



RISC-V MC CPU IP - Lattice Propel Builder 2023.1

User Guide

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Contents

Acronyms in This Document	5
1. Introduction	6
1.1. Quick Facts	6
1.2. Features	6
1.3. Conventions	6
2. Functional Descriptions	7
2.1. Overview	7
2.2. Modules Description	7
2.2.1. RISC-V Processor Core	7
2.2.2. Submodule (PIC/Timer)	10
2.3. Signal Description	13
2.3.1. Clock and Reset	13
2.3.2. Instruction and Data Interface	13
2.3.3. Interrupt interface	14
2.4. Attribute Summary	14
3. RISC-V MC CPU IP Generation	16
Appendix A. Resource Utilization	19
References	21
Technical Support Assistance	22
Revision History	23

Figures

Figure 2.1. RISC-V MC Soft IP Diagram	7
Figure 2.2. RISC-V MC Processor Core Block Diagram	8
Figure 2.3. PIC Block Diagram	10
Figure 2.4. Timer Block Diagram	12
Figure 3.1. Entering Component Name	16
Figure 3.2. Configuring Parameters	17
Figure 3.3. Verifying Results	17
Figure 3.4. Specifying Instance Name	18
Figure 3.5. Generated Instance.....	18

Tables

Table 1.1 RISC-V MC CPU IP Core Quick Facts	6
Table 2.1. RISC-V Processor Core Control and Status Registers	9
Table 2.2. PIC Registers.....	10
Table 2.3. Timer Registers	12
Table 2.4. Clock and Reset Ports.....	13
Table 2.5. Instruction Ports.....	13
Table 2.6. Data Ports.....	13
Table 2.7. Interrupt Ports.....	14
Table 2.8. Configurable Attributes.....	14
Table 2.9. Attributes Description	14
Table A.1. Resource Utilization in MachXO3D Device (with Cache Disabled)	19
Table A.2. Resource Utilization in CrossLink-NX Device (with Cache Disabled).....	19
Table A.3. Resource Utilization in CrossLink-NX Device (with Cache Enabled)	19
Table A.4. Resource Utilization in Lattice Avant Device (with Cache Disabled)	20
Table A.5. Resource Utilization in Lattice Avant Device (with Cache Enabled)	20
Table A.6. Resource Utilization in CertusPro-NX Device (with Cache Disabled).....	20
Table A.7. Resource Utilization in CertusPro-NX Device (with Cache Enabled).....	20

Acronyms in This Document

A list of acronyms used in this document.

Acronym	Definition
AHB-L	Advanced High-performance Bus – Lite
CPU	Central Processing Unit
CSR	Control and Status Register
DMIPS	Dhrystone MIPS (Million Instructions per Second)
FPGA	Field Programmable Gate Array
GDB	Gnu Debugger
HDL	Hardware Description Language
IP	Intellectual Property
IRQ	Interrupt Request
ISA	Instruction Set Architecture
JTAG	Joint Test Action Group
LUT	Lookup-Table
MC	Micro-Controller (RISC-V for Micro-Controller applications)
OpenOCD	Open On-Chip Debugger
PIC	Programmable Interrupt Controller
RISC-V	Reduced instruction set computer-V (five)
RV32IMC	RISC-V Integer, M and Compressed Instruction Sets
WFI	Wait For Interrupt

1. Introduction

The Lattice Semiconductor RISC-V MC CPU soft IP contains a 32-bit RISC-V processor core and optional submodules – Timer and Programmable Interrupt Controller (PIC). The CPU core is with instruction and data caches. The CPU core supports RV32IMC instruction set, external interrupts, and debug feature that is JTAG – IEEE 1149.1 compliant. The Timer submodule is a 64-bit real time counter, which compares a real-time register with another register to assert the timer interrupt. The PIC submodule aggregates up to eight external interrupt inputs into one external interrupt. The submodule registers are accessed by the processor core using a 32-bit Advanced High-performance Bus – Lite (AHB-L) interface.

The design is implemented using Verilog HDL, and it can be configured and generated using the Lattice Propel™ Builder software. It supports Lattice Avant™, MachXO5™-NX, Certus™-NX, CertusPro™-NX, CrossLink™-NX, MachXO3D™, MachXO3™, and MachXO2™ FPGA devices.

1.1. Quick Facts

Table 1.1 presents a summary of the RISC-V MC CPU IP Core.

Table 1.1 RISC-V MC CPU IP Core Quick Facts

IP Requirements	Supported FPGA Family	Lattice Avant, MachXO5-NX, Certus-NX, CertusPro-NX, CrossLink-NX, MachXO3D, MachXO3L™, MachXO3LF™, MachXO2
Resource Utilization	Targeted Devices	LAV-AT, LFMXO5, LFD2NX, LFPCNX, LIFCL, LAMXO3D, LCMXO3L, LCMXO3LF, LCMXO2
	Supported User Interfaces	AHB – Lite Interface
	Resources	See Table A.1 , Table A.2 , Table A.3 .
Design Tool Support	Lattice Implementation	Lattice Propel Builder 2023.1, Lattice Radiant 2023.1
	Simulation	For a list of supported simulators, see the Lattice Radiant™ and Lattice Diamond™ software user guide.

1.2. Features

The RISC-V MC soft IP has the following features:

- RV32IMC instruction set
- Five stages of pipelines
- Support the AHB-L bus standard for instruction/data port
- Optional caches, including a 4 KB two-way instruction cache and a 4 KB two-way data cache (for Lattice Avant, MachXO5-NX, Certus-NX, CertusPro-NX, and CrossLink-NX only)
- Optional debug using Gnu Debugger (GDB) and Open On-Chip Debugger (OpenOCD)
- Optional PIC module
- Optional Timer module
- Interrupt and exception handling under Machine Mode
- > 0.7 DMIPS/MHz performance
- > 100 MHz on CrossLink-NX devices (tested on the Hello World template provided by Propel)

1.3. Conventions

The nomenclature used in this document is based on Verilog HDL.

