <= 20'h00301;
            6'b010100: data <= 20'h08201;    6'b110100: data <= 20'h00102;
            6'b010101: data <= 20'h00500;    6'b110101: data <= 20'h02237;
            6'b010110: data <= 20'h08101;    6'b110110: data <= 20'h04004;
            6'b010111: data <= 20'h00602;    6'b110111: data <= 20'h00304;
            6'b011000: data <= 20'h04003;    6'b111000: data <= 20'h04040;
            6'b011001: data <= 20'h0241E;    6'b111001: data <= 20'h02500;
            6'b011010: data <= 20'h00301;    6'b111010: data <= 20'h02500;
            6'b011011: data <= 20'h00102;    6'b111011: data <= 20'h02500;
            6'b011100: data <= 20'h02122;    6'b111100: data <= 20'h0030D;
            6'b011101: data <= 20'h02021;    6'b111101: data <= 20'h02341;
            6'b011110: data <= 20'h00301;    6'b111110: data <= 20'h08201;
            6'b011111: data <= 20'h00102;    6'b111111: data <= 20'h0400D;
        endcase
    end
endmodule
```

Pipelined Distributed RAM HDL Coding Techniques

This section discusses Pipelined Distributed RAM HDL Coding Techniques, and includes:

- [About Pipelined Distributed RAM](#)
- [Pipelined Distributed RAM Log File](#)
- [Pipelined Distributed RAM Related Constraints](#)
- [Pipelined Distributed RAM Coding Examples](#)

About Pipelined Distributed RAM

In order to increase the speed of designs, XST can infer pipelined distributed RAM. By interspersing registers between the stages of distributed RAM, pipelining can significantly increase the overall frequency of your design. The effect of pipelining is similar to [Flip-Flop Retiming](#).

To insert pipeline stages:

1. Describe the necessary registers in your Hardware Description Language (HDL) code
2. Place them after any distributed RAM
3. Set [RAM Style \(RAM_STYLE\)](#) to:

pipe_distributed

In order to reach the maximum distributed RAM speed, XST uses the maximum number of available registers when:

- It detects valid registers for pipelining, and
- RAM_STYLE is set to:

pipe_distributed

In order to obtain the best frequency, XST automatically calculates the maximum number of registers for each RAM.

During the Advanced HDL Synthesis step, the XST HDL Advisor advises you to specify the optimum number of register stages if:

- You have not specified sufficient register stages, and
- RAM_STYLE is coded directly on a signal

XST implements the unused stages as shift registers if:

- The number of registers placed after the multiplier exceeds the maximum required, and
- Shift register extraction is activated

XST cannot pipeline RAM if registers contain asynchronous set/reset signals. XST can pipeline RAM if registers contain synchronous reset signals.

Pipelined Distributed RAM Log File

Following is a Pipelined Distributed RAM Log File Example.

Pipelined Distributed RAM Log File Example

```

=====
*                               HDL Synthesis                               *
=====
Synthesizing Unit <rams_22>.
  Related source file is "rams_22.vhd".
  Found 64x4-bit single-port RAM for signal <RAM>.
  Found 4-bit register for signal <do>.
  Summary:
  inferred   1 RAM(s).
  inferred   4 D-type flip-flop(s).
Unit <rams_22> synthesized.

=====
HDL Synthesis Report

Macro Statistics
# RAMs                : 1
 64x4-bit single-port RAM : 1
# Registers           : 1
 4-bit register       : 1

=====
*                               Advanced HDL Synthesis                       *
=====
INFO:Xst - Unit <rams_22> : The RAM <Mram_RAM> will be implemented as a
distributed RAM, absorbing the following register(s): <do>.

-----
| aspect ratio      | 64-word x 4-bit | | rise |
| clock            | connected to signal <clk> | | high |
| write enable     | connected to signal <we> | |      |
| address          | connected to signal <addr> | |      |
| data in          | connected to signal <di> | |      |
| data out         | connected to internal node | |      |
| ram_style        | distributed      | |      |
-----

Synthesizing (advanced) Unit <rams_22>.
Found pipelined ram on signal <_varindex0000>:
- 1 pipeline level(s) found in a register on signal <_varindex0000>.
Pushing register(s) into the ram macro.

INFO:Xst:2390 - HDL ADVISOR - You can improve the performance of
the ram Mram_RAM by adding 1 register level(s) on output signal _varindex0000.
Unit <rams_22> synthesized (advanced).

=====
Advanced HDL Synthesis Report
Macro Statistics
# RAMs                : 1
 64x4-bit registered single-port distributed RAM : 1
=====

```

Pipelined Distributed RAM Related Constraints

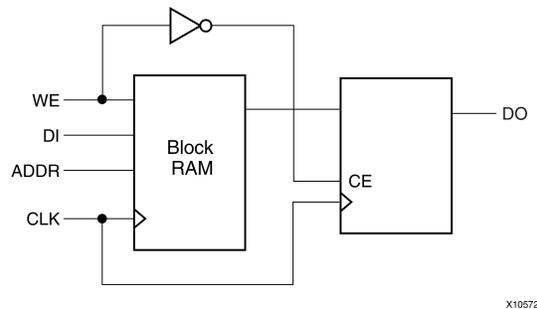
- [RAM Extraction \(RAM_EXTRACT\)](#)
- [RAM Style \(RAM_STYLE\)](#)
- [ROM Extraction \(ROM_EXTRACT\)](#)
- [ROM Style \(ROM_STYLE\)](#)
- [BRAM Utilization Ratio \(BRAM_UTILIZATION_RATIO\)](#)
- [Automatic BRAM Packing \(AUTO_BRAM_PACKING\)](#)

Pipelined Distributed RAM Coding Examples

Coding examples can be downloaded in text format from

http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Pipelined Distributed RAM Diagram



Pipelined Distributed RAM Pin Descriptions

| IO Pins | Description |
|---------|--|
| clk | Positive-Edge Clock |
| we | Synchronous Write Enable (active-High) |
| addr | Read/Write Address |
| di | Data Input |
| do | Data Output |

Pipelined Distributed RAM VHDL Coding Example

```
--
-- Pipeline distributed RAMs
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;

entity rams_22 is
  port (clk : in std_logic;
        we  : in std_logic;
        addr : in std_logic_vector(8 downto 0);
        di   : in std_logic_vector(3 downto 0);
        do   : out std_logic_vector(3 downto 0));
end rams_22;

architecture syn of rams_22 is
  type ram_type is array (511 downto 0) of std_logic_vector (3 downto 0);
  signal RAM : ram_type;

  signal pipe_reg: std_logic_vector(3 downto 0);

  attribute ram_style: string;
  attribute ram_style of RAM: signal is "pipe_distributed";
begin

  process (clk)
  begin
    if clk'event and clk = '1' then
      if we = '1' then
        RAM(conv_integer(addr)) <= di;
      else
        pipe_reg <= RAM( conv_integer(addr));
      end if;
    end if;
  end process;
end architecture;
```

```
        end if;
        do <= pipe_reg;
        end if;
    end process;

end syn;
```

Pipelined Distributed RAM Verilog Coding Example

```
//
// Pipeline distributed RAMs
//

module v_rams_22 (clk, we, addr, di, do);

    input  clk;
    input  we;
    input  [8:0] addr;
    input  [3:0] di;
    output [3:0] do;
    (*ram_style="pipe_distributed"*)
    reg    [3:0] RAM [511:0];
    reg    [3:0] do;
    reg    [3:0] pipe_reg;

    always @(posedge clk)
    begin
        if (we)
            RAM[addr] <= di;
        else
            pipe_reg <= RAM[addr];
        do <= pipe_reg;
    end

endmodule
```

FSM HDL Coding Techniques

This section discusses Finite State Machine (FSM) HDL Coding Techniques, and includes:

- [About FSM Components](#)
- [Describing an FSM Component](#)
- [State Encoding Techniques](#)
- [RAM-Based FSM Synthesis](#)
- [Safe FSM Implementation](#)
- [FSM Log File](#)
- [FSM Related Constraints](#)
- [FSM Coding Examples](#)

About FSM Components

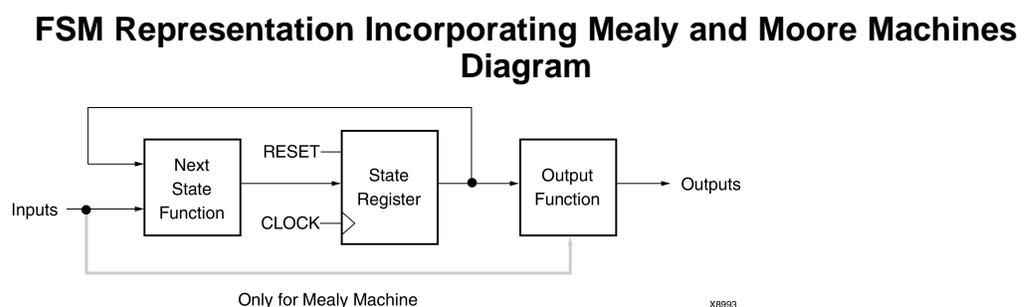
The Xilinx Synthesis Technology (XST) software:

- Includes a large set of templates to describe Finite State Machine (FSM) components
- Can apply several state encoding techniques to obtain better performance or less area
- Can re-encode your initial encoding
- Can handle only synchronous state machines

To disable FSM extraction, use [Automatic FSM Extraction \(FSM_EXTRACT\)](#).

Describing an FSM Component

There are many ways to describe a Finite State Machine (FSM) component. A traditional FSM representation incorporates Mealy and Moore machines, as shown in the following diagram. XST supports both models.



Describing FSM Components with Process and Always

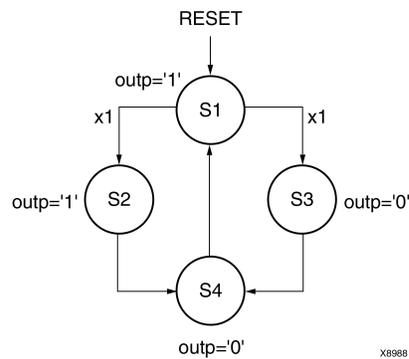
For HDL, **process** (VHDL) and **always** blocks (Verilog) are the best ways to describe FSM components. Xilinx® uses **process** to refer to both VHDL processes and Verilog **always** blocks.

You may have several processes (1, 2 or 3) in your description, depending upon how you consider and decompose the different parts of the preceding model. Following is an example of the Moore Machine with Asynchronous Reset, RESET.

- 4 states
 - **s1**
 - **s2**
 - **s3**
 - **s4**
- 5 transitions
- 1 input
x1com
- 1 output
outp

The above model is represented by the following bubble diagram.

Bubble Diagram



State Registers

For XST to successfully identify a Finite State Machine (FSM), descriptions of the state register should include either:

- A power-up state
The power-up state must use proper VHDL or Verilog signal initialization.
- An operational reset
The operational reset can be asynchronous or synchronous.

For coding examples on how to write Asynchronous and Synchronous initialization signals, see:

[Registers HDL Coding Techniques](#)

In VHDL, the type of a state register can be a different type, such as:

- **integer**
- **bit_vector**
- **std_logic_vector**

But it is common and convenient to define an enumerated type containing all possible state values and to declare your state register with that type.

In Verilog, the type of state register can be an integer or a set of defined parameters. In the following Verilog examples the state assignments could have been made as follows:

```
parameter [3:0]
    s1 = 4'b0001,
    s2 = 4'b0010,
    s3 = 4'b0100,
    s4 = 4'b1000;
reg [3:0] state;
```

These parameters can be modified to represent different state encoding schemes.

Next State Equations

Next state equations can be described directly in the sequential process or in a distinct combinatorial process. The simplest coding example is based on a **case** statement. If using a separate combinatorial process, its sensitivity list should contain the state signal and all FSM inputs.

Unreachable States

XST can detect unreachable states in an FSM. It lists them in the log file in the HDL Synthesis step.

Outputs and Inputs

Non-registered *outputs* are described either in the combinatorial process or in concurrent assignments. Registered outputs must be assigned within the sequential process.

Registered *inputs* are described using internal signals, which are assigned in the sequential process.

State Encoding Techniques

XST supports the following state encoding techniques:

- [Auto State Encoding](#)
- [One-Hot State Encoding](#)
- [Gray State Encoding](#)
- [Compact State Encoding](#)
- [Johnson State Encoding](#)
- [Sequential State Encoding](#)
- [Speed1 State Encoding](#)
- [User State Encoding](#)

Auto State Encoding

In Auto State Encoding, XST tries to select the best suited encoding algorithm for each Finite State Machine (FSM).

One-Hot State Encoding

One-Hot State Encoding:

- Is the default encoding scheme.
- Associates one code bit and one flip-flop to each state. At a given clock cycle during operation, one and only one bit of the state variable is asserted. Only two bits toggle during a transition between two states.
- Is appropriate with most FPGA targets where a large number of flip-flops are available.
- Is a good alternative when trying to optimize speed or to reduce power dissipation.

Gray State Encoding

Gray State Encoding:

- Guarantees that only one bit switches between two consecutive states.
- Is appropriate for controllers exhibiting long paths without branching.
- Minimizes hazards and glitches.
- Gives good results when implementing the state register with T flip-flops.

Compact State Encoding

Compact State Encoding:

- Minimizes the number of bits in the state variables and flip-flops.
- Is based on hypercube immersion.
- Is appropriate when trying to optimize area.

Johnson State Encoding

Like Gray State Encoding, Johnson State Encoding shows benefits with state machines containing long paths with no branching.

Sequential State Encoding

Sequential State Encoding:

- Identifies long paths and applies successive radix two codes to the states on these paths.
- Minimizes next state equations.

Speed1 State Encoding

Speed1 State Encoding is oriented for speed optimization. The number of bits for a state register depends on the particular FSM, but generally it is greater than the number of FSM states.

User State Encoding

In User State Encoding, XST uses the original encoding specified in the HDL file. For example, if you use enumerated types for a state register, use [Enumerated Encoding \(ENUM_ENCODING\)](#) to assign a specific binary value to each state.

For more information, see:

[XST Design Constraints](#)

RAM-Based FSM Synthesis

Large Finite State Machine (FSM) components can be made more compact and faster by implementing them in the block RAM resources provided in Virtex® devices and later technologies. [FSM Style \(FSM_STYLE\)](#) directs XST to use block RAM resources for FSMs.

Values for [FSM Style \(FSM_STYLE\)](#) are:

- **lut** (default)
XST maps the FSM using LUTs.
- **bram**
XST maps the FSM onto block RAM.

Invoke [FSM Style \(FSM_STYLE\)](#) as follows:

- ISE® Design Suite
Select **LUT** or **Block RAM** as instructed in the *HDL Options* topics of the ISE Design Suite Help.
- Command line
Use the **-fsm_style** command line option.
- Hardware Description Language (HDL) code
Use [FSM Style \(FSM_STYLE\)](#)

If it cannot implement a state machine on block RAM, XST:

- Issues a warning in the Advanced HDL Synthesis step of the log file.
- Automatically implements the state machine using LUTs.

For example, if FSM has an asynchronous reset, it cannot be implemented using block RAM. In this case XST informs you:

```

...
=====
*                               Advanced HDL Synthesis                               *
=====

WARNING:Xst - Unable to fit FSM <FSM_0> in BRAM (reset is
asynchronous).
Selecting encoding for FSM_0 ...
Optimizing FSM <FSM_0> on signal <current_state>
with one-hot encoding.
...

```

Safe FSM Implementation

XST can add logic to a Finite State Machine (FSM) implementation that will let a state machine recover from an invalid state. If during its execution, a state machine enters an invalid state, the logic added by XST brings it back to a known state, called a recovery state. This is known as Safe Implementation mode.

To activate Safe FSM implementation:

- In ISE® Design Suite, select Safe Implementation as instructed in the *HDL Options* topic of ISE Design Suite Help, or
- Apply [Safe Implementation \(SAFE_IMPLEMENTATION\)](#) to the hierarchical block or signal that represents the state register.

By default, XST automatically selects a reset state as the recovery state. If the FSM does not have an initialization signal, XST selects a power-up state as the recovery state. To manually define the recovery state, apply [Safe Recovery State \(SAFE_RECOVERY_STATE\)](#).

FSM Log File

The XST log file reports the full information of recognized Finite State Machine (FSM) components during the Macro Recognition step. If you allow XST to choose the best encoding algorithm for your FSMs, it reports the algorithm it chose for each FSM. As soon as encoding is selected, XST reports the original and final FSM encoding. If the target is an FPGA device, XST reports this encoding at the HDL Synthesis step. If the target is a CPLD device, then XST reports this encoding at the Low Level Optimization step.

FSM Log File Example

```
...
Synthesizing Unit <fsm_1>.
  Related source file is "/state_machines_1.vhd".
  Found finite state machine <FSM_0> for signal <state>.
-----
| States           | 4
| Transitions     | 5
| Inputs          | 1
| Outputs         | 4
| Clock           | clk (rising_edge)
| Reset           | reset (positive)
| Reset type      | asynchronous
| Reset State     | s1
| Power Up State  | s1
| Encoding        | automatic
| Implementation  | LUT
-----

Found 1-bit register for signal <outp>.
Summary:
  inferred 1 Finite State Machine(s).
  inferred 1 D-type flip-flop(s).
Unit <fsm_1> synthesized.
```

```
=====
HDL Synthesis Report
```

```
Macro Statistics
# Registers           : 1
  1-bit register      : 1
```

```
=====
*                   Advanced HDL Synthesis                   *
=====
```

```
Advanced Registered AddSub inference ...
Analyzing FSM <FSM_0> for best encoding.
Optimizing FSM <state/FSM_0> on signal <state[1:2]>
with gray encoding.
```

```
-----
State | Encoding
-----
s1    | 00
s2    | 01
s3    | 11
s4    | 10
```

```

-----
=====
HDL Synthesis Report

Macro Statistics
# FSMs                               : 1
=====

```

FSM Related Constraints

- [Automatic FSM Extraction \(FSM_EXTRACT\)](#)
- [FSM Style \(FSM_STYLE\)](#)
- [FSM Encoding Algorithm \(FSM_ENCODING\)](#)
- [Enumerated Encoding \(ENUM_ENCODING\)](#)
- [Safe Implementation \(SAFE_IMPLEMENTATION\)](#)
- [Safe Recovery State \(SAFE_RECOVERY_STATE\)](#)

FSM Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

FSM With One Process Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| clk | Positive-Edge Clock |
| reset | Asynchronous Reset (active-High) |
| x1 | FSM Input |
| outp | FSM Output |

FSM With One Process VHDL Coding Example

```

--
-- State Machine with a single process.
--

library IEEE;
use IEEE.std_logic_1164.all;
entity fsm_1 is
    port ( clk, reset, x1 : IN std_logic;
          outp           : OUT std_logic);
end entity;

architecture beh1 of fsm_1 is
    type state_type is (s1,s2,s3,s4);
    signal state: state_type ;
begin

    process (clk,reset)
    begin
        if (reset = '1') then
            state <= s1;
            outp <= '1';
        elsif (clk='1' and clk'event) then

```

```

        case state is
            when s1 => if x1='1' then
                state <= s2;
                outp <= '1';
            else
                state <= s3;
                outp <= '0';
            end if;
            when s2 => state <= s4; outp <= '0';
            when s3 => state <= s4; outp <= '0';
            when s4 => state <= s1; outp <= '1';
        end case;
    end if;
end process;

```

```
end beh1;
```

FSM With Single Always Block Verilog Coding Example

```

//
// State Machine with a single always block.
//

module v_fsm_1 (clk, reset, x1, outp);
    input  clk, reset, x1;
    output outp;
    reg    outp;
    reg    [1:0] state;

    parameter s1 = 2'b00; parameter s2 = 2'b01;
    parameter s3 = 2'b10; parameter s4 = 2'b11;

    initial begin
        state = 2'b00;
    end

    always@(posedge clk or posedge reset)
    begin
        if (reset)
            begin
                state <= s1; outp <= 1'b1;
            end
        else
            begin
                case (state)
                    s1: begin
                        if (x1==1'b1)
                            begin
                                state <= s2;
                                outp <= 1'b1;
                            end
                        else
                            begin
                                state <= s3;
                                outp <= 1'b0;
                            end
                        end
                    s2: begin
                        state <= s4; outp <= 1'b1;
                    end
                end case;
            end
        end
    end

```

```

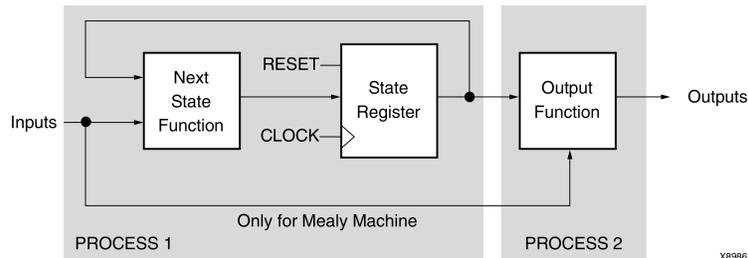
        end
        s3: begin
            state <= s4; outp <= 1'b0;
        end
        s4: begin
            state <= s1; outp <= 1'b0;
        end
    endcase
end
endmodule

```

FSM With Two Processes

To eliminate a register from the **outputs**, remove all assignments **outp <=...** from the Clock synchronization section. This can be done by introducing two processes as shown below.

FSM With Two Processes Diagram



FSM With Two Processes Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| clk | Positive-Edge Clock |
| reset | Asynchronous Reset (active-High) |
| x1 | FSM Input |
| outp | FSM Output |

FSM With Two Processes VHDL Coding Example

```

--
-- State Machine with two processes.
--

library IEEE;
use IEEE.std_logic_1164.all;
entity fsm_2 is
    port ( clk, reset, x1 : IN std_logic;
          outp           : OUT std_logic);
end entity;

architecture beh1 of fsm_2 is
    type state_type is (s1,s2,s3,s4);
    signal state: state_type ;
begin

```

```

process1: process (clk,reset)
begin
  if (reset = '1') then state <=s1;
  elsif (clk='1' and clk'Event) then
    case state is
      when s1 => if x1='1' then
                    state <= s2;
                  else
                    state <= s3;
                  end if;
      when s2 => state <= s4;
      when s3 => state <= s4;
      when s4 => state <= s1;
    end case;
  end if;
end process process1;

process2 : process (state)
begin
  case state is
    when s1 => outp <= '1';
    when s2 => outp <= '1';
    when s3 => outp <= '0';
    when s4 => outp <= '0';
  end case;
end process process2;

end beh1;

```

FSM With Two Always Blocks Verilog Coding Example

```

//
// State Machine with two always blocks.
//

module v_fsm_2 (clk, reset, x1, outp);
  input  clk, reset, x1;
  output outp;
  reg    outp;
  reg    [1:0] state;

  parameter s1 = 2'b00; parameter s2 = 2'b01;
  parameter s3 = 2'b10; parameter s4 = 2'b11;

  initial begin
    state = 2'b00;
  end

  always @(posedge clk or posedge reset)
  begin
    if (reset)
      state <= s1;
    else
      begin
        case (state)
          s1: if (x1==1'b1)
                state <= s2;
              else
                state <= s3;
        end case;
      end
    end
  end

```

```

                s2: state <= s4;
                s3: state <= s4;
                s4: state <= s1;
            endcase
        end
    end

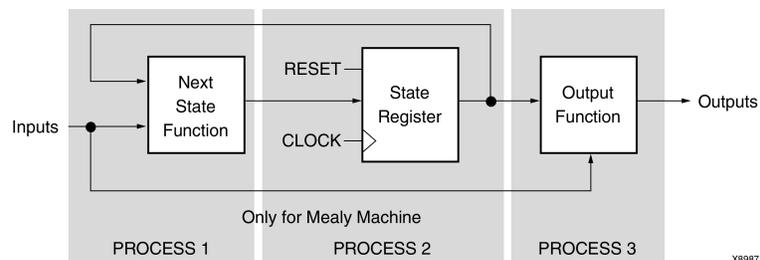
    always @(state)
    begin
        case (state)
            s1: outp = 1'b1;
            s2: outp = 1'b1;
            s3: outp = 1'b0;
            s4: outp = 1'b0;
        endcase
    end

endmodule

```

You can also separate the NEXT State function from the state register.

FSM With Three Processes Diagram



FSM With Three Processes Pin Descriptions

| IO Pins | Description |
|---------|----------------------------------|
| clk | Positive-Edge Clock |
| reset | Asynchronous Reset (active-High) |
| x1 | FSM Input |
| outp | FSM Output |

FSM With Three Processes VHDL Coding Example

```

--
-- State Machine with three processes.
--

library IEEE;
use IEEE.std_logic_1164.all;
entity fsm_3 is
    port ( clk, reset, x1 : IN std_logic;
          outp           : OUT std_logic);
end entity;

architecture beh1 of fsm_3 is
    type state_type is (s1,s2,s3,s4);
    signal state, next_state: state_type ;

```

```
begin

    process1: process (clk,reset)
    begin
        if (reset ='1') then
            state <=s1;
        elsif (clk='1' and clk'Event) then
            state <= next_state;
        end if;
    end process process1;

    process2 : process (state, x1)
    begin
        case state is
            when s1 => if x1='1' then
                next_state <= s2;
            else
                next_state <= s3;
            end if;
            when s2 => next_state <= s4;
            when s3 => next_state <= s4;
            when s4 => next_state <= s1;
        end case;
    end process process2;

    process3 : process (state)
    begin
        case state is
            when s1 => outp <= '1';
            when s2 => outp <= '1';
            when s3 => outp <= '0';
            when s4 => outp <= '0';
        end case;
    end process process3;

end beh1;
```

FSM With Three Always Blocks Verilog Coding Example

```
//  
// State Machine with three always blocks.  
//  
module v_fsm_3 (clk, reset, x1, outp);  
    input clk, reset, x1;  
    output outp;  
    reg outp;  
    reg [1:0] state;  
    reg [1:0] next_state;  
  
    parameter s1 = 2'b00; parameter s2 = 2'b01;  
    parameter s3 = 2'b10; parameter s4 = 2'b11;  
  
    initial begin  
        state = 2'b00;  
    end  
  
    always @(posedge clk or posedge reset)  
    begin  
        if (reset) state <= s1;  
        else state <= next_state;  
    end  
  
    always @(state or x1)  
    begin  
        case (state)  
            s1: if (x1==1'b1)  
                next_state = s2;  
                else  
                    next_state = s3;  
            s2: next_state = s4;  
            s3: next_state = s4;  
            s4: next_state = s1;  
        endcase  
    end  
  
    always @(state)  
    begin  
        case (state)  
            s1: outp = 1'b1;  
            s2: outp = 1'b1;  
            s3: outp = 1'b0;  
            s4: outp = 1'b0;  
        endcase  
    end  
  
endmodule
```

Black Boxes HDL Coding Techniques

This section discusses Black Boxes HDL Coding Techniques, and includes:

- [About Black Boxes](#)
- [Black Box Log File](#)
- [Black Box Related Constraints](#)
- [Black Box Coding Examples](#)

About Black Boxes

Your design may contain Electronic Data Interchange Format (EDIF) or NGC files generated by:

- Synthesis tools
- Schematic text editors
- Any other design entry mechanism

These modules must be instantiated in your code in order to be connected to the rest of your design. To do so in XST, use Black Box instantiation in the VHDL or Verilog code. The netlist is propagated to the final top-level netlist without being processed by XST. XST enables you to attach specific constraints to these Black Box instantiations, which are passed to the NGC file.

In addition, you may have a design block for which you have an Register Transfer Level (RTL) model, as well as your own implementation of this block in the form of an EDIF netlist. The RTL model is valid for simulation purposes only. Use [BoxType \(BOX_TYPE\)](#) to direct XST to skip synthesis of this RTL code and create a Black Box. The EDIF netlist is linked to the synthesized design during NGDBuild.

Once you make a design a Black Box, each instance of that design is a Black Box. While you can attach constraints to the instance, XST ignores any constraint attached to the original design.

For more information, see:

- [XST General Constraints](#)
- [Constraints Guide](#)

Black Box Log File

Since XST recognizes Black Boxes before macro inference, the Black Box log file differs from the log files generated for other macros.

Black Box Log File Example

```
...
Analyzing Entity <black_b> (Architecture <archi>).

WARNING:Xst:766 - black_box_1.vhd (Line 15).
Generating a Black Box for component <my_block>.
Entity <black_b> analyzed. Unit <black_b> generated
....
```

Black Box Related Constraints

[BoxType \(BOX_TYPE\)](#)

BoxType was introduced for device primitive instantiation in XST. Before using BoxType, see:

Device Primitive Support

Black Box Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Black Box VHDL Coding Example

```
--  
-- Black Box  
--  
  
library ieee;  
use ieee.std_logic_1164.all;  
  
entity black_box_1 is  
    port(DI_1, DI_2 : in std_logic;  
         DOUT : out std_logic);  
end black_box_1;  
  
architecture archi of black_box_1 is  
  
    component my_block  
    port (I1 : in std_logic;  
         I2 : in std_logic;  
         O : out std_logic);  
    end component;  
  
begin  
  
    inst: my_block port map (I1=>DI_1,I2=>DI_2,O=>DOUT);  
  
end archi;
```

Black Box Verilog Coding Example

```
//  
// Black Box  
//  
  
module v_my_block (in1, in2, dout);  
    input in1, in2;  
    output dout;  
endmodule  
  
module v_black_box_1 (DI_1, DI_2, DOUT);  
    input DI_1, DI_2;  
    output DOUT;  
  
    v_my_block inst (  
        .in1(DI_1),  
        .in2(DI_2),  
        .dout(DOUT));  
  
endmodule
```

For more information on component instantiation, see your VHDL and Verilog language reference manuals.

XST FPGA Optimization

This chapter discusses XST FPGA Optimization, and includes:

- [FPGA Synthesis and Optimization](#)
- [FPGA Specific Synthesis Options](#)
- [Macro Generation](#)
- [DSP48 Block Resources](#)
- [Mapping Logic Onto Block RAM](#)
- [Flip-Flop Retiming](#)
- [Partitions](#)
- [Speed Optimization Under Area Constraint](#)
- [FPGA Optimization Report](#)
- [Implementation Constraints](#)
- [FPGA Device Primitive Support](#)
- [Cores Processing](#)
- [Specifying INIT and RLOC](#)
- [Using PCI™ Flow With XST](#)

FPGA Synthesis and Optimization

XST performs the following steps during FPGA synthesis and optimization:

- Mapping and optimization on an entity by entity or module by module basis
- Global optimization on the complete design

The output is an NGC file.

FPGA Specific Synthesis Options

XST supports the following options to fine-tune FPGA synthesis to meet user constraints:

- Extract BUFGCE (BUFGCE)
- Cores Search Directories (-sd)
- Decoder Extraction (DECODER_EXTRACT)
- FSM Style (FSM_STYLE)
- Global Optimization Goal (-glob_opt)
- Keep Hierarchy (KEEP_HIERARCHY)
- Logical Shifter Extraction (SHIFT_EXTRACT)
- Map Logic on BRAM (BRAM_MAP)
- Max Fanout (MAX_FANOUT)
- Move First Stage (MOVE_FIRST_STAGE)
- Move Last Stage (MOVE_LAST_STAGE)
- Multiplier Style (MULT_STYLE)
- Mux Style (MUX_STYLE)
- Number of Global Clock Buffers (-bufg)
- Optimize Instantiated Primitives (OPTIMIZE_PRIMITIVES)
- Pack I/O Registers Into IOBs (IOB)
- Priority Encoder Extraction (PRIORITY_EXTRACT)
- RAM Style (RAM_STYLE)
- Register Balancing (REGISTER_BALANCING)
- Register Duplication (REGISTER_DUPLICATION)
- Signal Encoding (SIGNAL_ENCODING)
- Slice Packing (-slice_packing)
- Use Carry Chain (USE_CARRY_CHAIN)
- Write Timing Constraints (-write_timing_constraints)
- XOR Collapsing (XOR_COLLAPSE)

For more information, see:

[XST FPGA Constraints \(Non-Timing\)](#)

Macro Generation

The FPGA Device Macro Generator module provides the XST HDL Flow with a catalog of functions. These functions are identified by the inference engine from the Hardware Description Language (HDL) description. Their characteristics are handed to the Macro Generator for optimal implementation.

The set of inferred functions ranges in complexity from simple arithmetic operators (such as adders, accumulators, counters and multiplexers), to more complex building blocks (such as multipliers, shift registers and memories).

Inferred functions are optimized to deliver the highest levels of performance and efficiency for the selected Virtex® architecture or Spartan® architecture, and then integrated into the rest of the design. In addition, the generated functions are optimized through their borders depending on the design context.

This section categorizes, by function, all available macros and briefly describes technology resources used in the building and optimization phase.

Macro Generation can be controlled through attributes. These attributes are listed in each subsection.

XST uses dedicated carry chain logic to implement many macros. In some situations carry chain logic may result in less than ideal optimization. [Use Carry Chain \(USE_CARRY_CHAIN\)](#) deactivates this feature.

For more information, see:

[XST Design Constraints](#)

Arithmetic Functions in Macro Generation

For Arithmetic Functions, XST provides the following elements:

- Adders, Subtractors and Adder/Subtractors
- Cascadable Binary Counters
- Accumulators
- Incrementers, Decrementers and Incrementer/Decrementers
- Signed and Unsigned Multipliers

XST uses fast carry logic (MUXCY) to provide fast arithmetic carry capability for high-speed arithmetic functions. The sum logic formed from two XOR gates is implemented using LUTs and the dedicated carry-XORs (XORCY). In addition, XST benefits from a dedicated carry-ANDs (MULTAND) resource for high-speed multiplier implementation.

Loadable Functions in Macro Generation

For Loadable functions XST provides the following elements:

- Loadable Up, Down and Up/Down Binary Counters
- Loadable Up, Down and Up/Down Accumulators

XST can provide synchronously loadable, cascadable binary counters and accumulators inferred in the HDL flow. Fast carry logic is used to cascade the different stages of the macros. Synchronous loading and count functions are packed in the same LUT primitive for optimal implementation.

For Up/Down counters and accumulators, XST uses dedicated carry-ANDs to improve performance.

Multiplexers in Macro Generation

For multiplexers, the Macro Generator provides the following two architectures:

- MUXFx based multiplexers
- Dedicated Carry-MUXs based multiplexers

For Virtex®-4 devices, XST can implement multiplexers using the primitives shown in the following table.

| Multiplexer | CLB | Primitive |
|-------------|-----------------|-----------|
| 16:1 | single CLB | MUXF7 |
| 32:1 | across two CLBs | MUXF8 |

To better control the implementation of the inferred multiplexer, XST offers a way to select the generation of either the MUXF5/MUXF6 or Dedicated Carry-MUXs architectures. The attribute [MUX_STYLE \(Mux Style\)](#) specifies that an inferred multiplexer be implemented on a MUXF_x based architecture if the value is MUXF, or a Dedicated Carry-MUXs based architecture if the value is MUXCY.

You can apply this attribute to either a signal that defines the multiplexer or the instance name of the multiplexer. This attribute can also be global.

The attribute [MUX_EXTRACT \(Mux Extraction\)](#) with, respectively, the value **no** or **force** can be used to disable or force the inference of the multiplexer.

You still may have MUXF_x elements in the final netlist even if multiplexer inference is disabled using the [MUX_EXTRACT \(Mux Extraction\)](#) constraint. These elements come from the general mapping procedure of Boolean equations.

Priority Encoders in Macro Generation

The **if/elsif** structure described in [Priority Encoders HDL Coding Techniques](#) is implemented with a *1-of-n* priority encoder.

XST uses the MUXCY primitive to chain the conditions of the priority encoder, which results in its high-speed implementation.

Use [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#) to enable or disable priority encoder inference.

XST does not generally infer (and therefore does not generate) a large number of priority encoders. To enable priority encoders, use [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#) with the **force** option.

Decoders in Macro Generation

A decoder is a demultiplexer whose inputs are all constant with distinct one-hot (or one-cold) coded values. An *n-bit* or *1-of-m* decoder is mainly characterized by an *m-bit* data output and an *n-bit* selection input, such that:

$$n^{*(2-1)} < m \leq n^{*2}$$

Once XST has inferred the decoder, the implementation uses the MUXF5 or MUXCY primitive depending on the size of the decoder.

Use [Decoder Extraction \(DECODER_EXTRACT\)](#) to enable or disable decoder inference.

RAMs in Macro Generation

Two types of RAM are available during inference and generation:

- Distributed RAM
If the RAM is *asynchronous* READ, Distributed RAM is inferred and generated.
- Block RAM (default)
If the RAM is *synchronous* READ, block RAM is inferred. In this case, XST can implement block RAM or distributed RAM.

Primitives Used by XST

This section applies to the following devices:

- Virtex®-4
- Spartan®-3

For these devices, XST uses the primitives shown in the following table.

| RAM | Clock Edge | Primitives |
|---|--|---|
| Single-Port Synchronous Distributed RAM | Distributed Single-Port RAM with positive clock edge | RAM16X1S, RAM16X2S, RAM16X4S, RAM16X8S, RAM32X1S, RAM32X2S, RAM32X4S, RAM32X8S, RAM64X1S, RAM64X2S, RAM128X1S |
| Single-Port Synchronous Distributed RAM | Distributed Single-Port RAM with negative clock edge | RAM16X1S_1, RAM32X1S_1, RAM64X1S_1, RAM128X1S_1 |
| Dual-Port Synchronous Distributed RAM | Distributed Dual-Port RAM with positive clock edge | RAM16X1D, RAM32X1D, RAM64X1D |
| Dual-Port Synchronous Distributed RAM | Distributed Dual-Port RAM with negative clock edge | RAM16X1D_1, RAM32X1D_1, RAM64X1D_1 |
| Single-Port Synchronous Block RAM | N/A | RAMB4_Sn |
| Dual-Port Synchronous Block RAM | N/A | RAMB4_Sm_Sn |

Controlling Implementation of Inferred RAM

To better control the implementation of the inferred RAM, XST offers a way to control RAM inference, and to select the generation of distributed RAM or block RAMs (if possible).

The [RAM Style \(RAM_STYLE\)](#) attribute specifies that an inferred RAM be generated using:

- Block RAM if the value is *block*
- Distributed RAM if the value is *distributed*

Apply the [RAM Style \(RAM_STYLE\)](#) attribute to:

- A signal that defines the RAM, or
- The instance name of the RAM

The [RAM Style \(RAM_STYLE\)](#) attribute can also be global.

If the RAM resources are limited, XST can generate additional RAMs using registers. To generate additional RAMs using registers, use [RAM Extraction \(RAM_EXTRACT\)](#) with the value set to **no**.

ROMs in Macro Generation

This section discusses ROMs in Macro Generation, and includes:

- [Inferring ROM When Assigned Contexts are Constants](#)
- [Inferring ROM from an Array](#)
- [Types of ROM Available During Inference and Generation](#)
- [Type of Synchronous ROM Inferred by XST](#)
- [Applying RAM Style](#)

Inferring ROM When Assigned Contexts are Constants

A ROM can be inferred when all assigned contexts in a **case** or **if...else** statement are constants. Macro inference considers only ROMs of at least 16 words with no width restriction. For example, the following Hardware Description Language (HDL) equation can be implemented with a ROM of 16 words of 4 bits:

```
data = if address = 0000 then 0010
      if address = 0001 then 1100
      if address = 0010 then 1011
      ...
      if address = 1111 then 0001
```

Inferring ROM from an Array

A ROM can also be inferred from an array composed entirely of constants, as shown in the following coding example.

```
type ROM_TYPE is array(15 downto 0) of std_logic_vector(3 downto 0);
constant ROM : rom_type := ("0010", "1100", "1011", ..., "0001");
...
data <= ROM(conv_integer(address));
```

[ROM Extraction \(ROM_EXTRACT\)](#) can be used to disable the inference of ROMs.

- To *enable* ROM inference, set the value to **yes**.
- To *disable* ROM inference, set the value to **no**.

The default is **yes**.

Types of ROM Available During Inference and Generation

Two types of ROM are available during inference and generation:

- **Distributed ROM**
Distributed ROMs are generated by using the optimal tree structure of LUT, MUXF5, MUXF6, MUXF7 and MUXF8 primitives, which allows compact implementation of large inferred ROMs.
- **Block ROM**
Block ROMs are generated by using block RAM resources. When a synchronous ROM is identified, it can be inferred either as a distributed ROM plus a register, or it can be inferred using block RAM resources.

Type of Synchronous ROM Inferred by XST

[ROM Style \(ROM_STYLE\)](#) specifies which type of synchronous ROM XST infers as shown in the following table.

| Option | XST Behavior |
|-----------------------|--|
| block | Infers the ROM using block RAM resources, provided the ROM fits entirely on a single block of RAM. |
| distributed | Infers a distributed ROM plus register. |
| auto (default) | Determines the most efficient method to use, and infers the ROM accordingly. |

Applying RAM Style

You can apply [RAM Style \(RAM_STYLE\)](#) as a VHDL attribute or a Verilog meta comment to:

- An individual signal
- The entity or module of the ROM

[RAM Style \(RAM_STYLE\)](#) can also be applied globally from:

- ISE® Design Suite in:
 Process > Process Properties
- The command line

DSP48 Block Resources

This section discusses DSP48 Block Resources, and includes:

- [Macro Implementation on DSP48 Blocks](#)
- [Disabling Automatic DSP Resource Management](#)
- [Maximum Macro Configuration](#)
- [Asynchronous Set/Reset Signals](#)
- [Interconnected Macros](#)

Macro Implementation on DSP48 Blocks

XST can automatically implement the following macros on a DSP48 block:

- Adders/subtractors
- Accumulators
- Multipliers
- Multiply adder/subtractors
- Multiply accumulate (MAC)

XST also supports the registered versions of these macros.

Macro implementation on DSP48 blocks is controlled by [Use DSP48 \(USE_DSP48\)](#) with a default value of **auto**.

In **auto** mode, XST attempts to implement accumulators, multipliers, multiply adder/subtractors and MACs on DSP48 resources. XST does not implement adders/subtractors on DSP48 resources in **auto** mode. To push adder/subtractors into a DSP48, set [Use DSP48 \(USE_DSP48\)](#) to **yes**.

XST performs automatic resource control in **auto** mode for all macros. Use the [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#) constraint in this mode to control available DSP48 resources for the synthesis. By default, XST tries to utilize all available DSP48 resources as much as possible.

Disabling Automatic DSP Resource Management

If the number of user-specified DSP slices exceeds the number of available DSP resources on the target FPGA device, XST issues a warning, and uses only available DSP resources on the chip for synthesis. Disable automatic DSP resource management to see the number of DSPs that XST can potentially infer for a specific design. To disable automatic DSP resource management, set *value* = **-1**.

Maximum Macro Configuration

To deliver the best performance, XST by default tries to infer and implement the maximum macro configuration, including as many registers in the DSP48 as possible. Use [Keep \(KEEP\)](#) to shape a macro in a specific way. For example, if your design has a multiplier with two register levels on each input, place [Keep \(KEEP\)](#) constraints on the outputs of these registers to exclude the first register stage from the DSP48.

Asynchronous Set/Reset Signals

DSP48 blocks do not support registers with Asynchronous Set/Reset signals. Since such registers cannot be absorbed by DSP48, this may lead to sub-optimal performance. The [Asynchronous to Synchronous \(ASYNC_TO_SYNC\)](#) constraint allows you to replace Asynchronous Set/Reset signals with Synchronous signals throughout the entire design. This allows absorption of registers by DSP48, thereby improving quality of results.

Replacing Asynchronous Set/Reset signals by Synchronous signals makes the generated NGC netlist NOT equivalent to the initial RTL description. You must ensure that the synthesized design satisfies the initial specification. For more information, see [Asynchronous to Synchronous \(ASYNC_TO_SYNC\)](#).

For more information on individual macro processing, see:

[XST HDL Coding Techniques](#)

Interconnected Macros

If your design contains several interconnected macros, where each macro can be implemented on DSP48, XST attempts to interconnect DSP48 blocks using fast **BCIN/BCOUT** and **PCIN/PCOUT** connections. Such situations are typical in filter and complex multiplier descriptions.

XST can build complex DSP macros and DSP48 chains across the hierarchy when [Keep Hierarchy \(KEEP_HIERARCHY\)](#) is set to **no**. This is the default in ISE® Design Suite.

Mapping Logic Onto Block RAM

If your design does not fit into the target device, you can place some of the design logic into unused block RAM:

1. Put the part of the RTL description to be placed into block RAM in a separate hierarchical block.
2. Attach a [BRAM_MAP \(Map Logic on BRAM\)](#) constraint to the separate hierarchical block, either directly in Hardware Description Language (HDL) code, or in the XST Constraint File (XCF).

XST cannot automatically decide which logic can be placed in block RAM.

Logic placed into a separate block must satisfy the following criteria:

- All outputs are registered.
- The block contains only one level of registers, which are output registers.
- All output registers have the same control signals.
- The output registers have a Synchronous Reset signal.
- The block does not contain multisources or tristate buses.
- [Keep \(KEEP\)](#) is not allowed on intermediate signals.

XST attempts to map the logic onto block RAM during the Advanced Synthesis step. If any of the listed requirements are not satisfied, XST does not map the logic onto block RAM, and issues a warning. If the logic cannot be placed in a single block RAM primitive, XST spreads it over several block RAMs.

Mapping Logic Onto Block RAM Log File Example One

```

...
=====
*                               HDL Synthesis                               *
=====
e is "bram_map_1.vhd".
  Found 4-bit register for signal <RES>.
  Found 4-bit adder for signal <$n0001> created at line 29.
  Summary:
    inferred   4 D-type flip-flop(s).
    inferred   1 Adder/Subtractor(s).
Unit <logic_bram_1> synthesized.

=====
*                               Advanced HDL Synthesis                       *
=====
...
Entity <logic_bram_1> mapped on BRAM.
...
=====
HDL Synthesis Report

Macro Statistics
# Block RAMs                               : 1
 256x4-bit single-port block RAM           : 1

=====
...

```

Mapping Logic Onto Block RAM Log File Example Two

```

...
=====
*                          Advanced HDL Synthesis                          *
=====
...
INFO:Xst:1789 - Unable to map block <no_logic_bram> on BRAM.
                Output FF <RES> must have a synchronous reset.

```

8-Bit Adders With Constant in a Single Block Ram Primitive VHDL Coding Example

```

--
-- The following example places 8-bit adders with
-- constant in a single block RAM primitive
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity logic_bram_1 is
port (clk, rst : in std_logic;
      A,B : in unsigned (3 downto 0);
      RES : out unsigned (3 downto 0));

    attribute bram_map: string;
    attribute bram_map of logic_bram_1: entity is "yes";

end logic_bram_1;

architecture beh of logic_bram_1 is
begin

    process (clk)
    begin
        if (clk'event and clk='1') then
            if (rst = '1') then
                RES <= "0000";
            else
                RES <= A + B + "0001";
            end if;
        end if;
    end process;

end beh;

```

8-Bit Adders With Constant in a Single Block Ram Primitive Verilog Coding Example

```
//  
// The following example places 8-bit adders with  
// constant in a single block RAM primitive  
//  
(* bram_map="yes" *)  
module v_logic_bram_1 (clk, rst, A, B, RES);  
  
    input  clk, rst;  
    input  [3:0] A, B;  
    output [3:0] RES;  
    reg    [3:0] RES;  
  
    always @(posedge clk)  
    begin  
        if (rst)  
            RES <= 4'b0000;  
        else  
            RES <= A + B + 8'b0001;  
        end  
    end  
  
endmodule
```

Asynchronous Reset VHDL Coding Example

```
--
-- In the following example, an asynchronous reset is used and
-- so, the logic is not mapped onto block RAM
--

library ieee;
use ieee.std_logic_1164.all;
use ieee.numeric_std.all;

entity logic_bram_2 is
port (clk, rst : in std_logic;
      A,B       : in unsigned (3 downto 0);
      RES       : out unsigned (3 downto 0));

      attribute bram_map : string;
      attribute bram_map of logic_bram_2 : entity is "yes";

end logic_bram_2;

architecture beh of logic_bram_2 is
begin

    process (clk, rst)
    begin
        if (rst='1') then
            RES <= "0000";
        elsif (clk'event and clk='1') then
            RES <= A + B + "0001";
        end if;
    end process;

end beh;
```

Asynchronous Reset Verilog Coding Example

```
//
// In the following example, an asynchronous reset is used and
// so, the logic is not mapped onto block RAM
//

(* bram_map="yes" *)
module v_logic_bram_2 (clk, rst, A, B, RES);

    input  clk, rst;
    input  [3:0] A, B;
    output [3:0] RES;
    reg    [3:0] RES;

    always @(posedge clk or posedge rst)
    begin
        if (rst)
            RES <= 4'b0000;
        else
            RES <= A + B + 8'b0001;
        end
    end

endmodule
```

Flip-Flop Retiming

This section discusses Flip-Flop Retiming, and includes:

- [About Flip-Flop Retiming](#)
- [Global Optimization](#)
- [Flip-Flop Retiming Messages](#)
- [Limitations of Flip-Flop Retiming](#)
- [Controlling Flip-Flop Retiming](#)

About Flip-Flop Retiming

Flip-flop retiming consists of moving flip-flops and latches across logic for the purpose of improving timing, thus increasing clock frequency.

Flip-flop retiming can be either forward or backward:

- Forward retiming moves a set of flip-flops that are the input of a LUT to a single flip-flop at its output.
- Backward retiming moves a flip-flop that is at the output of a LUT to a set of flip-flops at its input.

Flip-flop retiming can:

- Significantly increase the number of flip-flops
- Remove some flip-flops

Nevertheless, the behavior of the designs remains the same. Only timing delays are modified.

Global Optimization

Flip-flop retiming is part of global optimization. It respects the same constraints as all other optimization techniques. Since retiming is incremental, a flip-flop that is the result of a retiming can be moved again in the same direction (forward or backward) if it results in better timing. The only limit for the retiming occurs when the timing constraints are satisfied, or if no more improvements in timing can be obtained.

Flip-Flop Retiming Messages

For each flip-flop moved, a message is printed specifying:

- The original and new flip-flop names
- Whether it is a forward or backward retiming

Limitations of Flip-Flop Retiming

Flip-flop retiming has the following limitations:

- Flip-flop retiming is not applied to flip-flops that have the `IOB=TRUE` property.
- Flip-flops are not moved forward if the flip-flop or the output signal has the [Keep \(KEEP\)](#) property.
- Flip-flops are not moved backward if the input signal has the [Keep \(KEEP\)](#) property.
- Instantiated flip-flops are moved only if the [Optimize Instantiated Primitives](#) constraint or command line option is set to `yes`.
- Flip-Flops are moved across instantiated primitives only if the [Optimize Instantiated Primitives](#) command line option or constraint is set to `yes`.
- Flip-flops with both a set and a reset are not moved.

Controlling Flip-Flop Retiming

Use the following constraints to control flip-flop retiming:

- [Register Balancing \(REGISTER_BALANCING\)](#)
- [Move First Stage \(MOVE_FIRST_STAGE\)](#)
- [Move Last Stage \(MOVE_LAST_STAGE\)](#)

Partitions

XST now supports Partitions in place of Incremental Synthesis. Incremental Synthesis is no longer supported. The `incremental_synthesis` and `resynthesize` constraints are no longer supported. For more information on Partitions, see the ISE® Design Suite Help.

Speed Optimization Under Area Constraint

XST performs timing optimization under the area constraint. This option is named:

- LUT-FF Pairs Utilization Ratio
Virtex®-5 devices
- [Slice \(LUT-FF Pairs\) Utilization Ratio \(SLICE_UTILIZATION_RATIO\)](#)
All other FPGA devices

Define in ISE® Design Suite with:

Process > Process Properties > XST Synthesis Options.

By default this constraint is set to 100% of the selected device size.

This constraint has influence at low level synthesis only. It does not control inference.

If this constraint is specified, XST makes an area estimation. If the specified constraint is met, XST continues timing optimization trying not to exceed the constraint. If the design is larger than requested, XST tries to reduce the area first. If the area constraint is met, XST begins timing optimization.

Example One (100%)

In the following example the area constraint was specified as 100% and initial estimation shows that in fact it occupies 102% of the selected device. XST begins optimization and reaches 95%.

```

...
=====
*
*                               Low Level Synthesis
*
=====

Found area constraint ratio of 100 (+ 5) on block tge,
actual ratio is 102.
Optimizing block <tge> to meet ratio 100 (+ 5) of 1536
slices :
Area constraint is met for block <tge>, final ratio is 95.
=====

```

Example Two (70%)

If the area constraint cannot be met, XST ignores it during timing optimization and runs low level synthesis to achieve the best frequency. In the following example, the target area constraint is set to 70%. Since XST was unable to satisfy the target area constraint, XST issues the following warning:

```

...
=====
*
*           Low Level Synthesis
*
=====
Found area constraint ratio of 70 (+ 5) on block fpga_hm,
actual ratio is 64.
Optimizing block <fpga_hm> to meet ratio 70 (+ 5) of 1536
slices :
WARNING:Xst - Area constraint could not be met for block <tge>,
final ratio is 94
...
=====
...

```

Note (+5) stands for the max margin of the area constraint. If the area constraint is not met, but the difference between the requested area and obtained area during area optimization is less or equal then 5%, then XST runs timing optimization taking into account the achieved area, not exceeding it.

Example Three (55%)

In the following example, the area was specified as 55%. XST achieved only 60%. But taking into account that the difference between requested and achieved area is not more than 5%, XST considers that the area constraint was met.

