Quantum® Trion® Primitives User Guide

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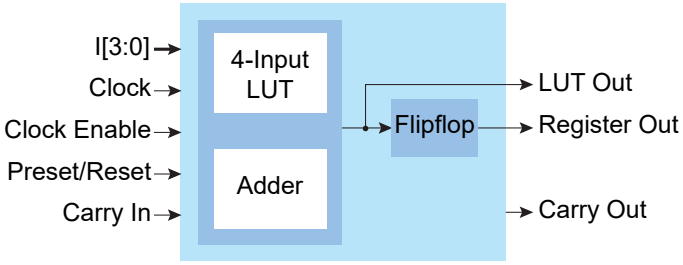
Introduction

This document defines the Efinity® software technology-mapped logic primitives, which are the basic building blocks of the user netlist that is passed to the place-and-route tool.

Logic Cell

The logic cell consists of combinational logic, which can be a 4-input LUT or a full adder and a register. The register may be bypassed.

Figure 1: Logic Cell (Logical View)



Logic cell primitives:

- EFX_LUT4 on page 4
- EFX_ADD on page 7
- EFX_FF on page 10

EFX_LUT4

Simple 4-Input LUT ROM

The EFX_LUT4 primitive is a simple 4-input LUT ROM. Leave unused LUT inputs unconnected and set the LUTMASK value so that it does not depend on them. The software generates an error if the LUTMASK depends on an unconnected input.

EFX_LUT4 Ports

Figure 2: EFX_LUT4 Symbol

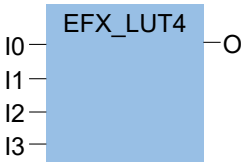


Table 1: EFX_LUT4 Ports

Port	Direction	Description
I0	Input	Data in 0.
I1	Input	Data in 1.
I2	Input	Data in 2.
I3	Input	Data in 3.
O	Output	Data out.

EFX_LUT4 Parameters

Table 2: EFX_LUT4 Parameters

Parameter	Allowed Values	Description
LUTMASK	Any 16 bit hexadecimal number	Content of LUT ROM.

EFX_LUT4 Function

Table 3: EFX_LUT4 Function

Inputs				Output
I3	I2	I1	I0	O
0	0	0	0	LUTMASK[0]
0	0	0	1	LUTMASK[1]
0	0	1	0	LUTMASK[2]

Inputs				Output
I3	I2	I1	I0	O
0	0	1	1	LUTMASK[3]
0	1	0	0	LUTMASK[4]
0	1	0	1	LUTMASK[5]
0	1	1	0	LUTMASK[6]
0	1	1	1	LUTMASK[7]
1	0	0	0	LUTMASK[8]
1	0	0	1	LUTMASK[9]
1	0	1	0	LUTMASK[10]
1	0	1	1	LUTMASK[11]
1	1	0	0	LUTMASK[12]
1	1	0	1	LUTMASK[13]
1	1	1	0	LUTMASK[14]
1	1	1	1	LUTMASK[15]

Figure 3: EFX_LUT4 Verilog HDL Instantiation

```
EFX_LUT4 # (
    .LUTMASK(16'hFFFE) // LUT contents (4 input 'OR')
) EFX_LUT4_inst (
    .O(O),          // LUT output
    .I0(I0),        // LUT input 0
    .I1(I1),        // LUT input 1
    .I2(I2),        // LUT input 2
    .I3(I3)         // LUT input 3
);
```

Figure 4: EFX_LUT4 VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity LUT4_VHDL is
   port
   (
      din : in std_logic_vector(3 downto 0);
      dout : out std_logic
   );
end entity LUT4_VHDL;

architecture Behavioral of LUT4_VHDL is
begin

 EFX_LUT4_inst : EFX_LUT4
   generic map (
      LUTMASK => x"8888"
   )
   port map (
      I0 => din(0),
      I1 => din(1),
      I2 => din(2),
      I3 => din(3),
      O => dout
   );

end architecture Behavioral;
```

EFX_ADD

Simple Full Adder

The EFX_ADD primitive is a simple full adder. The carry-in (CI) and carry-out (CO) connections are dedicated routing between logic cells. Therefore, the first CI in an adder chain must be tied to ground. To access the CO signal through general logic, insert one adder cell to the end of the adder chain to propagate the CO to the sum.

If unused, connect the adder inputs (I1 and I0) to ground.

EFX_ADD Ports

Figure 5: EFX_ADD Symbol

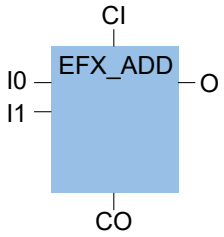


Table 4: EFX_ADD Ports

Port	Direction	Description
I0	Input	Data in 0.
I1	Input	Data in 1.
CI	Input	Carry in.
O	Output	Sum out.
CO	Output	Carry out.

EFX_ADD Parameters

Table 5: EFX_ADD Parameters

Parameter	Allowed Values	Description
IO_POLARITY	0, 1	0: Inverting, 1: Non-inverting (default).
I1_POLARITY	0, 1	0: Inverting, 1: Non-inverting (default).

EFX_ADD Function

Table 6: EFX_ADD Function

Inputs			Outputs	
CI	**I1**	**I0**	**CO**	**O**
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

Figure 6: EFX_ADD Verilog HDL Instantiation