2. Functional Descriptions

2.1. Overview

The RISC-V MC CPU IP processes data and instructions while monitoring external interrupts. As shown in Figure 2.1, the CPU IP has a 32-bit processor core and optional submodules. It uses one AHB-L interface (Read-Only) for instruction fetch and another AHB-L interface (Read/Write Access) for data access. See Table 2.5 and Table 2.6 for the AHB-L Instruction Fetch and Data Accessing ports definition. The CPU core, PIC, Timer and AHB-L multiplexor run in the system clock domain. The Core Debug runs in both system clock domain and JTAG clock domain.

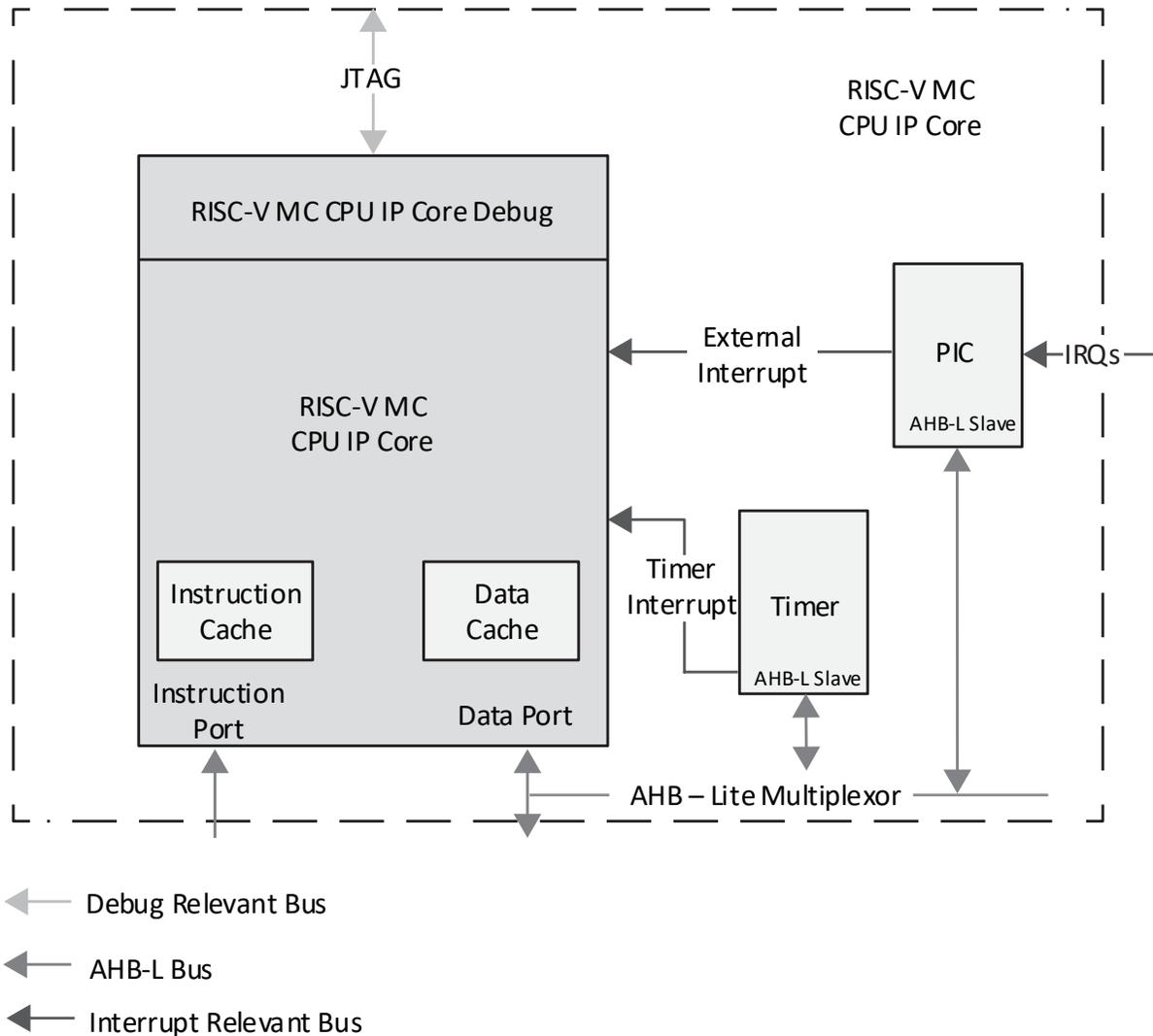


Figure 2.1. RISC-V MC Soft IP Diagram

2.2. Modules Description

2.2.1. RISC-V Processor Core

The processor core follows the RV32IMC instruction set. Figure 2.2 shows the processor core block diagram.

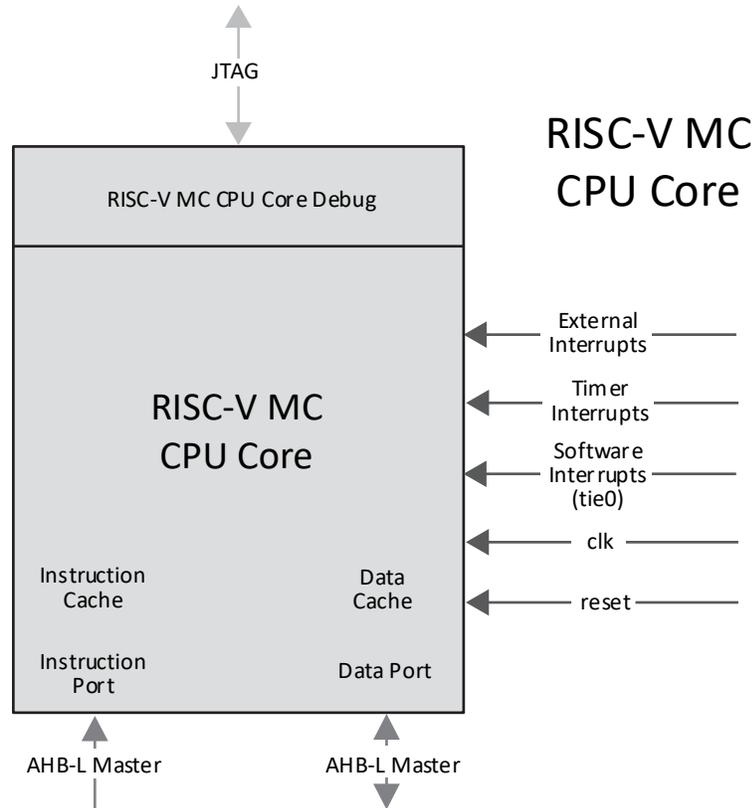


Figure 2.2. RISC-V MC Processor Core Block Diagram

2.2.1.1. Interrupt

Whenever an interrupt occurs, it has to remain in its active level until it is cleared by the processor core interrupt service routine.

