Using Distributed SelectRAM Memory

Introduction

In addition to 18Kb SelectRAM blocks, Virtex-II devices feature distributed SelectRAM modules. Each function generator or LUT of a CLB resource can implement a 16 x 1-bit synchronous RAM resource. Distributed SelectRAM memory writes synchronously and reads asynchronously. However, a synchronous read can be implemented using the register that is available in the same slice. This 16 x 1-bit RAM is cascadable for a deeper and/or wider memory implementation, with a minimal timing penalty incurred through specialized logic resources.

Distributed SelectRAM modules up to a size of 128 x 1 are available as primitives. Two 16 x 1 RAM resources can be combined to form a dual-port 16 x 1 RAM with one dedicated read/write port and a second read-only port. One port writes into both 16 x1 RAMs simultaneously, but the second port reads independently.

This section provides generic VHDL and Verilog reference code examples implementing *n*-bit-wide single-port and dual-port distributed SelectRAM memory.

Distributed SelectRAM memory enables many high-speed applications that require relatively small embedded RAM blocks, such as FIFOs, which are close to the logic that uses them.

Virtex-II Distributed SelectRAM memories can be generated using the CORE Generator Distributed Memory module (V2.0 or later). The user can also generate Distributed RAM-based Asynchronous and Synchronous FIFOs using the CORE Generator.

Single-Port and Dual-Port RAM

Data Flow

Distributed SelectRAM memory supports the following:

- Single-port RAM with synchronous write and asynchronous read
- Dual-port RAM with one synchronous write and two asynchronous read ports

As illustrated in the Figure 2-46, the dual port has one read/write port and an independent read port.

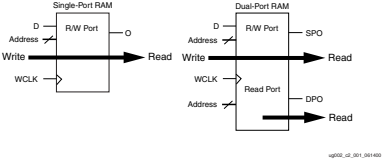

Figure 2-46: **Single-Port and Dual-Port Distributed SelectRAM**

Any read/write operation can occur simultaneously with and independently of a read operation on the other port.

Write Operations

The write operation is a single clock-edge operation, with a write enable that is active High by default. When the write enable is Low, no data is written into the RAM. When the write enable is High, the clock edge latches the write address and writes the data on D into the RAM.

Read Operation

The read operation is a combinatorial operation. The address port (single or dual port) is asynchronous with an access time equivalent to the logic delay.

Read During Write

When new data is synchronously written, the output reflects the data in the memory cell addressed (transparent mode). The timing diagram in Figure 2-47 illustrates a write operation, with the previous data read on the output port, before the clock edge and then the new data.

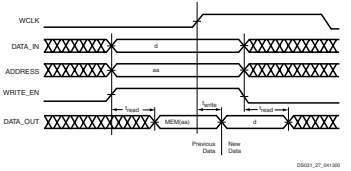

Figure 2-47: **Write Timing Diagram**

Characteristics

- A write operation requires only one clock edge.
- A read operation requires only the logic access time.
- Outputs are asynchronous and dependent only on the logic delay.
- Data and address inputs are latched with the write clock and have a setup-to-clock timing specification. There is no hold time requirement.
- For dual-port RAM, one address is the write and read address, the other address is an independent read address.

Library Primitives

Seven library primitives from 16 x 1-bit to 128 x 1-bit are available. Four primitives are single-port RAM and three primitives are True Dual-Port RAM, as shown in Table 2-16.

Table 2-16: **Single-Port and Dual-Port Distributed SelectRAM**

Primitive	RAM Size	Type	Address Inputs
RAM16X1S	16 bits	single-port	A3, A2, A1, A0
RAM32X1S	32 bits	single-port	A4, A3, A2, A1, A0
RAM64X1S	64 bits	single-port	A5, A3, A2, A1, A0
RAM128X1S	128 bits	single-port	A6, A4, A3, A2, A1, A0
RAM16X1D	16 bits	dual-port	A3, A2, A1, A0
RAM32X1D	32 bits	dual-port	A4, A3, A2, A1, A0
RAM64X1D	64 bits	dual-port	A5, A4, A3, A2, A1, A0

The input and output data are 1-bit wide. However, several distributed SelectRAM memories can be used to implement wide memory blocks.