```
EFX_ADD # (
    .IO_POLARITY(1'b1),    // 0 inverting, 1 non-inverting
    .I1_POLARITY(1'b0)     // 0 inverting, 1 non-inverting
) EFX_ADD_inst (
    .O(O),          // Sum output
    .CO(CO),        // Carry output
    .I0(I0),        // Adder input 0
    .I1(I1),        // Adder input 1
    .CI(CI)         // Carry input
);
```

Figure 7: EFX_ADD VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity ADDER_VHDL is
   port
   (
      din_a  : in std_logic_vector(2 downto 0);
      din_b  : in std_logic_vector(2 downto 0);
      sum : out std_logic_vector(2 downto 0)
   );
end entity ADDER_VHDL;

architecture Behavioral of ADDER_VHDL is
signal carry_out : std_logic_vector(1 downto 0);
begin

 EFX_ADD_inst_1 : EFX_ADD
   generic map (
      I0_POLARITY => 1,
      I1_POLARITY => 1
   )
   port map (
      I0 => din_a(0),
      I1 => din_b(0),
      CI => '0',
      O => sum(0),
      CO => carry_out(0)
   );

 EFX_ADD_inst_2 : EFX_ADD
   generic map (
      I0_POLARITY => 1,
      I1_POLARITY => 1
   )
   port map (
      I0 => din_a(1),
      I1 => din_b(1),
      CI => carry_out(0),
      O => sum(1),
      CO => carry_out(1)
   );

 EFX_ADD_inst_3 : EFX_ADD
   generic map (
      I0_POLARITY => 1,
      I1_POLARITY => 1
   )
   port map (
      I0 => din_a(2),
      I1 => din_b(2),
      CI => carry_out(1),
      O => sum(2)
   );

end architecture Behavioral;
```

EFX_FF

D Flip-flop with Clock Enable and Set/Reset Pin

The basic EFX_FF primitive is a D flip-flop with a clock enable and a set/reset pin that can be either asynchronous or synchronously asserted. You can positively or negatively trigger the clock, clock-enable and set/reset pins.

All input ports must be connected. If you do not use a flip-flop control port, connect it to ground or V_{CC}, depending on the polarity. The software issues a warning if a clock port is set to V_{CC} or ground.

EFX_FF Ports

Figure 8: EFX_FF Symbol

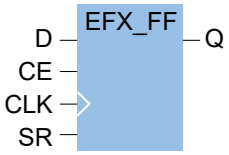


Table 7: EFX_FF Ports

Port	Direction	Description
D	Input	Input data.
CE	Input	Clock Enable.
CLK	Input	Clock.
SR	Input	Asynchronous/synchronous set/reset.
Q	Output	Output data.

EFX_FF Parameters

Table 8: EFX_FF Parameters

Parameter	Allowed Values	Description
CLK_POLARITY	0, 1	0 falling edge, 1 rising edge (default).
CE_POLARITY	0, 1	0 active low, 1 active high (default).
SR_POLARITY	0, 1	0 active low, 1 active high (default).
D_POLARITY	0, 1	0 inverting, 1 non-inverting (default).
SR_SYNC	0, 1	0 asynchronous (default), 1 synchronous.
SR_VALUE	0, 1	0 reset (default), 1 set.
SR_SYNC_PRIORITY	1	Reserved

EFX_FF Function

When the SR_SYNC parameter is asynchronous, the SR port overrides all other ports. When the SR_SYNC parameter is synchronous, the SR port is synchronous with the clock and higher priority than the CE port (the SR port takes effect even if CE is disabled).

Figure 9: EFX_FF Verilog HDL Instantiation

```
EFX_FF # (
    .CLK_POLARITY(1'b1),   // 0 falling edge, 1 rising edge
    .CE_POLARITY(1'b1),    // 0 active low, 1 active high
    .SR_POLARITY(1'b0),    // 0 active low, 1 active high
    .D_POLARITY(1'b1),     // 0 inverting, 1 non-inverting
    .SR_SYNC(1'b0),        // 0 asynchronous, 1 synchronous
    .SR_VALUE(1'b0)        // 0 reset, 1 set
) EFX_FF_inst (
    .Q(Q),         // FF output
    .D(D),         // D input
    .CE(CE),       // Clock-enable input
    .CLK(CLK),     // Clock input
    .SR(SR) // Set/reset input
);
```