If an interrupt occurs, before jumping to the interrupt service routine, the processor core stops the prefetch stage and waits for all instructions in the later pipeline stages to complete their execution.

2.2.1.2. Exception

If an exception occurs, the processor core stops the corresponding instruction, flushes all previous instructions, and waits until the terminated instruction reaches the writeback stage before jumping to the exception service routine.

2.2.1.3. Low Power Mode

Processor core enters into low power mode with WFI command, PC halts during low power mode, and processor wakes up if there is external/timer interrupt.

2.2.1.4. Debug

The processor core supports the IEEE-1149.1 JTAG debug logic with two hardware breakpoints.

Users should select soft JTAG on Lattice Avant family devices. This feature is for Lattice Avant only. To debug with soft JTAG, extra pin assignment efforts are required at post-synthesis. TCK must be assigned to a PCLK pin.

2.2.1.5. Instruction and Data Caches

The processor core supports instruction and data caches.

The instruction and data caches are both 4 KB two-way set associative, each cache line contains 32 bytes. The cache strategy for data cache is write through, and the cache eviction policy of both caches is round robin.

The instruction and data caches can be enabled/disabled together by checking/unchecking the “CACHE_ENABLE” option when instantiating CPU in Propel, and the cacheable address range can be configured by setting the “CACHEABLE_ADDR_LOW” and “CACHEABLE_ADDR_HIGH” parameters.

When cache is enabled, it is required to store the instructions into the instruction cache range.

It should be noted that the instruction and data caches should only be enabled for Certus-NX, CertusPro-NX, CrossLink-NX and MachXO5-NX devices, as they have enough resources to support the caches.

2.2.1.6. Control and Status Registers

The processor core supports the Control and Status Registers (CSRs) listed in [Table 2.1](#).

Table 2.1. RISC-V Processor Core Control and Status Registers

CSR No.	CSR Name	Access	Fields
0x300	mstatus (machine status register)	read/write	bit[12:11]: mpp, privilege mode before entering trap, should always be 2'b11 (machine mode) in this CPU core. bit[7]: mpie, mie before entering trap, updated to mie value when entering to trap. bit[3]: mie, global interrupt enable.
0x304	mie (machine interrupt enable register)	read/write	bit[11]: meie, machine mode external interrupt enable. bit[7]: mtie, machine mode timer interrupt enable. bit[3]: msie, machine mode software interrupt enable.
0x305	mtvec	read/write (initialized to 0x20)	bit[31:2]: trap vector base address, 4-byte aligned. bit[0]: trap vector mode, all traps set the program counter to the base address in RISC-V MC CPU core. Bit[1] is not supported. Only 1'0 - direct mode and 1'b1 - vectored mode are available.
0x340	mscratch	read/write	bit[31:0]: for use by machine mode, it is used to hold a pointer to a machine-mode hart-local context space and swapped with a user register upon entry to a machine mode trap handler.
0x341	mepc (machine exception program counter)	read/write	bit[31:0]: when trap is taken into machine mode, mepc is used to store the address of the instruction that encountered exception.
0x342	mcause (machine cause register)	read only	bit[31]: 1'b1 - interrupt, 1'b0 - exception bit[3:0]: exception code for interrupt : 3 - machine software interrupt 7 - machine timer interrupt 11 - machine external interrupt for exception : 0 - instruction address misaligned 1 - instruction access fault 2 - illegal instruction 4 - load address misaligned 5 - load access fault
0x343	mtval (machine trap value register)	read only	bit[31:0]: When a hardware breakpoint is triggered, or an instruction fetch, load or store address is misaligned or access exception occurs, mtval is written with the fault address. It may also be written with illegal instruction when an illegal instruction occurs.
0x344	mip (machine interrupt pending register)	read/write	bit[11]: meip, machine mode external interrupt pending, read only. bit[7] mtip, machine mode timer interrupt pending, read only. bit[3] msip, machine mode software interrupt pending, readable and writable.

2.2.2. Submodule (PIC/Timer)

The CPU soft IP contains submodules: PIC and Timer. The PIC and Timer share the same start address in the memory map and a fixed two KB address range is allocated, if either PIC or Timer is enabled.

2.2.2.1. PIC

The PIC aggregates up to eight external interrupt inputs (IRQs) into one interrupt output to processor core. The interrupt status register can be used to read the values of IRQs. Individual IRQs can be configured by programming the corresponding PIC_STATUS, PIC_ENABLE, PIC_SET, and PIC_POL registers. All registers can be accessed through an AHB-L interface, as shown in Figure 2.3.

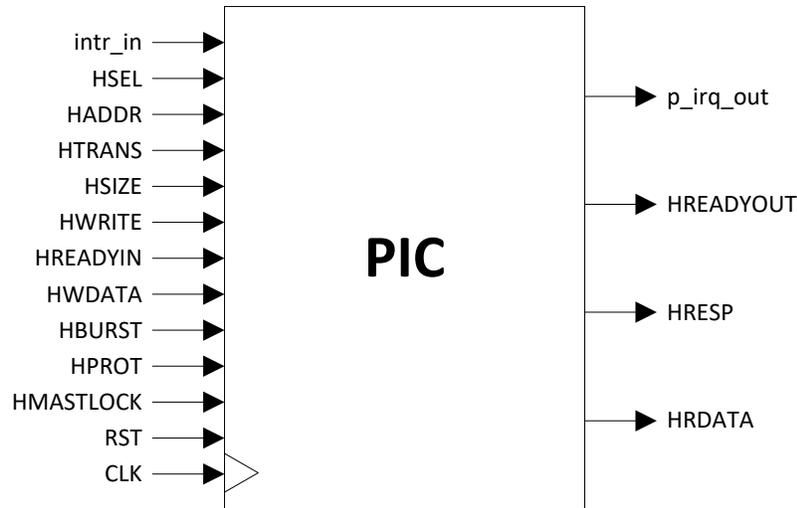


Figure 2.3. PIC Block Diagram

Table 2.2 provides the description of PIC registers.