```

...
=====
*
*           Low Level Synthesis
*
=====
Found area constraint ratio of 55 (+ 5) on block fpga_hm,
actual ratio is 64.
Optimizing block <fpga_hm> to meet ratio 55 (+ 5) of 1536
slices :
Area constraint is met for block <fpga_hm>, final ratio is 60.
=====
...

```

In some situations, it is important to disable automatic resource management. To do so, specify `-1` as the value for `SLICE_UTILIZATION_RATIO`.

[Slice \(LUT-FF Pairs\) Utilization Ratio \(SLICE_UTILIZATION_RATIO\)](#) can be attached to a specific block of a design. You can specify an absolute number of slices (or FF-LUT pairs) as a percentage of the total number.

FPGA Device Optimization Report Section

This section discusses FPGA Device Optimization Report Section, and includes:

- [About FPGA Device Optimization Report Section](#)
- [Cell Usage Report](#)
- [Timing Report](#)

About FPGA Device Optimization Report Section

During design optimization, XST reports:

- Potential removal of equivalent flip-flops
Two flip-flops (latches) are equivalent when they have the same data and control pins.
- Register replication
Register replication is used to:
 - Improve timing performance
 - Satisfy `MAX_FANOUT` constraintsUse [Register Duplication \(REGISTER_DUPLICATION\)](#) to turn off register replication.

FPGA Device Optimization Report Section Example

```
Starting low level synthesis ...
Optimizing unit <down4cnt> ...
Optimizing unit <doc_readwrite> ...
...
Optimizing unit <doc> ...
Building and optimizing final netlist ...
The FF/Latch <doc_readwrite/state_D2> in Unit <doc> is
equivalent to the following 2 FFs/Latches,
which will be removed : <doc_readwrite/state_P2>
<doc_readwrite/state_M2>Register
doc_reset_I_reset_out has been replicated 2 time(s)
Register wr_1 has been replicated 2 time(s)
```

Cell Usage Report

The Cell Usage section of the Final Report gives the count of all the primitives used in the design. The primitives are classified in the following groups:

- [BELS Cell Usage](#)
- [Flip-Flops and Latches Cell Usage](#)
- [RAMS Cell Usage](#)
- [SHIFTERS Cell Usage](#)
- [Tristates Cell Usage](#)
- [Clock Buffers Cell Usage](#)
- [IO Buffers Cell Usage](#)
- [LOGICAL Cell Usage](#)
- [OTHER Cell Usage](#)

BELS Cell Usage

The BELS group in the Cell Usage section of the Final Report contains all the logical cells that are basic elements of the targeted FPGA device family, for example:

- LUTs
- MUXCY
- MUXF5
- MUXF6
- MUXF7
- MUXF8

Flip-Flops and Latches Cell Usage

The Flip-Flops and Latches group in the Cell Usage section of the Final Report contains all the flip-flops and latches that are primitives of the targeted FPGA device family, for example:

- FDR
- FDRE
- LD

RAMS Cell Usage

The RAMS group in the Cell Usage section of the Final Report contains all the RAMs.

SHIFTERS Cell Usage

The SHIFTERS group in the Cell Usage section of the Final Report contains all the shift registers that use the Virtex® device primitive:

- TSRL16
- SRL16_1
- SRL16E
- SRL16E_1
- SRLC

Tristates Cell Usage

The Tristates group in the Cell Usage section of the Final Report contains all the tristate primitives:

BUFT

Clock Buffers Cell Usage

The Clock Buffers group in the Cell Usage section of the Final Report contains all the clock buffers:

- BUFG
- BUFGP
- BUFGDLL

IO Buffers Cell Usage

The IO Buffers group in the Cell Usage section of the Final Report contains all the standard I/O buffers (except the clock buffer):

- IBUF
- OBUF
- IOBUF
- OBUFT
- IBUF_GTL ...

LOGICAL Cell Usage

The LOGICAL group in the Cell Usage section of the Final Report contains all the logical cells primitives that are not basic elements:

- AND2
- OR2 ...

OTHER Cell Usage

The OTHER group in the Cell Usage section of the Final Report contains all the cells that have not been classified in the previous groups.

Cell Usage Report Example

```

=====
...
Cell Usage :
# BELS                : 70
#     LUT2             : 34
#     LUT3             : 3
#     LUT4             : 34
# FlipFlops/Latches  : 9
#     FDC              : 8
#     FDP              : 1
# Clock Buffers      : 1
#     BUFGP           : 1
# IO Buffers         : 24
#     IBUF            : 16
#     OBUF            : 8
=====

```

Where XST estimates the number of slices and gives, for example, the number of flip-flops, IOBs, and BRAMS. This report closely resembles the report produced by MAP.

Short tables give information about:

- The number of clocks in the design, how each clock is buffered, and how many loads it has
- The number of asynchronous set/reset signals in the design, how each signal is buffered, and how many loads it has

Timing Report

This section discusses Timing Report, and includes:

- [About Timing Report](#)
- [Timing Report Timing Summary Section](#)
- [Timing Report Timing Detail Section](#)
- [Timing Report Paths and Ports](#)

About Timing Report

At the end of synthesis, XST reports the timing information for the design. The Timing Report shows the information for all four possible domains of a netlist:

- register to register
- input to register
- register to outpad
- inpad to outpad

Timing Report Example

These timing numbers are only a synthesis estimate. For accurate timing information, see the TRACE report generated after place-and-route.

Clock Information:

| Clock Signal | Clock buffer (FF name) | Load |
|--------------|------------------------|------|
| CLK | BUFGP | 11 |

Asynchronous Control Signals Information:

| Control Signal | Buffer (FF name) | Load |
|---------------------------------------|--------------------------------|------|
| rstint(MACHINE/current_state_Out01:0) | NONE(sixty/lsbcount/qoutsig_3) | 4 |
| RESET | IBUF | 3 |
| sixty/msbclr(sixty/msbclr:0) | NONE(sixty/msbcount/qoutsig_3) | 4 |

Timing Summary:

Speed Grade: -12

Minimum period: 2.644ns (Maximum Frequency: 378.165MHz)
 Minimum input arrival time before clock: 2.148ns
 Maximum output required time after clock: 4.803ns
 Maximum combinational path delay: 4.473ns

Timing Detail:

All values displayed in nanoseconds (ns)

=====
 Timing constraint: Default period analysis for Clock 'CLK'
 Clock period: 2.644ns (frequency: 378.165MHz)
 Total number of paths / destination ports: 77 / 11
 =====

Delay: 2.644ns (Levels of Logic = 3)
 Source: MACHINE/current_state_FFd3 (FF)
 Destination: sixty/msbcount/qoutsig_3 (FF)
 Source Clock: CLK rising
 Destination Clock: CLK rising

Data Path: MACHINE/current_state_FFd3 to sixty/msbcount/qoutsig_3

| Cell:in->out | fanout | Gate Delay | Net Delay | Logical Name (Net Name) |
|--------------|--------|--|-----------|---|
| FDC:C->Q | 8 | 0.272 | 0.642 | MACHINE/current_state_FFd3 (MACHINE/current_state_FFd3) |
| LUT3:I0->O | 3 | 0.147 | 0.541 | Ker81 (clkenable) |
| LUT4_D:I1->O | 1 | 0.147 | 0.451 | sixty/msbce (sixty/msbce) |
| LUT3:I2->O | 1 | 0.147 | 0.000 | sixty/msbcount/qoutsig_3_rstpot (N43) |
| FDC:D | | 0.297 | | sixty/msbcount/qoutsig_3 |
| Total | | 2.644ns (1.010ns logic, 1.634ns route) | | (38.2% logic, 61.8% route) |

Timing Report Timing Summary Section

The Timing Summary section of the Timing Report summarizes the timing paths for all four domains:

- The path from any clock to any clock in the design:
Minimum period: 7.523ns (Maximum Frequency: 132.926MHz)
- The maximum path from all primary inputs to the sequential elements:
Minimum input arrival time before clock: 8.945ns
- The maximum path from the sequential elements to all primary outputs:
Maximum output required time before clock: 14.220ns
- The maximum path from inputs to outputs:
Maximum combinational path delay: 10.899ns

If there is no path in the domain, *No path found* is printed instead of the value.

Timing Report Timing Detail Section

The Timing Detail section of the Timing Report describes the most critical path in detail for each region:

- Start point of the path
- End point of the path
- Maximum delay of the path
- Slack

The start and end points can be:

- Clock (with the phase: rising/falling), or
 - Port
- Path from Clock 'sysclk' rising to Clock 'sysclk' rising : 7.523ns (Slack: -7.523ns)

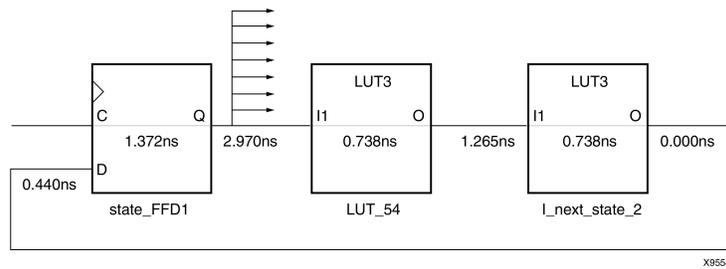
The detailed path shows:

- Cell type
- Input and output of this gate
- Fanout at the output
- Gate delay
- Net delay estimate
- Name of the instance.

When entering a hierarchical block, **begin scope** is printed. When exiting a hierarchical block, **end scope** is printed.

The preceding report corresponds to the following schematic.

Timing Report Schematic



Timing Report Paths and Ports

The Timing Report section shows the number of analyzed paths and ports. If XST is run with timing constraints, it also shows the number of failed paths and ports. The number of analyzed and failed paths shows how many timing problems there are in the design. The number of analyzed and failed ports may show how they are spread in the design. The number of ports in a timing report represent the number of destination elements for a timing constraint.

For example, if you use the following timing constraints:

```
TIMESPEC "TSidentifier"=FROM "source_group" TO "dest_group" value
units;
```

then the number of ports corresponds to the number of elements in the destination group.

For a given timing constraint, XST may report that the number of failed paths is 100, but that the number of failed destination ports is only two flip-flops. In that case, it is sufficient to analyze the design description for these two flip-flops only in order to detect the changes necessary to meet timing.

Implementation Constraints

XST writes all implementation constraints generated from Hardware Description Language (HDL) or constraint file attributes (such as [LOC](#)) into the output NGC file.

[Keep \(KEEP\)](#) properties are generated during buffer insertion for maximum fanout control or for optimization.

FPGA Device Primitive Support

This section discusses FPGA Device Primitive Support, and includes:

- [About FPGA Device Primitive Support](#)
- [Generating Primitives Through Attributes](#)
- [Primitives and Black Boxes](#)
- [VHDL and Verilog Device Primitives Libraries](#)
- [Reporting of Instantiated Device Primitives](#)
- [Primitives Related Constraints](#)
- [Primitives Coding Examples](#)
- [Using the UniMacro Library](#)

About FPGA Device Primitive Support

XST enables you to instantiate device primitives directly in VHDL or Verilog code. Primitives such as the following can be manually inserted in a Hardware Description Language (HDL) design through instantiation:

- MUXCY_L
- LUT4_L
- CLKDLL
- RAMB4_S1_S16
- IBUFG_PCI33_5
- NAND3b2

These primitives:

- Are compiled in the UNISIM library
- Are not optimized by XST by default
- Are available in the final NGC file

Use [Optimize Instantiated Primitives](#) synthesis to optimize instantiated primitives and obtain better results. Timing information is available for most of the primitives, allowing XST to perform efficient timing-driven optimization.

In order to simplify instantiation of complex primitives as RAMs, XST supports an additional library called UniMacro.

For more information, see the [Libraries Guides](#).

Generating Primitives Through Attributes

Some primitives can be generated through attributes:

- [Buffer Type \(BUFFER_TYPE\)](#)

Can be assigned to the primary input or internal signal to force the use of the following:

- BUFGDLL
- IBUFG
- BUFR
- BUFGP

The same constraints can be used to disable buffer insertion.

- [I/O Standard \(IOSTANDARD\)](#)

Can be used to assign an I/O standard to an I/O primitive.

For example, the following assigns PCI33_5 I/O standard to the I/O port:

```
// synthesis attribute IOSTANDARD of in1 is PCI33_5
```

Primitives and Black Boxes

The primitive support is based on the concept of the black box. For information on the basics of black box support, see [Safe FSM Implementation](#).

There is a significant difference between black box and primitive support. Assume you have a design with a submodule called MUXF5. In general, the MUXF5 can be your own functional block or a Xilinx® device primitive. To avoid confusion about how XST interprets this module, attach [BoxType \(BOX_TYPE\)](#) to the component declaration of MUXF5.

If [BoxType \(BOX_TYPE\)](#) is attached to the MUXF5 with a value of:

- **primitive**, or **black_box**

XST tries to interpret this module as a Xilinx device primitive and use its parameters, for instance, in critical path estimation.

- **user_black_box**

XST processes it as a regular user black box.

If the name of the user black box is the same as that of a Xilinx device primitive, XST renames it to a unique name and issues a warning. For example, MUX5 could be renamed to MUX51 as shown in the following log file example.

```
...
=====
*                               Low Level Synthesis                               *
=====

WARNING:Xst:79 - Model 'muxf5' has different characteristics in
destination library
WARNING:Xst:80 - Model name has been changed to 'muxf51'
...
```

If [BoxType \(BOX_TYPE\)](#) is not attached to the MUXF5, XST processes this block as a user hierarchical block. If the name of the user black box is the same as that of a Xilinx device primitive, XST renames it to a unique name and issues a warning.

VHDL and Verilog Device Primitives Libraries

XST provides dedicated libraries, both in VHDL and Verilog, simplifying instantiation of Xilinx® device primitives in your HDL source code. These libraries contain the complete set of Xilinx device primitives declarations with a [BoxType \(BOX_TYPE\)](#) constraint attached to each component.

Device Libraries

In VHDL, declare library UNISIM with its package **vcomponents** in your source code:

```
library unisim;  
use unisim.vcomponents.all;
```

The source code of this package can be found in the following file of the XST installation:

```
vhdl\src\ unisims\unisims_vcomp.vhd
```

In Verilog, the UNISIM library is precompiled. XST automatically links it with your design.

Primitive Instantiation Guidelines

Use UPPERCASE for generic (VHDL) and parameter (Verilog) values when instantiating primitives. For example the ODDR element has the following component declaration in the UNISIM library:

```
component ODDR  
generic  
  (DDR_CLK_EDGE : string := "OPPOSITE_EDGE";  
   INIT : bit := '0';  
   SRTYPE : string := "SYNC");  
  
port(Q : out std_ulogic;  
     C : in std_ulogic;  
     CE : in std_ulogic;  
     D1 : in std_ulogic;  
     D2 : in std_ulogic;  
     R : in std_ulogic;  
     S : in std_ulogic);  
end component;
```

When you instantiate this primitive in your code, the values of `DDR_CLK_EDGE` and `SRTYPE` generics must be in UPPERCASE. If not, XST issues a warning stating that unknown values are used.

Some primitives, such as LUT1, enable you to use an INIT during instantiation. The two ways to pass an INIT to the final netlist are:

- Attach an INIT attribute to the instantiated primitive.
- Pass the INIT with the generics mechanism (VHDL), or the parameters mechanism (Verilog). Xilinx recommends this method, since it allows you to use the same code for synthesis and simulation.

Reporting of Instantiated Device Primitives

XST does not issue any message concerning instantiation of instantiated device primitives during HDL synthesis because the [BoxType \(BOX_TYPE\)](#) attribute with its value, *primitive*, is attached to each primitive in the UNISIM library.

XST issues a warning as shown in the log file example below if:

- You instantiate a block (non primitive) in your design
AND
- The block has no contents (no logic description)
OR
- The block has a logic description
AND
- You attach a [BoxType \(BOX_TYPE\)](#) constraint to it with a value of *user_black_box*.

Log File Example

```
...
Analyzing Entity <black_b> (Architecture <archi>).
WARNING : (VHDL_0103). c:\jm\des.vhd (Line 23).
Generating a Black Box for component <my_block>.
Entity <black_b> analyzed. Unit <black_b> generated.
...
```

Primitives Related Constraints

- [BoxType \(BOX_TYPE\)](#)
- The PAR constraints that can be passed from HDL to NGC without processing

Primitives Coding Examples

Coding examples can be downloaded in text format from
http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

Passing an INIT Value Via the INIT Constraint VHDL Coding Example

```
--
-- Passing an INIT value via the INIT constraint.
--

library ieee;
use ieee.std_logic_1164.all;

library unisim;
use unisim.vcomponents.all;

entity primitive_1 is
    port(I0,I1 : in std_logic;
         O      : out std_logic);
end primitive_1;

architecture beh of primitive_1 is

    attribute INIT: string;
    attribute INIT of inst: label is "1";

begin

    inst: LUT2 port map (I0=>I0,I1=>I1,O=>O);

end beh;
```

Passing an INIT Value Via the INIT Constraint Verilog Coding Example

```
//  
// Passing an INIT value via the INIT constraint.  
//  
  
module v_primitive_1 (I0,I1,O);  
    input I0,I1;  
    output O;  
  
    (* INIT="1" *)  
    LUT2 inst (.I0(I0), .I1(I1), .O(O));  
  
endmodule
```

Passing an INIT Value Via the Generics Mechanism VHDL Coding Example

```
--  
-- Passing an INIT value via the generics mechanism.  
--  
  
library ieee;  
use ieee.std_logic_1164.all;  
  
library unisim;  
use unisim.vcomponents.all;  
  
entity primitive_2 is  
    port(I0,I1 : in std_logic;  
         O      : out std_logic);  
end primitive_2;  
  
architecture beh of primitive_2 is  
begin  
  
    inst: LUT2 generic map (INIT=>"1")  
        port map (I0=>I0,I1=>I1,O=>O);  
  
end beh;
```

Passing an INIT Value Via the Parameters Mechanism Verilog Coding Example

```
//  
// Passing an INIT value via the parameters mechanism.  
//  
  
module v_primitive_2 (I0,I1,O);  
    input I0,I1;  
    output O;  
  
    LUT2 #(4'h1) inst (.I0(I0), .I1(I1), .O(O));  
  
endmodule
```

Passing an INIT Value Via the Defparam Mechanism Verilog Coding Example

```
//  
// Passing an INIT value via the defparam mechanism.  
//  
  
module v_primitive_3 (I0,I1,O);  
    input I0,I1;  
    output O;  
  
    LUT2 inst (.I0(I0), .I1(I1), .O(O));  
    defparam inst.INIT = 4'h1;  
  
endmodule
```

Using the UniMacro Library

This section discusses Using the UniMacro Library, and includes:

- [About Using the UniMacro Library](#)
- [UniMacro Library Device Support](#)
- [Using the UniMacro Library in VHDL](#)
- [Using the UniMacro Library in Verilog](#)

About Using the UniMacro Library

In order to simplify instantiation of such complex primitives as RAMs, XST supports an additional library called UniMacro.

For more information, see the [Libraries Guides](#).

UniMacro Library Device Support

The UniMacro library supports the following devices:

- Virtex®-4
- Virtex-5 and newer

Using the UniMacro Library in VHDL

In VHDL, declare the library **unimacro** with its package **vcomponents** in your source code:

```
library unimacro;  
use unimacro.vcomponents.all;
```

The source code of this package is located in the following file in the XST installation:

```
vhdl\src\unisims\unisims_vcomp.vhd
```

Using the UniMacro Library in Verilog

In Verilog, the UniMacro library is precompiled. XST automatically links it with your design.

Cores Processing

If a design contains cores represented by an Electronic Data Interchange Format (EDIF) or an NGC file, XST can automatically read them for timing estimation and area utilization control. Use ISE® Design Suite **Process > Process Properties > Synthesis Options > Read Cores** to enable or disable this feature. Using the `read_cores` option of the `run` command from the command line, you can also specify `optimize`. This enables cores processing, and allows XST to integrate the core netlist into the overall design. XST reads cores by default.

If Read Cores is disabled, XST estimates Maximum Combinational Path Delay as 6.639ns (critical path goes through a simple AND function) and an area of one slice.

If Read Cores is enabled, XST issues the following messages during Low Level Synthesis:

```
...
=====
*
*                               Low Level Synthesis
*
=====

Launcher: Executing edif2ngd -noa "my_add.edn" "my_add.ngo"
INFO:NgdBuild - Release 6.1i - edif2ngd G.21
INFO:NgdBuild - Copyright (c) 1995-2003 Xilinx, Inc.
All rights reserved.
Writing the design to "my_add.ngo"...
Loading core <my_add> for timing and area information
for instance <inst>.

=====
...
```

Estimation of Maximum Combinational Path Delay is 8.281ns with an area of five slices.

By default, XST reads Electronic Data Interchange Format (EDIF) and NGC cores from the current (project) directory. If the cores are not in the project directory, specify the directory in which the cores are located with [Cores Search Directories \(-sd\)](#).

Coding Example

In the following VHDL coding example, the block **my_add** is an adder, which is represented as a black box in the design whose netlist was generated by the CORE Generator™ software.

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_signed.all;

entity read_cores is
  port(
    A, B : in std_logic_vector (7 downto 0);
    a1, b1 : in std_logic;
    SUM : out std_logic_vector (7 downto 0);
    res : out std_logic);
end read_cores;

architecture beh of read_cores is
  component my_add
  port (
    A, B : in std_logic_vector (7 downto 0);
    S : out std_logic_vector (7 downto 0));
  end component;

begin
  res <= a1 and b1;
  inst: my_add port map (A => A, B => B, S => SUM);
end beh;
```

Specifying INIT and RLOC

Use the UNISIM library to directly instantiate LUT components in your Hardware Description Language (HDL) code. To specify a function that a particular LUT must execute, apply an INIT constraint to the instance of the LUT. To place an instantiated LUT or register in a particular slice of the chip, attach an RLOC constraint to the same instance.

It is not always convenient to calculate INIT functions and different methods that can be used to achieve this. Instead, you can describe the function that you want to map onto a single LUT in your VHDL or Verilog code in a separate block.

Attaching a [Map Entity on a Single LUT \(LUT_MAP\)](#) constraint to this block indicates to XST that this block must be mapped on a single LUT. XST automatically calculates the INIT value for the LUT and preserves this LUT during optimization.

XST automatically recognizes the XC_MAP constraint supported by Synopsys.

Passing an INIT Value Via the LUT_MAP Constraint Coding Examples

Coding examples can be downloaded in text format from http://www.xilinx.com/tpatches/pub/documentation/misc/xstug_examples.zip

The following coding examples show how to pass an INIT value using the LUT_MAP constraint.

In these examples, the **top** block contains the instantiation of two AND gates, described in **and_one** and **and_two** blocks. XST generates two LUT2s and does not merge them.

For more information, see:

[Map Entity on a Single LUT \(LUT_MAP\)](#)

Passing an INIT Value Via the LUT_MAP Constraint VHDL Coding Example

```
--
-- Mapping on LUTs via LUT_MAP constraint
--

library ieee;
use ieee.std_logic_1164.all;
entity and_one is
    port (A, B : in std_logic;
          REZ : out std_logic);

    attribute LUT_MAP: string;
    attribute LUT_MAP of and_one: entity is "yes";
end and_one;

architecture beh of and_one is
begin
    REZ <= A and B;
end beh;

-----

library ieee;
use ieee.std_logic_1164.all;
entity and_two is
    port(A, B : in std_logic;
          REZ : out std_logic);

    attribute LUT_MAP: string;
    attribute LUT_MAP of and_two: entity is "yes";
end and_two;

architecture beh of and_two is
begin
    REZ <= A or B;
end beh;

-----

library ieee;
use ieee.std_logic_1164.all;
entity inits_rlocs_1 is
    port(A,B,C : in std_logic;
          REZ : out std_logic);
end inits_rlocs_1;

architecture beh of inits_rlocs_1 is

    component and_one
    port(A, B : in std_logic;
          REZ : out std_logic);
    end component;

    component and_two
    port(A, B : in std_logic;
          REZ : out std_logic);
    end component;

    signal tmp: std_logic;
begin
    inst_and_one: and_one port map (A => A, B => B, REZ => tmp);
    inst_and_two: and_two port map (A => tmp, B => C, REZ => REZ);
end beh;
```

Passing an INIT Value Via the LUT_MAP Constraint Verilog Coding Example

```
//  
// Mapping on LUTs via LUT_MAP constraint  
//  
(* LUT_MAP="yes" *)  
module v_and_one (A, B, REZ);  
    input A, B;  
    output REZ;  
  
    and and_inst(REZ, A, B);  
  
endmodule  
  
// -----  
(* LUT_MAP="yes" *)  
module v_and_two (A, B, REZ);  
    input A, B;  
    output REZ;  
  
    or or_inst(REZ, A, B);  
  
endmodule  
  
// -----  
module v_inits_rlocs_1 (A, B, C, REZ);  
    input A, B, C;  
    output REZ;  
  
    wire tmp;  
  
    v_and_one inst_and_one (A, B, tmp);  
    v_and_two inst_and_two (tmp, C, REZ);  
  
endmodule
```

Specifying INIT Value for a Flip-Flop Coding Examples

If a function cannot be mapped on a single LUT, XST issues an error message and interrupts synthesis. To define an INIT value for a flip-flop or a shift register, described at RTL level, assign its initial value in the signal declaration stage. This value is not ignored during synthesis and is propagated to the final netlist as an INIT constraint attached to the flip-flop or shift register.

In the following coding examples, a 4-bit register is inferred for signal **tmp**.

An INIT value equal **1011** is attached to the inferred register and propagated to the final netlist.

Specifying INIT Value for a Flip-Flop VHDL Coding Example

```
--
-- Specification on an INIT value for a flip-flop,
-- described at RTL level
--

library ieee;
use ieee.std_logic_1164.all;

entity inits_rlocs_2 is
    port (CLK : in std_logic;
          DI  : in std_logic_vector(3 downto 0);
          DO  : out std_logic_vector(3 downto 0));
end inits_rlocs_2;

architecture beh of inits_rlocs_2 is signal
    tmp: std_logic_vector(3 downto 0):="1011";
begin

    process (CLK)
    begin
        if (clk'event and clk='1') then
            tmp <= DI;
        end if;
    end process;

    DO <= tmp;

end beh;
```

Specifying INIT Value for a Flip-Flop Verilog Coding Example

```
//
// Specification on an INIT value for a flip-flop,
// described at RTL level
//

module v_inits_rlocs_2 (clk, di, do);
    input  clk;
    input  [3:0] di;
    output [3:0] do;
    reg    [3:0] tmp;

    initial begin
        tmp = 4'b1011;
    end

    always @(posedge clk)
    begin
        tmp <= di;
    end

    assign do = tmp;

endmodule
```

Specifying INIT and RLOC Values for a Flip-Flop Coding Examples

To infer a register and place it in a specific location of a chip, attach an **RLOC** constraint to the **tmp** signal as shown in the following coding examples.

XST propagates it to the final netlist. XST supports this feature is supported for:

- Registers, and
- Inferred block RAM if it can be implemented on a single block RAM primitive

Specifying INIT and RLOC Values for a Flip-Flop VHDL Coding Example

```
--
-- Specification on an INIT and RLOC values for a flip-flop,
-- described at RTL level
--

library ieee;
use ieee.std_logic_1164.all;

entity inits_rlocs_3 is
    port (CLK : in std_logic;
          DI  : in std_logic_vector(3 downto 0);
          DO  : out std_logic_vector(3 downto 0));
end inits_rlocs_3;

architecture beh of inits_rlocs_3 is
    signal tmp: std_logic_vector(3 downto 0):="1011";

    attribute RLOC: string;
    attribute RLOC of tmp: signal is "X3Y0 X2Y0 X1Y0 X0Y0";
begin

    process (CLK)
    begin
        if (clk'event and clk='1') then
            tmp <= DI;
        end if;
    end process;

    DO <= tmp;

end beh;
```

Specifying INIT and RLOC Values for a Flip-Flop Verilog Coding Example

```
//  
// Specification on an INIT and RLOC values for a flip-flop,  
// described at RTL level  
//  
module v_inits_rlocs_3 (clk, di, do);  
    input  clk;  
    input  [3:0] di;  
    output [3:0] do;  
    (* RLOC="X3Y0 X2Y0 X1Y0 X0Y0" *)  
    reg    [3:0] tmp;  
  
    initial begin  
        tmp = 4'b1011;  
    end  
  
    always @(posedge clk)  
    begin  
        tmp <= di;  
    end  
  
    assign do = tmp;  
  
endmodule
```

Using PCI Flow With XST

This section discusses Using PCI™ Flow With XST, and includes:

- [Rules for Using PCI Flow With XST](#)
- [Preventing Logic and Flip-Flop Replication](#)
- [Disabling Read Cores](#)

Rules for Using PCI Flow With XST

Follow these rules to satisfy placement constraints and meet timing requirements when using PCI flow with XST.

- For VHDL, ensure that the names in the generated netlist are all in *UPPER* case. The default case is *lower*.
Specify the case in ISE® Design Suite in:
Process > Process Properties > Synthesis Options > Case
- For Verilog, ensure that Case is set to *maintain*. The default case is *maintain*.
Specify the case in ISE Design Suite in:
Process > Process Properties > Synthesis Options > Case
- Preserve the hierarchy of the design.
Specify the [Keep Hierarchy \(KEEP_HIERARCHY\)](#) setting in ISE Design Suite in:
Process > Process Properties > Synthesis Options > Keep Hierarchy
- Preserve equivalent flip-flops.
XST removes equivalent flip-flops by default.
Specify the [Equivalent Register Removal \(EQUIVALENT_REGISTER_REMOVAL\)](#) setting in ISE Design Suite in:
Process > Process Properties > Xilinx® Specific Options > Equivalent Register Removal

Preventing Logic and Flip-Flop Replication

To prevent logic and flip-flop replication caused by a high fanout flip-flop set/reset signal:

- Set a high maximum fanout value for the entire design in ISE® Design Suite in:
Process > Process Properties > Synthesis Options > Max Fanout, or
- Use [Max Fanout \(MAX_FANOUT\)](#) to set a high maximum fanout value for the initialization signal connected to the RST port of the PCI™ core.

Example:

```
max_fanout=2048
```

Disabling Read Cores

Disabling Read Cores prevents XST from automatically reading PCI™ cores for timing and area estimation. In reading PCI cores, XST may perform logic optimization that does not allow the design to meet timing requirements, or which might lead to errors during MAP. By default, XST reads cores for timing and area estimation. To disable Read Cores, uncheck it in ISE® Design Suite in:

Process > Process Properties > Synthesis Options > Read Cores

XST CPLD Optimization

This chapter discusses XST CPLD Optimization, and includes:

- [CPLD Synthesis Options](#)
- [Implementation Details for Macro Generation](#)
- [CPLD Synthesis Log File Analysis](#)
- [CPLD Synthesis Constraints](#)
- [Improving Results in CPLD Synthesis](#)

CPLD Synthesis Options

This section discusses the XST options related *only* to CPLD synthesis that can be set in ISE® Design Suite in:

Process > Process Properties

XST generates an NGC file ready for the CPLD fitter.

The general flow of XST for CPLD synthesis is:

1. Hardware Description Language (HDL) synthesis of VHDL or Verilog designs
2. Macro inference
3. Module optimization
4. NGC file generation

CPLD Synthesis Supported Devices

XST supports CPLD synthesis for the following devices:

- CoolRunner™ XPLA3
- CoolRunner-II
- XC9500
- XC9500XL

The synthesis for CoolRunner XPLA3 device families and XC9500XL device families includes clock enable processing. You can allow or invalidate the clock enable signal. When invalidated, it is replaced by equivalent logic.

The selection of the macros that use the clock enable (counters, for instance) depends on the device type. A counter with clock enable is accepted for the CoolRunner XPLA3 device families and XC9500XL device families, but rejected (replaced by equivalent logic) for XC9500 devices.

Setting CPLD Synthesis Options

Set the following CPLD synthesis options in ISE® Design Suite in:

Process > Process Properties > Synthesis Options

- [Keep Hierarchy \(KEEP_HIERARCHY\)](#)
- [Macro Preserve \(-pld_mp\)](#)
- [XOR Preserve \(-pld_xp\)](#)
- [Equivalent Register Removal \(EQUIVALENT_REGISTER_REMOVAL\)](#)
- [Clock Enable \(-pld_ce\)](#)
- [WYSIWYG \(-wysiwyg\)](#)
- [No Reduce \(NOREDUCE\)](#)

For more information, see:

[XST CPLD Constraints \(Non-Timing\)](#)

Implementation Details for Macro Generation

XST processes the following macros:

- Adders
- Subtractors
- Add/sub
- Multipliers
- Comparators
- Multiplexers
- Counters
- Logical shifters
- Registers (flip-flops and latches)
- XORs

The macro generation is decided by the Macro Preserve command line option, which can take two values:

- **yes**
Macro generation is allowed.
- **no**
Macro generation is inhibited.

The general macro generation flow is:

1. Hardware Description Language (HDL) infers macros and submits them to the low-level synthesizer.
2. Low-level synthesizer accepts or rejects the macros depending on the resources required for the macro implementations.

An accepted macro is generated by an internal macro generator. A rejected macro is replaced by equivalent logic generated by the HDL synthesizer. A rejected macro may be decomposed by the HDL synthesizer into component blocks so that one component may be a new macro requiring fewer resources than the initial one, and another smaller macro may be accepted by XST. For instance, a flip-flop macro with clock enable (CE) cannot be accepted when mapping onto the XC9500. In this case the HDL synthesizer submits two new macros:

- A flip-flop macro without clock enable signal
- A MUX macro implementing the clock enable function

A generated macro is optimized separately and then merged with surrounded logic because optimization gives better results for larger components.

CPLD Synthesis Log File Analysis

XST messages related to CPLD synthesis are located after the following message:

```
Low Level Synthesis
```

The XST log file contains:

- Tracing of progressive unit optimizations
 - Optimizing unit unit_name ...
- Information, warnings or fatal messages related to unit optimization:
 - When equation shaping is applied (XC9500 devices only):
 - Collapsing ...
 - Removing equivalent flip-flops
 - Register *ff1* equivalent to *ff2* has been removed
 - User constraints fulfilled by XST:
 - implementation constraint: *constraint_name[=value]: signal_name*
- Final results statistics

```
Final Results
Top Level Output file name : file_name
Output format : ngc
Optimization goal : {area | speed}
Target Technology : {9500 | 9500x1 | 9500xv | xpla3 | xbr | cr2s}
Keep Hierarchy : {yes | soft | no}
Macro Preserve : {yes | no}
XOR Preserve : {yes | no}
Design Statistics
NGC Instances: nb_of_instances
I/Os: nb_of_io_ports
Macro Statistics
# FSMs: nb_of_FSMs
# Registers: nb_of_registers
# Tristates: nb_of_tristates
# Comparators: nb_of_comparators
  n-bit comparator {equal | not equal | greater | less | greatequal | lessequal}:
  nb_of_n_bit_comparators
# Multiplexers: nb_of_multiplexers
  n-bit m-to-1 multiplexer :
  nb_of_n_bit_m_to_1_multiplexers
# Adders/Subtractors: nb_of_adds_subs
  n-bit adder: nb_of_n_bit_adds
  n-bit subtractor: nb_of_n_bit_subs
# Multipliers: nb_of_multipliers
# Logic Shifters: nb_of_logic_shifters
# Counters: nb_of_counters
  n-bit {up | down | updown} counter: nb_of_n_bit_counters
# XORs: nb_of_xors
Cell Usage :
# BELS: nb_of_bels
  # AND...: nb_of_and...
  # OR...: nb_of_or...
  # INV: nb_of_inv
  # XOR2: nb_of_xor2
  # GND: nb_of_gnd # VCC: nb_of_vcc
# FlipFlops/Latches: nb_of_ff_latch
  # FD...: nb_of_fd...
  # LD...: nb_of_ld...
# Tri-States: nb_of_tristates
  # BUFE: nb_of_bufe
  # BUFT: nb_of_buft
# IO Buffers: nb_of_iobuffers
  # IBUF: nb_of_ibuf
  # OBUF: nb_of_obuf
  # IOBUF: nb_of_iobuf
  # OBUFE: nb_of_obufe
  # OBUFT: nb_of_obuft # Others: nb_of_others
```

CPLD Synthesis Constraints

The constraints (attributes) specified in the Hardware Description Language (HDL) design or in the constraint files are written by XST into the NGC file as signal properties.

Improving Results in CPLD Synthesis

XST produces optimized netlists for the CPLD fitter, which:

- Fits them in specified devices
- Creates the download programmable files

The CPLD low-level optimization of XST consists of:

- Logic minimization
- Subfunction collapsing
- Logic factorization
- Logic decomposition

Optimization results in an NGC netlist corresponding to Boolean equations. The CPLD fitter reassembles these equations to fit the best of the macrocell capacities. A special XST optimization process, known as equation shaping, is applied for XC9500 and XC9500XL devices when the following options are selected:

- Keep Hierarchy
No
- Optimization Effort
2 or High
- Macro Preserve
No

The equation shaping processing also includes a critical path optimization algorithm. This algorithm tries to reduce the number of levels of critical paths.

Xilinx® recommends CPLD fitter multilevel optimization because of the special optimizations done by the fitter:

- D to T flip-flop conversion
- De Morgan Boolean expression selection

Obtaining Better Frequency

The frequency depends on the number of logic levels (logic depth). To reduce the number of levels, Xilinx® recommends the following options:

- Optimization Effort
Set Optimization Effort to **2 or High**.
This value implies the calling of the collapsing algorithm, which tries to reduce the number of levels without increasing the complexity beyond certain limits.
- Optimization Goal
Set Optimization Goal to **Speed**.
The priority is the reduction of number of levels.

Obtaining the best frequency depends on the CPLD fitter optimization. Xilinx recommends running the multi-level optimization of the CPLD fitter with different values for the **-pterns** options, beginning with 20 and finishing with 50 with a step of 5. Statistically the value 30 gives the best results for frequency.

The following tries, in this order, may give successively better results for frequency:

- [Obtaining Better Frequency Try 1](#)
- [Obtaining Better Frequency Try 2](#)
- [Obtaining Better Frequency Try 3](#)
- [Obtaining Better Frequency Try 4](#)

The CPU time increases from Try 1 to Try 4.

Obtaining Better Frequency Try 1

Select only optimization effort 2 and speed optimization. The other options have default values.

- Optimization effort
2 or **High**
- Optimization Goal
Speed

Obtaining Better Frequency Try 2

Flatten the user hierarchy. In this case optimization has a global view of the design, and the depth reduction may be better.

- Optimization effort
1/**Normal** or 2/**High**
- Optimization Goal
Speed
- Keep Hierarchy
no

Obtaining Better Frequency Try 3

Merge the macros with surrounded logic. The design flattening is increased.

- Optimization effort
1 or **Normal**
- Optimization Goal
Speed
- Keep Hierarchy
no
- Macro Preserve
no

Obtaining Better Frequency Try 4

Apply the equation shaping algorithm. Options to be selected:

- Optimization effort
2 or **High**
- Macro Preserve
no
- Keep Hierarchy
no

Fitting a Large Design

A design may not fit in the target device because it exceeds the number of device macrocells or device P-Term capacity. In that event, you may:

- [Select an Area Optimization for XST](#), or
- [Use the WYSIWYG Command Line Option](#)

Select an Area Optimization for XST

When you select an area optimization for XST, statistically the best area results are obtained with the following options:

- Optimization effort
1 (Normal) or 2 (High)
- Optimization Goal
area
- Default values for other options

Use the WYSIWYG Command Line Option

Another option for fitting a large design is to use the [WYSIWYG \(-wysiwyg\)](#) command line option with the following setting:

-wysiwyg yes

The WYSIWYG command line option may be useful when:

- The design cannot be simplified by default optimization strategies, and
- The complexity (in number of P-Terms) is near the device capacity.

Default optimizations, by trying to reduce the number of logic levels, may create larger equations. This increases the number of P-Terms and prevents the design from fitting. Unlike those optimizations, the [WYSIWYG \(-wysiwyg\)](#) command line option enables an approach that does not increase the number of P-Terms, ideally allowing the design to fit.

XST Design Constraints

This chapter gives general information about XST Design Constraints, and includes:

- [About XST Design Constraints](#)
- [Mechanisms for Specifying Constraints](#)
- [Global and Local Constraint Settings](#)
- [Rules for Applying Constraints](#)
- [Setting Global Constraints and Options](#)
- [VHDL Attribute Syntax](#)
- [Verilog-2001 Attributes](#)
- [XST Constraint File \(XCF\)](#)
- [Constraints Priority](#)
- [XST Specific Non-Timing Options](#)
- [XST Command Line Only Options](#)

For information about specific XST design constraints, see:

- [XST General Constraints](#)
- [XST HDL Constraints](#)
- [XST FPGA Constraints \(Non-Timing\)](#)
- [XST CPLD Constraints \(Non-Timing\)](#)
- [XST Timing Constraints](#)
- [XST Implementation Constraints](#)
- [XST-Supported Third Party Constraints](#)

About XST Design Constraints

Constraints help you meet your design goals and obtain the best implementation of your circuit. Constraints control various aspects of synthesis, as well as placement and routing. Synthesis algorithms and heuristics automatically provide optimal results in most situations. If synthesis fails to initially achieve optimal results, use available constraints to try other synthesis alternatives.

Mechanisms for Specifying Constraints

The following mechanisms are available to specify constraints:

- Options provide global control of most synthesis aspects. They can be set either in:
 - ISE® Design Suite in **Process > Properties > Synthesis Options**, or
 - by the **run** command from the command line
- In VHDL, attributes can be directly inserted into the VHDL code and attached to individual elements of the design to control both synthesis, and placement and routing.
- In Verilog, constraints can be added as:
 - Verilog attributes (preferred)
 - Verilog meta comments
- Constraints can be specified in a separate constraint file.

Global and Local Constraint Settings

Global synthesis settings are typically defined in ISE® Design Suite in **Process > Properties > Synthesis Options**, or from the command line. VHDL and Verilog attributes and Verilog meta comments can be inserted in your source code to specify different choices for individual parts of the design.

The local specification of a constraint overrides its global setting. Similarly, if a constraint is set both on a node (or an instance) and on the enclosing design unit, the former takes precedence for the considered node (or instance).

Rules for Applying Constraints

Follow these general rules when applying constraints:

- Several constraints can be applied on signals. In this case, the constraint must be placed in the block where the signal is declared and used.
- If a constraint can be applied on an entity (VHDL), then it can also be applied on the component declaration. The ability to apply constraints on components is not explicitly stated for each individual constraint, since it is a general XST rule.
- Some third party synthesis tools allow you to apply constraints on architectures. XST allows constraints on architectures only for those third party constraints automatically supported by XST.

Setting Global Constraints and Options

This section discusses Setting Global Constraints and Options, and includes:

- [Setting Synthesis Options](#)
- [Setting HDL Options](#)
- [Setting Xilinx Specific Options](#)
- [Setting Other XST Command Line Options](#)
- [Custom Compile File List](#)

This section explains how to set global constraints and options in ISE® Design Suite in **Process > Process Properties**.

For a description of each constraint that applies generally (that is, to FPGA devices, CPLD devices, VHDL, and Verilog) see the [Constraints Guide](#).

Except for **Value** fields with check boxes, there is a pulldown arrow or browse button in each **Value** field. The arrow is not visible until you click in the **Value** field.

Setting Synthesis Options

To set Hardware Description Language (HDL) synthesis options from ISE® Design Suite:

1. Select a source file from the **Source File** window.
2. Right-click **Synthesize - XST** in the **Process** window.
3. Select **Properties**.
4. Select **Synthesis Options**.
5. Depending on the device type you have selected (FPGA or CPLD devices), one of two dialog boxes opens.
6. Select any of the following synthesis options:
 - [Optimization Goal \(OPT_MODE\)](#)
 - [Optimization Effort \(OPT_LEVEL\)](#)
 - [Use Synthesis Constraints File \(-iuc\)](#)
 - [Synthesis Constraint File \(-uc\)](#)
 - [Library Search Order \(-lso\)](#)
 - [Global Optimization Goal \(-glob_opt\)](#)
 - [Generate RTL Schematic \(-rtlview\)](#)
 - [Write Timing Constraints \(-write_timing_constraints\)](#)
 - [Verilog 2001 \(-verilog2001\)](#)

Select **Edit > Preferences > Processes > Property Display Level > Advanced** to view the following options:

- [Keep Hierarchy \(KEEP_HIERARCHY\)](#)
- [Cores Search Directories \(-sd\)](#)
- [Cross Clock Analysis \(-cross_clock_analysis\)](#)
- [Hierarchy Separator \(-hierarchy_separator\)](#)
- [Bus Delimiter \(-bus_delimiter\)](#)
- [Case \(-case\)](#)
- [Work Directory \(-xsthdpdir\)](#)
- [HDL Library Mapping File \(-xsthdpini\)](#)
- [Verilog Include Directories \(-vlgindir\)](#)
- [Slice \(LUT-FF Pairs\) Utilization Ratio \(SLICE_UTILIZATION_RATIO\)](#)

Setting HDL Options

This section discusses Setting HDL Options, and includes:

- [How to Set HDL Options](#)
- [Setting HDL Options for FPGA Devices](#)
- [Setting HDL Options for CPLD Devices](#)

How to Set HDL Options

To set Hardware Description Language (HDL) options for FPGA devices and CPLD devices in ISE® Design Suite select:

Process > Process Properties > Synthesize - XST > HDL Options

Setting HDL Options for FPGA Devices

The following HDL Options can be set for FPGA devices:

- [FSM Encoding Algorithm \(FSM_ENCODING\)](#)
- [Safe Implementation \(SAFE_IMPLEMENTATION\)](#)
- [Case Implementation Style \(-vlgcase\)](#)
- [FSM Style \(FSM_STYLE\)](#)

To view FSM Style, select **Edit > Preferences > Processes > Property Display Level > Advanced**

- [RAM Extraction \(RAM_EXTRACT\)](#)
- [RAM Style \(RAM_STYLE\)](#)
- [ROM Extraction \(ROM_EXTRACT\)](#)
- [ROM Style \(ROM_STYLE\)](#)
- [Mux Extraction \(MUX_EXTRACT\)](#)
- [Mux Style \(MUX_STYLE\)](#)
- [Decoder Extraction \(DECODER_EXTRACT\)](#)
- [Priority Encoder Extraction \(PRIORITY_EXTRACT\)](#)
- [Shift Register Extraction \(SHREG_EXTRACT\)](#)
- [Logical Shifter Extraction \(SHIFT_EXTRACT\)](#)
- [XOR Collapsing \(XOR_COLLAPSE\)](#)
- [Resource Sharing \(RESOURCE_SHARING\)](#)
- [Multiplier Style \(MULT_STYLE\)](#)

For later devices, Multiplier Style is renamed as follows:

- Use DSP48
 - Virtex®-4 devices
- Use DSP Block
 - Virtex-5 devices and Spartan®-3A DSP devices
- [Use DSP48 \(USE_DSP48\)](#)

Setting HDL Options for CPLD Devices

The following HDL Options can be set for CPLD devices:

- [FSM Encoding Algorithm \(FSM_ENCODING\)](#)
- [Safe Implementation \(SAFE_IMPLEMENTATION\)](#)
- [Case Implementation Style \(-vlgcase\)](#)
- [Mux Extraction \(MUX_EXTRACT\)](#)
- [Resource Sharing \(RESOURCE_SHARING\)](#)

Setting Xilinx Specific Options

This section discusses Setting Xilinx® Specific Options, and includes:

- [How to Set Xilinx Specific Options](#)
- [Setting Xilinx Specific Options for FPGA Devices](#)
- [Setting Xilinx Specific Options for CPLD Devices](#)

How to Set Xilinx Specific Options

To set Xilinx specific options in ISE® Design Suite, select:

Process > Process Properties > Synthesis Options > Xilinx Specific Options

Setting Xilinx Specific Options for FPGA Devices

The following Xilinx specific options can be set for FPGA devices:

- [Add I/O Buffers \(-iobuf\)](#)
- [LUT Combining \(LC\)](#)
- [Max Fanout \(MAX_FANOUT\)](#)
- [Register Duplication \(REGISTER_DUPLICATION\)](#)
- [Reduce Control Sets \(REDUCE_CONTROL_SETS\)](#)
- [Equivalent Register Removal \(EQUIVALENT_REGISTER_REMOVAL\)](#)
- [Register Balancing \(REGISTER_BALANCING\)](#)
- [Move First Stage \(MOVE_FIRST_STAGE\)](#)
- [Move Last Stage \(MOVE_LAST_STAGE\)](#)
- [Convert Tristates to Logic \(TRISTATE2LOGIC\)](#)
Convert Tristate to Logic appears only when working with devices with internal tristate resources.
- [Use Clock Enable \(USE_CLOCK_ENABLE\)](#)
- [Use Synchronous Set \(USE_SYNC_SET\)](#)
- [Use Synchronous Reset \(USE_SYNC_RESET\)](#)

Select **Edit > Preferences > Processes > Property Display Level > Advanced** in ISE Design Suite to display the following options:

- [Number of Global Clock Buffers \(-bufg\)](#)
- [Number of Regional Clock Buffers \(-bufr\)](#)

Setting Xilinx Specific Options for CPLD Devices

The following Xilinx specific options can be set for CPLD devices:

- [Add I/O Buffers \(-iobuf\)](#)
- [Equivalent Register Removal \(EQUIVALENT_REGISTER_REMOVAL\)](#)
- [Clock Enable \(-pld_ce\)](#)
- [Macro Preserve \(-pld_mp\)](#)
- [XOR Preserve \(-pld_xp\)](#)
- [WYSIWYG \(-wysiwyg\)](#)

Setting Other XST Command Line Options

This section discusses Setting Other XST Command Line Options, and includes:

- [Setting Options in ISE Design Suite](#)
- [Tips for Setting Options](#)
- [Options Precedence](#)
- [Illegal or Unrecognized Options](#)

Setting Options in ISE Design Suite

Set other XST command line options in ISE® Design Suite in:

Process > Process Properties > Other XST Command Line Options

This is an advanced property.

Tips for Setting Options

When setting XST command line options:

- Use the syntax described in [XST Command Line Mode](#).
- Separate multiple options with a space.

Options Precedence

While this property is intended for options not listed in **Process > Process Properties**, if an option already listed is entered, precedence is given to that option.

Illegal or Unrecognized Options

Illegal or unrecognized options cause XST to stop processing and generate a message such as:

```
ERROR:Xst:1363 - Option "-verilog2002" is not available
for command run.
```

Custom Compile File List

Use the Custom Compile File List property to change the order in which XST processes source files are processed. With this property, you select a user-defined compile list file that XST uses to determine the order in which it processes libraries and design files. Otherwise, XST uses an automatically generated list.

List all design files and their libraries in the order in which they are to be compiled, from top to bottom. Type each file and library pair on its own line, with a semicolon separating the library from the file as follows:

```
library_name; file_name [library_name;file_name] ...
```

Example:

```
work;stopwatch.vhd
work;statmach.vhd
...
```

Since this property is not connected to **Simulation Properties > Custom Compile File List**, a different compile list file is used for synthesis than for simulation.

VHDL Attribute Syntax

You can describe constraints with VHDL attributes in the VHDL code.

Declare as follows:

```
attribute AttributeName : Type;
```

Syntax Example One

```
attribute RLOC : string ;
```

The attribute type defines the type of the attribute value. The only allowed type for XST is **string**. An attribute can be declared in an entity or architecture. If declared in the entity, it is visible both in the entity and the architecture body. If the attribute is declared in the architecture, it cannot be used in the entity declaration.

Specify as follows:

```
attribute AttributeName of ObjectList : ObjectType is AttributeValue ;
```

Syntax Example Two

```
attribute RLOC of u123 : label is R11C1.S0 ; attribute bufg of my_signal : signal is sr;
```

Accepted Object Types

The object list is a comma separated list of identifiers. Accepted object types are:

- entity
- component
- label
- signal
- variable
- type

General Rules

- If a constraint can be applied on an entity (VHDL), then it can also be applied on the component declaration. The ability to apply constraints on components is not explicitly stated for each individual constraint, since it is a general XST rule.
- Some third party synthesis tools allow you to apply constraints on architectures. XST allows constraints on architectures only for those third party constraints automatically supported by XST.

Verilog-2001 Attributes

XST supports Verilog-2001 attribute statements. Attributes are comments that pass specific information to software tools such as synthesis tools. Verilog-2001 attributes can be specified anywhere for operators or signals within module declarations and instantiations. Other attribute declarations may be supported by the compiler, but are ignored by XST.

Verilog-2001 Attributes Syntax

Verilog-2001 attributes are bounded by the asterisk character (*).

```
(* attribute_name = attribute_value *)
```

where

- *attribute* precedes the signal, module, or instance declaration to which it refers.
- *attribute_value* is a string. No integer or scalar values are allowed.
- *attribute_value* is between quotes.
- The default is 1.
- (** attribute_name **) is the same as (** attribute_name = "1" **).

Syntax Example One

```
(* clock_buffer = "IBUFG" *) input CLK;
```

Syntax Example Two

```
(* INIT = "0000" *) reg [3:0] d_out;
```

Syntax Example Three

```
always@(current_state or reset) begin (* parallel_case *) (* full_case *) case
(current_state) ...
```

Syntax Example Four

```
(* mult_style = "pipe_lut" *) MULT my_mult (a, b, c);
```

Verilog-2001 Limitations

Verilog-2001 attributes are not supported for:

- Signal declarations
- Statements
- Port connections
- Expression operators

Verilog-2001 Meta Comments

Constraints can also be specified in Verilog code using meta comments. The Verilog-2001 format is the preferred syntax, but the meta comment style is still supported. Use the following syntax:

```
// synthesis attribute AttributeName [of] ObjectName [is] AttributeValue
```

Verilog-2001 Meta Comments Examples

```
// synthesis attribute RLOC of u123 is R11C1.S0
// synthesis attribute HU_SET u1 MY_SET
// synthesis attribute bufg of my_clock is "clk"
```

The following constraints use a different syntax:

- [Parallel Case \(PARALLEL_CASE\)](#)
- [Full Case \(FULL_CASE\)](#)
- [Translate Off \(TRANSLATE_OFF\)](#) and [Translate On \(TRANSLATE_ON\)](#)

For more information, see:

[Verilog Attributes and Meta Comments](#)

XST Constraint File (XCF)

This section includes:

- [Specifying Constraints in the XCF](#)
- [XCF Syntax and Utilization](#)
- [Native and Non-Native UCF Constraints Syntax](#)
- [XCF Syntax Limitations](#)

Specifying Constraints in the XCF

XST constraints can be specified in the XST Constraint File (XCF).

The XCF has an extension of `.xcf`.

You can specify the XCF in:

- ISE® Design Suite

For more information, see:

[ISE Design Suite Help](#)

- Command Line Mode

To specify the XCF in command line mode, use [Synthesis Constraint File \(-uc\)](#) with the `run` command.

For more information, see:

[XST Command Line Mode](#)

XCF Syntax and Utilization

This section discusses XCF Syntax and Utilization, and includes:

- [About XCF Syntax and Utilization](#)
- [Syntax](#)
- [Syntax Examples and Settings](#)
- [XST Synthesis Constraints](#)

About XCF Syntax and Utilization

The XST Constraint File (XCF) syntax enables you to specify a specific constraint for:

- The entire device (globally), or
- Specific modules

The XCF syntax is basically the same as the User Constraints File (UCF) syntax for applying constraints to nets or instances, but with an extension to the syntax to allow constraints to be applied to specific levels of hierarchy. Use the keyword **MODEL** to define the entity or module to which the constraint is applied. If a constraint is applied to an entity or module, the constraint is applied to each instance of the entity or module.

Define constraints in ISE® Design Suite in **Process > Process Properties**, or the XST run script, if running on the command line. Specify exceptions in the XCF file. The constraints specified in the XCF file are applied *only* to the module listed, and not to any submodules below it.

Syntax

To apply a constraint to the entire entity or module use the following syntax:

```
MODEL entityname constraintname = constraintvalue;
```

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XCF Syntax Example One

```
MODEL top mux_extract = false; MODEL my_design max_fanout = 256;
```

If the entity *my_design* is instantiated several times in the design, the *max_fanout=256* constraint is applied to each instance of *my_design*.

To apply constraints to specific instances or signals within an entity or module, use the **INST** or **NET** keywords. XST does not support constraints that are applied to VHDL variables.

```
BEGIN MODEL entityname
```

```
INST instancename constraintname = constraintvalue;
```

```
NET signalname constraintname = constraintvalue;
```

```
END;
```

XCF Syntax Example Two

```
BEGIN MODEL crc32
  INST stopwatch opt_mode = area ;
  INST U2 ram_style = block ;
  NET myclock clock_buffer = true ;
  NET data_in iob = true ;
END;
```

XST Synthesis Constraints

For a complete list of XST synthesis constraints, see:

[XST Specific Non-Timing Options](#)

Native and Non-Native UCF Constraints Syntax

All constraints supported by XST can be divided into two groups:

- [Native UCF Constraints](#)
- [Non-Native UCF Constraints](#)

Native UCF Constraints

Only Timing and Area Group constraints use native User Constraints File (UCF) syntax.

Use native UCF syntax, including wildcards and hierarchical names, for native UCF constraints such as:

- [Period \(PERIOD\)](#)
- [Offset \(OFFSET\)](#)
- [Timing Name on a Net \(TNM_NET\)](#)
- [Timegroup \(TIMEGRP\)](#)
- [Timing Ignore \(TIG\)](#)
- [From-To \(FROM-TO\)](#)

Restriction Do not use these constraints inside the **BEGIN MODEL... END** construct. If you do, XST issues an error.

Non-Native UCF Constraints

For all non-native User Constraints File (UCF) constraints, use the **MODEL** or **BEGIN MODEL... END** constructs. This includes:

- Pure XST constraints such as:
 - [Automatic FSM Extraction \(FSM_EXTRACT\)](#)
 - [RAM Style \(RAM_STYLE\)](#)
- Implementation non-timing constraints such as:
 - [RLOC](#)
 - [Keep \(KEEP\)](#)

If you specify timing constraints in the XST Constraint File (XCF), Xilinx® recommends that you use a forward slash (/) as a hierarchy separator instead of an underscore (_).

For more information, see:

[Hierarchy Separator \(-hierarchy_separator\)](#)

XCF Syntax Limitations

XST Constraint File (XCF) syntax has the following limitations:

- Nested model statements are not supported.
- Instance or signal names listed between the **BEGIN MODEL** statement and the **END** statement are only the ones visible inside the entity. Hierarchical instance or signal names are not supported.
- Wildcards in instance and signal names are not supported, except in timing constraints.
- Not all native User Constraints File (UCF) constraints are supported.

For more information, see the [Constraints Guide](#).

Constraints Priority

Constraints priority depends on the file in which the constraint appears. A constraint in a file accessed later in the design flow overrides a constraint in a file accessed earlier in the design flow.