Figure 10: EFX_FF VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity D_FF_VHDL is
   port
   (
      clk : in std_logic;
      rst : in std_logic;
      ce  : in std_logic;
      d : in std_logic;
      q : out std_logic
   );
end entity D_FF_VHDL;

architecture Behavioral of D_FF_VHDL is
begin

 EFX_FF_inst : EFX_FF
   generic map (
      CLK_POLARITY => 1,
      CE_POLARITY => 1,
      SR_POLARITY => 1,
      D_POLARITY => 1,
      SR_SYNC => 1,
      SR_VALUE => 0,
      SR_SYNC_PRIORITY => 1
   )
   port map (
      D => d,
      CE => ce,
      CLK => clk,
      SR => rst,
      Q => q
   );

end architecture Behavioral;
```

EFX_RAM_5K

5 Kbit RAM Block

The EFX_RAM_5K primitive represents a configurable 5K bit RAM block that supports a variety of widths and depths. All inputs have programmable inversion, allowing positively or negatively triggered control signals.

The memory read and write ports have 8 modes (256 x 16, 512 x 8, 1024 x 4, 2048 x 2, 4096 x 1, 256 x 20, 512 x 10, 1024 x 5) for addressing the memory. The read and write ports support independently configured data widths.

Table 9: EFX_RAM_5K Allowed Read and Write Mode Combinations

		Write Mode							
	Memory Depth x Data Width	**256 x 16**	**512 x 8**	**1024 x 4**	**2048 x 2**	**4096 x 1**	**256 x 20**	**512 x 10**	**1024 x 5**
Read Mode	**256 x 16**	✓	✓	✓	✓	✓			
	512 x 8	✓	✓	✓	✓	✓			
	1024 x 4	✓	✓	✓	✓	✓			
	2048 x 2	✓	✓	✓	✓	✓			
	4096 x 1	✓	✓	✓	✓	✓			
	256 x 20						✓	✓	✓
	512 x 10						✓	✓	✓
	1024 x 5						✓	✓	✓

The following formula shows how the memory content is addressed for the different data widths:

[((ADDR + 1) * WIDTH) - 1 : (ADDR * WIDTH)]

You define the initial RAM content using INIT_N parameters. There are 20 INIT_N parameters and each parameter represents 256 bits of memory. The memory space covered by each INIT_N parameter uses the formula:

[((N+1) * 256) - 1 : (N * 256)]

When implementing an EFX_RAM_5K block:

- You must connect the RAM control ports (WCLK, WE, WCLKE, RCLK, and RE). If your design does not use these ports, connect them to ground or V_{CC} depending on their polarity. The software issues a warning if the read or write clock is connected to ground or VCC (except when implementing a ROM). The RAM contains an optional output register that improves t_{CO} at a cost of one latency stage. It uses the same clock signals as the read port, and is always enabled[(1)].
- You can only use the address lines that are valid in the particular mode, and you should connect all of them. Leave all other address lines unconnected. Connect required unused address lines to ground.

(1) Always enabled means the read data is always output one cycle after the address read, including the cycle after read-enable is disabled.

- Leave unused data lines unconnected.
- When implementing a ROM connect the WE, WCLK, and WCLKE to ground. Leave WDATA unconnected. Connect WADDR to ground or leave it unconnected based on the write mode you select. The write mode must be compatible with the read mode even though the write ports of the ROM are unused.

When you connect the same clock signal to the read and write clock ports, use the WRITE_MODE parameter to control the read port behavior when writing.

Note: If you use different clocks for the read and write clock ports, you must use READ_UNKNOWN.

EFX_RAM_5K Ports

Figure 11: EFX_RAM_5K Symbol

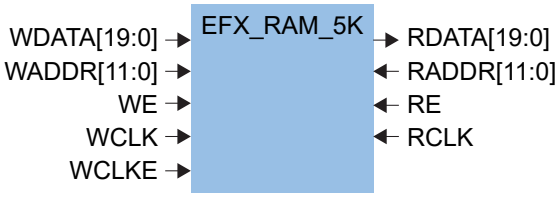


Table 10: EFX_RAM_5K Ports

Port Name	Direction	Description
WDATA[19:0]	Input	Write data
WADDR[11:0]	Input	Write address
WE	Input	Write enable
WCLK	Input	Write clock
WCLKE	Input	Write clock enable
RDATA[19:0]	Output	Read data
RADDR[11:0]	Input	Read address
RE	Input	Read enable
RCLK	Input	Read clock

EFX_RAM_5K Parameters

Table 11: EFX_RAM_5K Parameters

Every input port has programmable inversion support defined by <*port name*>_POLARITY.

Parameter Name	Allowed Values	Description
INIT_<*n*>	256 bit hexadecimal number	Initial RAM content (default = 0)
READ_WIDTH WRITE_WIDTH	16	256 x 16 (default)
	8	512 x 8
	4	1024 x 4
	2	2048 x 2
	1	4096 x 1
	20	256 x 20
	10	512 x 10
	5	1024 x 5
OUTPUT_REG	0, 1	0: disable output register (default) 1: enable output register
<*port name*>_POLARITY	0, 1	0: active low 1: active high (default)
WRITE_MODE	READ_FIRST, WRITE_FIRST, READ_UNKNOWN	When using the same clock for RCLK and WCLK, this parameter controls whether the read data is old or new. READ_FIRST–Old memory content is read. (default) WRITE_FIRST–Write data is passed to the read port. READ_UNKNOWN–Read and writes are unsynchronized, therefore, the results of the address can conflict.

EFX_RAM_5K Function

The EFXBRAM is physically implemented as a 256 x 20 memory array with decoder logic that maps to the read and write modes. The read and write ports are independent:

- Writes are guaranteed
- Read behavior depends on the WRITE_MODE value

The address at the physical memory array must not conflict.

Figure 12: EFX_RAM_5K Verilog HDL Instantiation