Table 2.2. PIC Registers

Offset	Name	Description																									
0x000	PIC_STATUS	<p>Interrupt Status Register (read-write) (parameterizable width, min=2, max=8) Indicate the pending interrupt at corresponding interrupt request port(irq[i] at top level).</p> <table border="1"> <thead> <tr> <th>Field</th> <th>Name</th> <th>Access</th> <th>Width</th> <th>Reset</th> </tr> </thead> <tbody> <tr> <td>[N-1]</td> <td>PIC_STATUS [N-1]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>...</td> <td>...</td> <td>...</td> <td>...</td> <td>...</td> </tr> <tr> <td>[1]</td> <td>PIC_STATUS [1]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>[0]</td> <td>PIC_STATUS [0]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> </tbody> </table> <p>PIC_STATUS[i]: Read</p> <ul style="list-style-type: none"> 0 – no interrupt at irq[i] 1 – interrupt pending at irq[i] <p>Write</p> <ul style="list-style-type: none"> 0 – no effect 1 – clear interrupt status for irq[i] 	Field	Name	Access	Width	Reset	[N-1]	PIC_STATUS [N-1]	RW	1	0x0	[1]	PIC_STATUS [1]	RW	1	0x0	[0]	PIC_STATUS [0]	RW	1	0x0
Field	Name	Access	Width	Reset																							
[N-1]	PIC_STATUS [N-1]	RW	1	0x0																							
...																							
[1]	PIC_STATUS [1]	RW	1	0x0																							
[0]	PIC_STATUS [0]	RW	1	0x0																							

Offset	Name	Description																									
0x004	PIC_ENABLE	<p>Interrupt Enable Register (read-write) (parameterizable width, min=2, max=8) Indicate whether the processor responds to the interrupt from corresponding interrupt request port (irq[i]) or not.</p> <table border="1"> <thead> <tr> <th>Field</th> <th>Name</th> <th>Access</th> <th>Width</th> <th>Reset</th> </tr> </thead> <tbody> <tr> <td>[N-1]</td> <td>PIC_ENABLE[N-1]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>...</td> <td>...</td> <td>...</td> <td>...</td> <td>...</td> </tr> <tr> <td>[1]</td> <td>PIC_ENABLE[1]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>[0]</td> <td>PIC_ENABLE[0]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> </tbody> </table> <p>PIC_ENABLE[i]: Read</p> <ul style="list-style-type: none"> 0 – irq[i] disabled 1 – irq[i] enabled <p>Write</p> <ul style="list-style-type: none"> 0 – disable irq[i] 1 – enable irq[i] 	Field	Name	Access	Width	Reset	[N-1]	PIC_ENABLE[N-1]	RW	1	0x0	[1]	PIC_ENABLE[1]	RW	1	0x0	[0]	PIC_ENABLE[0]	RW	1	0x0
Field	Name	Access	Width	Reset																							
[N-1]	PIC_ENABLE[N-1]	RW	1	0x0																							
...																							
[1]	PIC_ENABLE[1]	RW	1	0x0																							
[0]	PIC_ENABLE[0]	RW	1	0x0																							
0x008	PIC_SET	<p>Interrupt Set Register (write-only) (parameterizable width, min=2, max=8) Set the interrupt status for corresponding interrupt request port(irq[i]).</p> <table border="1"> <thead> <tr> <th>Field</th> <th>Name</th> <th>Access</th> <th>Width</th> <th>Reset</th> </tr> </thead> <tbody> <tr> <td>[N-1]</td> <td>PIC_SET [N-1]</td> <td>W</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>...</td> <td>...</td> <td>...</td> <td>...</td> <td>...</td> </tr> <tr> <td>[1]</td> <td>PIC_SET [1]</td> <td>W</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>[0]</td> <td>PIC_SET [0]</td> <td>W</td> <td>1</td> <td>0x0</td> </tr> </tbody> </table> <p>PIC_SET[i]: Read</p> <ul style="list-style-type: none"> Invalid operation gets 0. <p>Write</p> <ul style="list-style-type: none"> 0 – no effect 1 – set interrupt status for irq[i] (set PIC_STATUS[i]) 	Field	Name	Access	Width	Reset	[N-1]	PIC_SET [N-1]	W	1	0x0	[1]	PIC_SET [1]	W	1	0x0	[0]	PIC_SET [0]	W	1	0x0
Field	Name	Access	Width	Reset																							
[N-1]	PIC_SET [N-1]	W	1	0x0																							
...																							
[1]	PIC_SET [1]	W	1	0x0																							
[0]	PIC_SET [0]	W	1	0x0																							
0x00C	PIC_POL	<p>Interrupt Polarity Register (read-write) (parameterizable width, min=2, max=8) Indicates the polarity of corresponding interrupt request (irq[i]) port.</p> <table border="1"> <thead> <tr> <th>Field</th> <th>Name</th> <th>Access</th> <th>Width</th> <th>Reset</th> </tr> </thead> <tbody> <tr> <td>[N]</td> <td>PIC_POL [N]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>...</td> <td>...</td> <td>...</td> <td>...</td> <td>...</td> </tr> <tr> <td>[1]</td> <td>PIC_POL I[1]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> <tr> <td>[0]</td> <td>PIC_POL [0]</td> <td>RW</td> <td>1</td> <td>0x0</td> </tr> </tbody> </table> <p>PIC_POL[i]: Read</p> <ul style="list-style-type: none"> 0 – irq[i] is active high 1 – irq[i] is active low <p>Write</p> <ul style="list-style-type: none"> 0 – Set irq[i] active high 1 – Set irq[i] active low 	Field	Name	Access	Width	Reset	[N]	PIC_POL [N]	RW	1	0x0	[1]	PIC_POL I[1]	RW	1	0x0	[0]	PIC_POL [0]	RW	1	0x0
Field	Name	Access	Width	Reset																							
[N]	PIC_POL [N]	RW	1	0x0																							
...																							
[1]	PIC_POL I[1]	RW	1	0x0																							
[0]	PIC_POL [0]	RW	1	0x0																							

Note: The register definition of PIC follows Lattice Interrupt Interface (LINTR) Standard, refer to [Lattice Memory Mapped Interface \(LMMI\)](#) and [Lattice Interrupt Interface \(LINTR\) User Guide \(FPGA-UG-02039\)](#) for more information.

