



Lattice Nexus 2 Embedded Memory User Guide

Preliminary Technical Note

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Abbreviations in This Document

A list of abbreviations used in this document.

Abbreviation	Definition
ASCII	American Standard Code for Information Interchange
BE	Byte Enable
CS	Chip Select
EBR	Embedded Block RAM
ECC	Error Correction Code
FIFO	First In First Out
GSR	Global Set/Reset
HDL	Hardware Description Language
IP	Intellectual Property
LSB	Least Significant Bit
LUT	Look-Up Table
MSB	Most Significant Bit
PFU	Programmable Function Unit
PMI	Parameterizable Module Instantiation
RAM	Random Access Memory
ROM	Read Only Memory
RST	Reset
SRAM	Static Random Access Memory
VHDL	VHSIC Hardware Description Language

1. Introduction

This technical note discusses memory usage for the Lattice Semiconductor devices built on the Lattice Nexus™ 2 platform. Use this document as a guide when integrating the Embedded block RAM (EBR)-based and Programmable Function Unit (PFU)-based memories for these device families in the Lattice Radiant™ software.

The architecture of these devices provides many resources for memory-intensive applications. The sysMEM™ EBR complements its distributed PFU-based memory. Single-port random access memory (RAM), dual-port RAM, pseudo dual-port RAM, First In First Out (FIFO), and read only memory (ROM) can be constructed using the EBR. The look-up tables (LUTs) and PFUs can implement distributed single-port RAM, dual-port RAM, and ROM. LUTs within PFUs can implement distributed single-port RAM, dual-port RAM, and ROM.

The capabilities of the EBR and PFU RAM are described in this document. You can use the memory primitives in three separate ways:

- Through the IP Catalog – The IP Catalog interface allows you to specify the memory type and size required. The IP Catalog takes this specification and constructs a netlist to implement the desired memory by using one or more of the memory primitives.
- Through Parameterizable Module Instantiation (PMI) – PMI allows you to skip the graphical interface and use the configurable memory primitives on the fly from the Lattice Radiant project navigator. You can set the parameters and the control signals needed either in Verilog or VHDL. The top-level design has the parameters defined and signals declared so the interface can automatically generate the black box during synthesis.
- Through the instantiation of memory primitives – Memory primitives are called directly by the top-level module and instantiated in the design. This is an advanced method and requires a thorough understanding of memory hook-ups and design interfaces.

The remainder of this document discusses these methods.

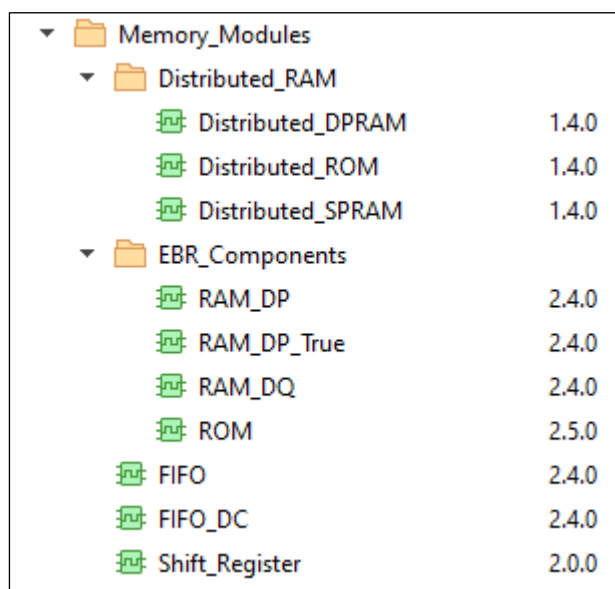
2. Memory Generation

You can use the IP Catalog to specify a variety of memories in the designs. These modules are constructed using one or more memory primitives along with general-purpose routing and LUTs as required.

The available modules in the IP Catalog are as follows.

- Distributed memory modules
 - Distributed pseudo dual-port RAM, Distributed_DPRAM
 - Distributed ROM, Distributed_ROM
 - Distributed single-port RAM, Distributed_SPRAM
- EBR components or EBR-based modules
 - Dual-port RAM, RAM_DP_TRUE
 - Pseudo dual-port RAM, RAM_DP
 - Single-port RAM, RAM_DQ
 - Read only memory, ROM
- First In First Out memory, EBR-based or LUT-based
 - Single-clock FIFO, FIFO
 - Dual-clock FIFO, FIFO_DC

Figure 2.1 shows the memory modules under the IP Catalog in the Lattice Radiant software.



▼	Memory_Modules	
▼	Distributed_RAM	
	Distributed_DPRAM	1.4.0
	Distributed_ROM	1.4.0
	Distributed_SPRAM	1.4.0
▼	EBR_Components	
	RAM_DP	2.4.0
	RAM_DP_True	2.4.0
	RAM_DQ	2.4.0
	ROM	2.5.0
	FIFO	2.4.0
	FIFO_DC	2.4.0
	Shift_Register	2.0.0

Figure 2.1. Memory Modules Available in the IP Catalog

2.1. IP Catalog Flow

The IP Catalog allows you to generate, create, or open any of the available modules for Lattice Nexus 2 platform devices. In the Lattice Radiant software, choose **View > Show Views > IP Catalog**, or click the IP Catalog icon in the toolbar. This opens the IP Catalog window, as shown in Figure 2.2.

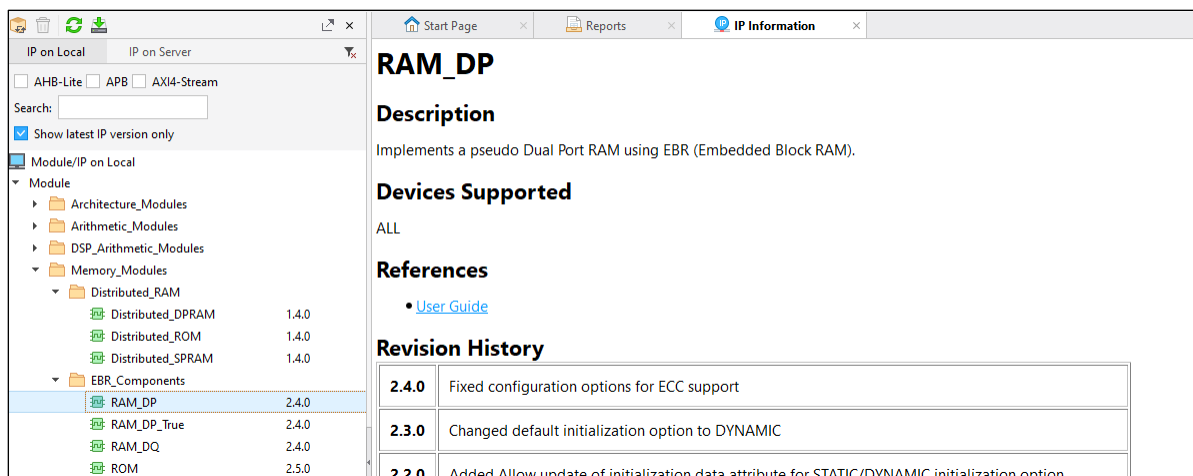


Figure 2.2. IP Catalog in the Lattice Radiant Software

The left section of the IP Catalog window includes the module tree. The memory modules are categorized as Distributed RAM, EBR Components, FIFOs, and Shift Register. The right section of the window shows the description of the module selected and links to the documentation for additional information.

This section provides an example of generating an EBR-based pseudo dual-port RAM of size 512 × 36.

To generate an EBR-based pseudo dual-port RAM:

1. Double-click **ram_dp** under **EBR_Components**.
2. Fill out the module information, as shown in Figure 2.3.
3. Click the **Next** button.

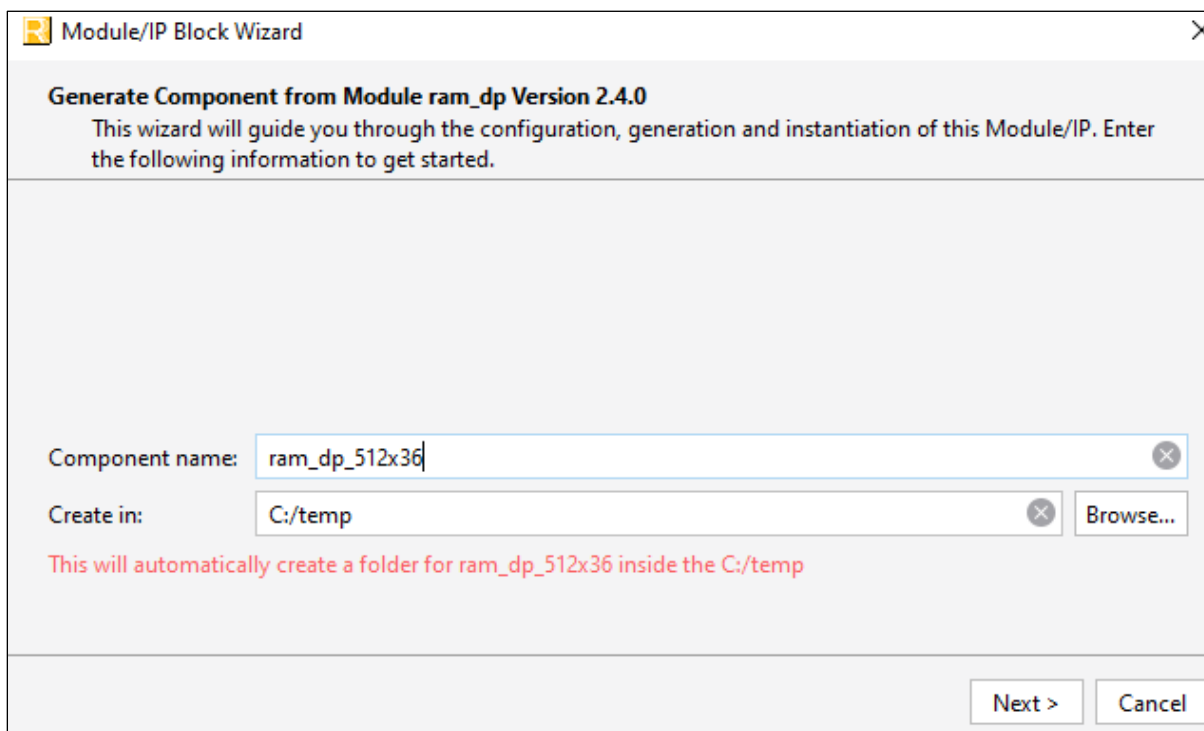


Figure 2.3. Example: Generating Pseudo Dual-Port RAM ram_dp Using the IP Catalog

4. Customize the EBR-based DPRAM in the **Module/IP Block Wizard** window, as shown in [Figure 2.4](#).

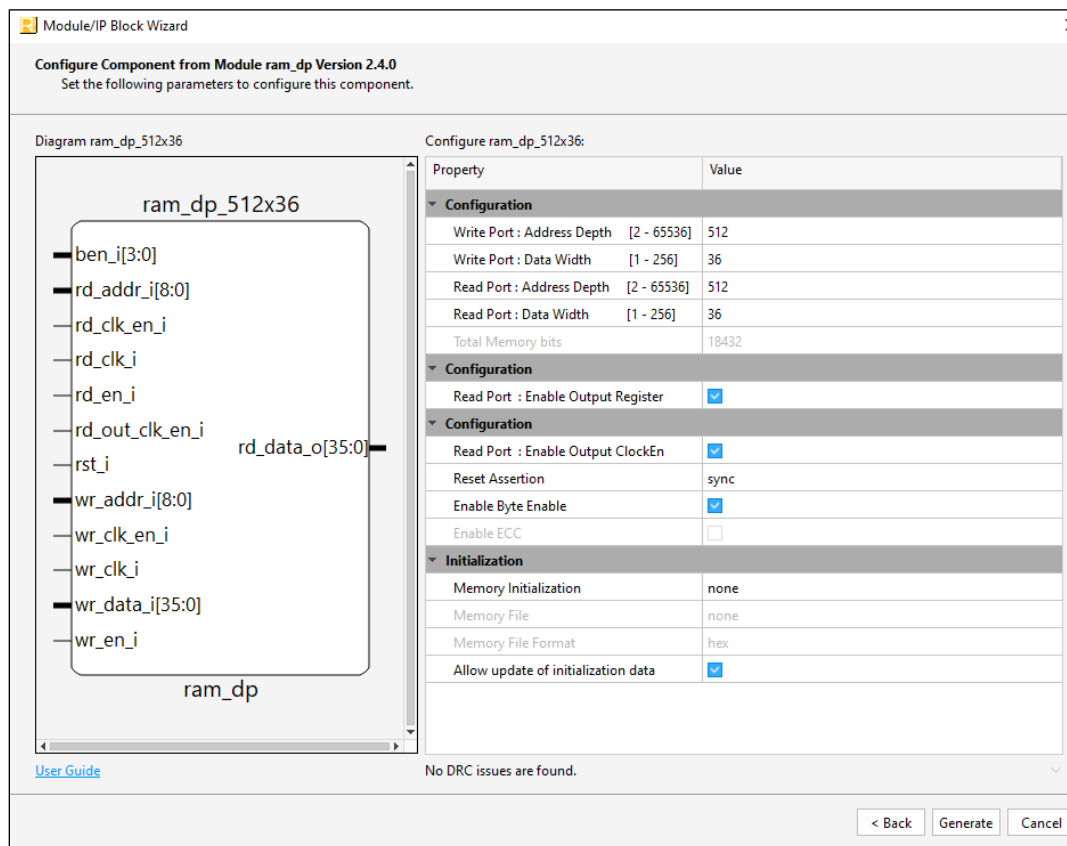


Figure 2.4. Example: Generating Pseudo Dual-Port RAM ram_dp Module Customization – General Options

5. When all the options of the module being generated are filled out, click **Generate**.
Once this module is in the Lattice Radiant project, it can be instantiated within other modules.

2.2. Utilizing PMI

You can set the parameters and control signals needed in either Verilog or VHDL. The top-level design includes the defined memory parameters and declared signals. The interface can then automatically generate the black box during synthesis and the Lattice Radiant software can generate the netlist on-the-fly. Lattice memories are the same as industry-standard memories, so you can get the parameters for each module from any memory-related guide, which is available through the Online Help system.

To do this, create Verilog or VHDL behavioral code for the memory; the synthesis tool automatically identifies it as memory and synthesizes it as a distributed or EBR memory. In general, memory sizes smaller than 1 kb are automatically mapped to the distributed mode and those larger than 1 kb are implemented using EBRs. This default option can be overridden using the `syn_ramstyle` or `syn_romstyle` attribute in Synopsys Synplify Pro®.

2.3. Utilizing Direct Instantiation of Memory Primitives

Another way to use the memories in the designs is by directly instantiating the memory primitives for the Lattice Nexus 2 platform devices. When instantiating the primitives, you must work at the EBR block level. In case there is a need to have a memory that spans multiple modules, you are required to create the cascading memory on its own.

Lattice provides library files containing all the primitives in a VHDL/Verilog file under the `cae_library/synthesis` folder in the Lattice Radiant software installation folder.

3. Memory Features

The RAMs can be generated with error correction and byte enable features that mask selective bits. These features are available in the EBR-based RAM modules.

3.1. ECC in Memory Modules

An error correction code (ECC) is a system of adding redundant data or parity data to a message, such that it can be recovered by a receiver even when a number of errors are introduced, either during the process of transmission or on storage.

The IP Catalog allows you to implement ECC in EBR-based memory modules. There is a check box to enable ECC in the Configuration tab for the module.

The Enable ECC check box allows error correction of single errors and detection of 2-bit errors. ECC write is supported only in x64 write mode with 8-bit ECC. ECC read may be performed in x1, x2, x4, x8, x16, x32, or x64 modes.

The two bits indicate the error, if any, and the following shows you what each of these bits means:

- `one_err_det_o = 1` indicates there is a 1-bit error that is fixed.
- `two_err_det_o = 1` indicates there is a 2-bit error that cannot be corrected.

The error flags are aligned to the output data and are available in the same cycle as the respective data.

3.2. Byte Enable

Byte enable is a feature available in selected RAM modules where you can mask the bytes written in the RAM. The byte enable feature is available only when data width is greater than nine bits. Each byte enable bit controls the write data operation enable for the nine bits. The selection can be made in the IP Catalog while generating the module.

Each bit of the BE signal corresponds to the corresponding 9-bit selection, starting from the LSB side. For example, if you add byte enable to a 72-bit wide RAM, then [Table 3.1](#) explains how the written data, that is, Data In, is masked for a 9-bit byte size. Bits 8, 17, 26, 35, 44, 53, 62, and 71 are parity bits, which you ignore in x8, x16, x32, and x64 modes.

Table 3.1. Masked Data in Bits for a 9-Bit Byte Size

Byte Enable Bit	Data In Bits that Get Masked with 9-bit Byte Size
ByteEn(0)	Data(8:0)
ByteEn(1)	Data(17:9)
ByteEn(2)	Data(26:18)
ByteEn(3)	Data(35:27)
ByteEn(4)	Data(44:36)
ByteEn(5)	Data(53:45)
ByteEn(6)	Data(62:54)
ByteEn(7)	Data(71:63)

Note that in the ECC mode, all bytes of write data are written regardless of the value of ByteEn bits.

4. Memory Modules

The following sections discuss the different memory modules, the size of memory that each EBR block or the distributed primitive can support, and any special options for the module.

When you specify the width and depth of the memory in the IP Catalog, the tool generates the memory by depth cascading and/or width cascading, or EBR blocks, or distributed RAM primitives. The IP Catalog automatically allows you to create memories larger than the width and depth supported for each primitive.

4.1. Memory Cascading

For memory sizes that are smaller than what can fit in a single EBR block or the distributed primitive, the module uses the complete block or primitive.

For memory sizes larger than that of a single module, multiple modules are cascaded either in depth or width to create a larger module.

4.1.1. Input and Output Register

The architecture of the EBR blocks in Lattice Nexus 2 platform devices is designed such that the inputs that go into the memory are always registered. This means that the input data and address are always registered at the input of the memory array. The output data of the memory is optionally registered at the output. You can choose this option by selecting the Enable Output Register check box in the IP Catalog while customizing the module.

Control signals such as WE and Byte Enable that go into the EBR block are also registered.

4.1.2. Reset

The EBRs also support the Reset signal. The Reset or RST signal only resets input and output registers of the RAM. It does not reset the contents of the memory. The global set/reset (GSR) signal also controls the output registers.

4.1.3. Timing

To correctly write to a memory cell in the EBR block, the correct address must be registered by the logic. Hence, it is important to note that while running the trace on the EBR blocks, there should be no setup and hold time violations on the address registers. Failing to meet these requirements can result in incorrect addressing and hence lead to corruption of memory contents.

During a read cycle, a similar issue can occur such that the correct contents are not read if the address is not correctly registered in the memory.

A post-place and route timing report in the Lattice Radiant software can be run to verify that no such timing errors occur. For more information, refer to the timing preferences in the Online Help document of the Lattice Radiant software.

4.2. Single-Port RAM – EBR-Based

This section describes the single-port RAM, RAM_DQ, which is EBR-based.

FPGAs built on the Lattice Nexus 2 platform support all the features of the single-port RAM memory module, RAM_DQ. The IP Catalog allows you to generate the Verilog-HDL or VHDL for the memory size as per design requirement.

The IP Catalog generates the memory module, as shown in Figure 4.1.

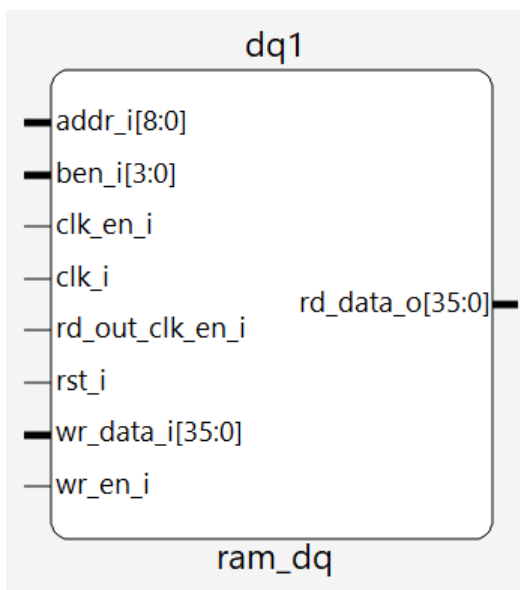


Figure 4.1. Single-Port Memory Module Generated by the IP Catalog

Figure 4.2 shows the primitive that can be instantiated for the single-port RAM. The primitive name is SP32K and it can be directly instantiated in the code. Check the details of the ports and port names under the primitives available under the cae_library/synthesis folder in the Lattice Radiant software installation folder.

Note that each EBR can accommodate 36 kb of memory. If the memory required is larger than 36 kb, then use the CS port to cascade blocks. In this case, the CS port is CS[2:0].