Priority is as follows, from highest to lowest:

1. Synthesis Constraint File
2. Hardware Description Language (HDL) file
3. ISE® Design Suite **Process > Process Properties**, or the command line

XST Specific Non-Timing Options

The following table shows:

- Allowed values for each constraint
- Type of objects to which they can be applied
- Usage restrictions

In many cases, a particular constraint can be applied globally to an entire entity or model, or alternatively, it can be applied locally to individual signals, nets or instances.

| Constraint Name | Constraint Value | VHDL Target | Verilog Target | XCF Target | Command Line | Command Value |
|-----------------------------|---|----------------------------|----------------------------|-----------------------------------|--------------------------------------|---------------------------|
| BoxType | primitive black_box user_black_box | entity inst | module inst | model inst (in model) | N/A | N/A |
| Map Logic on BRAM | yes no | entity | module | model | N/A | N/A |
| Buffer Type | bufgdl1 ibufg bufg bufgp ibuf bufr none | signal | signal | net (in model) | N/A | N/A |
| Extract BUFGCE | yes no | primary clock signal | primary clock signal | net (in model) | -bufgce | yes no default: no |
| Clock Signal | yes no | clock signal | clock signal | clock signal net (in model) | N/A | N/A |
| Decoder Extraction | yes no | entity signal | entity signal | model net (in model) | -decoder _extract | yes no default: yes |
| Enumerated Encoding | string containing space-separated binary codes | type | signal | net (in model) | N/A | N/A |
| Equivalent Register Removal | yes no | entity signal | module signal | model net (in model) | -equivalent _register _removal | yes no default: yes |

| Constraint Name | Constraint Value | VHDL Target | Verilog Target | XCF Target | Command Line | Command Value |
|------------------------------|---|---------------------------------|---------------------------------|-----------------------------------|---------------------|--|
| FSM Encoding Algorithm | auto one-hot compact sequential gray johnson speed1 user | entity signal | module signal | model net (in model) | -fsm _encoding | auto one-hot compact sequential gray johnson speed1 user default: auto |
| Automatic FSM Extraction | yes no | entity signal | module signal | model net (in model) | -fsm _extract | yes no default: yes |
| FSM Style | lut bram | entity signal | module signal | model net (in model) | -fsm _style | lut bram default: lut |
| Full Case | N/A | N/A | case statement | N/A | N/A | N/A |
| Pack I/O Registers Into IOBs | true false auto | signal instance | signal instance | net (in model) inst (in model) | -iob | true false auto default: auto |
| I/O Standard | string For more information, see the Constraints Guide . | signal instance | signal instance | net (in model) inst (in model) | N/A | N/A |
| Keep | true false soft | signal | signal | net (in model) | N/A | N/A |
| Keep Hierarchy | yes no soft | entity | module | model | -keep _hierarchy | yes default (CPLD) no default (FPGA) soft |
| LOC | string | signal (primary IO) instance | signal (primary IO) instance | net (in model) inst (in model) | N/A | N/A |
| Map Entity on a Single LUT | yes no | entity architecture | module | model | N/A | N/A |

| Constraint Name | Constraint Value | VHDL Target | Verilog Target | XCF Target | Command Line | Command Value |
|---------------------|--|--------------------------------------|--------------------------------------|--|-------------------|---|
| Max Fanout | integer | entity signal | module signal | model net (in model) | -max_fanout | integer default: see detailed description |
| Move First Stage | yes no | entity primary clock signal | module primary clock signal | model primary clock signal net (in model) | -move_first_stage | yes no default: yes |
| Move Last Stage | yes no | entity primary clock signal | module primary clock signal | model primary clock signal net (in model) | -move_last_stage | yes no default: yes |
| Multiplier Style | auto block pipe_block kcm csd lut pipe_lut | entity signal | module signal | model net (in model) | -mult_style | auto block pipe_block kcm csd lut pipe_lut default: auto |
| Mux Extraction | yes no force | entity signal | module signal | model net (in model) | -mux_extract | yes no force default: yes |
| Mux Style | auto muxf muxcy | entity signal | module signal | model net (in model) | -mux_style | auto muxf muxcy default: auto |
| No Reduce | yes no | signal | signal | net (in model) | N/A | N/A |
| Optimization Effort | 1 2 | entity | module | model | -opt_level | 1 2 default: 1 |
| Optimization Goal | speed area | entity | module | model | -opt_mode | speed area default: speed |

| Constraint Name | Constraint Value | VHDL Target | Verilog Target | XCF Target | Command Line | Command Value |
|----------------------------------|--|---|---|--|---------------------------|---|
| Optimize Instantiated Primitives | yes no | entity instance | module instance | model instance (in model) | -optimize _primitives | yes no default: no |
| Parallel Case | N/A | N/A | case statement | N/A | N/A | N/A |
| Power Reduction | yes no | entity | module | model | -power | yes no default: no |
| Priority Encoder Extraction | yes no force | entity signal | module signal | model net (in model) | -priority _extract | yes no force default: yes |
| RAM Extraction | yes no | entity signal | module signal | model net (in model) | -ram _extract | yes no default: yes |
| RAM Style | auto block distributed pipe_distributed block_power1 block_power2 | entity signal | module signal | model net (in model) | -ram _style | auto block distributed default: auto |
| Read Cores | yes no optimize | entity component | module label | model inst (in model) | -read _cores | yes no optimize default: yes |
| Register Balancing | yes no forward backward | entity signal FF instance name | module signal FF instance name primary clock signal | model net (in model) inst (in model) | -register _balancing | yes no forward backward default: no |
| Register Duplication | yes no | entity signal | module | model net (in model) | -register _duplication | yes no default: yes |
| Resource Sharing | yes no | entity signal | module signal | model net (in model) | -resource _sharing | yes no default: yes |

| Constraint Name | Constraint Value | VHDL Target | Verilog Target | XCF Target | Command Line | Command Value |
|-------------------------------|---|-----------------------------|-----------------------------|--|------------------------------------|---|
| ROM Extraction | yes no | entity signal | module signal | model net (in model) | -rom_extract | yes no default: yes |
| ROM Style | auto block distributed | entity signal | module signal | model net (in model) | -rom_style | auto block distributed default: auto |
| Save | yes no | signal inst of primitive | signal inst of primitive | net (in model) inst of primitive (in model) | N/A | N/A |
| Safe Implementation | yes no | entity signal | module signal | model net (in model) | -safe_implementation | yes no default: no |
| Safe Recovery State | string | signal | signal | net (in model) | N/A | N/A |
| Logical Shifter Extraction | yes no | entity signal | module signal | model net (in model) | -shift_extract | yes no default: yes |
| Shift Register Extraction | yes no | entity signal | module signal | model net (in model) | -shreg_extract | yes no default: yes |
| Signal Encoding | auto one-hot user | entity signal | module signal | model net (in model) | -signal_encoding | auto one-hot user default: auto |
| Slice Utilization Ratio | integer (range -1 to 100) integer% (range -1 to 100) integer# | entity | module | model | -slice_utilization_ratio | integer (range -1 to 100) integer% (range -1 to 100) integer# default: 100 |
| Slice Utilization Ratio Delta | integer (range 0 to 100) integer% (range 0 to 100) integer# | entity | module | model | -slice_utilization_ratio_maxmargin | integer (range 0 to 100) integer% (range 0 to 100) integer# default: 0 |

| Constraint Name | Constraint Value | VHDL Target | Verilog Target | XCF Target | Command Line | Command Value |
|--------------------------------|-------------------|--|--|--|---------------------------|------------------------------------|
| Translate Off and Translate On | N/A | local no target | local no target | N/A | N/A | N/A |
| Convert Tristates to Logic | yes no | entity signal | modulesignal | model net (in model) | -tristate2logic | yes no default: yes |
| Use Carry Chain | yes no | entity signal | module signal | model net (in model) | -use _carry _chain | yes no default: yes |
| Use Clock Enable | auto yes no | entity signal FF instance name | module signal FF instance name | model net (in model) inst (in model) | -use _clock _enable | auto yes no default: auto |
| Use DSP48 | auto yes no | entity signal | module signal | model net (in model) | -use _dsp48 | auto yes no default: auto |
| Use Synchronous Reset | auto yes no | entity signal FF instance name | module signal FF instance name | model net (in model) inst (in model) | -use _sync _reset | auto yes no default: auto |
| Use Synchronous Set | auto yes no | entity signal FF instance name | module signal FF instance name | model net (in model) inst (in model) | -use _sync _set | auto yes no default: auto |
| XOR Collapsing | yes no | entity signal | module signal | model net (in model) | -xor _collapse | yes no default: yes |

XST Command Line Only Options

This section discusses XST Command Line Only Options, and includes:

- [XST Specific Non-Timing Options Supported Only in the Command Line](#)
- [Invoking XST Timing Options](#)
- [XST Timing Constraints Supported Only in Process > Process Properties, or the Command Line](#)
- [XST Timing Constraints Supported Only in the XCF](#)

XST Specific Non-Timing Options Supported Only in the Command Line

| Constraint Name | Command Line | Command Value |
|--|-----------------------------|---|
| VHDL Top Level Architecture | -arch | architecture_name default: N/A |
| Asynchronous to Synchronous | -async_to_sync | yes no default: no |
| Automatic BRAM Packing | -auto_bram_packing | yes no default: no |
| BRAM Utilization Ratio (BRAM_UTILIZATION_RATIO) | -bram_utilization_ ratio | integer (range -1 to 100) integer% (range -1 to 100) integer# default: 100 |
| Maximum Global Clock Buffers | -bufg | Integer default: max number of buffers in target device |
| Maximum Regional Clock Buffers | -bufr | Integer default: max number of buffers in target device |
| Bus Delimiter | -bus_delimiter | <> [] {} () default: <> |
| Case | -case | upper lower maintain default: maintain |
| Verilog Macros | -define | {name = value} default: N/A |

| Constraint Name | Command Line | Command Value |
|---|------------------------|---|
| DSP Utilization Ratio (DSP_UTILIZATION_RATIO) | -dsp_utilization_ratio | integer (range -1 to 100) integer% (range -1 to 100) integer# default: 100 |
| Duplication suffix | -duplication_suffix | string%dstring default: _%d |
| VHDL Top-Level block (Valid only when old VHDL project format is used (-ifmt VHDL). Use project format (-ifmt mixed) and - top option to specify which top level block to synthesize.) | -ent | entity_name default: N/A |
| Generics | -generics | {name = value} default: N/A |
| HDL File Compilation Order | -hdl_compilation_order | auto user default: auto |
| Hierarchy Separator | -hierarchy_separator | - / default: / |
| Input Format | -ifmt | mixed vhdl verilog default: mixed |
| Input/Project File Name | -ifn | file_name default: N/A |
| Add I/O Buffers | -iobuf | yes no default: yes |
| Ignore User Constraints | -iuc | yes no default: no |
| Library Search Order | -lso | file_name.lso default: N/A |
| LUT Combining | -lc | auto area off default: off |

| Constraint Name | Command Line | Command Value |
|----------------------------|----------------------|--|
| Netlist Hierarchy | -netlist_hierarchy | as_optimized rebuilt default: as_optimized |
| Output File Format | -ofmt | ngc default: ngc |
| Output File Name | -ofn | file_name default: N/A |
| Target Device | -P | part-package-speed (For example: xc5vfx30t-ff324-2) default: N/A |
| Clock Enable | -pld_ce | yes no default: yes |
| Macro Preserve | -pld_mp | yes no default: yes |
| XOR Preserve | -pld_xp | yes no default: yes |
| Reduce Control Sets | -reduce_control_sets | auto no default: no |
| Generate RTL Schematic | -rtlview | yes no only default: no |
| Cores Search Directories | -sd | directories default: N/A |
| Slice Packing | -slice_packing | yes no default: yes |
| Top Level Block | -top | block_name default: N/A |
| Synthesis Constraints File | -uc | file_name.xcf default: N/A |
| Verilog 2001 | -verilog2001 | yes no default: yes |

| Constraint Name | Command Line | Command Value |
|-----------------------------|--------------|---|
| Case Implementation Style | -vlgcase | full parallel full-parallel default: N/A |
| Verilog Include Directories | -vlgincdir | directories default: N/A |
| Work Library | -work_lib | directory default: work |
| wysiwyg | -wysiwyg | yes no default: no |
| Work Directory | -xsthdpdir | Directory default: ./xst |
| HDL Library Mapping File | -xsthdpini | file_name.ini default: N/A |

Invoking XST Timing Options

Invoke XST timing options from:

- ISE® Design Suite in **Process > Process Properties**
- Command line
- XST Constraint File (XCF)

XST Timing Constraints Supported Only in Process > Process Properties, or the Command Line

| Option | Process > Process Properties (ISE® Design Suite) | Values |
|--------------------------|--|---|
| glob_opt | Global Optimization Goal | allclocknetsinpad _to_outpadoffset _in_beforeoffset _out_aftermax _delay default: allclocknets |
| cross_clock_analysis | Cross Clock Analysis | yes no (default) |
| write_timing_constraints | Write Timing Constraints | yes no (default) |

XST Timing Constraints Supported Only in the XCF

The following XST timing constraints can be applied for synthesis only through the XST Constraint File (XCF):

- [Period \(PERIOD\)](#)
- [Offset \(OFFSET\)](#)
- [From-To \(FROM-TO\)](#)
- [Timing Name \(TNM\)](#)
- [Timing Name on a Net \(TNM_NET\)](#)
- [Timegroup \(TIMEGRP\)](#)
- [Timing Ignore \(TIG\)](#)
- [Timing Specifications \(TIMESPEC\)](#)
- [Timing Specification Identifier \(TSidentifier\)](#)

These timing constraints influence synthesis optimization, and can be passed on to place and route by selecting the [Write Timing Constraints](#) command line option.

For more information, see the [Constraints Guide](#).

XST General Constraints

This chapter discusses the following constraints:

- Add I/O Buffers (-iobuf)
- BoxType (BOX_TYPE)
- Bus Delimiter (-bus_delimiter)
- Case (-case)
- Case Implementation Style (-vlgcase)
- Duplication Suffix (-duplication_suffix)
- Full Case (FULL_CASE)
- Generate RTL Schematic (-rtlview)
- Generics (-generics)
- HDL Library Mapping File (-xsthdpini)
- Hierarchy Separator (-hierarchy_separator)
- I/O Standard (IOSTANDARD)
- Keep (KEEP)
- Keep Hierarchy (KEEP_HIERARCHY)
- Library Search Order (-lso)
- LOC
- Netlist Hierarchy (-netlist_hierarchy)
- Optimization Effort (OPT_LEVEL)
- Optimization Goal (OPT_MODE)
- Parallel Case (PARALLEL_CASE)
- RLOC
- Save (S / SAVE)
- Synthesis Constraint File (-uc)
- Translate Off (TRANSLATE_OFF) and Translate On (TRANSLATE_ON)
- Use Synthesis Constraints File (-iuc)
- Verilog 2001 (-verilog2001)
- Verilog Include Directories (-vlgindir)
- Verilog Macros (-define)
- Work Directory (-xsthdpdir)

Add I/O Buffers (-iobuf)

The Add I/O Buffers (**-iobuf**) command line option:

- Enables or disables I/O buffer insertion.
- Can be used to synthesize a part of a design to be instantiated later on.

XST automatically inserts Input/Output Buffers into the design. If you manually instantiate I/O Buffers for some or all the I/Os, XST inserts I/O Buffers only for the remaining I/Os. If you do not want XST to insert I/O Buffers, set **-iobuf** to **no**.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design.

Propagation Rules

Applies to design primary IOs.

Syntax

-iobuf {yes|no|true|false|soft}

- **yes** (default)
Tells XST to generate IBUF and OBUF primitives and connected them to I/O ports of the top-level module.
- **no**
Tells XST not to generate IBUF and OBUF primitives, and must be used when XST is called to synthesize an internal module that is instantiated later in a larger design. If I/O buffers are added to a design, this design cannot be used as a submodule of another design.
- **true**
- **false**
- **soft**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -iobuf yes
```

Adds I/O buffers to the top level module of the design.

ISE® Design Suite

Process > Process Properties > Xilinx®-Specific Options > Add I/O Buffers

BoxType (BOX_TYPE)

The BoxType (**BOX_TYPE**) constraint is a synthesis constraint.

If BoxType is applied to at least a single instance of a block of a design, BoxType is propagated to all other instances of the entire design. This feature was implemented for Verilog and XST Constraint File (XCF) in order to have a VHDL-like support, where BoxType can be applied to a component.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the following design elements:

- VHDL
component, entity
- Verilog
module, instance
- XST Constraint File (XCF)
model, instance

Propagation Rules

Applies to the design element to which it is attached.

Syntax

- **primitive**
- **black_box**
Equivalent to **primitive**. Will eventually become obsolete.
- **user_black_box**
XST reports inference of a black box in the log file unless **primitive** is specified.

These values instruct XST not to synthesize the behavior of a module.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute box_type: string;
```

Specify as follows:

```
attribute box_type of {component_name|entity_name} : {component|entity} is  
"{primitive|black_box|user_black_box}";
```

Verilog

Place immediately before the instantiation:

```
(* box_type = "{primitive|black_box|user_black_box}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" box_type = "{primitive|black_box|user_black_box}";
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
INST "instance_name"
box_type="{primitive|black_box|user_black_box}";
END;
```

Bus Delimiter (-bus_delimiter)

The Bus Delimiter (-bus_delimiter) command line option defines the format of signals belonging to buses in the output netlist.

Architecture Support

Architecture independent.

Applicable Elements

Applies to syntax.

Propagation Rules

Not applicable.

Syntax

```
-bus_delimiter {<>|[]|{}|() }
```

- <> (default)
- []
- {}
- ()

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -bus_delimiter []
```

Defines bus delimiters globally as square braces ([]).

ISE® Design Suite

Process > Process Properties > Synthesis Options > Bus Delimiter

Case (-case)

The Case (-case) command line option determines if instance and net names are written in the final netlist using all lowercase or uppercase letters, or if the case is maintained from the source.

The case can be maintained for either Verilog or VHDL.

Architecture Support

Architecture independent.

Applicable Elements

Applies to syntax.

Propagation Rules

Not applicable.

Syntax

`-case {upper|lower|maintain}`

- `upper`
- `lower`
- `maintain` (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -case upper
```

Defines case globally to uppercase.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Case

Case Implementation Style (-vlgcase)

The Case Implementation Style (-vlgcase) command line option:

- Is valid for Verilog designs only.
- Instructs XST how to interpret Verilog `case` statements.

For more information, see:

- [Multiplexers HDL Coding Techniques](#)
- [FULL_CASE \(Full Case\)](#)
- [PARALLEL_CASE \(Parallel Case\)](#)

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-vlgcase {full|parallel|full-parallel}`

- **full**
XST assumes that the case statements are complete, and avoids latch creation.
- **parallel**
XST assumes that the branches cannot occur in parallel, and does not use a priority encoder.
- **full-parallel**
XST assumes that the case statements are complete, and that the branches cannot occur in parallel, therefore saving latches and priority encoders.

By default, there is no value. If the option is not specified, XST implements the exact behavior of the **case** statements.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -vlgcase full
```

Defines Case Implementation Style globally to **full**.

ISE® Design Suite

Process > Process Properties > HDL Options > Case Implementation Style

Duplication Suffix (-duplication_suffix)

The Duplication Suffix (**-duplication_suffix**) command line option controls how XST names replicated flip-flops.

By default, when XST replicates a flip-flop, it creates a name for the new flip-flop by taking the name of the original flip-flop and adding `_n` to the end of it, where `n` is an index number.

For instance, if the original flip-flop name is **my_ff**, and this flip-flop was replicated three times, XST generates flip-flops with the following names:

- **my_ff_1**
- **my_ff_2**
- **my_ff_3**

Duplication Suffix lets you change the string that is added to the original name.

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

-duplication_suffix *string%dstring*

The default is **%d**.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line Example One

```
xst run -duplication_suffix_dupreg_%d
```

If the flip-flop named **my_ff** is duplicated three times, this command tells XST to generate the following names:

- **my_ff_dupreg_1**
- **my_ff_dupreg_2**
- **my_ff_dupreg_3**

XST Command Line Example Two

```
xst run -duplication_suffix_dup_%d_reg
```

The **%d** escape character can be placed anywhere in the suffix definition. If the flip-flop named **my_ff** is duplicated three times, this command tells XST to generate the following names:

- **my_ff_dup_1_reg**
- **my_ff_dup_2_reg**
- **my_ff_dup_3_reg**

ISE® Design Suite

Process > Process Properties > Synthesis Options > Property display level > Advanced > Other XST Command Line Options

Full Case (FULL_CASE)

The Full Case (FULL_CASE) constraint:

- Is valid for Verilog designs only.
- Indicates that all possible selector values have been expressed in a **case**, **casex**, or **casez** statement.
- Prevents XST from creating additional hardware for those conditions not expressed.

For more information, see:

[Multiplexers HDL Coding Techniques](#)

Architecture Support

Architecture independent.

Applicable Elements

Applies to **case** statements in Verilog meta comments.

Propagation Rules

Not applicable.

Syntax

-vlgcase [full | parallel | full-parallel]

- **full**
- **parallel**
- **full-parallel**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

Verilog

The syntax is:

(* full_case *)

Since FULL_CASE does not contain a target reference, the attribute immediately precedes the selector:

```
(* full_case *)
casex select
4'b1xxx: res = data1;
4'bxx1x: res = data2;
4'bxx1x: res = data3;
4'bxxx1: res = data4;
endcase
```

FULL_CASE is also available as a meta comment in the Verilog code. The syntax differs from the standard meta comment syntax as shown in the following:

```
// synthesis full_case
```

Since FULL_CASE does not contain a target reference, the meta comment immediately follows the selector:

```
case select // synthesis full_case
4'b1xxx: res = data1;
4'bxlxx: res = data2;
4'bxxlx: res = data3;
4'bxxx1: res = data4;
endcase
```

XST Command Line

```
xst run -vlgcase [full|parallel|full-parallel]
```

ISE® Design Suite

Process > Process Properties > Synthesis Options > Full Case.

For [Case Implementation Style](#), select **full**.

Generate RTL Schematic (-rtlview)

The Generate RTL Schematic (**-rtlview**) command line option tells XST to generate a netlist file representing a Register Transfer Level (RTL) structure of the design. This netlist can be viewed by the RTL and Technology Viewers.

The file containing the RTL view has an NGR file extension.

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

```
-rtlview {yes|no|only}
```

- **yes**
Tells XST to generate an RTL view.
- **no** (default)
Tells XST not to generate the RTL view.
- **only**
Tells XST to stop the synthesis once the RTL view is generated.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -rtlview yes
```

Tells XST to generate a netlist file representing the RTL structure of the design.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Generate RTL Schematic

Generics (-generics)

The Generics (**-generics**) command line option allows you to redefine generics (VHDL) or parameters (Verilog) values defined in the top-level design block.

This allows you to easily modify the design configuration without any Hardware Description Language (HDL) source modifications, such as for IP core generation and testing flows. If the defined value does not correspond to the data type defined in the VHDL or Verilog code, then XST tries to detect the situation and issues a warning, ignoring the command line definition.

In some situations, XST may fail to detect a type mismatch. In that case, XST attempts to apply this value by adopting it to the type defined in the VHDL or Verilog file without any warning. Be sure that the value you specified corresponds to the type defined in the VHDL or Verilog code. If a defined generic or parameter name does not exist in the design, no message is given, and the definition is ignored.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

```
-generics {name=valuename=value ...}
```

where

- *name* is the name of a generic or parameter of the top level design block
- *value* is the value of a generic or parameter of the top level design block

The default is an empty definition.

Follow these rules:

- Place the values inside curly braces ({...}).
- Separate the values with spaces.
- XST can accept as values only constants of scalar types. Composite data types (arrays or records) are supported only in the following situations:
 - **string**
 - **std_logic_vector**
 - **std_ulogic_vector**
 - **signed, unsigned**
 - **bit_vector**
- There are no spaces between the prefix and the corresponding value.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -generics {company="Xilinx" width=5 init_vector=b100101}
```

This command sets:

- *company* to Xilinx®
- *width* to 5
- *init_vector* to **b100101**

ISE® Design Suite

Process > Process Properties > Synthesis Options > Generics, Parameters

HDL Library Mapping File (-xsthdpini)

The HDL Library Mapping File (-**xsthdpini**) command line option defines the library mapping.

XST maintains two library mapping files:

- The pre-installed (default) INI file, which is installed during the Xilinx® software installation
- The user file, which you may define for your own projects

The pre-installed (default) INI file:

- Is named `xhdp.ini`.
- Is located in `%XILINX%\vhdl\xst`.
- Contains information about the locations of the standard VHDL and UNISIM libraries.
- Should not be modified

Note You can copy the syntax for your own library mapping file

A library mapping file looks like the following:

```
-- Default lib mapping for XST std=$XILINX/vhdl/xst/std
ieee=$XILINX/vhdl/xst/unisim unisim=$XILINX/vhdl/xst/unisim
aim=$XILINX/vhdl/xst/aim pls=$XILINX/vhdl/xst/pls
```

Use this file format to define where each of your own libraries must be placed. By default, all compiled VHDL files are stored in the `xst` subdirectory of the ISE Design Suite project directory.

The library mapping file contains a list of libraries, one per line with the following information:

- The library name
- The directory in which the library is compiled

You can give this library mapping file any name you wish, but it is best to keep the `.ini` classification.

The format for each line is:

```
library_name=path_to_compiled_directory
```

Use a double dash (`--`) to start a comment line.

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

```
-xsthdpini file_name
```

You can specify only one library mapping file.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst set -xsthdpini c:/data/my_libraries/my.ini file_name
```

Specifies `c:/data/my_libraries/my.ini` as the file that will point to all of your libraries.

You must run this **set** command before any **run** commands.

Following is an MY.INI example text:

```
work1=H:\Users\conf\my_lib\work1 work2=C:\mylib\work2
```

ISE® Design Suite

To set the library mapping file location in ISE Design Suite:

1. Select **Process > Process Properties > Synthesis Options**
2. From the **Property display level** list, select **Advanced**
3. Set the HDL **INI File** property.

Hierarchy Separator (-hierarchy_separator)

The Hierarchy Separator (**-hierarchy_separator**) command line option defines the hierarchy separator character that is used in name generation when the design hierarchy is flattened.

If a design contains a sub-block with instance INST1, and this sub-block contains a net called TMP_NET, then the hierarchy is flattened and the hierarchy separator character is / (forward slash). The name TMP_NET becomes INST1_TMP_NET. If the hierarchy separator character is _ (underscore), the net name is INST1_TMP_NET.

Using / (forward slash) as a hierarchy separator is useful in design debugging because the / (forward slash) separator makes it much easier to identify a name if it is hierarchical.

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

-hierarchy_separator {/ | _}

The two supported characters are:

- _ (underscore)
- / (forward slash)

The default is / (forward slash) for newly created projects.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -hierarchy_separator _
```

Sets the hierarchy separator to “_” (underscore)

ISE® Design Suite

1. Select **Process > Process Properties > Synthesis Options**.
2. From the **Property display level** list, select **Advanced**
3. Set the **Hierarchy Separator** property.

I/O Standard (IOSTANDARD)

The I/O Standard (**IOSTANDARD**) constraint assigns an I/O standard to an I/O primitive.

For more information about this constraint, see the [Constraints Guide](#).

Keep (KEEP)

Keep (Keep) is an advanced mapping constraint.

When a design is mapped, some nets may be absorbed into logic blocks. When a net is absorbed into a block, it can no longer be seen in the physical design database. This may happen, for example, if the components connected to each side of a net are mapped into the same logic block. The net may then be absorbed into the block containing the components. Keep prevents this from happening.

In addition to **true** and **false** values supported by the implementation flow, XST supports a **soft** value. If this value is specified XST preserves the designated net as in the case of the **true** value, but does not attach the Keep constraint in the final netlist to this net.

Keep preserves the existence of the signal in the final netlist, but not its structure. For example, if your design has a 2-bit multiplexer selector and you attach Keep to it, this signal is preserved in the final netlist. But the multiplexer could be automatically re-encoded by XST using one-hot encoding. As a consequence, this signal in the final netlist is four bits wide instead of the original two. To preserve the structure of the signal, in addition to Keep , you must also use [Enumerated Encoding \(ENUM_ENCODING\)](#)'

For more information about this constraint, see the [Constraints Guide](#).

Keep Hierarchy (KEEP_HIERARCHY)

The Keep Hierarchy (**KEEP_HIERARCHY**) constraint is a synthesis and implementation constraint.

If hierarchy is maintained during synthesis, the implementation tools use Keep Hierarchy to preserve the hierarchy throughout implementation, and allow a simulation netlist to be created with the desired hierarchy.

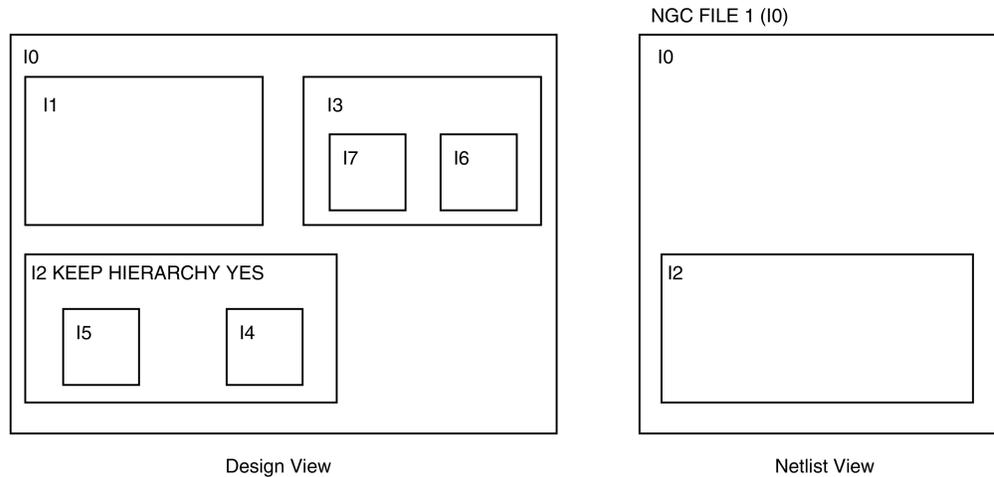
XST can flatten the design to obtain better results by optimizing entity or module boundaries. You can set Keep Hierarchy to **true** so that the generated netlist is hierarchical and respects the hierarchy and interface of any entity or module in your design.

Keep Hierarchy is related to the hierarchical blocks (VHDL entities, Verilog modules) specified in the Hardware Description Language (HDL) design, and does not concern the macros inferred by the HDL synthesizer.

In general, a Hardware Description Language (HDL) design is a collection of hierarchical blocks. Preserving the hierarchy gives the advantage of fast processing because the optimization is done on separate pieces of reduced complexity. Nevertheless, very often, merging the hierarchy blocks improves the fitting results (fewer PTerms and device macrocells, better frequency) because the optimization processes (collapsing, factorization) are applied globally on the entire logic.

In the following figure, if Keep Hierarchy is set to the entity or module **I2**, the hierarchy of **I2** is in the final netlist, but its contents **I4**, **I5** are flattened inside **I2**. **I1**, **I3**, **I6**, and **I7** are also flattened.

Keep Hierarchy Diagram



X9542

Architecture Support

Architecture independent.

Applicable Elements

Applies to logical blocks, including blocks of hierarchy or symbols.

Propagation Rules

Applies to the entity or module to which it is attached.

Syntax

`-keep_hierarchy {yes|no|soft}`

- **yes**
- **no**
- **true**

Allows the preservation of the design hierarchy, as described in the HDL project. If this value is applied to synthesis, it is also propagated to implementation.

The default is **true** for CPLD devices.

- **false**

Hierarchical blocks are merged in the top level module.

The default is **false** for FPGA devices.

- **soft**

Allows the preservation of the design hierarchy in synthesis, but `KEEP_HIERARCHY` is not propagated to implementation.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

Schematic Syntax Example

- Attach to the entity or module symbol.
- Attribute Name
KEEP_HIERARCHY
- Attribute Values
See *Syntax* section above.

VHDL

Declare as follows:

```
attribute keep_hierarchy : string;
```

Specify as follows:

```
attribute keep_hierarchy of architecture_name: architecture is "{yes|no|true|false|soft}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* keep_hierarchy = "{yes|no|true|false|soft}" *)
```

XCF

```
MODEL "entity_name" keep_hierarchy={yes|no|true|false|soft};
```

XST Command Line

```
xst run -keep_hierarchy {yes|no|soft}
```

For more information, see:

[XST Command Line Mode](#)

ISE® Design Suite

Process > Process Properties > Synthesis Options > Keep Hierarchy

Library Search Order (-lso)

The Library Search Order (-lso) command line option specifies the location of the library search order file.

For more information, see:

[Library Search Order \(LSO\) Files in Mixed Language Projects](#)

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

`-lso file_name.lso`

There is no default file name. If not specified, XST uses the default search order.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst elaborate -lso c:/data/my_libraries/my.lso
```

Specifies `c:/data/my_libraries/my.lso` as the file that sets your library search order.

ISE® Design Suite

To specify the library search order file in ISE Design Suite:

1. Select **Process > Process Properties > Synthesis Options**.
2. From the **Property display level** list, select **Advanced**
3. Set the **Library Search Order** property.

LOC

The LOC constraint defines where a design element can be placed within an FPGA or CPLD device.

For more information about this constraint, see the [Constraints Guide](#).

Netlist Hierarchy (-netlist_hierarchy)

The Netlist Hierarchy (`-netlist_hierarchy`) command line option:

- Controls the form in which the final NGC netlist is generated.
- Allows you to write the hierarchical netlist even if the optimization was done on a partially or fully flattened design.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-netlist_hierarchy {as_optimized|rebuilt}`

- **as_optimized** (default)

XST takes into account the [Keep Hierarchy \(KEEP_HIERARCHY\)](#) constraint, and generates the NGC netlist in the form in which it was optimized. In this mode, some hierarchical blocks can be flattened, and some can maintain hierarchy boundaries.

- **rebuilt**

XST writes a hierarchical NGC netlist, regardless of the [Keep Hierarchy \(KEEP_HIERARCHY\)](#) constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

`-netlist_hierarchy {as_optimized|rebuilt}`

ISE® Design Suite

1. Select **Process > Process Properties > Synthesis Options**.
2. From the **Property display level** list, select **Advanced**
3. Set the **Netlist Hierarchy** property.

Optimization Effort (OPT_LEVEL)

The Optimization Effort (**OPT_LEVEL**) constraint defines the synthesis optimization effort level.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity or module.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-opt_level {1|2}

- **1** (normal optimization) (default)

Use **1** (normal optimization) for very fast processing, especially for hierarchical designs. In speed optimization mode, Xilinx® recommends using **1** (normal optimization) for the majority of designs.

- **2** (higher optimization)

While **2** (higher optimization) is more time consuming, it sometimes gives better results in the number of slices/macrocells or maximum frequency. Selecting **2** (higher optimization) usually results in increased synthesis run times, and does not always bring optimization gain.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute opt_level: string;
```

Specify as follows:

```
attribute opt_level of entity_name: entity is "{1|2}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* opt_level = "{1|2}" *)
```

XCF

```
MODEL "entity_name" opt_level={1|2};
```

XST Command Line

```
xst run -opt_level {1|2}
```

ISE® Design Suite

Process > Process Properties > Synthesis Options > Optimization Effort

Optimization Goal (OPT_MODE)

The Optimization Goal (OPT_MODE) constraint defines the synthesis optimization strategy.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity or module.

Propagation Rules

Applies to the entity or module to which it is attached.

Syntax

-opt_mode {area|speed}

- **speed** (default)
The priority of **speed** is to reduce the number of logic levels and therefore to increase frequency.
- **area**
The priority of **area** is to reduce the total amount of logic used for design implementation and therefore improve design fitting.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute opt_mode: string;
```

Specify as follows:

```
attribute opt_mode of entity_name: entity is "{speed|area}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* opt_mode = "{speed|area}" *)
```

XCF

```
MODEL "entity_name" opt_mode={speed|area};
```

XST Command Line

```
xst run -opt_mode {area|speed}
```

ISE® Design Suite

Process > Process Properties > Synthesis Options > Optimization Goal

Parallel Case (PARALLEL_CASE)

The Parallel Case (PARALLEL_CASE) constraint:

- Is valid for Verilog designs only.
- Forces a **case** statement to be synthesized as a parallel multiplexer.
- Prevents the **case** statement from being transformed into a prioritized **if...elsif** cascade.

For more information, see:

[Multiplexers HDL Coding Techniques.](#)

Architecture Support

Architecture independent.

Applicable Elements

Applies to `case` statements in Verilog meta comments only.

Propagation Rules

Not applicable.

Syntax

`-vlgcase {full|parallel|full-parallel}`

- `full`
- `parallel`
- `full-parallel`

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

Verilog

(* parallel_case *)

Since PARALLEL_CASE does not contain a target reference, the attribute immediately precedes the selector.

```
(* parallel_case *)
case select
4'blxxx: res = data1;
4'bxlxx: res = data2;
4'bxxlx: res = data3;
4'bxxx1: res = data4;
endcase
```

PARALLEL_CASE is also available as a meta comment in the Verilog code. The syntax differs from the standard meta comment syntax as shown in the following:

```
// synthesis parallel_case
```

Since PARALLEL_CASE does not contain a target reference, the meta comment immediately follows the selector:

```
case select // synthesis parallel_case
4'blxxx: res = data1;
4'bxlxx: res = data2;
4'bxxlx: res = data3;
4'bxxx1: res = data4;
endcase
```

XST Command Line

```
xst run -vlgcase {full|parallel|full-parallel}
```

RLOC (RLOC)

The RLOC (RLOC) constraint:

- Is a basic mapping and placement constraint.
- Groups logic elements into discrete sets.
- Allows you to define the location of any element within the set relative to other elements in the set, regardless of eventual placement in the overall design.

For more information about this constraint, see the [Constraints Guide](#).

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

Verilog

Assuming an SRL16 instance named *sr11* to be placed at location *R9C0.S0*, you may specify the following in the Verilog code:

```
// synthesis attribute RLOC of sr11 : "R9C0.S0";
```

XCF

You may specify the same attribute in the XST Constraint File (XCF) as follows:

```
BEGIN MODEL ENTNAME  
INST sr11 RLOC=R9C0.S0;  
END;
```

The binary equivalent of the following line is written to the output NGC file:

```
INST sr11 RLOC=R9C0.S0;
```

Save (S)

The Save (S) constraint is an advanced mapping constraint.

When the design is mapped, some nets may be absorbed into logic blocks, and some elements such as LUTs can be optimized away. When a net is absorbed into a block, or a block is optimized away, it can no longer be seen in the physical design database. Save (S) prevents this from happening. Several optimization techniques such as nets or blocks replication and register balancing are also disabled by the Save (S) constraint.

If Save (S) is applied to a net, XST preserves the net with all elements directly connected to it in the final netlist. This includes nets connected to these elements.

If Save (S) is applied to a block such as a LUT, XST preserves the LUT with all signals connected to it.

For more information about this constraint, see the [Constraints Guide](#).

Synthesis Constraint File (-uc)

The Synthesis Constraint File (**-uc**) command line option specifies the synthesis constraint file for XST to use.

The XST Constraint File (XCF) has an extension of `.xcf`. If the extension is not `.xcf`, XST errors out and stops processing.

For more information, see:

[XST Constraint File \(XCF\)](#)

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

-uc *filename*

filename is the only value.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -uc my_constraints.xcf
```

Specifies `my_constraints.xcf` as the constraint file for this project.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Synthesis Constraint File

Translate Off (TRANSLATE_OFF) and Translate On (TRANSLATE_ON)

The Translate Off (TRANSLATE_OFF) and Translate On (TRANSLATE_ON) constraints:

- Instruct XST to ignore portions of VHDL or Verilog code that are not relevant for synthesis, such as simulation code.
- Are Synopsys directives that XST supports in Verilog. Automatic conversion is also available in VHDL and Verilog
- Can be used with the following words
 - synthesis
 - Synopsys
 - pragma
- Operate as follows:
 - TRANSLATE_OFF marks the beginning of the section to be ignored.
 - TRANSLATE_ON instructs XST to resume synthesis from that point.

Architecture Support

Architecture independent.

Applicable Elements

Applies locally.

Propagation Rules

Instructs the synthesis tool to enable or disable portions of code

Syntax

The following sections show the syntax for this constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

```
-- synthesis translate_off
...code not synthesized...
-- synthesis translate_on
```

Verilog

The Verilog syntax differs from the standard meta comment syntax presented earlier, as shown in the following coding example.

```
// synthesis translate_off
...code not synthesized...
// synthesis translate_on
```

Ignore Synthesis Constraints File (-iuc)

Use the Ignore Synthesis Constraints File (-iuc) command line option to ignore the constraint file specified with Synthesis Constraints File (-uc) during synthesis.

Architecture Support

Architecture independent.

Applicable Elements

Applies to files.

Propagation Rules

Not applicable.

Syntax

-iuc {yes|no}

- yes
- no (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -iuc yes
```

ISE Design Suite

Caution! Ignore Synthesis Constraints File is shown as Synthesis Constraints File in ISE® Design Suite. The constraint file is ignored if you uncheck this option. It is checked by default (therefore resulting in a -iuc no command line switch), meaning that any synthesis constraints file you specify is taken into account.

Process > Process Properties > Synthesis Options > Use Synthesis Constraints File

Verilog 2001 (-verilog2001)

The Verilog 2001 (-verilog2001) command line option enables or disables interpreting Verilog source code by the Verilog 2001 standard.

By default Verilog source code is interpreted as the Verilog 2001 standard.

Architecture Support

Architecture independent.

Applicable Elements

Applies to syntax.

Propagation Rules

Not applicable.

Syntax

`-verilog2001 {yes|no}`

- `yes` (default)
- `no`

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst elaborate -verilog2001 no
```

XST does not interpret Verilog code according to the Verilog 2001 standard.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Verilog 2001

Verilog Include Directories (-vlgincdir)

The Verilog Include Directories (`-vlgincdir`) command line option helps the parser find files referenced by `'include` statements.

When an `'include` statement references a file, XST looks in different areas in this order:

- Relative to the current directory.
- Relative to the inc directories.
- Relative to the current file.

Note Verilog Include Directories should be used with `'include`

Architecture Support

Architecture independent.

Applicable Elements

Applies to directories.

Propagation Rules

Not applicable.

Syntax

`-vlgindir { directory_path [directory_path]}`

where

directory_path is the name of a directory

For more information, see:

[Names With Spaces in Command Line Mode.](#)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst elaborate -vlgindir c:/my_verilog
```

Adds `c:/my_verilog` to the list of directories in which XST looks for a file.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Property display level > Advanced > Verilog Include Directories

Verilog Macros (-define)

The Verilog Macros (**-define**) command line option:

- Is valid for Verilog designs only.
- Allows you to define (or redefine) Verilog macros.

This allows you to easily modify the design configuration without modifying source code, such as for IP core generation and testing flows. If the defined macro is not used in the design, no message is given.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-define {name[=value] name[=value]}`

where

- *name* is a macro name
- *value* is the macro text

The default is an empty definition.

Note

- Values for macros are not mandatory.
- Place the values inside curly braces ({...}).
- Separate the values with spaces.
- Macro text can be specified between quotation marks ("..."), or without them. If the macro text contains spaces, you must use quotation marks ("...").

```
-define {macro1=Xilinx macro2="Xilinx Virtex4"}
```

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -define macro1=Xilinx macro2="Xilinx Virtex4"
```

Defines two macros named **macro1** and **macro2**.

ISE Design Suite

To define Verilog macros in ISE® Design Suite:

1. Select **Process > Process Properties > Synthesis Options**.
2. From the **Property display level** list, select **Advanced**.
3. Set the **Verilog Macros** property.

Do not use curly braces ({ . . . }) when specifying values in ISE Design Suite.

Work Directory (-xsthdpdir)

Work Directory (**-xsthdpdir**) defines the location in which VHDL-compiled files must be placed if the location is not defined by library mapping files.

To access Work Directory:

- In ISE® Design Suite, select:
Process > Process Properties > Synthesis Options > VHDL Working Directory
- In standalone mode, run the following command:
set -xsthdpdir *directory*

Assume for purposes of this example:

- Three different users are working on the same project.
- They share one standard, precompiled library, **shlib**.
- This library contains specific macro blocks for their project.
- Each user also maintains a local work library.
- User 3 places her local work library outside the project directory (for example, in `c:\temp`).
- Users 1 and 2 share another library (lib12) between them, but not with User 3.

The settings required for the three users are as follows:

Example User One

Mapping file

```
schlib=z:\sharedlibs\shlib lib12=z:\userlibs\lib12
```

Example User Two

Mapping file

```
schlib=z:\sharedlibs\shlib lib12=z:\userlibs\lib12
```

Example User Three

Mapping file

```
schlib=z:\sharedlibs\shlib
```

User Three will also set:

```
XSTHDPDIR = c:\temp
```

Architecture Support

Architecture independent.

Applicable Elements

Applies to directories.

Propagation Rules

Not applicable.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

Define Work Directory globally with **set -xsthdpdir** before running the **run** command:

```
set -xsthdpdir directory
```

Work Directory can accept a single path only. You must specify the directory. There is no default.

ISE Design Suite

Process > Process Properties > Synthesis Options > VHDL Work Directory

To view **Work Directory**, select:

Edit > Preferences > Processes > Property Display Level > Advanced

XST HDL Constraints

The following HDL constraints can be set globally in ISE® Design Suite in **Process > Process Properties > HDL Options**:

- [Automatic FSM Extraction \(FSM_EXTRACT\)](#)
- [Equivalent Register Removal \(EQUIVALENT_REGISTER_REMOVAL\)](#)
- [FSM Encoding Algorithm \(FSM_ENCODING\)](#)
- [Mux Extraction \(MUX_EXTRACT\)](#)
- [Resource Sharing \(RESOURCE_SHARING\)](#)
- [Safe Implementation \(SAFE_IMPLEMENTATION\)](#)

The following HDL constraints *cannot* be set in **Process > Process Properties**:

- [Enumerated Encoding \(ENUM_ENCODING\)](#)
- [Safe Recovery State \(SAFE_RECOVERY_STATE\)](#)
- [Signal Encoding \(SIGNAL_ENCODING\)](#)

Automatic FSM Extraction (FSM_EXTRACT)

The Automatic FSM Extraction (**FSM_EXTRACT**) constraint:

- Enables or disables Finite State Machine (FSM) extraction and specific synthesis optimizations.
- Must be enabled in order to set values for [FSM Encoding Algorithm \(FSM_ENCODING\)](#).

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-fsm_extract {yes|no}

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute fsm_extract: string;
```

Specify as follows:

```
attribute fsm_extract of {entity_name|signal_name} : {entity|signal} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* fsm_extract = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" fsm_extract={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" fsm_extract={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -fsm_extract {yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > FSM Encoding Algorithm

This option defines both `-fsm_extract` and [FSM Style \(FSM_STYLE\)](#).

- When [FSM Encoding Algorithm \(FSM_ENCODING\)](#) is set to **none**:
 - `-fsm_extract` is set to **no**
 - `-fsm_encoding` is irrelevant and is left unspecified
- When [FSM Encoding Algorithm \(FSM_ENCODING\)](#) is set to any other value:
 - `-fsm_extract` is set to **yes**
 - `-fsm_encoding` is set to the selected value

For more information about `-fsm_encoding`, see :

[FSM Encoding Algorithm \(FSM_ENCODING\)](#)

Enumerated Encoding (ENUM_ENCODING)

The Enumerated Encoding (ENUM_ENCODING) constraint:

- Applies a specific encoding to a VHDL enumerated type. The value is a string containing space-separated binary codes.
- Can be specified only as a VHDL constraint on the considered enumerated type.

When describing a Finite State Machine (FSM) using an enumerated type for the state register, you may specify a particular encoding scheme with ENUM_ENCODING.

In order for this encoding to be used by XST, set [FSM Encoding Algorithm \(FSM_ENCODING\)](#) to **user** for the considered state register.

Architecture Support

Architecture independent.

Applicable Elements

Applies to signals or types.

Because ENUM_ENCODING must preserve the external design interface, XST ignores ENUM_ENCODING when it is used on a port.

Propagation Rules

Applies to the signal or type to which it is attached.

Syntax

The following sections show the syntax for this constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Specify as a VHDL constraint on the considered enumerated type:

```
...
...
architecture behavior of example is
type statetype is (ST0, ST1, ST2, ST3);
attribute enum_encoding : string;
attribute enum_encoding of statetype : type is "001 010 100 111";
signal state1 : statetype;
signal state2 : statetype;
begin
...
```

XCF

```
BEGIN MODEL "entity_name"
NET "signal_name" enum_encoding="string";
END;
```

Equivalent Register Removal (EQUIVALENT_REGISTER_REMOVAL)

The Equivalent Register Removal (**EQUIVALENT_REGISTER_REMOVAL**) constraint enables or disables removal of equivalent registers described at the RTL Level.

By default, XST does not remove equivalent flip-flops if they are instantiated from a Xilinx® primitive library.

Flip-flop optimization includes removing:

- Equivalent flip-flops for FPGA and CPLD devices
- Flip-flops with constant inputs for CPLD devices

This processing increases the fitting success as a result of the logic simplification implied by the flip-flops elimination.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Removes equivalent flip-flops and flip-flops with constant inputs.

Syntax

`-equivalent_register_removal {yes|no}`

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

When the value is set to **yes**, flip-flop optimization is allowed.

When the value is set to **no**, flip-flop optimization is inhibited.

Tip The flip-flop optimization algorithm is time consuming. For fast processing, use **no**.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute equivalent_register_removal: string;
```

Specify as follows:

```
attribute equivalent_register_removal of {entity_name|signal_name} : {signal|entity}  
is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* equivalent_register_removal="{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" equivalent_register_removal= {yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL " entity_name"  
NET "signal_name" equivalent_register_removal= {yes|no|true|false};  
END;
```

XST Command Line

```
xst run -equivalent_register_removal {yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Equivalent Register Removal

FSM Encoding Algorithm (FSM_ENCODING)

The FSM Encoding Algorithm (FSM_ENCODING) constraint selects the Finite State Machine (FSM) coding technique.

In order to select a value for the FSM Encoding Algorithm, [Automatic FSM Extraction \(FSM_EXTRACT\)](#) must be enabled.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-fsm_encoding {auto|one-hot|compact|sequential|gray|johnson|speed1|user}`

- **auto** (default)
The best coding technique is automatically selected for each individual state machine.
- **one-hot**
- **compact**
- **sequential**
- **gray**
- **johnson**
- **speed1**
- **user**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute fsm_encoding: string;
```

Specify as follows:

```
attribute fsm_encoding of {entity_name|signal_name}: {entity|signal} is  
"{auto|one-hot|compact|sequential|gray|johnson|speed1|user}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* fsm_encoding = "{auto|one-hot|compact|sequential|gray|johnson|speed1|user}"  
*)
```

XCF Syntax Example One

```
MODEL "entity_name"  
fsm_encoding={auto|one-hot|compact|sequential|gray|johnson|speed1|user};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
  
NET "signal_name" fsm_encoding={auto  
|one-hot|compact|sequential|gray|johnson|speed1|user};  
  
END;
```

XST Command Line

```
run xst -fsm_encoding  
{auto|one-hot|compact|sequential|gray|johnson|speed1|user}
```

ISE® Design Suite

Process > Process Properties > HDL Options > FSM Encoding Algorithm

These options are:

- If the FSM Encoding Algorithm menu is set to **none**, and **-fsm_extract** is set to **no**, **-fsm_encoding** has no influence on the synthesis.
- In all other cases, **-fsm_extract** is set to **yes** and **-fsm_encoding** is set to the value selected in the menu.

For more information, see:

[Automatic FSM Extraction \(FSM_EXTRACT\)](#)

Mux Extraction (MUX_EXTRACT)

The Mux Extraction (MUX_EXTRACT) constraint enables or disables multiplexer macro inference.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-mux_extract {yes | no | force}

- **yes** (default)
- **no**
- **force**
- **true** (XCF only)
- **false** (XCF only)

By default, multiplexer inference is enabled with the **yes** option. For each identified multiplexer description, based on some internal decision rules, XST actually creates a macro or optimizes it with the rest of the logic. The **force** value overrides those decision rules, and forces XST to create the MUX macro.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute mux_extract: string;
```

Specify as follows:

```
attribute mux_extract of {signal_name|entity_name}: {entity|signal} is "{yes | no | force}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* mux_extract = "{yes | no | force}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" mux_extract={yes | no | true | false | force};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
NET "signal_name" mux_extract={yes | no | true | false | force};
END;
```

XST Command Line

```
xst run -mux_extract {yes | no | force}
```

ISE® Design Suite

Process > Process Properties > HDL Options

Resource Sharing (RESOURCE_SHARING)

The Resource Sharing (**RESOURCE_SHARING**) constraint enables or disables resource sharing of arithmetic operators.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to design elements.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-resource_sharing {yes|no}

- **yes** (default)
- **no**
- **force**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute resource_sharing: string;
```

Specify as follows:

```
attribute resource_sharing of entity_name: entity is "{yes|no}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* resource_sharing = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" resource_sharing={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" resource_sharing={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -resource_sharing {yes|no}
```

ISE® Design Suite

HDL Options > Resource Sharing

Safe Implementation (SAFE_IMPLEMENTATION)

The Safe Implementation (SAFE_IMPLEMENTATION) constraint implements Finite State Machine (FSM) components in Safe Implementation mode.

In Safe Implementation mode, XST generates additional logic that forces an FSM to a valid state (recovery state) if the FSM enters an invalid state. By default, XST automatically selects **reset** as the recovery state. If the FSM does not have an initialization signal, XST selects **power-up** as the recovery state.

Define the recovery state manually with [Safe Recovery State \(SAFE_RECOVERY_STATE\)](#).

Architecture Support

Architecture independent.

Applicable Elements

Applies to:

- An entire design through the XST command line
- A particular block (entity, architecture, component)
- A signal

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-safe_implementation {yes|no}`

- `yes`
- `no` (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute safe_implementation: string;
```

Specify as follows:

```
attribute safe_implementation of {entity_name|component_name|signal_name} :  
{entity|component|signal} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* safe_implementation = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" safe_implementation={yes | no | true | false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" safe_implementation={yes | no | true | false};  
END;
```

XST Command Line

```
xst run -safe_implementation {yes | no}
```

ISE® Design Suite

To activate Safe Implementation in:

- ISE Design Suite
Select **Process > Process Properties > HDL Options > Safe Implementation**
- Hardware Description Language (HDL)
Apply Safe Implementation to the hierarchical block or signal that represents the state register in the FSM.

Signal Encoding (SIGNAL_ENCODING)

The Signal Encoding (SIGNAL_ENCODING) constraint selects the coding technique to use for internal signals.

Architecture Support

Architecture independent.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

```
-signal_encoding {auto | one-hot | user}
```

- **auto** (default)
The best coding technique is automatically selected for each individual signal.
- **one-hot**
Forces the encoding to a one-hot encoding.
- **user**
Forces XST to keep your encoding.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute signal_encoding: string;
```

Specify as follows:

```
attribute signal_encoding of {component_name|signal_name|entity_name|label_name} :
{component|signal|entity|label} is "{auto|one-hot|user}";
```

Verilog

Place immediately before the signal declaration:

```
(* signal_encoding = "{auto|one-hot|user}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" signal_encoding = {auto|one-hot|user};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" signal_encoding = {auto|one-hot|user};
```

```
END;
```

XST Command Line

```
xst run -signal_encoding {auto|one-hot|user}
```

Safe Recovery State (SAFE_RECOVERY_STATE)

The Safe Recovery State (SAFE_RECOVERY_STATE) constraint defines a recovery state for use when a Finite State Machine (FSM) is implemented in Safe Implementation mode.

If the FSM enters an invalid state, XST uses additional logic to force the FSM to a valid recovery state. By implementing FSM in safe mode, XST collects all code not participating in the normal FSM behavior and treats it as illegal.

XST uses logic that returns the FSM synchronously to the:

- Known state
- Reset state
- Power up state
- State you specified using Safe Recovery State

For more information, see:

[Safe Implementation \(SAFE_IMPLEMENTATION\)](#)

Architecture Support

Architecture independent.

Applicable Elements

Applies to a signal representing a state register.

Propagation Rules

Applies to the signal to which it is attached.

Syntax

The following sections show the syntax for this constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute safe_recovery_state: string;
```

Specify as follows:

```
attribute safe_recovery_state of {signal_name}:signal is "<value>;"
```

Verilog

Place immediately before the signal declaration:

```
(* safe_recovery_state = "<value>" *)
```

XCF

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" safe_recovery_state="<value>;"
```

```
END;
```


XST FPGA Constraints (Non-Timing)

Important! The constraints described in this chapter apply to FPGA devices *only*. They *do not* apply to CPLD devices.

This chapter discusses the following constraints:

- Asynchronous to Synchronous (ASYNC_TO_SYNC)
- Automatic BRAM Packing (AUTO_BRAM_PACKING)
- BRAM Utilization Ratio (BRAM_UTILIZATION_RATIO)
- Buffer Type (BUFFER_TYPE)
- Convert Tristates to Logic (TRISTATE2LOGIC)
- Cores Search Directories (-sd)
- Decoder Extraction (DECODER_EXTRACT)
- DSP Utilization Ratio (DSP_UTILIZATION_RATIO)
- Extract BUFGCE (BUFGCE)
- FSM Style (FSM_STYLE)
- LUT Combining (LC)
- Power Reduction (POWER)
- Read Cores (READ_CORES)
- Logical Shifter Extraction (SHIFT_EXTRACT)
- Map Entity on a Single LUT (LUT_MAP)
- Map Logic on BRAM (BRAM_MAP)
- Max Fanout (MAX_FANOUT)
- Move First Stage (MOVE_FIRST_STAGE)
- Move Last Stage (MOVE_LAST_STAGE)
- Multiplier Style (MULT_STYLE)
- Mux Style (MUX_STYLE)
- Number of Global Clock Buffers (-bufg)
- Number of Regional Clock Buffers (-bufr)
- Optimize Instantiated Primitives (OPTIMIZE_PRIMITIVES)
- Pack I/O Registers Into IOBs (IOB)
- Priority Encoder Extraction (PRIORITY_EXTRACT)
- RAM Extraction (RAM_EXTRACT)
- RAM Style (RAM_STYLE)
- Reduce Control Sets (REDUCE_CONTROL_SETS)
- Register Balancing (REGISTER_BALANCING)
- Register Duplication (REGISTER_DUPLICATION)

- ROM Extraction (ROM_EXTRACT)
- ROM Style (ROM_STYLE)
- Shift Register Extraction (SHREG_EXTRACT)
- Slice Packing (-slice_packing)
- Slice (LUT-FF Pairs) Utilization Ratio (SLICE_UTILIZATION_RATIO)
- Slice (LUT-FF Pairs) Utilization Ratio Delta (SLICE_UTILIZATION_RATIO_MAXMARGIN)
- Use Carry Chain (USE_CARRY_CHAIN)
- Use Clock Enable (USE_CLOCK_ENABLE)
- Use Synchronous Set (USE_SYNC_SET)
- Use Synchronous Reset (USE_SYNC_RESET)
- Use DSP48 (USE_DSP48)
- XOR Collapsing (XOR_COLLAPSE)

Some constraints can be applied:

- *globally* to an entire entity or model, OR
- *locally* to individual signals, nets or instances

For valid constraint targets, see:

- [XST Specific Non-Timing Options](#)
- [XST Specific Non-Timing Options Supported Only in the Command Line](#)

Asynchronous to Synchronous (ASYNC_TO_SYNC)

The Asynchronous to Synchronous (ASYNC_TO_SYNC) constraint:

- Allows you to replace Asynchronous Set/Reset signals with Synchronous signals throughout the entire design.
- Allows absorption of registers by DSP48 and BRAMs, thereby improving quality of results.
- May have a positive impact on power optimization.

Although XST can place Finite State Machine (FSM) components on BRAMs, in most cases an FSM has an Asynchronous Set/Reset signal, which does not allow FSM implementation on BRAMs. ASYNC_TO_SYNC allows you to more easily place FSMs on BRAMs by eliminating the need to manually change the design.