2.2.2.2. Timer

The Timer module provides a 64-bit real-time counter register (*mtime*) and time compare register (*mtimecmp*). An output interrupt signal notifies the RISC-V processor core when the value of *mtime* is greater than or equal to the value of *mtimecmp*. All registers can be accessed through an AHB-L interface, as shown in Figure 2.4.

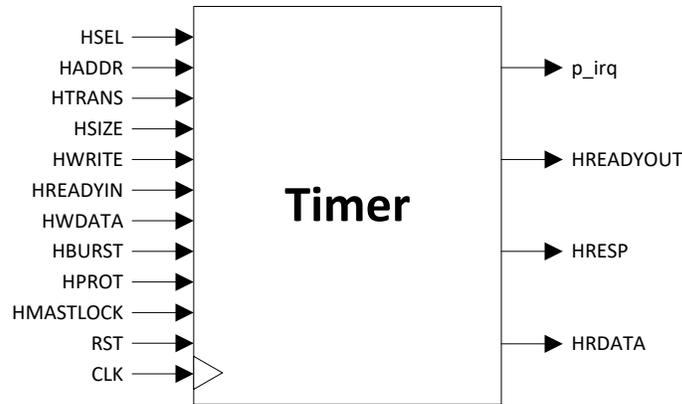


Figure 2.4. Timer Block Diagram

Table 2.3 provides the description of Timer registers.

Table 2.3. Timer Registers

Offset	Name	Description										
0x400	TIMER_CNT_L	<p>Lower 32 bits of Timer counter register.</p> <table border="1"> <thead> <tr> <th>Field</th> <th>Name</th> <th>Access</th> <th>Width</th> <th>Reset</th> </tr> </thead> <tbody> <tr> <td>[63:0]</td> <td><i>mtime</i></td> <td>RW</td> <td>64</td> <td>0x0</td> </tr> </tbody> </table> <p><i>mtime</i> A 64-bit real-time counter register. You must set the register to a non-zero value to start the counting process.</p>	Field	Name	Access	Width	Reset	[63:0]	<i>mtime</i>	RW	64	0x0
Field	Name	Access	Width	Reset								
[63:0]	<i>mtime</i>	RW	64	0x0								
0x404	TIMER_CNT_H	Higher 32 bits of Timer counter register.										
0x410	TIMER_CMP_L	<p>Lower 32 bits for Timer time compare register.</p> <table border="1"> <thead> <tr> <th>Field</th> <th>Name</th> <th>Access</th> <th>Width</th> <th>Reset</th> </tr> </thead> <tbody> <tr> <td>[63:0]</td> <td><i>mtimecmp</i></td> <td>RW</td> <td>64</td> <td>0x0</td> </tr> </tbody> </table> <p><i>mtimecmp</i> This register is used to generate or clear the timer interrupt (<i>mtip</i>). When the value of <i>mtime</i> register is greater than or equal to the value of <i>mtimecmp</i> register, the <i>cpu_mtip_o</i> is asserted. The interrupt remains posted until <i>mtimecmp</i> becomes greater than <i>mtime</i> (typically as a result of writing <i>mtimecmp</i>).</p>	Field	Name	Access	Width	Reset	[63:0]	<i>mtimecmp</i>	RW	64	0x0
Field	Name	Access	Width	Reset								
[63:0]	<i>mtimecmp</i>	RW	64	0x0								
0x400	TIMER_CNT_L	Higher 32 bits for Timer time compare register.										

2.3. Signal Description

Table 2.4 to Table 2.7 list the ports of the CPU soft IP in different categories.

2.3.1. Clock and Reset

Table 2.4. Clock and Reset Ports

Name	Direction	Width	Description
clk_i	In	1	RISC-V soft IP clock
rst_n_i	In	1	Global reset (active low)
system_resefn_o	Out	1	Combined Global reset and Debug Reset from JTAG

2.3.2. Instruction and Data Interface

Table 2.5. Instruction Ports

Name	Direction	Width	Description
AHBL_M0_INSTR - HADDR	Out	32	—
AHBL_M0_INSTR - HWRITE	Out	1	Fixed to 1'b0
AHBL_M0_INSTR - HSIZE	Out	3	Fixed to 3'b010
AHBL_M0_INSTR - HPROT	Out	4	Fixed to 4'b1110 when cache is not enabled
AHBL_M0_INSTR - HTRANS	Out	2	—
AHBL_M0_INSTR - HBURST	Out	3	—
AHBL_M0_INSTR - HMASTLOCK	Out	1	Fixed to 1'b0
AHBL_M0_INSTR - HWDATA	Out	32	—
AHBL_M0_INSTR - HRDATA	In	32	—
AHBL_M0_INSTR - HREADY	In	1	—
AHBL_M0_INSTR - HRESP	In	1	—

Table 2.6. Data Ports

Name	Direction	Width	Description
AHBL_M1_DATA - HADDR	Out	32	—
AHBL_M1_DATA - HWRITE	Out	1	—
AHBL_M1_DATA - HSIZE	Out	3	—
AHBL_M1_DATA - HPROT	Out	4	Fixed to 4'b1111 when cache is not enabled
AHBL_M1_DATA - HTRANS	Out	2	—
AHBL_M1_DATA - HBURST	Out	3	—
AHBL_M1_DATA - HMASTLOCK	Out	1	—
AHBL_M1_DATA - HSEL	Out	1	—
AHBL_M1_DATA - HWDATA	Out	32	—
AHBL_M1_DATA - HRDATA	In	32	—
AHBL_M1_DATA - HREADY	In	1	—

Note: Refer to [AMBA 3 AHB-Lite Protocol V1.0](#) for more information.

2.3.3. Interrupt interface

Table 2.7. Interrupt Ports

Name	Type	Width	Description
IRQ_Sx	In	1~8	Peripheral interrupts.
TIMER_IRQ_M0	Out	1	Timer interrupt output, exists only when "TIMER_ENABLE" is checked.
TIMER_IRQ_S0	In	1	Timer interrupt input, exists only when "TIMER_ENABLE" is unchecked.

2.4. Attribute Summary

The configurable attributes of the RISC-V MC CPU IP are shown in [Table 2.8](#) and are described in [Table 2.9](#).