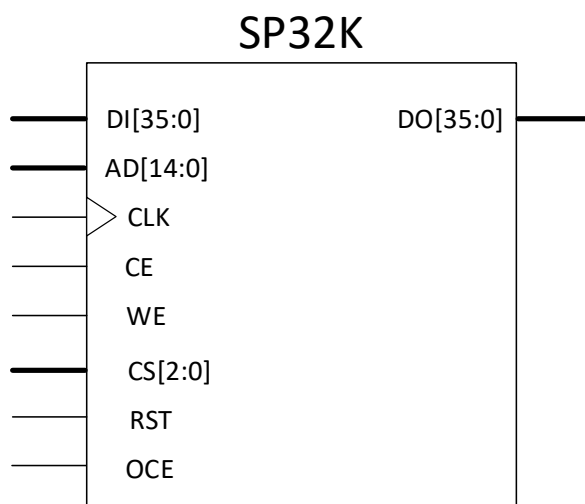


Figure 4.2. Single-Port RAM Primitive for Lattice Nexus 2 Platform Devices

The various ports and definitions for the single-port memory are listed in Table 4.1. The table shows the corresponding ports for the module generated by the IP Catalog.

Table 4.1. EBR-Based Single-Port Memory Port Definitions¹

Port Name	Direction	Width	Description
clk_i	Input	1	Clock
rst_i	Input	1	Reset
clk_en_i	Input	1	Input Clock Enable
rd_out_clk_en_i	Input	1	Read Output Register Enable Present if Enable Output Register == TRUE
wr_en_i	Input	1	Write Enable
wr_data_i	Input	Data Width	Data Input
addr_i	Input	Address Width	Address Bus
rd_data_o	Output	Data Width	Data Output
ben_i	Input	Byte Enable Width	Byte Enable

Note:

1. Address width is calculated from address depth.

Each EBR block consists of 36,864 bits of RAM. See Table 4.2 for each EBR block address value, x, and data value, y.

Table 4.2. Single-Port Memory Sizes for 36 kb Memory in Lattice Nexus 2 Platform Devices

Single-Port Memory Size	Input Data	Output Data	Address [MSB:LSB]
32,768 × 1	DI	DO	AD[14:0]
16,384 × 2	DI[1:0]	DO[1:0]	AD[13:0]
8,192 × 4	DI[3:0]	DO[3:0]	AD[12:0]
4,096 × 9	DI[8:0]	DO[8:0]	AD[11:0]
2,048 × 18	DI[17:0]	DO[17:0]	AD[10:0]
1,024 × 36	DI[35:0]	DO[35:0]	AD[9:0]
512 × 72	DI[71:0]	DO[71:0]	AD[8:0]

Table 4.3 shows the various attributes available for the single-port memory, RAM_DQ. You can select some of these attributes through the IP Catalog interface.

The ones without selectable options in the IP Catalog are handled by the engine. However, you can access these options if you are working with the direct primitive instantiation.

Table 4.3. Single-Port Memory Attributes in Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Address Depth	Address depth of the read and write port.	2—<Max that can fit in the device>	512
Data Width	Data word width of the read and write port.	1, 2, 4, 8/9, 16/18, or 36	36
Enable Output Register	Data Out port, Q, can be configured as registered or not using this selection.	true or false	true
Enable Output ClockEn	Clock Enable for the output clock. This option requires enabling Enable Output Register.	true or false	false
Enable Byte Enable	Allows you to select Byte Enable options.	true or false	false
Reset Assertion	Selection for the Reset to be synchronous or asynchronous to the Clock	async or sync	sync
Memory Initialization	Allows you to initialize the memories to all 1s, 0s, or to use a custom initialization by providing a memory file.	none, 0s, 1s, or file	none
Memory File	When Memory File is selected, you can browse to the memory file for custom initialization of RAM.	—	—

Configuration Tab Attribute	Description	Value	Default Value
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

You have the option to enable the output registers for RAM_DQ. The waveforms in Figure 4.3 and Figure 4.4 show the internal timing waveforms for the single-port RAM RAM_DQ, without output registers and with output registers respectively.

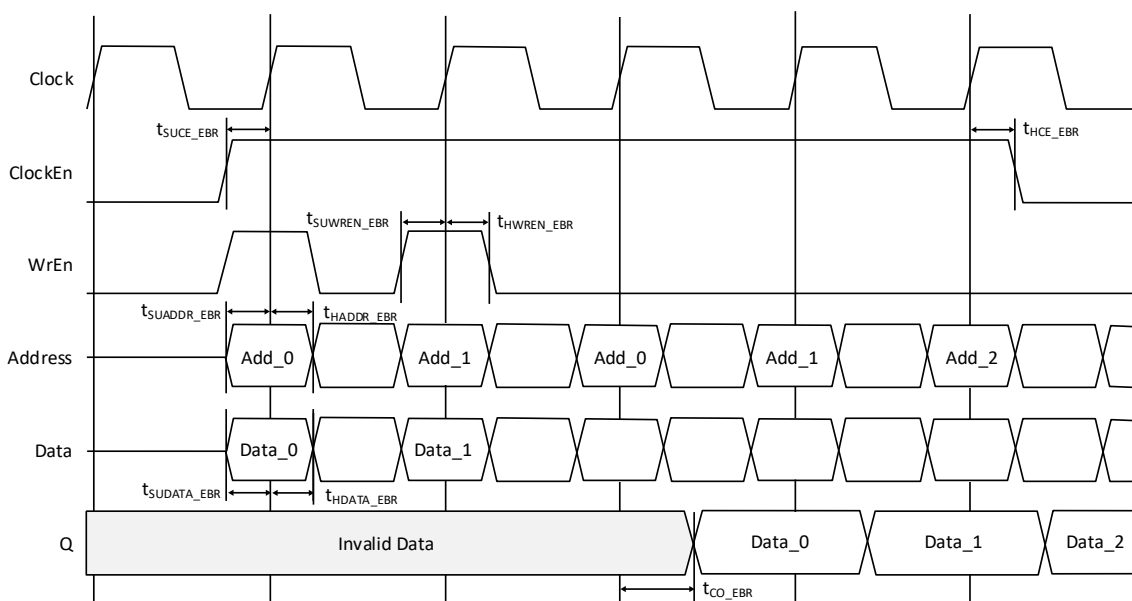


Figure 4.3. Single-Port RAM Timing Waveform – without Output Registers

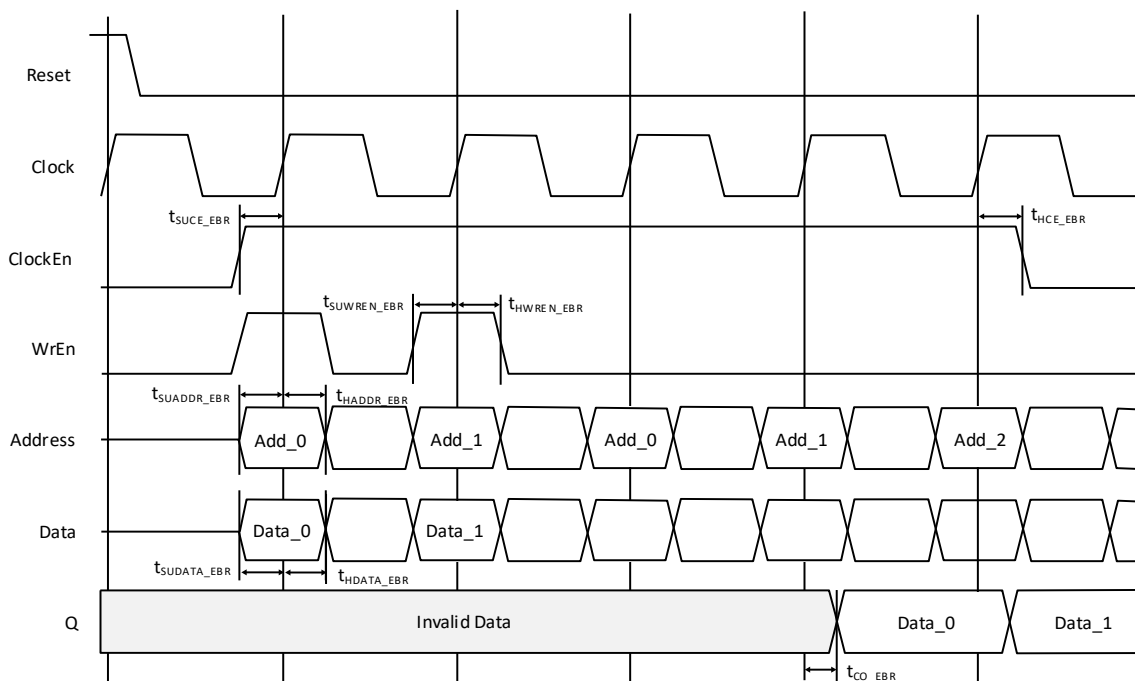


Figure 4.4. Single-Port RAM Timing Waveform – with Output Registers

4.3. True Dual-Port RAM – EBR-Based

This section describes the true dual-port RAM, RAM_DP_TRUE, which is EBR-based.

The EBR blocks in the Lattice Nexus 2 platform devices can be configured as true dual-port RAM, RAM_DP_TRUE. The IP Catalog allows you to generate the Verilog-HDL or VHDL for the memory size as per design requirements.

The IP Catalog generates the memory module, as shown in Figure 4.5.

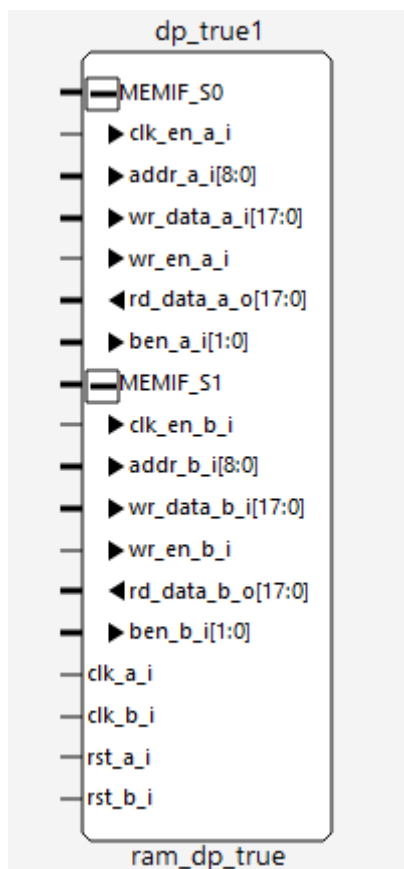


Figure 4.5. True Dual-Port Memory Module Generated by the IP Catalog

Figure 4.6 provides the primitive that can be instantiated for the true dual-port RAM. The primitive name is DP32K and it can be directly instantiated in the code. Check the details of the ports and port names under the primitives available under the cae_library/synthesis folder in the Lattice Radiant software installation folder.

Note that each EBR can accommodate 36 kb of memory. If the memory required is larger than 36 kb, then cascading can be used using the CS ports. In this case, the CS ports are CSA[2:0] and CSB[2:0].

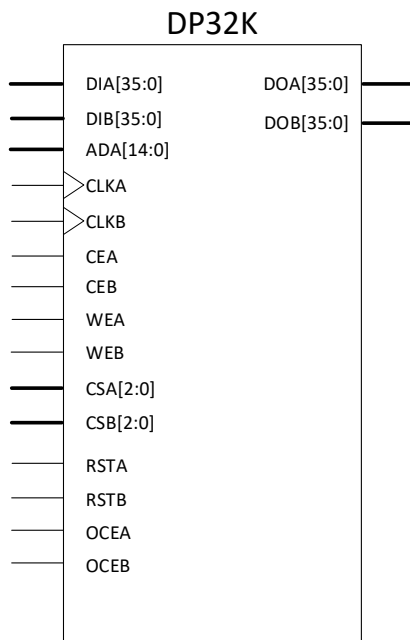


Figure 4.6. True Dual-Port RAM Primitive for Lattice Nexus 2 Platform Devices

The various ports and definitions for the true dual-port RAM are listed in [Table 4.4](#). The table shows the corresponding ports for the module generated by the IP Catalog.

Table 4.4. EBR-Based True Dual-Port Memory Port Definitions

Port Name	Direction	Width	Description
clk_a_i	Input	1	Clock for Port A
rst_a_i	Input	1	Reset for Port A
clk_en_a_i	Input	1	Clock Enable for Port A
wr_en_a_i	Input	1	Write Enable for Port A
wr_data_a_i	Input	Data Width	Data Input for Port A
addr_a_i	Input	Address Width	Address Bus for Port A
rd_data_a_o	Output	Data Width	Data Output for Port A
ben_a_i	Input	Byte Enable Width	Byte Enable for Port A
clk_b_i	Input	1	Clock for Port B
rst_b_i	Input	1	Reset for Port B
clk_en_b_i	Input	1	Clock Enable for Port B
wr_en_b_i	Input	1	Write Enable for Port B
wr_data_b_i	Input	Data Width	Data Input for Port B
addr_b_i	Input	Address Width	Address Bus for Port B
rd_data_b_o	Output	Data Width	Data Output for Port B
ben_b_i	Input	Byte Enable Width	Byte Enable for Port B

Each EBR block consists of 36,864 bits of RAM. See [Table 4.5](#) for each EBR block address value, w and x, and data value, y and z.

Table 4.5. Dual-Port Memory Sizes for 36 kb Memory for Lattice Nexus 2 Platform Devices

Dual-Port Memory Size	Input Data Port A	Input Data Port B	Output Data Port A	Output Data Port B	Address Port A	Address Port B
32,768 × 1	DataInA	DataInB	QA	QB	AddressA(14:0)	AddressB(14:0)
16,384 × 2	DataInA(1:0)	DataInB(1:0)	QA(1:0)	QB(1:0)	AddressA(13:0)	AddressB(13:0)

Dual-Port Memory Size	Input Data Port A	Input Data Port B	Output Data Port A	Output Data Port B	Address Port A	Address Port B
8,192 × 4	DataInA(3:0)	DataInB(3:0)	QA(3:0)	QB(3:0)	AddressA(12:0)	AddressB(12:0)
4,096 × 9	DataInA(8:0)	DataInB(8:0)	QA(8:0)	QB(8:0)	AddressA(11:0)	AddressB(11:0)
2,048 × 18	DataInA(17:0)	DataInB(17:0)	QA(17:0)	QB(17:0)	AddressA(10:0)	AddressB(10:0)
1,024 × 36	DataInA(35:0)	DataInB(35:0)	QA(35:0)	QB(35:0)	AddressA(9:0)	AddressB(9:0)

Table 4.6 shows the various attributes available for the true dual-port memory, RAM_DP_TRUE. You can select some of these attributes through the IP Catalog interface.

Table 4.6. True Dual-Port RAM Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Port A Address Depth	Port A Address depth of the read and write port	2–<Max that can fit in the device>	512
Port A Data Width	Port A Data word width of the read and write port	1–512	18
Port B Address Depth	Port B Address depth of the read and write port	2–<Max that can fit in the device>	512
Port B Data Width	Port B Data word width of the read and write port	1–512	18
Port A Enable Output Register	Port A Data Out port, QA, can be configured as registered or not using this selection.	true or false	true
Port B Enable Output Register	Port B Data Out port, QB, can be configured as registered or not using this selection.	true or false	true
Byte Enable A	Allows you to select Byte Enable options.	true or false	false
Byte Enable B	Allows you to select Byte Enable options.	true or false	false
Reset Assertion A	Selection for the Reset to be synchronous or asynchronous to the Clock	async or sync	sync
Reset Assertion B	Selection for the Reset to be synchronous or asynchronous to the Clock	async or sync	sync
Memory Initialization	Allows you to initialize the memories to all 1s, 0s, or to use a custom initialization by providing a memory file.	none, 0s, 1s, or file	none
Memory File	When Memory File is selected, you can browse to the memory file for custom initialization of RAM.	—	—
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

You have the option to enable the output registers for RAM_DP_TRUE. Waveforms in Figure 4.7 and Figure 4.8 show the internal timing waveforms for the true dual-port RAM RAM_DP_TRUE, without output registers and with output registers respectively.

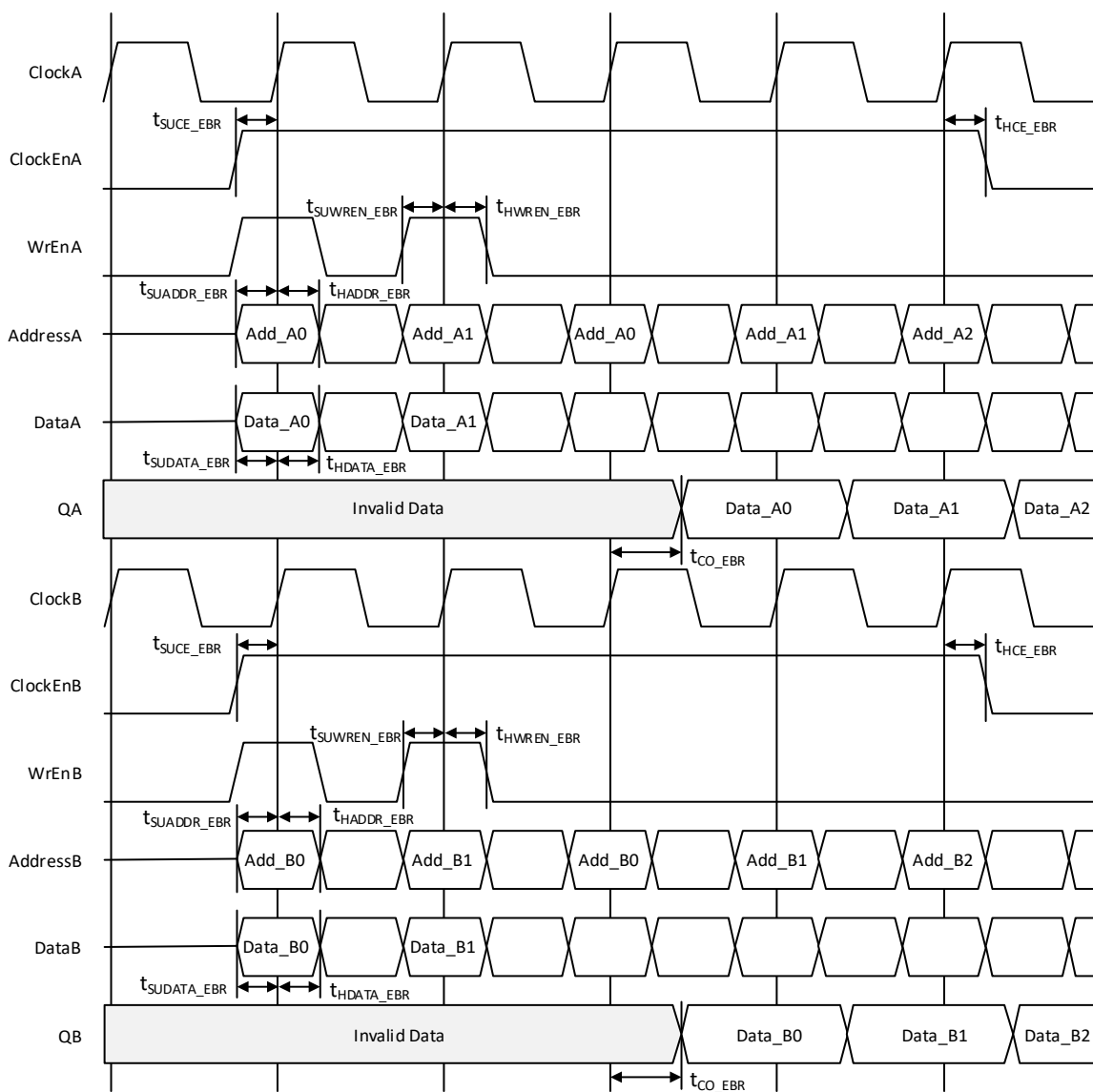


Figure 4.7. True Dual-Port RAM Timing Waveform – without Output Registers

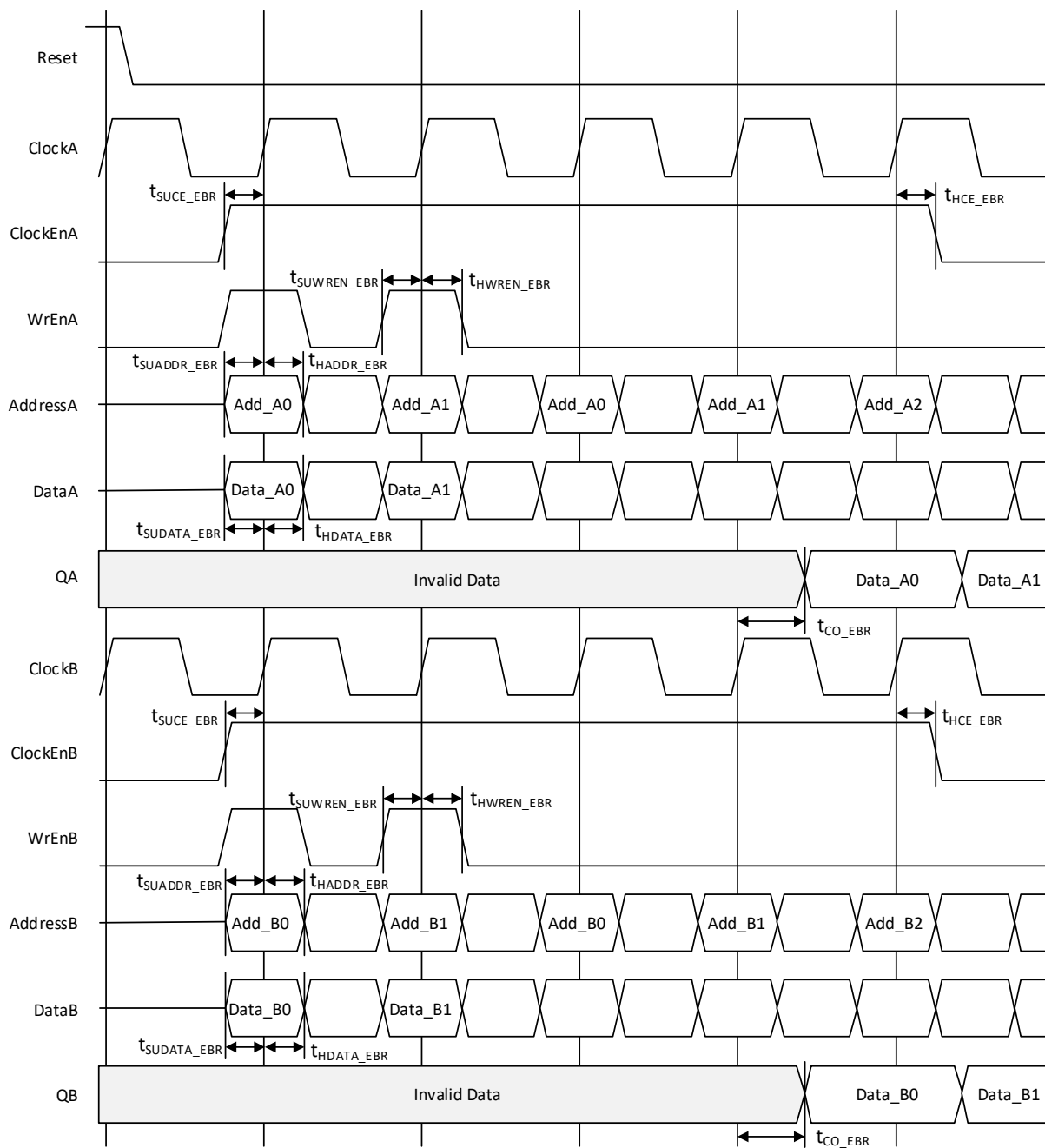


Figure 4.8. True Dual-Port RAM Timing Waveform – with Output Registers

4.4. Pseudo Dual-Port RAM – EBR-Based

This section describes the pseudo dual-port RAM, RAM_DP, which is EBR-based.