Replacing Asynchronous Set/Reset signals by Synchronous signals makes the generated NGC netlist NOT equivalent to the initial RTL description. You must ensure that the synthesized design satisfies the initial specification. XST issues the following warning:

```
WARNING: You have requested that asynchronous control signals of sequential elements be treated as if they were synchronous. If you haven't done so yet, please carefully review the related documentation material. If you have opted to asynchronously control flip-flop initialization, this feature allows you to better explore the possibilities offered by the Xilinx solution without having to go through a painful rewriting effort. However, be well aware that the synthesis result, while providing you with a good way to assess final device usage and design performance, is not functionally equivalent to your HDL description. As a result, you will not be able to validate your design by comparison of pre-synthesis and post-synthesis simulation results. Please also note that in general we strongly recommend synchronous flip-flop initialization.
```

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-async_to_sync {yes|no}`

- `yes`
- `no` (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -async_to_sync yes
```

ISE® Design Suite

Process > Process Properties > HDL Options > Asynchronous to Synchronous

Automatic BRAM Packing (AUTO_BRAM_PACKING)

The Automatic BRAM Packing (**AUTO_BRAM_PACKING**) constraint allows you to pack two small BRAMs in a single BRAM primitive as dual-port BRAM.

XST packs BRAMs together only if they are situated in the same hierarchical level.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

```
-auto_bram_packing {yes|no}
```

- yes
- no (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -auto_bram_packing no
```

ISE® Design Suite

Process > Process Properties > Automatic BRAM Packing

BRAM Utilization Ratio (BRAM_UTILIZATION_RATIO)

The BRAM Utilization Ratio (**BRAM_UTILIZATION_RATIO**) constraint defines the number of BRAM blocks that XST must not exceed during synthesis.

BRAMs in the design may come not only from BRAM inference processes, but from instantiation and BRAM mapping optimizations. You may isolate an RTL description of logic in a separate block, and then ask XST to map this logic to BRAM.

For more information, see:

Mapping Logic Onto Block RAM

Instantiated BRAMs are the primary candidates for available BRAM resources. The inferred RAMs are placed on the remaining BRAM resources. However, if the number of instantiated BRAMs exceeds the number of available resources, XST does not modify the instantiations and implement them as block RAMs. The same behavior occurs if you force specific RAMs to be implemented as BRAMs. If there are no resources, XST respects user constraints, even if the number of BRAM resources is exceeded.

If the number of user-specified BRAMs exceeds the number of available BRAM resources on the target FPGA device, XST issues a warning, and uses only available BRAM resources on the chip for synthesis. However, you may disable automatic BRAM resource management by using value `-1`. This can be used to see the number of BRAMs XST can potentially infer for a specific design.

You may experience significant synthesis time if the number of BRAMs in the design significantly exceeds the number of available BRAMs on the target FPGA device (hundreds of BRAMs). This may happen due to a significant increase in design complexity when all non-fittable BRAMs are converted to distributed RAMs.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

- %
- #

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -bram_utilization_ratio<integer>[%][#]
```

where

<integer> range is [-1 to 100] when % is used or both % and # are omitted

The default is 100.

XST Command Line Syntax Example One

```
xst run -bram_utilization_ratio 50
```

where

50 means 50% of BRAM blocks in the target device

XST Command Line Syntax Example Two

```
xst run -bram_utilization_ratio 50%
```

where

50% means 50% of BRAM blocks in the target device

XST Command Line Syntax Example Three

```
xst run -bram_utilization_ratio 50#
```

where

50# means 50 BRAM blocks

There must be no space between the integer value and the percent (%) or pound (#) characters.

In some situations, you can disable automatic BRAM resource management (for example, to see how many BRAMs XST can potentially infer for a specific design). To disable automatic resource management, specify **-1** (or any negative value) as a constraint value.

ISE® Design Suite

Process > Process Properties > Synthesis Options > BRAM Utilization Ratio

In ISE Design Suite, you can define the value of BRAM Utilization Ratio only as a percentage. The definition of the value in the form of absolute number of BRAMs is not supported.

Buffer Type (BUFFER_TYPE)

The Buffer Type (**BUFFER_TYPE**) constraint selects the type of buffer to be inserted on the input port or internal net.

XST supports the **bufr** value for Virtex®-4 devices and Virtex-5 devices only.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to signals.

Propagation Rules

Applies to the signal to which it is attached.

Syntax

- **bufgdl1**
- **ibufg**
- **bufgp**
- **ibuf**
- **bufr**
- **none**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute buffer_type: string;
```

Specify as follows:

```
attribute buffer_type of signal_name: signal is "  
{bufgdll|ibufg|bufgp|ibuf|bufr|none}";
```

Verilog

Place immediately before the signal declaration:

```
(* buffer_type = "{bufgdll|ibufg|bufgp|ibuf|bufr|none}" *)
```

XCF

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" buffer_type={bufgdll|ibufg|bufgp|ibuf|bufr|none};
```

```
END;
```

Convert Tristates to Logic (TRISTATE2LOGIC)

Since some devices do not support internal tristates, XST automatically replaces tristates with equivalent logic. Because the logic generated from tristates can be combined and optimized with surrounding logic, tristate to logic replacement for other devices can lead to better speed, and in some cases, better area optimization. But in general tristate to logic replacement may lead to area increase. If the optimization goal is Area, you should apply Convert Tristates to Logic set to **no**.

Limitations to Convert Tristates to Logic

Following are limitations to Convert Tristates to Logic:

- Only internal tristates are replaced by logic. The tristates of the top module connected to output pads are preserved.
- Convert Tristates to Logic does not apply to technologies that do not have internal tristates, such as Spartan®-3 devices or Virtex®-4 devices. In this case, the conversion of tristates to logic is performed automatically. In some situations XST is unable to make the replacement automatically, due to the fact that this may lead to wrong design behavior or multi-source. This may happen when the hierarchy is preserved or XST does not have full design visibility (for example, design is synthesized on a block-by-block basis). In these cases, XST issues a warning at the low level optimization step. Depending on the particular design situation, you may continue the design flow and the replacement could be done by MAP, or you can force the replacement by applying Convert Tristates to Logic set to **yes** on a particular block or signal.
- The situations in which XST is unable to replace a tristate by logic are:
 - The tristate is connected to a black box.
 - The tristate is connected to the output of a block, and the hierarchy of the block is preserved.
 - The tristate is connected to a top-level output.
 - Convert Tristates to Logic is set to **no** on the block where tristates are placed, or on the signals to which tristates are connected.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to:

- An entire design through the XST command line
- A particular block (entity, architecture, component)
- A signal

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-tristate2logic {yes | no}`

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute tristate2logic: string;
```

Specify as follows:

```
attribute tristate2logic of {entity_name|component_name|signal_name} :  
{entity|component|signal} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* tristate2logic = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" tristate2logic={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" tristate2logic={yes|no|true|false};
```

```
END;
```

XST Command Line

```
xst run -tristate2logic {yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Convert Tristates to Logic

Cores Search Directories (-sd)

The Cores Search Directories (-sd) command line option tells XST to look for cores in directories other than the default.

By default XST searches for cores in the directory specified in the -ifn option.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

```
-sd {directory_path [directory_path]}
```

The only value is *directory_path*. There is no default.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -sd c:/data/cores c:/ise/cores
```

Tells XST to search for cores in `c:/data/cores` and `c:/ise/cores` in addition to the default directory.

For more information, see:

[Names With Spaces in Command Line Mode](#)

ISE® Design Suite

Process > Process Properties > Synthesis Options > Cores Search Directory

Decoder Extraction (DECODER_EXTRACT)

The Decoder Extraction (DECODER_EXTRACT) constraint enables or disables decoder macro inference.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

When attached to a net or signal, Decoder Extraction applies to the attached signal.

When attached to an entity or module, Decoder Extraction is propagated to all applicable elements in the hierarchy within the entity or module.

Syntax

```
-decoder_extract {yes|no}
```

- yes (default)
- no

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute decoder_extract: string;
```

Specify as follows:

```
attribute decoder_extract of {entity_name|signal_name} : {entity|signal} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* decoder_extract "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" decoder_extract={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" decoder_extract={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -decoder_extract {yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > Decoder Extraction

DSP Utilization Ratio (DSP_UTILIZATION_RATIO)

The DSP Utilization Ratio (DSP_UTILIZATION_RATIO) constraint defines the number of DSP slices (in absolute number or percent of slices) that XST must not exceed during synthesis optimization.

The default is 100% of the target device.

DSP slices in the design may come not only from DSP inference processes, but also from instantiation. Instantiated DSP slices are the primary candidates for available DSP resources. The inferred DSPs are placed on the remaining DSP resources. If the number of instantiated DSPs exceeds the number of available resources, XST does not modify the instantiations and implement them as block DSP slices. The same behavior occurs if you force specific macro implementation to be implemented as DSP slices by using the [Use DSP48 \(USE_DSP48\)](#) constraint. If there are no resources, XST respects user constraints even if the number of DSP slices is exceeded.

If the number of user-specified DSP slices exceeds the number of available DSP resources on the target FPGA device, XST issues a warning, and uses only available DSP resources on the chip for synthesis.

You can disable automatic DSP resource management (for example, to see how many DSPs XST can potentially infer for a specific design) by specifying **-1** (or any negative value) as a constraint value.

Architecture Support

Applies to the following devices only. Does not apply to any other devices.

- Virtex®-4
- Virtex-5
- Spartan®-3A DSP

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

The following sections show the syntax for this constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

-dsp_utilization_ratio *integer*[%|#]

where

integer is [-1 to 100] when

- % is used, or
- both % and # are omitted

To specify a percent of total slices use %. To specify an absolute number of slices use #

The default is %.

For example:

- To specify 50% of DSP blocks of the target device enter :
-dsp_utilization_ratio 50
- To specify 50% of DSP blocks of the target device enter:
-dsp_utilization_ratio 50%
- To specify 50 DSP blocks enter:
-dsp_utilization_ratio 50#

Note There must be no space between the integer value and the percent (%) or pound (#) characters.

ISE® Design Suite

Process > Process Properties > Synthesis Options > DSP Utilization Ratio

In ISE Design Suite, you can define the value of DSP Utilization Ratio only as a percentage. You can not define the value as an absolute number of slices.

Extract BUFGCE (BUFGCE)

The Extract BUFGCE (**BUFGCE**) constraint:

- Implements BUFGMUX functionality by inferring a BUFGMUX primitive.
This operation reduces the wiring. Clock and clock enable signals are driven to n sequential components by a single wire.
- Must be attached to the primary clock signal.
- Is accessible through Hardware Description Language (HDL) code.
If **bufgce=yes**, XST implements BUFGMUX functionality if possible. All flip-flops must have the same clock enable signal.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to clock signals.

Propagation Rules

Applies to the signal to which it is attached.

Syntax

- **yes**
- **no**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL Syntax Example

Declare as follows:

```
attribute bufgce : string;
```

Specify as follows:

```
attribute bufgce of signal_name: signal is "{yes|no}";
```

Verilog

Place immediately before the signal declaration:

```
(* bufgce = "{yes|no}" *)
```

XCF

```
BEGIN MODEL "entity_name"
```

```
NET "primary_clock_signal" bufgce={yes|no|true|false};
```

```
END;
```

FSM Style (FSM_STYLE)

The FSM Style (FSM_STYLE) constraint:

- Is both a global and a local constraint.
- Can make large Finite State Machine (FSM) components more compact and faster by implementing them in the block RAM resources provided in Virtex® devices and later.
- Can be used to direct XST to use block RAM resources rather than LUTs (default) to implement FSMs.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

- `lut` (default)
- `bram`

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute fsm_style: string;
```

Declare as follows:

```
attribute fsm_style of {entity_name|signal_name} : {entity|signal} is "{lut|bram}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* fsm_style = "{lut|bram}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" fsm_style = {lut|bram};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" fsm_style = {lut|bram};
```

```
END;
```

XCF Syntax Example Three

```
BEGIN MODEL "entity_name"  
INST "instance_name" fsm_style = {lut|bram};  
END;
```

ISE® Design Suite

Process > Process Properties > Synthesis Options > FSM Style

Logical Shifter Extraction (SHIFT_EXTRACT)

The Logical Shifter Extraction (SHIFT_EXTRACT) constraint enables or disables logical shifter macro inference.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to design elements and nets.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-shift_extract {yes|no}

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute shift_extract: string;
```

Specify as follows:

```
attribute shift_extract of {entity_name|signal_name}: {signal|entity} is "{yes|no}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* shift_extract = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" shift_extract={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" shift_extract={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -shift_extract {yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > Logical Shifter Extraction

LUT Combining (LC)

The LUT Combining (LC) constraint enables the merging of LUT pairs with common inputs into single dual-output LUT6s in order to improve design area. This optimization process may reduce design speed.

Architecture Support

Applies to Virtex®-5 devices only. Does not apply to any other devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

```
-lc {auto|area|off}
```

- **auto**
XST tries to make a trade-off between area and speed.
- **area**
XST performs maximum LUT combining to provide as small an implementation as possible.
- **off** (default)
Disables LUT Combining.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -lc {auto|area|off}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > LUT Combining

Map Entity on a Single LUT (LUT_MAP)

The Map Entity on a Single LUT (**LUT_MAP**) constraint forces XST to map a single block into a single LUT. If a described function on an RTL level description does not fit in a single LUT, XST issues an error message.

Use the UNISIM library to directly instantiate LUT components in your Hardware Description Language (HDL) code. To specify a function that a particular LUT must execute, apply an INIT constraint to the instance of the LUT. To place an instantiated LUT or register in a particular slice, attach an **RLOC** constraint to the same instance.

It is not always convenient to calculate INIT functions and different methods can be used to achieve this. Instead, you can describe the function that you want to map onto a single LUT in your VHDL or Verilog code in a separate block. Attaching a **LUT_MAP** constraint to this block indicates to XST that this block must be mapped on a single LUT. XST automatically calculates the INIT value for the LUT and preserves this LUT during optimization.

For more information, see:

[Specifying INIT and RLOC](#)

XST automatically recognizes the XC_MAP constraint supported by Synopsys.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to a VHDL entity or Verilog module.

Propagation Rules

Applies to the entity or module to which it is attached.

Syntax

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute lut_map: string;
```

Specify as follows:

```
attribute lut_map of entity_name : entity is "{yes|no}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* lut_map = "{yes|no}" *)
```

XCF

```
MODEL "entity_name" lut_map={yes|no|true|false};
```

Map Logic on BRAM (BRAM_MAP)

The Map Logic on BRAM (**BRAM_MAP**) constraint:

- Is both a global and a local constraint.
- Is used to map an entire hierarchical block on the block RAM resources available in Virtex® devices and later technologies.

For more information, see:

[Mapping Logic Onto Block RAM](#)

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

BRAMs.

Propagation Rules

Isolate the logic (including output register) to be mapped on RAM in a separate hierarchical level. Logic that does not fit on a single block RAM is not mapped. Ensure that the whole entity fits, not just part of it.

The attribute **BRAM_MAP** is set on the instance or entity. If no block RAM can be inferred, the logic is passed to Global Optimization, where it is optimized. The macros *are not* inferred. Be sure that XST has mapped the logic.

Syntax

- **yes**
- **no** (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute bram_map: string;
```

Specify as follows:

```
attribute bram_map of component_name: component is "{yes|no}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* bram_map = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" bram_map = {yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
INST "instance_name" bram_map = {yes|no|true|false};
```

```
END;
```

Max Fanout (MAX_FANOUT)

The Max Fanout (MAX_FANOUT) constraint:

- Is both a global and a local constraint.
- Limits the fanout of nets or signals.

Large fanouts can cause routability problems. See *Constraint Values* below. XST tries to limit fanout by duplicating gates or by inserting buffers. This limit is not a technology limit, but only a guide to XST. This limit may not be precisely respected, especially when the limit is small (less than 30).

In most cases, fanout control is performed by duplicating the gate driving the net with a large fanout. If the duplication cannot be performed, buffers are inserted. These buffers are protected against logic trimming at the implementation level by defining a [Keep \(KEEP\)](#) attribute in the NGC file.

If the register replication option is set to **no**, only buffers are used to control fanout of flip-flops and latches.

Max Fanout is global for the design, but you can control maximum fanout independently for each entity or module or for given individual signals by using constraints.

If the actual net fanout is less than the Max Fanout value, XST behavior depends on how Max Fanout is specified.

- If the value of Max Fanout is set in ISE® Design Suite or in the command line, or is attached to a specific hierarchical block, XST interprets its value as a guidance.
- If Max Fanout is attached to a specific net, XST does not perform logic replication. Placing Max Fanout on the net may prevent XST from improving timing optimization.

For example, suppose the following:

- The critical path goes through the net.
- The actual fanout is 80.
- The Max Fanout value is set to 100.

In that instance:

- If Max Fanout is specified in ISE Design Suite, XST may replicate it, trying to improve timing.
- If Max Fanout is attached to the net itself, XST does not perform logic replication.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-max_fanout integer`

The constraint value is an integer. The default value varies depending on the targeted device family as shown in the following table.

Max Fanout Default Value

| Devices | Default Value |
|--|-------------------------------|
| Spartan®-3 Spartan-3E Spartan-3A Spartan-3A DSP | 500 |
| Virtex®-4 | 500 |
| Virtex-5 | 100000 (One Hundred Thousand) |

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute max_fanout: string;
```

Specify as follows:

```
attribute max_fanout of {signal_name|entity_name}: {signal|entity} is "integer";
```

Verilog

Place immediately before the signal declaration:

```
(* max_fanout = "integer" *)
```

XCF Syntax Example One

```
MODEL "entity_name" max_fanout=integer;
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" max_fanout=integer;  
END;
```

XST Command Line

```
xst run -max_fanout integer
```

ISE Design Suite

Process > Process Properties > Xilinx® Specific Options > Max Fanout

Move First Stage (MOVE_FIRST_STAGE)

The Move First Stage (**MOVE_FIRST_STAGE**) constraint controls the retiming of registers with paths coming from primary inputs.

Both Move First Stage and [Move Last Stage \(MOVE_LAST_STAGE\)](#) relate to Register Balancing.

Several constraints influence register balancing.

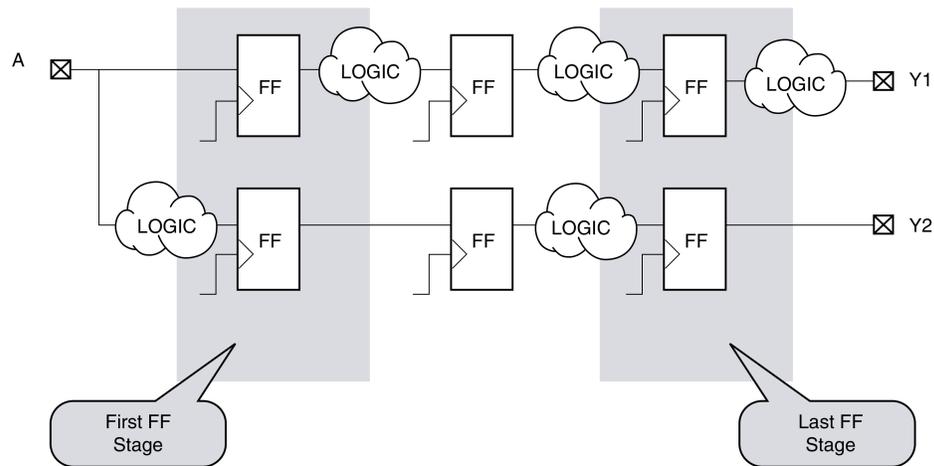
For more information, see:

[Register Balancing \(REGISTER_BALANCING\)](#)

Note

- A flip-flop (FF in the diagram) belongs to the First Stage if it is on the paths coming from primary inputs.
- A flip-flop belongs to the Last Stage if it is on the paths going to primary outputs.

Move First Stage Diagram



X9564

During Register Balancing

During register balancing:

- First Stage flip-flops are moved forward
- Last Stage flip-flops are moved backward.

This process can dramatically increase input-to-clock and clock-to-output timing, which is not desirable. To prevent this, you may use `OFFSET_IN_BEFORE` and `OFFSET_IN_AFTER` constraints.

If:

- The design does not have a strong requirements, or
- You want to see the first results without touching the first and last flip-flop stages,

You can use two additional constraints:

- Move First Stage
- Move Last Stage

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the following only:

- Entire design
- Single modules or entities
- Primary clock signal

Propagation Rules

For Move First Stage propagation rules, see the figure above.

Syntax

`-move_first_stage {yes|no}`

Both Move First Stage and Move Last Stage may have either of two values:

- **yes**
- **no**
 - **MOVE_FIRST_STAGE=no**
Prevents the first flip-flop stage from moving
 - **MOVE_LAST_STAGE=no**
Prevents the last flip-flop stage from moving

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute move_first_stage : string;
```

Specify as follows:

```
attribute move_first_stage of {entity_name|signal_name} : {signal|entity} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* move_first_stage = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" move_first_stage={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "primary_clock_signal" move_first_stage={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -move_first_stage {yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Move First Flip-Flop Stage

Move Last Stage (MOVE_LAST_STAGE)

The Move Last Stage (**MOVE_LAST_STAGE**) constraint controls the retiming of registers with paths going to primary outputs.

Both Move Last Stage and [Move First Stage \(MOVE_FIRST_STAGE\)](#) relate to Register Balancing.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the following:

- Entire design
- Single modules or entities
- Primary clock signal

Propagation Rules

See [Move First Stage \(MOVE_FIRST_STAGE\)](#).

Syntax

-move_last_stage {yes|no}

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute move_last_stage : string;
```

Specify as follows:

```
attribute move_last_stage of {entity_name|signal_name} : {signal|entity} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* move_last_stage = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" move_last_stage={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "primary_clock_signal" move_last_stage={yes|no|true|false};
```

```
END;
```

XST Command Line

```
xst run -move_last_stage {yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Move Last Stage

Multiplier Style (MULT_STYLE)

The Multiplier Style (**MULT_STYLE**) constraint controls the way the macrogenerator implements the multiplier macros.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

```
-mult_style {auto|block|kcm|csd|lut|pipe_lut}
```

- **auto** (default)
Instructs XST to look for the best implementation for each considered macro.
- **block**
- **pipe_block**
 - Used to pipeline DSP48 based multipliers.
 - Available for the following devices only:
 - ◆ Virtex®-4
 - ◆ Virtex-5
 - ◆ Spartan®-3A DSP
- **kcm**
- **csd**
- **lut**
- **pipe_lut**
For pipeline slice-based multipliers only.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute mult_style: string;
```

Specify as follows:

```
attribute mult_style of {signal_name|entity_name} : {signal|entity} is
"{auto|block|pipe_block|kcm|csd|lut|pipe_lut}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* mult_style = "{auto|block|pipe_block|kcm|csd|lut|pipe_lut}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" mult_style={auto|block|pipe_block|kcm|csd|lut|pipe_lut};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
NET "signal_name" mult_style={auto|block|pipe_block|kcm|csd|lut|pipe_lut};
END;
```

XST Command Line

```
xst run -mult_style {auto|block|kcm|csd|lut|pipe_lut}
```

The `-mult_style` command line option is not supported for the following devices:

- Virtex-4
- Virtex-5
- Spartan-3A

For those devices, use:

```
-use_dsp48
```

ISE® Design Suite

Process > Process Properties > HDL Options > Multiplier Style

Mux Style (MUX_STYLE)

The Mux Style (`MUX_STYLE`) constraint controls the way the macrogenerator implements the multiplexer macros.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Available Devices

| Devices | Resources |
|----------------|-----------|
| Spartan®-3 | MUXF |
| Spartan-3E | MUXF6 |
| Spartan-3A | MUXCY |
| Spartan-3A DSP | MUXF7 |
| Virtex®-4 | MUXF8 |
| Virtex-5 | |

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

mux_style {auto | muxf | muxcy}

- **auto** (default)
XST looks for the best implementation for each considered macro.
- **muxf**
- **muxcy**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute mux_style: string;
```

Specify as follows:

```
attribute mux_style of {signal_name|entity_name} : {signal|entity} is  
"{auto|muxf|muxcy}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* mux_style = "{auto|muxf|muxcy}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" mux_style={auto|muxf|muxcy};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
NET "signal_name" mux_style={auto|muxf|muxcy};
END;
```

XST Command Line

```
xst run -mux_style {auto|muxf|muxcy}
```

ISE® Design Suite

Process > Process Properties > HDL Options > Mux Style

Number of Global Clock Buffers (-bufg)

The Number of Global Clock Buffers (**-bufg**) command line option controls the maximum number of BUFG components created by XST.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

-bufg *integer*

The value is an integer. The default value depends on the target device, and is equal to the maximum number of available BUFG components. Defaults for selected architectures are shown below.

| Devices | Default Value |
|----------------|---------------|
| Virtex®-4 | 32 |
| Virtex-5 | |
| Spartan®-3 | 8 |
| Spartan-3E | 24 |
| Spartan-3A | |
| Spartan-3A DSP | |

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -bufg 8
```

Sets the number of global clock buffers to 8.

ISE® Design Suite

To set the number of global clock buffers in ISE Design Suite:

1. Select **Process > Process Properties > Xilinx®-Specific Options**.
2. From the **Property display level** list, select **Advanced**
3. Set the **Number of Clock Buffers** property.

Number of Regional Clock Buffers (-bufr)

The Number of Regional Clock Buffers (**-bufr**) command line option controls the maximum number of BUFRs created by XST.

Architecture Support

- May be used with Virtex®-4 devices only.
- May NOT be used with Virtex-5 devices.
- May NOT be used with Spartan®-3 devices.
- May NOT be used with CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

```
-bufr integer
```

The value is an integer. The default value depends on the target device, and is equal to the maximum number of available BUFRs.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -bufr 6 6
```

Sets the number of regional clock buffers to 6.

ISE® Design Suite

To set the number of regional clock buffers in ISE Design Suite:

1. Select **Process > Process Properties > Xilinx®-Specific Options**
2. From the **Property display level** list, select **Advanced**
3. Set the **Number of Regional Clock Buffers** property.

Optimize Instantiated Primitives (OPTIMIZE_PRIMITIVES)

The Optimize Instantiated Primitives (OPTIMIZE_PRIMITIVES) constraint:

- Switches off the default by which XST does not optimize instantiated primitives in Hardware Description Language (HDL) designs.
- Allows XST to optimize Xilinx® library primitives that have been instantiated in an HDL design.

Optimization of instantiated primitives is limited by the following factors:

- If an instantiated primitive has specific constraints such as **RLOC** attached, XST preserves it as is.
- Not all primitives are considered by XST for optimization. Such hardware elements as the following are not optimized (modified) even if optimization of instantiated primitives is enabled:
 - **MULT18x18**
 - **BRAM**
 - **DSP48**

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to hierarchical blocks, components, and instances.

Propagation Rules

Applies to the component or instance to which it is attached.

Syntax

- **yes**
- **no** (default)
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

Schematic Syntax Examples

- Attach to a valid instance
- Attribute Name
OPTIMIZE_PRIMITIVES
- Attribute Values
See *Syntax* section above.

VHDL

Declare as follows:

```
attribute optimize_primitives: string;
```

Specify as follows:

```
attribute optimize_primitives of {component_name|entity_name|label_name} :  
{component|entity|label} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* optimize_primitives = "{yes|no}" *)
```

XCF

```
MODEL "entity_name" optimize_primitives = {yes|no|true|false};
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Optimize Instantiated Primitives

Pack I/O Registers Into IOBs (IOB)

The Pack I/O Registers Into IOBs (**IOB**) constraint packs flip-flops in the I/Os to improve input/output path timing.

When IOB is set to **auto**, the action XST takes depends on the Optimization setting:

- If Optimization is set to **area**, XST packs registers as tightly as possible to the IOBs in order to reduce the number of slices occupied by the design.
- If Optimization is set to **speed**, XST packs registers to the IOBs provided they are not covered by timing constraints (in other words, they are not taken into account by timing optimization). For example, if you specify a period constraint, XST packs a register to the IOB if it is not covered by the period constraint. If a register is covered by timing optimization, but you do want to pack it to an IOB, you must apply the IOB constraint locally to the register.

For more information about this constraint, see the [Constraints Guide](#).

Power Reduction (POWER)

The Power Reduction (**POWER**) constraint instructs XST to optimize the design to consume as little power as possible.

Macro processing decisions are made to implement functions in a manner than uses minimal power. Although POWER is allowed in both AREA and SPEED modes, it may negatively impact the final overall area and speed of the design.

In the current release, power optimization done by XST is dedicated to DSP48 and BRAM blocks.

XST supports two BRAM optimization methods:

- Method One does not significantly impact area and speed. Method One is used by default when power optimization is enabled.
- Method Two saves more power, but may significantly impact area and speed.

Both methods can be controlled by using the [RAM Style \(RAM_STYLE\)](#) constraint with **block_power1** for Method One and **block_power2** for Method Two.

In some situations, XST may issue an HDL Advisor message giving you tips on how to improve your design. For example, if XST detects that Read First mode is used for BRAM, XST recommends that you use Write First or No Change modes.

Architecture Support

Applies to Virtex®-4 devices and Virtex-5 devices only. Does not apply to any other FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to:

- A component or entity (VHDL)
- A model or label (instance) (Verilog)
- A model or INST (in model) (XCF)
- The entire design (XST command line)

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-power {yes | no}

- **yes**
- **no** (default)
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

attribute power: string;

Specify as follows:

attribute power of {component_name | entity_name} : {component_name | entity_name} is "yes | no";

Verilog

Place immediately before the module declaration or instantiation:

```
(* power = "{yes|no}" *)
```

XCF

```
MODEL "entity_name" power = {yes|no|true|false};
```

The default is **false**.

XST Command Line

```
xst run -power {yes|no}
```

ISE® Design Suite

Process > Process Properties > Synthesis Options > Power Reduction

Priority Encoder Extraction (PRIORITY_EXTRACT)

The Priority Encoder Extraction (**PRIORITY_EXTRACT**) constraint enables or disables priority encoder macro inference.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

- **yes** (default)
- **no**
- **force**
- **true** (XCF only)
- **false** (XCF only)

For each identified priority encoder description, based on internal decision rules, XST creates a macro or optimizes it with the rest of the logic. The **force** value allows you to override those internal decision rules and force XST to extract the macro.

```
-priority_extract {yes|no|force}
```

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute priority_extract: string;
```

Specify as follows:

```
attribute priority_extract of {signal_name|entity_name} : {signal|entity} is  
"{yes|no|force}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* priority_extract = "{yes|no|force}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" priority_extract={yes|no|true|false|force};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" priority_extract={yes|no|true|false|force};  
END;
```

XST Command Line

```
xst run -priority_extract {yes|no|force}
```

ISE® Design Suite

Process > Process Properties > HDL Options > Priority Encoder Extraction

RAM Extraction (RAM_EXTRACT)

The RAM Extraction (RAM_EXTRACT) constraint enables or disables RAM macro inference.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-ram_extract {yes|no}

- yes (default)
- no
- true (XCF only)
- false (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute ram_extract: string;
```

Specify as follows:

```
attribute ram_extract of {signal_name|entity_name} : {signal|entity} is "{yes|no}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* ram_extract = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" ram_extract={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" ram_extract={yes|no|true|false};
```

```
END;
```

XST Command Line

```
xst run -ram_extract {yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > RAM Extraction

RAM Style (RAM_STYLE)

The RAM Style (**RAM_STYLE**) constraint controls the way the macrogenerator implements the inferred RAM macros.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

The following are supported for Virtex®-4 devices and Virtex-5 devices only:

- **block_power1**
- **block_power2**

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

ram_style {**auto** | **block** | **distributed**}

- **auto** (default)
- **block**
- **distributed**
- **pipe_distributed**
- **block_power1**
- **block_power2**

XST looks for the best implementation for each inferred RAM.

You must use **block_power1** and **block_power2** in order to achieve power-oriented BRAM optimization.

For more information, see:

[Power Reduction \(POWER\)](#)

The implementation style can be manually forced to use block RAM or distributed RAM resources.

You can specify the following only through VHDL, Verilog, or XCF constraints:

- **pipe_distributed**
- **block_power1**
- **block_power2**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute ram_style: string;
```

Specify as follows:

```
attribute ram_style of {signal_name | entity_name} : {signal | entity} is  
"{auto | block | distributed | pipe_distributed | block_power1 | block_power2}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* ram_style =  
"{auto|block|distributed|pipe_distributed|block_power1|block_power2}" *)
```

XCF Syntax Example One

```
MODEL "entity_name"  
ram_style={auto|block|distributed|pipe_distributed|block_power1|block_power2};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name"  
ram_style={auto|block|distributed|pipe_distributed|block_power1|block_power2};  
END;
```

XST Command Line

```
xst run -ram_style {auto|block|distributed}
```

The `pipe_distributed` value is not accessible through the command line.

ISE® Design Suite

Process > Process Properties > HDL Options > RAM Style

Read Cores (READ_CORES)

The Read Cores (**READ_CORES**) constraint enables or disables the ability of XST to read Electronic Data Interchange Format (EDIF) or NGC core files for timing estimation and device utilization control.

By reading a specific core, XST is better able to optimize logic around the core, since it sees how the logic is connected. However, in some cases the Read Cores operation must be disabled in XST in order to obtain the desired results. For example, the PCI™ core must not be visible to XST, since the logic directly connected to the PCI core must be optimized differently as compared to other cores. Read Cores allows you to enable or disable read operations on a core by core basis.

For more information, see:

[Cores Processing](#)

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Since this constraint can be used with [BoxType \(BOX_TYPE\)](#) the set of objects on which the both constraints can be applied must be the same.

Apply Read Cores to:

- A component or entity (VHDL)
- A model or label (instance) (Verilog)
- A model or INST (in model) (XCF)
- The entire design (XST command line)

If Read Cores is applied to at least a single instance of a block, then Read Cores is applied to all other instances of this block for the entire design.

Propagation Rules

Not applicable.

Syntax

`-read_cores {yes|no|optimize}`

- **no (false)**
Disables cores processing
- **yes (true) (default)**
Enables cores processing, but maintains the core as a black box and does not further incorporate the core into the design
- **optimize**
Enables cores processing, and merges the cores netlist into the overall design. This value is available through the XST command line mode only.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute read_cores: string;
```

Specify as follows:

```
attribute read_cores of {component_name|entity_name} : {component|entity} is
"{yes|no|optimize}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* read_cores = "{yes|no|optimize}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" read_cores = {yes|no|true|false|optimize};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name" END;
```

```
INST "instance_name" read_cores = {yes|no|true|false|optimize};
```

```
END;
```

XST Command Line

```
xst run -read_cores {yes|no|optimize}
```

ISE® Design Suite

Process > Process Properties > Synthesis Options > Read Cores

Note The **optimize** option is not available in ISE Design Suite.

Reduce Control Sets (REDUCE_CONTROL_SETS)

The Reduce Control Sets (**REDUCE_CONTROL_SETS**) constraint allows you to reduce the number of control sets and, as a consequence, reduce the design area.

Reducing the number of control sets should:

- Improve the packing process in **map**.
- Reduce the number of used slices even if the number of LUTs is increased.

Architecture Support

Applies to Virtex®-5 devices only. Does not apply to any other devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

-reduce_control_sets {auto | no}

- **auto**
XST optimizes automatically, and reduces the existing control sets in the design.
- **no** (default)
XST performs no control set optimization.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -reduce_control_sets {auto | no}
```

ISE® Design Suite

Process > Process Properties > Xilinx Specific Options > Reduce Control Sets

Register Balancing (REGISTER_BALANCING)

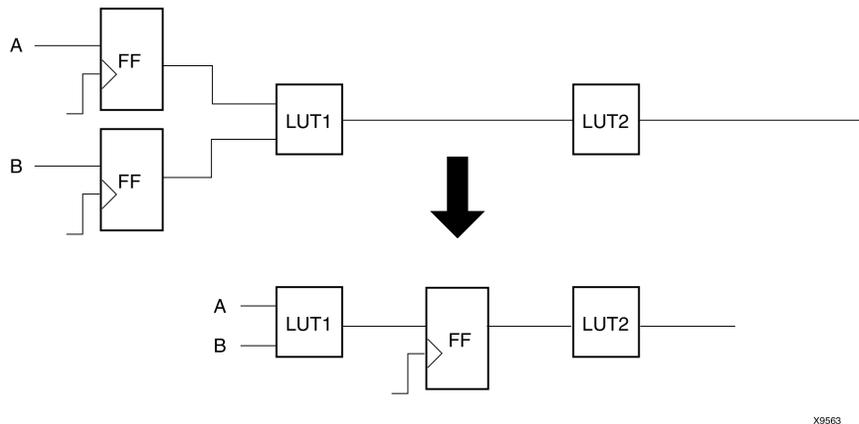
The Register Balancing (**REGISTER_BALANCING**) constraint enables flip-flop retiming.

The main goal of register balancing is to move flip-flops and latches across logic to increase clock frequency.

The two categories of **REGISTER_BALANCING** are:

- Forward Register Balancing
- Backward Register Balancing

Forward Register Balancing

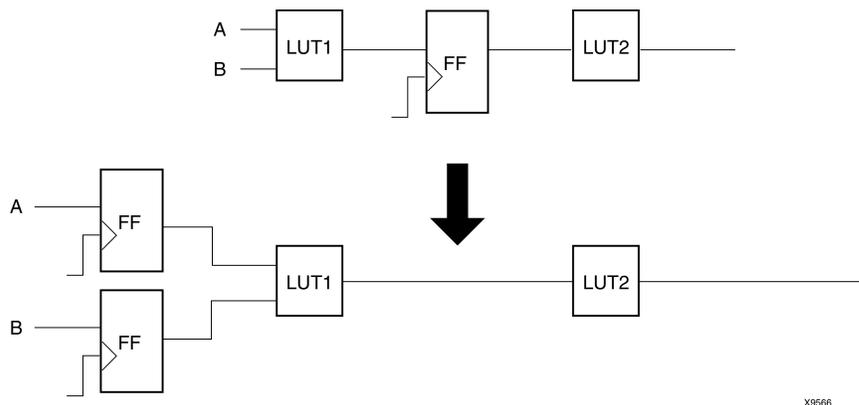


Forward Register Balancing moves a set of flip-flops at the inputs of a LUT to a single flip-flop at its output.

When replacing several flip-flops with one, select the name based on the name of the LUT across which the flip-flops are moving as shown in the following:

LutName_FRBId

Backward Register Balancing



Backward Register Balancing moves a flip-flop at the output of a LUT to a set of flip-flops at its inputs.

As a consequence the number of flip-flops in the design can be increased or decreased.

The new flip-flop has the same name as the original flip-flop with an indexed suffix as shown in the following:

OriginalFFName_BRBId

Additional Constraints That Impact Register Balancing

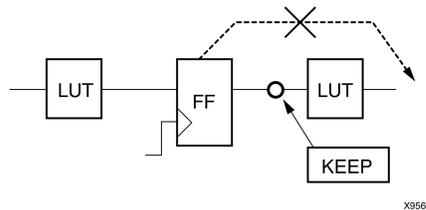
Two additional constraints control register balancing:

- [Move First Stage \(MOVE_FIRST_STAGE\)](#)
- [Move Last Stage \(MOVE_LAST_STAGE\)](#)

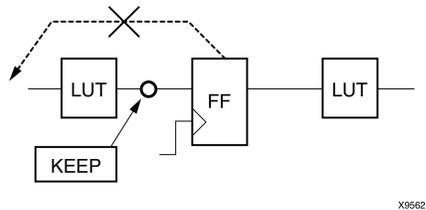
Several other constraints also influence register balancing:

- **Keep Hierarchy (KEEP_HIERARCHY)**
 - If the hierarchy is preserved, flip-flops are moved only inside the block boundaries.
 - If the hierarchy is flattened, flip-flops may leave the block boundaries.
- **Pack I/O Registers Into IOBs (IOB)**
If **IOB=TRUE**, register balancing is not applied to the flip-flops having this property.
- **Optimize Instantiated Primitives (OPTIMIZE_PRIMITIVES)**
Instantiated flip-flops are moved only if **OPTIMIZE_PRIMITIVES=YES**.
- Flip-flops are moved across instantiated primitives only if **OPTIMIZE_PRIMITIVES=YES**.
- **Keep (KEEP)**
If applied to the output flip-flop signal, the flip-flop is not moved forward.

Applied to the Input Flip-Flop Signal



If applied to the input flip-flop signal, the flip-flop is not moved backward.



If applied to both the input and output of the flip-flop, it is equivalent to **REGISTER_BALANCING=no**

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to:

- The entire design using the command line or ISE® Design Suite
- An entity or module
- A signal corresponding to the flip-flop description (RTL)
- A flip-flop instance
- The Primary Clock Signal

In this case the register balancing is performed only for flip-flops synchronized by this clock.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-register_balancing {yes | no | forward | backward}

- **yes**
Both forward and backward retiming are allowed.
- **no** (default)
Neither forward nor backward retiming is allowed.
- **forward**
Only forward retiming is allowed
- **backward**
Only backward retiming is allowed.
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute register_balancing: string;
```

Specify as follows:

```
attribute register_balancing of {signal_name | entity_name}: {signal | entity} is
"{yes | no | forward | backward}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* register_balancing = "{yes | no | forward | backward}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" register_balancing={yes | no | true | false | forward | backward};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
NET "primary_clock_signal"
register_balancing={yes | no | true | false | forward | backward};"
END;
```

XCF Example Three

```
BEGIN MODEL "entity_name"
```

```
INST "instance_name" register_balancing={yes|no|true|false|forward|backward};  
END;
```

XST Command Line

```
xst run -register_balancing {yes|no|forward|backward}
```

ISE Design Suite

Process > Process Properties > Xilinx Specific Options > Register Balancing

Register Duplication (REGISTER_DUPLICATION)

The Register Duplication (REGISTER_DUPLICATION) constraint:

- Enables or disables register replication.
- Is enabled, and is performed during timing optimization and fanout control.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity or module to which it is attached.

Syntax

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute register_duplication: string;
```

Specify as follows:

```
attribute register_duplication of entity_name: entity is "{yes|no}";
```

Verilog

Place immediately before the module declaration or instantiation:

```
(* register_duplication = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" register_duplication={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" register_duplication={yes|no|true|false};  
END;
```

ISE® Design Suite

Process > Process Properties > Xilinx Specific Options > Register Duplication

ROM Extraction (ROM_EXTRACT)

The ROM Extraction (ROM_EXTRACT) constraint enables or disables ROM macro inference.

Typically, a ROM can be inferred from a **case** statement where all assigned contexts are constant values.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to a design element or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

```
-rom_extract {yes|no}
```

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

attribute rom_extract: string;

Specify as follows:

attribute rom_extract of {*signal_name*|*entity_name* } : {**signal**|**entity**} is "{yes|no}";

Verilog

Place immediately before the module or signal declaration:

```
(* rom_extract = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" rom_extract={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" rom_extract={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -rom_extract {yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > ROM Extraction

ROM Style (ROM_STYLE)

The ROM Style (**ROM_STYLE**) constraint controls the way the macrogenerator implements the inferred ROM macros.

Caution! ROM Extraction (**ROM_EXTRACT**) must be set to **yes** in order to use ROM Style (**ROM_STYLE**).

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-rom_style {auto|block|distributed}

- **auto** (default)

XST looks for the best implementation for each inferred ROM. The implementation style can be manually forced to use block ROM or distributed ROM resources.

- **block**
- **distributed**

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute rom_style: string;
```

Specify as follows:

```
attribute rom_style of {signal_name|entity_name} : {signal|entity} is
"{auto|block|distributed}";
```

Verilog

Declare as follows:

```
(* rom_style = "{auto|block|distributed}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" rom_style={auto|block|distributed};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" rom_style={auto|block|distributed};
```

```
END;
```

XST Command Line

```
xst run -rom_style {auto|block|distributed}
```

ISE® Design Suite

Process > Process Properties > HDL Options > ROM Style

Shift Register Extraction (SHREG_EXTRACT)

The Shift Register Extraction (SHREG_EXTRACT) constraint:

- Enables or disables shift register macro inference.
- Results in the usage of dedicated hardware resources such as SRL16 and SRLC16.

For more information, see:

Shift Registers HDL Coding Techniques

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to a design element or signal.

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-shreg_extract {yes | no}`

- `yes` (default)
- `no`
- `true` (XCF only)
- `false` (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute shreg_extract : string;
```

Specify as follows:

```
attribute shreg_extract of {signal_name | entity_name} : {signal | entity} is "{yes | no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* shreg_extract = "{yes | no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" shreg_extract={yes | no | true | false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" shreg_extract={yes | no | true | false};
```

```
END;
```

XST Command Line

```
xst run -shreg_extract {yes | no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > Shift Register Extraction

Slice (LUT-FF Pairs) Utilization Ratio (SLICE_UTILIZATION_RATIO)

The Slice (LUT-FF Pairs) Utilization Ratio (SLICE_UTILIZATION_RATIO) constraint defines the area size in absolute numbers or percent of total numbers of the following components that XST must not exceed during timing optimization:

- LUT-FF pairs (Virtex®-5 devices)
- slices (all other devices)

If the area constraint cannot be satisfied, XST makes timing optimization regardless of the area constraint. To disable automatic resource management, specify **-1** as a constraint value.

For more information, see:

[Speed Optimization Under Area Constraint](#)

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity or module to which it is attached.

Syntax

The following sections show the syntax for this constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute slice_utilization_ratio: string;
```

Specify as follows:

```
attribute slice_utilization_ratio of entity_name : entity is "integer";
```

```
attribute slice_utilization_ratio of entity_name : entity is "integer%";
```

```
attribute slice_utilization_ratio of entity_name : entity is "integer#";
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is **0** to **100** when percent (%) is used or both percent (%) and pound (#) are omitted.

Verilog

Place immediately before the module declaration or instantiation:

```
(* slice_utilization_ratio = "integer" *)
```

```
(* slice_utilization_ratio = "integer%" *)
```

```
(* slice_utilization_ratio = "integer#" *)
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

XCF

```
MODEL "entity_name" slice_utilization_ratio=integer;
```

```
MODEL "entity_name" slice_utilization_ratio=integer%;
```

```
MODEL "entity_name" slice_utilization_ratio=integer#;
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

There must be no space between the integer value and the percent (%) or pound (#) characters.

You must surround the integer value and the percent (%) and pound (#) characters with double quotes ("...") because the percent (%) and pound (#) characters are special characters in the XST Constraint File (XCF).

XST Command Line

```
xst run -slice_utilization_ratio integer
```

```
xst run -slice_utilization_ratio integer%
```

```
xst run -slice_utilization_ratio integer#
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Slice Utilization Ratio or **Process > Process Properties > Synthesis Options > LUT-FF Pairs Utilization Ratio**

In ISE Design Suite, you can define the value of Slice (LUT-FF Pairs) Utilization Ratio only as a percentage. You can not define the value as an absolute number of slices.

Slice (LUT-FF Pairs) Utilization Ratio Delta (SLICE_UTILIZATION_RATIO_MAXMARGIN)

The Slice (LUT-FF Pairs) Utilization Ratio Delta (SLICE_UTILIZATION_RATIO_MAXMARGIN) constraint:

- Is closely related to [Slice \(LUT-FF Pairs\) Utilization Ratio \(SLICE_UTILIZATION_RATIO\)](#).
- Defines the tolerance margin for [Slice \(LUT-FF Pairs\) Utilization Ratio \(SLICE_UTILIZATION_RATIO\)](#).

The value of the parameter can be defined in the form of *percentage* as well as an *absolute number* of slices or LUT-FF pairs.

If the ratio is within the margin set, the constraint is met and timing optimization can continue.

For more information, see:

[Speed Optimization Under Area Constraint](#)

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to an entity, component, module, or signal.

Propagation Rules

Applies to the entity or module to which it is attached.

Syntax

The following sections show the syntax for this constraint.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute slice_utilization_ratio_maxmargin: string;
```

Specify as follows:

```
attribute slice_utilization_ratio_maxmargin of entity_name : entity is "integer";
```

```
attribute slice_utilization_ratio_maxmargin of entity_name : entity is "integer%";
```

```
attribute slice_utilization_ratio_maxmargin of entity_name : entity is "integer#";
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

Verilog

Place immediately before the module declaration or instantiation:

```
(* slice_utilization_ratio_maxmargin = "integer" *)
```

```
(* slice_utilization_ratio_maxmargin = "integer%" *)
```

```
(* slice_utilization_ratio_maxmargin = "integer#" *)
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

XCF

```
MODEL "entity_name" slice_utilization_ratio_maxmargin=integer;
```

```
MODEL "entity_name" slice_utilization_ratio_maxmargin="integer%";
```

```
MODEL "entity_name" slice_utilization_ratio_maxmargin="integer#";
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

There must be no space between the integer value and the percent (%) or pound (#) characters.

You must surround the integer value and the percent (%) and pound (#) characters with double quotes ("...") because the percent (%) and pound (#) characters are special characters in the XST Constraint File (XCF).

XST Command Line

```
xst run -slice_utilization_ratio_maxmargin integer
```

```
xst run -slice_utilization_ratio_maxmargin integer%
```

```
xst run -slice_utilization_ratio_maxmargin integer#
```

XST interprets the integer values in the first two examples above as a percentage and in the last example as an absolute number of slices or FF-LUT pairs.

The integer value range is 0 to 100 when percent (%) is used or both percent (%) and pound (#) are omitted.

Slice Packing (-slice_packing)

The Slice Packing (-slice_packing) command line option enables the XST internal packer.

The packer attempts to pack critical LUT-to-LUT connections within a slice or a CLB. This exploits the fast feedback connections among the LUTs in a CLB.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-slice_packing {yes|no}`

- `yes`
- `no`

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -slice_packing no
```

Disables the XST internal slice packer.

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Slice Packing

Use Low Skew Lines (USELOWSKEWLINES)

The Use Low Skew Lines (USELOWSKEWLINES) constraint:

- Is a basic routing constraint.
- Prevents XST from using dedicated clock resources and logic replication during synthesis, based on the value of the [Max Fanout \(MAX_FANOUT\)](#) constraint.
- Specifies the use of low skew routing resources for any net.

For more information about this constraint, see the [Constraints Guide](#).

Use Carry Chain (USE_CARRY_CHAIN)

The Use Carry Chain (USE_CARRY_CHAIN) constraint:

- Is both a global and a local constraint
- Can deactivate carry chain use for macro generation

XST uses carry chain resources to implement certain macros, but there are situations where you can obtain better results by not using carry chain.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design, or to signals.

Propagation Rules

Applies to the signal to which it is attached.

Syntax

`-use_carry_chain {yes|no}`

- `yes` (default)
- `no`
- `true` (XCF only)
- `false` (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

Schematic

- Attach to a valid instance
- Attribute Name
`USE_CARRY_CHAIN`
- Attribute Values
See *Syntax* section above.

VHDL

Declare as follows:

```
attribute use_carry_chain: string;
```

Specify as follows:

```
attribute use_carry_chain of signal_name: signal is "{yes|no}";
```

Verilog

Place immediately before the signal declaration:

```
(* use_carry_chain = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" use_carry_chain={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" use_carry_chain={yes|no|true|false};  
END;
```

XST Command Line

```
xst run -use_carry_chain {yes|no}
```

Use Clock Enable (USE_CLOCK_ENABLE)

The Use Clock Enable (USE_CLOCK_ENABLE) constraint enables or disables the clock enable function in flip-flops.

The disabling of the clock enable function is typically used for ASIC prototyping on FPGA devices.

By detecting Use Clock Enable with a value of **no** or **false**, XST avoids using CE resources in the final implementation. Moreover, for some designs, putting the Clock Enable function on the data input of the flip-flop allows better logic optimization and therefore better quality of results.

In **auto** mode, XST tries to estimate a trade off between using a dedicated clock enable input of a flip-flop input and putting clock enable logic on the D input of a flip-flop. In a case where a flip-flop is instantiated by you, XST removes the clock enable only if the Optimize Instantiated Primitives option is set to **yes**.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to:

- An entire design through the XST command line
- A particular block (entity, architecture, component)
- A signal representing a flip-flop
- An instance representing an instantiated flip-flop

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

-use_clock_enable {auto|yes|no}

- **auto** (default)
- **yes**
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute use_clock_enable: string;
```

Specify as follows:

```
attribute use_clock_enable of {entity_name|component_name|signal_name|instance_name}
: {entity|component|signal|label} is "{auto|yes|no}";
```

Verilog

Place immediately before the instance, module, or signal declaration:

```
(* use_clock_enable = "{auto|yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" use_clock_enable={auto|yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
NET "signal_name" use_clock_enable={auto|yes|no|true|false};
END
```

XCF Syntax Example Three

```
BEGIN MODEL "entity_name ";
INST "instance_name" use_clock_enable={auto|yes|no|true|false};
END
```

XST Command Line

```
xst run -use_clock_enable {auto|yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx Specific Options > Use Clock Enable

USE_DSP48 (Use DSP48)

This constraint is called:

- Use DSP48
Virtex®-4 devices
- Use DSP Block
Virtex-5 devices and Spartan®-3A DSP devices

XST enables you to use the resources of the DSP48 blocks introduced in Virtex-4 devices.

In **auto** mode, XST automatically implements such macros as MAC and accumulates on DSP48, but some of them as adders are implemented on slices. You have to force their implementation on DSP48 using a value of **yes** or **true**.

For more information on supported macros and their implementation control, see:

[XST HDL Coding Techniques](#)

Several macros (for example, MAC) that can be placed on DSP48 are in fact a composition of simpler macros such as multipliers, accumulators, and registers. To achieve the best performance, XST by default tries to infer and implement the maximum macro configuration. To shape a macro in a specific way, use the [Keep \(KEEP\)](#) constraint. For example, DSP48 allows you to implement a multiple with two input registers. To leave the first register stage outside of the DSP48, place the [Keep \(KEEP\)](#) constraint in their outputs.

Architecture Support

Applies to the following devices only. Does not apply to any other devices.

- Spartan-3A DSP
- Virtex-4
- Virtex-5

Applicable Elements

Applies to:

- An entire design through the XST command line
- A particular block (entity, architecture, component)
- A signal representing a macro described at the RTL level

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-use_dsp48 {auto|yes|no}`

- **auto** (default)
- **yes**
- **no**
- **true** (XCF only)
- **false** (XCF only)

In **auto** mode you can control the number of available DSP48 resources for synthesis using [DSP Utilization Ratio \(DSP_UTILIZATION_RATIO\)](#). By default, XST tries to utilize, as much as possible, all available DSP48 resources.

For more information, see:

[DSP48 Block Resources](#)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute use_dsp48: string;
```

Specify as follows:

```
attribute use_dsp48 of {"entity_name|component_name|signal_name"} :  
{entity|component|signal} is "{auto|yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* use_dsp48 = "{auto|yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" use_dsp48={auto|yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" use_dsp48={auto|yes|no|true|false};  
END;"
```

XST Command Line

```
xst run -use_dsp48 {auto|yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > Use DSP48

Use Synchronous Set (USE_SYNC_SET)

The Use Synchronous Set (USE_SYNC_SET) constraint enables or disables the synchronous set function in flip-flops.

Disabling the synchronous set function is typically used for ASIC prototyping on FPGA devices. When XST detects Use Synchronous Set with a value of **no** or **false**, XST avoids using synchronous reset resources in the final implementation. For some designs, putting synchronous reset function on data input of the flip-flop allows better logic optimization and therefore gives better quality of results.

In **auto** mode, XST tries to estimate a trade off between using dedicated Synchronous Set input of a flip-flop input and putting Synchronous Set logic on the D input of a flip-flop. When a flip-flop is instantiated by the designer, XST removes the synchronous reset only if [Optimize Instantiated Primitives](#) is set to **yes**.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to:

- An entire design through the XST command line
- A particular block (entity, architecture, component)
- A signal representing a flip-flop
- An instance representing an instantiated flip-flop

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-use_sync_set {auto|yes|no}`

- **auto** (default)
- **yes**
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute use_sync_set: string;
```

Specify as follows:

```
attribute use_sync_set of {entity_name|component_name|signal_name|instance_name}:  
{entity|component|signal|label} is "{auto|yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* use_sync_set = "{auto|yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" use_sync_set={auto|yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" use_sync_set={auto|yes|no|true|false};  
END;
```

XCF Syntax Example Three

```
BEGIN MODEL "entity_name"  
INST "instance_name" use_sync_set={auto|yes|no|true|false};  
END;
```

XST Command Line

```
xst run -use_sync_set {auto|yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > Use Synchronous Set

Use Synchronous Reset (USE_SYNC_RESET)

The Use Synchronous Reset (`USE_SYNC_RESET`) constraint enables or disables the usage of synchronous reset function of flip-flops.

Disabling synchronous reset can be used for ASIC prototyping flow on FPGA devices.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to:

- An entire design through the XST command line
- A particular block (entity, architecture, component)
- A signal representing a flip-flop
- An instance representing an instantiated flip-flop

Propagation Rules

Applies to the entity, component, module, or signal to which it is attached.

Syntax

`-use_sync_reset {auto|yes|no}`

- **auto** (default)
- **yes**
- **no**
- **true** (XCF only)
- **false** (XCF only)

When XST detects Use Synchronous Reset with a value of **no** or **false**, XST avoids using synchronous reset resources in the final implementation. For some designs, putting synchronous reset function on data input of the flip-flop allows better logic optimization and therefore better quality of results.

In **auto** mode, XST tries to estimate a trade off between using a dedicated Synchronous Reset input on a flip-flop input and putting Synchronous Reset logic on the D input of a flip-flop. When a flip-flop is instantiated by a designer, XST removes the synchronous reset only if the Optimize Instantiated Primitives option is set to **yes**.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute use_sync_reset: string;
```

Specify as follows:

```
attribute use_sync_reset of {entity_name|component_name|signal_name|instance_name}  
: {entity|component|signal|label} is "{auto|yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* use_sync_reset = "{auto|yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" use_sync_reset={auto|yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"  
NET "signal_name" use_sync_reset={auto|yes|no|true|false};  
END;
```

XCF Syntax Example Three

```
BEGIN MODEL "entity_name"  
INST "instance_name" use_sync_reset={auto|yes|no|true|false};  
END;
```

XST Command Line

```
xst run -use_sync_reset {auto|yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx Specific Options > Use Synchronous Reset

XOR Collapsing (XOR_COLLAPSE)

The XOR Collapsing (XOR_COLLAPSE) constraint controls whether cascaded XORs should be collapsed into a single XOR.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to cascaded XORs.

Propagation Rules

Not applicable.

Syntax

`-xor_collapse {yes|no}`

- `yes` (default)
- `no`
- `true` (XCF only)
- `false` (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute xor_collapse: string;
```

Specify as follows:

```
attribute xor_collapse {signal_name|entity_name} : {signal|entity} is "{yes|no}";
```

Verilog

Place immediately before the module or signal declaration:

```
(* xor_collapse = "{yes|no}" *)
```

XCF Syntax Example One

```
MODEL "entity_name" xor_collapse={yes|no|true|false};
```

XCF Syntax Example Two

```
BEGIN MODEL "entity_name"
```

```
NET "signal_name" xor_collapse={yes|no|true|false};
```

```
END;
```

XST Command Line

```
xst run -xor_collapse {yes|no}
```

ISE® Design Suite

Process > Process Properties > HDL Options > XOR Collapsing

XST CPLD Constraints (Non-Timing)

Important! The constraints described in this chapter apply to CPLD devices *only*. They *do not* apply to FPGA devices.