Figure 2-48 shows generic single-port and dual-port distributed SelectRAM primitives. The A and DPRA signals are address busses.

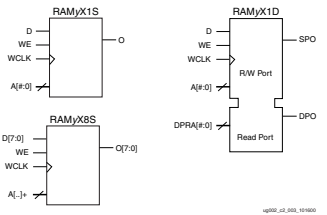

Figure 2-48: **Single-Port and Dual-Port Distributed SelectRAM Primitive**

As shown in Table 2-17, wider library primitives are available for 2-bit, 4-bit, and 8-bit RAM.

Table 2-17: **Wider Library Primitives**

Primitive	RAM Size	Data Inputs	Address Inputs	Data Outputs
RAM16x2S	16 x 2-bit	D1, D0	A3, A2, A1, A0	O1, O0
RAM32X2S	32 x 2-bit	D1, D0	A4, A3, A2, A1, A0	O1, O0
RAM64X2S	64 x 2-bit	D1, D0	A5, A4, A3, A2, A1, A0	O1, O0
RAM16X4S	16 x 4-bit	D3, D2, D1, D0	A3, A2, A1, A0	O3, O2, O1, O0
RAM32X4S	32 x 4-bit	D3, D2, D1, D0	A4,A3, A2, A1, A0	O3, O2, O1, O0
RAM16X8S	16 x 8-bit	D <7:0>	A3, A2, A1, A0	O <7:0>
RAM32X8S	32 x 8-bit	D <7:0>	A4,A3, A2, A1, A0	O <7:0>

VHDL and Verilog Instantiation

VHDL and Verilog instantiations templates are available as examples (see "VHDL and Verilog Templates" on page 208).

In VHDL, each template has a component declaration section and an architecture section. Each part of the template should be inserted within the VHDL design file. The port map of the architecture section should include the design signal names.

The SelectRAM_xS templates (with *x* = 16, 32, 64, or 128) are single-port modules and instantiate the corresponding XC2V_RAMxX1_S_SUBM primitive.

SelectRAM_xD templates (with *x* = 16, 32, or 64) are dual-port modules and instantiate the corresponding XC2V_RAMxX1_D_SUBM primitive.

Ports Signals

Each distributed SelectRAM port operates independently of the other while reading the same set of memory cells.

Clock - WCLK

The clock is used for the synchronous write. The data and the address input pins have setup time referenced to the WCLK pin.

Enable - WE

The enable pin affects the write functionality of the port. An inactive Write Enable prevents any writing to memory cells. An active Write Enable causes the clock edge to write the data input signal to the memory location pointed to by the address inputs.

Address - A0, A1, A2, A3 (A4, A5, A6)

The address inputs select the memory cells for read or write. The width of the port determines the required address inputs. Note that the address inputs are not a bus in VHDL or Verilog instantiations.

Data In - D

The data input provides the new data value to be written into the RAM.

Data Out - O, SPO, and DPO

The data out O (Single-Port or SPO) and DPO (Dual-Port) reflects the contents of the memory cells referenced by the address inputs. Following an active write clock edge, the data out (O or SPO) reflects the newly written data.

Inverting Control Pins

The two control pins (WCLK and WE) each have an individual inversion option. Any control signal, including the clock, can be active at 0 (negative edge for the clock) or at 1 (positive edge for the clock) without requiring other logic resources.

GSR

The global set/reset (GSR) signal does not affect distributed SelectRAM modules.

Attributes

Content Initialization - INIT

With the INIT attributes, users can define the initial memory contents after configuration. By default distributed SelectRAM memory is initialized with all zeros during the device configuration sequence. The initialization attribute INIT represents the specified memory

contents. Each INIT is a hex-encoded bit vector. Table 2-18 shows the length of the INIT attribute for each primitive.