FPGAs built on the Lattice Nexus 2 platform support all the features of the pseudo dual-port RAM memory module, RAM_DP. The IP Catalog allows you to generate the Verilog-HDL or VHDL for the memory size as per design requirement.

The IP Catalog generates the memory module, as shown in Figure 4.9.

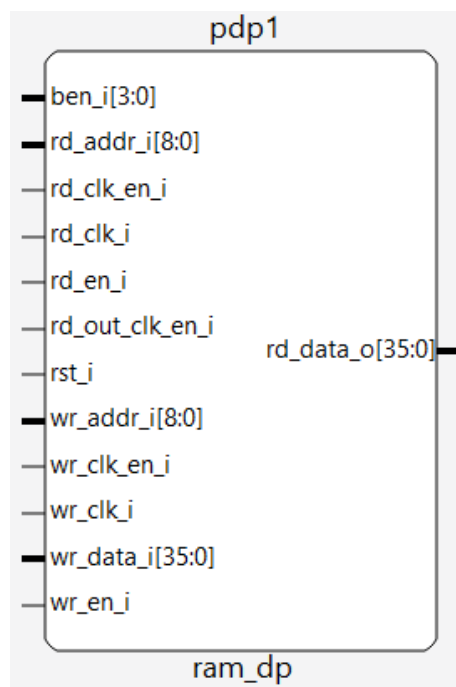


Figure 4.9. Pseudo Dual-Port Memory Module Generated by the IP Catalog

Figure 4.10 shows the primitive that can be instantiated for the pseudo dual-port RAM. The primitive name is PDP32K and it can be directly instantiated in the code. Check the details of the ports and port names under the primitives available under the cae_library/synthesis folder in the Lattice Radiant software installation folder.

Note that each EBR can accommodate 36 kb of memory. If the memory required is larger than 36 kb, then cascading can be used using the CS ports. In this case, the CS ports are CSW[2:0] and CSR[2:0].

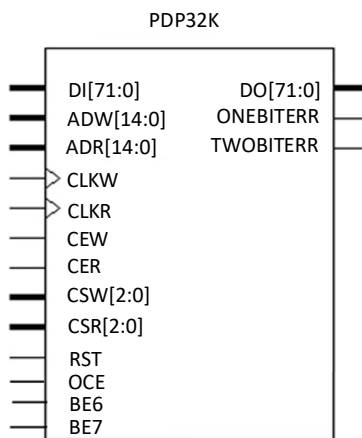


Figure 4.10. Pseudo Dual-Port RAM Primitive for Lattice Nexus 2 Platform Devices

The various ports and definitions for the pseudo dual-port memory are listed in Table 4.7. The table shows the corresponding ports for the module generated by the IP Catalog.

Table 4.7. EBR-Based Pseudo Dual-Port Memory Port Definitions

Port Name	Direction	Width	Description
wr_clk_i	Input	1	Write Clock
rd_clk_i	Input	1	Read Clock
rst_i	Input	1	Reset
wr_clk_en_i	Input	1	Write Clock Enable
rd_en_i	Input	1	Read Enable
rd_clk_en_i	Input	1	Read Clock Enable
rd_out_clk_en_i	Input	1	Read Output Register Clock Enable
wr_en_i	Input	1	Write Enable
ben_i	Input	Byte Enable Width	Byte Enable
wr_data_i	Input	Write Port Data Width	Write Data
wr_addr_i	Input	Write Port Address Width	Write Address
rd_addr_i	Input	Read Address Width	Read Address
rd_data_o	Output	Read Port Data Width	Read Data

Each EBR block consists of 36,864 bits of RAM. See Table 4.8 for each EBR block address value, w and x, and data value, y and z.

Table 4.8. Pseudo Dual-Port Memory Sizes for 36 kb Memory for Lattice Nexus 2 Platform Devices

Dual-Port Memory Size	Input Data Write Port	Output Data Read Port	Address Write Port	Address Read Port
32,768 × 1	Data	Q	WrAddress(14:0)	RdAddress(14:0)
16,384 × 2	Data(1:0)	Q(1:0)	WrAddress(13:0)	RdAddress(13:0)
8,192 × 4	Data(3:0)	Q(3:0)	WrAddress(12:0)	RdAddress(12:0)
4,096 × 9	Data(8:0)	Q(8:0)	WrAddress(11:0)	RdAddress(11:0)
2,048 × 18	Data(17:0)	Q(17:0)	WrAddress(10:0)	RdAddress(10:0)
1,024 × 36	Data(35:0)	Q(35:0)	WrAddress(9:0)	RdAddress(9:0)
512 × 72	Data(71:0)	Q(71:0)	WrAddress(8:0)	RdAddress(8:0)

Table 4.9 shows the various attributes available for the pseudo dual-port memory, RAM_DP. You can select some of these attributes through the IP Catalog interface.

Table 4.9. Pseudo Dual-Port RAM Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Read Port Address Depth	Read Port Address depth of the read and write port	2–65536	512
Read Port Data Width	Read Port Data word width of the read and write port	1–256	36
Write Port Address Depth	Write Port Address depth of the read and write port	2–65536	512
Write Port Data Width	Write Port Data word width of the read and write port	1–256	36
Enable Output Register	Data Out port, Q, can be configured as registered or not using this selection.	true or false	true
Enable Output ClockEn	Clock Enable for the output clock This option requires enabling Enable Output Register.	true or false	false
Enable Byte Enable	Allows you to select Byte Enable options.	true or false	false
Enable ECC	This option allows you to enable error correction codes.	true or false	false
Reset Assertion	Selection for the Reset to be synchronous or asynchronous to the Clock	async or sync	sync
Memory Initialization	Allows you to initialize the memories to all 1s, 0s, or to have a custom initialization by providing a memory file.	none, 0s, 1s, or file	none

Configuration Tab Attribute	Description	Value	Default Value
Memory File	When Memory File is selected, you can browse to the memory file for custom initialization of RAM.	—	—
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

You have the option to enable the output registers for the pseudo dual-port RAM, RAM_DP. Waveforms in [Figure 4.11](#) and [Figure 4.12](#) show the internal timing waveforms for the pseudo dual-port RAM without output registers and with output registers respectively.

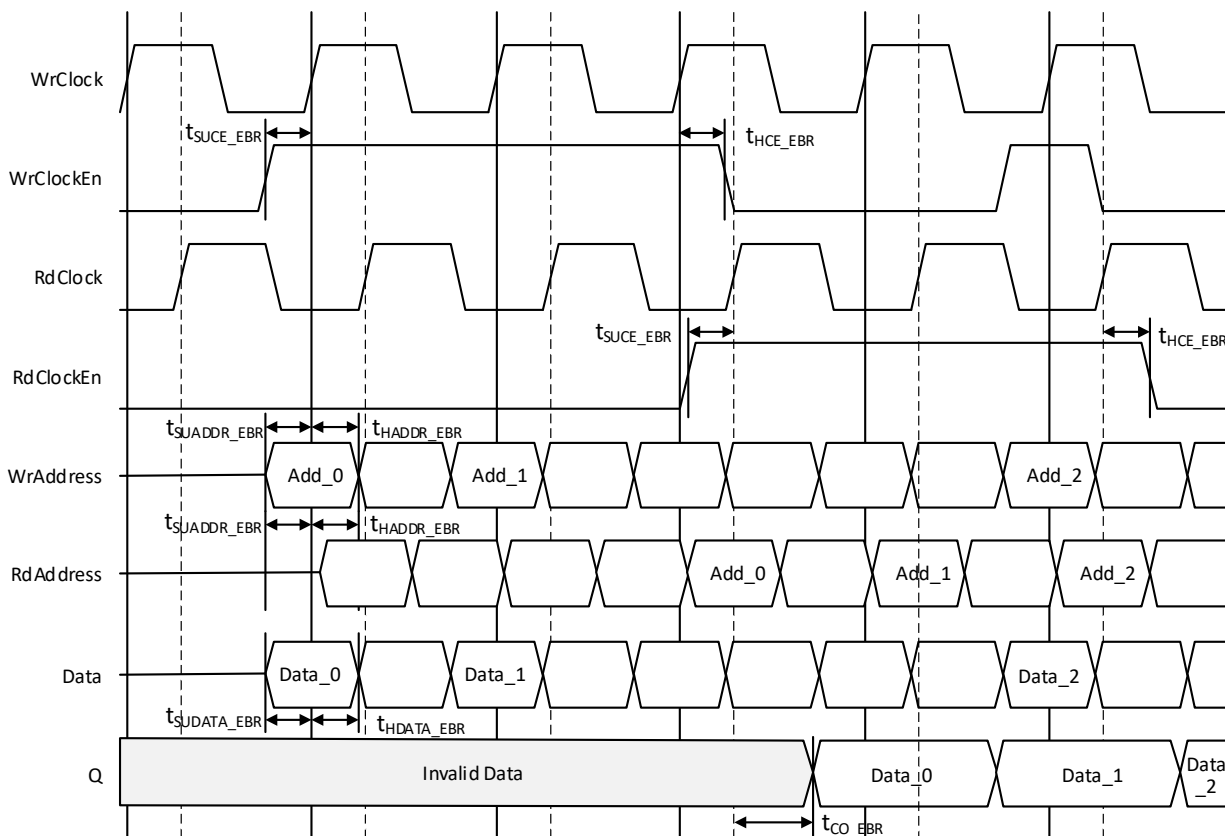


Figure 4.11. Pseudo Dual-Port RAM Timing Waveform – without Output Registers

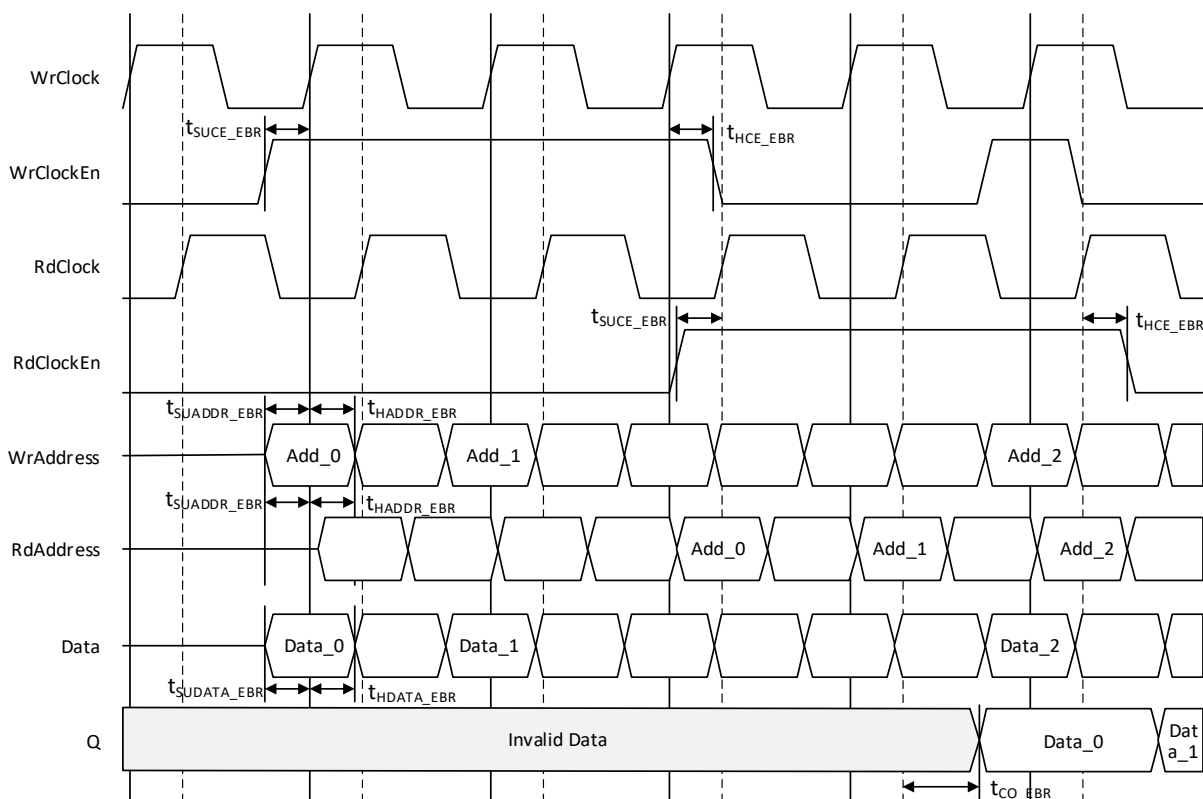


Figure 4.12. Pseudo Dual-Port RAM Timing Waveform – with Output Registers

4.5. Read Only Memory – EBR-Based

This section describes the read only memory, ROM, which is EBR-based.

FPGAs built on the Lattice Nexus 2 platform support all the features of the ROM memory module. The IP Catalog allows you to generate the Verilog-HDL or VHDL for the memory size as per design requirements. You must provide the ROM memory content in the form of an initialization file.

The IP Catalog generates the memory module, as shown in Figure 4.13.

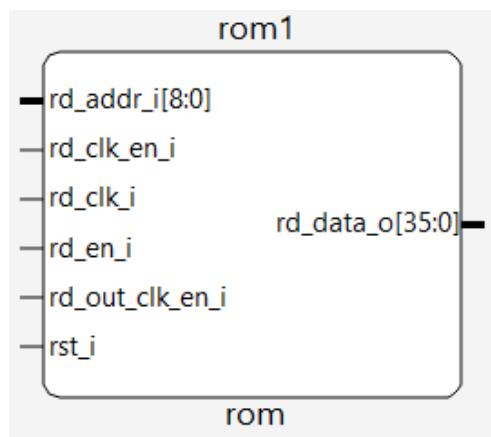


Figure 4.13. ROM – Read Only Memory Module Generated by the IP Catalog

The various ports and definitions are listed in Table 4.10. The table below lists the corresponding ports for the module generated by the IP Catalog and for the ROM primitive.

Table 4.10. EBR-Based ROM Port Definitions

Port Name	Direction	Width	Description
rd_clk_i	Input	1	Clock
rst_i	Input	1	Reset
rd_en_i	Input	1	Read Enable
rd_clk_en_i	Input	1	Input Clock Enable
rd_out_clk_en_i	Input	1	Output Clock Enable
rd_addr_i	Input	Address Width	Address Bus
rd_data_o	Output	Data Width	Data Output

When generating ROM using the IP Catalog, you must provide the initialization file to pre-initialize the contents of the ROM. These files are the *.mem files and they can be of binary or hex formats. The initialization files are discussed in detail in the [Initializing Memory](#) section.

Each EBR block consists of 36,864 bits of RAM. See [Table 4.11](#) for each EBR block address value, x, and data value, y.

Table 4.11. ROM Memory Sizes for 36 kb Memory for Lattice Nexus 2 Platform Devices

Dual-Port Memory Size	Output Data Read Port	Address Read Port
32,768 × 1	Q	RdAddress(14:0)
16,384 × 2	Q(1:0)	RdAddress(13:0)
8,192 × 4	Q(3:0)	RdAddress(12:0)
4,096 × 9	Q(8:0)	RdAddress(11:0)
2,048 × 18	Q(17:0)	RdAddress(10:0)
1,024 × 36	Q(35:0)	RdAddress(9:0)
512 × 72	Q(71:0)	RdAddress(8:0)

[Table 4.12](#) shows the various attributes available for the read only memory, ROM. You can select some of these attributes through the IP Catalog interface.

Table 4.12. ROM Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Address Depth	Address depth of the read and write port	2–65536	512
Data Width	Data word width of the read and write port	1–512	36
Enable Output Register	Data Out port, Q, can be registered or not using this selection.	true or false	true
Enable Output ClockEn	Enables read output clock.	true or false	false
Reset Assertion	Selection for the Reset to be synchronous or asynchronous to the Clock	async or sync	sync
Memory Initialization	Allows you to initialize the memories to all 1s, 0s, or to use a custom initialization by providing a memory file.	0s, 1s, or file	0s
Memory File	When Memory File is selected, you can browse to the memory file for custom initialization of RAM.	—	—
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

You have the option to enable the output registers for read only memory, ROM. [Figure 4.14](#) and [Figure 4.15](#) show the internal timing waveforms for ROM without output registers and with output registers respectively.

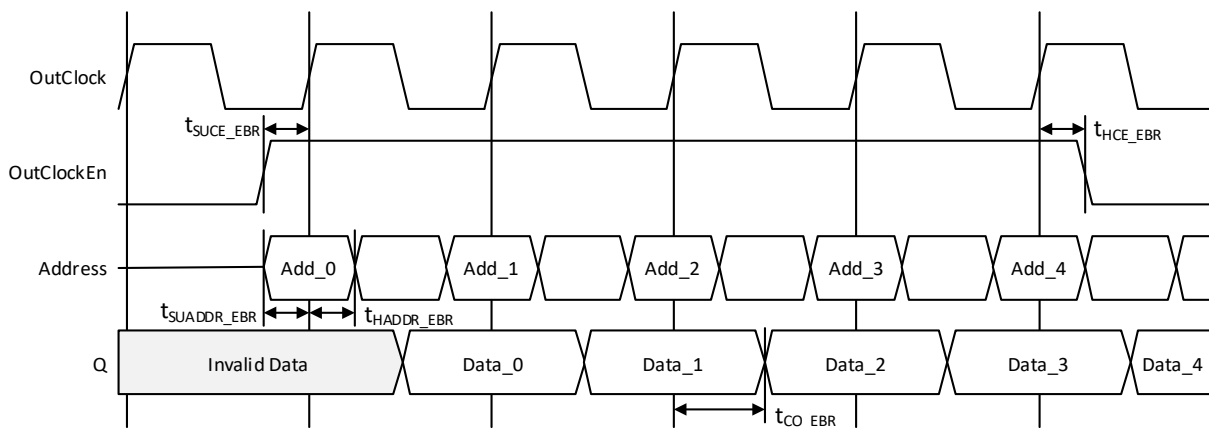


Figure 4.14. ROM Timing Waveform – without Output Registers

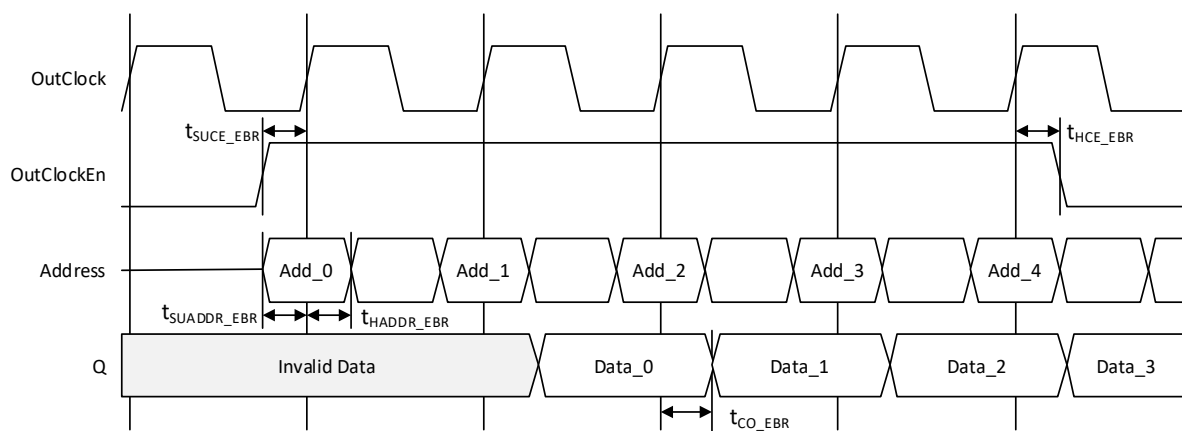


Figure 4.15. ROM Timing Waveform – with Output Registers

5. FIFO Memory

Lattice Nexus 2 platform devices support two different types of FIFOs:

- Single-clock FIFO, FIFO
- Dual-clock FIFO, FIFO_DC

The EBR blocks in Lattice Nexus 2 platform devices can be configured as LUT-based or EBR-based, as well as single-clock First In First Out memory, FIFO, or dual-clock First In First Out memory, FIFO_DC. The IP Catalog allows you to generate the Verilog-HDL or VHDL netlist for various memory sizes depending on design requirements.