```
EFX_RAM_5K # (
   .READ_WIDTH(20),              // 20 256x20
   .WRITE_WIDTH(20),             // 20 256x20
   .OUTPUT_REG(1'b0),            // 1 add pipe-line read register
   .RCLK_POLARITY(1'b1),         // 0 falling edge, 1 rising edge
   .RE_POLARITY(1'b1),           // 0 active low, 1 active high
   .WCLK_POLARITY(1'b1),         // 0 falling edge, 1 rising edge
   .WE_POLARITY(1'b1),           // 0 active low, 1 active high
   .WCLKE_POLARITY(1'b1),        // 0 active low, 1 active high
   .WRITE_MODE("READ_FIRST"),    // Output "old" data
   .INIT_0(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_1(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_2(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_3(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_4(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_5(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_6(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_7(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_8(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_9(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_A(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_B(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_C(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_D(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_E(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_F(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_10(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_11(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_12(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_13(256'h0000000000000000000000000000000000000000000000000000000000000000)
   ) EFX_RAM_5K_inst (
      .RDATA(RDATA),     // Read data output
      .RADDR(RADDR),     // Read address input
      .RCLK(RCLK),       // Read clock input
      .RE(RE),           // Read-enable input
      .WDATA(WDATA),     // Write data input
      .WADDR(WADDR),     // Write address input
      .WCLK(WCLK),       // Write clock input
      .WE(WE),           // Write-enable input
      .WCLKE(WCLKE)      // Write clock-enable input
);
```

Figure 13: EFX_RAM_5K VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity rominit1i_5k is
   generic (
      ADD_SIZE : integer := 11;
      ADD_DEPTH : integer := 2**ADD_SIZE;
      DATA_DEPTH : integer := 2
   );
   port (
      RCLK : in std_logic;
      RADD : in std_logic_vector(ADD_SIZE-1 downto 0);
      RDATA : out std_logic_vector(DATA_DEPTH-1 downto 0)
   );
end entity rominit1i_5k;

architecture Behavioral of rominit1i_5k is
signal data_zeros : std_logic_vector(DATA_DEPTH-1 downto 0);
```

```
signal addr_zeros : std_logic_vector(ADD_SIZE-1 downto 0);
begin

   data_zeros <= (others => '0');
   addr_zeros <= (others => '0');

   MEM : EFX_RAM_5K
      generic map (
         READ_WIDTH => 2,
         WRITE_WIDTH => 2,
         WCLK_POLARITY => 1,
         WCLKE_POLARITY => 1,
         WE_POLARITY => 1,
         RCLK_POLARITY => 1,
         RE_POLARITY => 1,

         -- First segment of 512 (formed from 2301)
         INIT_0 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_1 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_2 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_3 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",

         -- Next segment 512 - 1024 (formed from 0123)
         INIT_4 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_5 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_6 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_7 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",

         -- Next segment 1024 - 1536
         INIT_8 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_9 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_A => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_B => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",

         -- Next segment 1024 - 2048
         INIT_C => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_D => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_E => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_F => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",

         INIT_10 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_11 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_12 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00",
         INIT_13 => x"00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00_00"
      )
      port map (
         WCLK => '0',
         WE => '0',
         WCLKE => '0',
         RCLK => RCLK,
         RE => '1',
         WADDR => addr_zeros,
         WDATA => data_zeros,
         RADDR => RADD,
         RDATA => RDATA
      );

end architecture Behavioral; -- rominit1i_5k
```

EFX_DPRAM_5K

5 Kbit True-Dual-Port RAM Block

The EFX_DPRAM_5K primitive represents a 5 Kbit true-dual-port RAM block that can be configured to support a variety of widths and depths. All inputs have programmable inversion capabilities, which allows you to trigger the control signals positively or negatively. To address the memory contents, you configure the memory A and B ports as 512 x 8, 1024 x 4, 2048 x 2, 4096 x 1, 512 x 10, or 1024 x 5. The read and write ports support independently configured data widths.