Table 2-18: **INIT Attributes Length**

Primitive	Template	INIT Attribute Length
RAM16X1S	SelectRAM_16S	4 digits
RAM32X1S	SelectRAM_32S	8 digits
RAM64X1S	SelectRAM_64S	16 digits
RAM128X1S	SelectRAM_128S	32 digits
RAM16X1D	SelectRAM_16S	4 digits
RAM32X1D	SelectRAM_32S	8 digits
RAM64X1D	SelectRAM_64S	16 digits

Initialization in VHDL or Verilog Codes

Distributed SelectRAM memory structures can be initialized in VHDL or Verilog code for both synthesis and simulation. For synthesis, the attributes are attached to the distributed SelectRAM instantiation and are copied in the EDIF output file to be compiled by Xilinx Alliance Series™ tools. The VHDL code simulation uses a `generic` parameter to pass the attributes. The Verilog code simulation uses a `defparam` parameter to pass the attributes.

The distributed SelectRAM instantiation templates (in VHDL and Verilog) illustrate these techniques (see "VHDL and Verilog Templates" on page 208).

Location Constraints

The CLB has four slices S0, S1, S2 and S3. As an example, in the bottom left CLB, the slices have the coordinates shown below: S

Slice S3	Slice S2	Slice S1	Slice S0
X1Y1	X1Y0	X0Y1	X0Y0

Distributed SelectRAM instances can have LOC properties attached to them to constrain placement. The XC2V_RAM16X1_S_SUBM primitive fits in any LUT of slices S0 or S1.

For example, the instance `U_RAM16` is placed in slice X0Y0 with the following LOC properties:

```
INST "U_RAM16" LOC = "SLICE_X0Y0";
```

The XC2V_RAM16x1_D_SUBM primitive occupies half of two slices, as shown in Figure 2-49. The first slice (output SPO) implements the read/write port with the same address A[3:0] for read and write. The second slice implements the second read port with

the address DPRA[3:0] and is written simultaneously with the first slice to the address A[3:0].

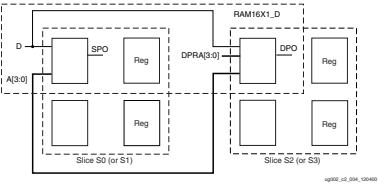

Figure 2-49: **RAM16X1_D Placement**

In the same CLB module, the dual-port RAM16X1_D either occupies half of slices S0 (X0Y0) and S2 (X1Y0), or half of slices S1 (X0Y1) and S3 (X1Y1).

If a dual-port 16 x 2-bit module is built, the two RAM16X1_D primitives occupy two slices, as long as they share the same clock and write enable, as illustrated in Figure 2-50.

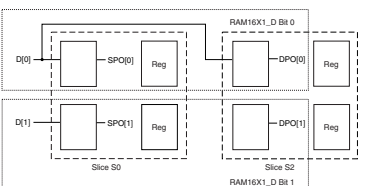

Figure 2-50: **Two RAM16X1_D Placement**

A RAM32X1S primitive fits in one slice, as shown in Figure 2-51.

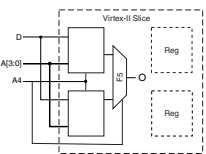

Figure 2-51: **RAM32X1_S Placement**

Following the same rules, a RAM32X1_D primitive fits in two slices, with one slice implementing the read/write port and the second slice implementing the second read port.

The RAM64X1_S primitive occupies two slices and the RAM64X1_D primitive occupies four slices (one CLB element), with two slices implementing the read/write port and two other slices implementing the second read port. The RAM64X1_S read path is built on the MUXF5 and MUXF6 multiplexers.

The RAM128X1_S primitive occupies four slices, equivalent to one CLB element.

Distributed SelectRAM placement locations use the slice location naming convention, allowing LOC properties to transfer easily from array to array.

Applications

Creating Larger RAM Structures

The memory compiler program generates wider and/or deeper memory structures using distributed SelectRAM instances. Along with an EDIF file for inclusion in a design, this program produces VHDL and Verilog instantiation templates and simulation models.

Table 2-19 shows the generic VHDL and Verilog distributed SelectRAM examples provided to implement *n*-bit-wide memories.