The IP Catalog generated FIFO modules and the operation are discussed in detail in the following sections.

5.1. Single-Clock FIFO – EBR-Based or LUT-Based

This section describes the single-clock FIFO, which is named FIFO and can be EBR-based or LUT-based.

Figure 5.1 shows the module generated by the IP Catalog for FIFO.

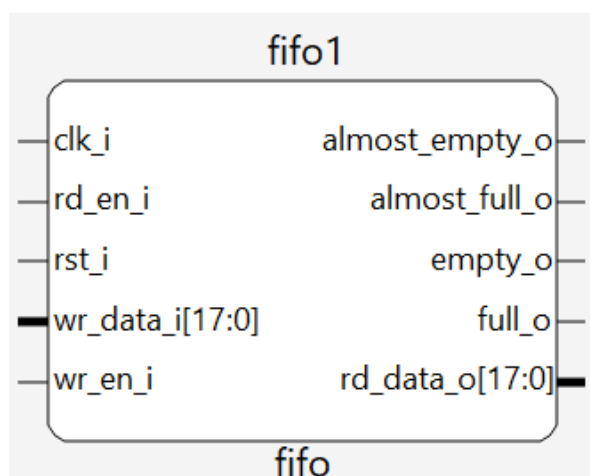


Figure 5.1. FIFO Module Generated by the IP Catalog

The various ports and definitions for the FIFO are listed in Table 5.1.

Table 5.1. Port Names and Definitions for FIFO

Port Name	Direction	Width	Description
clk_i	Input	1	Write Clock
rst_i	Input	1	Reset
wr_en_i	Input	1	Write Enable
rd_en_i	Input	1	Read Enable
wr_data_i	Input	Data Width	Write Data
rd_data_o	Output	Data Width	Read Data
full_o	Output	1	Full Flag
empty_o	Output	1	Empty Flag
almost_full_o	Output	1	Almost Full Flag
almost_empty_o	Output	1	Almost Empty Flag
data_cnt_o	Output	Address Width	Data Counter Width based on the MEM Address Width

Table 5.2. FIFO Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Implementation Type	EBR-based or LUT-based	EBR, LUT	EBR
Address Depth	Address depth of the read and write port Values are powers of two.	2-<Max that can fit in the device>	1024
Controller Implementation	FIFO controller implementation option To enable the implementation type as LUT-based, or enable the Data Count output, you need to select LUT.	LUT or HW	HW
Enable FWFT	Enables the First Word Fall Through mode. This is only available in HW mode.	true or false	false
Data Width	Data word width of the read and write port	1–256	18
Enable Output Register	Data Out port, Q, can be registered or not using this selection.	true or false	true
Reset Assertion	Selection for the Reset to be synchronous or asynchronous to the Clock	async or sync	sync
Enable Almost Empty Flag	Enables the generation of the Almost Empty flag.	true or false	true
Almost Empty Assertion Type	This option allows you to select the type of threshold to be used for the Almost Empty flag. The static threshold is set by the constant parameter, while the dynamic threshold is set through the input ports. The single threshold provides only the assertion level, while the dual threshold provides both the assertion and deassertion levels.	Static-Single, Static-Dual, Dynamic-Single, or Dynamic-Dual	Static-Dual
Almost Empty Assert Level	This option allows you to set the assertion level of the Almost Empty flag. This is applicable for the Static-Single/Static-Dual threshold mode.	1–Address Depth	1
Almost Empty Deassert Level	This option allows you to set the deassertion level of the Almost Empty flag after it goes high. This is applicable only for the Static-Dual threshold mode.	1–Address Depth	2
Enable Almost Full Flag	Enables the generation of the Almost Full flag.	true or false	true
Almost Full Assertion Type	This option allows you to select the type of threshold to be used for the Almost Full flag. The Static threshold is set by the constant parameter, while the Dynamic threshold is set through the input ports. The single threshold provides only the assertion level, while the dual threshold provides both the assertion and deassertion levels.	Static-Single, Static-Dual, Dynamic-Single, or Dynamic-Dual	Static-Dual
Almost Full Assert Level	This option allows you to set the assertion level of the Almost Full flag. This is applicable for the Static-Single/Static-Dual threshold mode.	1–Address Depth	1023
Almost Full Deassert Level	This option allows you to set the deassertion level of the Almost Full flag after it goes high. This option is applicable only for the Static-Dual threshold mode.	1–Address Depth	1022
Enable Data Count	This option allows you to enable the generation of the write data count.	true or false	false

This section first describes the non-pipelined FIFO, that is, the FIFO without output registers. Figure 5.2 shows the operation of the FIFO when it is empty and the data begins to be written into the FIFO.

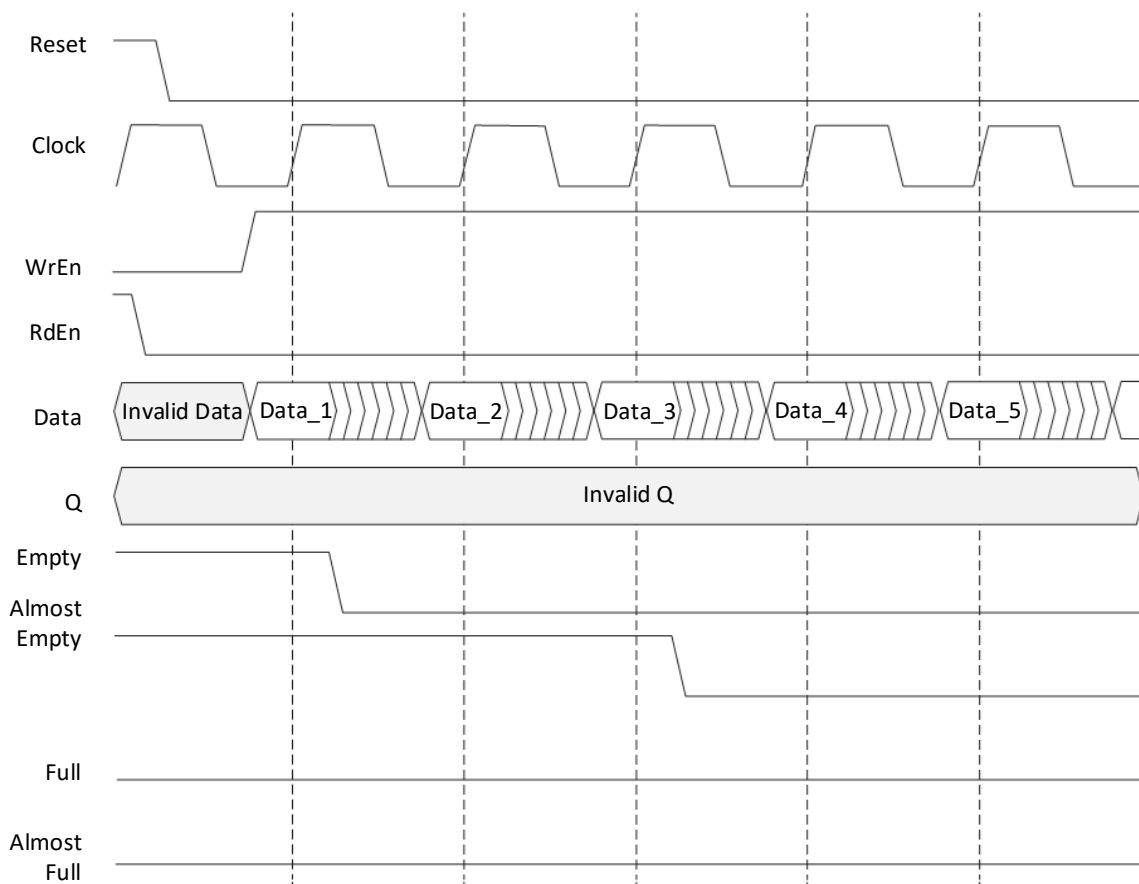


Figure 5.2. FIFO without Output Registers – Start of Data Write Cycle

The WrEn signal must be high to start writing to the FIFO. The Empty and Almost Empty flags are high to begin and the Full and Almost Full flags are low.

When the first data is written to the FIFO, the Empty flag deasserts or goes low since the FIFO is no longer empty. In this figure, it is assumed that the Almost Empty flag is set to three, that is, address location three. As such, the Almost Empty flag is deasserted when the third address location is filled.

Assume that you continue to write into the FIFO to fill it. When the FIFO is filled, the Almost Full and Full flags are asserted. Figure 5.3 shows the behavior of these flags. In this figure, it is assumed that the FIFO depth is N.

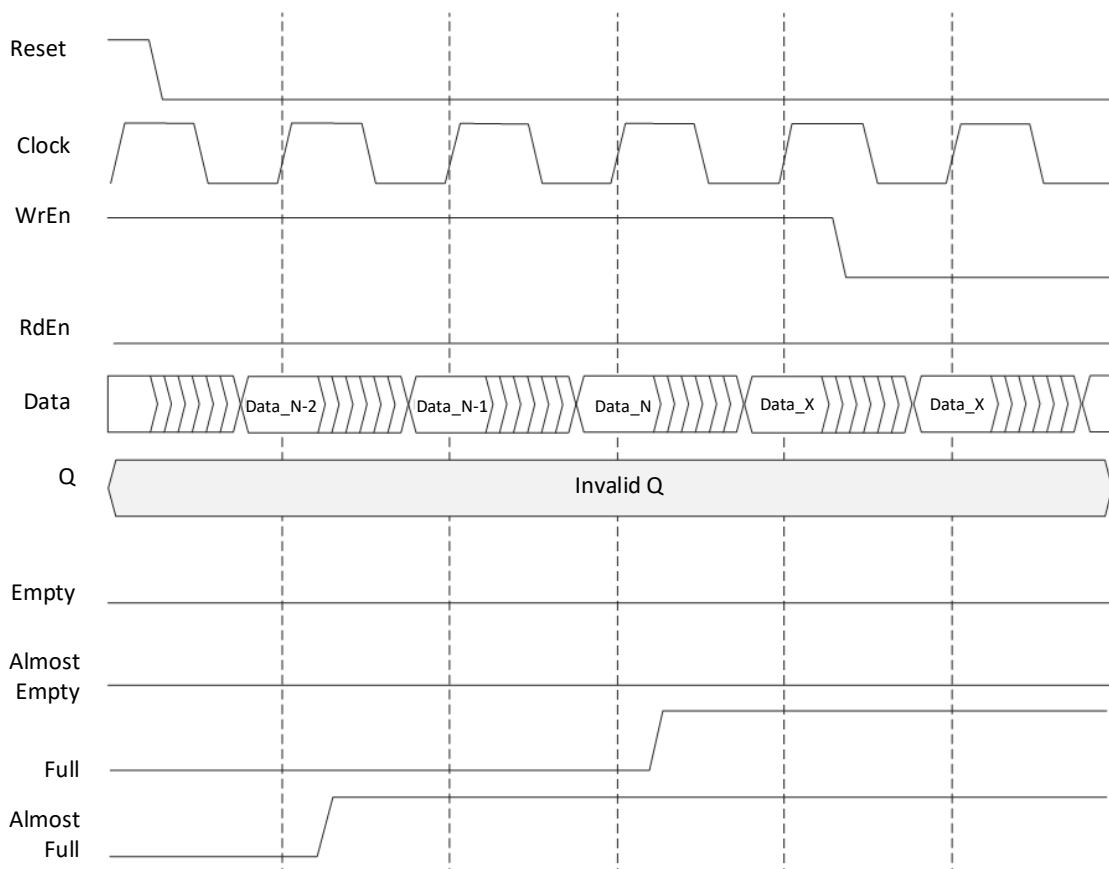


Figure 5.3. FIFO without Output Registers – End of Data Write Cycle

In Figure 5.3, the Almost Full flag is two locations before the FIFO is filled. The Almost Full flag is asserted when the N-2 location is written, and the Full flag is asserted when the last word is written into the FIFO.

Data_X data inputs are not written because the FIFO is full, with the Full flag being high.

Examine the waveforms when the contents of the FIFO are read out. Figure 5.4 shows the start of the read cycle. The RdEn signal goes high and the data read starts. The Full and Almost Full flags are deasserted.

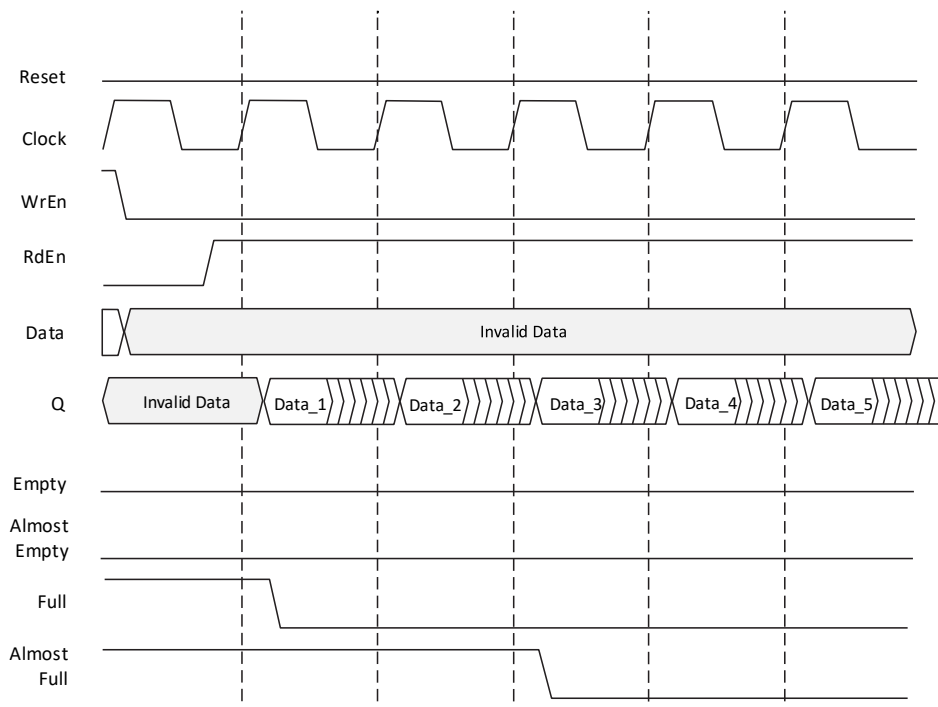


Figure 5.4. FIFO without Output Registers – Start of Data Read Cycle

Similarly, as the data is read out and the FIFO is emptied, the Almost Empty and Empty flags are asserted (Figure 5.5).

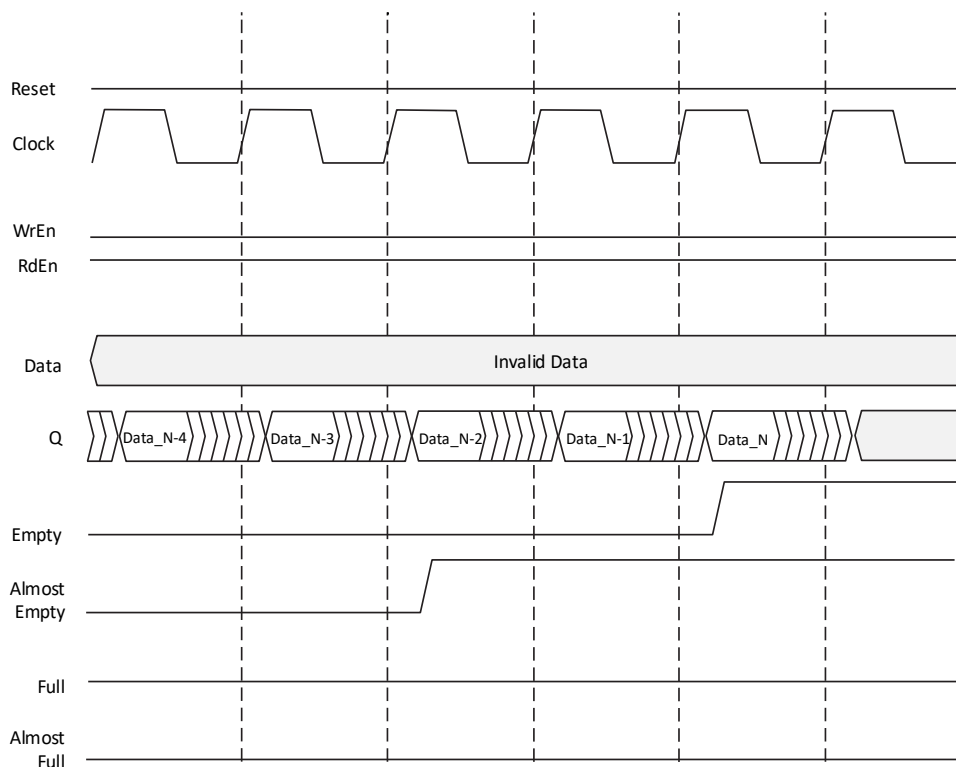


Figure 5.5. FIFO without Output Registers – End of Data Read Cycle

Figure 5.2 to Figure 5.5 show the behavior of non-pipelined FIFO or FIFO without output registers. When the registers are pipelined, the output data is delayed by one clock cycle. There is also an option for output registers to be enabled by the RdEn signal.

Figure 5.6 to Figure 5.9 show similar waveforms for the FIFO with output registers and Figure 5.10 shows the FIFO with output registers enabled by RdEn. Note that flags are asserted and deasserted with similar timing to the FIFO without output registers.

Only the data out Q is delayed by one clock cycle.