The true-dual-port RAM uses the same address bus for reading and writing on a port. Therefore, when a port has mixed widths, the software uses the widest address bus size to determine the address bus width. The direction (read or write) operating in the shallower address size ignores the address bus's LSB because they describe addresses that are outside the legal range for that mode. For example, for a 512 x 8 read and a 1024 x 4 write, the address is 10 bits wide to address all 1024 words being written. The write data is 4 bits wide and the read data is 8 bits wide. The true-dual-port RAM only uses the upper 9 bits of the address port during reading because it can only read 512 words from the memory.

Table 12: EFX_DPRAM_5K Allowed Read and Write Mode Combinations

		Write Mode					
	Memory Depth x Data Width	**512 x 8**	**1024 x 4**	**2048 x 2**	**4096 x 1**	**512 x 10** [2]	**1024 x 5** [2]
Read Mode	**512 x 8**	✓	✓	✓	✓		
	1024 x 4	✓	✓	✓	✓		
	2048 x 2	✓	✓	✓	✓		
	4096 x 1	✓	✓	✓	✓		
	512 x 10					✓	✓
	1024 x 5					✓	✓

The following formula shows how the memory content is addressed for the different data widths:

[((ADDR + 1) * WIDTH) - 1 : (ADDR * WIDTH)]

You define the initial RAM content through INIT_N parameters. Each INIT_N parameter represents 256 bits of memory; 20 parameters cover the 5K memory contents. The memory space covered by each INIT_N parameter uses this formula:

[((N+1) * 256) - 1 : (N * 256)]

When connecting the ports, use the following guidelines:

- You must connect the BRAM control ports (CLKA, WEA, CLKEA, CLKB, WEB, and CLKEB). Connect unused ports to GND or VCC depending on their polarity.
- If you want to disable a RAM port (A or B), disable the clock, write enable, clock enable, and address ports.
- WDATA can be disabled or disconnected.

[2] 5 Kbits only available in 512 x 10 and 1024 x 5modes.

- RDATA should be disconnected.

Note: Each BRAM output port contains an optional output register to improve t_{CO} at a cost of one stage of latency. It uses the same clock signals as the read port, and is always enabled[3].

When writing to a memory port, the WRITE_MODE_A/B parameters control the read port behavior:

You can only use the address lines that are valid for the mode you are using. For example, use only address bits ADDRA[8:0] if port A is in 512 x 8 mode.

All of the address lines for a mode should be connected. Connect unused, required address lines to GND. Leave all other address lines unconnected. For example, if the RAM port B is in 512 x 8 mode but is only implementing a 64 x 2 memory:

- ADDRB[11:9] are unconnected
- ADDRB[8:6] are connected to GND
- ADDRB[5:0] are used

Leave unused data lines unconnected. For example, if the RAM port A is in 512 x 8 mode, but is only implementing a 64 x 2 memory:

- WDATAA[19:2] and RDATAA[19:2] are unused and unconnected
- WDATAA[1:0] and RDATAA[1:0] are used and connected

When implementing a ROM:

- Connect WEA and WEB to GND
- Leave WDATAA and WDATAB unconnected or disabled

EFX_DPRAM_5K Ports

Figure 14: EFX_DPRAM_5K Symbol

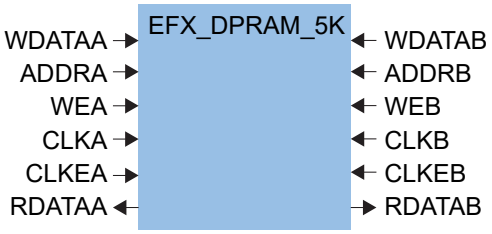


Table 13: EFX_DPRAM_5K Ports

Port Name	Direction	Description
WDATAA[9:0] WDATAB[9:0]	Input	Write data port A/B
ADDRA[11:0] ADDRB[11:0]	Input	Address port A/B
WEA WEB	Input	Write enable port A/B
CLKA CLKB	Input	Clock port A/B

[3] Always enabled means the read data is always output one cycle after the address read, including the cycle after read-enable is disabled.

Port Name	Direction	Description
CLKEA CLKEB	Input	Clock enable port A/B
RDATA[9:0] RDATB[9:0]	Output	Read data port A/B

EFX_DPRAM_5K Parameters

Table 14: EFX_DPRAM_5K Parameters

Every input port has programmable inversion support defined by <*port name*>_POLARITY.

Parameter Name	Allowed Values	Description
INIT_<*n*>	256 bit hexadecimal number	Initial RAM content (default = 0)
READ_WIDTH_A READ_WIDTH_B WRITE_WIDTH_A WRITE_WIDTH_B	8	512 x 8 (default)
	4	1024 x 4
	2	2048 x 2
	1	4096 x 1
	10	512 x 10
	5	1024 x 5
WRITE_MODE_A WRITE_MODE_B	READ_FIRST, WRITE_FIRST, NO_CHANGE	Controls the read port behavior READ_FIRST–Old memory content is read. (default) WRITE_FIRST–Write data is passed to the read port. NO_CHANGE–Previously read data is held.
OUTPUT_REG_A OUTPUT_REG_B	0, 1	0: disable output register (default) 1: enable output register
<*port name*>_POLARITY	0, 1	0: active low 1: active high (default)

EFX_DPRAM_5K Function

The BRAM is physically implemented as a 256 x 20 memory array with decoder logic to map to the read and write modes. The A and B ports are independent and the behavior is undefined when addresses conflict. The address at the physical memory array must not conflict.