The attributes can be configured through the Propel Builder software.

Table 2.8. Configurable Attributes

Attribute	Selectable Values	Default	Dependency on Other Attributes
General			
SIMULATION	Checked, Unchecked	UnChecked	—
CACHE_ENABLE	Checked, Unchecked	Checked	Disabled when SIMULATION
ICACHE_RANGE_LOW	0 ~ 0xFFFFFFFF	0	Enabled when CACHE_ENABLE
ICACHE_RANGE_HIGH	0 ~ 0xFFFFFFFF	0xF0000000	Enabled when CACHE_ENABLE
DCACHE_RANGE_LOW	0 ~ 0xFFFFFFFF	0	Enabled when CACHE_ENABLE
DCACHE_RANGE_HIGH	0 ~ 0xFFFFFFFF	0xF0000000	Enabled when CACHE_ENABLE
DEBUG_ENABLE	Checked, Unchecked	Checked	—
SOFT_JTAG	Checked, Unchecked	Checked when DEBUG_ENABLE and DEVICE == "LAV-AT"	—
TIMER_ENABLE	Checked, Unchecked	Checked	—
PIC_ENABLE	Checked, Unchecked	Checked	—
PICTIMER_START_ADDR	0 ~ 0xFFFFFB00	0xFFFF0000	Enabled when PIC_ENABLE or TIMER_ENABLE
IRQ_NUM	2 ~ 8	8	Enabled when PIC_ENABLE
C_EXT	Checked, Unchecked	Checked	—
M_EXT	Checked, Unchecked	Unchecked	Enabled when C_EXT (For Certus-NX, CertusPro-NX, CrossLink-NX, MachXO5-NX devices only.)
JTAG_CHANNEL	14~16	14	Enabled when DEBUG_ENABLE

Table 2.9. Attributes Description

Attribute	Description
SIMULATION	1: simulation mode 0: synthesis mode
ICACHE_ENABLE	1: enable instruction cache 0: disable instruction cache
DCACHE_ENABLE	1: enable data cache 0: disable data cache
ICACHE_RANGE_LOW	Lower limit of cacheable address range for instruction cache, this address itself is included.
ICACHE_RANGE_HIGH	Higher limit of cacheable address range for instruction cache, this address itself is included.
DCACHE_RANGE_LOW	Lower limit of cacheable address range for data cache, this address itself is included.

Attribute	Description
DCACHE_RANGE_HIGH	Higher limit of cacheable address range for data cache, this address itself is included.
DEBUG_ENABLE	1: debug function enable 0: debug function disable
SOFT_JTAG	1: debug with hard JTAG 0: debug with soft JTAG
TIMER_ENABLE	1: timer enable 0: timer disable
PIC_ENABLE	1: pic enable 0: pic disable
PICTIMER_START_ADDR	Start address of PIC and Timer
IRQ_NUM	Number of Peripheral Interrupts
C_EXT	1: support for compressed instruction 0: no support for compressed instruction
M_EXT	1: support for M standard extension 0: no support for M standard extension
JTAG_CHANNEL	JTAG channel select

Notes:

- “ICACHE_ENABLE” and “DCACHE_ENABLE” should only be enabled when using CrossLink-NX Devices with sufficient resources. For MachXO2, MachXO3L, MachXO3LF and MachXO3D devices, cache features are not supported as their resources are limited.
- “ICACHE_RANGE_LOW” should not be larger than “ICACHE_RANGE_HIGH”, and address range between “ICACHE_RANGE_LOW” and “ICACHE_RANGE_HIGH” should not be overlapped with peripheral device address ranges. The memory which stores instructions should always be fixed in this range.
- Similarly, “DCACHE_RANGE_LOW” should not be larger than “DCACHE_RANGE_HIGH”, and address range between “DCACHE_RANGE_LOW” and “DCACHE_RANGE_HIGH” should not be overlapped with peripheral devices address ranges.
- “SIMULATION” and “DEBUG_ENABLE” cannot be enabled at the same time.

3. RISC-V MC CPU IP Generation

This section provides information on how to generate the CPU IP Core module using Propel Builder.

To generate the CPU IP Core module:

1. In Propel Builder, create a new design. Select the CPU package.
2. Enter the component name, as shown in [Figure 3.1](#). Click **Next**.