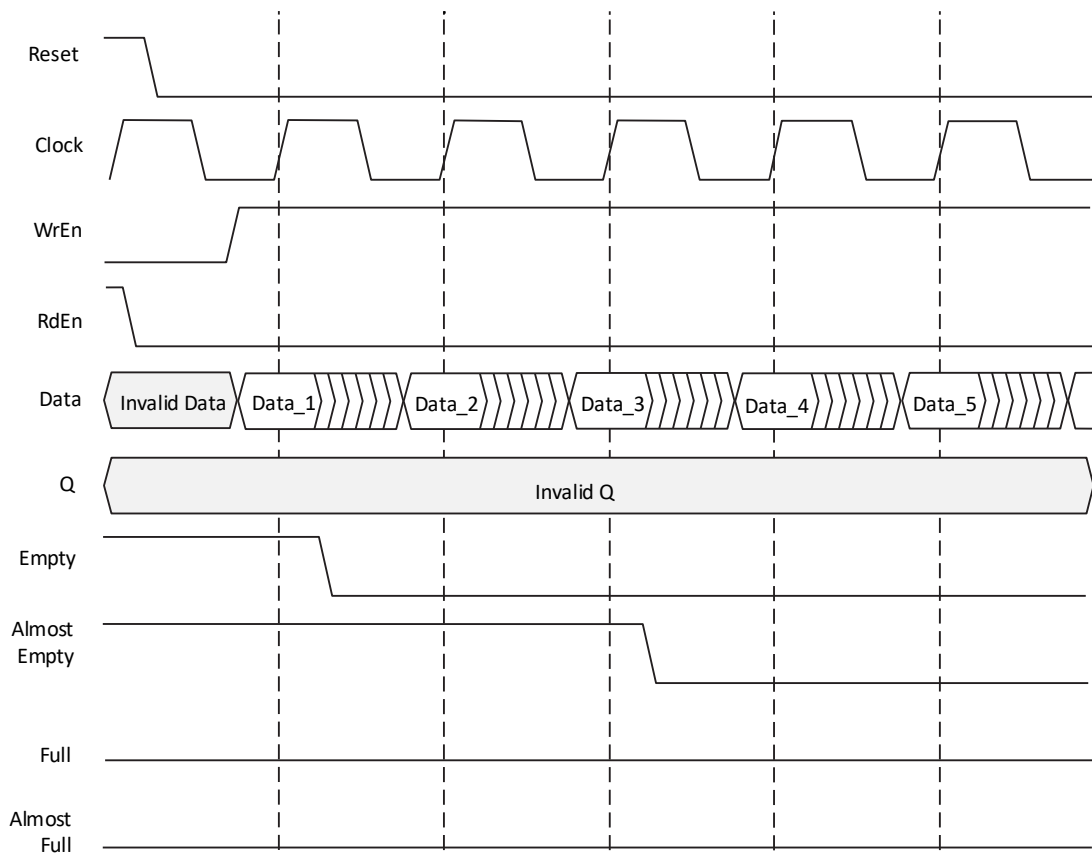


Figure 5.6. FIFO with Output Registers – Start of Data Write Cycle

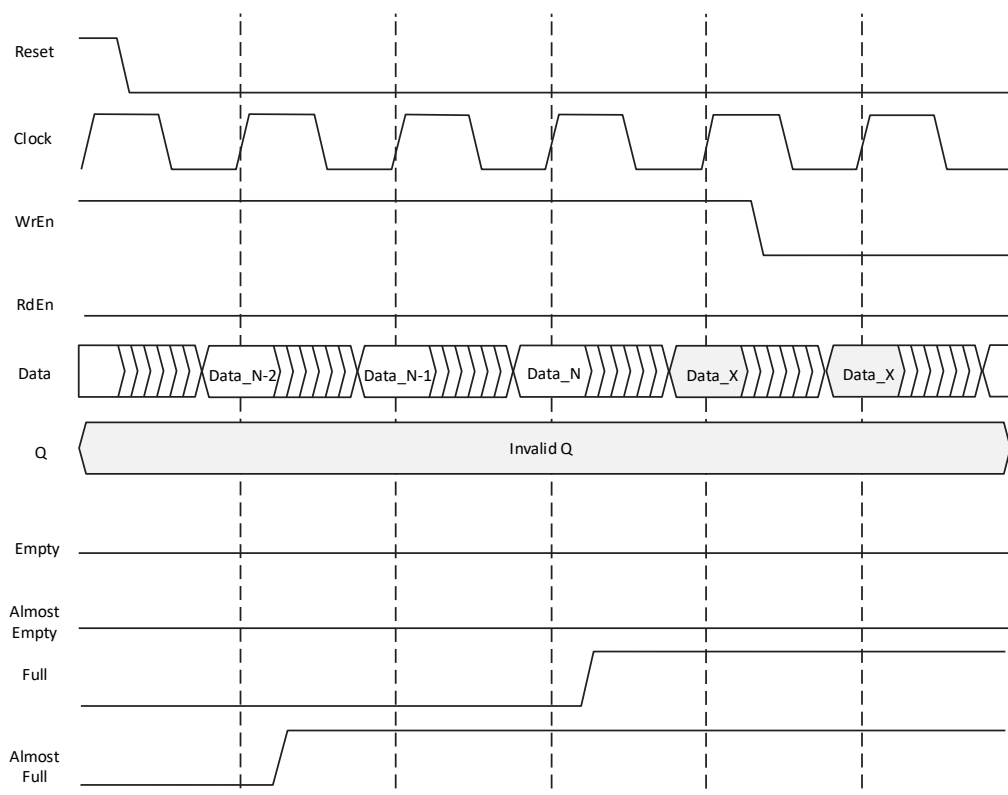


Figure 5.7. FIFO with Output Registers – End of Data Write Cycle

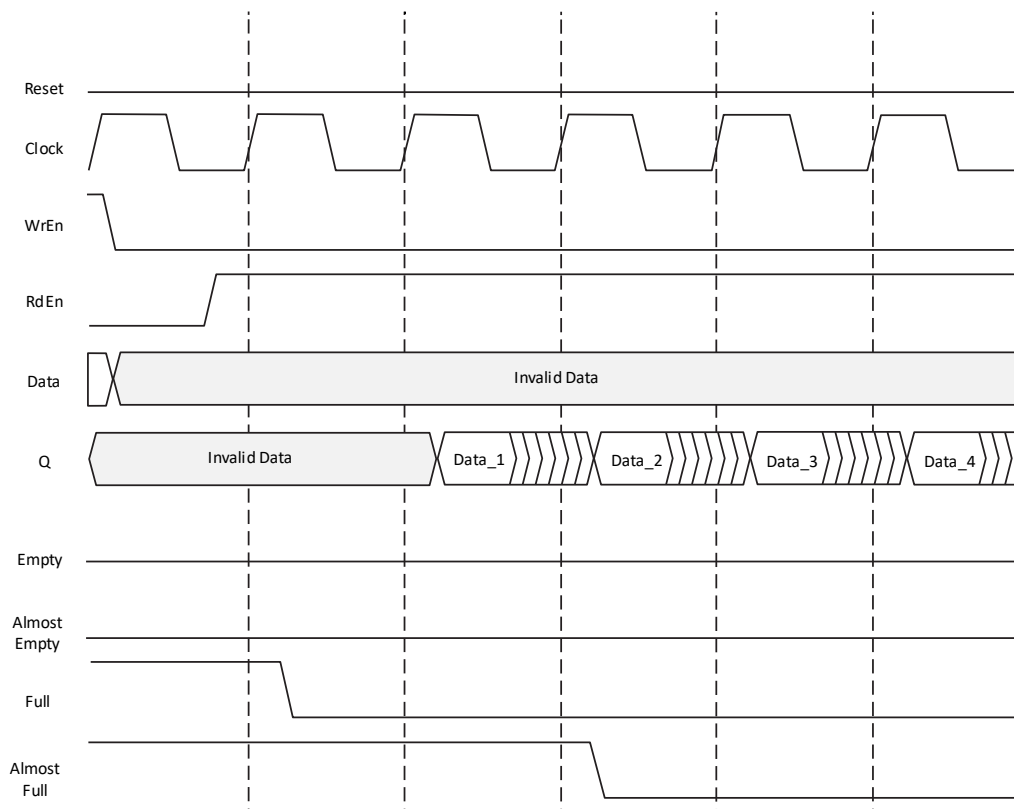


Figure 5.8. FIFO with Output Registers – Start of Data Read Cycle

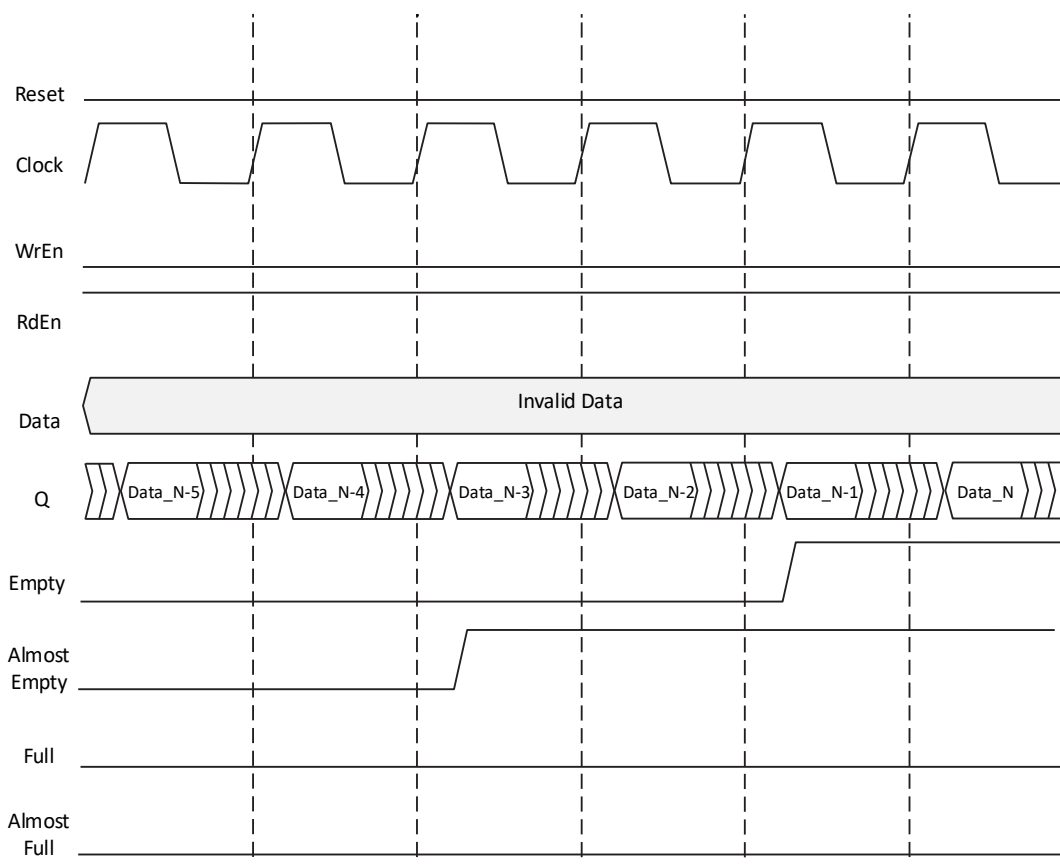


Figure 5.9. FIFO with Output Registers – End of Data Read Cycle

If the option enable output register with RdEn is selected, it still delays the data out by one clock cycle, as compared to the non-pipelined FIFO. RdEn must be high during that clock cycle. Otherwise, the data takes an extra clock cycle when RdEn goes true.

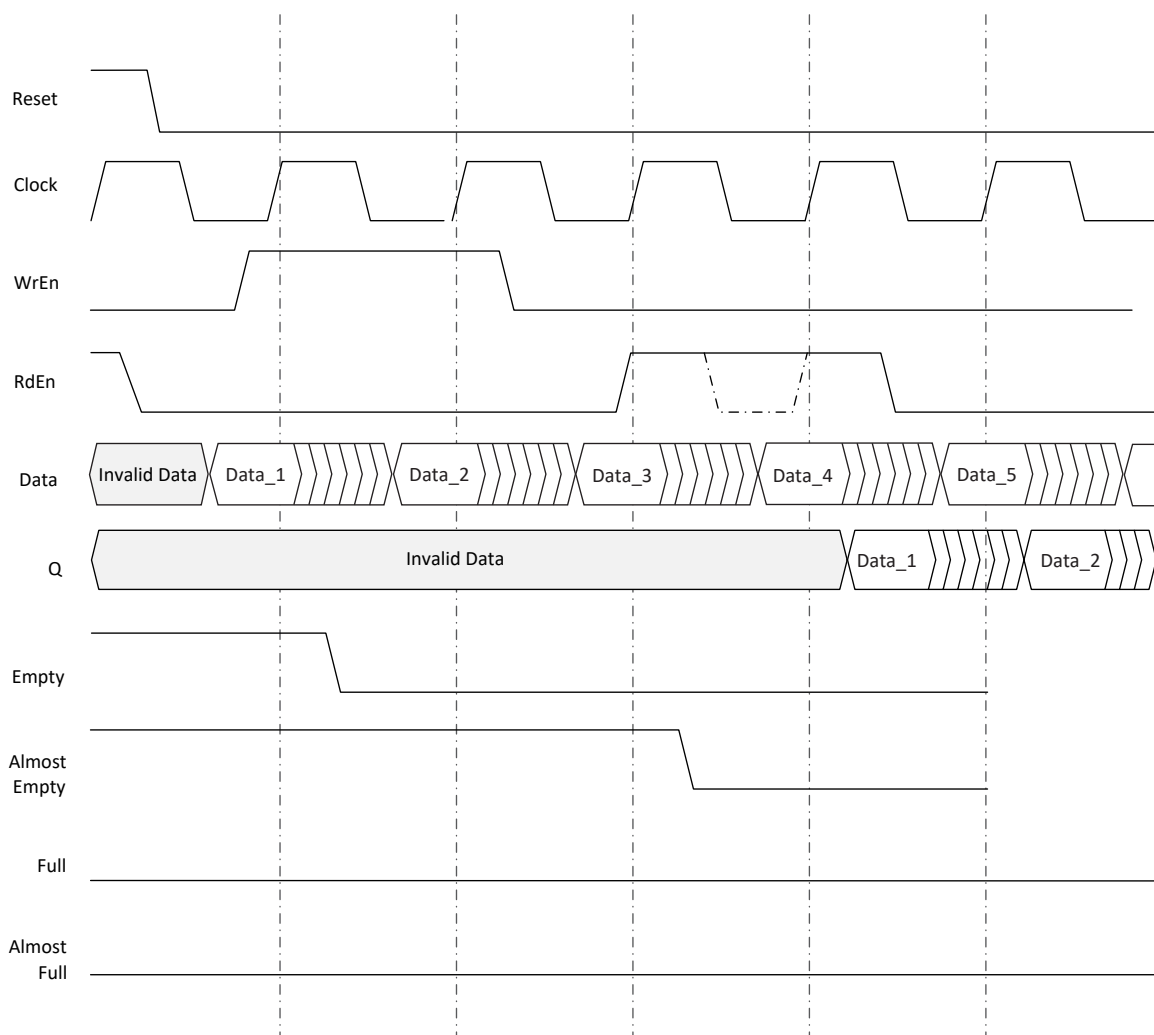


Figure 5.10. FIFO with Output Registers and RdEn on Output Registers

5.2. Dual-Clock FIFO – EBR-Based or LUT-Based

This section describes the dual-clock FIFO, FIFO_DC, which can be EBR-based or LUT-based.

Figure 5.11 shows the module generated by the IP Catalog for FIFO_DC.

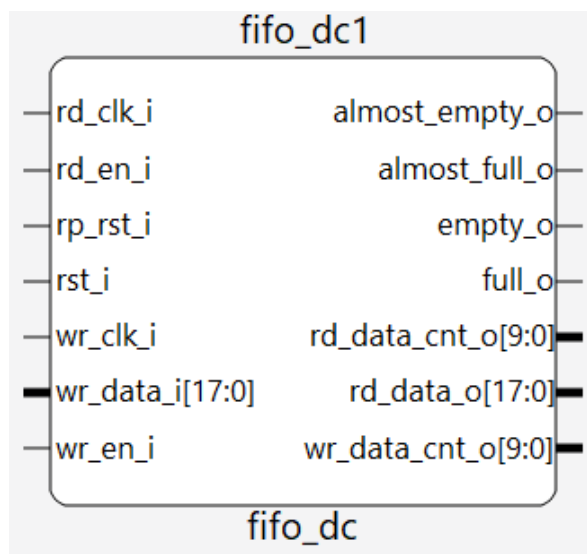


Figure 5.11. FIFO_DC Module Generated by the IP Catalog

The various ports and definitions for the FIFO_DC are listed in Table 5.3. The software attributes are listed in Table 5.4.

Table 5.3. Port Names and Definitions for FIFO_DC

Port Name	Direction	Width	Description
wr_clk_i	Input	1	Write Clock
rd_clk_i	Input	1	Read Clock
rst_i	Input	1	Reset
rp_rst_i	Input	1	Read Pointer Reset
wr_en_i	Input	1	Write Enable
rd_en_i	Input	1	Read Enable
wr_data_i	Input	Data Width	Write Data
rd_data_o	Output	Data Width	Read Data
full_o	Output	1	Full Flag
empty_o	Output	1	Empty Flag
almost_full_o	Output	1	Almost Full Flag
almost_empty_o	Output	1	Almost Empty Flag
wr_data_cnt_o	Output	Address Width	Write Data Counter
rd_data_cnt_o	Output	Address Width	Read Data Counter

Table 5.4. FIFO_DC Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Write Address Depth	Address depth of the write port Values are powers of two.	2—<Max that can fit in the device>	512
Write Data Width	Data word width write port	1–256	18
Read Address Depth	Address depth of the read port. Note: If not equal to Write Address Depth, the valid values are powers of two such that the ratio between the write and read data widths is also a power of two.	2—<Max that can fit in the device>	512
Read Data Width	Data word width read port	1–256	18
Controller Implementation	FIFO Controller Implementation Option To enable the implementation type as LUT-based or enable the Data Count output, you need to select LUT.	LUT or HW	HW
Enable FWFT	Enables the First Word Fall Through mode. This is only available in HW mode.	true or false	false
Implementation Type	EBR-based or LUT-based	EBR or LUT	EBR
Enable Output Register	Data Out port, rd_data_o, can be registered or not using this selection.	true or false	false
Reset Mode	Selection for the Reset to be synchronous or asynchronous to the clock	async or sync	sync
Enable Almost Empty Flag	Enables the generation of the Almost Empty flag.	true or false	true
Almost Empty Assertion Type	This option allows you to select the type of threshold to be used for the Almost Empty flag. The static threshold is set by the constant parameter, while the dynamic threshold is set through the input ports. The single threshold provides only the assertion level, while the dual threshold provides both assertion and deassertion levels.	Static-Single, Static-Dual, Dynamic-Single, or Dynamic-Dual	Static-Dual
Almost Empty Assert Level	This option allows you to set the assertion level of the Almost Empty flag. This is applicable for the Static-Single/Static-Dual threshold mode.	1–Address Depth	1
Almost Empty Deassert Level	This option allows you to set the deassertion level of the Almost Empty flag after it goes high. This is applicable only for the Static-Dual threshold mode.	1–Address Depth	2
Enable Almost Full Flag	Enables the generation of the Almost Full flag.	true or false	false
Almost Full Assertion Type	This option allows you to select the type of threshold to be used for the Almost Full flag. The static threshold is set by the constant parameter, while the dynamic threshold is set through the input ports. The single threshold provides only the assertion level, while the dual threshold provides both assertion and deassertion levels.	Static-Single, Static-Dual, Dynamic-Single, or Dynamic-Dual	Static-Dual
Almost Full Assert Level	This option allows you to set the assertion level of the Almost Full flag. This is applicable for the Static-Single/Static-Dual threshold mode.	1–Address Depth	511
Almost Full Deassert Level	This option allows you to set the deassertion level of the Almost Full flag after it goes high. This is applicable only for the Static-Dual threshold mode.	1–Address Depth	510
Enable Data Count Synchronized to the Write Clock	This option allows you to enable the generation of the write data count.	true or false	false
Enable Data Count Synchronized to the Read Clock	This option allows you to enable the generation of the read data count.	true or false	false

5.3. FIFO_DC Flags

Unlike devices with emulated FIFO, FIFO_DC is a hardware FIFO that avoids latency to the flags during assertion or deassertion.

Figure 5.12 and Figure 5.13 are waveforms for FIFO_DC without output registers. Figure 5.12 shows the operation of the FIFO_DC when it is empty and the data begins to be written into the FIFO.

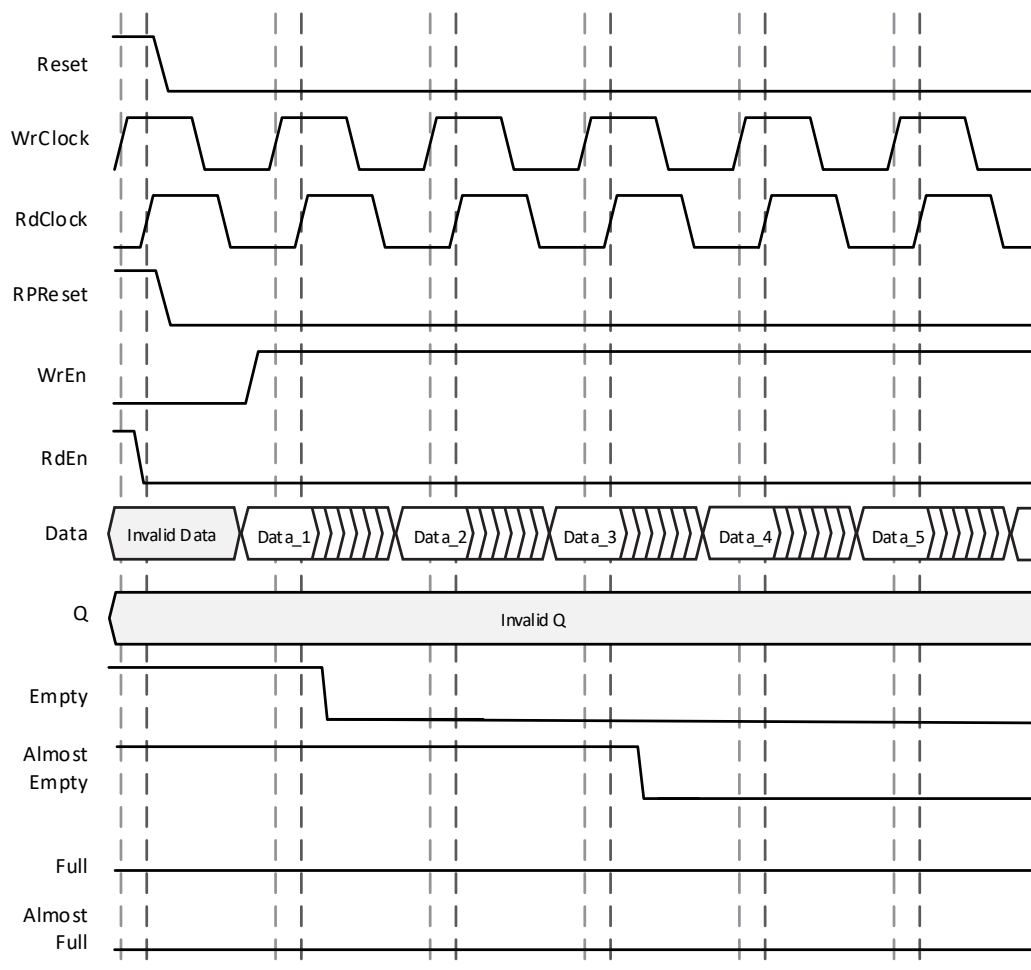


Figure 5.12. FIFO_DC without Output Registers – Start of Data Write Cycle

The WrEn signal has to be high to start writing into the FIFO_DC. When first initializing the FIFO, the Empty and Almost Empty flags are high while the Full and Almost Full flags are low.