This chapter discusses the following constraints:

- Clock Enable (-pld_ce)
- Data Gate (DATA_GATE)
- Macro Preserve (-pld_mp)
- No Reduce (NOREDUCE)
- WYSIWYG (-wysiwyg)
- XOR Preserve (-pld_xp)

Clock Enable (-pld_ce)

The Clock Enable (-pld_ce) command line option specifies how sequential logic should be implemented when it contains a clock enable, either using the specific device resources available for the clock enable or generating equivalent logic.

Keeping or not keeping the clock enable signal depends on the design logic. When the clock enable is the result of a Boolean expression, setting Clock Enable to **no** may improve the fitting result. The input data of the flip-flop is simplified when it is merged with the clock enable expression.

Architecture Support

Applies to all CPLD devices. Does not apply to FPGA devices.

Applicable Elements

Applies to an entire design through the XST command line.

Propagation Rules

Not applicable.

Syntax

-pld_ce {yes|no}

- **yes** (default)
The synthesizer implements the clock enable signal of the device.
- **no**
The clock enable function is implemented through equivalent logic.

Syntax Examples and Settings

```
xst run -pld_ce yes
```

Defines Clock Enable globally to **yes**. The clock enable function is implemented through equivalent logic.

ISE® Design Suite

Process > Process Properties > Xilinx-Specific Options > Clock Enable

Data Gate (DATA_GATE)

The Data Gate (DATA_GATE) constraint:

- Applies to CoolRunner™-II devices only.
- Provides a direct means of reducing power consumption in your design.

Each I/O pin input signal passes through a latch that can block the propagation of incident transitions during periods when such transitions are not of interest to your CPLD design.

Input transitions that do not affect the CPLD design function still consume power, if not latched, since they are routed among the CPLD's Function Blocks. By asserting the Data Gate control I/O pin on the device, selected I/O pin inputs become latched, eliminating the power dissipation associated with external transitions on those pins.

For more information about this constraint, see the [Constraints Guide](#).

Macro Preserve (-pld_mp)

The Macro Preserve (-pld_mp) command line option:

- Makes macro handling independent of design hierarchy processing.
- Allows you to merge all hierarchical blocks in the top module, while still keeping the macros as hierarchical modules

You can keep the design hierarchy except for the macros, which are merged with the surrounding logic. Merging the macros sometimes gives better results for design fitting.

Architecture Support

Applies to all CPLD devices. Does not apply to FPGA devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-pld_mp {yes|no}`

- **yes** (default)
Macros are preserved and generated by Macro+.
- **no**
Macros are rejected and generated by HDL synthesizer

Depending on the Flatten Hierarchy value, a rejected macro is either merged in the design logic, or becomes a hierarchical block as shown in the following table.

| Flatten Hierarchy Value | Disposition |
|-------------------------|------------------------------|
| yes | Merged in the design logic |
| no | Becomes a hierarchical block |

Very small macros such as 2-bit adders and 4-bit multiplexers are always merged, independent of the Macro Preserve or Flatten Hierarchy options.

Syntax and Settings Examples

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -pld_mp no
```

Macros are rejected and generated by HDL synthesizer.

ISE® Design Suite

Process > Process Properties > Xilinx®-Specific Options > Macro Preserve

No Reduce (NOREDUCE)

The No Reduce (NOREDUCE) constraint:

- Prevents minimization of redundant logic terms that are typically included in a design to avoid logic hazards or race conditions.
- Identifies the output node of a combinatorial feedback loop to ensure correct mapping.

For more information about this constraint, see the [Constraints Guide](#).

WYSIWYG (-wysiwyg)

The WYSIWYG (`-wysiwyg`) command line option makes a netlist reflect the user specification as closely as possible. That is, all the nodes declared in the Hardware Description Language (HDL) design are preserved.

If WYSIWYG mode is enabled (**yes**), XST:

- Preserves all user internal signals (nodes)
- Creates SOURCE_NODE constraints in the NGC file for all these nodes
- Skips design optimization (collapse, factorization)

Only Boolean equation minimization is performed.

Architecture Support

Applies to all CPLD devices. Does not apply to FPGA devices.

Applicable Elements

Applies to an entire design through the XST command line.

Propagation Rules

Not applicable.

Syntax

- **yes**
- **no** (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -wysiwyg {yes|no}
```

ISE® Design Suite

Process > Process Properties > Xilinx® Specific Options > WYSIWYG

XOR Preserve (-pld_xp)

The XOR Preserve (**-pld_xp**) command line option enables or disables hierarchical flattening of XOR macros.

The XORs inferred by Hardware Description Language (HDL) synthesis are also considered as macro blocks in the CPLD flow. They are processed separately to give more flexibility for using device macrocells XOR gates. You can flatten its design (Flatten Hierarchy **yes**, Macro Preserve **no**) but Xilinx® recommends preserving the XORs to:

- Reduce design complexity
- Reduce the number of PTerms

Set the value **no** to obtain completely flat netlists. Applying global optimization on a completely flat design sometimes improves design fitting.

Architecture Support

Applies to all CPLD devices. Does not apply to FPGA devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-pld_xp {yes|no}`

- **yes** (default)
- **no**

yes preserves XOR macros.

no merges XOR macros with surrounded logic.

Select the following options to obtain a completely flattened design:

- Flatten Hierarchy
yes
- Macro Preserve
no
- XOR Preserve
no

The **no** value does not guarantee the elimination of the XOR operator from the Electronic Data Interchange Format (EDIF) netlist. During the netlist generation, the netlist mapper tries to recognize and infer XOR gates in order to decrease the logic complexity. This process is independent of the XOR preservation done by Hardware Description Language (HDL) synthesis, and is guided only by the goal of complexity reduction.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -pld_xp yes
```

Preserves XOR macros.

ISE® Design Suite

Process > Process Properties > Xilinx-Specific Options > XOR Preserve

XST Timing Constraints

This chapter discusses the following constraints:

- [Clock Signal \(CLOCK_SIGNAL\)](#)
- [Cross Clock Analysis \(-cross_clock_analysis\)](#)
- [From-To \(FROM-TO\)](#)
- [Global Optimization Goal \(-glob_opt\)](#)
- [Offset \(OFFSET\)](#)
- [Period \(PERIOD\)](#)
- [Timing Name \(TNM\)](#)
- [Timing Name on a Net \(TNM_NET\)](#)
- [Timegroup \(TIMEGRP\)](#)
- [Timing Ignore \(TIG\)](#)
- [Write Timing Constraints \(-write_timing_constraints\)](#)

For more information, see:

- [Applying Timing Constraints](#)
- [XCF Timing Constraint Support](#)

Applying Timing Constraints

This section includes:

- [About Applying Timing Constraints](#)
- [Applying Timing Constraints Using Global Optimization Goal](#)
- [Applying Timing Constraints Using the UCF](#)
- [Writing Constraints to the NGC File](#)
- [Additional Options Affecting Timing Constraint Processing](#)

About Applying Timing Constraints

Apply XST-supported timing constraints with:

- [Global Optimization Goal \(-glob_opt\)](#)
- ISE® Design Suite in:
Process > Properties > Synthesis Options > Global Optimization Goal
- User Constraints File (UCF)

Applying Timing Constraints Using Global Optimization Goal

[Global Optimization Goal \(-glob_opt\)](#) allows you to apply the five global timing constraints:

- ALLCLOCKNETS
- OFFSET_IN_BEFORE
- OFFSET_OUT_AFTER
- INPAD_TO_OUTPAD
- MAX_DELAY

These constraints are applied globally to the entire design. You cannot specify a value for these constraints, since XST optimizes them for the best performance. These constraints are overridden by constraints specified in the User Constraints File (UCF).

Applying Timing Constraints Using the UCF

The User Constraints File (UCF) allows you to specify timing constraints using native UCF syntax. XST supports constraints such as:

- [Timing Name \(TNM\)](#)
- [Timegroup \(TIMEGRP\)](#)
- [Period \(PERIOD\)](#)
- [Timing Ignore \(TIG\)](#)
- [From-To \(FROM-TO\)](#)

XST supports wildcards and hierarchical names with these constraints.

Writing Constraints to the NGC File

Timing constraints are not written to the NGC file by default. Timing constraints are written to the NGC file only when:

- **Write Timing Constraints** is checked **yes** in ISE Design Suite in **Process > Process Properties**, or
- The `-write_timing_constraints` option is specified when using the command line.

Additional Options Affecting Timing Constraint Processing

Three additional options affect timing constraint processing, regardless of how the timing constraints are specified:

- [Cross Clock Analysis \(-cross_clock_analysis\)](#)
- [Write Timing Constraints \(-write_timing_constraints\)](#)
- [Clock Signal \(CLOCK_SIGNAL\)](#)

XCF Timing Constraint Support

This section discusses XST Constraint File (XCF) Timing Constraint Support and includes:

- [Hierarchy Separator](#)
- [Supported Timing Constraints](#)
- [Unsupported Timing Constraints](#)

Hierarchy Separator

If you specify timing constraints in the XST Constraint File (XCF), Xilinx® recommends that you use a forward slash (/) as a hierarchy separator instead of an underscore (_).

For more information, see:

[Hierarchy Separator \(-hierarchy_separator\)](#)

Supported Timing Constraints

The XST Constraint File (XCF) supports the following timing constraints:

- [Period \(PERIOD\)](#)
- [Offset \(OFFSET\)](#)
- [From-To \(FROM-TO\)](#)
- [Timing Name \(TNM\)](#)
- [Timing Name on a Net \(TNM_NET\)](#)
- [Timegroup \(TIMEGRP\)](#)
- [Timing Ignore \(TIG\)](#)

Unsupported Timing Constraints

If XST does not support all or part of a specified timing constraint, then XST:

- Issues a warning, and
- Ignores the unsupported timing constraint (or unsupported part of it) in the Timing Optimization step

If [Write Timing Constraints](#) is set to **yes**, XST propagates the entire constraint to the final netlist, even if it was ignored at the Timing Optimization step.

Clock Signal (CLOCK_SIGNAL)

The Clock Signal (CLOCK_SIGNAL) constraint allows you to define a clock signal when the signal goes through combinatorial logic before being connected to the clock input of a flip-flop.

In that instance, XST cannot identify which input pin or internal signal is the real clock signal. You must define it manually

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to signals.

Propagation Rules

Applies to clock signals.

Syntax

- **yes** (default)
- **no**
- **true** (XCF only)
- **false** (XCF only)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

VHDL

Declare as follows:

```
attribute clock_signal : string;
```

Specify as follows:

```
attribute clock_signal of signal_name : signal is {yes|no};
```

Verilog

Place immediately before the signal declaration:

```
(* clock_signal = "{yes|no}" *)
```

XCF

```
BEGIN MODEL "entity_name"
```

```
NET "primary_clock_signal" clock_signal={yes|no|true|false};
```

```
END;
```

Cross Clock Analysis (-cross_clock_analysis)

The Cross Clock Analysis (-cross_clock_analysis) command line option tells XST to perform inter-clock domain analysis during timing optimization.

Architecture Support

Applies to all FPGA devices. Does not apply to CPLD devices.

Applicable Elements

Applies to the entire design.

Propagation Rules

Not applicable.

Syntax

`-cross_clock_analysis {yes|no}`

- `yes`
- `no` (default)

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -cross_clock_analysis yes
```

Tells XST to perform inter-clock domain analysis during timing optimization.

ISE® Design Suite

Process > Process Properties > Synthesis Options > Cross Clock Analysis

From-To (FROM-TO)

The From-To (**FROM-TO**) constraint defines a timing constraint between two groups.

A group can be user-defined or predefined:

- FF
- PAD
- RAM

For more information about this constraint, see the [Constraints Guide](#).

Syntax Example

```
TIMESPEC TSname = FROM group1 TO group2 value;
```

Global Optimization Goal (-glob_opt)

The Global Optimization Goal (**-glob_opt**) command line option selects the global optimization goal.

Depending on the Global Optimization Goal, XST can optimize the following design regions:

- Register to Register
- Inpad to Register
- Register to Outpad
- Inpad to Outpad

For a detailed description of supported timing constraints, see:

Partitions

Apply the following constraints with Global Optimization Goal:

- **ALLCLOCKNETS** (Register to Register)
Optimizes the period of the entire design.
XST identifies, by default, all paths from register to register on the same clock for all clocks in a design. To take inter-clock domain delays into account, set [Cross Clock Analysis \(-cross_clock_analysis\)](#) to **yes**.
- **OFFSET_IN_BEFORE** (Inpad to Register)
Optimizes the maximum delay from input pad to clock, either for a specific clock or for an entire design.
XST identifies all paths from either all sequential elements or the sequential elements driven by the given clock signal name to all primary output ports.
- **OFFSET_OUT_AFTER** (Register to Outpad)
Optimizes the maximum delay from clock to output pad, either for a specific clock or for an entire design.
XST identifies all paths from all primary input ports to either all sequential elements or the sequential elements driven by the given clock signal name.
- **INPAD_TO_OUTPAD** (Inpad to Outpad)
Optimizes the maximum delay from input pad to output pad throughout an entire design.
- **MAX_DELAY**
Incorporates all previously mentioned constraints

These constraints affect the entire design. They apply only if no timing constraints are specified in the constraint file.

Syntax

```
-glob_opt
{allclocknets|offset_in_before|offset_out_after|inpad_to_outpad|max_delay}
```

You cannot specify a value for Global Optimization Goal. XST optimizes the entire design for the best performance.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -glob_opt OFFSET_OUT_AFTER
```

Optimizes the maximum delay from clock to output pad for the entire design

ISE® Design Suite

Process > Process Properties > Synthesis Options > Global Optimization Goal

Global Optimization Goal Domain Definitions

The possible domains are shown in the following schematic.

- **ALLCLOCKNETS** (register to register)

Identifies, by default, all paths from register to register on the same clock for all clocks in a design. To take inter-clock domain delays into account, set [Cross Clock Analysis \(-cross_clock_analysis\)](#) to **yes**.
- **OFFSET_IN_BEFORE** (inpad to register)

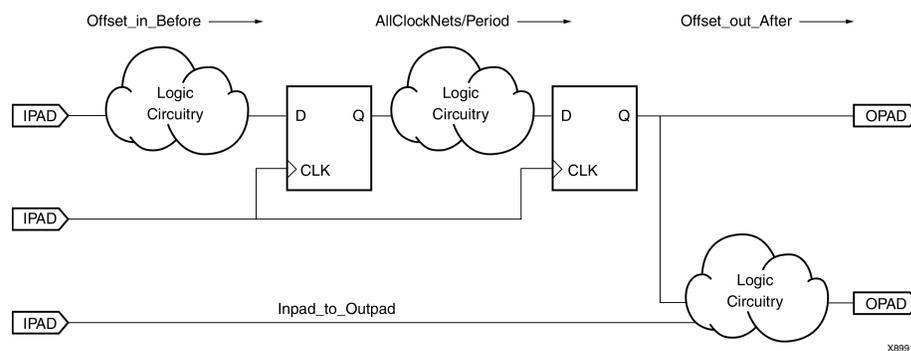
Identifies all paths from all primary input ports to either all sequential elements or the sequential elements driven by the given clock signal name.
- **OFFSET_OUT_AFTER** (register to outpad)

Similar to the previous constraint, but sets the constraint from the sequential elements to all primary output ports.
- **INPAD_TO_OUTPAD** (inpad to outpad)

Sets a maximum combinatorial path constraint.
- **MAX_DELAY**

Identifies all paths defined by the following timing constraints:

 - **ALLCLOCKNETS**
 - **OFFSET_IN_BEFORE**
 - **OFFSET_OUT_AFTER**
 - **INPAD_TO_OUTPAD**



Offset (OFFSET)

The Offset (**OFFSET**) constraint:

- Is a basic timing constraint.
- Specifies the timing relationship between an external clock and its associated data-in or data-out pin.
- Is used only for pad-related signals.
- Cannot be used to extend the arrival time specification method to the internal signals in a design.
- Allows you to:
 - Calculate whether a setup time is being violated at a flip-flop whose data and clock inputs are derived from external nets.
 - Specify the delay of an external output net derived from the Q output of an internal flip-flop being clocked from an external device pin.

For more information about this constraint, see the [Constraints Guide](#).

Syntax

```
OFFSET = {IN|OUT} offset_time [units] {BEFORE|AFTER} clk_name [TIMEGRP  
group_name];
```

Period (PERIOD)

The Period (**PERIOD**) constraint is a basic timing constraint and synthesis constraint.

A clock period specification checks timing between all synchronous elements within the clock domain as defined in the destination element group. The group may contain paths that pass between clock domains if the clocks are defined as a function of one or the other.

For more information about this constraint, see the [Constraints Guide](#).

Syntax

```
NET netname PERIOD = value [{HIGH|LOW} value];
```

Timing Name (TNM)

The Timing Name (TNM) constraint:

- Is a basic grouping constraint.
- Identifies the elements that make up a group to be used in a timing specification.
- Tags the following specific elements as members of a group to simplify the application of timing specifications to the group.
 - FF
 - RAM
 - LATCH
 - PAD
 - CPU
 - BRAM_PORTA
 - BRAM_PORTB
 - HSIO
 - MULT

The **RISING** and **FALLING** keywords may be used with TNM constraints.

For more information about this constraint, see the [Constraints Guide](#).

Syntax

```
{INST|NET|PIN} inst_net_or_pin_name TNM = [predefined_group:] identifier;
```

Timing Name on a Net (TNM_NET)

The Timing Name on a Net (TNM_NET) constraint:

- Is essentially equivalent to [Timing Name \(TNM\)](#) on a net *except* for input pad nets.

Note Special rules apply when using Timing Name on a Net with the [Period \(PERIOD\)](#) constraint for DLL and DCM components.

For more information, see:

PERIOD Specifications on CLKDLLs and DCMs in the [Constraints Guide](#)

- Is a property that you normally use in conjunction with a Hardware Description Language (HDL) design to tag a specific net.

Note All downstream synchronous elements and pads tagged with the Timing Name on a Net identifier are considered a group.

For more information about this constraint, see the [Constraints Guide](#).

Syntax

```
NET netname TNM_NET = [predefined_group:] identifier;
```

Timegroup (TIMEGRP)

The Timegroup (TIMEGRP) constraint is a basic grouping constraint.

In addition to naming groups using the TNM identifier, you can also define groups in terms of other groups. You can create a group that is a combination of existing groups by defining a Timegroup constraint.

Place Timegroup constraints in an XST Constraint File (XCF) or a Netlist Constraints File (NCF).

Use Timegroup attributes to create groups using the following methods:

- Combining multiple groups into one
- Defining flip-flop subgroups by clock sense

For more information about this constraint, see the [Constraints Guide](#).

Syntax

```
TIMEGRP newgroup = existing_grp1 existing_grp2 [existing_grp3 ...];
```

Timing Ignore (TIG)

The Timing Ignore (TIG) constraint:

- Causes all paths going through a specific net to be ignored for timing analyses and optimization purposes.
- Can be applied to the name of the signal affected.

For more information about this constraint, see the [Constraints Guide](#).

Syntax

```
NET net_name TIG;
```

Write Timing Constraints (-write_timing_constraints)

The Write Timing Constraints (-write_timing_constraints) command line option specifies when timing constraints are written to the NGC file.

Timing constraints are written to the NGC file only when:

- **Write Timing Constraints** is checked **yes** in ISE® Design Suite in **Process > Process Properties**, or
- The -write_timing_constraints option is specified when using the command line.

Timing constraints are not written to the NGC file by default.

Architecture Support

Architecture independent.

Applicable Elements

Applies to an entire design through the XST command line.

Propagation Rules

Not applicable.

Syntax

```
-write_timing_constraints {yes|no}
```

- yes (default)
- no

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XST Command Line

```
xst run -write_timing_constraints yes
```

Timing constraints are written to the NGC file.

ISE Design Suite

Process > Process Properties > Synthesis Options > Write Timing Constraints

XST Implementation Constraints

This chapter discusses the following constraints:

- [No Reduce \(NOREDUCED\)](#)
- [Power Mode \(PWR_MODE\)](#)
- [RLOC](#)

Implementation constraints control placement and routing. They are not directly used by XST, but are propagated and made available to the implementation tools. The object to which an implementation constraint is attached is preserved.

A binary equivalent of the implementation constraint is written to the NGC file. Since the file is binary, you cannot edit an implementation constraint in the NGC file.

You can code an implementation constraint in the XST Constraint File (XCF) as illustrated in [Implementation Constraints Syntax Examples](#).

For more information, see the [Constraints Guide](#).

Implementation Constraints Syntax Examples

This section gives the following Implementation Constraints syntax examples:

- [XCF Syntax Examples](#)
- [VHDL Syntax Examples](#)
- [Verilog Syntax Examples](#)

XCF Syntax Examples

This section gives two XCF Syntax Examples, including, for each example, one for Method One and one for Method Two.

XCF Syntax Example One

To apply an implementation constraint to an entire entity, use either of the following XST Constraint File (XCF) syntaxes:

Method One

```
MODEL EntityName PropertyName;
```

Method Two

```
MODEL EntityName PropertyName=PropertyValue;
```

XCF Syntax Example Two

To apply an implementation constraint to specific instances, nets, or pins within an entity, use either of the following syntaxes:

Method One

```
BEGIN MODEL EntityName {NET|INST|PIN} {NetName|InstName|SigName}
PropertyName;
END;
```

Method Two

```
BEGIN MODEL EntityName {NET|INST|PIN} {NetName|InstName|SigName}
PropertyName=PropertyValue;
END;
```

VHDL Syntax Examples

Specify implementation constraints in VHDL as follows:

```
attribute PropertyName of {NetName|InstName|PinName} : {signal|label} is
"PropertyValue";
```

Verilog Syntax Examples

Specify implementation constraints in Verilog as follows:

```
// synthesis attribute PropertyName of {NetName|InstName|PinName} is "PropertyValue";
```

In Verilog-2001, where descriptions precede the signal, module, or instance to which they refer, specify implementation constraints as follows:

```
(* PropertyName="PropertyValue" *)
```

No Reduce (NOREDUCE)

Applies to all CPLD devices. Does not apply to FPGA devices.

No Reduce (NOREDUCE) prevents the optimization of the Boolean equation generating a given signal. Assuming a local signal is assigned the arbitrary function below, and No Reduce attached to the signal *s*:

```
signal s : std_logic;
attribute NOREDUCE : boolean;
attribute NOREDUCE of s : signal is "true";
...
s <= a or (a and b);
```

Specify No Reduce in the XST Constraint File (XCF) as follows:

```
BEGIN MODEL ENTNAME
NET s NOREDUCE;
NET s KEEP;
END;
```

XST writes the following statements to the NGC file:

```
NET s NOREDUCE;
NET s KEEP;
```

For more information, see the [Constraints Guide](#).

Power Mode (PWR_MODE)

The Power Mode (**PWR_MODE**) constraint controls the power consumption characteristics of macrocells.

The following VHDL statement specifies that the function generating signal *s* should be optimized for low power consumption:

```
attribute PWR_MODE : string;  
attribute PWR_MODE of s : signal is "LOW";
```

XST writes the following statement to the NGC file:

```
NET s PWR_MODE=LOW;  
NET s KEEP;
```

The HDL attribute can be applied to the signal on which XST infers the instance if:

- The attribute applies to an instance, and
- The instance is not available (not instantiated) in the HDL source

Examples of instances include:

- [Pack I/O Registers Into IOBs \(IOB\)](#)
- DRIVE
- IOSTANDARD

Architecture Support

Applies to all CPLD devices. Does not apply to FPGA devices.

Syntax Examples and Settings

The following syntax examples and settings show how to use this constraint or command line option with particular tools or methods. If a tool or method is not listed, you cannot use this constraint or command line option with it.

XCF

```
MODEL ENTNAME  
  NET s PWR_MODE=LOW;  
  NET s KEEP;  
END;
```

RLOC (RLOC)

See:

[RLOC \(RLOC\)](#)

XST Supported Third Party Constraints

This chapter describes XST Supported Third Party Constraints, and includes:

- [XST Equivalents to Third Party Constraints](#)
- [Third Party Constraints Syntax Examples](#)

XST Equivalents to Third Party Constraints

This section shows the XST equivalent for each of the third party constraints. For specific information on these constraints, see the vendor documentation.

Several third party constraints are automatically supported by XST, as shown in the table below. Constraints marked **yes** are fully supported. If a constraint is only partially supported, the support conditions are shown in the Automatic Recognition column.

The following rules apply:

- VHDL uses standard attribute syntax. No changes are needed to the Hardware Description Language (HDL) code.
- For Verilog with third party meta-comment syntax, the meta-comment syntax must be changed to conform to XST conventions. The constraint name and its value can be used as shown in the third party tool.
- For Verilog 2001 attributes, no changes are needed to the HDL code. The constraint is automatically translated as in the case of VHDL attribute syntax.

XST Equivalents to Third Party Constraints

| Name | Vendor | XST Equivalent | Automatic Recognition | Available For |
|--------------------|----------|-------------------------------|-----------------------|---------------|
| black_box | Synopsys | BoxType | N/A | VHDL, Verilog |
| black_box_pad_pin | Synopsys | N/A | N/A | N/A |
| black_box_tri_pins | Synopsys | N/A | N/A | N/A |
| cell_list | Synopsys | N/A | N/A | N/A |
| clock_list | Synopsys | N/A | N/A | N/A |
| Enum | Synopsys | N/A | N/A | N/A |
| full_case | Synopsys | Full Case | N/A | Verilog |
| ispad | Synopsys | N/A | N/A | N/A |
| map_to_module | Synopsys | N/A | N/A | N/A |
| net_name | Synopsys | N/A | N/A | N/A |
| parallel_case | Synopsys | Parallel Case | N/A | Verilog |
| return_port_name | Synopsys | N/A | N/A | N/A |

| Name | Vendor | XST Equivalent | Automatic Recognition | Available For |
|-----------------------------|----------|--|--|---------------|
| resource_sharing_directives | Synopsys | Resource Sharing | N/A | VHDL, Verilog |
| set_dont_touch_network | Synopsys | not required | N/A | N/A |
| set_dont_touch | Synopsys | not required | N/A | N/A |
| set_dont_use_cel_name | Synopsys | not required | N/A | N/A |
| set_prefer | Synopsys | N/A | N/A | N/A |
| state_vector | Synopsys | N/A | N/A | N/A |
| syn_allow_retiming | Synopsys | Register Balancing | N/A | VHDL, Verilog |
| syn_black_box | Synopsys | BoxType | Yes | VHDL, Verilog |
| syn_direct_enable | Synopsys | N/A | N/A | N/A |
| syn_edif_bit_format | Synopsys | N/A | N/A | N/A |
| syn_edif_scalar_format | Synopsys | N/A | N/A | N/A |
| syn_encoding | Synopsys | FSM Encoding Algorithm | Yes (The value <i>safe</i> is not supported for automatic recognition. Use Safe Implementation in XST to activate this mode.) | VHDL, Verilog |
| syn_enum_encoding | Synopsys | Enumerated Encoding | N/A | VHDL |
| syn_hier | Synopsys | Keep Hierarchy | Yes syn_hier = hard recognized askeep_hierarchy = soft syn_hier = remove recognized askeep_hierarchy = no (XST supports only the values <i>hard</i> and <i>remove</i> for syn_hier in automatic recognition.) | VHDL, Verilog |
| syn_isclock | Synopsys | N/A | N/A | N/A |
| syn_keep | Synopsys | Keep | Yes (XST preserves the designated net in the final netlist, but does not attach any KEEP constraint to it.) | VHDL, Verilog |
| syn_maxfan | Synopsys | Max Fanout | Yes | VHDL, Verilog |
| syn_netlist_hierarchy | Synopsys | Netlist Hierarchy | N/A | VHDL, Verilog |
| syn_noarrayports | Synopsys | N/A | N/A | N/A |
| syn_noclockbuf | Synopsys | Buffer Type | Yes | VHDL, Verilog |
| syn_noprune | Synopsys | Optimize Instantiated Primitives | Yes | VHDL, Verilog |

| Name | Vendor | XST Equivalent | Automatic Recognition | Available For |
|---|----------|---|--|---------------|
| syn_pipeline | Synopsys | Register Balancing | N/A | VHDL, Verilog |
| syn_preserve | Synopsys | Equivalent Register Removal | Yes | VHDL, Verilog |
| syn_ramstyle | Synopsys | ram_extract and ram_style | Yes XST implements RAMs in no_rw_check mode regardless if no_rw_check is specified or not the area value is ignored | VHDL, Verilog |
| syn_reference_clock | Synopsys | N/A | N/A | N/A |
| syn_replicate | Synopsys | Register Duplication | Yes | VHDL, Verilog |
| syn_romstyle | Synopsys | rom_extract and rom_style | Yes | VHDL, Verilog |
| syn_sharing | Synopsys | N/A | N/A | VHDL, Verilog |
| syn_state_machine | Synopsys | Automatic FSM Extraction | Yes | VHDL, Verilog |
| syn_tco <n> | Synopsys | N/A | N/A | N/A |
| syn_tpd <n> | Synopsys | N/A | N/A | N/A |
| syn_tristate | Synopsys | N/A | N/A | N/A |
| syn_tristatetomux | Synopsys | N/A | N/A | N/A |
| syn_tsu <n> | Synopsys | N/A | N/A | N/A |
| syn_useenables | Synopsys | N/A | N/A | N/A |
| syn_useioff | Synopsys | Pack I/O Registers Into IOBs | N/A | VHDL, Verilog |
| synthesis translate_off synthesis translate_on | Synopsys | Translate Off Translate On | Yes | VHDL, Verilog |
| xc_alias | Synopsys | N/A | N/A | N/A |
| xc_clockbuftype | Synopsys | Buffer Type | N/A | VHDL, Verilog |
| xc_fast | Synopsys | FAST | N/A | VHDL, Verilog |
| xc_fast_auto | Synopsys | FAST | N/A | VHDL, Verilog |
| xc_global_buffers | Synopsys | BUFG (XST) | N/A | VHDL, Verilog |
| xc_ioff | Synopsys | Pack I/O Registers Into IOBs | N/A | VHDL, Verilog |
| xc_isgsr | Synopsys | N/A | N/A | N/A |
| xc_loc | Synopsys | LOC | Yes | VHDL, Verilog |
| xc_map | Synopsys | LUT_MAP | Yes (XST supports only the value lut for automatic recognition.) | VHDL, Verilog |
| xc_ncf_auto_relax | Synopsys | N/A | N/A | N/A |

| Name | Vendor | XST Equivalent | Automatic Recognition | Available For |
|------------|----------|----------------|-----------------------|---------------|
| xc_nodelay | Synopsys | NODELAY | N/A | VHDL, Verilog |
| xc_padtype | Synopsys | I/O Standard | N/A | VHDL, Verilog |
| xc_props | Synopsys | N/A | N/A | N/A |
| xc_pullup | Synopsys | PULLUP | N/A | VHDL, Verilog |
| xc_rloc | Synopsys | RLOC | Yes | VHDL, Verilog |
| xc_fast | Synopsys | FAST | N/A | VHDL, Verilog |
| xc_slow | Synopsys | N/A | N/A | N/A |
| xc_uset | Synopsys | U_SET | Yes | VHDL, Verilog |

Third Party Constraints Syntax Examples

The following third party constraints syntax examples are the only ways to:

- Preserve a signal/net in a Hardware Description Language (HDL) design, and
- Prevent optimization on the signal or net during synthesis

Third Party Constraints Verilog Syntax Example

```
module testkeep (in1, in2, out1);
  input in1;
  input in2;
  output out1;
  (* keep = "yes" *) wire aux1;
  (* keep = "yes" *) wire aux2;
  assign aux1 = in1;
  assign aux2 = in2;
  assign out1 = aux1 & aux2;
endmodule
```

Third Party Constraints XCF Syntax Example

Keep (KEEP) can also be applied through the separate synthesis constraint file:

```
BEGIN MODEL testkeep
  NET aux1 KEEP=true;
END;
```

XST VHDL Language Support

This chapter:

- Explains how XST supports the VHSIC Hardware Description Language (VHDL)
- Provides details on VHDL supported constructs and synthesis options

This chapter includes:

- [VHDL Logic Descriptions](#)
- [VHDL IEEE Support](#)
- [VHDL File Type Support](#)
- [VHDL Debugging Using Write Operation](#)
- [VHDL Data Types](#)
- [VHDL Record Types](#)
- [VHDL Initial Values](#)
- [VHDL Objects](#)
- [VHDL Operators](#)
- [VHDL Entity and Architecture Descriptions](#)
- [VHDL Combinatorial Circuits](#)
- [VHDL Sequential Circuits](#)
- [VHDL Functions and Procedures](#)
- [VHDL Assert Statements](#)
- [VHDL Models Defined Using Packages](#)
- [VHDL Constructs Supported in XST](#)
- [VHDL Reserved Words](#)

VHDL Logic Descriptions

VHDL offers a broad set of constructs for compactly describing complicated logic:

- Allows the description of the structure of a system:
 - How it is decomposed into subsystems
 - How those subsystems are interconnected
- Allows the specification of the function of a system using familiar programming language forms.
- Allows the design of a system to be simulated before being implemented and manufactured. This feature allows you to test for correctness without the delay and expense of hardware prototyping.
- Provides a mechanism for easily producing a detailed, device-dependent version of a design to be synthesized from a more abstract specification. This feature allows

you to concentrate on more strategic design decisions, and reduce the overall time to market for the design.

For more information, see:

- [IEEE VHDL Language Reference Manual](#)
- [XST Design Constraints](#)
- [VHDL Attribute Syntax](#)

VHDL IEEE Support

This section discusses VHDL IEEE Support, and includes:

- [Supported VHDL IEEE Standards](#)
- [VHDL IEEE Conflicts](#)
- [Non-LRM Compliant Constructs in VHDL](#)

Supported VHDL IEEE Standards

XST supports the following VHDL IEEE standards:

- **Std 1076-1987**
- **Std 1076-1993**
- **Std 1076-2006**

Note Std 1076-2006 is only partially implemented. XST allows instantiation for Std 1076-2006 as shown in the following table.

| Formal Port | Associated Actual |
|-------------|-------------------|
| buffer | out |
| out | buffer |

VHDL IEEE Conflicts

VHDL IEEE **Std 1076-1987** constructs are accepted if they do not conflict with VHDL IEEE **Std 1076-1993**. In case of a conflict, **Std 1076-1993** behavior overrides **Std 1076-1987**.

In cases where:

- **Std 1076-1993** requires a construct to be an erroneous case, but
- **Std 1076-1987** accepts it,

XST issues a warning instead of an error. An error would stop analysis.

VHDL IEEE Conflict Example

Following is an example of a VHDL IEEE conflict:

- **Std 1076-1993** requires an impure function to use the **impure** keyword while declaring a function.
- **Std 1076-1987** has no such requirement.

In this case, XST:

- Accepts the VHDL code written for **Std 1076-1987**
- Issues a warning stating **Std 1076-1993** behavior

Non-LRM Compliant Constructs in VHDL

XST supports some non-LRM compliant constructs. XST supports a specific non-LRM compliant construct when:

- A majority of synthesis or simulation third-party tools support the construct, and
- It is a real language limitation for design coding, and has no impact on quality of results or problem detection in the design.

For example, the LRM does not allow instantiation when the formal port is a **buffer** and the effective one is an **out** (and vice-versa).

VHDL File Type Support

XST supports a limited File Read and File Write capability for VHDL as shown in the following table.

| Capability | Usage Examples |
|------------|---|
| File Read | Initialize RAMs from an external file |
| File Write | <ul style="list-style-type: none"> • Debug processes • Write a specific constant or generic value to an external file |

For more information, see:

[Initializing RAM Coding Examples](#)

Use any of the read functions shown in the following table. These read functions are supported by the following packages:

- **standard**
- **std.textio**
- **ieee.std_logic_textio**

| Function | Package |
|--------------------------------------|------------|
| file (type text only) | standard |
| access (type line only) | standard |
| file_open (file, name, open_kind) | standard |
| file_close (file) | standard |
| endfile (file) | standard |
| text | std.textio |
| line | std.textio |
| width | std.textio |
| readline (text, line) | std.textio |
| readline (line, bit, boolean) | std.textio |
| read (line, bit) | std.textio |
| readline (line, bit_vector, boolean) | std.textio |
| read (line, bit_vector) | std.textio |
| read (line, boolean, boolean) | std.textio |
| read (line, boolean) | std.textio |
| read (line, character, boolean) | std.textio |

| Function | Package |
|--|-----------------------|
| read (line, character) | std.textio |
| read (line, string, boolean) | std.textio |
| read (line, string) | std.textio |
| write (file, line) | std.textio |
| write (line, bit, boolean) | std.textio |
| write (line, bit) | std.textio |
| write (line, bit_vector, boolean) | std.textio |
| write (line, bit_vector) | std.textio |
| write (line, boolean, boolean) | std.textio |
| write (line, boolean) | std.textio |
| write (line, character, boolean) | std.textio |
| write (line, character) | std.textio |
| write (line, integer, boolean) | std.textio |
| write (line, integer) | std.textio |
| write (line, string, boolean) | std.textio |
| write (line, string) | std.textio |
| read (line, std_ulogic, boolean) | ieee.std_logic_textio |
| read (line, std_ulogic) | ieee.std_logic_textio |
| read (line, std_ulogic_vector), boolean | ieee.std_logic_textio |
| read (line, std_ulogic_vector) | ieee.std_logic_textio |
| read (line, std_logic_vector, boolean) | ieee.std_logic_textio |
| read (line, std_logic_vector) | ieee.std_logic_textio |
| write (line, std_ulogic, boolean) | ieee.std_logic_textio |
| write (line, std_ulogic) | ieee.std_logic_textio |
| write (line, std_ulogic_vector, boolean) | ieee.std_logic_textio |
| write (line, std_ulogic_vector) | ieee.std_logic_textio |
| write (line, std_logic_vector, boolean) | ieee.std_logic_textio |
| write (line, std_logic_vector) | ieee.std_logic_textio |
| hread | ieee.std_logic_textio |

VHDL Debugging Using Write Operation

This section discusses VHDL Debugging Using Write Operation, and includes:

- [Rules for Debugging](#)
- [Using the Endfile Function](#)

Rules for Debugging

Follow these rules for debugging using write operation in VHDL:

- During a **std_logic** read operation, the only allowed characters are **0** and **1**. Other values such as **X** and **Z** are not allowed. XST rejects the design if the file includes characters other than **0** and **1**, except that XST ignores a blank space character.
- Do not use identical names for files placed in different directories.
- Do not use conditional calls to read procedures, as shown in the following coding example.

```
if SEL = '1' then
    read (MY_LINE, A(3 downto 0));
else
    read (MY_LINE, A(1 downto 0));
end if;
```

Using the Endfile Function

XST rejects the design if you use the following description style with the **endfile** function:

```
while (not endfile (MY_FILE)) loop
    readline (MY_FILE, MY_LINE);
    read (MY_LINE, MY_DATA);
end loop;
```

XST issues the following error message:

Line <MY_LINE> has not enough elements for target <MY_DATA>.

To fix the problem, add **exit when endfile (MY_FILE);** to the **while** loop.

```
while (not endfile (MY_FILE)) loop
    readline (MY_FILE, MY_LINE);
    exit when endfile (MY_FILE);
    read (MY_LINE, MY_DATA);
end loop;
```

Coding Example

```

--
-- Print 2 constants to the output file
--

library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.STD_LOGIC_arith.ALL;
use IEEE.STD_LOGIC_UNSIGNED.ALL;
use STD.TEXTIO.all;
use IEEE.STD_LOGIC_TEXTIO.all;

entity file_support_1 is
    generic (data_width: integer:= 4);
    port( clk, sel: in std_logic;
          din: in std_logic_vector (data_width - 1 downto 0);
          dout: out std_logic_vector (data_width - 1 downto 0));
end file_support_1;

architecture Behavioral of file_support_1 is
    file results : text is out "test.dat";
    constant base_const: std_logic_vector(data_width - 1 downto 0):= conv_std_logic_vector(3,data_width);
    constant new_const:  std_logic_vector(data_width - 1 downto 0):= base_const + "1000";
begin

    process(clk)
        variable txtline : LINE;
    begin
        write(txtline,string'("-----"));
        writeline(results, txtline);
        write(txtline,string'("Base Const: "));
        write(txtline,base_const);
        writeline(results, txtline);

        write(txtline,string'("New  Const: "));
        write(txtline,new_const);
        writeline(results, txtline);
        write(txtline,string'("-----"));
        writeline(results, txtline);

        if (clk'event and clk='1') then
            if (sel = '1') then
                dout <= new_const;
            else
                dout <= din;
            end if;
        end if;
    end process;
end Behavioral;

```

VHDL Data Types

This section discusses VHDL Data Types, and includes:

- [Accepted VHDL Data Types](#)
- [VHDL Overloaded Data Types](#)
- [VHDL Multi-Dimensional Array Types](#)

Accepted VHDL Data Types

XST accepts the following VHDL data types:

- [VHDL Enumerated Types](#)
- [VHDL User-Defined Enumerated Types](#)
- [VHDL Bit Vector Types](#)
- [VHDL Integer Types](#)
- [VHDL Predefined Types](#)
- [VHDL STD_LOGIC_1164 IEEE Types](#)

VHDL Enumerated Types

| Type | Values | Meaning | Comment |
|-----------|--------------|----------------|---------------------------|
| BIT | 0, 1 | -- | -- |
| BOOLEAN | false, true | -- | -- |
| REAL | \$.- to \$+. | -- | -- |
| STD_LOGIC | U | uninitialized | Not accepted by XST |
| | X | unknown | Treated as don't care |
| | 0 | low | Treated identically to L |
| | 1 | high | Treated identically to H |
| | Z | high impedance | Treated as high impedance |
| | W | weak unknown | Not accepted by XST |
| | L | weak low | Treated identically to 0 |
| | H | weak high | Treated identically to 1 |
| | - | don't care | Treated as don't care |

VHDL User-Defined Enumerated Types

```
type COLOR is (RED, GREEN, YELLOW);
```

VHDL Bit Vector Types

- BIT_VECTOR
- STD_LOGIC_VECTOR

VHDL Integer Types

```
INTEGER
```

VHDL Predefined Types

- BIT
- BOOLEAN
- BIT_VECTOR
- INTEGER
- REAL

VHDL STD_LOGIC_1164 IEEE Types

The following types are declared in the STD_LOGIC_1164 IEEE package:

- STD_LOGIC
- STD_LOGIC_VECTOR

This package is compiled in the IEEE library. To use one of these types, add the following two lines to the VHDL specification:

```
library IEEE; use IEEE.STD_LOGIC_1164.all;
```

VHDL Overloaded Data Types

The following data types can be overloaded:

- [VHDL Overloaded Enumerated Types](#)
- [VHDL Overloaded Bit Vector Types](#)
- [VHDL Overloaded Integer Types](#)
- [VHDL Overloaded STD_LOGIC_1164 IEEE Types](#)
- [VHDL Overloaded STD_LOGIC_ARITH IEEE Types](#)

VHDL Overloaded Enumerated Types

- STD_ULOGIC
Contains the same nine values as the STD_LOGIC type, but does not contain predefined resolution functions
- X01
Subtype of STD_ULOGIC containing the X, 0 and 1 values
- X01Z
Subtype of STD_ULOGIC containing the X, 0, 1 and Z values
- UX01
Subtype of STD_ULOGIC containing the U, X, 0 and 1 values
- UX01Z
Subtype of STD_ULOGIC containing the U, X, 0, 1, and Z values

VHDL Overloaded Bit Vector Types

- STD_ULOGIC_VECTOR
- UNSIGNED
- SIGNED

Unconstrained types (types whose length is not defined) are not accepted.

VHDL Overloaded Integer Types

- NATURAL
- POSITIVE

Any integer type within a user-defined range. For example:

type MSB is range 8 to 15;

means any integer:

- greater than 7, or
- less than 16

The types NATURAL and POSITIVE are VHDL predefined types.

VHDL Overloaded STD_LOGIC_1164 IEEE Types

The following types are declared in the STD_LOGIC_1164 IEEE package:

- STD_ULOGIC (and subtypes X01, X01Z, UX01, UX01Z)
- STD_LOGIC
- STD_ULOGIC_VECTOR
- STD_LOGIC_VECTOR

This package is compiled in the library IEEE. To use one of these types, add the following two lines to the VHDL specification:

```
library IEEE;  
use IEEE.STD_LOGIC_1164.all;
```

VHDL Overloaded STD_LOGIC_ARITH IEEE Types

The types UNSIGNED and SIGNED (defined as an array of STD_LOGIC) are declared in the STD_LOGIC_ARITH IEEE package.

This package is compiled in the library IEEE. To use these types, add the following two lines to the VHDL specification:

```
library IEEE;  
use IEEE.STD_LOGIC_ARITH.all;
```

VHDL Multi-Dimensional Array Types

XST supports multi-dimensional array types of up to three dimensions. BRAMs are not inferred. Arrays can be:

- Signals
- Constants
- VHDL variables

You can do assignments and arithmetic operations with arrays. You can also pass multi-dimensional arrays to functions, and use them in instantiations.

Coding Example One

The array must be fully constrained in all dimensions, as shown in the following coding example.

```
subtype WORD8 is STD_LOGIC_VECTOR (7 downto 0);  
type TAB12 is array (11 downto 0) of WORD8;  
type TAB03 is array (2 downto 0) of TAB12;
```

Coding Example Two

You can also declare an array as a matrix, as shown in the following coding example.

```
subtype TAB13 is array (7 downto 0, 4 downto 0) of
STD_LOGIC_VECTOR (8 downto 0);
```

Consider the following declarations:

```
subtype WORD8 is STD_LOGIC_VECTOR (7 downto 0);
type TAB05 is array (4 downto 0) of WORD8;
type TAB03 is array (2 downto 0) of TAB05;

signal WORD_A : WORD8;
signal TAB_A, TAB_B : TAB05;
signal TAB_C, TAB_D : TAB03;
constant CNST_A : TAB03 := (
("00000000", "01000001", "01000010", "10000011", "00001100"),

("00100000", "00100001", "00101010", "10100011", "00101100"),

("01000010", "01000010", "01000100", "01000111", "01000100"));
```

The following can now be specified:

- A multi-dimensional array signal or variable

```
TAB_A <= TAB_B; TAB_C <= TAB_D; TAB_C <= CNST_A;
```
- An index of one array

```
TAB_A (5) <= WORD_A; TAB_C (1) <= TAB_A;
```
- Indexes of the maximum number of dimensions

```
TAB_A (5) (0) <= '1'; TAB_C (2) (5) (0) <= '0'
```
- A slice of the first array

```
TAB_A (4 downto 1) <= TAB_B (3 downto 0);
```
- An index of a higher level array and a slice of a lower level array:

```
TAB_C (2) (5) (3 downto 0) <= TAB_B (3) (4 downto 1); TAB_D
(0) (4) (2 downto 0) <= CNST_A (5 downto 3)
```

Coding Example Three

Add the following declaration:

```
subtype MATRIX15 is array(4 downto 0, 2 downto 0) of
STD_LOGIC_VECTOR (7 downto 0); signal MATRIX_A : MATRIX15;
```

The following can now be specified:

- A multi-dimensional array signal or variable
`MATRIXA <= CNST_A;`
- An index of one row of the array
`MATRIXA (5) <= TAB_A;`
- Indexes of the maximum number of dimensions
`MATRIXA (5,0) (0) <= '1';`

Indexes may be variable.

VHDL Record Types

XST supports VHDL record types, as shown in the following Coding Example.

- Record types can contain other record types.
- Constants can be record types.
- Record types cannot contain attributes.
- XST supports aggregate assignments to record signals.

Coding Example

```
type REC1 is record
  field1: std_logic;
  field2: std_logic_vector (3 downto 0)
end record;
```

VHDL Initial Values

This section discusses VHDL Initial Values, and includes:

- [Initializing Registers](#)
- [VHDL Local Reset/Global Reset](#)
- [Default Initial Values on Memory Elements in VHDL](#)

Initializing Registers

In VHDL, you can initialize registers when you declare them.

The value:

- Is a constant
- Cannot depend on earlier initial values
- Cannot be a function or task call
- Can be a parameter value propagated to a register

Coding Example One

When you give a register an initial value in a declaration, XST sets this value:

- On the output of the register at global reset, or
- At power up

The assigned value:

- Is carried in the NGC file as an INIT attribute on the register
- Is independent of any local reset

```
signal arb_onebit : std_logic := '0';
signal arb_priority : std_logic_vector(3 downto 0) := "1011";
```

Coding Example Two

You can also assign a set/reset value to a register in behavioral VHDL code. Assign a value to a register when the register reset line goes to the appropriate value.

```
process (clk, rst)
begin
  if rst='1' then
    arb_onebit <= '0';
  end if;
end process;
```

When you set the initial value of a variable in the behavioral code, it is implemented in the design as a flip-flop whose output can be controlled by a local reset. As such, it is carried in the NGC file as an FDP or FDC flip-flop.

VHDL Local Reset/Global Reset

Local reset is independent of global reset. Registers controlled by a local reset may be set to a different value from registers whose value is only reset at global reset (power up). In the following coding example, the register **arb_onebit** is set to **1** at global reset, but a pulse on the local **reset (rst)** can change its value to **0**.

Local Reset/Global Reset VHDL Coding Example

The following coding example sets the initial value on the register output to **1** (one) at initial power up, but since this is dependent upon a local reset, the value changes to **0** (zero) whenever the local set/reset is activated.

```
entity top is
  Port (
    clk, rst : in std_logic;
    a_in : in std_logic;
    dout : out std_logic);
end top;
architecture Behavioral of top is
  signal arb_onebit : std_logic := '1';

begin
  process (clk, rst)
  begin
    if rst='1' then
      arb_onebit <= '0';
    elsif (clk'event and clk='1') then
      arb_onebit <= a_in;
    end if;
  end process;
```

```

end process;

dout <= arb_onebit;
end Behavioral;

```

Default Initial Values on Memory Elements in VHDL

Because every memory element in a Xilinx® FPGA device must come up in a known state, in certain cases, XST does not use IEEE standards for initial values. In the [Local Reset/Global Reset VHDL Coding Example](#), if signal `arb_onebit` were not initialized to **1** (one), XST would assign it a default of **0** (zero) as its initial state. In this case, XST does not follow the IEEE standard, where **U** is the default for `std_logic`. This process of initialization is the same for both registers and RAMs.

Where possible, XST adheres to the IEEE VHDL standard when initializing signal values. If no initial values are supplied in the VHDL code, XST uses the default values (where possible) as shown in the XST column in the following table.

| Type | IEEE | XST |
|-------------------------------|------------------|---|
| bit | '0' | '0' |
| std_logic | 'U' | '0' |
| bit_vector (3 downto 0) | 0000 | 0000 |
| std_logic_vector (3 downto 0) | 0000 | 0000 |
| integer (unconstrained) | integer'left | integer'left |
| integer range 7 downto 0 | integer'left = 7 | integer'left = 7 (coded as 111) |
| integer range 0 to 7 | integer'left = 0 | integer'left = 0 (coded as 000) |
| Boolean | FALSE | FALSE (coded as 0) |
| enum(S0,S1,S2,S3) | type'left = S0 | type'left = S0 (coded as 000) |

Unconnected output ports default to the values shown in the XST column of VHDL Initial Values. If the output port has an initial condition, XST ties the unconnected output port to the explicitly defined initial condition. According to the IEEE VHDL specification, input ports cannot be left unconnected. As a result, XST issues an error message if an input port is not connected. Even the `open` keyword is not sufficient for an unconnected input port.

VHDL Objects

This section discusses VHDL Objects, and include:

- [Signals in VHDL](#)
- [Variables in VHDL](#)
- [Constants in VHDL](#)

Signals in VHDL

Signals in VHDL can be:

- Declared in an architecture declarative part.
- Used anywhere within the architecture.
- Declared in a block.
- Used within that block.
- Assigned by the assignment operator `<=`.

Coding Example

```
signal sig1 : std_logic; sig1 <= '1';
```

Variables in VHDL

Variables in VHDL:

- Are declared in a process or a subprogram.
- Are used within that process or that subprogram.
- Can be assigned by the assignment operator:
:=

Coding Example

```
variable var1 : std_logic_vector (7 downto 0); var1 := "01010011";
```

Constants in VHDL

Constants in VHDL:

- Can be declared in any declarative region.
- Can be used within that region.
- Cannot have their values be changed once declared.

Coding Example

```
signal sig1 : std_logic_vector (5 downto 0);  
constant init0 : std_logic_vector (5 downto 0) := "010111";  
sig1 <= init0;
```

VHDL Operators

Supported operators are listed in [VHDL Expressions](#). This section provides coding examples for each shift operator.

Shift Left Logical VHDL Coding Example

```
sll (Shift Left Logical) sig1 <= A(4 downto 0) sll 2
```

logically equivalent to:

```
sig1 <= A(2 downto 0) & "00";
```

Shift Right Logical VHDL Coding Example

```
srl (Shift Right Logical) sig1 <= A(4 downto 0) srl 2
```

logically equivalent to:

```
sig1 <= "00" & A(4 downto 2);
```

Shift Left Arithmetic VHDL Coding Example

```
sla (Shift Left Arithmetic) sig1 <= A(4 downto 0) sla 2
```

logically equivalent to:

```
sig1 <= A(2 downto 0) & A(0) & A(0);
```

Shift Right Arithmetic VHDL Coding Example

```
sra (Shift Right Arithmetic) sig1 <= A(4 downto 0) sra 2
```

logically equivalent to:

```
sig1 <= A(4) & A(4) & A(4 downto 2);
```

Rotate Left VHDL Coding Example

```
rol (Rotate Left) sig1 <= A(4 downto 0) rol 2
```

logically equivalent to:

```
sig1 <= A(2 downto 0) & A(4 downto 3);
```

Rotate Right VHDL Coding Example

```
ror (Rotate Right) A(4 downto 0) ror 2
```

logically equivalent to:

```
sig1 <= A(1 downto 0) & A(4 downto 2);
```

VHDL Entity and Architecture Descriptions

VHDL entity and architecture descriptions include:

- [Circuit Descriptions](#)
- [Entity Declarations](#)
- [Architecture Declarations](#)
- [Component Instantiation](#)
- [Recursive Component Instantiation](#)
- [Component Configuration](#)
- [Generic Parameter Declarations](#)
- [Generic and Attribute Conflict](#)

VHDL Circuit Descriptions

A circuit description in VHDL consists of two parts:

- The interface (defining the I/O ports)
- The body

In VHDL:

- The entity corresponds to the interface
- The architecture describes the behavior

VHDL Entity Declarations

The I/O ports of the circuit are declared in the entity. Each port has:

- A name
- A mode
 - **in**
 - **out**
 - **inout**
 - **buffer**
- A type (one of the following ports in the [Entity and Architecture Declaration VHDL Coding Example](#))
 - **A**
 - **B**
 - **C**
 - **D**
 - **E**

Not more than one-dimensional array types are accepted as ports.

VHDL Architecture Declarations

Internal signals may be declared in the architecture. Each internal signal has:

- A name
- A type

Signal T as shown below in the following coding example

Coding Example

```

Library IEEE;
use IEEE.std_logic_1164.all;
entity EXAMPLE is
  port (
    A,B,C : in std_logic;
    D,E : out std_logic );
end EXAMPLE;

architecture ARCHI of EXAMPLE is
  signal T : std_logic;
begin
  ...
end ARCHI;

```

VHDL Component Instantiation

Structural descriptions assemble several blocks, and allow the introduction of hierarchy in a design.

| Concept | Description |
|-----------|--|
| Component | Building or basic block |
| Port | Component I/O connector |
| Signal | Corresponds to a wire between components |

In VHDL, a component is represented by a design entity. The design entity is a composite consisting of the concepts shown in the following table.

| Concept | View | Describes |
|--------------------|----------|--|
| Entity declaration | External | What can be seen from the outside, including the component ports |
| Architecture body | Internal | The behavior or the structure of the component |

The connections between components are specified within component instantiation statements. These statements specify an instance of a component occurring inside an architecture of another component. Each component instantiation statement is labeled with an identifier.

Besides naming a component declared in a local component declaration, a component instantiation statement contains an association list -- the parenthesized list following the reserved word port map. The association list specifies which actual signals or ports are associated with which local ports of the component declaration.

XST supports unconstrained vectors in component declarations.

Coding Example

The following coding example shows the structural description of a half adder composed of four nand2 components:

```
entity NAND2 is
  port (
    A,B : in BIT;
    Y : out BIT );
end NAND2;

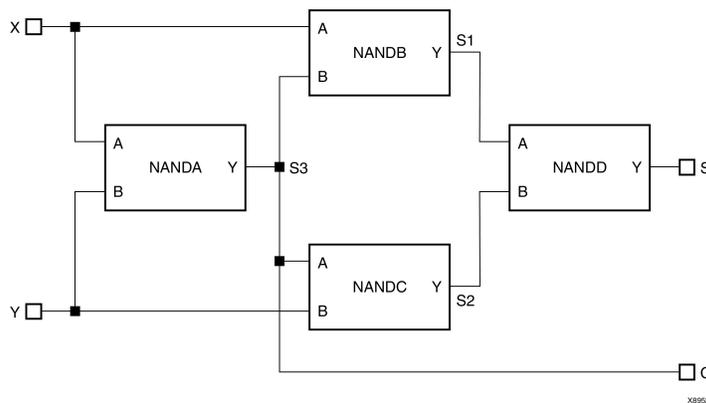
architecture ARCH1 of NAND2 is
begin
  Y <= A nand B;
end ARCH1;

entity HALFADDER is
  port (
    X,Y : in BIT;
    C,S : out BIT );
end HALFADDER;

architecture ARCH1 of HALFADDER is
  component NAND2
  port (
    A,B : in BIT;
    Y : out BIT );
  end component;

  for all : NAND2 use entity work.NAND2(ARCH1);
  signal S1, S2, S3 : BIT;
begin
  NANDA : NAND2 port map (X,Y,S3);
  NANDB : NAND2 port map (X,S3,S1);
  NANDC : NAND2 port map (S3,Y,S2);
  NANDD : NAND2 port map (S1,S2,S);
  C <= S3;
end ARCH1;
```

Synthesized Top Level Netlist Diagram



VHDL Recursive Component Instantiation

XST supports recursive component instantiation. Direct instantiation is not supported for recursion. To prevent endless recursive calls, the number of recursions is limited by default to 64. Use `-recursion_iteration_limit` to control the number of allowed recursive calls.

4-Bit Shift Register With Recursive Component Instantiation VHDL Coding Example

```
library ieee;
use ieee.std_logic_1164.all;
library unisim;
use unisim.vcomponents.all;

entity single_stage is
  generic (sh_st: integer:=4);
  port (
    CLK : in std_logic;
    DI  : in std_logic;
    DO  : out std_logic );
end entity single_stage;

architecture recursive of single_stage is
  component single_stage
    generic (sh_st: integer);
    port (
      CLK : in std_logic;
      DI  : in std_logic;
      DO  : out std_logic );
  end component;

  signal tmp : std_logic;

begin
  GEN_FD_LAST: if sh_st=1 generate
    inst_fd: FD port map (D=>DI, C=>CLK, Q=>DO);
  end generate;
  GEN_FD_INTERM: if sh_st /= 1 generate
    inst_fd: FD port map (D=>DI, C=>CLK, Q=>tmp);
    inst_sstage: single_stage generic map (sh_st => sh_st-1)
      port map (DI=>tmp, CLK=>CLK, DO=>DO);
  end generate;
end recursive;
```

VHDL Component Configuration

Associating an entity and architecture pair to a component instance provides the means of linking components with the appropriate model (entity and architecture pair).

XST supports component configuration in the declarative part of the architecture:

for *instantiation_list*: *component_name* **use** *LibName.entity_Name*(*Architecture_Name*);

Coding Example

The following coding example shows how to use a configuration clause for component instantiation. The example contains a **for all** statement.