Table 2-19: **VHDL and Verilog Submodules**

Submodules	Primitive	Size	Type
XC2V_RAM16XN_S_SUBM	RAM16X1S	16 words x *n*-bit	single-port
XC2V_RAM32XN_S_SUBM	RAM32X1S	32 words x *n*-bit	single-port
XC2V_RAM64XN_S_SUBM	RAM64X1S	64 words x *n*-bit	single-port
XC2V_RAM128XN_S_SUBM	RAM128X1S	128 words x *n*-bit	single-port
XC2V_RAM16XN_S_SUBM	RAM16X1D	16 words x *n*-bit	dual-port
XC2V_RAM32XN_D_SUBM	RAM32X1D	32 words x *n*-bit	dual-port
XC2V_RAM64XN_D_SUBM	RAM64X1D	64 words x *n*-bit	dual-port

By using the read/write port for the write address and the second read port for the read address, a FIFO that can read and write simultaneously is easily generated. Simultaneous access doubles the effective throughput of the memory.

VHDL and Verilog Templates

VHDL and Verilog templates are available for all single-port and dual-port primitives. The number in each template indicates the number of bits (for example, SelectRAM_16S is the template for the 16 x 1-bit RAM); S indicates single-port, and D indicates dual-port.

In VHDL, each template has a component declaration section and an architecture section. Each part of the template should be inserted within the VHDL design file. The port map of the architecture section should include the design signal names.

The following are single-port templates:

- SelectRAM_16S
- SelectRAM_32S
- SelectRAM_64S
- SelectRAM_128S

The following are dual-port templates:

- SelectRAM_16D
- SelectRAM_32D
- SelectRAM_64D

Templates for the SelectRAM_16S module are provided in VHDL and Verilog code as examples.

VHDL Template

```
--
-- Module: SelectRAM_16S
--
-- Description: VHDL instantiation template
--              Distributed SelectRAM
--              Single Port 16 x 1
--              can be used also for RAM16X1S_1
--
-- Device: Virtex-II Family
--
-------------------------------------------------------------------
--
-- Components Declarations:
--
component RAM16X1S
-- pragma translate_off
  generic (
-- RAM initialization ("0" by default) for functional simulation:
       INIT : bit_vector := X"0000"
       );
-- pragma translate_on
  port (
       D    : in std_logic;
       WE   : in std_logic;
       WCLK : in std_logic;
       A0   : in std_logic;
       A1   : in std_logic;
       A2   : in std_logic;
       A3   : in std_logic;
       O    : out std_logic
       );
end component;
--
-------------------------------------------------------------------
--
-- Architecture  section:
--
-- Attributes for RAM initialization ("0" by default):
attribute INIT: string;
--
attribute INIT of U_RAM16X1S: label is "0000";
--
-- Distributed SelectRAM Instantiation
U_RAM16X1S: RAM16X1S
  port map (
    D     => , -- insert input signal
    WE    => , -- insert Write Enable signal
    WCLK  => , -- insert Write Clock signal
    A0    => , -- insert Address 0 signal
    A1    => , -- insert Address 1 signal
    A2    => , -- insert Address 2 signal
    A3    => , -- insert Address 3 signal
    O     =>   -- insert output signal
  );
--
-------------------------------------------------------------------
```

Verilog Template

```
//
// Module: SelectRAM_16S
//
// Description: Verilog instantiation template
//              Distributed SelectRAM
//              Single Port 16 x 1
//              can be used also for RAM16X1S_1
//
// Device: Virtex-II Family
//
//-----------------------------------------------------------------------
//
//
// Syntax for Synopsys FPGA Express
// synopsys translate_off

  defparam

       //RAM initialization ("0" by default) for functional simulation:
  U_RAM16X1S.INIT = 16'h0000;
// synopsys translate_on


//Distributed SelectRAM Instantiation
RAM16X1S U_RAM16X1S (  .D(),      // insert input signal
                       .WE(),     // insert Write Enable signal
                      .WCLK(),   // insert Write Clock signal
                       .A0(),     // insert Address 0 signal
                       .A1(),     // insert Address 1 signal
                       .A2(),     // insert Address 2 signal
                       .A3(),     // insert Address 3 signal
                       .O()       // insert output signal
                        );

// synthesis attribute declarations
  /* synopsys attribute

  INIT "0000"
   */
```