When the first data is written into the FIFO_DC, the Empty flag deasserts or goes low, as the FIFO_DC is no longer empty. In this figure, it is assumed that the Almost Empty flag is set to three, that is, address location three. The Almost Empty flag is deasserted when the third address location is filled.

Assume that you continue to write into the FIFO_DC to fill it. When the FIFO_DC is filled, the Almost Full and Full flags are asserted. Figure 5.13 shows the behavior of these flags. In this figure, it is assumed that the FIFO_DC depth is N.

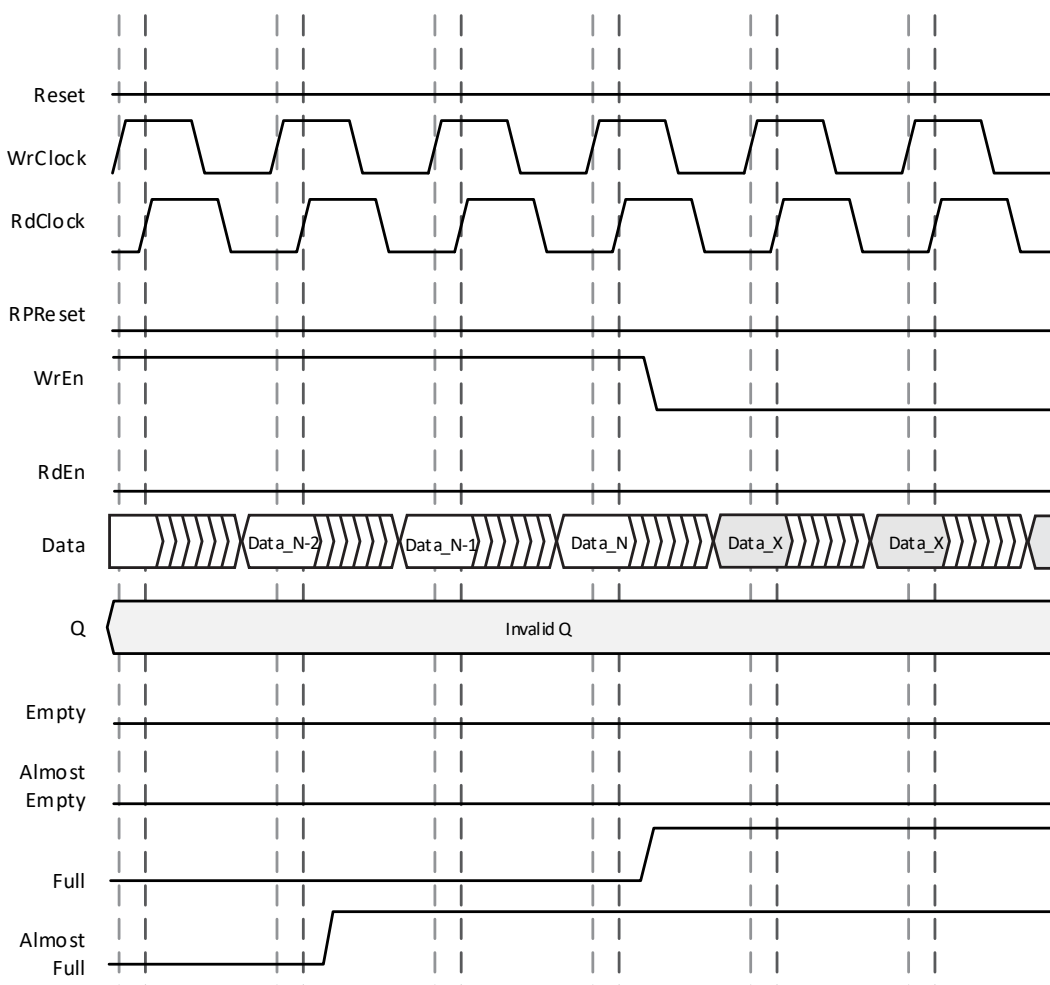


Figure 5.13. FIFO_DC without Output Registers – End of Data Write Cycle

In Figure 5.13, the Almost Full flag is two locations before the FIFO_DC is filled. The Almost Full flag is asserted when the N-2 location is written, and the Full flag is asserted when the last word is written into the FIFO_DC.

Data_X data inputs are not written because the FIFO_DC is full, with the Full flag being high.

Note that the assertion of these flags is immediate and there is no latency when they go true.

Examine the waveforms when the contents of the FIFO_DC are read out. Figure 5.14 shows the start of the read cycle. RdEn goes high and the data read starts. The Full and Almost Full flags are deasserted, as shown in Figure 5.14.

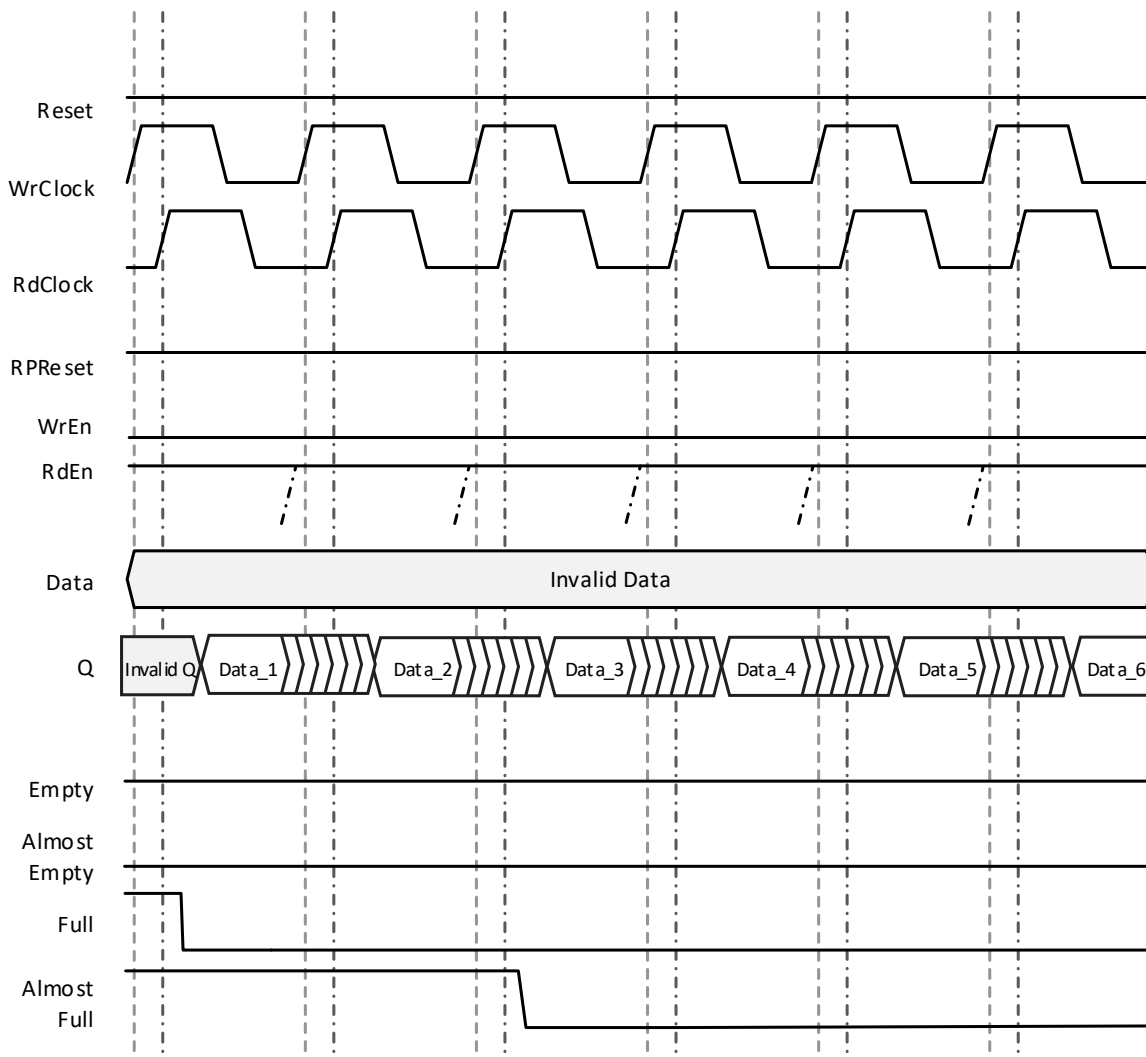


Figure 5.14. FIFO_DC without Output Registers – Start of Data Read Cycle

Similarly, as the data is read out and FIFO_DC is emptied, the Almost Empty and Empty flags are asserted (Figure 5.15).

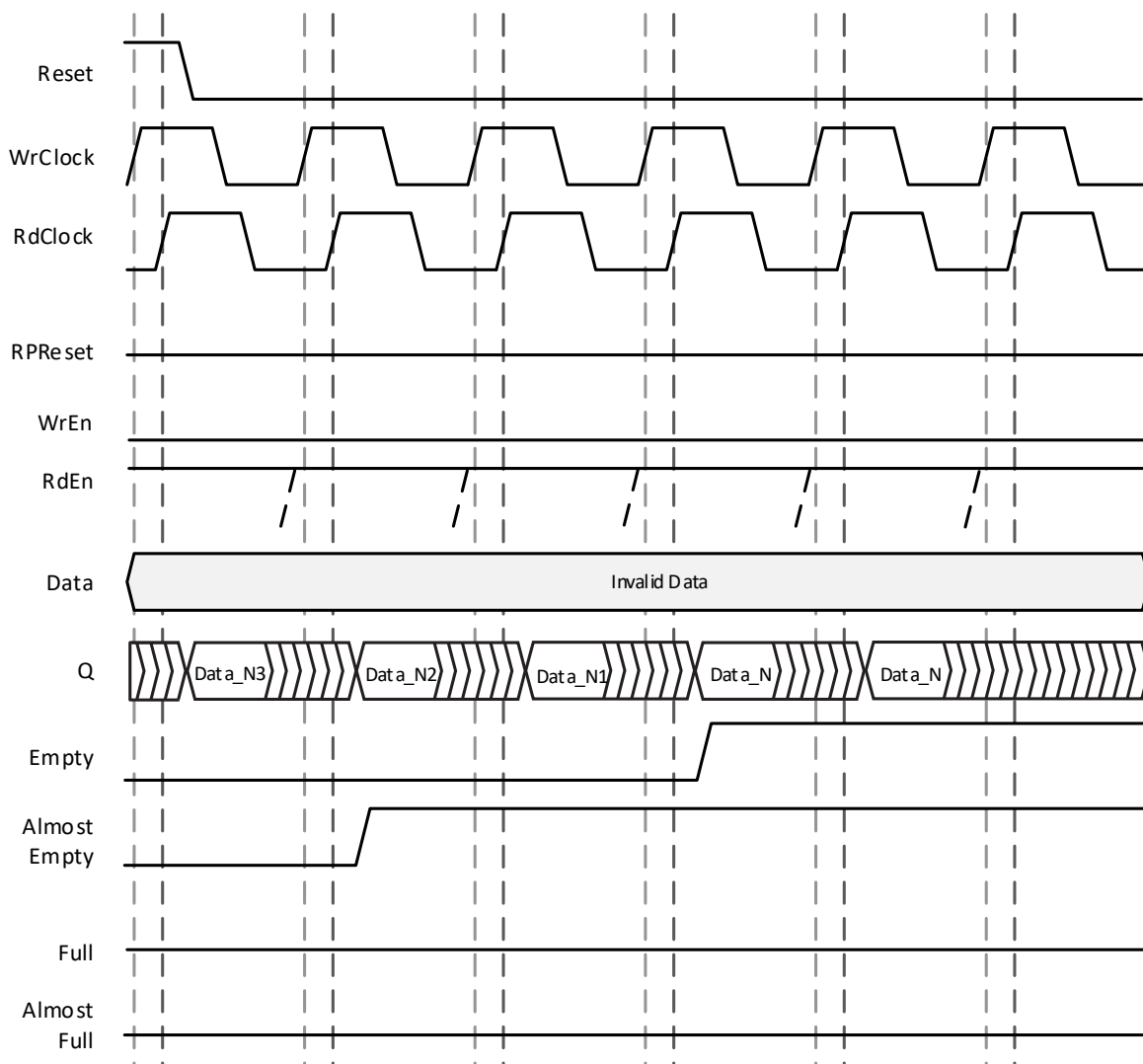


Figure 5.15. FIFO_DC without Output Registers – End of Data Read Cycle

Figure 5.12 to Figure 5.15 show the behavior of the non-pipelined FIFO_DC or FIFO_DC without output registers. When you pipeline the registers, the output data is delayed by one clock cycle. There is an extra option for output registers to be enabled by the RdEn signal.

Figure 5.16 to Figure 5.19 show similar waveforms for FIFO_DC with output registers and Figure 5.20 shows FIFO_DC with output registers enabled by RdEn. Note that flags are asserted and deasserted with timing similar to the FIFO_DC without output registers. However, only the data out Q is delayed by one clock cycle.