```
for all : NAND2 use entity work.NAND2(ARCHI);
```

This statement indicates that all NAND2 components use the entity NAND2 and Architecture ARCH1.

When the configuration clause is missing for a component instantiation, XST links the component to the entity with the same name (and same interface) and the selected architecture to the most recently compiled architecture. If no entity or architecture is found, a black box is generated during synthesis.

In command line mode, you may also use a dedicated configuration declaration to link component instantiations in your design to design entities and architectures. In this case, the value of the mandatory Top Module Name (**-top**) option in the **run** command is the configuration name instead of the top level entity name.

VHDL Generic Parameter Declarations

The **Generics (-generics)** VHDL command line option allows you to redefine generics values defined in the top-level design block. This allows you to easily modify the design configuration without any Hardware Description Language (HDL) source modifications, such as for IP core generation and testing flows.

Generic parameters may be declared in the entity declaration part. XST supports all types for generics including, for example:

- Integer
- Boolean
- String
- Real
- **std_logic_vector**

An example of using generic parameters is setting the width of the design.

Coding Example

By describing circuits with generic ports, the same component can be instantiated repeatedly with different values of generic ports as shown in the following coding example.

```
Library IEEE;
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;

entity addern is
  generic (width : integer := 8);
  port (
    A,B : in std_logic_vector (width-1 downto 0);
    Y   : out std_logic_vector (width-1 downto 0) );
end addern;

architecture bhv of addern is
  begin
    Y <= A + B;
  end bhv;

Library IEEE;
use IEEE.std_logic_1164.all;

entity top is
  port (
    X, Y, Z : in std_logic_vector (12 downto 0);
    A, B : in std_logic_vector (4 downto 0);
```

```

        S :out std_logic_vector (16 downto 0) );
end top;

architecture bhv of top is
    component addern
        generic (width : integer := 8);
        port (
            A,B : in std_logic_vector (width-1 downto 0);
            Y   : out std_logic_vector (width-1 downto 0) );
    end component;

    for all : addern use entity work.addern(bhv);
    signal C1 : std_logic_vector (12 downto 0);
    signal C2, C3 : std_logic_vector (16 downto 0);
begin
    U1 : addern generic map (n=>13) port map (X,Y,C1);
    C2 <= C1 & A;
    C3 <= Z & B;
    U2 : addern generic map (n=>17) port map (C2,C3,S);
end bhv;

```

VHDL Generic and Attribute Conflicts

Since generics and attributes can be applied to both instances and components in the VHDL code, and attributes can also be specified in a constraints file, from time to time, conflicts may arise. To resolve these conflicts, XST uses the following rules of precedence:

1. Whatever is specified on an instance (lower level) takes precedence over what is specified on a component (higher level).
2. If a generic and an attribute are specified on either the same instance or the same component, the generic takes precedence, and XST issues a message warning of the conflict.
3. An attribute specified in the XST Constraint File (XCF) always takes precedence over attributes or generics specified in the VHDL code.

When an attribute specified on an instance overrides a generic specified on a component in XST, it is possible that your simulation tool may nevertheless use the generic. This may cause the simulation results to not match the synthesis results.

Precedence in VHDL

| | Generic on an Instance | Generic on a Component |
|--------------------------|-------------------------------------|--|
| Attribute on an Instance | Apply Generic (XST issues warning) | Apply Attribute (possible simulation mismatch) |
| Attribute on a Component | Apply Generic | Apply Generic (XST issues warning) |
| Attribute in XCF | Apply Attribute XST issues warning) | Apply Attribute |

Security attributes on the block definition always have higher precedence than any other attribute or generic.

VHDL Combinatorial Circuits

XST supports the following VHDL combinatorial circuits:

- [Concurrent Signal Assignments](#)
- [Generate Statements](#)
- [Combinatorial Processes](#)
- [If...Else Statements](#)
- [Case Statements](#)
- [For...Loop Statements](#)

VHDL Concurrent Signal Assignments

Combinatorial logic in VHDL may be described using concurrent signal assignments. These can be defined within the body of the architecture. VHDL offers three types of concurrent signal assignments:

- Simple
- Selected
- Conditional

You can describe as many concurrent statements as needed. The order of concurrent signal definition in the architecture is irrelevant.

A concurrent assignment consists of two sides:

- Left-hand
- Right-hand

The assignment changes when any signal in the right side changes. In this case, the result is assigned to the signal on the left side.

Simple Signal Assignment VHDL Coding Example

```
T <= A and B;
```

MUX Description Using Selected Signal Assignment VHDL Coding Example

```
library IEEE;
use IEEE.std_logic_1164.all;

entity select_bhv is
  generic (width: integer := 8);
  port (
    a, b, c, d : in std_logic_vector (width-1 downto 0);
    selector : in std_logic_vector (1 downto 0);
    T : out std_logic_vector (width-1 downto 0) );
end select_bhv;

architecture bhv of select_bhv is
begin
  with selector select
    T <= a when "00",
         b when "01",
         c when "10",
         d when others;
end bhv;
```

MUX Description Using Conditional Signal Assignment VHDL Coding Example

```

entity when_ent is
  generic (width: integer := 8);
  port (
    a, b, c, d : in std_logic_vector (width-1 downto 0);
    selector : in std_logic_vector (1 downto 0);
    T : out std_logic_vector (width-1 downto 0) );
end when_ent;

architecture bhv of when_ent is
  begin
    T <= a when selector = "00" else
        b when selector = "01" else
        c when selector = "10" else
        d;
  end bhv;

```

VHDL Generate Statements

Repetitive structures are declared with the **generate** VHDL statement. For this purpose, **for I in 1 to N generate** means that the bit slice description is repeated N times.

8-Bit Adder Described With For...Generate Statement VHDL Coding Example

The following coding example describes an 8-bit adder by declaring the bit slice structure.

```

entity EXAMPLE is
  port (
    A,B : in BIT_VECTOR (0 to 7);
    CIN : in BIT;
    SUM : out BIT_VECTOR (0 to 7);
    COUT : out BIT );
end EXAMPLE;

architecture ARCH1 of EXAMPLE is
  signal C : BIT_VECTOR (0 to 8);
  begin
    C(0) <= CIN;
    COUT <= C(8);
    LOOP_ADD : for I in 0 to 7 generate
      SUM(I) <= A(I) xor B(I) xor C(I);
      C(I+1) <= (A(I) and B(I)) or (A(I) and C(I)) or (B(I) and C(I));
    end generate;
  end ARCH1;

```

N-Bit Adder Described With If...Generate and For... Generate Statement VHDL Coding Example

XST supports the **if condition generate** statement for static (non-dynamic) conditions. The following coding example shows a generic N-bit adder with a width ranging between 4 and 32.

```
entity EXAMPLE is
  generic (N : INTEGER := 8);
  port (
    A,B : in BIT_VECTOR (N downto 0);
    CIN : in BIT;
    SUM : out BIT_VECTOR (N downto 0);
    COUT : out BIT );
end EXAMPLE;

architecture ARCHI of EXAMPLE is
  signal C : BIT_VECTOR (N+1 downto 0);
  begin
  L1: if (N>=4 and N<=32) generate
    C(0) <= CIN;
    COUT <= C(N+1);
    LOOP_ADD : for I in 0 to N generate
      SUM(I) <= A(I) xor B(I) xor C(I);
      C(I+1) <= (A(I) and B(I)) or (A(I) and C(I)) or (B(I) and C(I));
    end generate;
  end generate;
end ARCHI;
```

VHDL Combinatorial Processes

A process assigns values to signals differently than when using concurrent signal assignments. The value assignments are made in a sequential mode. Later assignments may cancel previous ones. See *Assignments in a Process VHDL Coding Example*. First the signal *S* is assigned to **0**, but later on (*for (A and B) =1*), the value for *S* is changed to **1**.

A process is combinatorial when its inferred hardware does not involve any memory elements. Said differently, when all assigned signals in a process are always explicitly assigned in all paths of the Process statements, the process is combinatorial.

A combinatorial process has a sensitivity list appearing within parentheses after the word **process**. A process is activated if an event (value change) appears on one of the sensitivity list signals. For a combinatorial process, this sensitivity list must contain:

- All signals in conditions (for example, **if** and **case**)
- All signals on the right-hand side of an assignment

If one or more signals are missing from the sensitivity list, XST issues a warning message for the missing signals and adds them to the sensitivity list. In this case, the result of the synthesis may be different from the initial design specification.

A process may contain local variables. The variables are handled in a similar manner as signals (but are not, of course, outputs to the design).

In *Combinatorial Process VHDL Coding Example One*, a variable named *AUX* is declared in the declarative part of the process, and is assigned to a value (with **:=**) in the statement part of the process.

In combinatorial processes, if a signal is not explicitly assigned in all branches of **if** or **case** statements, XST generates a latch to hold the last value. To avoid latch creation, ensure that all assigned signals in a combinatorial process are always explicitly assigned in all paths of the Process statements.

Different statements can be used in a process:

- Variable and signal assignment
- **If** statement
- **Case** statement
- **For...Loop** statement
- Function and procedure call

Assignments in a Process VHDL Coding Example

```
entity EXAMPLE is
  port (
    A, B : in BIT;
    S : out BIT );
end EXAMPLE;

architecture ARCHI of EXAMPLE is
begin
  process (A, B)
  begin
    S <= '0' ;
    if ((A and B) = '1') then
      S <= '1' ;
    end if;
  end process;
end ARCHI;
```

Coding Example One

```
library ASYL;
use ASYL.ARITH.all;

entity ADDSUB is
  port (
    A,B : in BIT_VECTOR (3 downto 0);
    ADD_SUB : in BIT;
    S : out BIT_VECTOR (3 downto 0) );
end ADDSUB;

architecture ARCHI of ADDSUB is
begin
  process (A, B, ADD_SUB)
    variable AUX : BIT_VECTOR (3 downto 0);
  begin
    if ADD_SUB = '1' then
      AUX := A + B ;
    else
      AUX := A - B ;
    end if;
    S <= AUX;
  end process;
end ARCHI;
```

Coding Example Two

```
entity EXAMPLE is
  port (
    A, B : in BIT;
    S : out BIT );
end EXAMPLE;

architecture ARCHI of EXAMPLE is
begin
  process (A,B)
    variable X, Y : BIT;
  begin
    X := A and B;
    Y := B and A;
    if X = Y then
      S <= '1' ;
    end if;
  end process;
end ARCHI;
```

VHDL If...Else Statements

If...else statements:

- Use **true** and **false** conditions to execute statements.
- May be nested.
- May be executed in a block of multiple statements using **begin** and **end** keywords.

| Expression Evaluates To | Statement Executed |
|-------------------------|--------------------|
| true | First statement |
| false | else statement |
| x | else statement |
| z | else statement |

Coding Example

```
library IEEE;
use IEEE.std_logic_1164.all;

entity mux4 is
  port (
    a, b, c, d : in std_logic_vector (7 downto 0);
    sel1, sel2 : in std_logic;
    outmux : out std_logic_vector (7 downto 0));
end mux4;

architecture behavior of mux4 is
begin
  process (a, b, c, d, sel1, sel2)
  begin
    if (sel1 = '1') then
      if (sel2 = '1') then
        outmux <= a;
      else
        outmux <= b;
      end if;
    end if;
  end process;
end behavior;
```

```
        end if;
    else
        if (sel2 = '1') then
            outmux <= c;
        else
            outmux <= d;
        end if;
    end if;
end process;
end behavior;
```

VHDL Case Statements

Case statements perform a comparison to an expression to evaluate one of a number of parallel branches. The **case** statement evaluates the branches in the order they are written. The first branch that evaluates to true is executed. If none of the branches match, the default branch is executed.

VHDL Case Statement Coding Example

```
library IEEE;
use IEEE.std_logic_1164.all;

entity mux4 is
    port (
        a, b, c, d : in std_logic_vector (7 downto 0);
        sel : in std_logic_vector (1 downto 0);
        outmux : out std_logic_vector (7 downto 0));
end mux4;
architecture behavior of mux4 is
begin
    process (a, b, c, d, sel)
    begin
        case sel is
            when "00" => outmux <= a;
            when "01" => outmux <= b;
            when "10" => outmux <= c;
            when others => outmux <= d; -- case statement
                                         -- must be complete
        end case;
    end process;
end behavior;
```

VHDL For...Loop Statements

XST supports the **for** statement for:

- Constant bounds
- Stop test condition using any of the following operators:
 - <
 - <=
 - >
 - >=
- Next step computation falling within one of the following specifications:
 - *var* = *var* + step
 - *var* = *var* - step

where

 - ◆ *var* is the loop variable
 - ◆ *step* is a constant value
- **Next** and **exit** statements

VHDL For...Loop Statement Coding Example

```
library IEEE;
use IEEE.std_logic_1164.all;
use IEEE.std_logic_unsigned.all;

entity countzeros is
  port (
    a : in std_logic_vector (7 downto 0);
    Count : out std_logic_vector (2 downto 0) );
end mux4;

architecture behavior of mux4 is
  signal Count_Aux: std_logic_vector (2 downto 0);
begin
  process (a)
  begin
    Count_Aux <= "000";
    for i in a'range loop
      if (a[i] = '0') then
        Count_Aux <= Count_Aux + 1; -- operator "+" defined
                                   -- in std_logic_unsigned
      end if;
    end loop;
    Count <= Count_Aux;
  end process;
end behavior;
```

VHDL Sequential Circuits

Sequential circuits can be described using sequential processes. XST allows:

- [VHDL Sequential Process With a Sensitivity List](#)
- [VHDL Sequential Process Without a Sensitivity List](#)

VHDL Sequential Process With a Sensitivity List

A process is sequential when it is not a combinatorial process. In other words, a process is sequential when some assigned signals are not explicitly assigned in all paths of the statements. In this case, the hardware generated has an internal state or memory (flip-flops or latches).

The following coding example provides a template for describing sequential circuits.

For more information, see:

[XST HDL Coding Techniques](#)

This topic describes macro inference (for example, registers and counters).

Coding Example

Declare asynchronous signals in the sensitivity list. Otherwise, XST issues a warning and adds them to the sensitivity list. In this case, the behavior of the synthesis result may be different from the initial specification.

```
process (CLK, RST) ...
begin
  if RST = <'0' | '1'> then
    -- an asynchronous part may appear here
    -- optional part
    .....
  elsif <CLK'EVENT | not CLK'STABLE>
    and CLK = <'0' | '1'> then
    -- synchronous part
    -- sequential statements may appear here
  end if;
end process;
```

VHDL Sequential Process Without a Sensitivity List

Sequential processes without a sensitivity list must contain a **Wait** statement. The **Wait** statement must be the first statement of the process. The condition in the **Wait** statement must be a condition on the clock signal. Several **Wait** statements in the same process are accepted, but a set of specific conditions must be respected.

For more information, see:

[VHDL Multiple Wait Statements Descriptions](#)

An asynchronous part cannot be specified within processes without a sensitivity list.

VHDL Sequential Process Without a Sensitivity List Coding Example

The following VHDL coding example shows the skeleton of the process described in this section. The clock condition may be a falling or a rising edge.

```
process ...
begin
  wait until <CLK'EVENT | not CLK' STABLE> and CLK = <'0' | '1'>;
  ... -- a synchronous part may be specified here.
end process;
```

XST does not support clock and clock enable descriptions within the same **Wait** statement. Instead, code these descriptions as shown in *Clock and Clock Enable (Supported) VHDL Coding Example*.

XST does not support Wait statements for latch descriptions.

Clock and Clock Enable (Not Supported) VHDL Coding Example**Caution!** This coding style is NOT supported.

```
wait until CLOCK'event and CLOCK = '0' and ENABLE = '1' ;
```

Clock and Clock Enable (Supported) VHDL Coding Example

"8 Bit Counter Description Using a Process with a Sensitivity List" if ENABLE = '1' then ...

Register and Counter Descriptions VHDL Coding Examples

Coding examples can be downloaded in text format from

http://www.xilinx.com/txpatches/pub/documentation/misc/xstug_examples.zip

8-Bit Register Description Using a Process With a Sensitivity List VHDL Coding Example

```
entity EXAMPLE is
  port (
    DI  : in BIT_VECTOR (7 downto 0);
    CLK : in BIT;
    DO  : out BIT_VECTOR (7 downto 0) );
end EXAMPLE;
```

```
architecture ARCHI of EXAMPLE is
begin
  process (CLK)
  begin
    if CLK'EVENT and CLK = '1' then
      DO <= DI ;
    end if;
  end process;
end ARCHI;
```

8 Bit Register Description Using a Process Without a Sensitivity List Containing a Wait Statement VHDL Coding Example

```
entity EXAMPLE is
  port (
    DI  : in BIT_VECTOR (7 downto 0);
    CLK : in BIT;
    DO  : out BIT_VECTOR (7 downto 0) );
end EXAMPLE;
```

```
architecture ARCHI of EXAMPLE is
begin
  process begin
    wait until CLK'EVENT and CLK = '1';
    DO <= DI;
  end process;
end ARCHI;
```

8-Bit Register With Clock Signal and Asynchronous Reset Signal VHDL Coding Example

```
entity EXAMPLE is
  port (
    DI : in BIT_VECTOR (7 downto 0);
    CLK : in BIT;
    RST : in BIT;
    DO : out BIT_VECTOR (7 downto 0));
end EXAMPLE;

architecture ARCHI of EXAMPLE is
begin
  process (CLK, RST)
  begin
    if RST = '1' then
      DO <= "00000000";
    elsif CLK'EVENT and CLK = '1' then
      DO <= DI ;
    end if;
  end process;
end ARCHI;
```

8-Bit Counter Description Using a Process With a Sensitivity List VHDL Coding Example

```
library ASYL;
use ASYL.PKG_ARITH.all;

entity EXAMPLE is
  port (
    CLK : in BIT;
    RST : in BIT;
    DO : out BIT_VECTOR (7 downto 0));
end EXAMPLE;

architecture ARCHI of EXAMPLE is
begin
  process (CLK, RST)
  variable COUNT : BIT_VECTOR (7 downto 0);
  begin
    if RST = '1' then
      COUNT := "00000000";
    elsif CLK'EVENT and CLK = '1' then
      COUNT := COUNT + "00000001";
    end if;
    DO <= COUNT;
  end process;
end ARCHI;
```

VHDL Multiple Wait Statements Descriptions

Sequential circuits can be described in VHDL with multiple **wait** statements in a process. Follow these rules when using multiple **wait** statements:

- The process contains only one **loop** statement.
- The first statement in the loop is a **wait** statement.
- After each **wait** statement, a **next** or **exit** statement is defined.
- The condition in the **wait** statements is the same for each **wait** statement.
- This condition use only one signal — the clock signal.
- This condition has the following form:

```
"wait [on clock_signal] until [(clock_signal'EVENT | not clock_signal'STABLE) and ]  
clock_signal = {'0' | '1'};"
```

Coding Example

The following VHDL coding example uses multiple **wait** statements. This example describes a sequential circuit performing four different operations in sequence. The design cycle is delimited by two successive rising edges of the clock signal. A synchronous reset is defined providing a way to restart the sequence of operations at the beginning. The sequence of operations consists of assigning each of the following four inputs to the output RESULT:

- DATA1
- DATA2
- DATA3
- DATA4

```
library IEEE;
use IEEE.STD_LOGIC_1164.all;

entity EXAMPLE is
  port (
    DATA1, DATA2, DATA3, DATA4 : in STD_LOGIC_VECTOR (3 downto 0);
    RESULT : out STD_LOGIC_VECTOR (3 downto 0);
    CLK : in STD_LOGIC;
    RST : in STD_LOGIC );
end EXAMPLE;

architecture ARCH of EXAMPLE is
begin
  process begin
    SEQ_LOOP : loop
      wait until CLK'EVENT and CLK = '1';
      exit SEQ_LOOP when RST = '1';
      RESULT <= DATA1;

      wait until CLK'EVENT and CLK = '1';
      exit SEQ_LOOP when RST = '1';
      RESULT <= DATA2;

      wait until CLK'EVENT and CLK = '1';
      exit SEQ_LOOP when RST = '1';
      RESULT <= DATA3;

      wait until CLK'EVENT and CLK = '1';
      exit SEQ_LOOP when RST = '1';
      RESULT <= DATA4;
    end loop;
  end process;
end ARCH;
```

VHDL Functions and Procedures

The declaration of a function or a procedure in VHDL provides a mechanism for handling blocks used multiple times in a design. Functions and procedures can be declared in the declarative part of an entity, in an architecture or in packages. The heading part contains:

- Input parameters for functions and input
- Output and inout parameters for procedures.

These parameters can be unconstrained. They are not constrained to a given bound. The content is similar to the combinatorial process content.

Resolution functions are not supported except the one defined in the IEEE `std_logic_1164` package.

Function Declaration and Function Call VHDL Coding Example

The following VHDL coding example shows a function declared within a package. The ADD function declared here is a single bit adder. This function is called four times with the proper parameters in the architecture to create a 4-bit adder. The same example using a procedure is shown in *Procedure Declaration and Procedure Call VHDL Coding Example*.

```
package PKG is
    function ADD (A,B, CIN : BIT )
        return BIT_VECTOR;
end PKG;

package body PKG is
    function ADD (A,B, CIN : BIT )
        return BIT_VECTOR is
        variable S, COUT : BIT;
        variable RESULT : BIT_VECTOR (1 downto 0);
    begin
        S := A xor B xor CIN;
        COUT := (A and B) or (A and CIN) or (B and CIN);
        RESULT := COUT & S;
        return RESULT;
    end ADD;
end PKG;

use work.PKG.all;

entity EXAMPLE is
    port (
        A,B : in BIT_VECTOR (3 downto 0);
        CIN : in BIT;
        S : out BIT_VECTOR (3 downto 0);
        COUT : out BIT );
end EXAMPLE;

architecture ARCHI of EXAMPLE is
    signal S0, S1, S2, S3 : BIT_VECTOR (1 downto 0);
    begin
        S0 <= ADD (A(0), B(0), CIN);
        S1 <= ADD (A(1), B(1), S0(1));
        S2 <= ADD (A(2), B(2), S1(1));
        S3 <= ADD (A(3), B(3), S2(1));
        S <= S3(0) & S2(0) & S1(0) & S0(0);
        COUT <= S3(1);
    end ARCHI;
```

Procedure Declaration and Procedure Call VHDL Coding Example

```

package PKG is
  procedure ADD (
    A,B, CIN : in BIT;
    C : out BIT_VECTOR (1 downto 0) );
end PKG;

package body PKG is
  procedure ADD (
    A,B, CIN : in BIT;
    C : out BIT_VECTOR (1 downto 0)
  ) is
    variable S, COUT : BIT;
  begin
    S := A xor B xor CIN;
    COUT := (A and B) or (A and CIN) or (B and CIN);
    C := COUT & S;
  end ADD;
end PKG;

use work.PKG.all;

entity EXAMPLE is
  port (
    A,B : in BIT_VECTOR (3 downto 0);
    CIN : in BIT;
    S : out BIT_VECTOR (3 downto 0);
    COUT : out BIT );
end EXAMPLE;

architecture ARCH1 of EXAMPLE is
  begin
    process (A,B,CIN)
      variable S0, S1, S2, S3 : BIT_VECTOR (1 downto 0);
    begin
      ADD (A(0), B(0), CIN, S0);
      ADD (A(1), B(1), S0(1), S1);
      ADD (A(2), B(2), S1(1), S2);
      ADD (A(3), B(3), S2(1), S3);
      S <= S3(0) & S2(0) & S1(0) & S0(0);
      COUT <= S3(1);
    end process;
  end ARCH1;

```

Recursive Function VHDL Coding Example

XST supports recursive functions. The following coding example represents $n!$ function:

```

function my_func(x : integer) return integer is
  begin
    if x = 1 then
      return x;
    else
      return (x*my_func(x-1));
    end if;
  end function my_func;

```

VHDL Assert Statements

XST supports VHDL **Assert** statements. **Assert** statements enable you to detect undesirable conditions in VHDL designs, such as bad values for:

- conditions:
 - generics
 - constants
 - generate
- parameters in called functions

For any failed condition in an **Assert** statement, XST (depending on the severity level) either:

- Issues a warning message, or
- Rejects the design and issues an error message.

XST supports the **Assert** statement only with static condition.

Coding Example

The following coding example contains a block **SINGLE_SRL** which describes a shift register. The size of the shift register depends on the **SRL_WIDTH** generic value. The **Assert** statement ensures that the implementation of a single shift register does not exceed the size of a single Shift Register LUT (SRL).

Since the size of the SRL is 16 bit, and XST implements the last stage of the shift register using a flip-flop in a slice, then the maximum size of the shift register cannot exceed 17 bits. The **SINGLE_SRL** block is instantiated twice in the entity named **TOP**:

- first with **SRL_WIDTH** equal to 13
- second with **SRL_WIDTH** equal to 18

```

library ieee;
use ieee.std_logic_1164.all;

entity SINGLE_SRL is
  generic (SRL_WIDTH : integer := 16);
  port (
    clk : in std_logic;
    inp : in std_logic;
    outp : out std_logic);
end SINGLE_SRL;

architecture beh of SINGLE_SRL is
  signal shift_reg : std_logic_vector (SRL_WIDTH-1 downto 0);
begin

  assert SRL_WIDTH <= 17
  report "The size of Shift Register exceeds the size of a single SRL"
  severity FAILURE;

  process (clk)
  begin
    if (clk'event and clk = '1') then
      shift_reg <= shift_reg (SRL_WIDTH-1 downto 1) & inp;
    end if;
  end process;
  outp <= shift_reg(SRL_WIDTH-1);
end beh;

library ieee;
use ieee.std_logic_1164.all;

entity TOP is
  port (
    clk : in std_logic;
    inp1, inp2 : in std_logic;
    outp1, outp2 : out std_logic);
end TOP;

architecture beh of TOP is
  component SINGLE_SRL is
    generic (SRL_WIDTH : integer := 16);
    port(
      clk : in std_logic;
      inp : in std_logic;
      outp : out std_logic);
  end component;
begin
  inst1: SINGLE_SRL generic map (SRL_WIDTH => 13)
  port map(
    clk => clk,
    inp => inp1,
    outp => outp1 );
  inst2: SINGLE_SRL generic map (SRL_WIDTH => 18)
  port map(
    clk => clk,
    inp => inp2,
    outp => outp2 );
end beh;

```

Error Message

If you run the coding example above, XST issues the following error message:

```
...
=====
*                               HDL Analysis                               *
=====
Analyzing Entity <top> (Architecture <beh>).
Entity <top> analyzed. Unit <top> generated.

Analyzing generic Entity <single_srl> (Architecture <beh>).
  SRL_WIDTH = 13
Entity <single_srl> analyzed. Unit <single_srl> generated.

Analyzing generic Entity <single_srl> (Architecture <beh>).
  SRL_WIDTH = 18
ERROR:Xst - assert_1.vhd line 15: FAILURE:
The size of Shift Register exceeds the size of a single SRL
...

```

VHDL Models Defined Using Packages

This section discusses VHDL Models Defined Using Packages, and includes:

- [About VHDL Models Defined Using Packages](#)
- [Using Standard Packages to Define VHDL Models](#)
- [Using IEEE Packages to Define VHDL Models](#)
- [Using Synopsys Packages to Define VHDL Models](#)

About VHDL Models Defined Using Packages

VHDL models may be defined using packages. Packages contain:

- Type and subtype declarations
- Constant definitions
- Function and procedure definitions
- Component declarations

Using packages to define VHDL models provides the ability to change parameters and constants of the design, such as constant values and function definitions.

Packages may contain two declarative parts:

- Body declaration
- Package declaration

The body declaration includes the description of function bodies declared in the package declaration.

```
library lib_pack;  
-- lib_pack is the name of the library specified  
-- where the package has been compiled (work by default)  
use lib_pack.pack_name.all;  
-- pack_name is the name of the defined package.
```

XST also supports predefined packages. These packages are pre-compiled and can be included in VHDL designs. These packages are intended for use during *synthesis*, but may also be used for *simulation*.

Using Standard Packages to Define VHDL Models

The Standard package:

- Is included by default
- Contains basic types:
 - **bit**
 - **bit_vector**
 - **integer**

VHDL Models Defined Using IEEE Packages

XST supports the following IEEE packages:

- **std_logic_1164**

Supports the following types:

- **std_logic**
- **std_ulogic**
- **std_logic_vector**
- **std_ulogic_vector**

XST also supports conversion functions based on these types.

- **numeric_bit**

Supports the following types based on type **bit**:

- Unsigned vectors
- Signed vectors

XST also supports:

- ◆ All overloaded arithmetic operators on these types
- ◆ Conversion and extended functions for these types

- **numeric_std**

Supports the following types based on type **std_logic**:

- Unsigned vectors
- Signed vectors

This package is equivalent to **std_logic_arith**.

- **math_real**

Supports the following:

- Real number constants as shown in VHDL Real Number Constants
- Real number functions as shown in VHDL Real Number Constants
- The procedure **uniform**, which generates successive values between 0.0 and 1.0

VHDL Real Number Constants

| Constant | Value | Constant | Value |
|------------------|-------|-------------------|--------|
| math_e | e | math_log_of_2 | ln2 |
| math_1_over_e | 1/e | math_log_of_10 | ln10 |
| math_pi | | math_log2_of_e | log2e |
| math_2_pi | | math_log10_of_e | log10e |
| math_1_over_pi | | math_sqrt_2 | |
| math_pi_over_2 | | math_1_oversqrt_2 | |
| math_pi_over_3 | | math_sqrt_pi | |
| math_pi_over_4 | | math_deg_to_rad | |
| math_3_pi_over_2 | | math_rad_to_deg | |

VHDL Real Number Functions

| | | | | |
|------------|--------------|----------|-------------|------------|
| ceil(x) | realmax(x,y) | exp(x) | cos(x) | cosh(x) |
| floor(x) | realmin(x,y) | log(x) | tan(x) | tanh(x) |
| round(x) | sqrt(x) | log2(x) | arcsin(x) | arcsinh(x) |
| trunc(x) | cbrt(x) | log10(x) | arctan(x) | arccosh(x) |
| sign(x) | ***"(n,y) | log(x,y) | arctan(y,x) | arctanh(x) |
| "mod"(x,y) | ***"(x,y) | sin(x) | sinh(x) | |

Functions and procedures in the **math_real** packages, as well as the **real** type, are for calculations only. They are not supported for synthesis in XST.

Coding Example

```
library ieee;
use IEEE.std_logic_signed.all;
signal a, b, c : std_logic_vector (5 downto 0);
c <= a + b;
-- this operator "+" is defined in package std_logic_signed.
-- Operands are converted to signed vectors, and function "+"
-- defined in package std_logic_arith is called with signed
-- operands.
```

Using Synopsys Packages to Define VHDL Models

The following Synopsys packages are supported in the IEEE library:

- **std_logic_arith**
Supports types unsigned, signed vectors, and all overloaded arithmetic operators on these types. It also defines conversion and extended functions for these types.
- **std_logic_unsigned**
Defines arithmetic operators on **std_ulogic_vector** and considers them as unsigned operators.
- **std_logic_signed**
Defines arithmetic operators on **std_logic_vector** and considers them as signed operators.
- **std_logic_misc**
Defines supplemental types, subtypes, constants, and functions for the **std_logic_1164** package, such as:
 - **and_reduce**
 - **or_reduce**

VHDL Constructs Supported in XST

XST supports the following VHDL Constructs:

- [Design Entities and Configurations](#)
- [Expressions](#)
- [Statements](#)

VHDL Design Entities and Configurations

Note XST does not allow underscores as the first character of signal names (for example, `_DATA_1`).

XST supports VHDL design entities and configurations except as shown in the following sections:

- [VHDL Entity Headers](#)
- [VHDL Packages](#)
- [VHDL Physical Types](#)
- [VHDL Modes](#)
- [VHDL Declarations](#)
- [VHDL Objects](#)
- [VHDL Specifications](#)

VHDL Entity Headers

- Generics
Supported
- Ports
Supported
- Entity Statement Part
Partial support. Allowed statements include:
 - Attribute declarations
 - Attribute specifications
 - Constant declarations

VHDL Packages

STANDARD

Type TIME is not supported

VHDL Physical Types

- TIME
Ignored
- REAL
Supported, but only in functions for constant calculations

VHDL Modes

Linkage

Unsupported

VHDL Declarations

Type

Supported for:

- enumerated types
- types with positive range having constant bounds
- bit vector types
- multi-dimensional arrays

VHDL Objects

- Constant Declaration

Supported except for deferred constant

- Signal Declaration

Supported except for register and bus type signals

- Attribute Declaration

Supported for some attributes, otherwise skipped

For more information, see:

[XST Design Constraints](#)

VHDL Specifications

- Attribute

Supported for some predefined attributes only:

- HIGH
- LOW
- LEFT
- RIGHT
- RANGE
- REVERSE_RANGE
- LENGTH
- POS
- ASCENDING
- EVENT
- LAST_VALUE

- Configuration

Supported only with the **all** clause for instances list. If no clause is added, XST looks for the entity or architecture compiled in the default library

- Disconnection

Unsupported

VHDL Expressions

XST supports the following expressions:

- [VHDL Operators](#)
- [VHDL Operands](#)

VHDL Operators

| Operator | Supported/Unsupported |
|--|---|
| Logical Operators: and, or, nand, nor, xor, xnor, not | Supported |
| Relational Operators: =, /=, <, <=, >, >= | Supported |
| & (concatenation) | Supported |
| Adding Operators: +, - | Supported |
| * | Supported |
| /, rem | Supported if the right operand is a constant power of 2 |
| mod | Supported if the right operand is a constant power of 2 |
| Shift Operators: sll, srl, sla, sra, rol, ror | Supported |
| abs | Supported |
| ** | Only supported if the left operand is 2 |
| Sign: +, - | Supported |

VHDL Operands

| Operand | Supported/Unsupported |
|-----------------------|--|
| Abstract Literals | Only integer literals are supported |
| Physical Literals | Ignored |
| Enumeration Literals | Supported |
| String Literals | Supported |
| Bit String Literals | Supported |
| Record Aggregates | Supported |
| Array Aggregates | Supported |
| Function Call | Supported |
| Qualified Expressions | Supported for accepted predefined attributes |
| Types Conversions | Supported |
| Allocators | Unsupported |
| Static Expressions | Supported |

VHDL Statements

XST supports all VHDL statements except as shown in the following sections:

- [VHDL Wait Statements](#)
- [VHDL Loop Statements](#)
- [VHDL Concurrent Statements](#)

VHDL Wait Statements

| Wait Statement | Supported/Unsupported |
|---|---|
| Wait on <i>sensitivity_list</i> until <i>Boolean_expression</i> . For more information, see: VHDL Sequential Circuits | Supported with one signal in the sensitivity list and in the Boolean expression. In case of multiple Wait statements, the sensitivity list and the Boolean expression must be the same for each Wait statement. Note XST does not support Wait statements for latch descriptions. |
| Wait for <i>time_expression</i> ... For more information, see: VHDL Sequential Circuits | Unsupported |
| Assertion Statement | Supported (only for static conditions) |
| Signal Assignment Statement | Supported (delay is ignored) |

VHDL Loop Statements

| Loop Statement | Supported/Unsupported |
|-------------------------|---|
| for... loop... end loop | Supported for constant bounds only. Disable statements are not supported. |
| loop ... end loop | Only supported in the particular case of multiple Wait statements |

VHDL Concurrent Statements

| Concurrent Statement | Supported/Unsupported |
|--|---|
| Concurrent Signal Assignment Statement | Supported (no after clause, no transport or guarded options, no waveforms) UNAFFECTED is supported. |
| For ... Generate | Statement supported for constant bounds only |
| If ... Generate | Statement supported for static condition only |

VHDL Reserved Words

| | | | |
|-----------|---------------|--------------|------------|
| abs | access | after | alias |
| all | and | architecture | array |
| assert | attribute | begin | block |
| body | buffer | bus | case |
| component | configuration | constant | disconnect |
| downto | else | elsif | end |
| entity | exit | file | for |
| function | generate | generic | group |
| guarded | if | impure | in |
| inertial | inout | is | label |
| library | linkage | literal | loop |
| map | mod | nand | new |
| next | nor | not | null |
| of | on | open | or |
| others | out | package | port |
| postponed | procedure | process | pure |
| range | record | register | reject |
| rem | report | return | rol |
| ror | select | severity | signal |
| shared | sla | sll | sra |
| srl | subtype | then | to |
| transport | type | unaffected | units |
| until | use | variable | wait |
| when | while | with | xnor |
| xor | | | |

XST Verilog Language Support

This chapter discusses XST Verilog Language Support, and includes:

- [About XST Verilog Language Support](#)
- [Behavioral Verilog](#)
- [Variable Part Selects](#)
- [Structural Verilog Features](#)
- [Verilog Parameters](#)
- [Verilog Parameter and Attribute Conflicts](#)
- [Verilog Limitations in XST](#)
- [Verilog Attributes and Meta Comments](#)
- [Verilog Constructs Supported in XST](#)
- [Verilog System Tasks and Functions Supported in XST](#)
- [Verilog Primitives](#)
- [Verilog Reserved Keywords](#)
- [Verilog-2001 Support in XST](#)

About XST Verilog Language Support

Complex circuits are commonly designed using a top down methodology. Various specification levels are required at each stage of the design process. For example, at the architectural level, a specification may correspond to a block diagram or an Algorithmic State Machine (ASM) chart. A block or ASM stage corresponds to a register transfer block where the connections are N-bit wires, such as:

- Register
- Adder
- Counter
- Multiplexer
- Glue logic
- Finite State Machine (FSM)

A Hardware Description Language (HDL) such as Verilog allows the expression of notations such as ASM charts and circuit diagrams in a computer language.

Verilog provides both behavioral and structural language structures. These structures allow expressing design objects at high and low levels of abstraction. Designing hardware with a language such as Verilog allows using software concepts such as parallel processing and object-oriented programming. Verilog has a syntax similar to C and Pascal. XST supports it as IEEE 1364.

The Verilog support in XST provides an efficient way to describe both the global circuit and each block according to the most efficient style. Synthesis is then performed with the best synthesis flow for each block. Synthesis in this context is the compilation of high-level behavioral and structural Verilog Hardware Description Language (HDL) statements into a flattened gate-level netlist, which can then be used to custom program a programmable logic device such as a Virtex® device. Different synthesis methods are used for arithmetic blocks, glue logic, and Finite State Machine (FSM) components.

The *XST User Guide for Virtex-4, Virtex-5, Spartan-3, and Newer CPLD Devices* assumes that you are familiar with basic Verilog concepts.

For more information, see:

- Verilog design constraints and options
[XST Design Constraints](#)
- Verilog attribute syntax
[Verilog-2001 Attributes](#)
- Setting Verilog options in the Process window of ISE® Design Suite
[XST General Constraints](#)
- General Verilog information
IEEE Verilog HDL Reference Manual

Behavioral Verilog

For information about Behavioral Verilog, see:

[XST Behavioral Verilog Language Support](#)

Variable Part Selects

Verilog 2001 adds the capability of using variables to select a group of bits from a vector. A variable part select is defined by the starting point of its range and the width of the vector, instead of being bounded by two explicit values. The starting point of the part select can vary, but the width of the part select remains constant.

Variable Part Select Symbols

| Symbol | Meaning |
|-----------|--|
| + (plus) | The part select <i>increases</i> from the starting point |
| - (minus) | The part select <i>decreases</i> from the starting point |

Coding Example

```
reg [3:0] data;
  reg [3:0] select; // a value from 0 to 7
  wire [7:0] byte = data[select +: 8];
```

Structural Verilog Features

This section discusses Structural Verilog Features, and includes:

- [About Structural Verilog Features](#)
- [Instantiating Pre-Defined Primitives](#)

About Structural Verilog Features

Structural Verilog descriptions assemble several blocks of code and allow the introduction of hierarchy in a design. The basic concepts of hardware structure are:

- **Component**
The building or basic block
- **Port**
A component I/O connector
- **Signal**
Corresponds to a wire between components

In Verilog, a component is represented by a design module. The module declaration provides the external view of the component. It describes what can be seen from the outside, including the component ports. The module body provides an internal view. It describes the behavior or the structure of the component.

The connections between components are specified within component instantiation statements. These statements specify an instance of a component occurring within another component or the circuit. Each component instantiation statement is labeled with an identifier.

Besides naming a component declared in a local component declaration, a component instantiation statement contains an association list (the parenthesized list) that specifies which actual signals or ports are associated with which local ports of the component declaration.

Verilog provides a large set of built-in logic gates which can be instantiated to build larger logic circuits. The set of logical functions described by the built-in gates includes:

- **AND**
- **OR**
- **XOR**
- **NAND**
- **NOR**
- **NOT**

Building a Basic XOR Function Structural Verilog Coding Example

Following is an example of building a basic **XOR** function of two single bit inputs **a** and **b**:

```
module build_xor (a, b, c);
    input a, b;
    output c;
    wire c, a_not, b_not;
    not a_inv (a_not, a);
    not b_inv (b_not, b);
    and a1 (x, a_not, b);
    and a2 (y, b_not, a);
    or out (c, x, y);
endmodule
```

Each instance of the built-in modules has a unique instantiation name such as:

- **a_inv**
- **b_inv**
- **out**

Structural Description of a Half Adder Structural Verilog Coding Example

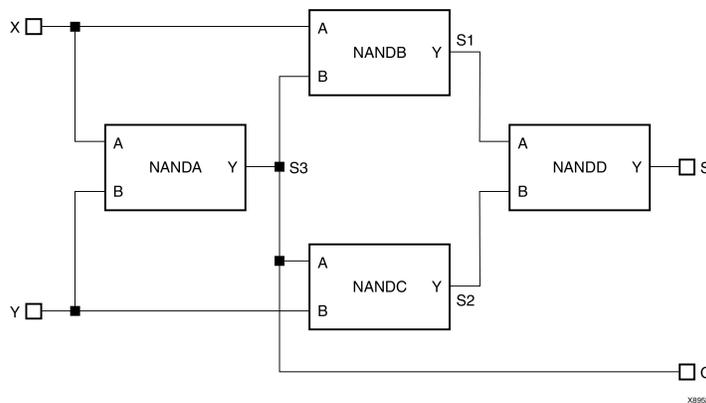
The following coding example shows the structural description of a half adder composed of four, 2 input nand modules:

```

module halfadd (X, Y, C, S);
  input X, Y;
  output C, S;
  wire S1, S2, S3;
  nand NANDA (S3, X, Y);
  nand NANDB (S1, X, S3);
  nand NANDC (S2, S3, Y);
  nand NANDD (S, S1, S2);
  assign C = S3;
endmodule

```

Synthesized Top Level Netlist Diagram



Instantiating Pre-Defined Primitives

The structural features of Verilog also allow you to design circuits by instantiating pre-defined primitives such as:

- gates
- registers
- Xilinx® specific primitives such as:
 - CLKDLL
 - BUFG

These primitives are other than those included in Verilog. These pre-defined primitives are supplied with the XST Verilog libraries (`unisim_comp.v`).

Structural Instantiation of REGISTER and BUFG Structural Verilog Coding Example

```
module foo (sysclk, in, reset, out);
input sysclk, in, reset;
output out;
reg out;
wire sysclk_out;
FDC register (out, sysclk_out, reset, in);
//position based referencing
BUFG clk (.O(sysclk_out),.I(sysclk));
//name based referencing
...
endmodule
```

The `unisim_comp.v` library file supplied with XST, includes the definitions for:

- **FDC**
- **BUFG**

```
(* BOX_TYPE="PRIMITIVE" *) // Verilog-2001
module FDC (Q, C, CLR, D);
parameter INIT = 1'b0;
output Q;
input C;
input CLR;
input D;
endmodule
```

```
(* BOX_TYPE="PRIMITIVE" *) // Verilog-2001
module BUFG ( O, I);
output O;
input I;
endmodule
```

Verilog Parameters

Verilog modules allow you to define constants known as parameters. Parameters can be passed to module instances to define circuits of arbitrary widths. Parameters form the basis of creating and using parameterized blocks in a design to achieve hierarchy.

Coding Example

The following Verilog coding example shows the use of parameters. Null string parameters are not supported.

```
module lpm_reg (out, in, en, reset, clk);
    parameter SIZE = 1;
    input in, en, reset, clk;
    output out;
    wire [SIZE-1 : 0] in;
    reg [SIZE-1 : 0] out;
    always @(posedge clk or negedge reset)
        begin
            if (!reset)
                out <= 1'b0;
            else
                if (en)
                    out <= in;
                else
                    out <= out;    //redundant assignment
            end
        end
    endmodule
module top ();    //portlist left blank intentionally
    ...
    wire [7:0] sys_in, sys_out;
    wire sys_en, sys_reset, sysclk;
    lpm_reg #8 buf_373 (sys_out, sys_in, sys_en, sys_reset, sysclk);
    ...
endmodule
```

Instantiation of the module **lpm_reg** with a instantiation width of **8** causes the instance **buf_373** to be **8** bits wide.

The [Generics \(-generics\)](#) command line option allows you to redefine parameters (Verilog) values defined in the top-level design block. This allows you to easily modify the design configuration without any Hardware Description Language (HDL) source modifications, such as for IP core generation and testing flows.

Verilog Parameter and Attribute Conflicts

This section discusses Verilog Parameter and Attribute Conflicts, and includes:

- [Resolving Verilog Parameter and Attribute Conflicts](#)
- [Verilog Parameter and Attribute Conflicts Precedence](#)

Resolving Verilog Parameter and Attribute Conflicts

Since parameters and attributes can be applied to both instances and modules in Verilog code, and attributes can also be specified in a constraints file, conflicts will occasionally arise.

XST uses the following rules of precedence to resolve these conflicts:

1. Specifications on an instance (lower level) takes precedence over specifications on a module (higher level).
2. If a parameter and an attribute are specified on either the same instance or the same module, the parameter takes precedence. XST issues a warning message.
3. An attribute specified in the XST Constraint File (XCF) takes precedence over attributes or parameters specified in the Verilog code.

When an attribute specified on an instance overrides a parameter specified on a module in XST, the simulation tool may use the parameter anyway. If that happens, the *simulation* results may not match the *synthesis* results.

Verilog Parameter and Attribute Conflicts Precedence

| | Parameter on an Instance | Parameter on a Module |
|--------------------------|--------------------------------------|--|
| Attribute on an Instance | Apply Parameter (XST issues warning) | Apply Attribute (possible simulation mismatch) |
| Attribute on a Module | Apply Parameter | Apply Parameter (XST issues warning) |
| Attribute in XCF | Apply Attribute (XST issues warning) | Apply Attribute |

Security attributes on the module definition always have higher precedence than any other attribute or parameter.

Verilog Limitations in XST

This section describes Verilog Limitations in XST, and includes:

- [Verilog Case Sensitivity](#)
- [Verilog Blocking and Nonblocking Assignments](#)
- [Verilog Integer Handling](#)

Verilog Case Sensitivity

Since Verilog is case sensitive, module and instance names can be made unique by changing capitalization. However, for compatibility with file names, mixed language support, and other tools, Xilinx® recommends that you do not rely on capitalization only to make instance names unique.

XST does not allow module names to differ by capitalization only. It renames instances and signal names to ensure that lack of case sensitivity support in other tools in your flow does not adversely impact your design.

XST Support for Verilog Case Sensitivity

XST supports Verilog case sensitivity as follows:

- Designs can use case equivalent names for I/O ports, nets, regs and memories.
- Equivalent names are renamed using a postfix (rnm<Index>).
- A rename construct is generated in the NGC file.
- Designs can use Verilog identifiers that differ in case only. XST renames them using a postfix as with equivalent names.

For instance:

```
module upperlower4 (input1, INPUT1, output1, output2);
    input input1;
    input INPUT1;
```

For this example, **INPUT1** is renamed to **INPUT1_rnm0**.

Verilog Restrictions Within XST

XST rejects code using equivalent names (named blocks, tasks, and functions) such as the following:

```
...
always @(clk)
begin: fir_main5
    reg [4:0] fir_main5_w1;
    reg [4:0] fir_main5_W1;
```

XST issues the following error message:

```
ERROR:Xst:863 - "design.v", line 6: Name conflict
(<fir_main5/fir_main5_w1> and <fir_main5/fir_main5_W1>)
```

Code using case equivalent module names such as the following is rejected:

```
module UPPERLOWER10 (...);
...
module upperlower10 (...);
...

```

XST issues the following error message:

```
ERROR:Xst:909 - Module name conflict (UPPERLOWER10 and
upperlower10)
```

Verilog Blocking and Nonblocking Assignments

This section gives two rejected coding examples for blocking and nonblocking assignments.

Rejected Coding Example One

XST rejects Verilog designs if a given signal is assigned through both blocking and nonblocking assignments as shown in the following coding example.

```
always @(in1)
begin
    if (in2)
        out1 = in1;
    else
        out1 <= in2;
end
```

Rejected Coding Example Two

The following coding example is rejected even if there is no real mixing of blocking and nonblocking assignments.

```
if (in2)
begin
    out1[0] = 1'b0;
    out1[1] <= in1;
end
else
begin
    out1[0] = in2;
    out1[1] <= 1'b1;
end
```

If a variable is assigned in both a blocking and nonblocking assignment, XST issues the following error message:

```
ERROR:Xst:880 - "design.v", line n:
Cannot mix blocking and non-blocking assignments on signal <out1>.
```

There are also restrictions when mixing blocking and nonblocking assignments on bits and slices.

Errors are checked at the signal level, not at the bit level.

If there is more than one blocking or nonblocking error, only the first is reported.

In some cases, the line number for the error might be incorrect (as there might be multiple lines where the signal has been assigned).

Verilog Integer Handling

XST handles Verilog integers differently from other synthesis tools in several instances. They must be coded in a particular way. Unsized integers in Verilog case item expressions and concatenations may cause unpredictable results

Unsized Integers in Verilog Case Item Expressions

Unsized integers in Verilog case item expressions may cause unpredictable results.

In the following coding example, the case item expression **4** is an unsized integer that causes unpredictable results. To avoid problems, size the **4** to 3 bits as follows:

```
reg [2:0] condition1;

always @(condition1)
begin
    case(condition1)
        4      : data_out = 2;    // < will generate bad logic
        3'd4   : data_out = 2;    // < will work
    endcase
end
```

Unsized Integers in Verilog Concatenations

Unsized integers in Verilog concatenations may cause unpredictable results.

If you use an expression that results in an unsized integer:

1. Assign the expression to a temporary signal.
2. Use the temporary signal in the concatenation as follows:

```
reg [31:0] temp;
assign temp = 4'b1111 % 2;
assign dout = {12/3,temp,din};
```

Verilog Attributes and Meta Comments

XST supports both of the following in Verilog:

- Verilog-2001 style attributes
Xilinx® recommends Verilog-2001 attributes since they are more generally accepted.
- Verilog meta comments
Meta comments are comments that are understood by the Verilog parser.

Verilog-2001 Attributes

XST supports Verilog-2001 attribute statements. Attributes are comments that pass specific information to software tools such as synthesis tools. Verilog-2001 attributes can be specified anywhere for operators or signals within module declarations and instantiations. Other attribute declarations may be supported by the compiler, but are ignored by XST.

Verilog Meta Comments

Use Verilog meta comments to:

- Set constraints on individual objects such as:
 - module
 - instance
 - net
- Set directives on synthesis:
 - **parallel_case** and **full_case** directives
 - **translate_on** and **translate_off** directives
 - all tool specific directives

Example:

syn_sharing

For more information, see:

[XST Design Constraints](#)

XST supports both C-style and Verilog style meta comments.

Writing Verilog Meta Comments

| Style | Syntax | Line Rules |
|---------------|------------------------|-------------------------------------|
| C-style | <code>/* ... */</code> | Comments can be multiple line |
| Verilog style | <code>// ...</code> | Comments end at the end of the line |

Supported Constraints

XST supports the following constraints:

- [Translate Off \(TRANSLATE_OFF\)](#) and [Translate On \(TRANSLATE_ON\)](#)

```
// synthesis translate_on
// synthesis translate_off
```

- [Parallel Case \(PARALLEL_CASE\)](#)

```
// synthesis parallel_case full_case
// synthesis parallel_case
// synthesis full_case
```

- Constraints on individual objects

Syntax

```
// synthesis attribute [of] ObjectName [is] AttributeValue
```

Coding Example

```
// synthesis attribute RLOC of u123 is R11C1.S0
// synthesis attribute HUSER u1 MY_SET
// synthesis attribute fsm_extract of State2 is "yes"
// synthesis attribute fsm_encoding of State2 is "gray"
```

Verilog Constructs Supported in XST

This section discusses Verilog Constructs Supported in XST, including:

- [Constants](#)
- [Data Types](#)
- [Continuous Assignments](#)
- [Procedural Assignments](#)
- [Design Hierarchies](#)
- [Compiler Directives](#)

Note XST does not allow underscores as the first character of signal names (for example, `_DATA_1`)

Verilog Constants Supported in XST

| Constant | Supported/Unsupported |
|-------------------|-----------------------|
| Integer Constants | Supported |
| Real Constants | Supported |
| Strings Constants | Unsupported |

Verilog Data Types Supported in XST

XST supports all Verilog data types except as shown in the following table.

| Net Types | Drive Strengths | Registers | Named Events |
|--|----------------------------------|--|-----------------------------------|
| <code>tri0</code> , <code>tri1</code> , and <code>trireg</code> are unsupported. | All drive strengths are ignored. | Real and realtime registers are unsupported. | All named events are unsupported. |

Verilog Continuous Assignments Supported in XST

| Continuous Assignment | Supported/Unsupported |
|-----------------------|-----------------------|
| Drive Strength | Ignored |
| Delay | Ignored |

Verilog Procedural Assignments Supported in XST

XST supports Verilog Procedural Assignments except as noted below:

- **assign**
Supported with limitations
For more information, see:
[Behavioral Verilog Assign and Deassign Statements](#)
- **deassign**
Supported with limitations.
For more information, see:
[Behavioral Verilog Assign and Deassign Statements](#)
- **force**
Unsupported

- **release**
Unsupported
- **forever** statements
Unsupported
- **repeat** statements
Supported, but repeat value must be constant
- **for** statements
Supported, but bounds must be static
- **delay (#)**
Ignored
- **event (@)**
Unsupported
- **wait**
Unsupported
- **Named Events**
Unsupported
- **Parallel Blocks**
Unsupported
- **Specify Blocks**
Ignored
- **Disable**
Supported except in For and Repeat Loop statements.

Verilog Design Hierarchies Supported in XST

| Design Hierarchy | Supported/Unsupported |
|------------------------|-----------------------|
| module definition | Supported |
| macromodule definition | Unsupported |
| hierarchical names | Unsupported |
| defparam | Supported |
| array of instances | Supported |

Verilog Compiler Directives Support in XST

| Compiler Directive | Supported/Unsupported |
|--|-----------------------|
| 'celldefine 'endcelldefine | Ignored |
| 'default_nettype | Supported |
| 'define | Supported |
| 'ifdef 'else 'endif | Supported |
| 'undef, 'ifndef, 'elsif, | Supported |
| 'include | Supported |
| 'resetall | Ignored |
| 'timescale | Ignored |
| 'unconnected_drive 'nounconnected_drive | Ignored |
| 'uselib | Unsupported |
| 'file, 'line | Supported |

Verilog System Tasks and Functions Supported in XST

This section discusses Verilog System Tasks and Functions Supported in XST, and includes:

- [Supported System Tasks and Functions](#)
- [Unsupported System Tasks](#)
- [Signed and Unsigned System Tasks](#)
- [Readmemb and Readmemh System Tasks](#)
- [Other System Tasks](#)
- [Verilog Display Syntax Example](#)

Supported System Tasks and Functions

| System Task or Function | Supported/Unsupported | Comment |
|-------------------------|-----------------------|---|
| \$display | Supported | Escape sequences are limited to %d, %b, %h, %o, %c and %s |
| \$fclose | Supported | |
| \$fdisplay | Supported | |
| \$fgets | Supported | |
| \$finish | Supported | \$finish is supported for statically never active conditional branches only |
| \$fopen | Supported | |
| \$fscanf | Supported | Escape sequences are limited to %b and %d |
| \$fwrite | Supported | |
| \$monitor | Ignored | |
| \$random | Ignored | |
| \$readmemb | Supported | |
| \$readmemh | Supported | |
| \$signed | Supported | |
| \$stop | Ignored | |
| \$strobe | Ignored | |
| \$time | Ignored | |
| \$unsigned | Supported | |
| \$write | Supported | Escape sequences are limited to %d, %b, %h, %o, %c and %s |
| all others | Ignored | |

Unsupported System Tasks

The XST Verilog compiler ignores unsupported system tasks.

Signed and Unsigned System Tasks

The `$signed` and `$unsigned` system tasks can be called on any expression using the following syntax:

- `$signed(expr)` or
- `$unsigned(expr)`

The return value from these calls is the same size as the input value. Its sign is forced regardless of any previous sign.

Readmemb and Readmemh System Tasks

The `$readmemb` and `$readmemh` system tasks can be used to initialize block memories.

For more information, see:

[Initializing RAM From an External File Coding Examples](#)

Use `$readmemb` for binary and `$readmemh` for hexadecimal representation. To avoid the possible difference between XST and simulator behavior, Xilinx® recommends that you use index parameters in these system tasks. See the following coding example.