Using Shift Register Look-Up Tables

Introduction

Virtex-II can configure any look-up table (LUT) as a 16-bit shift register without using the flip-flops available in each slice. Shift-in operations are synchronous with the clock, and output length is dynamically selectable. A separate dedicated output allows the cascading of any number of 16-bit shift registers to create whatever size shift register is needed. Each CLB resource can be configured using the 8 LUTs as a 128-bit shift register.

This section provides generic VHDL and Verilog submodules and reference code examples for implementing from 16-bit up to 128-bit shift registers. These submodules are built from 16-bit shift-register primitives and from dedicated MUXF5, MUXF6, MUXF7, and MUXF8 multiplexers.

These shift registers enable the development of efficient designs for applications that require delay or latency compensation. Shift registers are also useful in synchronous FIFO and content-addressable memory (CAM) designs. To quickly generate a Virtex-II shift register without using flip-flops (i.e., using the SRL16 element(s)), use the CORE Generator RAM-based Shift Register module.

Shift Register Operations

Data Flow

Each shift register (SRL16 primitive) supports:

- Synchronous shift-in
- Asynchronous 1-bit output when the address is changed dynamically
- Synchronous shift-out when the address is fixed

In addition, cascadable shift registers (SRLC16) support synchronous shift-out output of the last (16th) bit. This output has a dedicated connection to the input of the next SRLC16 inside the CLB resource. Two primitives are illustrated in Figure 2-52.

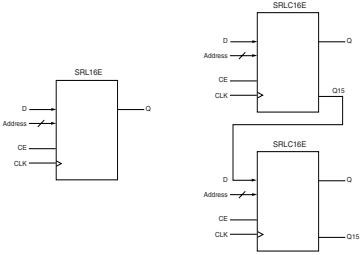

Figure 2-52: **Shift Register and Cascadable Shift Register**

Shift Operation

The shift operation is a single clock-edge operation, with an active High clock enable feature. When enable is High, the input (D) is loaded into the first bit of the shift register, and each bit is shifted to the next highest bit position. In a cascadable shift register configuration (such as SRLC16), the last bit is shifted out on the Q15 output.

The bit selected by the 4-bit address appears on the Q output.

Dynamic Read Operation

The Q output is determined by the 4-bit address. Each time a new address is applied to the 4-input address pins, the new bit position value is available on the Q output after the time delay to access the LUT. This operation is asynchronous and independent of the clock and clock enable signals.

Figure 2-53 illustrates the shift and dynamic read operations.

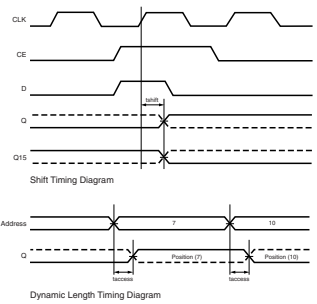

Figure 2-53: **Shift- and Dynamic-Length Timing Diagrams**

Static Read Operation

If the 4-bit address is fixed, the Q output always uses the same bit position. This mode implements any shift register length up 1 to 16 bits in one LUT. Shift register length is (N+1) where N is the input address.

The Q output changes synchronously with each shift operation. The previous bit is shifted to the next position and appears on the Q output.

Characteristics

- A shift operation requires one clock edge.
- Dynamic-length read operations are asynchronous (Q output).
- Static-length read operations are synchronous (Q output).
- The data input has a setup-to-clock timing specification.
- In a cascadable configuration, the Q15 output always contains the last bit value.
- The Q15 output changes synchronously after each shift operation.

Library Primitives and Submodules

Eight library primitives are available that offer optional clock enable (CE), inverted clock ($\overline{CLK}$) and cascadable output (Q15) combinations.