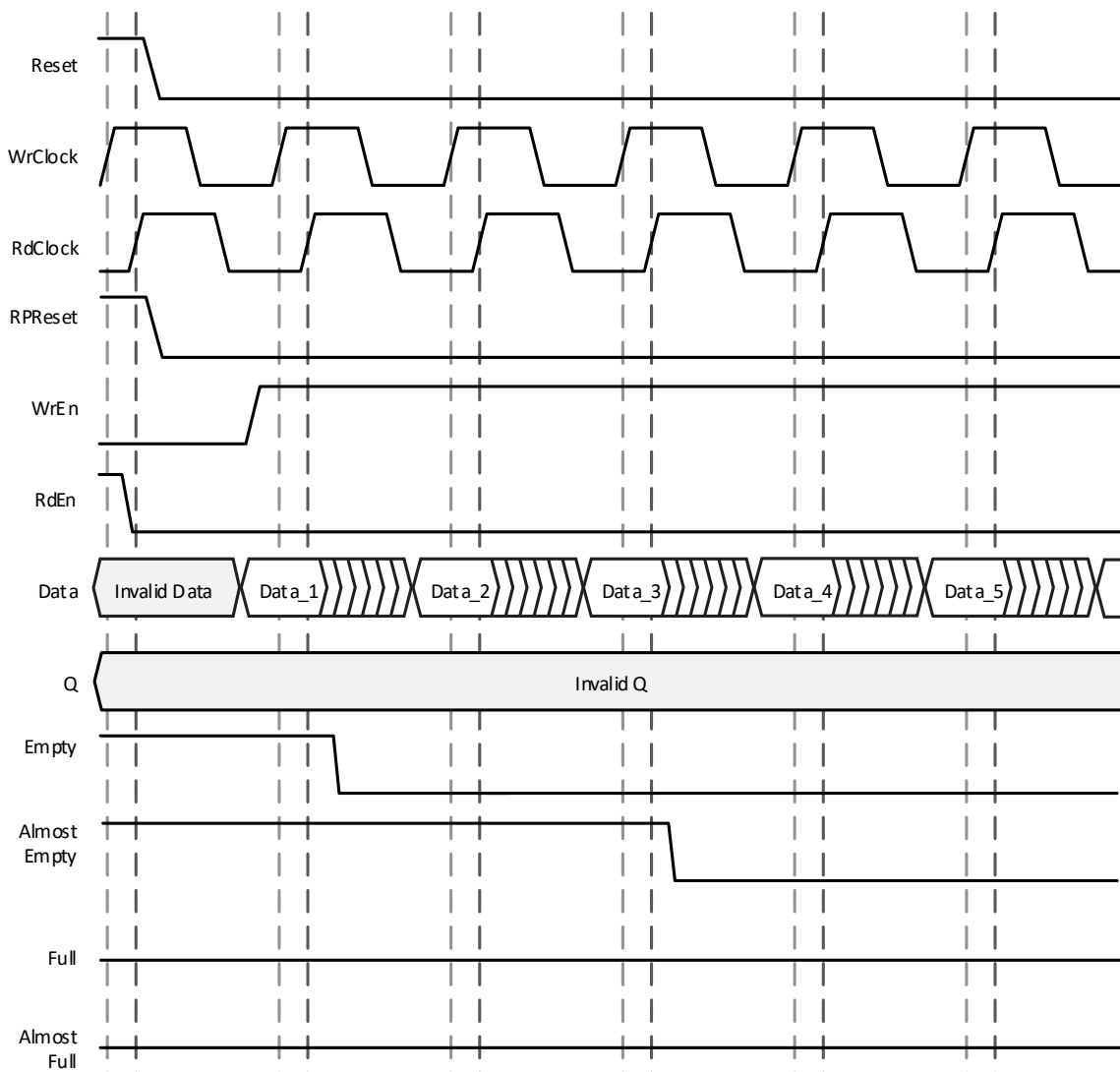


Figure 5.16. FIFO_DC with Output Registers – Start of Data Write Cycle

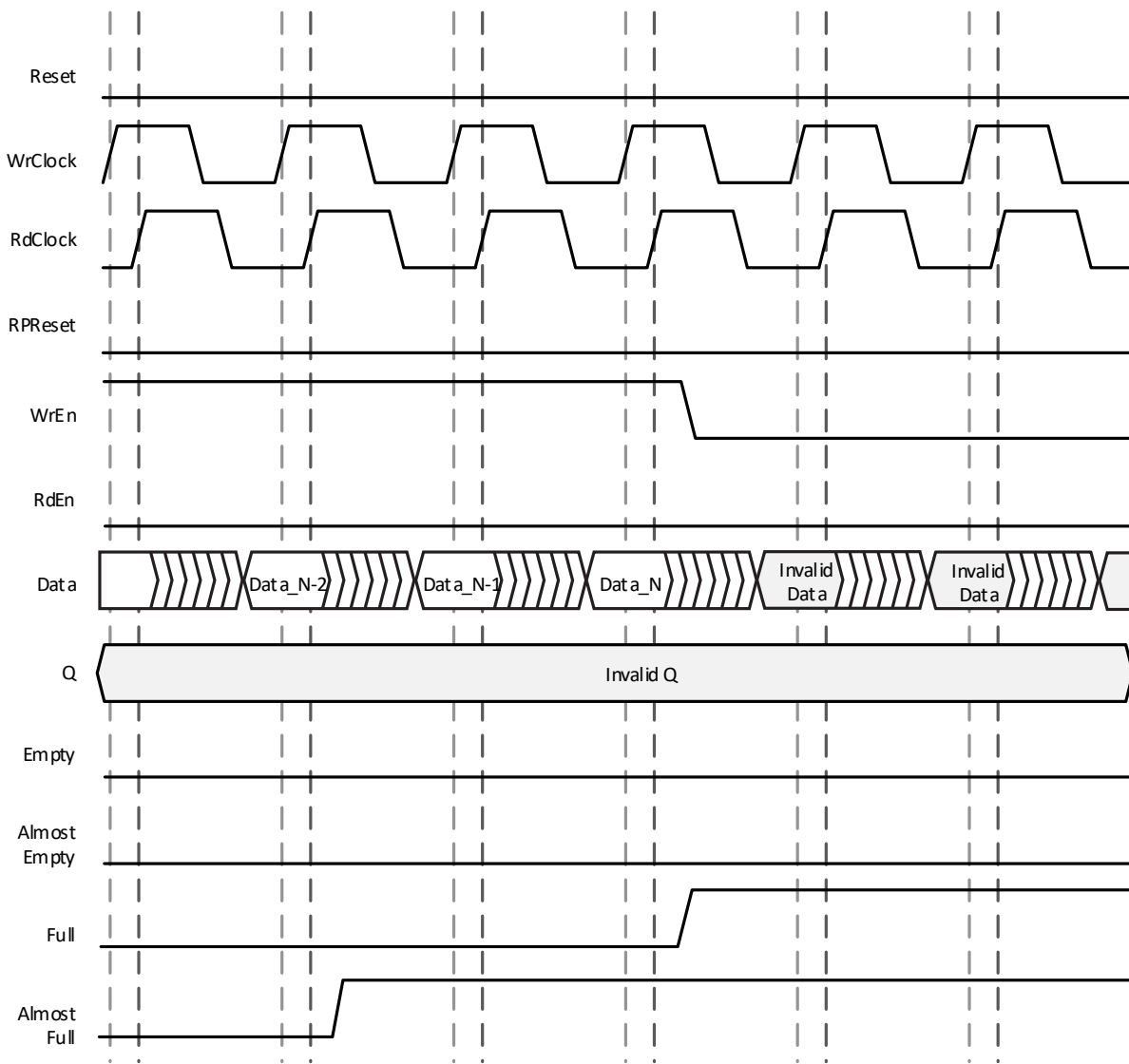


Figure 5.17. FIFO_DC with Output Registers – End of Data Write Cycle

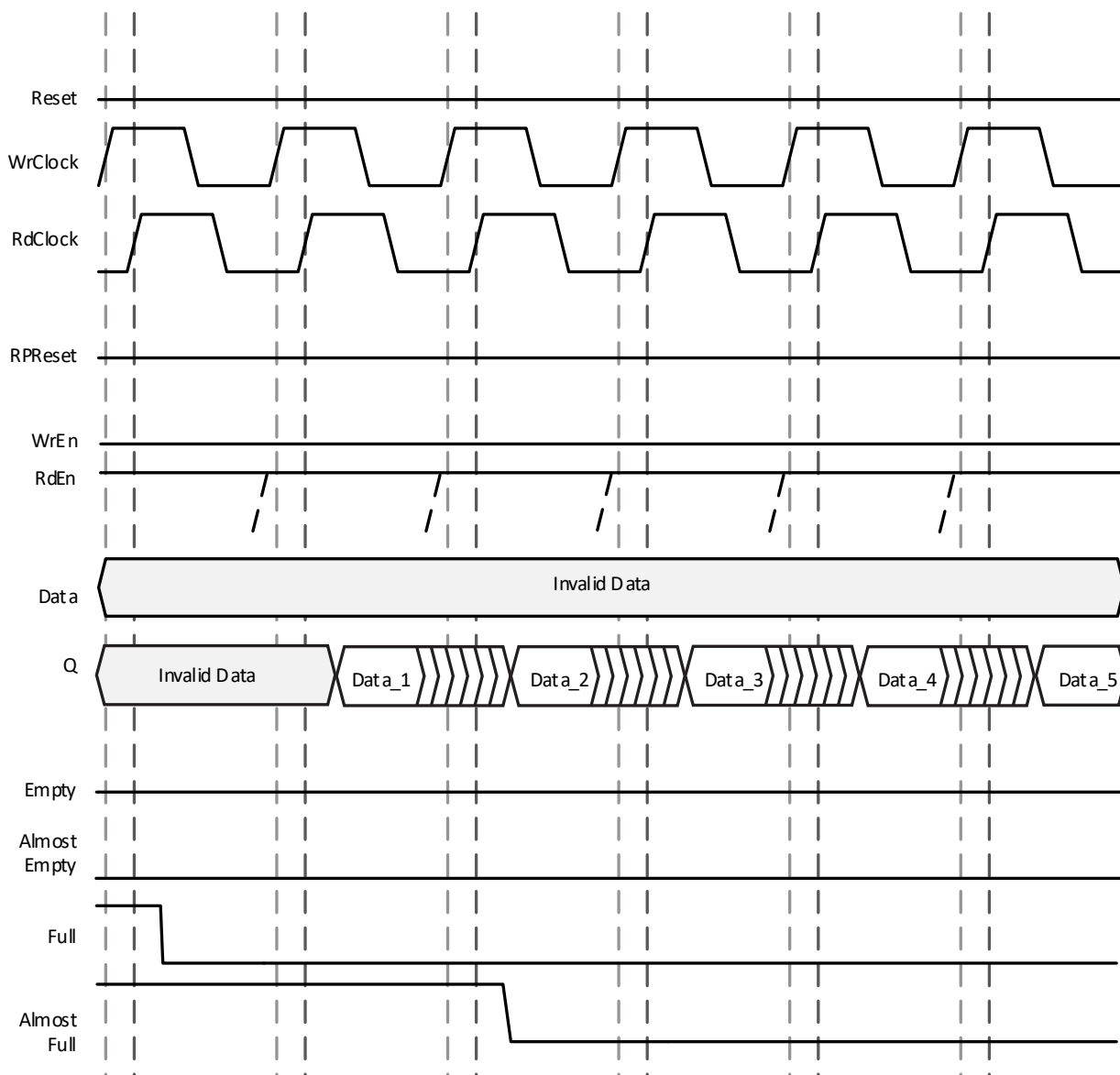


Figure 5.18. FIFO_DC with Output Registers – Start of Data Read Cycle

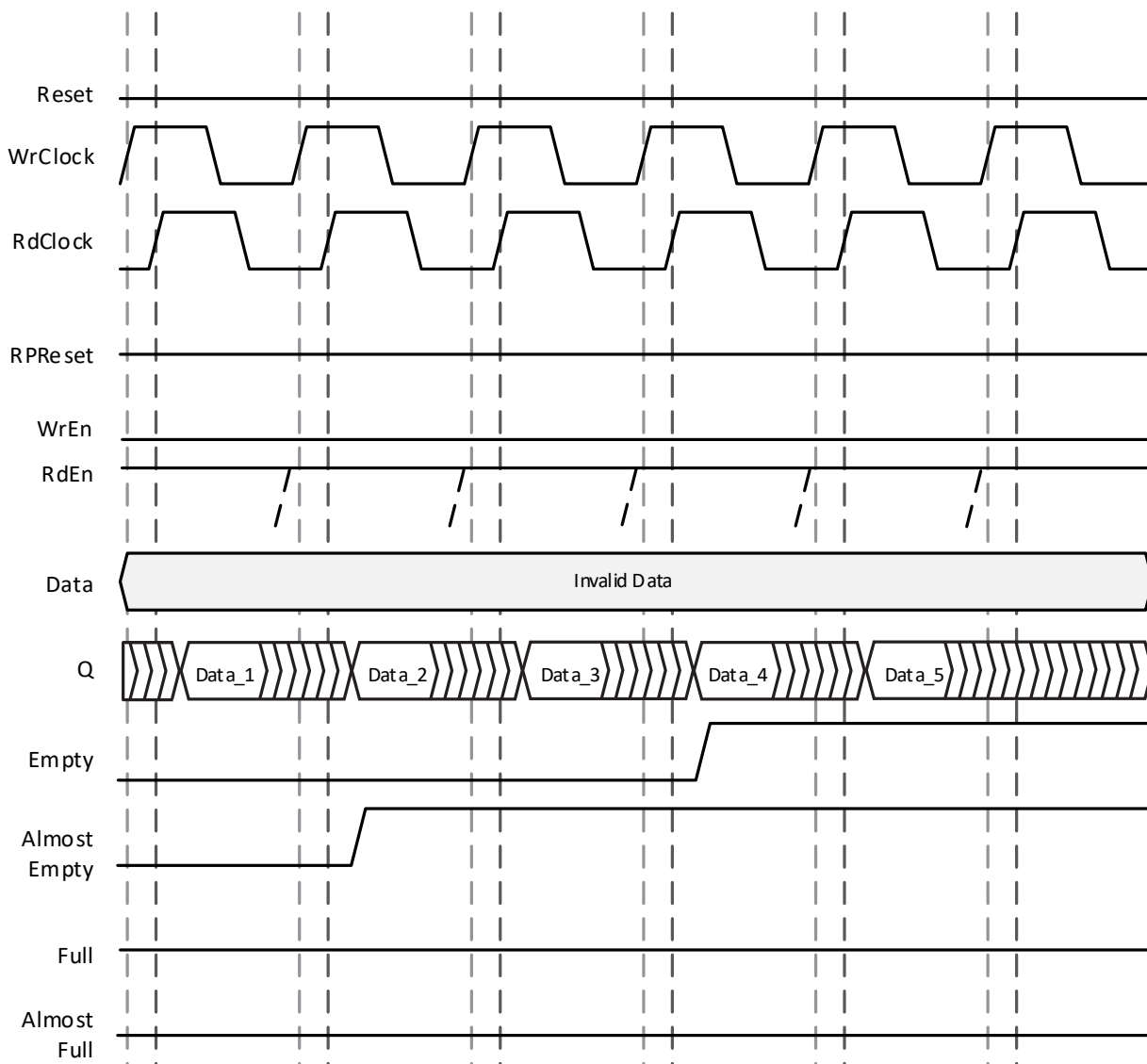


Figure 5.19. FIFO_DC with Output Registers – End of Data Read Cycle

If you select the option to enable output register with RdEn, data out is still delayed by one clock cycle, as compared to the non-pipelined FIFO_DC. The RdEn signal must be high during that clock cycle. Otherwise, the data takes an extra clock cycle when the RdEn signal goes true.

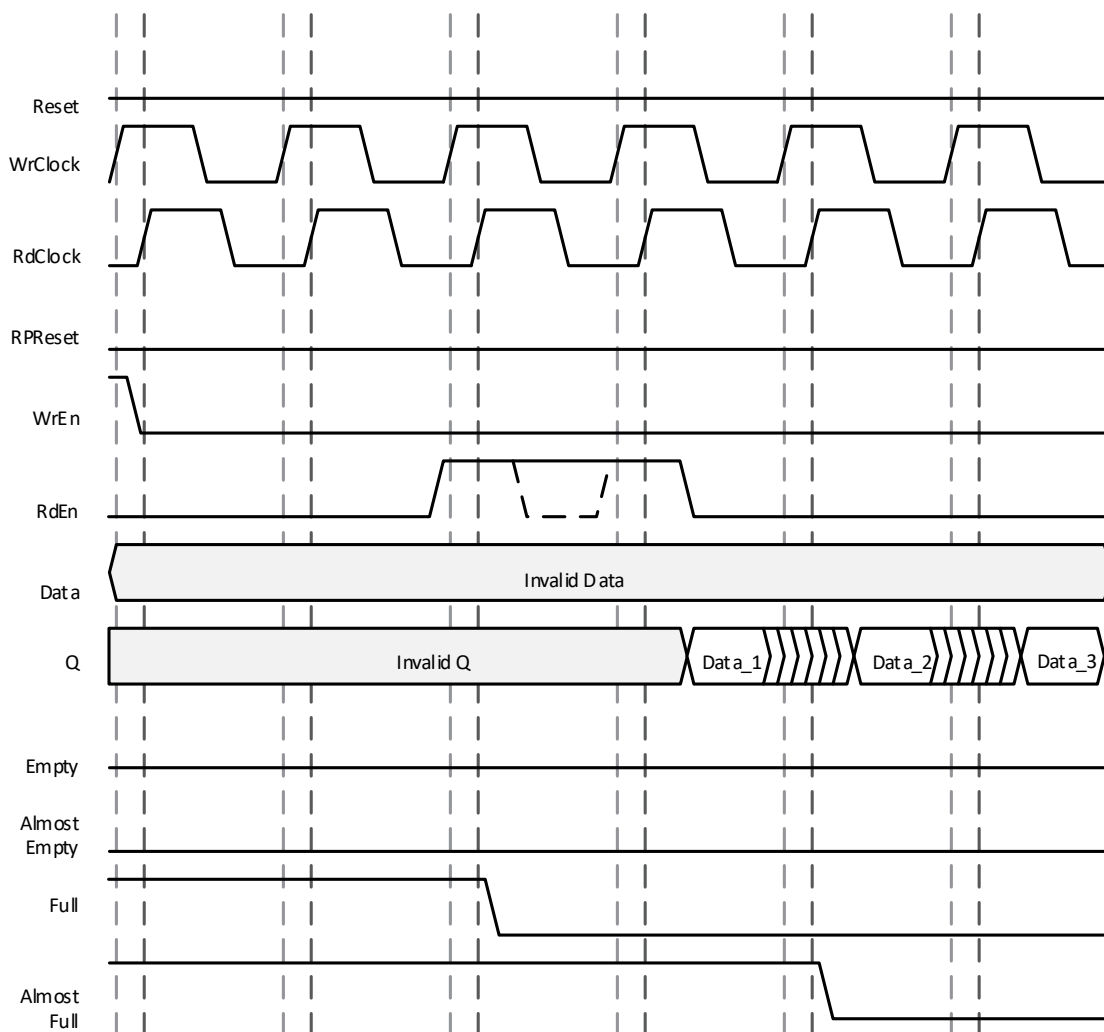


Figure 5.20. FIFO_DC with Output Registers and RdEn on Output Registers

When using FIFO_DC with different data widths on read and write ports, make sure that the wider data width is the multiple of the smaller one. In addition to that, the words written or read out must follow the same relationship. For example, assume that the width of the write port DataIn is 8 bits and the read port DataOut is 16 bits. In this case, there is a factor of two between the two. For every two words written in the FIFO_DC, one word is read out. If you write an odd number of words, such as seven, then the read port reads three complete words and one half word. The other half of the incomplete word is either all zeroes or prior data written at the eighth location.

If you reverse the number of bits on DataIn and DataOut, then, for every written word, two words are read out. To completely read the FIFO_DC, you need twice the number of clock cycles on the write port.

FIFO_DC does not include any arbitration logic. It must be implemented outside the FIFO_DC. Read and Write Count pointers can be used to aid in counting the number of written or read words.

6. Distributed Single-Port RAM – PFU-Based

This section describes the distributed single-port RAM, Distributed_SPRAM, which is PFU-based.

PFU-based distributed single-port RAM is created using the 4-input LUTs available in the PFU. These LUTs can be cascaded to create larger distributed memory sizes.

Figure 6.1 shows the distributed single-port RAM module generated by the IP Catalog.

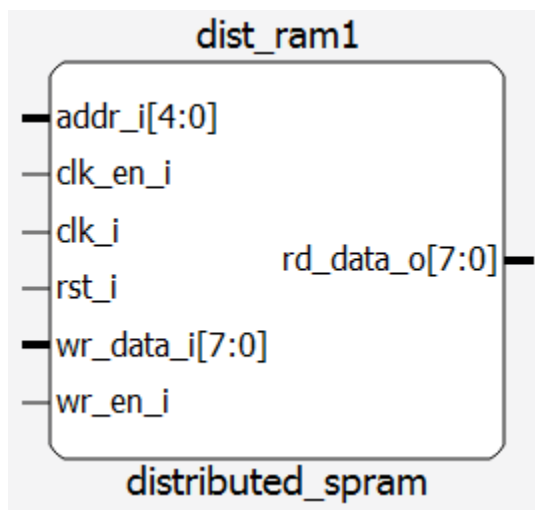


Figure 6.1. Distributed Single-Port RAM Module Generated by the IP Catalog

The generated module makes use of the 4-input LUTs available in the PFU. Additional logic, such as a clock or reset, is generated by using the resources available in the PFU.

Note that for distributed RAM, the read is asynchronous and sensitive to address changes, whereas the write operation is synchronous. When Wr_En is deasserted, the RAM begins to read from the address specified on the addr_i port. Enabling the output register allows the device to behave like a synchronous RAM during its read operation.

Ports such as Read Clock, RdClock, and Read Clock Enable, RdClockEn, are not available in the hardware primitive. These are generated by the IP Catalog when you want to enable the output registers in the IP Catalog configuration.

Figure 6.2 provides the primitive that can be instantiated for the single-port distributed RAM. The primitive name is SPR16X4A, and it can be directly instantiated in the code. Check the details of the ports and port names under the primitives available under the cae_library/synthesis folder in the Lattice Radiant software installation folder.

Every three slices can accommodate 64 bits of memory. If the memory required is larger than 64 bits, then cascading can be used. Furthermore, the ports can be registered using external PFU registers.

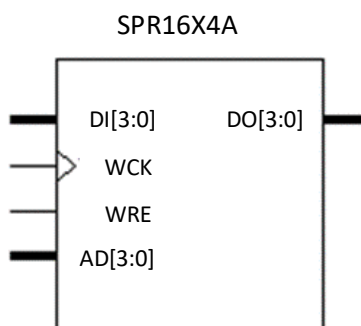


Figure 6.2. Single-Port Distributed RAM Primitive for Lattice Nexus 2 Platform Devices

Table 6.1 lists the corresponding ports for the module generated by the IP Catalog and for the primitive.

Table 6.1. PFU-Based Distributed Single-Port RAM Port Definitions

Port Name	Direction	Width	Description
clk_i	Input	1	Clock
rst_i	Input	1	Reset
clk_en_i	Input	1	Clock Enable
we_i	Input	1	Write Enable
wr_data_i	Input	Data Width	Write Data
addr_i	Input	Address Width	Address
rd_data_o	Output	Data Width	Read Data

The software attributes for the distributed SPRAM are listed in Table 6.2.

Table 6.2. Distributed_SPRAM Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Address Depth	Address depth of the read and write port	2-<Max that can fit in the device>	32
Data Width	Data word width of the read and write port	1-256	8
Enable Output Register	Data Out port, Q, can be configured as registered or not using this selection.	true or false	true
Reset Mode	Selection for the Reset to be synchronous or asynchronous to the clock	async or sync	sync
Memory Initialization	Allows you to initialize the memories to all 1s, 0s, or to have a custom initialization by providing a memory file.	none, 0s, 1s, or memory file	none
Memory File	When Memory File is selected, you can browse to the mem file for custom initialization of RAM.	—	—
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

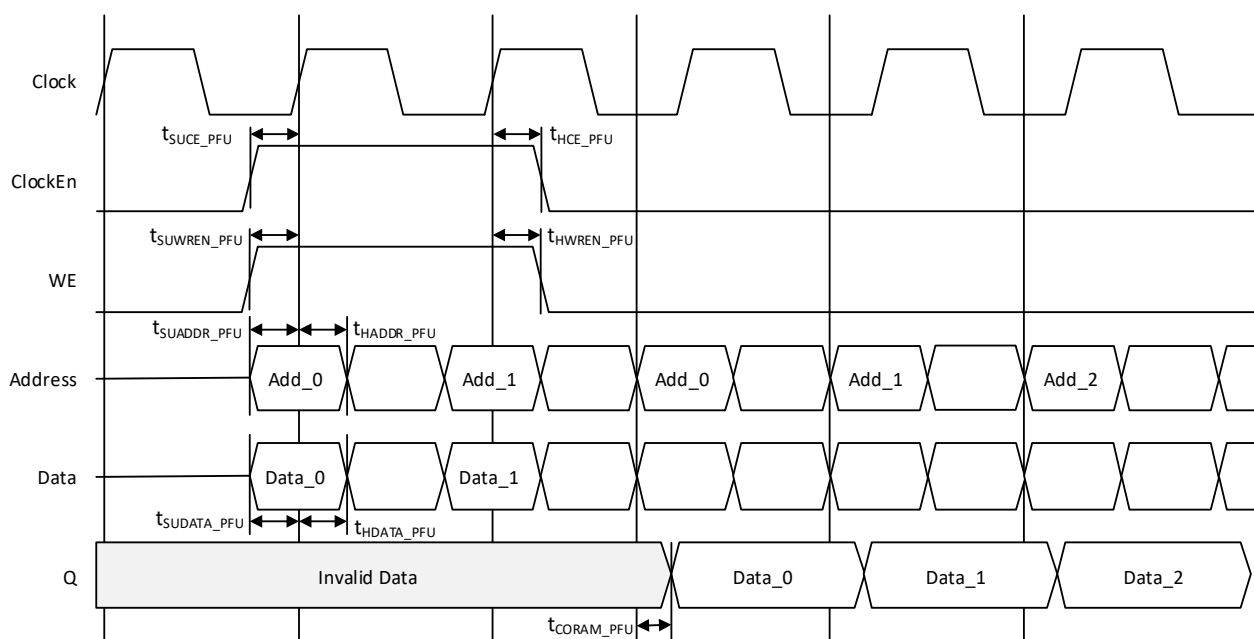


Figure 6.3. PFU-Based Distributed Single-Port RAM Timing Waveform – without Output Registers

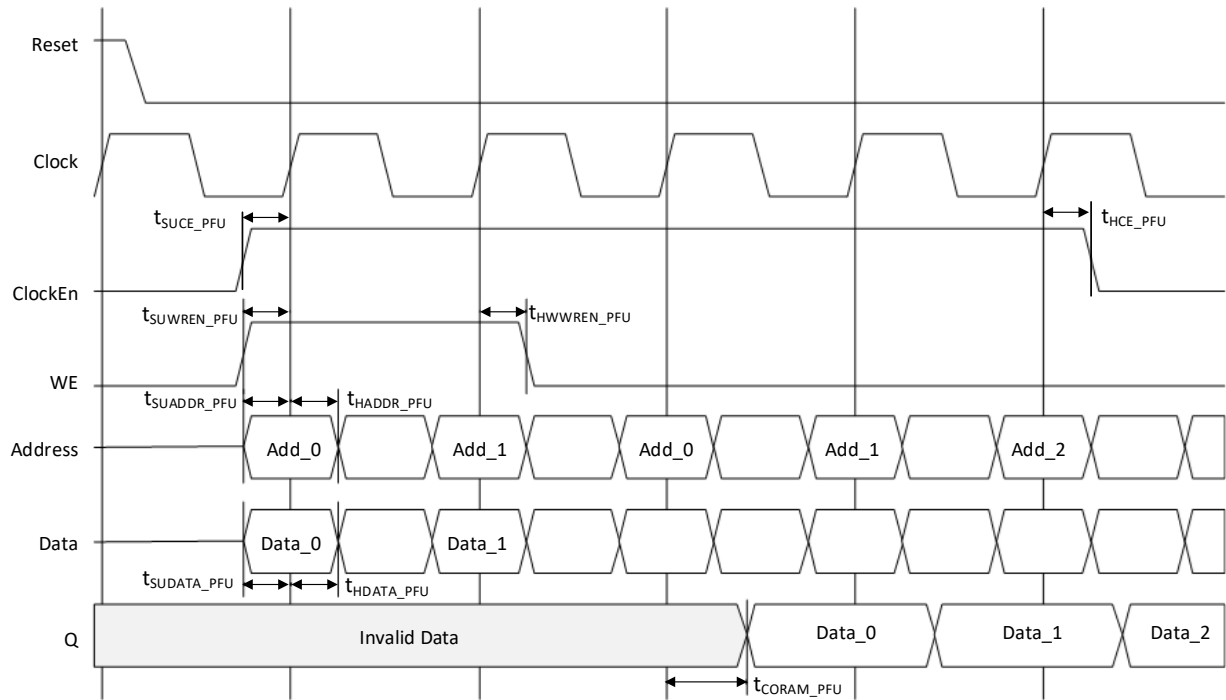


Figure 6.4. PFU-Based Distributed Single-Port RAM Timing Waveform – with Output Registers

7. Distributed Dual-Port RAM – PFU-Based

This section describes the distributed dual-port RAM, Distributed_DPRAM, which is PFU-based.