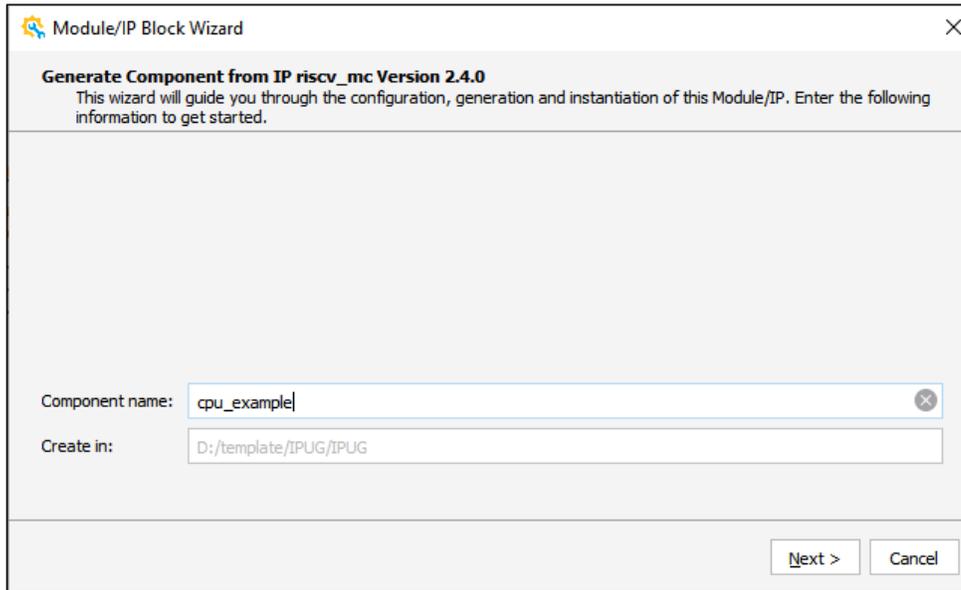


Figure 3.1. Entering Component Name

3. Configure the parameters, as shown in [Figure 3.2](#). Click **Generate**.

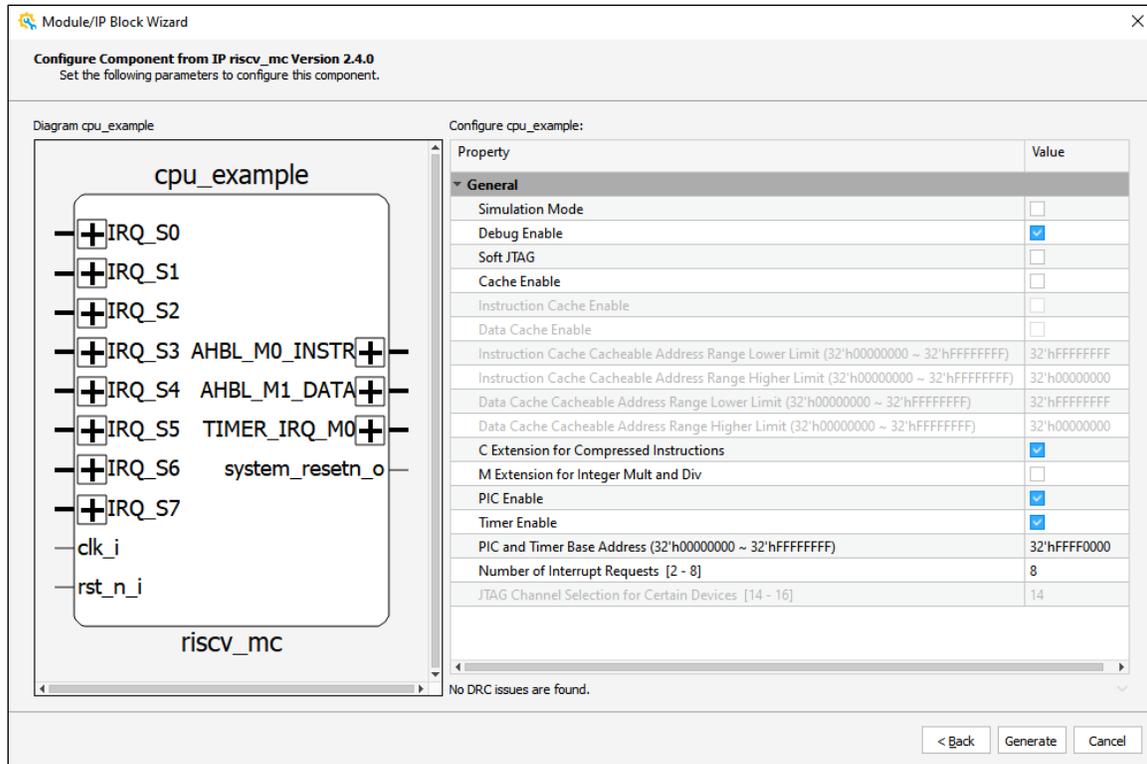


Figure 3.2. Configuring Parameters

- Verify the information. Click **Finish**.

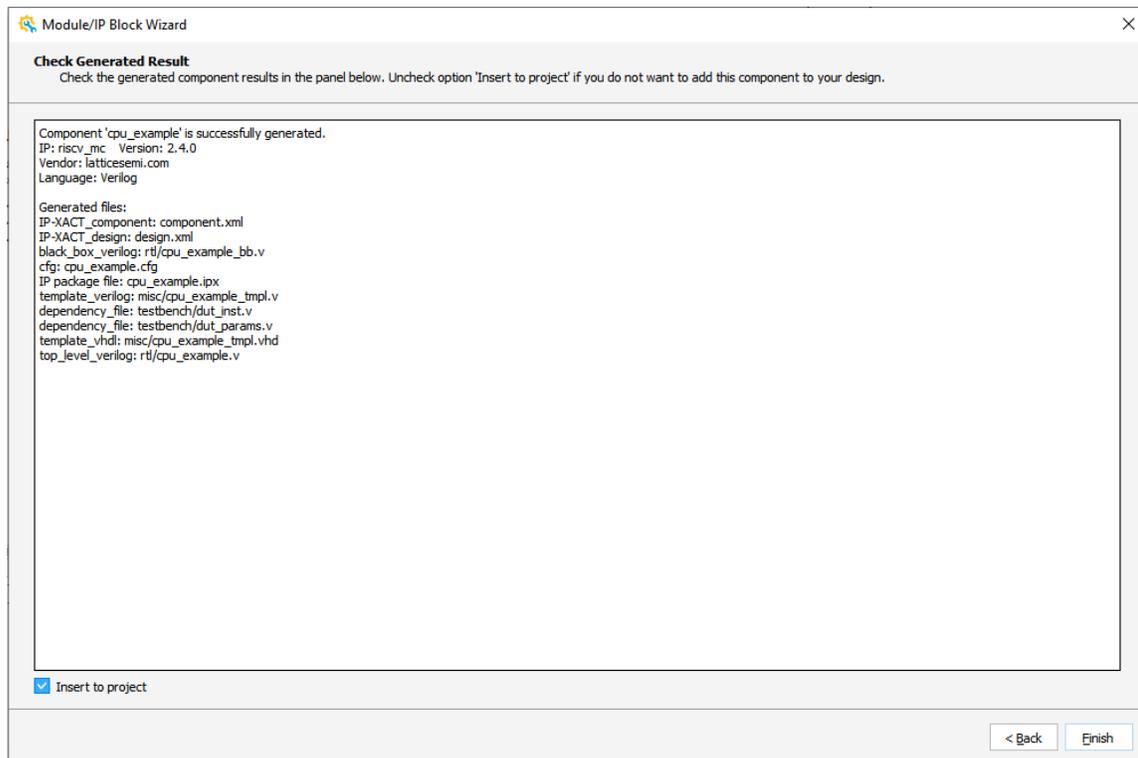


Figure 3.3. Verifying Results

5. Confirm or modify the module instance name. Click **OK**.

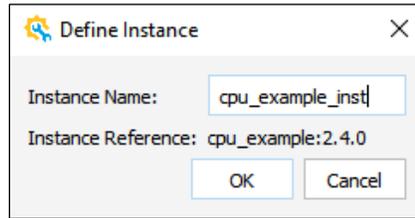


Figure 3.4. Specifying Instance Name

The CPU IP instance is successfully generated, as shown in [Figure 3.5](#).