Table 2-20 lists all of the available primitives for synthesis and simulation.

Table 2-20: **Shift Register Primitives**

Primitive	Length	Control	Address Inputs	Output
SRL16	16 bits	CLK	A3,A2,A1,A0	Q
SRL16E	16 bits	CLK, CE	A3,A2,A1,A0	Q
SRL16_1	16 bits	$\overline{CLK}$	A3,A2,A1,A0	Q
SRL16E_1	16 bits	$\overline{CLK}$, CE	A3,A2,A1,A0	Q
SRLC16	16 bits	CLK	A3,A2,A1,A0	Q, Q15
SRLC16E	16 bits	CLK, CE	A3,A2,A1,A0	Q, Q15
SRLC16_1	16 bits	$\overline{CLK}$	A3,A2,A1,A0	Q, Q15
SRLC16E_1	16 bits	$\overline{CLK}$, CE	A3,A2,A1,A0	Q, Q15

In addition to the 16-bit primitives, three submodules that implement 32-bit, 64-bit, and 128-bit cascadable shift registers are provided in VHDL and Verilog code. Table 2-21 lists available submodules.

Table 2-21: **Shift Register Submodules**

Submodule	Length	Control	Address Inputs	Output
SRLC32E_SUBM	32 bits	CLK, CE	A4,A3,A2,A1,A0	Q, Q31
SRLC64E_SUBM	64 bits	CLK, CE	A5, A4, A3,A2,A1,A0	Q, Q63
SRLC128E_SUBM	128 bits	CLK, CE	A6, A5, A4, A3,A2,A1,A0	Q, Q127
SRLC256E_SUBM	256 bits	CLK, CE		

The submodules are based on SRLC16E primitives, which are associated with dedicated multiplexers (MUXF5, MUXF6, and so forth). This implementation allows a fast static- and dynamic-length mode, even for very large shift registers.

Figure 2-54 represents the cascadable shift registers (32-bit and 64-bit) implemented by the submodules in Table 2-21.

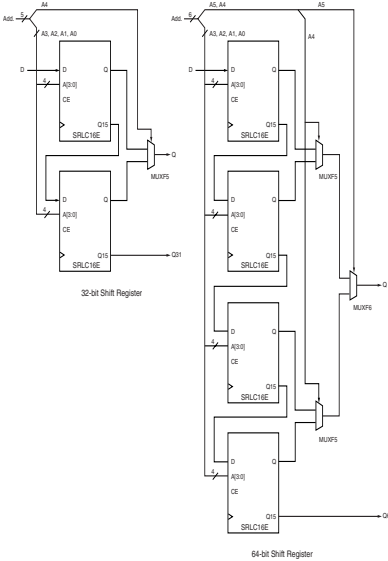

Figure 2-54: **Shift-Register Submodules (32-bit, 64-bit)**

A 128-bit shift register is built on the same scheme and uses MUXF7 (address input A6).

All clock enable (CE) and clock (CLK) inputs are connected to one global clock enable and one clock signal per submodule. If a global static- or dynamic-length mode is not required, the SRLC16E primitive can be cascaded without multiplexers.

Initialization in VHDL and Verilog Code

A shift register can be initialized in VHDL or Verilog code for both synthesis and simulation. For synthesis, the attribute is attached to the 16-bit shift register instantiation and is copied in the EDIF output file to be compiled by Xilinx Alliance Series tools. The VHDL code simulation uses a `generic` parameter to pass the attributes. The Verilog code simulation uses a `defparam` parameter to pass the attributes.

The V2_SRL16E shift register instantiation code examples (in VHDL and Verilog) illustrate these techniques (see "VHDL and Verilog Templates" on page 219). V2_SRL16E.vhd and .v files are not a part of the documentation.

Port Signals

Clock - CLK

Either the rising edge or the falling edge of the clock is used for the synchronous shift-in. The data and clock enable input pins have set-up times referenced to the chosen edge of CLK.

Data In - D

The data input provides new data (one bit) to be shifted into the shift register.