Figure 15: EFX_DPRAM_5K Verilog HDL Instantiation

```
EFX_DPRAM_5K # (
    .READ_WIDTH_A(8),               // 8 512x8
    .WRITE_WIDTH_A(8),              // 8 512x8
    .OUTPUT_REG_A(1'b0),            // 1 add pipe-line read register
    .CLKA_POLARITY(1'b1),           // 0 falling edge, 1 rising edge
    .WEA_POLARITY(1'b1),            // 0 active low, 1 active high
    .CLKEA_POLARITY(1'b1),          // 0 falling edge, 1 rising edge
    .WRITE_MODE_A("READ_FIRST"),    // Output "old" data
    .READ_WIDTH_B(8),               // 8 512x8
    .WRITE_WIDTH_B(8),              // 8 512x8
    .OUTPUT_REG_B(1'b0),            // 1 add pipe-line read register
    .CLKB_POLARITY(1'b1),           // 0 falling edge, 1 rising edge
    .WEB_POLARITY(1'b1),            // 0 active low, 1 active high
```

```
   .CLKEB_POLARITY(1'b1),          // 0 falling edge, 1 rising edge
   .WRITE_MODE_B("READ_FIRST"),    // Output "old" data
   .INIT_0(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_1(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_2(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_3(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_4(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_5(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_6(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_7(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_8(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_9(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_A(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_B(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_C(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_D(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_E(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_F(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_10(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_11(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_12(256'h0000000000000000000000000000000000000000000000000000000000000000),
   .INIT_13(256'h0000000000000000000000000000000000000000000000000000000000000000)
   ) EFX_DPRAM_5K_inst (
      .RDATAA(RDATAA),    // Read data output A
      .ADDRA(ADDRA),      // Address input A
      .CLKA(CLKA),        // Clock input A
      .CLKEA(CLKEA),      // Clock-enable input A
      .WEA(WEA),          // Write-enable input A
      .WDATAA(WDATAA),    // Write data input A
      .RDATAB(RDATAB),    // Read data output B
      .ADDRB(ADDRB),      // Address input B
      .CLKB(CLKB),        // Clock input B
      .CLKEB(CLKEB),      // Clock-enable input B
      .WEB(WEB),          // Write-enable input B
      .WDATAB(WDATAB)     // Write data input B
);
```

Figure 16: EFX_DPRAM_5K VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.NUMERIC_STD.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity ram512x8_tdp_rbwi_VHDL is
   generic (
      AWIDTH : integer := 9;
      DWIDTH : integer := 8
   );
   port
   (
      wdataA, wdataB : in std_logic_vector(DWIDTH-1 downto 0);
      addrA, addrB : in std_logic_vector(AWIDTH-1 downto 0);
      clkA, weA : in std_logic;
      clkB, weB : in std_logic;
      rdataA, rdataB : out std_logic_vector(DWIDTH-1 downto 0)
   );
end entity ram512x8_tdp_rbwi_VHDL;

architecture Behavioral of ram512x8_tdp_rbwi_VHDL is
   constant INIT_0 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_1 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_2 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_3 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_4 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_5 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_6 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_7 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_8 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_9 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_A : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
```

```
   constant INIT_B : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_C : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_D : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_E : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_F : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_10 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_11 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_12 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
   constant INIT_13 : unsigned(255 downto 0) :=
 x"0000000000000000000000000000000000000000000000000000000000000000";
begin

   ram : EFX_DPRAM_5K
     generic map (
       READ_WIDTH_A => DWIDTH,
       WRITE_WIDTH_A => DWIDTH,
       READ_WIDTH_B => DWIDTH,
       WRITE_WIDTH_B => DWIDTH,
       WRITE_MODE_A => "READ_FIRST",
       WRITE_MODE_B => "READ_FIRST",
       INIT_0 => INIT_0,
       INIT_1 => INIT_1,
       INIT_2 => INIT_2,
       INIT_3 => INIT_3,
       INIT_4 => INIT_4,
       INIT_5 => INIT_5,
       INIT_6 => INIT_6,
       INIT_7 => INIT_7,
       INIT_8 => INIT_8,
       INIT_9 => INIT_9,
       INIT_A => INIT_A,
       INIT_B => INIT_B,
       INIT_C => INIT_C,
       INIT_D => INIT_D,
       INIT_E => INIT_E,
       INIT_F => INIT_F,
       INIT_10 => INIT_10,
       INIT_11 => INIT_11,
       INIT_12 => INIT_12,
       INIT_13 => INIT_13
     )
     port map (
       WDATAA => wdataA,
       ADDRA => addrA,
       CLKA => clkA,
       CLKEA => '1',
       WEA => weA,
       RDATAA => rdataA,
       WDATAB => wdataB,
       ADDRB => addrB,
       CLKB => clkB,
       CLKEB => '1',
       WEB => weB,
       RDATAB => rdataB
     );