PFU-based distributed dual-port RAM is also created using the 4-input LUTs available in the PFU. These LUTs can be cascaded to create larger distributed memory sizes.

Figure 7.1 shows the distributed dual-port RAM module as generated by the IP Catalog.

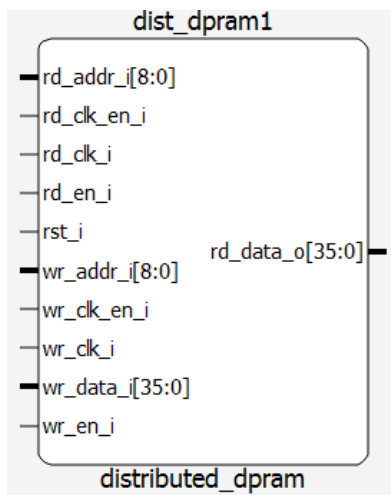


Figure 7.1. Distributed Dual-Port RAM Module Generated by the IP Catalog

The generated module makes use of the 4-input LUTs available in the PFU. Additional logic, such as a clock or reset, is generated by using the resources available in the PFU.

Note that for distributed RAM, the read operation is asynchronous and sensitive to address changes, whereas the write operation is synchronous. As a result, without an output register, the read port still reads when the read address, `rd_addr_i`, changes. Enabling the output register allows the device to behave like a synchronous RAM during its read operation, with the output gated by the read enable signal, `rd_en_i`, and the read clock enable signal, `rd_clk_en_i`.

Ports such as the Read Clock and Read Clock Enable are not available in the hardware primitive. These are generated by the IP Catalog when you want to enable the output registers in the IP Catalog configuration.

Figure 7.2 provides the primitive that can be instantiated for the dual-port distributed RAM. The primitive name is `DPR16X4A`, and it can be directly instantiated in the code. Check the details of the ports and port names under the primitives available under the `cae_library/synthesis` folder in the Lattice Radiant software installation folder.

It is to be noted that every three slices can accommodate 64 bits of memory. If the memory required is larger than 64 bits, then cascading can be used. Furthermore, the ports can be registered using external PFU registers.

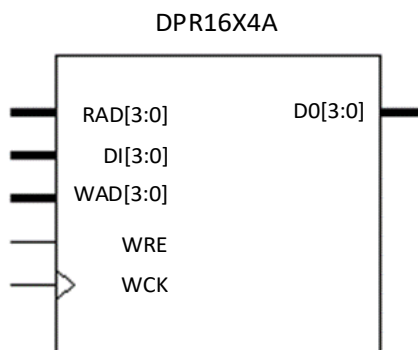


Figure 7.2. Dual-Port Distributed RAM Primitive for Lattice Nexus 2 Platform Devices

The various ports and definitions are listed in [Table 7.1](#). The table lists the corresponding ports for the module generated by the IP Catalog and for the primitive.

Table 7.1. PFU-Based Distributed Dual-Port RAM Port Definitions

Port Name	Direction	Width	Description
wr_clk_i	Input	1	Write Clock
rd_clk_i	Input	1	Read Clock
rst_i	Input	1	Reset
wr_clk_en_i	Input	1	Write Clock Enable
rd_clk_en_i	Input	1	Read Clock Enable
rd_en_i	Input	1	Read Enable
wr_en_i	Input	1	Write Enable
wr_data_i	Input	Data Width	Write Data
wr_addr_i	Input	Address Width	Write Address
rd_addr_i	Input	Address Width	Read Address
rd_data_o	Output	Data Width	Read Data

The software attributes for the distributed DPRAM are described in [Table 7.2](#).

Table 7.2. Distributed_DPRAM Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Address Depth	Address depth of the read and write port	2-<Max that can fit in the device>	512
Data Width	Data word width of the read and write port	1-256	36
Enable Output Register	Data Out port, Q, can be registered or not using this selection.	true or false	true
Reset Mode	Selection for the Reset to be synchronous or asynchronous to the clock	async or sync	sync
Memory Initialization	This option allows you to initialize memories to all 1s, 0s, or to use a custom initialization by providing a memory file.	none, 0s, 1s, or memory file	none
Memory File	When Memory File is selected, you can browse to the memory file for custom initialization of RAM.	—	—
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

You have the option of enabling the output registers for the distributed dual-port RAM, Distributed_DPRAM. [Figure 7.3](#) and [Figure 7.4](#) show the internal timing waveforms for the distributed dual-port RAM without output registers and with output registers, respectively.

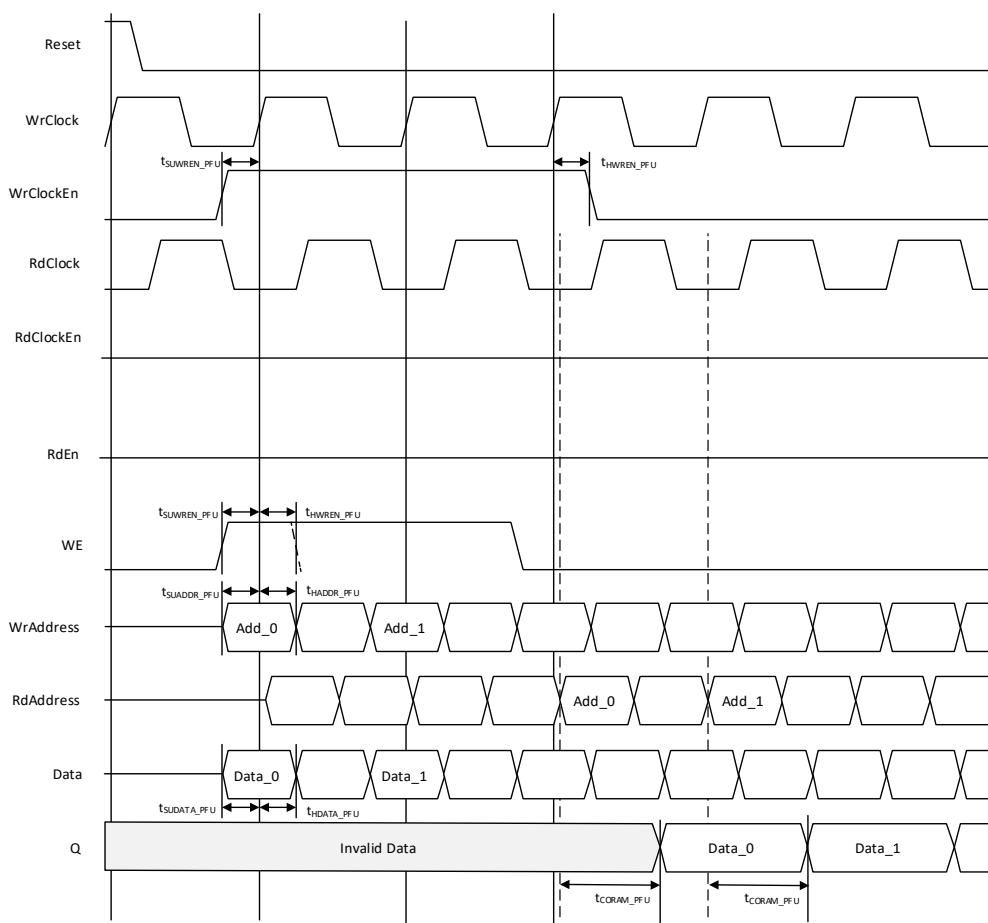


Figure 7.3. PFU-Based Distributed Dual-Port RAM Timing Waveform – without Output Registers



8. Distributed ROM – PFU-Based

This section describes the distributed ROM, Distributed_ROM, which is PFU-based.

PFU-based distributed ROM is also created using the 4-input LUTs available in the PFU. These LUTs can be cascaded to create larger distributed memory sizes.

Figure 8.1 shows the distributed ROM module generated by the IP Catalog.

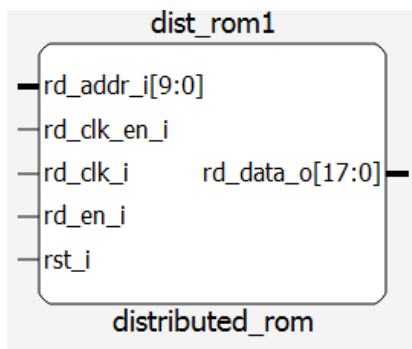


Figure 8.1. Distributed ROM Generated by the IP Catalog

The generated module makes use of the 4-input LUTs available in the PFU. Additional logic, such as a clock or reset, is generated by using the resources available in the PFU.

Ports such as Out Clock and Out Clock Enable are not available in the hardware primitive. These are generated by the IP Catalog when you want to enable the output registers in the IP Catalog configuration.

If the memory required is larger than what can fit in the primitive bits, then cascading can be used. Furthermore, the ports can be registered using external PFU registers.

Note that for distributed ROM, the read is asynchronous and sensitive to address changes. Enabling the output register allows the device to behave like a synchronous ROM during its read operation.

Table 8.1 lists the corresponding ports for the module generated by the IP Catalog and for the primitive.

Table 8.1. PFU-Based Distributed ROM Port Definitions

Port Name	Direction	Width	Description
clk_i	Input	1	Clock
rst_i	Input	1	Reset
clk_en_i	Input	1	Clock Enable
addr_i	Input	Address Width	Address
rd_data_o	Output	Data Width	Read Data

The software attributes for the distributed ROM are listed in Table 8.2.

Table 8.2. Distributed_ROM Attributes for Lattice Nexus 2 Platform Devices

Configuration Tab Attribute	Description	Value	Default Value
Address Depth	Address depth of the read port	2—<Max that can fit in the device>	1024
Data Width	Data word width of the read port	1–256	18
Enable Output Register	Data Out port, Q, can be configured as registered or not using this selection.	true or false	true
Reset Mode	Selection for the Reset to be synchronous or asynchronous to the clock	async or sync	sync
Memory File	When Memory File is selected, you can browse to the memory	—	—

Configuration Tab Attribute	Description	Value	Default Value
	file for custom initialization of RAM.		
Memory File Format	This option allows you to select if the memory file is formatted as binary or hex.	binary or hex	hex

You have the option to enable the output registers for the distributed ROM, Distributed_ROM. Figure 8.2 and Figure 8.3 show the internal timing waveforms for the distributed ROM without output registers and with output registers, respectively.

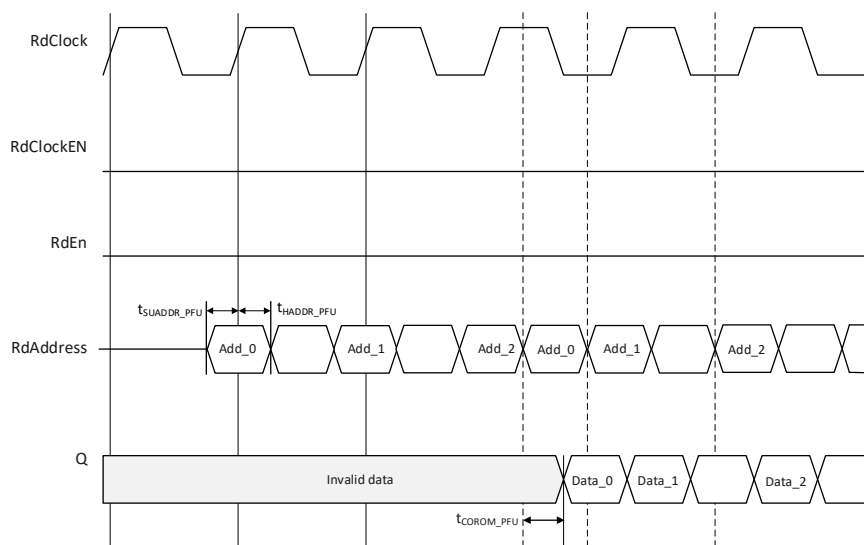


Figure 8.2. PFU-Based Distributed ROM Timing Waveform – without Output Registers

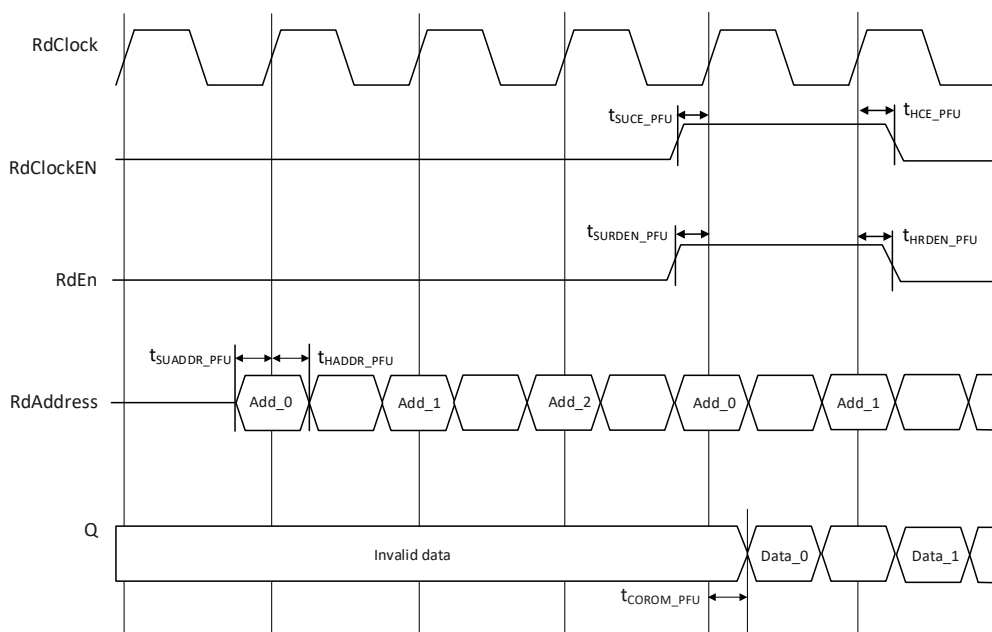


Figure 8.3. PFU-Based Distributed ROM Timing Waveform – with Output Registers

9. Initializing Memory

In each memory mode, it is possible to specify the power-on state of each bit in the memory array. This allows the memory to be used as ROM if desired. Each bit in the memory array can have a value of 0 or 1.

9.1. Initialization File Formats

The initialization file is an ASCII file, which you can create or edit using any ASCII editor. The IP Catalog supports two memory file formats:

- Binary file
- Hex file

The file name for the memory initialization file is *.mem, that is, <file_name>.mem. Each row includes the value to be stored in a particular memory location. The number of characters or the number of columns represents the number of bits for each address or the width of the memory module, respectively.

The memory initialization can be static or dynamic. In the case of static initialization, the memory values are stored in the bitstream. The dynamic initialization of memories involves memory values stored in the external flash and can be updated by user logic if it knows the EBR address locations. The size of the bitstream, the bit or rbt file, is larger due to static values stored in them.

The initialization file is primarily used for configuring the ROMs. RAMs can also use the initialization file to preload memory contents.

9.1.1. Binary File

The binary file is a text file of 0s and 1s. The rows indicate the number of words, and the columns indicate the width of the memory.

Memory Size 20 × 32

```
00100000010000000010000001000000
0000000100000001000000010000001
00000010000000010000000100000010
00000011000000110000001100000011
0000010000000100000001000000100
00000101000001010000010100000101
00000110000001100000011000000110
00000111000001110000011100000111
00001000010010000000100001001000
0000100100100100100001001001001
00001010010010100000101001001010
00001011010010110000101101001011
00001100000011000000110000001100
00001101001011010000110100101101
00001110001111100000111000111110
00001111001111110000111100111111
0001000000010000000100000010000
00010001000100010001000100010001
00010010000100100001001000010010
00010011000100110001001100010011
```

9.1.2. Hex File

The hex file is a text file of hexadecimal characters arranged in a similar row-column arrangement. The number of rows in the file is the same as the number of address locations, with each row indicating the content of the memory location.

Memory Size 8×16

```
A001
0B03
1004
CE06
0007
040A
0017
02A4
```

References

For more information, refer to:

- [Certus Nexus 2 Family Devices](#) web page
- [Mach Nexus 2 Family Devices](#) web page
- [Lattice Radiant](#) FPGA design software
- [Lattice Insights](#) for Lattice Semiconductor training courses and learning plans

Technical Support Assistance

Submit a technical support case through www.latticesemi.com/techsupport.

For frequently asked questions, refer to the Lattice Answer Database at www.latticesemi.com/Support/AnswerDatabase.

Revision History

Revision 0.82, September 2026

Section	Change Summary
All	Made editorial fixes.
Memory Modules	- Updated Figure 4.3. Single-Port RAM Timing Waveform – without Output Registers. - In Table 4.11. ROM Memory Sizes for 36 kb Memory for Lattice Nexus 2 Platform Devices, changed Dual-Port Memory Size $2,049 \times 18$ to $2,048 \times 18$.
Dual-Clock FIFO – EBR-Based or LUT-Based	In the FIFO_DC Flags section, changed the statement <i>The Empty and Almost Empty flags are high to begin and Full and Almost Full flags are low</i> to <i>When first initializing the FIFO, the Empty and Almost Empty flags are high while the Full and Almost Full flags are low</i> .
Distributed Single-Port RAM – PFU-Based	- Added the following paragraph: <i>Note that for distributed RAM, the read is asynchronous and sensitive to address changes, whereas the write operation is synchronous. When Wr_En is deasserted, the RAM begins to read from the address specified on the addr_i port. Enabling the output register allows the device to behave like a synchronous RAM during its read operation.</i> - Updated Figure 6.3. PFU-Based Distributed Single-Port RAM Timing Waveform – without Output Registers.
Distributed Dual-Port RAM – PFU-Based	- Added the following paragraph: <i>Note that for distributed RAM, the read operation is asynchronous and sensitive to address changes, whereas the write operation is synchronous. As a result, without an output register, the read port still reads when the read address, rd_addr_i, changes. Enabling the output register allows the device to behave like a synchronous RAM during its read operation, with the output gated by the read enable signal, rd_en_i, and the read clock enable signal, rd_clk_en_i.</i> - Updated Figure 7.3. PFU-Based Distributed Dual-Port RAM Timing Waveform – without Output Registers. - Updated Figure 7.4. PFU-Based Distributed Dual-Port RAM Timing Waveform – with Output Registers.
Distributed ROM – PFU-Based	- Added the following paragraph: <i>Note that for distributed ROM, the read is asynchronous and sensitive to address changes. Enabling the output register allows the device to behave like a synchronous ROM during its read operation.</i> - Updated Figure 8.2. PFU-Based Distributed ROM Timing Waveform – without Output Registers and its caption. - Updated Figure 8.3. PFU-Based Distributed ROM Timing Waveform – with Output Registers and its caption.
References	Updated this section.

Revision 0.81, October 2024

Section	Change Summary
All	Globally changed the platform name from <i>Lattice Khronos</i> to <i>Lattice Nexus 2</i> .
Abbreviations in This Document	- Added <i>ASCII</i>, <i>LSB</i>, <i>MSB</i>, and <i>RST</i> to the abbreviation list. - Removed <i>AW</i> and <i>DW</i>, as they are not used in this document.
Memory Modules	- Updated the title of section 4.2 from <i>Single-Port RAM (RAM_DQ) – EBR-Based</i> to <i>Single-Port RAM – EBR-Based</i>. - Updated the title of section 4.3 from <i>True Dual-Port RAM (RAM_DP_TRUE) – EBR-Based</i> to <i>True Dual-Port RAM – EBR-Based</i>. - Updated the title of section 4.4 from <i>Pseudo Dual-Port RAM (RAM_DP) – EBR-Based</i> to <i>Pseudo Dual-Port RAM – EBR-Based</i>. - Updated the title of section 4.5 from <i>Read Only Memory (ROM) – EBR-Based</i> to <i>Read Only Memory – EBR-Based</i>.
FIFO Memory	Updated the title of section 5.1 from <i>Single-Clock FIFO (FIFO) – EBR-Based or LUT-Based</i> to <i>Single-Clock FIFO – EBR-Based or LUT-Based</i> .
Dual-Clock FIFO – EBR-Based or LUT-Based	Updated the section title from <i>Dual-Clock First-In-First-Out (FIFO_DC) – EBR-Based or LUT-Based</i> to <i>Dual-Clock FIFO – EBR-Based or LUT-Based</i> .

Section	Change Summary
Distributed Single-Port RAM – PFU-Based	Updated the section title from <i>Distributed Single-Port RAM (Distributed_SPRAM) – PFU-Based</i> to <i>Distributed Single-Port RAM – PFU-Based</i> .
Distributed Dual-Port RAM – PFU-Based	Updated the section title from <i>Distributed Dual-Port RAM (Distributed_DPRAM) – PFU-Based</i> to <i>Distributed Dual-Port RAM – PFU-Based</i> .
Distributed ROM – PFU-Based	Updated the section title from <i>Distributed ROM (Distributed_ROM) – PFU-Based</i> to <i>Distributed ROM – PFU-Based</i> .
Memory Generation	Updated Figure 2.2. IP Catalog in the Lattice Radiant Software to reflect the latest IP Catalog in the Lattice Radiant software GUI.

Revision 0.80, September 2024

Section	Change Summary
All	Preliminary release.



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