Clock Enable - CE (optional)

The clock enable pin affects shift functionality. An inactive clock enable pin does not shift data into the shift register and does not write new data. Activating the clock enable allows the data in (D) to be written to the first location and all data to be shifted by one location. When available, new data appears on output pins (Q) and the cascadable output pin (Q15).

Address - A0, A1, A2, A3

Address inputs select the bit (range 0 to 15) to be read. The n^{th} bit is available on the output pin (Q). Address inputs have no effect on the cascadable output pin (Q15), which is always the last bit of the shift register (bit 15).

Data Out - Q

The data output Q provides the data value (1 bit) selected by the address inputs.

Data Out - Q15 (optional)

The data output Q15 provides the last bit value of the 16-bit shift register. New data becomes available after each shift-in operation.

Inverting Control Pins

The two control pins (CLK, CE) have an individual inversion option. The default is the rising clock edge and active High clock enable.

GSR

The global set/reset (GSR) signal has no impact on shift registers.

Attributes

Content Initialization - INIT

The INIT attribute defines the initial shift register contents. The INIT attribute is a hex-encoded bit vector with four digits (0000). The left-most hexadecimal digit is the most significant bit. By default the shift register is initialized with all zeros during the device configuration sequence, but any other configuration value can be specified.

Location Constraints

Each CLB resource has four slices: S0, S1, S2, and S3. As an example, in the bottom left CLB resource, each slice has the coordinates shown in Table 2-22.

Table 2-22: **Slice Coordinates in the Bottom-Left CLB Resource**

Slice S3	Slice S2	Slice S1	Slice S0
X1Y1	X1Y0	X0Y1	X0Y0

To constrain placement, shift register instances can have LOC properties attached to them. Each 16-bit shift register fits in one LUT.

A 32-bit shift register in static or dynamic address mode fits in one slice (two LUTs and one MUXF5). This shift register can be placed in any slice.

A 64-bit shift register in static or dynamic address mode fits in two slices. These slices are either S0 and S1, or S2 and S3. Figure 2-55illustrates the position of the four slices in a CLB resource.

The dedicated CLB shift chain runs from the top slice to the bottom slice. The data input pin must either be in slice S1 or in S3. The address selected as the output pin (Q) is the MUXF6 output.

A 128-bit shift register in static or dynamic address mode fits in a four-slice CLB resource. The data input pin has to be in slice S3. The address selected as the output pin (Q) is the MUXF7 output.

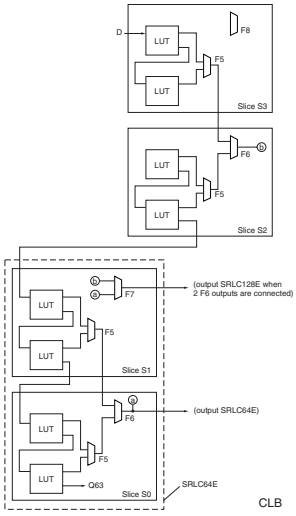

Figure 2-55: **Shift Register Placement**

Fully Synchronous Shift Registers

All shift-register primitives and submodules do not use the register(s) available in the same slice(s). To implement a fully synchronous read and write shift register, output pin Q must be connected to a flip-flop. Both the shift register and the flip-flop share the same clock, as shown in Figure 2-56.

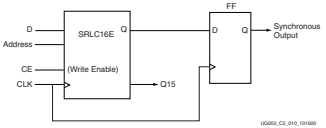

Figure 2-56: **Fully Synchronous Shift Register**

This configuration provides a better timing solution and simplifies the design. Because the flip-flop must be considered to be the last register in the shift-register chain, the static or dynamic address should point to the desired length minus one. If needed, the cascadable output can also be registered in a flip-flop.

Static-Length Shift Registers

The cascadable16-bit shift register implements any static length mode shift register without the dedicated multiplexers (MUXF5, MUXF6,…). Figure 2-57 illustrates a 40-bit shift register. Only the last SRLC16E primitive needs to have its address inputs tied to "1000". Alternatively, shift register length can be limited to 39 bits (address tied to "0111") and a flip-flop can be used as the last register.