end architecture Behavioral;
```

EFX_MULT

18 x 18 Multiplier

The EFX_MULT logical block represents a signed integer multiplier with optional input and output registers. The Quantum® fabric supports an 18 x 18 multiplier. All inputs have programmable inversion allowing positively or negatively triggered control signals.

When implementing an EFX_MULT block:

- If emulating an unsigned multiplier, set the MSB bit to ground.
- You must connect the multiplier control ports (CLK, CEA, RSTA, CEB, RSTB, CEO, and RSTO). Connect unused ports to V_{CC} or ground depending on their polarity. The software issues a warning if the clock is connected to V_{CC} or ground and the design does not bypass the registers.
- You must connect all data lines. Connect unused, required data lines to a sign bit. For example, when implementing a signed 8 x 8 multiplier, the software uses bits A[7:0]. Connect data bits A[17:8] to the signal driving A[7].

The command-line option `--max_mult` controls the maximum number of multiplier blocks that the software can infer.

- `-1` is auto and the tool infers as many blocks as appropriate
- `0` infers none
- *n* infers no more than *n* blocks

EFX_MULT Ports

Figure 17: EFX_MULT Symbol

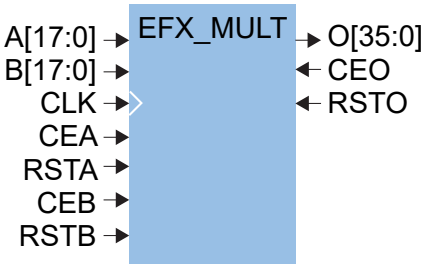


Table 15: EFX_MULT Ports

Port Name	Direction	Description
A[17:0]	Input	Operand A
B[17:0]	Input	Operand B
CLK	Input	Clock
CEA	Input	Clock enable A
RSTA	Input	Set/reset A
CEB	Input	Clock enable B
RSTB	Input	Set/reset B
O[35:0]	Output	Multiplier output

Port Name	Direction	Description
CEO	Input	Clock enable O
RSTO	Input	Set/reset O

EFX_MULT Parameters

Table 16: EFX_MULT Parameters

Every input port has programmable inversion support defined by <*port name*>_POLARITY.

Parameter Name	Allowed Values	Description
WIDTH	18	18 x 18 multiplier
A_REG	0, 1	0: Disable A registers (default) 1: Enable A registers
B_REG	0, 1	0: Disable B registers (default) 1: Enable B registers
O_REG	0, 1	0: Disable output registers (default) 1: Enable output registers
RSTA_SYNC	0, 1	0: Asynchronous (default) 1: Synchronous on A registers
RSTA_VALUE	0, 1	0: Reset (default) 1: Set on A register
RSTB_SYNC	0, 1	0: Asynchronous (default) 1: Synchronous on B registers
RSTB_VALUE	0, 1	0: Reset (default) 1: Set on B register
RSTO_SYNC	0, 1	0: Asynchronous (default) 1: Synchronous on output registers
RSTO_VALUE	0, 1	0: Reset (default) 1: Set on output register
<*port name*>_POLARITY	0, 1	0: Active low 1: Active high (default)
SR_SYNC_PRIORITY	0	Reserved

EFX_MULT Function

The EFX_MULT is a signed integer multiplier.

Figure 18: EFX_MULT Verilog HDL Instantiation

```
EFX_MULT # (
   .WIDTH(18),
   .A_REG(1),
   .B_REG(1),
   .O_REG(1),
   .CLK_POLARITY(1'b1),  // 0 falling edge, 1 rising edge
   .CEA_POLARITY(1'b1),  // 0 falling edge, 1 rising edge
   .RSTA_POLARITY(1'b0), // 0 falling edge, 1 rising edge
   .RSTA_SYNC(1'b0),     // 0 aynchronous, 1 synchronous
   .RSTA_VALUE(1'b0),    // 0 reset, 1 set
   .CEB_POLARITY(1'b1),  // 0 falling edge, 1 rising edge
   .RSTB_POLARITY(1'b0), // 0 falling edge, 1 rising edge
```