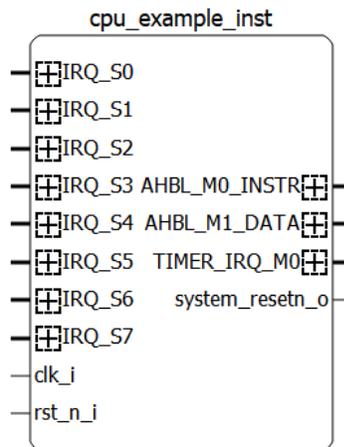


Figure 3.5. Generated Instance

Appendix A. Resource Utilization

Table A.1. Resource Utilization in MachXO3D Device (with Cache Disabled)

Configuration	LUTs	Registers	EBRs
Processor core only	1450	806	4
Processor core + PIC	1559	845	4
Processor core + Timer	1844	955	4
Processor core + Debug	1726	1108	4
Processor core + C_EXT	1738	860	4
Processor core + PIC + Timer	1927	989	4
Processor core + PIC + Timer + Debug	2162	1287	4
Processor core + PIC + Timer + Debug + C_EXT	2385	1345	4

Note: Resource utilization characteristics are generated using Lattice Diamond software.

Table A.2. Resource Utilization in CrossLink-NX Device (with Cache Disabled)

Configuration	LUTs	Registers	EBRs	DSP
Processor core only	1620	821	2	0
Processor core + PIC	1789	859	2	0
Processor core + Timer	2103	959	2	0
Processor core + Debug	1979	1194	2	0
Processor core + C_EXT	1911	830	2	0
Processor core + C_EXT + M_EXT	2417	1172	2	6
Processor core + PIC + Timer	2226	994	2	0
Processor core + PIC + Timer + Debug	2494	1375	2	0
Processor core + PIC + Timer + Debug + C_EXT	2790	1450	2	0

Note: Resource utilization characteristics are generated using Lattice Radiant software.

Table A.3. Resource Utilization in CrossLink-NX Device (with Cache Enabled)

Configuration	LUTs	Registers	EBRs	DSP
Processor core + only	3372	1423	16	0
Processor core + PIC	3568	1479	16	0
Processor core + Timer	3753	1574	16	0
Processor core + Debug	3687	1810	16	0
Processor core + C_EXT	3711	1551	16	0
Processor core + C_EXT + M_EXT	4133	1879	16	6
Processor core + PIC + Timer	3894	1606	16	0
Processor core + PIC + Timer + Debug	4309	1980	16	0
Processor core + PIC + Timer + Debug + C_EXT	4568	2032	16	0

Note: Resource utilization characteristics are generated using Lattice Radiant software.

Table A.4. Resource Utilization in Lattice Avant Device (with Cache Disabled)

Configuration	LUTs	Registers	EBRs	DSP
Processor core + only	2015	867	2	0
Processor core + PIC	2097	886	2	0
Processor core + Timer	2456	979	2	0
Processor core + Debug	2376	1268	2	0
Processor core + C_EXT	2202	860	2	0
Processor core + C_EXT + M_EXT	2731	1284	2	6
Processor core + PIC + Timer	2535	1017	2	0
Processor core + PIC + Timer + Debug	2869	1444	2	0
Processor core + PIC + Timer + Debug + C_EXT	3128	1528	2	0

Note: Resource utilization characteristics are generated using Lattice Radiant software.

Table A.5. Resource Utilization in Lattice Avant Device (with Cache Enabled)

Configuration	LUTs	Registers	EBRs	DSP
Processor core + only	3340	1364	18	0
Processor core + PIC	3437	1406	18	0
Processor core + Timer	3857	1548	18	0
Processor core + Debug	3708	1806	18	0
Processor core + C_EXT	3671	1546	18	0
Processor core + C_EXT + M_EXT	4431	1861	18	6
Processor core + PIC + Timer	3809	1655	18	0
Processor core + PIC + Timer + Debug	4381	1995	18	0
Processor core + PIC + Timer + Debug + C_EXT	4559	2168	18	0

Note: Resource utilization characteristics are generated using Lattice Radiant software.

Table A.6. Resource Utilization in CertusPro-NX Device (with Cache Disabled)

Configuration	LUTs	Registers	EBRs	DSP
Processor core + only	1978	834	2	0
Processor core + PIC	2105	886	2	0
Processor core + Timer	2446	990	2	0
Processor core + Debug	2304	1218	2	0
Processor core + C_EXT	2288	896	2	0
Processor core + C_EXT + M_EXT	2790	1185	2	6
Processor core + PIC + Timer	2578	1032	2	0
Processor core + PIC + Timer + Debug	2871	1390	2	0
Processor core + PIC + Timer + Debug + C_EXT	3220	1461	2	0

Note: Resource utilization characteristics are generated using Lattice Radiant software.

Table A.7. Resource Utilization in CertusPro-NX Device (with Cache Enabled)

Configuration	LUTs	Registers	EBRs	DSP
Processor core + only	3031	1461	20	0
Processor core + PIC	3391	1505	20	0
Processor core + Timer	3812	1607	20	0
Processor core + Debug	3667	1854	20	0
Processor core + C_EXT	3691	1613	19	0
Processor core + C_EXT + M_EXT	4334	2007	19	6
Processor core + PIC + Timer	3926	1671	20	0
Processor core + PIC + Timer + Debug	4139	2012	20	0
Processor core + PIC + Timer + Debug + C_EXT	4450	2169	19	0

Note: Resource utilization characteristics are generated using Lattice Radiant software.

References

- [Lattice Propel Builder 2023.1 User Guide \(FPGA-UG-02185\)](#)
- [AMBA 3 AHB-Lite Protocol V1.0](#)
- [RISC-V Privileged Specification \(20190608\)](#)
- [RISC-V Instruction Set Manual \(20190608\)](#)
- [Lattice Memory Mapped Interface \(LMMI\) and Lattice Interrupt Interface \(LINTR\) User Guide \(FPGA-UG-02039\)](#)

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 1.0, May 2023

Section	Change Summary
All	Production release.



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