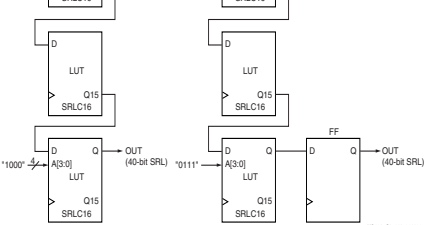

Figure 2-57: **40-bit Static-Length Shift Register**

VHDL and Verilog Instantiation

VHDL and Verilog instantiation templates are available for all primitives and submodules.

In VHDL, each template has a component declaration section and an architecture section. Each part of the template should be inserted within the VHDL design file. The port map of the architecture section should include the design signal names.

The ShiftRegister_C_x (with x = 16, 32, 64, 128, or 256) templates are cascadable modules and instantiate the corresponding SRLCxE primitive (16) or submodule (32, 64, 128, or 256).

The ShiftRegister_16 template can be used to instantiate an SRL16 primitive.

VHDL and Verilog Templates

In template names, the number indicates the number of bits (for example, SHIFT_SELECT_16 is the template for the 16-bit shift register) and the "C" extension means the template is cascadable.

The following are templates for primitives:

- SHIFT_REGISTER_16
- SHIFT_REGISTER_16_C

The following are templates for submodules:

- SHIFT_REGISTER_32_C (submodule: SRLC32E_SUBM)
- SHIFT_REGISTER_64_C (submodule: SRLC64E_SUBM)
- SHIFT_REGISTER_128_C (submodule: SRLC128E_SUBM)

The corresponding submodules have to be synthesized with the design.

Templates for the SHIFT_SELECT_16_C module are provided in VHDL and Verilog code as an example.

VHDL Template:

```
-- Module: SHIFT_REGISTER_C_16
-- Description: VHDL instantiation template
--  CASCADABLE 16-bit shift register with enable (SRL16E)
-- Device: Virtex-II Family
-------------------------------------------------------------------
-- Components Declarations:
--
component SRLC16E
-- pragma translate_off
  generic (
-- Shift Register initialization ("0" by default) for functional
simulation:
        INIT : bit_vector := X"0000"
  );
-- pragma translate_on
  port (
        D : in std_logic;
        CE   : in std_logic;
        CLK  : in std_logic;
        A0   : in std_logic;
        A1   : in std_logic;
        A2   : in std_logic;
        A3   : in std_logic;
        Q    : out std_logic;
        Q15  : out std_logic
  );
end component;
```

```
-- Architecture  Section:
--
-- Attributes for Shift Register initialization ("0" by default):
attribute INIT: string;
--
attribute INIT of U_SRLC16E: label is "0000";
--
-- ShiftRegister Instantiation
U_SRLC16E: SRLC16E
  port map (
  D     => , -- insert input signal
  CE    => , -- insert Clock Enable signal (optional)
  CLK   => , -- insert Clock signal
  A0    => , -- insert Address 0 signal
  A1    => , -- insert Address 1 signal
  A2    => , -- insert Address 2 signal
  A3    => , -- insert Address 3 signal
  Q     => , -- insert output signal
  Q15   =>   -- insert cascadable output signal
  );
```

Verilog Template:

```
// Module: SHIFT_REGISTER_16
// Description: Verilog instantiation template
// 16 bit Shift Register with Carry and Clock Enable
// Device: Virtex-II Family
//-----------------------------------------------------------------------
// Syntax for Synopsys FPGA Express
// synopsys translate_off

  defparam

//Shift Register initialization ("0" by default) for functional
simulation:
  U_SRLC16E.INIT = 16'h0000;
// synopsys translate_on

//SelectShiftRegister-II Instantiation
    SRLC16E U_SRLC16E   ( .D(),
                          .A0(),
                          .A1(),
                          .A2(),
                         .A3(),
                          .CLK(),
                          .CE(),
                          .Q(),
                         .Q15()
            );

// synthesis attribute declarations
  /* synopsys attribute
  INIT "0000"
  */
```