```
$readmemb("rams_20c.data", ram, 0, 7);
```

Other System Tasks

The remainder of the system tasks can be used to display information to your computer screen and log file during processing, or to open and use a file during synthesis. You must call these tasks from within initial blocks. XST supports a subset of escape sequences, specifically:

- `%h`
- `%d`
- `%o`
- `%b`
- `%c`
- `%s`

Verilog Display Syntax Example

The following example shows the syntax for `$display` that reports the value of a binary constant in decimal format:

```
parameter c = 8'b00101010;
initial
begin
    $display ("The value of c is %d", c);
end
```

The following information is written to the log file during the HDL Analysis phase:

```
Analyzing top module <example>.
c = 8'b00101010
"foo.v" line 9: $display : The value of c is 42
```

Verilog Primitives

This section discusses Verilog Primitives, and includes:

- [Supported Primitives](#)
- [Unsupported Primitives](#)
- [Syntax](#)

Supported Primitives

XST supports the following Verilog gate-level primitives except as indicated:

- Pulldown and Pullup
Unsupported
- Drive strength and delay
Ignored
- Arrays of primitives
Unsupported

Unsupported Primitives

XST does not support:

- Verilog switch-level primitives, such as:
 - cmos, nmos, pmos, rcmos, rnmos, rpmos
 - rtran, rtranif0, rtranif1, tran, tranif0, tranif1
- Verilog user-defined primitives

Syntax

gate_type instance_name (output, inputs,...);

Coding Example

```
and U1 (out, in1, in2); bufif1 U2 (triout, data, trienable);
```

Verilog Reserved Keywords

Keywords marked with an asterisk (*) are reserved by Verilog, but are not supported by XST.

| | | | |
|------------------------|-----------------------|-------------------|--------------|
| always | and | assign | automatic |
| begin | buf | bufif0 | bufif1 |
| case | casex | casez | cell* |
| cmos | config* | deassign | default |
| defparam | design* | disable | edge |
| else | end | endcase | endconfig* |
| endfunction | endgenerate | endmodule | endprimitive |
| endspecify | endtable | endtask | event |
| for | force | forever | fork |
| function | generate | genvar | highz0 |
| highz1 | if | ifnone | incdir* |
| include* | initial | inout | input |
| instance* | integer | join | large |
| liblist* | library* | localparam* | macromodule |
| medium | module | nand | negege |
| nmos | nor | noshow-cancelled* | not |
| notif0 | notif1 | or | output |
| parameter | pmos | posedge | primitive |
| pull0 | pull1 | pullup | pulldown |
| pulsestyle- _ondetect* | pulsestyle- _onevent* | rcmos | real |
| realtime | reg | release | repeat |
| rnmos | rpmos | rtran | rtranif0 |
| rtranif1 | scalared | show-cancelled* | signed |
| small | specify | specparam | strong0 |
| strong1 | supply0 | supply1 | table |
| task | time | tran | tranif0 |
| tranif1 | tri | tri0 | tri1 |
| triand | trior | trireg | use* |
| vectored | wait | wand | weak0 |
| weak1 | while | wire | wor |
| xnor | xor | | |

Verilog-2001 Support in XST

XST supports the following Verilog-2001 features:

- Generate statements
- Combined port/data type declarations
- ANSI-style port lists
- Module parameter port lists
- ANSI C style task/function declarations
- Comma separated sensitivity list
- Combinatorial logic sensitivity
- Default nets with continuous assigns
- Disable default net declarations
- Indexed vector part selects
- Multi-dimensional arrays
- Arrays of net and real data types
- Array bit and part selects
- Signed reg, net, and port declarations
- Signed based integer numbers
- Signed arithmetic expressions
- Arithmetic shift operators
- Automatic width extension past 32 bits
- Power operator
- N sized parameters
- Explicit in-line parameter passing
- Fixed local parameters
- Enhanced conditional compilation
- File and line compiler directives
- Variable part selects
- Recursive Tasks and Functions
- Constant Functions

For more information, see:

- Sutherland, Stuart. *Verilog 2001: A Guide to the New Features of the VERILOG Hardware Description Language* (2002)
- IEEE Standards Association. *1364-2001: IEEE Standard Verilog Hardware Description Language* (2001)

XST Behavioral Verilog Language Support

This chapter discusses XST Behavioral Verilog Language Support, and includes:

- Behavioral Verilog Variable Declarations
- Behavioral Verilog Initial Values
- Behavioral Verilog Local Reset
- Behavioral Verilog Arrays
- Behavioral Verilog Multi-Dimensional Arrays
- Behavioral Verilog Data Types
- Behavioral Verilog Legal Statements
- Behavioral Verilog Expressions
- Behavioral Verilog Blocks
- Behavioral Verilog Modules
- Behavioral Verilog Module Declarations
- Behavioral Verilog Continuous Assignments
- Behavioral Verilog Procedural Assignments
- Behavioral Verilog Constants
- Behavioral Verilog Macros
- Behavioral Verilog Include Files
- Behavioral Verilog Comments
- Behavioral Verilog Generate Statements

Behavioral Verilog Variable Declarations

Variables in Verilog may be declared as integers or real. These declarations are intended for use in test code only. Verilog provides data types such as **reg** and **wire** for actual hardware description.

Variables in Verilog

| Data Type | Variable Given Value In | Default Width | Verilog-2001 |
|-------------|-------------------------|------------------|--------------------|
| reg | procedural block | one bit (scalar) | signed or unsigned |
| wire | continuous assignment | one bit (scalar) | signed or unsigned |

Coding Example

To specify an *N-bit* width (vectors) for a declared **reg** or **wire**, the left and right bit positions are defined in square brackets separated by a colon.

```
reg [3:0] arb_priority;  
wire [31:0] arb_request;  
wire signed [8:0] arb_signed;
```

where

- **arb_request[31]** is the MSB
- **arb_request[0]** is the LSB

Behavioral Verilog Initial Values

In Verilog-2001, you can initialize registers when you declare them.

The value:

- Is a constant
- Cannot depend on earlier initial values
- Cannot be a function or task call
- Can be a parameter value propagated to the register
- Specifies all bits of a vector

When you assign a register an initial value in a declaration, XST sets this initial value on the output of the register:

- At global reset, or
- At power up

An initial value assigned in this manner:

- Is carried in the NGC file as an INIT attribute on the register
- Is independent of any local reset

```
reg arb_onebit = 1'b0;  
reg [3:0] arb_priority = 4'b1011;
```

You can also assign a set/reset (initial) value to a register in the behavioral Verilog code. Assign a value to a register when the register reset line goes to the appropriate value as shown in the following coding example.

```
always @(posedge clk)  
begin  
    if (rst)  
        arb_onebit <= 1'b0;  
    end  
end
```

When you set the initial value of a variable in the behavioral code, it is implemented in the design as a flip-flop whose output can be controlled by a local reset. As such, it is carried in the NGC file as an FDP or FDC flip-flop.

Behavioral Verilog Local Reset

Local reset is independent of global reset. Registers controlled by a local reset may be set to a different value than ones whose value is only reset at global reset (power up). In the following coding example, the register, **arb_onebit**, is set to **0** at global reset, but a pulse on the local reset (**rst**) can change its value to **1**.

Coding Example

```
module mult(clk, rst, A_IN, B_OUT);
  input clk,rst,A_IN;
  output B_OUT;

  reg arb_onebit = 1'b0;

  always @(posedge clk or posedge rst)
  begin
    if (rst)
      arb_onebit <= 1'b1;
    else
      arb_onebit <= A_IN;
    end
  end
  B_OUT <= arb_onebit;
endmodule
```

This sets the set/reset value on the register output at initial power up, but since this is dependent upon a local reset, the value changes whenever the local set/reset is activated.

Behavioral Verilog Arrays

Verilog allows arrays of **reg** and **wires** to be defined as shown in the following coding examples.

Behavioral Verilog Arrays Coding Example

The following coding example describes an array of 32 elements each, 4 bits wide which can be assigned in *behavioral* Verilog code:

```
reg [3:0] mem_array [31:0];
```

Structural Verilog Arrays Coding Example

The following coding example describes an array of 64 elements each 8 bits wide which can be assigned only in *structural* Verilog code:

```
wire [7:0] mem_array [63:0];
```

Behavioral Verilog Multi-Dimensional Arrays

XST supports multi-dimensional array types of up to two dimensions. Multi-dimensional arrays can be any net or any variable data type. You can code assignments and arithmetic operations with arrays, but you cannot select more than one element of an array at one time. You cannot pass multi-dimensional arrays to system tasks or functions, or to regular tasks or functions.

Coding Example One

The following Verilog coding example describes an array of 256 x 16 wire elements each 8 bits wide, which can be assigned only in *structural* Verilog code:

```
wire [7:0] array2 [0:255][0:15];
```

Coding Example Two

The following Verilog coding example describes an array of 256 x 8 register elements, each 64 bits wide, which can be assigned in *behavioral* Verilog code:

```
reg [63:0] regarray2 [255:0][7:0];
```

Behavioral Verilog Data Types

This section discusses Behavioral Verilog Data Types, and includes:

- [Bit Data Type Values](#)
- [Supported Verilog Data Types](#)
- [Nets and Registers](#)

Bit Data Type Values

The Verilog representation of the bit data type contains the following values:

- **0**
logic zero
- **1**
logic one
- **x**
unknown logic value
- **z**
high impedance

Supported Verilog Data Types

XST supports the following Verilog data types:

- Net
 - **wire**
 - **tri**
 - **triand/wand**
 - **trior/wor**
- Registers
 - **reg**
 - **integer**
- Supply nets
 - **supply0**
 - **supply1**
- Constants
 - parameter**
- Multi-Dimensional Arrays (Memories)

Nets and Registers

Nets and registers can be either:

- Single bit (scalar)
- Multiple bit (vectors)

Coding Example

The following Behavioral Verilog coding example shows sample Verilog data types found in the declaration section of a Verilog module.

```
wire net1; // single bit net
reg r1; // single bit register
tri [7:0] bus1; // 8 bit tristate bus
reg [15:0] bus1; // 15 bit register
reg [7:0] mem[0:127]; // 8x128 memory register
parameter state1 = 3'b001; // 3 bit constant
parameter component = "TMS380C16"; // string
```

Behavioral Verilog Legal Statements

The following statements are legal in Behavioral Verilog.

- Variable and signal assignments
 - *Variable* = expression
 - **if** (condition) statement
 - **else** statement
 - **case** (expression)

```
expression: statement
...
default: statement
endcase
```
 - **for** (variable = expression; condition; variable = variable + expression) statement
 - **while** (condition) statement
 - **forever** statement
 - functions and tasks
- All variables are declared as **integer** or **reg**.

Note A variable cannot be declared as a **wire**.

Behavioral Verilog Expressions

An expression involves constants and variables with arithmetic, logical, relational, and conditional operators as shown in *Operators Supported in Behavioral Verilog*.

The logical operators are further divided as bit-wise versus logical, depending on whether it is applied to an expression involving several bits or a single bit.

Operators Supported in Behavioral Verilog

| Arithmetic | Logical | Relational | Conditional |
|------------|---------|------------|-------------|
| + | & | < | ? |
| - | && | == | |
| * | | === | |
| ** | | <= | |
| / | ^ | >= | |
| % | ~ | > | |
| | ~^ | != | |
| | ^~ | != | |
| | << | > | |
| | >> | | |
| | <<< | | |
| | >>> | | |

Expressions Supported in Behavioral Verilog

| Expression | Symbol | Supported/Unsupported |
|----------------|--|--|
| Concatenation | {} | Supported |
| Replication | {} | Supported |
| Arithmetic | +, -, **, * | Supported |
| / | Supported only if second operand is a power of 2 | |
| Modulus | % | Supported only if second operand is a power of 2 |
| Addition | + | Supported |
| Subtraction | - | Supported |
| Multiplication | * | Supported |

| Expression | Symbol | Supported/Unsupported |
|----------------------|--------------|--|
| Power | ** | Supported <ul style="list-style-type: none"> Both operands are constants, with the second operand being non-negative. If the first operand is a 2, then the second operand may be a variable. XST does not support the real data type. Any combination of operands that results in a real type causes an error. The values X (unknown) and Z (high impedance) are not allowed. |
| Division | / | Supported XST generates incorrect logic for the division operator between signed and unsigned constants. Example: <code>-1235/3'b111</code> |
| Relational | >, <, >=, <= | Supported |
| Logical Negation | ! | Supported |
| Logical AND | && | Supported |
| Logical OR | | Supported |
| Logical Equality | == | Supported |
| Logical Inequality | != | Supported |
| Case Equality | === | Supported |
| Case Inequality | !== | Supported |
| Bitwise Negation | ~ | Supported |
| Bitwise AND | & | Supported |
| Bitwise Inclusive OR | | Supported |
| Bitwise Exclusive OR | ^ | Supported |
| Bitwise Equivalence | ~^, ^~ | Supported |
| Reduction AND | & | Supported |
| Reduction NAND | ~& | Supported |
| Reduction OR | | Supported |
| Reduction NOR | ~ | Supported |
| Reduction XOR | ^ | Supported |
| Reduction XNOR | ~^, ^~ | Supported |
| Left Shift | << | Supported |
| Right Shift Signed | >>> | Supported |
| Left Shift Signed | <<< | Supported |
| Right Shift | >> | Supported |
| Conditional | ?: | Supported |
| Event OR | or, '' | Supported |

Results of Evaluating Expressions in Behavioral Verilog

The following table lists the results of evaluating expressions using the more frequently used operators supported by XST.

The (`===`) and (`!==`) operators are special comparison operators useful in simulations to check if a variable is assigned a value of (`x`) or (`z`). They are treated as (`==`) or (`!=`) in synthesis.

| a b | a==b | a===b | a!=b | a!==b | a&b | a&&b | a b | a b | a^b |
|-----|------|-------|------|-------|-----|------|-----|------|-----|
| 0 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 0 x | x | 0 | x | 1 | 0 | 0 | x | x | x |
| 0 z | x | 0 | x | 1 | 0 | 0 | x | x | x |
| 1 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 |
| 1 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 0 |
| 1 x | x | 0 | x | 1 | x | x | 1 | 1 | x |
| 1 z | x | 0 | x | 1 | x | x | 1 | 1 | x |
| x 0 | x | 0 | x | 1 | 0 | 0 | x | x | x |
| x 1 | x | 0 | x | 1 | x | x | 1 | 1 | x |
| x x | x | 1 | x | 0 | x | x | x | x | x |
| x z | x | 0 | x | 1 | x | x | x | x | x |
| z 0 | x | 0 | x | 1 | 0 | 0 | x | x | x |
| z 1 | x | 0 | x | 1 | x | x | 1 | 1 | x |
| z x | x | 0 | x | 1 | x | x | x | x | x |
| z z | x | 1 | x | 0 | x | x | x | x | x |

Behavioral Verilog Blocks

Block statements are used to group statements together.

XST supports sequential blocks only. Within these blocks, the statements are executed in the order listed.

Block statements are designated by **begin** and **end** keywords.

XST does not support parallel blocks.

Behavioral Verilog Modules

In Verilog a design component is represented by a module. The connections between components are specified within module instantiation statements. Such a statement specifies an instance of a module. Each module instantiation statement has a name (instance name). In addition to the name, a module instantiation statement contains an association list that specifies which actual nets or ports are associated with which local ports (formals) of the module declaration.

All procedural statements occur in blocks that are defined inside modules. The two kinds of procedural blocks are:

- **initial** block
- **always** block

Within each block, Verilog uses a **begin** and **end** to enclose the statements. Since **initial** blocks are ignored during synthesis, only **always** blocks are discussed. The **always** blocks usually take the following format:

```
always
  begin
    statement
    . . . .
  end
```

Each statement is a procedural assignment line terminated by a semicolon.

Behavioral Verilog Module Declarations

The I/O ports of the circuit are declared in the module declaration. Each port has:

- A name
- A mode
 - **in**
 - **out**
 - **inout**

The input and output ports defined in the module declaration called EXAMPLE in the following coding example are the basic input and output I/O signals for the design. The in-out port in Verilog is analogous to a bi-directional I/O pin on the device with the data flow for output versus input being controlled by the enable signal to the tristate buffer.

The following coding example describes E as a tristate buffer with a high-true output enable signal.

- If **oe = 1**, the value of signal A is output on the pin represented by E.
- If **oe = 0**, the buffer is in high impedance (Z), and any input value driven on the pin E (from the external logic) is brought into the device and fed to the signal represented by D.

Coding Example

```
module EXAMPLE (A, B, C, D, E);
    input A, B, C;
    output D;
    inout E;
    wire D, E;
    ...
    assign E = oe ? A : 1'bz;
    assign D = B & E;
    ...
endmodule
```

Behavioral Verilog Continuous Assignments

Continuous assignments model combinatorial logic in a concise way.

XST supports both *explicit* and *implicit* continuous assignments.

- *Explicit* continuous assignments are introduced by the **assign** keyword after the net has been separately declared.
- *Implicit* continuous assignments combine declaration and assignment.
- XST ignores delays and strengths given to a continuous assignment.
- Continuous assignments are allowed on **wire** and **tri** data types only.

***Explicit* Continuous Assignment Coding Example**

```
wire par_eq_1;  
....  
assign par_eq_1 = select ? b : a;
```

***Implicit* Continuous Assignment Coding Example**

```
wire temp_hold = a | b;
```

Behavioral Verilog Procedural Assignments

This section discusses Behavioral Verilog Procedural Assignments, and includes:

- [About Behavioral Verilog Procedural Assignments](#)
- [Behavioral Verilog Combinatorial Always Blocks](#)
- [Behavioral Verilog If... Else Statement](#)
- [Behavioral Verilog Case Statements](#)
- [Behavioral Verilog For and Repeat Loops](#)
- [Behavioral Verilog While Loops](#)
- [Behavioral Verilog Sequential Always Blocks](#)
- [Behavioral Verilog Assign and Deassign Statements](#)
- [Behavioral Verilog Assignment Extension Past 32 Bits](#)
- [Behavioral Verilog Tasks and Functions](#)
- [Behavioral Verilog Recursive Tasks and Functions](#)
- [Behavioral Verilog Constant Functions](#)
- [Behavioral Verilog Blocking Versus Non-Blocking Procedural Assignments](#)

About Behavioral Verilog Procedural Assignments

Behavioral Verilog procedural assignments are:

- Used to assign values to variables declared as regs.
- Introduced by always blocks, tasks, and functions
- Usually used to model registers and Finite State Machine (FSM) components.

XST supports:

- Combinatorial functions
- Combinatorial and sequential tasks
- Combinatorial and sequential always blocks

Behavioral Verilog Combinatorial Always Blocks

Combinatorial logic can be modeled efficiently using two forms of Verilog time control statements:

- # (pound)
- * (asterisk)

Since the # (pound) time control statement is ignored for synthesis, this discussion describes modeling combinatorial logic with the * (asterisk) time control statement.

A combinatorial **always** block has a sensitivity list appearing within parentheses after the word **always**. An **always** block is activated if an event (value change or edge) appears on one of the sensitivity list signals. This sensitivity list can contain any signal that appears in conditions (**if** or **case**, for example), and any signal appearing on the right-hand side of an assignment. By substituting an * (asterisk) without parentheses for a list of signals, the **always** block is activated for an event in any of the **always** block's signals as described above.

In combinatorial processes, if a signal is not explicitly assigned in all branches of **if** or **case** statements, XST generates a latch to hold the last value. To avoid latch creation, be sure that all assigned signals in a combinatorial process are always explicitly assigned in all paths of the process statements.

The following statements can be used in a process:

- Variable and signal assignment
- **if...else** statement
- **case** statement
- **for** and **while loop** statement
- Function and task call

Behavioral Verilog If... Else Statement

If... **else** statements use **true/false** conditions to execute statements.

- If the expression evaluates to **true**, the first statement is executed.
- If the expression evaluates to **false** (or **x** or **z**) the **else** statement is executed.

A block of multiple statements may be executed using **begin** and **end** keywords.

If... **else** statements may be nested.

Coding Example

The following coding example shows how a MUX can be described using an **if... else** statement:

```

module mux4 (sel, a, b, c, d, outmux);
input [1:0] sel;
input [1:0] a, b, c, d;
output [1:0] outmux;
reg [1:0] outmux;

    always @(sel or a or b or c or d)
    begin
        if (sel[1])
            if (sel[0])
                outmux = d;
            else
                outmux = c;
        else
            if (sel[0])
                outmux = b;
            else
                outmux = a;
        end
    endmodule

```

Behavioral Verilog Case Statements

A **case** statement:

- Performs a comparison to an expression to evaluate one of a number of parallel branches.
- Evaluates the branches in the order they are written.
 - The first branch that evaluates to **true** is executed.
 - If none of the branches match, the default branch is executed.

Do not use unsized integers in case statements. Always size integers to a specific number of bits, or results can be unpredictable.

casez treats all **z** values in any bit position of the branch alternative as a **dont care**.

casex treats all **x** and **z** values in any bit position of the branch alternative as a **dont care**.

The question mark (?) can be used as a **dont care** in either the **casez** or **casex** case statements.

Coding Example

The following coding example shows how a MUX can be described using a **case** statement:

```
module mux4 (sel, a, b, c, d, outmux);
input [1:0] sel;
input [1:0] a, b, c, d;
output [1:0] outmux;
reg [1:0] outmux;

always @(sel or a or b or c or d)
begin
case (sel)
2'b00: outmux = a;
2'b01: outmux = b;
2'b10: outmux = c;
default: outmux = d;
endcase
end
endmodule
```

The preceding **case** statement evaluates the values of the input **sel** in priority order. To avoid priority processing, Xilinx® recommends that you use a parallel-case Verilog attribute to ensure parallel evaluation of the **sel** inputs as shown in the following:

```
(* parallel_case *) case(sel)
```

Behavioral Verilog For and Repeat Loops

When using **always** blocks, repetitive or bit slice structures can also be described using the **for** statement or the **repeat** statement.

For Statement

The **for** statement is supported for:

- Constant bounds
- Stop test condition using one of the following operators:
 - <
 - <=
 - >
 - >=
- Next step computation falling in one of the following specifications:
 - *var* = *var* + **step**
 - *var* = *var* - **step**

where

 - ◆ *var* is the loop variable
 - ◆ **step** is a constant value

Repeat Statement

The repeat statement is supported for constant values only.

Disable Statements

Disable statements are not supported.

Coding Example

```

module countzeros (a, Count);
input [7:0] a;
output [2:0] Count;
reg [2:0] Count;
reg [2:0] Count_Aux;
integer i;

always @(a)
begin
    Count_Aux = 3'b0;
    for (i = 0; i < 8; i = i+1)
    begin
        if (!a[i])
            Count_Aux = Count_Aux+1;
        end
    Count = Count_Aux;
end

endmodule

```

Behavioral Verilog While Loops

When using **always** blocks, use the **while** statement to execute repetitive procedures. A **while** loop executes other statements until its test expression becomes **false**. It is not executed if the test expression is initially **false**.

- The test expression is any valid Verilog expression.
- To prevent endless loops, use **-loop_iteration_limit**.
- **while** loops can have **disable** statements. The **disable** statement is used inside a labeled block, since the syntax is **disable <blockname>**.

Coding Example

```

parameter P = 4;
always @(ID_complete)
begin : UNIDENTIFIED
    integer i;
    reg found;
    unidentified = 0;
    i = 0;
    found = 0;
    while (!found && (i < P))
    begin
        found = !ID_complete[i];
        unidentified[i] = !ID_complete[i];
        i = i + 1;
    end
end
end

```

Behavioral Verilog Sequential Always Blocks

Sequential circuit description is based on always blocks with a sensitivity list. The sensitivity list contains a maximum of three edge-triggered events:

- A clock signal event (mandatory)
- A reset signal event (possibly)
- A set signal event

One, and only one, **if...else** statement is accepted in such an **always** block.

An asynchronous part may appear before the synchronous part in the first and the second branch of the **if...else** statement. Signals assigned in the asynchronous part are assigned to the following constant values:

- 0
- 1
- X
- Z
- Any vector composed of these values

These same signals are also assigned in the synchronous part (that is, the last branch of the **if...else** statement). The clock signal condition is the condition of the last branch of the **if...else** statement.

8 Bit Register Using an Always Block Behavioral Verilog Coding Example

```
module seq1 (DI, CLK, DO);
  input [7:0] DI;
  input CLK;
  output [7:0] DO;
  reg [7:0] DO;

  always @(posedge CLK)
    DO <= DI ;
```

8 Bit Register with Asynchronous Reset (High-True) Using an Always Block Behavioral Verilog Coding Example

```
module EXAMPLE (DI, CLK, RST, DO);
  input [7:0] DI;
  input CLK, RST;
  output [7:0] DO;
  reg [7:0] DO;

  always @(posedge CLK or posedge RST)
    if (RST == 1'b1)
      DO <= 8'b00000000;
    else
      DO <= DI;
endmodule
```

8 Bit Counter with Asynchronous Reset (Low-True) Using an Always Block Behavioral Verilog Coding Example

```

module seq2 (CLK, RST, DO);
  input CLK, RST;
  output [7:0] DO;
  reg [7:0] DO;

  always @(posedge CLK or posedge RST)
    if (RST == 1'b1)
      DO <= 8'b00000000;
    else
      DO <= DO + 8'b00000001;
endmodule

```

Behavioral Verilog Assign and Deassign Statements

Assign and deassign statements are supported within simple templates.

Behavioral Verilog Assign and Deassign Statements General Template

```

module assign (RST, SELECT, STATE, CLOCK, DATA_IN);
  input RST;
  input SELECT;
  input CLOCK;
  input [0:3] DATA_IN;
  output [0:3] STATE;
  reg [0:3] STATE;

  always @ (RST)
    if(RST)
      begin
        assign STATE = 4'b0;
      end
    else
      begin
        deassign STATE;
      end

  always @ (posedge CLOCK)
    begin
      STATE <= DATA_IN;
    end
endmodule

```

The main limitations on support of the assign/deassign statement in XST are:

- For a given signal, there is only one assign/deassign statement.
- The assign/deassign statement is performed in the same always block through an if/else statement.
- You cannot assign a bit/part select of a signal through an assign/deassign statement.

Behavioral Verilog Assign/Deassign Statement

For a given signal, there is only one assign/deassign statement. For example, XST rejects the following design:

```

module dflop (RST, SET, STATE, CLOCK, DATA_IN);
    input RST;
    input SET;
    input CLOCK;
    input DATA_IN;
    output STATE;
    reg STATE;

    always @ (RST)           // block b1
        if(RST)
            assign STATE = 1'b0;
        else
            deassign STATE;

    always @ (SET)           // block b1
        if(SET)
            assign STATE = 1'b1;
        else
            deassign STATE;

    always @ (posedge CLOCK) // block b2
        begin
            STATE <= DATA_IN;
        end
endmodule

```

Behavioral Verilog Assign/Deassign Statement Performed in Same Always Block

The assign/deassign statement is performed in the same always block through an **if...else** statement. For example, XST rejects the following design:

```

module dflop (RST, SET, STATE, CLOCK, DATA_IN);
    input RST;
    input SET;
    input CLOCK;
    input DATA_IN;
    output STATE;

    reg STATE;

    always @ (RST or SET)    // block b1
        case ({RST,SET})
            2'b00: assign STATE = 1'b0;
            2'b01: assign STATE = 1'b0;
            2'b10: assign STATE = 1'b1;
            2'b11: deassign STATE;
        endcase

    always @ (posedge CLOCK) // block b2
        begin
            STATE <= DATA_IN;
        end
endmodule

```

Cannot Assign Bit/Part Select of Signal Through Assign/Deassign Statement

You cannot assign a bit/part select of a signal through an assign/deassign statement. For example, XST rejects the following design:

```

module assig (RST, SELECT, STATE, CLOCK, DATA_IN);
    input RST;
    input SELECT;
    input CLOCK;
    input [0:7] DATA_IN;
    output [0:7] STATE;

    reg [0:7] STATE;

    always @ (RST) // block b1
        if(RST)
            begin
                assign STATE[0:7] = 8'b0;
            end
        else
            begin
                deassign STATE[0:7];
            end

    always @ (posedge CLOCK) // block b2
        begin
            if (SELECT)
                STATE [0:3] <= DATA_IN[0:3];
            else
                STATE [4:7] <= DATA_IN[4:7];
        end
end

```

Behavioral Verilog Assignment Extension Past 32 Bits

If the expression on the left-hand side of an assignment is wider than the expression on the right-hand side, the left-hand side is padded to the left according to the following rules:

- If the right-hand expression is signed, the left-hand expression is padded with the sign bit:
 - 0 for positive
 - 1 for negative
 - z for high impedance
 - x for unknown
- If the right-hand expression is unsigned, the left-hand expression is padded with 0(zeros).
- For unsized x or z constants only, the following rule applies. If the value of the right-hand expression's leftmost bit is z (high impedance) or x (unknown), regardless of whether the right-hand expression is signed or unsigned, the left-hand expression is padded with that value (z or x, respectively).

These rules follow the Verilog-2001 standard. They are not backwardly compatible with Verilog-1995.

Behavioral Verilog Tasks and Functions

The declaration of a function or task is intended for handling blocks used multiple times in a design. They must be declared and used in a module. The heading part contains the parameters: input parameters (only) for functions and input/output/inout parameters for tasks. The return value of a function can be declared either signed or unsigned. The content is similar to the combinatorial always block content.

Coding Example One

The following coding example shows a function declared within a module.

- The ADD function declared is a single-bit adder.
- This function is called four times with the proper parameters in the architecture to create a 4-bit adder.

```
module comb15 (A, B, CIN, S, COUT);
    input [3:0] A, B;
    input CIN;
    output [3:0] S;
    output COUT;
    wire [1:0] S0, S1, S2, S3;
    function signed [1:0] ADD;
        input A, B, CIN;
        reg S, COUT;
        begin
            S = A ^ B ^ CIN;
            COUT = (A&B) | (A&CIN) | (B&CIN);
            ADD = {COUT, S};
        end
    endfunction

    assign S0 = ADD (A[0], B[0], CIN),
           S1 = ADD (A[1], B[1], S0[1]),
           S2 = ADD (A[2], B[2], S1[1]),
           S3 = ADD (A[3], B[3], S2[1]),
           S = {S3[0], S2[0], S1[0], S0[0]},

           COUT = S3[1];
endmodule
```

Coding Example Two

The following coding example shows Coding Example One described with a task.

```
module EXAMPLE (A, B, CIN, S, COUT);
    input [3:0] A, B;
    input CIN;
    output [3:0] S;
    output COUT;
    reg [3:0] S;
    reg COUT;
    reg [1:0] S0, S1, S2, S3;

    task ADD;
        input A, B, CIN;
        output [1:0] C;
        reg [1:0] C;
        reg S, COUT;

        begin
            S = A ^ B ^ CIN;
            COUT = (A&B) | (A&CIN) | (B&CIN);
            C = {COUT, S};
        end
    endtask

    always @(A or B or CIN)
    begin
        ADD (A[0], B[0], CIN, S0);
        ADD (A[1], B[1], S0[1], S1);
        ADD (A[2], B[2], S1[1], S2);
        ADD (A[3], B[3], S2[1], S3);
        S = {S3[0], S2[0], S1[0], S0[0]};
        COUT = S3[1];
    end
endmodule
```

Behavioral Verilog Recursive Tasks and Functions

Verilog-2001 supports recursive tasks and functions.

You can use recursion only with the **automatic** keyword.

To prevent endless recursive calls, the number of recursions is limited by default to 64. Use **-recursion_iteration_limit** to control the number of allowed recursive calls.

Coding Example

```
function automatic [31:0] fac;
input [15:0] n;
if (n == 1)
    fac = 1;
else
    fac = n * fac(n-1); //recursive function call
endfunction
```

Behavioral Verilog Constant Functions

Verilog-2001 adds support for constant functions. XST supports function calls to calculate constant values.

Coding Example

```
module rams_cf (clk, we, a, di, do);
parameter DEPTH=1024;
input clk;
input we;
input [4:0] a;
input [3:0] di;
output [3:0] do;

reg [3:0] ram [size(DEPTH):0];

always @(posedge clk) begin
if (we)
ram[a] <= di;
end
assign do = ram[a];

function integer size;
input depth;
integer i;
begin
size=1;
for (i=0; 2**i<depth; i=i+1)
size=i+1;
end
endfunction

endmodule
```

Behavioral Verilog Blocking Versus Non-Blocking Procedural Assignments

The pound (#) and at symbol (@) time control statements delay execution of the statement following them until the specified event is evaluated as true. Blocking and non-blocking procedural assignments have time control built into their respective assignment statement. The pound (#) delay is ignored for synthesis.

Behavioral Verilog *Blocking* Procedural Assignment Syntax Example

The syntax for a *blocking* procedural assignment is shown in the following example.

```
reg a; a = #10 (b | c);
```

or

```
if (in1) out = 1'b0; else out = in2;
```

As the name implies, these types of assignments block the current process from continuing to execute additional statements at the same time. These should mainly be used in simulation.

Non-blocking assignments, on the other hand, evaluate the expression when the statement executes, but allow other statements in the same process to execute as well at the same time. The variable change occurs only after the specified delay.

Behavioral Verilog *Non-Blocking* Procedural Assignment Syntax Example

The following syntax example shows the syntax for a *non-blocking* procedural assignment.

```
variable <= @(posedge_or_negedge_bit) expression;
```

Coding Example

The following coding example shows how to use a non-blocking procedural assignment.

```
if (in1) out <= 1'b1; else out <= in2;
```

Behavioral Verilog Constants

By default, constants in Verilog are assumed to be decimal integers. They can be specified explicitly in binary, octal, decimal, or hexadecimal by prefacing them with the appropriate syntax. For example, the following all represent the same value:

- 4'b1010
- 4'o12
- 4'd10
- 4'ha

Behavioral Verilog Macros

Verilog provides a way to define macros as shown in the following coding example.

```
`define TESTEQ1 4'b1101
```

Later in the design code, a reference to the defined macro is made as follows:

```
if (request == `TESTEQ1)
```

This is shown in the following coding example.

```
`define myzero 0  
assign mysig = `myzero;
```

The Verilog **'ifdef** and **'endif** constructs determine whether or not a macro is defined. These constructs are used to define conditional compilation. If the macro called out by the **'ifdef** command has been defined, that code is compiled. If not, the code following the **'else** command is compiled. The **'else** is not required, but **'endif** must complete the conditional statement.

The **'ifdef** and **'endif** constructs are shown in the following coding example.

```
`ifdef MYVAR  
module if_MYVAR_is_declared;  
...  
endmodule  
'else  
module if_MYVAR_is_not_declared;  
...  
endmodule  
'endif
```

Verilog Macros (-define) allows you to define (or redefine) Verilog macros. This allows you to easily modify the design configuration without any Hardware Description Language (HDL) source modifications, such as for IP core generation and testing flows.

Behavioral Verilog Include Files

Verilog allows you to separate source code into more than one file. To reference the code contained in another file, use the following syntax in the current file:

```
'include "path/file-to-be-included"
```

The path can be relative or absolute.

Multiple **'include** statements are allowed in a single Verilog file. This feature makes your code more manageable in a team design environment where different files describe different modules of the design.

Identifying the Directory

To enable the file in your **'include** statement to be recognized, identify the directory where it resides, either to ISE® Design Suite or to XST.

- Since ISE Design Suite searches the ISE Design Suite project directory by default, adding the file to your project directory identifies the file to ISE Design Suite
- To direct ISE Design Suite to a different directory, include a path (relative or absolute) in the **'include** statement in your source code.
- To point XST directly to your include file directory, use [Verilog Include Directories \(-vlgindir\)](#)
- If the **'include** file is required for ISE Design Suite to construct the design hierarchy, the file *need not* be added to the project, but the file must either:
 - Reside in the project directory
 - or*
 - Be referenced by a relative or absolute path

Include File Conflicts

Conflicts may occur when the specified file:

- Has been added to an ISE Design Suite project directory
- and*
- Is specified with **'include**

Coding Example

```
`timescale 1 ns/1 ps
`include "modules.v"
...
```

XST issues an error message:

```
ERROR:Xst:1068 - fifo.v, line 2. Duplicate declarations of
module'RAMB4_S8_S8'
```

Behavioral Verilog Comments

Behavioral Verilog supports two forms of comments as shown in the following table. Behavioral Verilog comments are similar to the comments used in a language such as C++.

| Symbol | Description | Used for | Example |
|--------|----------------------|---------------------|---|
| // | Double forward slash | One-line comments | // Define a one-line comment as illustrated by this sentence |
| /* | Slash asterisk | Multi-line comments | /* Define a multi-line comment by enclosing it as illustrated by this sentence */ |

Behavioral Verilog Generate Statements

A **generate** statement allows you to dynamically create Verilog code from conditional statements. This allows you to create repetitive structures or structures that are appropriate only under certain conditions.

Structures likely to be created using a **generate** statement are:

- Primitive or module instances
- Initial or always procedural blocks
- Continuous assignments
- Net and variable declarations
- Parameter redefinitions
- Task or function definitions

Generate For Statements

Use a Behavioral Verilog **generate for** loop to create one or more instances that can be placed inside a module. Use the **generate for** loop the same way you would a normal Verilog **for** loop, with the following limitations:

- The index for a **generate for** loop has a *genvar* variable.
- The assignments in the **for** loop control refers to the *genvar* variable.
- The contents of the **for** loop are enclosed by **begin** and **end** statements. The **begin** statement is named with a unique qualifier.

Coding Example

Following is an 8-bit adder using a generate for loop behavioral Verilog coding example.

```
generate
genvar i;

    for (i=0; i<=7; i=i+1)
        begin : for_name
            adder add (a[8*i+7 : 8*i], b[8*i+7 : 8*i],          ci[i], sum_for[8*i+7 : 8*i], c0_or[i+1]);    end
        endgenerate
```

Generate If... else Statements

Use a Behavioral Verilog **generate if... else** statement inside a **generate** block to conditionally control which objects are generated.

Coding Example

In the following coding example of a **generate if... else** statement:

- **generate** controls the type of multiplier that is instantiated
- The contents of each branch of the **if... else** statement are enclosed by **begin** and **end** statements.
- The **begin** statement is named with a unique qualifier.

```
generate
  if (IF_WIDTH < 10)
    begin : if_name
      adder # (IF_WIDTH) u1 (a, b, sum_if);
    end
  else
    begin : else_name
      subtractor # (IF_WIDTH) u2 (a, b, sum_if);
    end
endgenerate
```

Generate Case Statements

Use a Behavioral Verilog **generate case** statement inside a **generate** block to conditionally control which objects are generated. Use a **generate case** statement when there are several conditions to be tested to determine what the generated code would be.

- Each test statement in a **generate case** is enclosed by **begin** and **end** statements.
- The **begin** statement is named with a unique qualifier.

Coding Example

In the following coding example of a **generate case** statement, **generate** controls the type of adder that is instantiated:

```
generate
  case (WIDTH)
    1:
      begin : case1_name
        adder #(WIDTH*8) x1 (a, b, ci, sum_case, c0_case);
      end
    2:
      begin : case2_name
        adder #(WIDTH*4) x2 (a, b, ci, sum_case, c0_case);
      end
    default:
      begin : d_case_name
        adder x3 (a, b, ci, sum_case, c0_case);
      end
  endcase
endgenerate
```

XST Mixed Language Support

This chapter discusses XST Mixed Language Support, and includes:

- [About XST Mixed Language Support](#)
- [Mixed Language Project Files](#)
- [VHDL and Verilog Boundary Rules in Mixed Language Projects](#)
- [Port Mapping in Mixed Language Projects](#)
- [Generics Support in Mixed Language Projects](#)
- [LSO Files in Mixed Language Projects](#)

About XST Mixed Language Support

XST supports mixed VHDL and Verilog projects.

- Mixing VHDL and Verilog is restricted to design unit (cell) instantiation only.
 - A VHDL design can instantiate a Verilog module.
 - A Verilog design can instantiate a VHDL entity.
 - No other mixing between VHDL and Verilog is not supported.
- In a VHDL design, a restricted subset of VHDL types, generics, and ports is allowed on the boundary to a Verilog module.
- In a Verilog design, a restricted subset of Verilog types, parameters, and ports is allowed on the boundary to a VHDL entity or configuration.
- XST binds VHDL design units to a Verilog module during Elaboration.
- Component instantiation based on default binding is used for binding Verilog modules to a VHDL design unit.
- Configuration specification, direct instantiation and component configurations are not supported for a Verilog module instantiation in VHDL.
- VHDL and Verilog project files are unified.
- VHDL and Verilog libraries are logically unified.
- Specification of the work directory for compilation (`xsthdpdir`), previously available only for VHDL, is now available for Verilog.
- The `xhdp.ini` mechanism for mapping a logical library name to a physical directory name on the host file system, previously available only for VHDL, is now available for Verilog.
- Mixed language projects accept a search order used for searching unified logical libraries in design units (cells). During Elaboration, XST follows this search order for picking and binding a VHDL entity or a Verilog module to the mixed language project.

Mixed Language Project Files

XST uses dedicated mixed language project files to support mixed VHDL and Verilog designs. You can use this mixed language format not only for mixed projects, but also for purely VHDL or Verilog projects.

- If you run XST from ISE® Design Suite, XST creates the project file. It is always a mixed language project file.
- If you run XST from the command line, you must create the mixed language project file yourself.

| Project Type | Set -ifmt to |
|--------------|-------------------------------|
| command line | <i>mixed</i> or value omitted |
| VHDL | <i>vhdl</i> |
| Verilog | <i>verilog</i> |

The VHDL and Verilog formats can be used for existing designs.

The syntax for invoking a library or any external file in a mixed language project is:

language library file_name.ext

Coding Example

The following example shows how to invoke libraries in a mixed language project.

```
vhdl      work      my_vhdl1.vhd
verilog   work      my_vlg1.v
vhdl      my_vhdl_lib my_vhdl2.vhd
verilog   my_vlg_lib my_vlg2.v
```

- Each row specifies a single Hardware Description Language (HDL) design file.
- Each column has the meaning shown in the following table.

| Column | Syntax | Example | Specifies |
|--------|---------------|--------------|---|
| First | language | vhdl | Whether the HDL file is VHDL or Verilog |
| Second | library | work | The logic library where the HDL is compiled. The default logic library is work . |
| Third | file_name.ext | my_vhdl1.vhd | The name of the HDL file. |

VHDL and Verilog Boundary Rules in Mixed Language Projects

The boundary between VHDL and Verilog is enforced at the design unit level.

A VHDL design can instantiate a Verilog module.

A Verilog design can instantiate a VHDL entity.

Instantiating a Verilog Module in a VHDL Design

To instantiate a Verilog module in a VHDL design:

1. Declare a VHDL component with the same name (respecting case sensitivity) as the Verilog module you want to instantiate. If the Verilog module name is not all lowercase, use the **case** property to preserve the case of your Verilog module.
 - a. In ISE® Design Suite, select:
Process > Process Properties > Synthesis Options > Case > Maintain
or
 - b. Set the **-case** command line option to **maintain**
2. Instantiate the Verilog component as if you were instantiating a VHDL component.

Using a VHDL configuration declaration, you could attempt to bind this component to a particular design unit from a particular library. Such binding is not supported. Only default Verilog module binding is supported.

The only Verilog construct that can be instantiated in a VHDL design is a Verilog module. No other Verilog constructs are visible to VHDL code.

During elaboration, all components subject to default binding are regarded as design units with the same name as the corresponding component name. During binding, XST treats a component name as a VHDL design unit name and searches for it in the logical library **work**. If XST finds a VHDL design unit, XST binds it. If XST cannot find a VHDL design unit, it treats the component name as a Verilog module name, and searches for it using a case sensitive search. XST searches for the Verilog module in the user-specified list of unified logical libraries in the user-specified search order.

For more information, see:

[Library Search Order \(LSO\) Files in Mixed Language Projects](#)

XST selects the first Verilog module matching the name, and binds it.

Since libraries are unified, a Verilog cell by the same name as that of a VHDL design unit cannot co-exist in the same logical library. A newly compiled cell/unit overrides a previously compiled one.

Instantiating a VHDL Design Unit in a Verilog Design

This section includes:

- [How to Instantiate a VHDL Entity](#)
- [Binding](#)
- [Limitations](#)

How to Instantiate a VHDL Entity

To instantiate a VHDL entity:

1. Declare a module name with the same as name as the VHDL entity (optionally followed by an architecture name) that you want to instantiate.
2. Perform a normal Verilog instantiation.

The only VHDL construct that can be instantiated in a Verilog design is a VHDL entity. No other VHDL constructs are visible to Verilog code. When you do this, XST uses the entity/architecture pair as the Verilog/VHDL boundary.

Binding

XST performs the binding during elaboration.

XST first:

1. Searches for a Verilog module as follows:
 - Uses the name of the instantiated module.
 - Searches in the user-specified list of unified logical libraries.
 - Searches in the user-specified order.
 - Ignores any architecture name specified in the module instantiation.
2. Binds the name if found.

If XST cannot find a Verilog module, then XST:

1. Treats the name of the instantiated module as a VHDL entity.
2. Searches for the VHDL entity as follows:
 - Performs a case sensitive search
 - Searches in the user-specified list of unified logical libraries
 - Searches in the user-specified order

Note This assumes that a VHDL design unit was stored with an extended identifier.

3. Selects the first VHDL entity matching the name.
4. Binds the entity.

For more information, see:

[Library Search Order \(LSO\) Files in Mixed Language Projects](#)

Limitations

XST has the following limitations when instantiating a VHDL design unit from a Verilog module:

- Use explicit port association. Specify formal and effective port names in the port map.
- All parameters are passed at instantiation, even if they are unchanged.
- The parameter override is named and not ordered. The parameter override occurs through instantiation, and not through defparams.

Correct Use of Parameter Override Coding Example

```
ff #(.init(2'b01)) u1 (.sel(sel), .din(din), .dout(dout));
```

Incorrect Use of Parameter Override Coding Example

XST does not accept the following:

```
ff u1 (.sel(sel), .din(din), .dout(dout));  
defparam u1.init = 2'b01;
```

Port Mapping in Mixed Language Projects

Port Mapping in mixed language projects includes:

- [VHDL in Verilog Port Mapping](#)
- [Verilog in VHDL Port Mapping](#)
- [VHDL in Mixed Language Port Mapping](#)
- [Verilog in Mixed Language Port Mapping](#)

VHDL in Verilog Port Mapping

For VHDL entities instantiated in Verilog designs, XST supports the following port types:

- **in**
- **out**
- **inout**

XST does not support VHDL buffer and linkage ports.

Verilog in VHDL Port Mapping

For Verilog modules instantiated in VHDL designs, XST supports the following port types:

- **input**
- **output**
- **inout**

XST does not support connection to bi-directional pass options in Verilog.

XST does not support unnamed Verilog ports for mixed language boundaries.

Use an equivalent component declaration for connecting to a case sensitive port in a Verilog module. By default, XST assumes Verilog ports are in all lowercase.

VHDL in Mixed Language Port Mapping

XST supports the following VHDL data types for mixed language designs:

- **bit**
- **bit_vector**
- **std_logic**
- **std_ulogic**
- **std_logic_vector**
- **std_ulogic_vector**

Verilog in Mixed Language Port Mapping

XST supports the following Verilog data types for mixed language designs:

- **wire**
- **reg**

Generics Support in Mixed Language Projects

XST supports the following VHDL generic types and their Verilog equivalents for mixed language designs:

- **integer**
- **real**
- **string**
- **boolean**

LSO Files in Mixed Language Projects

The Library Search Order (LSO) file specifies the search order that XST uses to link the libraries used in VHDL and Verilog mixed language designs. By default, XST searches the files specified in the project file in the order in which they appear in that file.

XST uses the default search order when:

- The **DEFAULT_SEARCH_ORDER** keyword is used in the LSO file, or
- The LSO file is not specified

Specifying the LSO File in ISE Design Suite

In ISE® Design Suite, the default name for the Library Search Order (LSO) file is `project_name.lso`. If a `project_name.lso` file does not already exist, ISE Design Suite automatically creates one.

If ISE Design Suite detects an existing `project_name.lso` file, this file is preserved and used as is. In ISE Design Suite, the name of the project is the name of the top-level block. In creating a default LSO file, ISE Design Suite places the **DEFAULT_SEARCH_ORDER** keyword in the first line of the file.

Specifying the LSO File in the Command Line

Library Search Order (LSO) (-lso) specifies the Library Search Order (LSO) file when running XST from the command line. If **-lso** is omitted, XST uses the default library search order without using an LSO file.

LSO Rules

When processing a mixed language project, XST obeys the following search order rules, depending on the contents of the Library Search Order (LSO) file:

- Library Search Order (LSO) Empty
- **DEFAULT_SEARCH_ORDER** Keyword Only
- **DEFAULT_SEARCH_ORDER** Keyword and List of Libraries
- List of Libraries Only
- **DEFAULT_SEARCH_ORDER** Keyword and Non-Existent Library Name"

Library Search Order (LSO) Empty

When the Library Search Order (LSO) file is empty, XST:

- Issues a warning stating that the LSO file is empty
- Searches the files specified in the project file using the default library search order
- Updates the LSO file by adding the list of libraries in the order that they appear in the project file.

DEFAULT_SEARCH_ORDER Keyword Only

When the Library Search Order (LSO) file contains only the **DEFAULT_SEARCH_ORDER** keyword, XST:

- Searches the specified library files in the order in which they appear in the project file
- Updates the LSO file by:
 - Removing the **DEFAULT_SEARCH_ORDER** keyword
 - Adding the list of libraries to the LSO file in the order in which they appear in the project file

For a project file, `my_proj.prj`, with the following contents:

```
vhdl vllib1 f1.vhd verilog rtllib f1.v vhdl vllib2 f3.vhd LSO  
file Created by ProjNav
```

and an LSO file, `my_proj.lso`, created by ISE® Design Suite, with the following contents:

```
DEFAULT_SEARCH_ORDER
```

XST uses the following search order.