```
   .RSTB_SYNC(1'b0),     // 0 aynchronous, 1 synchronous
   .RSTB_VALUE(1'b0),    // 0 reset, 1 set
   .CEO_POLARITY(1'b1),  // 0 falling edge, 1 rising edge
   .RSTO_POLARITY(1'b0), // 0 falling edge, 1 rising edge
   .RSTO_SYNC(1'b0),     // 0 aynchronous, 1 synchronous
   .RSTO_VALUE(1'b0)     // 0 reset, 1 set
   ) mult (
      .CLK(CLK),
      .CEA(CEA),
      .RSTA(SRA),
      .CEB(CEB),
      .RSTB(SRB),
      .CEO(CEO),
      .RSTO(SRO),
      .A(A),
      .B(B),
      .O(O)
);
```

Figure 19: EFX_MULT VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity mult_s18xs18_ffesr2i_VHDL is
   port
   (
      clk : in std_logic;
      cea, clra : in std_logic;
      ceb, clrb : in std_logic;
      cex, clrx : in std_logic;
      a,b : in std_logic_vector(17 downto 0);
      x : out std_logic_vector(35 downto 0)
   );
end entity mult_s18xs18_ffesr2i_VHDL;

architecture Behavioral of mult_s18xs18_ffesr2i_VHDL is
begin

 EFX_MULT_inst : EFX_MULT
   generic map (
      WIDTH => 18,
      A_REG => 1,
      B_REG => 1,
      O_REG => 1,
      RSTA_SYNC => 1,
      RSTB_SYNC => 1,
      RSTO_SYNC => 1,
      SR_SYNC_PRIORITY => 0
   )
   port map (
      CLK => clk,
      CEA => cea,
      RSTA => clra,
      CEB => ceb,
      RSTB => clrb,
      CEO => cex,
      RSTO => clrx,
      A => a,
      B => b,
      O => x
   );

end architecture Behavioral;
```

EFX_GBUFCE

Global Clock Buffer

The EFX_GBUFCE logic block represents the global clock buffer driving the global clock network. The CE port gates the clock and is active high.

You must connect all EFX_GBUFCE input ports. If you do not use a port, connect it to ground or V_{CC} depending on its polarity. The software issues an error if the clock input I is set to V_{CC} or ground.

Synthesis creates EFX_GBUFCE logical blocks for every clock source in the user netlist. This implementation allows the place-and-route tools to identify the clock sources that should be placed on pins capable of being clocks or to route core-generated clocks.

EFX_GBUFCE Ports

Figure 20: EFX_GBUFCE Symbol

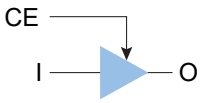


Table 17: EFX_GBUFCE Ports

Port Name	Direction	Description
I	Input	Input data
CE	Input	Clock enable
O	Output	Output data

EFX_GBUFCE Parameters

Table 18: EFX_GBUFCE Parameters

Parameter Name	Allowed Values	Description
CE_POLARITY	0, 1	0 active low, 1 active high (default)

EFX_GBUFCE Function

The function table assumes all inputs are active-high polarity.

Table 19: EFX_GBUFCE Function

Inputs		Output
CE	**I**	**O**
0	X	0
1	0	0
1	1	1

Figure 21: EFX_GBUFCE Verilog HDL Instantiation

```
EFX_GBUFCE # (
   .CE_POLARITY(1'b1)   // 0 active low, 1 active high
) EFX_GBUFCE_inst (
   .O(O),               // Clock output to global clock network
   .I(I),               // Clock input
   .CE(CE)              // Clock gate
);
```

Figure 22: EFX_GBUFCE VHDL Instantiation

```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
library efxphysicallib;
use efxphysicallib.efxcomponents.all;

entity gbufce_i_VHDL is
   port
   (
      clk, d, ce : in std_logic;
      q : out std_logic
   );
end gbufce_i_VHDL;

architecture behavioral of gbufce_i_VHDL is
signal clknet : std_logic;
begin

  dut : EFX_GBUFCE
    port map (
       CE => ce,
       I => clk,
       O => clknet
    );

  ffx : EFX_FF
    port map (
       Q => q,
       D => d,
       CLK => clknet,
       CE => '1',
       SR => '0'
    );

end behavioral;
```

Revision History

Table 20: Revision History

Date	Version	Description
November 2023	4.6	Improved Allowed Read and Write Mode Combinations tables for EFX_RAM_5K and EFX_DRRAM_5K. (DOC-1566)
June 2023	4.5	Updated table EFX_FF Parameters and EFX_MULT Parameters. (DOC-1237)
March 2022	4.4	Updated description for the optional output register in EFX_RAM_5K and EFX_DPRAM_5K.
June 2021	4.3	Renamed as Quantum Trion Primitives User Guide.
June 2020	4.2	Added primitive instantiation examples in VHDL. Removed EFX_RAM_10K block description. Updated document formatting.
October 2018	4.1	Added the EFX_RAM_10K primitive. Removed the EFX_LATCH primitive.
April 2018	4.0	EFX_RAM_5K–Added description of the READ_UNKNOWN option for the WRITE_MODE parameter. EFX_MULT–Changed the following signals: • SRA to RSTA • SRB to RSTB • SBO to RSTO
November 2017	3.1	Added EFX_DPRAM_5K primitive. Updated EFX_RAM_5K description. Removed EFX_GBUF description.
May 2017	3.0	Removed OPM family information. Changed OPH family name to Quantum. Added GBUF primitive.
May 2016	2.0	Added EFX_RAM_5K and EFX_MULT primitive descriptions.
April 2015	1.0	Initial release.