```
vllib1 rtllib vllib2
```

After processing, the contents of `my_proj.lso` is:

```
vllib1 rtllib vllib2
```

DEFAULT_SEARCH_ORDER Keyword and List of Libraries

When the Library Search Order (LSO) file contains the **DEFAULT_SEARCH_ORDER** keyword, and a list of the libraries, XST:

- Searches the specified library files in the order in which they appear in the project file
- Ignores the list of library files in the LSO file
- Leaves the LSO file unchanged

For a project file, `my_proj.prj`, with the following contents:

```
vhdl vllib1 f1.vhd verilog rtllib f1.v vhdl vllib2 f3.vhd
```

and an LSO file, `my_proj.lso`, created with the following contents:

```
rtllib vllib2 vllib1 DEFAULT_SEARCH_ORDER
```

XST uses the following search order:

```
vllib1 rtllib vllib2
```

After processing, the contents of `my_proj.lso` is:

```
rtllib vllib2 vllib1 DEFAULT_SEARCH_ORDER
```

List of Libraries Only

When the Library Search Order (LSO) file contains a list of the libraries without the **DEFAULT_SEARCH_ORDER** keyword, XST:

- Searches the library files in the order in which they appear in the LSO file
- Leaves the LSO file unchanged

For a project file, `my_proj.prj`, with the following contents:

```
vhdl vllib1 f1.vhd verilog rtllib f1.v vhdl vllib2 f3.vhd
```

and an LSO file, `my_proj.lso`, created with the following contents:

```
rtfllib vllib2 vllib1
```

XST uses the following search order:

```
rtfllib vllib2 vllib1
```

After processing, the contents of `my_proj.lso` is:

```
rtfllib vllib2 vllib1
```

DEFAULT_SEARCH_ORDER Keyword and Non-Existent Library Name

When the Library Search Order (LSO) file contains a library name that does not exist in the project or INI file, and the LSO file does not contain the **DEFAULT_SEARCH_ORDER** keyword, XST ignores the library.

For a project file, `my_proj.prj`, with the following contents:

```
vhdl vllib1 f1.vhd verilog rtfllib f1.v vhdl vllib2 f3.vhd
```

and an LSO file, `my_proj.lso`, created with the following contents:

```
personal_lib rtfllib vllib2 vllib1
```

XST uses the following search order:

```
rtfllib vllib2 vllib1
```

After processing, the contents of `my_proj.lso` is:

```
rtfllib vllib2 vllib1
```

XST Log File

This chapter discusses the XST Log File, and includes:

- [XST Log File Contents](#)
- [Reducing the Size of the XST Log File](#)
- [Macros in XST Log Files](#)
- [XST Log File Examples](#)

XST FPGA Log File Contents

The XST FPGA log file contains:

- [Copyright Statement](#)
- [Table of Contents](#)
- [Synthesis Options Summary](#)
- [HDL Compilation](#)
- [Design Hierarchy Analyzer](#)
- [HDL Analysis](#)
- [HDL Synthesis Report](#)
- [Advanced HDL Synthesis Report](#)
- [Low Level Synthesis](#)
- [Partition Report](#)
- [Final Report](#)

Copyright Statement

The XST FPGA log file copyright statement contains:

- ISE® Design Suite release number
- Xilinx® notice of copyright

Table of Contents

The XST FPGA log file table of contents lists the major sections in the log file. These headings are not linked. Use the Find function in your text editor.

Synthesis Options Summary

The XST FPGA log file Synthesis Options Summary contains information relating to:

- Source Parameters
- Target Parameters
- Source Options
- Target Options
- General Options
- Other Options

HDL Compilation

For information on Hardware Description Language (HDL) Compilation, see:

[XST FPGA Log File HDL Analysis](#)

Design Hierarchy Analyzer

For information on Design Hierarchy Analyzer, see:

[XST FPGA Log File HDL Analysis](#)

HDL Analysis

During Hardware Description Language (HDL) Compilation, Design Hierarchy Analyzer, and HDL Analysis, XST:

- Parses and analyzes VHDL and Verilog files
- Recognizes the design hierarchy
- Gives the names of the libraries into which they are compiled

During this step, XST may report:

- Potential mismatches between synthesis and simulation results
- Potential multi-sources
- Other issues

HDL Synthesis Report

During Hardware Description Language (HDL) Synthesis, XST tries to recognize as many basic macros as possible to create a technology-specific implementation. This is done on a block by block basis. At the end of this step, XST issues the HDL Synthesis Report.

For more information about the processing of each macro and the corresponding messages issued during synthesis, see:

[XST HDL Coding Techniques](#)

Advanced HDL Synthesis Report

XST performs advanced macro recognition and inference. In this step, XST:

- Recognizes, for example, dynamic shift registers
- Implements pipelined multipliers
- Codes state machines

The Advanced HDL Synthesis Report contains a summary of recognized macros in the overall design, sorted by macro type.

Low Level Synthesis

In the XST FPGA Log File Low Level Synthesis phase, XST reports the potential removal of, for example:

- equivalent flip-flops
- register replication

For more information, see:

[FPGA Optimization Report Section](#)

Partition Report

If the design is partitioned, the XST FPGA log file Partition Report contains information detailing the design partitions.

Final Report

The XST FPGA log file Final Report includes:

- Final Results, including
 - RTL Top Level Output File Name (for example, `stopwatch.ngf`)
 - Top Level Output File Name (for example, `stopwatch`)
 - Output Format (for example, NGC)
 - Optimization Goal (for example, Speed)
 - Whether the Keep Hierarchy constraint is used (for example, No)
- Cell usage

Cell usage reports on, for example, the number and type of BELS, Clock Buffers, and IO Buffers.
- Device Utilization Summary

The Device Utilization Summary estimates the number of slices, and gives, for example, the number of flip-flops, IOBs, and BRAMS. The Device Utilization Summary closely approximates the report produced by MAP.
- Partition Resource Summary

The Partition Resource Summary estimates the number of slices, and gives, for example, the number of flip-flops, IOBs, and BRAMS for each partition. The Partition Resource Summary closely resembles the report produced by MAP.
- Timing Report

At the end of synthesis, XST reports the timing information for the design. The Timing Report shows the information for all four possible domains of a netlist:

 - register to register
 - input to register
 - register to outpad
 - inpad to outpad

For an example, see:
Timing Report section in [XST FPGA Log File Example](#)

For more information, see:
[FPGA Optimization Report Section](#)
- Encrypted Modules

If a design contains encrypted modules, XST hides the information about these modules.

Reducing the Size of the XST Log File

To reduce the size of the XST Log File:

- [Use Message Filtering](#)
- [Use Quiet Mode](#)
- [Use Silent Mode](#)
- [Hide Specific Messages](#)

Use Message Filtering

When running XST from ISE® Design Suite, use the Message Filtering wizard to filter specific messages out of the log file.

For more information, see:

Using the Message Filters in the ISE Design Suite Help

Use Quiet Mode

Quiet Mode limits the number of messages printed to the computer screen (**stdout**).

To invoke Quiet Mode, set **-intstyle** to either of the following:

- **ise**
Formats messages for ISE® Design Suite
- **xflow**
Formats messages for XFLOW

Normally, XST prints the entire log to **stdout**. In Quiet Mode, XST does *not* print the following portions of the log to **stdout**:

- Copyright Message
- Table of Contents
- Synthesis Options Summary
- The following portions of the Final Report
 - Final Results header for CPLD devices
 - Final Results section for FPGA devices
 - A note in the Timing Report stating that the timing numbers are only a synthesis estimate.
 - Timing Detail
 - CPU (XST runtime)
 - Memory usage

The following sections are still available for FPGA devices:

- Device Utilization Summary
- Clock Information
- Timing Summary

Use Silent Mode

Silent Mode prevents any messages from being sent to the computer screen (**stdout**), although XST continues to generate the entire log file.

To invoke Silent Mode, set the **-intstyle** command line option to:

silent

Hide Specific Messages

This section includes:

- [XIL_XST_HIDEMESSAGES Environment Variable Values](#)
- [Messages Hidden When Value is Set to hdl_level and hdl_and_low_levels](#)
- [Messages Hidden When Value is Set to low_level or hdl_and_low_levels](#)

XIL_XST_HIDEMESSAGES Environment Variable Values

To hide specific messages at the HDL or Low Level Synthesis steps, set the *XIL_XST_HIDEMESSAGES* environment variable to one of the values shown in the following table.

| Value | Meaning |
|--------------------|--|
| none (default) | Maximum verbosity. All messages are printed out. |
| hdl_level | Reduce verbosity during VHDL or Verilog Analysis and HDL Basic and Advanced Synthesis. |
| low_level | Reduce verbosity during Low-level Synthesis. |
| hdl_and_low_levels | Reduce verbosity at all stages. |

Messages Hidden When Value is Set to hdl_level and hdl_and_low_levels

The following messages are hidden when the value of the *XIL_XST_HIDEMESSAGES* environment variable is set to **hdl_level** and **hdl_and_low_levels**:

- WARNING:HDLCompilers:38 - design.v line 5 Macro 'my_macro' redefined
Note This message is issued by the Verilog compiler only.
- WARNING:Xst:916 - design.vhd line 5: Delay is ignored for synthesis.
- WARNING:Xst:766 - design.vhd line 5: Generating a Black Box for component comp.
- Instantiating component comp from Library lib.
- Set user-defined property "LOC = X1Y1" for instance inst in unit block.
- Set user-defined property "RLOC = X1Y1" for instance inst in unit block.
- Set user-defined property "INIT = 1" for instance inst in unit block.
- Register reg1 equivalent to reg2 has been removed.

Messages Hidden When Value is Set to `low_level` or `hdl_and_low_levels`

The following messages are hidden when the value of the `XIL_XST_HIDEMESSAGES` environment variable is set to `low_level` or `hdl_and_low_levels`:

- WARNING:Xst:382 - Register reg1 is equivalent to reg2. Register reg1 equivalent to reg2 has been removed.
- WARNING:Xst:1710 - FF/Latch reg (without init value) is constant in block block.
- WARNING:Xst 1293 - FF/Latch reg is constant in block block.
- WARNING:Xst:1291 - FF/Latch reg is unconnected in block block.
- WARNING:Xst:1426 - The value init of the FF/Latch reg hinders the constant cleaning in the block block. You could achieve better results by setting this init to value.

Macros in XST Log Files

XST Log Files contain detailed information about the set of macros and associated signals inferred by XST from the VHDL or Verilog source on a block by block basis.

Macro inference is done in two steps:

1. HDL Synthesis

XST recognizes as many simple macro blocks as possible, such as adders, subtractors, and registers.

2. Advanced HDL Synthesis

XST does additional macro processing by improving the macros (for example, pipelining of multipliers) recognized at the HDL synthesis step, or by creating the new, more complex ones, such as dynamic shift registers. The Macro Recognition report at the Advanced HDL Synthesis step is formatted the same as the corresponding report at the HDL Synthesis step.

XST gives overall statistics of recognized macros twice:

- After the HDL Synthesis step
- After the Advanced HDL Synthesis step

XST no longer lists statistics of preserved macros in the final report.

XST Log File Examples

This section includes:

- [Recognized Macros XST Log File Example](#)
- [Additional Macro Processing XST Log File Example](#)
- [XST FPGA Log File Example](#)
- [XST CPLD Log File Example](#)

Recognized Macros XST Log File Example

The following log file example shows the set of recognized macros on a block by block basis, as well as the overall macro statistics after this step.

```

=====
*                      HDL Synthesis                      *
=====
...
Synthesizing Unit <decode>.
  Related source file is "decode.vhd".
  Found 16x10-bit ROM for signal <one_hot>.
  Summary:
    inferred 1 ROM(s).
Unit <decode> synthesized.

Synthesizing Unit <statmach>.
  Related source file is "statmach.vhd".
  Found finite state machine <FSM_0> for signal <current_state>.
-----
| States           | 6 |
| Transitions     | 11|
| Inputs          | 1 |
| Outputs         | 2 |
| Clock           | CLK (rising_edge) |
| Reset           | RESET (positive) |
| Reset type      | asynchronous |
| Reset State     | clear |
| Power Up State  | clear |
| Encoding        | automatic |
| Implementation  | LUT |
-----
  Summary:
    inferred 1 Finite State Machine(s).
Unit <statmach> synthesized.
...
=====
HDL Synthesis Report

Macro Statistics
# ROMs                : 3
  16x10-bit ROM       : 1
  16x7-bit ROM        : 2
# Counters            : 2
  4-bit up counter    : 2
=====
...

```

Additional Macro Processing XST Log File Example

The following XST FPGA log file example shows the additional macro processing done during the Advanced HDL Synthesis step and the overall macro statistics after this step.

```

=====
*           Advanced HDL Synthesis           *
=====

Analyzing FSM <FSM_0> for best encoding.
Optimizing FSM <MACHINE/current_state/FSM_0> on signal <current_state[1:3]> with gray encoding.
-----
State   | Encoding
-----
clear   | 000
zero    | 001
start   | 011
counting| 010
stop    | 110
stopped | 111
-----

=====
Advanced HDL Synthesis Report

Macro Statistics
# FSMs                : 1
# ROMs                : 3
  16x10-bit ROM       : 1
  16x7-bit ROM        : 2
# Counters            : 2
  4-bit up counter    : 2
# Registers           : 3
  Flip-Flops/Latches : 3

=====
...

```

XST FPGA Log File Example

The following is an example of an XST log file for FPGA synthesis. Release 10.1 - xst K.31 (nt64)

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- 1) Synthesis Options Summary
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- 7) Low Level Synthesis
- 8) Partition Report
- 9) Final Report
 - 9.1) Device utilization summary
 - 9.2) Partition Resource Summary
 - 9.3) TIMING REPORT

```
=====
* Synthesis Options Summary *
=====
---- Source Parameters
Input File Name : "stopwatch.prj"
Input Format : mixed
Ignore Synthesis Constraint File : NO
---- Target Parameters
Output File Name : "stopwatch"
Output Format : NGC
Target Device : xc4vlx15-12-sf363
---- Source Options
Top Module Name : stopwatch
Automatic FSM Extraction : YES
FSM Encoding Algorithm : Auto
Safe Implementation : No
FSM Style : lut
RAM Extraction : Yes
RAM Style : Auto
ROM Extraction : Yes
Mux Style : Auto
Decoder Extraction : YES
Priority Encoder Extraction : YES
Shift Register Extraction : YES
Logical Shifter Extraction : YES
XOR Collapsing : YES
ROM Style : Auto
Mux Extraction : YES
Resource Sharing : YES
Asynchronous To Synchronous : NO
Use DSP Block : auto
Automatic Register Balancing : No
---- Target Options
Add IO Buffers : YES
Global Maximum Fanout : 500
Add Generic Clock Buffer(BUFG) : 32
Number of Regional Clock Buffers : 16
Register Duplication : YES
```

```
Slice Packing : YES
Optimize Instantiated Primitives : NO
Use Clock Enable : Auto
Use Synchronous Set : Auto
Use Synchronous Reset : Auto
Pack IO Registers into IOBs : auto
Equivalent register Removal : YES
---- General Options
Optimization Goal : Speed
Optimization Effort : 1
Power Reduction : NO
Library Search Order : stopwatch.lso
Keep Hierarchy : NO
Netlist Hierarchy : as_optimized
RTL Output : Yes
Global Optimization : AllClockNets
Read Cores : YES
Write Timing Constraints : NO
Cross Clock Analysis : NO
Hierarchy Separator : /
Bus Delimiter : <>
Case Specifier : maintain
Slice Utilization Ratio : 100
BRAM Utilization Ratio : 100
DSP48 Utilization Ratio : 100
Verilog 2001 : YES
Auto BRAM Packing : NO
Slice Utilization Ratio Delta : 5
=====
=====
* HDL Compilation *
=====
Compiling verilog file "smallcntr.v" in library work
Compiling verilog file "statmach.v" in library work
Module <smallcntr> compiled
Compiling verilog file "hex2led.v" in library work
Module <statmach> compiled
Compiling verilog file "decode.v" in library work
```

```
Module <hex2led> compiled
Compiling verilog file "cnt60.v" in library work
Module <decode> compiled
Compiling verilog file "stopwatch.v" in library work
Module <cnt60> compiled
Module <stopwatch> compiled
No errors in compilation
Analysis of file <"stopwatch.prj"> succeeded.
Compiling vhdl file "C:/xst/watchver/tenths.vhd" in Library work.
Entity <tenths> compiled.
Entity <tenths> (Architecture <tenths_a>) compiled.
Compiling vhdl file "C:/xst/watchver/dcml.vhd" in Library work.
Entity <dcml> compiled.
Entity <dcml> (Architecture <BEHAVIORAL>) compiled.
=====
* Design Hierarchy Analysis *
=====
Analyzing hierarchy for module <stopwatch> in library <work>.
Analyzing hierarchy for entity <dcml> in library <work>
(architecture <BEHAVIORAL>).
Analyzing hierarchy for module <statmach> in library <work> with
parameters.
clear = "000001"
counting = "001000"
start = "000100"
stop = "010000"
stopped = "100000"
zero = "000010"
Analyzing hierarchy for module <decode> in library <work>.
Analyzing hierarchy for module <cnt60> in library <work>.
Analyzing hierarchy for module <hex2led> in library <work>.
Analyzing hierarchy for module <smallcntr> in library <work>.
=====
* HDL Analysis *
=====
Analyzing top module <stopwatch>.
Module <stopwatch> is correct for synthesis.
Analyzing Entity <dcml> in library <work> (Architecture
<BEHAVIORAL>).
```

```
Set user-defined property "CAPACITANCE = DONT_CARE" for instance
<CLKIN_IBUFG_INST> in unit <dcml>.

Set user-defined property "IBUF_DELAY_VALUE = 0" for instance
<CLKIN_IBUFG_INST> in unit <dcml>.

Set user-defined property "IOSTANDARD = DEFAULT" for instance
<CLKIN_IBUFG_INST> in unit <dcml>.

Set user-defined property "CLKDV_DIVIDE = 2.0000000000000000" for
instance <DCM_INST> in unit <dcml>.

Set user-defined property "CLKFX_DIVIDE = 1" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "CLKFX_MULTIPLY = 4" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "CLKIN_DIVIDE_BY_2 = FALSE" for
instance <DCM_INST> in unit <dcml>.

Set user-defined property "CLKIN_PERIOD = 20.0000000000000000"
for instance <DCM_INST> in unit <dcml>.

Set user-defined property "CLKOUT_PHASE_SHIFT = NONE" for
instance <DCM_INST> in unit <dcml>.

Set user-defined property "CLK_FEEDBACK = 1X" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "DESKEW_ADJUST = SYSTEM_SYNCHRONOUS"
for instance <DCM_INST> in unit <dcml>.

Set user-defined property "DFS_FREQUENCY_MODE = LOW" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "DLL_FREQUENCY_MODE = LOW" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "DSS_MODE = NONE" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "DUTY_CYCLE_CORRECTION = TRUE" for
instance <DCM_INST> in unit <dcml>.

Set user-defined property "FACTORY_JF = C080" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "PHASE_SHIFT = 0" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "SIM_MODE = SAFE" for instance
<DCM_INST> in unit <dcml>.

Set user-defined property "STARTUP_WAIT = TRUE" for instance
<DCM_INST> in unit <dcml>.

Entity <dcml> analyzed. Unit <dcml> generated.

Analyzing module <statmach> in library <work>.

clear = 6'b000001
counting = 6'b001000
start = 6'b000100
stop = 6'b010000
stopped = 6'b100000
```

```

zero = 6'b000010
Module <statmach> is correct for synthesis.
Analyzing module <decode> in library <work>.
Module <decode> is correct for synthesis.
Analyzing module <cnt60> in library <work>.
Module <cnt60> is correct for synthesis.
Analyzing module <smallcntr> in library <work>.
Module <smallcntr> is correct for synthesis.
Analyzing module <hex2led> in library <work>.
Module <hex2led> is correct for synthesis.
=====
* HDL Synthesis *
=====
Performing bidirectional port resolution...
Synthesizing Unit <statmach>.
Related source file is "statmach.v".
Found finite state machine <FSM_0> for signal <current_state>.
-----
| States | 6 |
| Transitions | 15 |
| Inputs | 2 |
| Outputs | 2 |
| Clock | CLK (rising_edge) |
| Reset | RESET (positive) |
| Reset type | asynchronous |
| Reset State | 000001 |
| Encoding | automatic |
| Implementation | LUT |
-----
Found 1-bit register for signal <CLKEN>.
Found 1-bit register for signal <RST>.
Summary:
inferred 1 Finite State Machine(s).
inferred 2 D-type flip-flop(s).
Unit <statmach> synthesized.
Synthesizing Unit <decode>.
Related source file is "decode.v".
Found 16x10-bit ROM for signal <ONE_HOT>.

```

```
Summary:
inferred 1 ROM(s).
Unit <decode> synthesized.
Synthesizing Unit <hex2led>.
Related source file is "hex2led.v".
Found 16x7-bit ROM for signal <LED>.
Summary:
inferred 1 ROM(s).
Unit <hex2led> synthesized.
Synthesizing Unit <smallcntr>.
Related source file is "smallcntr.v".
Found 4-bit up counter for signal <QOUT>.
Summary:
inferred 1 Counter(s).
Unit <smallcntr> synthesized.
Synthesizing Unit <dcml>.
Related source file is "C:/xst/watchver/dcml.vhd".
Unit <dcml> synthesized.
Synthesizing Unit <cnt60>.
Related source file is "cnt60.v".
Unit <cnt60> synthesized.
Synthesizing Unit <stopwatch>.
Related source file is "stopwatch.v".
Unit <stopwatch> synthesized.
=====
HDL Synthesis Report
Macro Statistics
# ROMs : 3
16x10-bit ROM : 1
16x7-bit ROM : 2
# Counters : 2
4-bit up counter : 2
# Registers : 2
1-bit register : 2
=====
=====
* Advanced HDL Synthesis *
=====
```

Analyzing FSM <FSM_0> for best encoding.

Optimizing FSM <MACHINE/current_state/FSM> on signal
<current_state[1:3]> with sequential encoding.

State | Encoding

000001 | 000

000010 | 001

000100 | 010

001000 | 011

010000 | 100

100000 | 101

Loading device for application Rf_Device from file '4v1x15.nph'
in environment C:\xilinx.

Executing edif2ngd -noa "tenths.edn" "tenths.ngo"

Release 10.1 - edif2ngd K.31 (nt64)

Copyright (c) 1995-2008 Xilinx, Inc. All rights reserved.

INFO:NgdBuild - Release 10.1 edif2ngd K.31 (nt64)

INFO:NgdBuild - Copyright (c) 1995-2008 Xilinx, Inc. All rights
reserved.

Writing module to "tenths.ngo"...

Reading core <tenths_c_counter_binary_v8_0_xst_1.ngc>.

Loading core <tenths_c_counter_binary_v8_0_xst_1> for timing and
area information for instance <BU2>.

Loading core <tenths> for timing and area information for
instance <xcounter>.

=====

Advanced HDL Synthesis Report

Macro Statistics

ROMs : 3

16x10-bit ROM : 1

16x7-bit ROM : 2

Counters : 2

4-bit up counter : 2

Registers : 5

Flip-Flops : 5

=====

=====

* Low Level Synthesis *

```
=====
Optimizing unit <stopwatch> ...
Mapping all equations...
Building and optimizing final netlist ...
Found area constraint ratio of 100 (+ 5) on block stopwatch,
actual ratio is 0.
Number of LUT replicated for flop-pair packing : 0
Final Macro Processing ...
=====
Final Register Report
Macro Statistics
# Registers : 13
Flip-Flops : 13
=====
=====
* Partition Report *
=====
Partition Implementation Status
-----
No Partitions were found in this design.
-----
=====
* Final Report *
=====
Final Results
RTL Top Level Output File Name : stopwatch.ngr
Top Level Output File Name : stopwatch
Output Format : NGC
Optimization Goal : Speed
Keep Hierarchy : NO
Design Statistics
# IOs : 27
Cell Usage :
# BELS : 70
# GND : 2
# INV : 1
# LUT1 : 3
# LUT2 : 1
# LUT2_L : 1
```

```
# LUT3 : 8
# LUT3_D : 1
# LUT3_L : 1
# LUT4 : 37
# LUT4_D : 1
# LUT4_L : 4
# MUXCY : 3
# MUXF5 : 2
# VCC : 1
# XORCY : 4
# FlipFlops/Latches : 17
# FDC : 13
# FDCE : 4
# Clock Buffers : 1
# BUFG : 1
# IO Buffers : 27
# IBUF : 2
# IBUFG : 1
# OBUF : 24
# DCM_ADVs : 1
# DCM_ADV : 1
=====
Device utilization summary:
-----
Selected Device : 4vlx15sf363-12
Number of Slices: 32 out of 6144 0%
Number of Slice Flip Flops: 17 out of 12288 0%
Number of 4 input LUTs: 58 out of 12288 0%
Number of IOs: 27
Number of bonded IOBs: 27 out of 240 11%
Number of GCLKs: 1 out of 32 3%
Number of DCM_ADVs: 1 out of 4 25%
-----
Partition Resource Summary:
-----
No Partitions were found in this design.
-----
=====
```

TIMING REPORT

NOTE: THESE TIMING NUMBERS ARE ONLY A SYNTHESIS ESTIMATE.

FOR ACCURATE TIMING INFORMATION PLEASE REFER TO THE TRACE REPORT
GENERATED AFTER PLACE-and-ROUTE.

Clock Information:

```
-----
-----+-----
Clock Signal | Clock buffer (FF name) | Load |
-----+-----
CLK | Inst_dcml/DCM_INST:CLK0 | 17 |
-----+-----
```

Asynchronous Control Signals Information:

```
-----
-----+-----
Control Signal | Buffer (FF name) | Load |
-----+-----
MACHINE/RST(MACHINE/RST:Q) | NONE(sixty/lsbcount/QOUT_1) | 8 |
RESET | IBUF | 5 |
sixty/msbclr(sixty/msbclr_f5:0) | NONE(sixty/msbcount/QOUT_0) |
4 |
-----+-----
```

Timing Summary:

```
-----
Speed Grade: -12
Minimum period: 2.282ns (Maximum Frequency: 438.212MHz)
Minimum input arrival time before clock: 1.655ns
Maximum output required time after clock: 4.617ns
Maximum combinational path delay: No path found
```

Timing Detail:

```
-----
All values displayed in nanoseconds (ns)
=====
Timing constraint: Default period analysis for Clock 'CLK'
Clock period: 2.282ns (frequency: 438.212MHz)
Total number of paths / destination ports: 134 / 21
-----
Delay: 2.282ns (Levels of Logic = 4)
Source: xcounter/BU2/U0/q_i_1 (FF)
Destination: sixty/msbcount/QOUT_1 (FF)
```

```

Source Clock:  CLK rising
Destination Clock:  CLK rising
Data Path:  xcounter/BU2/U0/q_i_1 to sixty/msbcount/QOUT_1
Gate Net
Cell:in->out fanout Delay Delay Logical Name (Net Name)
-----
FDCE:C->Q 12 0.272 0.672 U0/q_i_1 (q(1))
LUT4:I0->O 11 0.147 0.492 U0/thresh0_i_cmp_eq00001 (thresh0)
end scope:  'BU2'
end scope:  'xcounter'
LUT4_D:I3->O 1 0.147 0.388 sixty/msbce (sixty/msbce)
LUT3:I2->O 1 0.147 0.000 sixty/msbcount/QOUT_1_rstpot
(sixty/msbcount/QOUT_1_rstpot)
FDC:D 0.017 sixty/msbcount/QOUT_1
-----
Total 2.282ns (0.730ns logic, 1.552ns route)
(32.0% logic, 68.0% route)
=====
Timing constraint:  Default OFFSET IN BEFORE for Clock 'CLK'
Total number of paths / destination ports:  4 / 3
-----
Offset:  1.655ns (Levels of Logic = 3)
Source:  STRTSTOP (PAD)
Destination:  MACHINE/current_state_FSM_FFd3 (FF)
Destination Clock:  CLK rising
Data Path:  STRTSTOP to MACHINE/current_state_FSM_FFd3
Gate Net
Cell:in->out fanout Delay Delay Logical Name (Net Name)
-----
IBUF:I->O 4 0.754 0.446 STRTSTOP_IBUF (STRTSTOP_IBUF)
LUT4:I2->O 1 0.147 0.000 MACHINE/current_state_FSM_FFd3-In_F
(N48)
MUXF5:I0->O 1 0.291 0.000 MACHINE/current_state_FSM_FFd3-In
(MACHINE/current_state_FSM_FFd3-In)
FDC:D 0.017 MACHINE/current_state_FSM_FFd3
-----
Total 1.655ns (1.209ns logic, 0.446ns route)
(73.0% logic, 27.0% route)
=====

```

```
Timing constraint: Default OFFSET OUT AFTER for Clock 'CLK'
Total number of paths / destination ports: 96 / 24
-----
Offset: 4.617ns (Levels of Logic = 2)
Source: sixty/lsbcount/QOUT_1 (FF)
Destination: ONESOUT<6> (PAD)
Source Clock: CLK rising
Data Path: sixty/lsbcount/QOUT_1 to ONESOUT<6>
Gate Net
Cell:in->out fanout Delay Delay Logical Name (Net Name)
-----
FDC:C->Q 13 0.272 0.677 sixty/lsbcount/QOUT_1
(sixty/lsbcount/QOUT_1)
LUT4:I0->O 1 0.147 0.266 lsbled/Mrom_LED21 (lsbled/Mrom_LED2)
OBUF:I->O 3.255 ONESOUT_2_OBUF (ONESOUT<2>)
-----
Total 4.617ns (3.674ns logic, 0.943ns route)
(79.6% logic, 20.4% route)
=====
Total REAL time to Xst completion: 20.00 secs
Total CPU time to Xst completion: 19.53 secs
-->
Total memory usage is 333688 kilobytes
Number of errors : 0 ( 0 filtered)
)Number of warnings : 0 ( 0 filtered)
Number of infos : 1 ( 0 filtered)
```

XST CPLD Log File Example

The following is an example of an XST log file for CPLD synthesis.

Release 10.1 - xst K.31 (nt64)

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6.1) Advanced HDL Synthesis Report

7) Low Level Synthesis

8) Partition Report

9) Final Report

=====

* Synthesis Options Summary *

=====

---- Source Parameters

Input File Name : "stopwatch.prj"

Input Format : mixed

Ignore Synthesis Constraint File : NO

---- Target Parameters

Output File Name : "stopwatch"

Output Format : NGC

Target Device : CoolRunner2 CPLDs

---- Source Options

Top Module Name : stopwatch

Automatic FSM Extraction : YES

FSM Encoding Algorithm : Auto

Safe Implementation : No

Mux Extraction : YES

Resource Sharing : YES

---- Target Options

Add IO Buffers : YES

MACRO Preserve : YES

XOR Preserve : YES

Equivalent register Removal : YES

---- General Options

Optimization Goal : Speed

Optimization Effort : 1

Library Search Order : stopwatch.lso

Keep Hierarchy : YES

Netlist Hierarchy : as_optimized

RTL Output : Yes

Hierarchy Separator : /

Bus Delimiter : <>

Case Specifier : maintain

Verilog 2001 : YES

```
----- Other Options
Clock Enable : YES
wysiwyg : NO
=====
=====
* HDL Compilation *
=====
Compiling verilog file "smallcntr.v" in library work
Compiling verilog file "tenths.v" in library work
Module <smallcntr> compiled
Compiling verilog file "statmach.v" in library work
Module <tenths> compiled
Compiling verilog file "hex2led.v" in library work
Module <statmach> compiled
Compiling verilog file "decode.v" in library work
Module <hex2led> compiled
Compiling verilog file "cnt60.v" in library work
Module <decode> compiled
Compiling verilog file "stopwatch.v" in library work
Module <cnt60> compiled
Module <stopwatch> compiled
No errors in compilation
Analysis of file <"stopwatch.prj"> succeeded.
=====
* Design Hierarchy Analysis *
=====
Analyzing hierarchy for module <stopwatch> in library <work>.
Analyzing hierarchy for module <statmach> in library <work> with
parameters.
clear = "000001"
counting = "001000"
start = "000100"
stop = "010000"
stopped = "100000"
zero = "000010"
Analyzing hierarchy for module <tenths> in library <work>.
Analyzing hierarchy for module <decode> in library <work>.
Analyzing hierarchy for module <cnt60> in library <work>.
Analyzing hierarchy for module <hex2led> in library <work>.
```

```

Analyzing hierarchy for module <smallcntr> in library <work>.
=====
* HDL Analysis *
=====
Analyzing top module <stopwatch>.
Module <stopwatch> is correct for synthesis.
Analyzing module <statmach> in library <work>.
clear = 6'b000001
counting = 6'b001000
start = 6'b000100
stop = 6'b010000
stopped = 6'b100000
zero = 6'b000010
Module <statmach> is correct for synthesis.
Analyzing module <tenths> in library <work>.
Module <tenths> is correct for synthesis.
Analyzing module <decode> in library <work>.
Module <decode> is correct for synthesis.
Analyzing module <cnt60> in library <work>.
Module <cnt60> is correct for synthesis.
Analyzing module <smallcntr> in library <work>.
Module <smallcntr> is correct for synthesis.
Analyzing module <hex2led> in library <work>.
Module <hex2led> is correct for synthesis.
=====
* HDL Synthesis *
=====
Performing bidirectional port resolution...
Synthesizing Unit <statmach>.
Related source file is "statmach.v".
Found finite state machine <FSM_0> for signal <current_state>.
-----
| States | 6 |
| Transitions | 15 |
| Inputs | 2 |
| Outputs | 2 |
| Clock | CLK (rising_edge) |
| Reset | RESET (positive) |

```

```
| Reset type | asynchronous |
| Reset State | 000001 |
| Encoding | automatic |
| Implementation | automatic |
```

Found 1-bit register for signal <CLKEN>.

Found 1-bit register for signal <RST>.

Summary:

inferred 1 Finite State Machine(s).

inferred 2 D-type flip-flop(s).

Unit <statmach> synthesized.

Synthesizing Unit <tenths>.

Related source file is "tenths.v".

Found 4-bit up counter for signal <Q>.

Summary:

inferred 1 Counter(s).

Unit <tenths> synthesized.

Synthesizing Unit <decode>.

Related source file is "decode.v".

Found 16x10-bit ROM for signal <ONE_HOT>.

Summary:

inferred 1 ROM(s).

.Unit <decode> synthesized

Synthesizing Unit <hex2led>.

Related source file is "hex2led.v".

Found 16x7-bit ROM for signal <LED>.

Summary:

inferred 1 ROM(s).

Unit <hex2led> synthesized.

Synthesizing Unit <smallcntr>.

Related source file is "smallcntr.v".

Found 4-bit up counter for signal <QOUT>.

Summary:

inferred 1 Counter(s).

Unit <smallcntr> synthesized.

Synthesizing Unit <cnt60>.

Related source file is "cnt60.v".

Unit <cnt60> synthesized.

```

Synthesizing Unit <stopwatch>.
Related source file is "stopwatch.v".
Found 1-bit register for signal <strtstopinv>.
Summary:
inferred 1 D-type flip-flop(s).
Unit <stopwatch> synthesized.
=====
HDL Synthesis Report
Macro Statistics
# ROMs : 3
16x10-bit ROM : 1
16x7-bit ROM : 2
# Counters : 3
4-bit up counter : 3
# Registers : 3
1-bit register : 3
=====
=====
* Advanced HDL Synthesis *
=====
Analyzing FSM <FSM_0> for best encoding.
Optimizing FSM <MACHINE/current_state/FSM> on signal
<current_state[1:3]> with sequential encoding.
-----
State | Encoding
-----
000001 | 000
000010 | 001
000100 | 010
001000 | 011
010000 | 100
100000 | 101
-----
=====
Advanced HDL Synthesis Report
Macro Statistics
# ROMs : 3
16x10-bit ROM : 1
16x7-bit ROM : 2

```

```
# Counters : 3
4-bit up counter : 3
# Registers : 6
Flip-Flops : 6
=====
=====
* Low Level Synthesis *
=====
Optimizing unit <stopwatch> ...
Optimizing unit <statmach> ...
Optimizing unit <decode> ...
Optimizing unit <hex2led> ...
Optimizing unit <tenths> ...
Optimizing unit <smallcntr> ...
Optimizing unit <cnt60> ...
=====
* Partition Report *
=====
Partition Implementation Status
-----
No Partitions were found in this design.
-----
=====
* Final Report *
=====
Final Results
RTL Top Level Output File Name : stopwatch.ngr
Top Level Output File Name : stopwatch
Output Format : NGC
Optimization Goal : Speed
Keep Hierarchy : YES
Target Technology : CoolRunner2 CPLDs
Macro Preserve : YES
XOR Preserve : YES
Clock Enable : YES
wysiwyg : NO
Design Statistics
# IOs : 28
```

```
Cell Usage :
# BELS : 413
# AND2 : 120
# AND3 : 10
# AND4 : 6
# INV : 174
# OR2 : 93
# OR3 : 1
# XOR2 : 9
# FlipFlops/Latches : 18
# FD : 1
# FDC : 5
# FDCE : 12
# IO Buffers : 28
# IBUF : 4
# OBUF : 24

=====
Total REAL time to Xst completion: 7.00 secs
Total CPU time to Xst completion: 6.83 secs
-->
Total memory usage is 196636 kilobytes
Number of errors : 0 ( 0 filtered)
Number of warnings : 0 ( 0 filtered)
Number of infos : 0 ( 0 filtered)
```

XST Naming Conventions

This chapter discusses XST Naming Conventions, and includes:

- [XST Net Naming Conventions](#)
- [XST Instance Naming Conventions](#)
- [XST Name Generation Control](#)

XST Net Naming Conventions

The following XST net naming conventions are listed in order of naming priority:

1. Maintain external pin names.
2. Keep hierarchy in signal names, using forward slashes (/) or underscores (_) as hierarchy designators.
3. Maintain output signal names of registers, including state bits. Use the hierarchical name from the level where the register was inferred.
4. Ensure that output signals of clock buffers **get_clockbuffertype** (such as **_BUFGP** or **_IBUFG**) follow the clock signal name.
5. Maintain input nets to registers and tristates names.
6. Maintain names of signals connected to primitives and black boxes.
7. Name output net names of IBUFs using the form **net_name_IBUF**. For example, for an IBUF with an output net name of **DIN**, the output IBUF net name is **DIN_IBUF**.
8. Name input net names to OBUFs using the form **net_name_OBUF**. For example, for an OBUF with an input net name of **DOUT**, the input OBUF net name is **DOUT_OBUF**.
9. Base names for internal (combinatorial) nets on user HDL signal names where possible.

XST Instance Naming Conventions

Xilinx® highly recommends that you use the following instance naming conventions.

To use instance naming conventions from previous releases of ISE® Design Suite, insert the following command line option in the XST command line:

```
-old_instance_names 1
```

The following rules are listed in order of naming priority:

1. Keep hierarchy in instance names, using forward slashes (/) or underscores (_) as hierarchy designators.

When instance names are generated from VHDL or Verilog generate statements, labels from generate statements are used in composition of instance names.

For example, for the following VHDL generate statement:

```

i1_loop: for i in 1 to 10 generate
inst_lut:LUT2 generic map (INIT => "00")

```

XST generates the following instance names for LUT2:

```

i1_loop[1].inst_lut
i1_loop[2].inst_lut
i1_loop[9].inst_lut
...
i1_loop[10].inst_lut

```

2. Name register instances, including state bits, for the output signal.
3. Name clock buffer instances **_clockbuffertype** (such as **_BUFGP** or **_IBUFG**) after the output signal.
4. Maintain instantiation instance names of black boxes.
5. Maintain instantiation instance names of library primitives.
6. Name input and output buffers using the form **_IBUF** or **_OBUF** after the pad name.
7. Name Output instance names of IBUFs using the form **instance_name_IBUF**.
8. Name input instance names to OBUFs using the form **instance_name_OBUF**.

XST Name Generation Control

The following constraints control how names are written.

- [Hierarchy Separator \(-hierarchy_separator\)](#)
- [Bus Delimiter \(-bus_delimiter\)](#)
- [Case \(-case\)](#)
- [Duplication Suffix \(-duplication_suffix\)](#)

Define in ISE Design Suite in:

- **Synthesis Properties**, OR
- The command line

For more information, see:

[XST Design Constraints](#)

XST Command Line Mode

This chapter discusses XST Command Line Mode, and includes:

- [About XST Command Line Mode](#)
- [Launching XST in Command Line Mode Using the XST Shell](#)
- [Launching XST in Command Line Mode Using a Script File](#)
- [Running XST in Script Mode \(VHDL\)](#)
- [Running XST in Script Mode \(Verilog\)](#)
- [Running XST in Script Mode \(Mixed Language\)](#)
- [Setting Up an XST Script Using the Run Command](#)
- [Setting Up an XST Script Using the Set Command](#)
- [Setting Up an XST Script Using the Elaborate Command](#)
- [Synthesizing VHDL Designs Using Command Line Mode](#)
- [Synthesizing Verilog Designs Using Command Line Mode](#)
- [Synthesizing Mixed Designs Using Command Line Mode](#)

About XST Command Line Mode

This section discusses About XST Command Line Mode, and includes:

- [Running XST in Command Line Mode](#)
- [XST File Types in Command Line Mode](#)
- [Temporary Files in Command Line Mode](#)
- [Names With Spaces in Command Line Mode](#)

Running XST in Command Line Mode

To run XST in command line mode:

- On a workstation, run `xst`
- On a PC, run `xst.exe`

XST File Types in Command Line Mode

XST generates the following files types in command line mode:

- Design output file, NGC (`.ngc`)
This file is generated in the current output directory (see the `-ofn` option).
- Register Transfer Level (RTL) netlist for RTL and Technology Viewers (`.ngr`)
- Synthesis log file (`.srp`)
- Temporary files

Temporary Files in Command Line Mode

Temporary files are generated in the XST `temp` directory in command line mode. By default, the XST `temp` directory is:

- Workstations
 `/tmp`

- Windows

The directory specified by either the `TEMP` or `TMP` environment variable

Use `set -tmpdir <directory>` to change the XST `temp` directory.

VHDL or Verilog compilation files are generated in the `temp` directory. The default `temp` directory is the `xst` subdirectory of the current directory.

Tip Xilinx® recommends that you clean the XST `temp` directory regularly. The `temp` directory contains the files resulting from the compilation of all VHDL and Verilog files during all XST sessions. Eventually, the number of files stored in the `temp` directory may severely impact CPU performance. XST does not automatically clean the `temp` directory.

Names With Spaces in Command Line Mode

XST supports file and directory names with spaces in command line mode.

Enclose file or directory names containing spaces in double quotes:

```
"C:\my project"
```

Enclose multiple directories in braces:

```
-vlgincdir {"C:\my project" C:\temp}
```

Launching XST in Command Line Mode Using the XST Shell

Type `xst` to enter directly into an XST shell. Enter your commands and execute them. To run synthesis, specify a complete command with all required options. XST does not accept a mode where you can first enter `set option_1`, then `set option_2`, and then enter `run`.

Since all options are set at the same time, Xilinx® recommends that you use a script file.

Launching XST in Command Line Mode Using a Script File

Store your commands in a separate script file and run them all at once. To execute your script file, run the following workstation or PC command:

```
xst -ifn in_file_name -ofn out_file_name -intstyle {silent|ise|xflo}
```

The `-ofn` option is not mandatory. If you omit it, XST automatically generates a log file with the file extension `.srp`, and all messages display on the screen. Use the following to limit the number of messages printed to the screen:

- The `-intstyle silent` option
- The `XIL_XST_HIDEMESSAGES` environment variable
- The message filter feature in ISE® Design Suite

For more information, see:

[Reducing the Size of the XST Log File](#)

For example, assume that the following text is contained in a file `foo.scr`:

```
run -ifn tt1.prj -top tt1 -ifmt MIXED -opt_mode SPEED -opt_level 1 -ofn tt1.ngc -p
<parttype>
```

This script file can be executed under XST using the following command:

```
xst -ifn foo.scr
```

You can also generate a log file with the following command:

```
xst -ifn foo.scr -ofn foo.log
```

A script file can be run either using `xst -ifn script name`, or executed under the XST prompt, by using the `script script_name` command.

```
script foo.scr
```

If you make a mistake in an XST command option, or its value, XST issues an error message and stops execution. For example, if in the previous script example VHDL is incorrectly spelled (“VHDLL”), XST gives the following error message:

```
--> ERROR:Xst:1361 - Syntax error in command run for option
"-ifmt" : parameter "VHDLL" is not allowed.
```

If you created your project using ISE Design Suite, and have run XST at least once from ISE Design Suite, you can switch to XST command line mode and use the script and project files that were created by ISE Design Suite.

To run XST from the command line, run the following command from project directory:

```
xst -ifn <top_level_block>.xst -ofn <top_level_block>.syr
```

Setting Up an XST Script Using the Run Command

This section discusses Setting Up an XST Script Using the Run Command, and includes:

- [About the Run Command](#)
- [Writing a Script File](#)
- [XST Specific Non-Timing Related Options](#)
- [Online Help](#)
- [Supported Families](#)
- [Commands for a Specific Device](#)
- [Run Command Options and Values \(Virtex-5 Devices\)](#)

About the Run Command

The `run` command:

- Is the main synthesis command.
- Allows you to run synthesis in its entirety, beginning with the parsing of the Hardware Description Language (HDL) files, and ending with the generation of the final netlist.
- Can be used only once per script file.
- Begins with a keyword `run`, which is followed by a set of options and its values:

```
run option_1 value option_2 value ...
```

Note Xilinx does not support or recommend the use of multiple run commands in a single script.

Writing a Script File

Observe the following rules when writing a script file:

- Place each option-value pair on a separate line.
- Use the pound (#) character to comment out options, or place additional comments in the script file.

```
run
option_1 value
# option_2 value
option_3 value
```

- The first line contains only the **run** command without any options.
- There are no blank lines in the middle of the command.
- Each option name begins with dash. For example: *-ifn*, *-ifnt*, *-ofn*.
- Each option has one value. There are no options without a value.
- The value for a given option can be one of the following:
 - Predefined by XST (for instance, **yes** or **no**)
 - Any string (for instance, a file name or a name of the top level entity). Options such as **-vlgindir** accept several directories as values. Separate the directories by spaces, and enclose them in braces ({}):

```
-vlgindir {c:\vlg1 c:\vlg2}
```

For more information, see [Names With Spaces in Command Line Mode](#).

- An integer

XST Specific Non-Timing Related Options

The following topics summarize XST specific non-timing related options, including **run** command options and their values:

- [XST Specific Non-Timing Options](#)
- [XST Specific Non-Timing Options: XST Command Line Only](#)

Online Help

XST provides online Help from the command line. The following information is available by typing *help* at the command line. The XST help function provides a list of supported families, available commands, options and their values for each supported device family.

To see a detailed explanation of an XST command, use the following syntax.

```
help -arch family_name -command command_name
```

where:

- *family_name* is a list of supported Xilinx® families in the current version of XST
- *command_name* is one of the following XST commands:
 - **run**
 - **set**
 - **elaborate**
 - **time**

Supported Families

To see a list of supported families, type **help** at the command line prompt with no argument. XST issues the following message.

```
--> help
ERROR:Xst:1356 - Help : Missing "-arch <family>".
Please specify what family you want to target
available families:
  acr2
  aspartan3
  aspartan3a
  aspartan3adsp
  aspartan3e
  avirtex4
  fpgacore
  qrvirtex4
  qvirtex4
  spartan3
  spartan3a
  spartan3adsp
  spartan3e
  virtex4
  virtex5
  xa9500x1
  xbr
  xc9500
  xc9500x1
  xpla3
```

Commands for a Specific Device

To see a list of commands for a specific device, type the following at the command line prompt with no argument.

```
help -arch family_name
```

For example:

```
help -arch virtex
```

Run Command Options and Values (Virtex-5 Devices)

Use the following command to see a list of options and values for the **run** command for Virtex®-5 devices.

```
--> help -arch virtex5 -command run
```

This command gives the following output:

```
-mult_style           : Multiplier Style
                      block / lut / auto / pipe_lut
-bufg                 : Maximum Global Buffers
                      *
-bufgce               : BUFGE Extraction
                      YES / NO
-decoder_extract      : Decoder Extraction
                      YES / NO
....

-ifn : *
-ifmt : Mixed / VHDL / Verilog
-ofn : *
-ofmt : NGC / NCD
-p : *
-ent : *
-top : *
-opt_mode : AREA / SPEED
-opt_level : 1 / 2
-keep_hierarchy : YES / NO
-vlginidir : *
-verilog2001 : YES / NO
-vlgcase : Full / Parallel / Full-Parallel
....
```

Setting Up an XST Script Using the Set Command

XST recognizes the **set** command.

For more information, see:

[XST Design Constraints](#)

Set Command Options

| Option | Description | Values |
|-------------------|---|-------------------------------|
| -tmpdir | Location of all temporary files generated by XST during a session | Any valid path to a directory |
| -xsthdpdir | Work Directory — location of all files resulting from VHDL or Verilog compilation | Any valid path to a directory |
| -xsthdpini | HDL Library Mapping File (.INI File) | file_name |

Setting Up an XST Script Using the Elaborate Command

Use the **elaborate** command to:

- Pre-compile VHDL and Verilog files in a specific library, or
- Verify Verilog files without synthesizing the design

Since compilation is included in the run, the **elaborate** command is optional.

For more information, see:

[XST Design Constraints](#)

Elaborate Command Options

| Option | Description | Values |
|---------------------|---|--|
| -ifn | Project File | file_name |
| -ifmt | Format | vhdl, verilog, mixed |
| -lso | Library Search Order | file_name.lso |
| -work_lib | Work Library for Compilation – library where the top level block was compiled | name, work |
| -verilog2001 | Verilog-2001 | yes, no |
| -vlgpath | Verilog Search Paths | Any valid path to directories separated by spaces, and enclosed in double quotes ("...") |
| -vlgincdir | Verilog Include Directories | Any valid path to directories separated by spaces, and enclosed in braces ({...}) |

Running XST in Script Mode (VHDL)

To run XST in script mode in VHDL:

1. Open a new file named `stopwatch.xst` in the current directory.
2. Put the previously executed XST shell command into this file and save it.

```
run -ifn watchvhd.prj -ifmt mixed -top stopwatch -ofn watchvhd.ngc
    -ofmt NGC -p xc5vfx30t-2-ff324 -opt_mode Speed -opt_level 1
```

3. From the `tcsh` or other shell, enter the following command to begin synthesis:

```
xst -ifn stopwatch.xst
```

Files Created During Run (VHDL)

During this run, XST creates the following files.

- `watchvhd.ngc`
An NGC file ready for the implementation tools
- `xst.srp`
The XST log file

Saving XST Messages in a Different Log File (VHDL)

To save XST messages in a different log file, run the following command:

```
xst -ifn stopwatch.xst -ofn <filename>.log
```

Following is an example using `watchvhd.log`:

```
xst -ifn stopwatch.xst -ofn watchvhd.log
```

For this example, `stopwatch.xst` appears as follows:

```
run
-ifn watchvhd.prj
-ifmt mixed
-top stopwatch
-ofn watchvhd.ngc
-ofmt NGC
-p xc5vfx30t-2-ff324
-opt_mode Speed
-opt_level 1
```

Improving Readability (VHDL)

Observe the following rules to improve the readability of the `stopwatch.xst` file, especially if you use many options to run synthesis:

- Each option with its value is on a separate line.
- The first line contains only the **run** command without any options.
- There are no blank lines in the middle of the command.
- Each line except the first begins with a dash.

Leading Spaces (VHDL)

An error occurs if a leading space is entered in the value field.

ISE® Design Suite automatically strips leading spaces from a process value. Accordingly, the `.xst` file written by ISE Design Suite is not affected by leading spaces.

If you hand-edit the `.xst` file and run XST from the command line, manually delete any leading spaces.

Running XST in Script Mode (Verilog)

This section discusses Running XST in Script Mode (Verilog), and includes:

- [How to Run XST in Script Mode \(Verilog\)](#)
- [Files Created During Run \(Verilog\)](#)
- [Saving XST Messages in a Different Log File \(Verilog\)](#)
- [Improving Readability \(Verilog\)](#)

How to Run XST in Script Mode (Verilog)

To run XST in script mode:

1. Open a new file called `design.xst` in the current directory. Put the previously executed XST shell command into this file and save it.

```
run
-ifn watchver.prj
-ifmt mixed
-ofn watchver.ngc
-ofmt NGC
-p xc5vfx30t-2-ff324
-opt_mode Speed
-opt_level 1
```

2. From the `tcsh` or other shell, enter the following command to begin synthesis.

```
xst -ifn design.xst
```

For the previous command example, the `design.xst` file should look like the following:

```
run
-ifn watchver.prj
-ifmt mixed
-top stopwatch
-ofn watchver.ngc
-ofmt NGC
-p xc5vfx30t-2-ff324
-opt_mode Speed
-opt_level 1
```

Files Created During Run (Verilog)

During this run, XST creates the following files.

- `watchvhd.ngc`
An NGC file ready for the implementation tools
- `design.srp`
The XST script log file

Saving XST Messages in a Different Log File (Verilog)

To save XST messages in a different log file (for example, `watchver.log`), run:

```
xst -ifn design.xst -ofn watchver.log
```

Improving Readability (Verilog)

To improve the readability of the `design.xst` file, especially if you use many options to run synthesis, place each option with its value on a separate line. Observe the following rules:

- The first line contains only the **run** command without any options.
- There are no blank lines in the middle of the command.
- Each line (except the first one) begins with a dash (-).

Running XST in Script Mode (Mixed Language)

This section discusses Running XST in Script Mode (Mixed Language), and includes:

- [How to Run XST in Script Mode \(Mixed Language\)](#)
- [Files Created During Run](#)
- [Saving XST Messages in a Different Log File \(Mixed Language\)](#)
- [Improving Readability \(Mixed Language\)](#)

How to Run XST in Script Mode (Mixed Language)

To run XST in script mode:

1. Open a new file called `stopwatch.xst` in the current directory. Put the previously executed XST shell command into this file and save it.

```
run
-ifn watchver.prj
-ifmt mixed
-top stopwatch
-ofn watchver.ngc
-ofmt NGC
-ofn watchver.ngc
-ofmt NGC
-p xc5vfx30t-2-ff324
-opt_mode Speed
-opt_level 1
```

2. From the `tcsh` or other shell, enter the following command to begin synthesis.

```
xst -ifn stopwatch.xst
```

For the previous command example, the `stopwatch.xst` file should look like:

```
run
-ifn watchver.prj
-ifmt mixed
-ofn watchver.ngc
-ofmt NGC
-p xc5vfx30t-2-ff324
-opt_mode Speed
-opt_level 1
```

Files Created During Run (Mixed Language)

During this run, XST creates the following files:

- `watchver.ngc`
An NGC file ready for the implementation tools
- `xst.srp`
The XST script log file

Saving XST Messages in a Different Log File (Mixed Language)

To save XST messages to a different log file (for example, `watchver.log`) run:

```
xst -ifn stopwatch.xst -ofn <filename>.log
```

Following is an example using `watchver.log`:

```
xst -ifn stopwatch.xst -ofn watchver.log
```

Improving Readability (Mixed Language)

To improve the readability of the `stopwatch.xst` file, especially if you use many options to run synthesis, place each option with its value on a separate line. Observe the following rules:

- The first line contains only the **run** command without any options.
- There are no blank lines in the middle of the command.
- Each line (except the first one) begins with a dash.

Synthesizing VHDL Designs Using Command Line Mode

This section discusses Synthesizing VHDL Designs Using Command Line Mode, and includes:

- [VHDL Design Files and Entities](#)
- [Example Using Command Line Mode](#)
- [Synthesizing the Design](#)
- [Library Names](#)
- [XST File Order Warning](#)

The following coding example shows how to synthesize a hierarchical VHDL design for a Virtex® device using command line mode.

VHDL Design Files and Entities

The example uses a VHDL design called `watchvhd`. The files for `watchvhd` are located in the `ISEexamples\watchvhd` directory of the ISE® Design Suite installation directory.

This design contains seven entities:

- `stopwatch`
- `statmach`
- `tenths` (a CORE Generator™ software core)
- `decode`
- `smallcntr`
- `cnt60`
- `hex2led`

Example Using Command Line Mode

Following is an example of how to synthesize a VHDL design using command line mode.

1. Create a new directory named `vhdl_m`.
2. Copy the following files from the `ISEexamples\watchvhd` directory of the ISE Design Suite installation directory to the newly created `vhdl_m` directory.
 - `stopwatch.vhd`
 - `statmach.vhd`
 - `decode.vhd`
 - `cnt60.vhd`
 - `smallcntr.vhd`
 - `tenths.vhd`
 - `hex2led.vhd`
3. To synthesize the design, which is now represented by seven VHDL files, create a project.

Synthesizing the Design

XST supports mixed VHDL and Verilog projects. Xilinx® recommends that you use the new project format, whether or not it is a real mixed language project. This example uses the new project format. To create a project file containing only VHDL files, place a list of VHDL files preceded by keyword *VHDL* in a separate file. The order of the files is not important. XST can recognize the hierarchy, and compile VHDL files in the correct order.

For the example, perform the following steps:

1. Open a new file called `watchvhd.prj`
2. Enter the names of the VHDL files in any order into this file and save the file:

```
vhdl work statmach.vhd
vhdl work decode.vhd
vhdl work stopwatch.vhd
vhdl work cnt60.vhd
vhdl work smallcntr.vhd
vhdl work tenths.vhd
vhdl work hex2led.vhd
```

3. To synthesize the design, execute the following command from the XST shell or the script file:

```
run -ifn watchvhd.prj -ifmt mixed -top stopwatch -ofn
watchvhd.ngc -ofmt NGC -p xc5vfx30t-2-ff324 -opt_mode Speed
-opt_level 1
```

You must specify a top-level design block with the **-top** command line option.

To synthesize just **hex2led** and check its performance independently of the other blocks, you can specify the top-level entity to synthesize on the command line, using the **-top** option.

```
run -ifn watchvhd.prj -ifmt mixed -ofn watchvhd.ngc -ofmt NGC -p
xc5vfx30t-2-ff324 -opt_mode Speed -opt_level 1 -top hex2led
```

For more information, see:

[XST Specific Non-Timing Options](#)

Library Names

During VHDL compilation, XST uses the library **work** as the default. If some VHDL files are to be compiled to different libraries, add the library name before the file name. For example, to compile **hex2led** into the library **my_lib**, write the project file as follows:

```
vhdl work statmach.vhd vhdl work decode.vhd vhdl work
stopwatch.vhd vhdl work cnt60.vhd vhdl work smallcntr.vhd vhdl
work tenths.vhd vhdl my_lib hex2led.vhd
```

XST File Order Warning

If XST does not recognize the file order, it issues the following warning:

```
WARNING:XST:3204. The sort of the vhdl files failed, they will
be compiled in the order of the project file.
```

In this case, you must:

- Put all VHDL files in the correct order.
- Add the **-hdl_compilation_order** option with value **user** to the XST **run** command:

```
run -ifn watchvhd.prj -ifmt mixed -top stopwatch -ofn
watchvhd.ngc -ofmt NGC -p xc5vfx30t-2-ff324 -opt_mode Speed
-opt_level 1 -top hex2led -hdl_compilation_order user
```

Synthesizing Verilog Designs Using Command Line Mode

This section discusses Synthesizing Verilog Designs Using Command Line Mode, and includes:

- [Verilog Design Files and Modules](#)
- [Example Using Command Line Mode](#)
- [Synthesizing the Design](#)
- [Synthesizing HEX2LED](#)

The following coding example shows the synthesis of a hierarchical Verilog design for a Virtex® device using command line mode.

Verilog Design Files and Modules

The example uses a Verilog design called *watchver*. These files are found in the following directory of the ISE® Design Suite installation directory:

```
ISEexamples\watchver
```

The files are:

- stopwatch.v
- statmach.v
- decode.v
- cnt60.v
- smallcntr.v
- tenths.v
- hex2led.v

This design contains seven modules:

- stopwatch
- statmach
- tenths (a CORE Generator™ software core)
- decode
- cnt60
- smallcntr
- hex2led

Example Using Command Line Mode

1. Create a new directory named `vlg_m`.
2. Copy the `watchver` design files from the `ISEexamples\watchver` directory of the ISE Design Suite installation directory to the newly created `vlg_m` directory.

Specify the top-level design block with the **-top** command line option.

Synthesizing the Design

To synthesize the design, which is now represented by seven Verilog files, create a project. XST now supports mixed VHDL and Verilog projects. Therefore, Xilinx® recommends that you use the new project format whether it is a real mixed language project or not. In this example, we use the new project format. To create a project file containing only Verilog files, place a list of Verilog files preceded by the keyword *verilog* in a separate file. The order of the files is not important. XST can recognize the hierarchy and compile Verilog files in the correct order.

1. Open a new file, called `watchver.v`.
2. Enter the names of the Verilog files into this file in any order and save it:

```
verilog work decode.v
verilog work statmach.v
verilog work stopwatch.v
verilog work cnt60.v
verilog work smallcntr.v
verilog work hex2led.v
```

3. To synthesize the design, execute the following command from the XST shell or a script file:

```
run -ifn watchver.v -ifmt mixed -top stopwatch -ofn
watchver.ngc -ofmt NGC -p xc5vfx30t-2-ff324 -opt_mode Speed
-opt_level 1
```

Synthesizing HEX2LED

To synthesize just HEX2LED and check its performance independently of the other blocks, specify the top-level module to synthesize in the command line, using the **-top** option.

```
run -ifn watchver.v -ifmt Verilog -ofn watchver.ngc -ofmt NGC -p
xc5vfx30t-2-ff324 -opt_mode Speed -opt_level 1 -top HEX2LED
```

For more information, see:

[XST Specific Non-Timing Options](#)

Synthesizing Mixed Designs Using Command Line Mode

This section discusses Synthesizing Mixed Designs Using Command Line Mode, and includes:

- [Example Using Command Line Mode](#)
- [Synthesizing the Design](#)
- [File Order](#)

This example shows the synthesis of a hierarchical mixed VHDL and Verilog design for a Virtex® device using command line mode.

Example Using Command Line Mode

1. Create a new directory named `vhdl_verilog`.
 2. Copy the following files from the `ISEexamples\watchvhd` directory of the ISE® Design Suite installation directory to the newly-created `vhdl_verilog` directory.
 - `stopwatch.vhd`
 - `statmach.vhd`
 - `decode.vhd`
 - `cnt60.vhd`
 - `smallcntr.vhd`
 - `tenths.vhd`
 3. Copy the `hex2led.v` file from the `ISEexamples\watchver` directory of the ISE Design Suite installation directory to the newly created `vhdl_verilog` directory.
- [

Synthesizing the Design

The design is now represented by six VHDL files and one Verilog file. To synthesize the design, create a project. To create a project file, place a list of VHDL files preceded by keyword `vhdl`, and a list of Verilog files preceded by keyword `verilog` in a separate file.

File Order

The order of the files is not important. XST recognizes the hierarchy and compiles Hardware Description Language (HDL) files in the correct order.