

HB0801

MiV_RV32IMAF_L1_AHB V2.0

Handbook

11 2017





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Revision History

The revision history describes the changes that were implemented in the document. The changes are listed by revision, starting with the most current publication.

1.1 Release 1.0

Revision 1.0 is the first production-level publication of this document. Created for MiV_RV32IMAF_L1_AHB v2.0.

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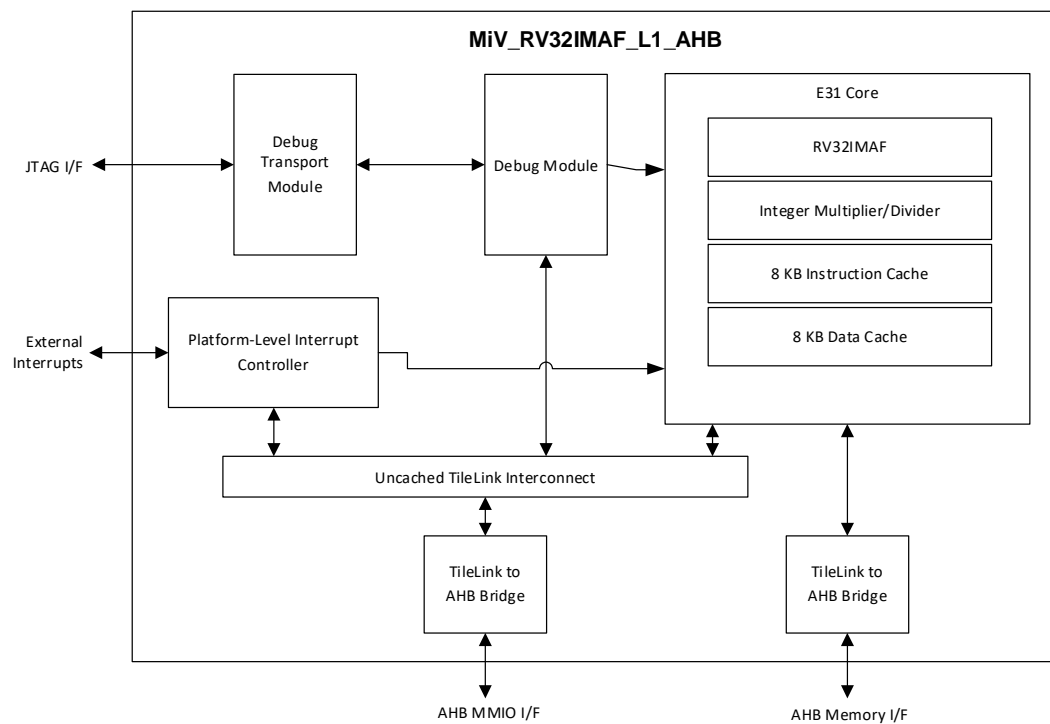
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2 Introduction

2.1 Overview

The MiV_RV32IMAF_L1_AHB is a softcore processor designed to implement the RISC-V instruction set for use in Microsemi FPGAs. The processor is based on the Coreplex E31 designed by SiFive, containing a high-performance single-issue, in-order execution pipeline E31 32-bit RISC-V core. The core includes an industry-standard JTAG interface to facilitate debug access, along with separate AHB bus interfaces for memory access and support for 31 dedicated interrupt ports.

Figure 1 MiV_RV32IMAF_L1_AHB Block Diagram



2.2 Features

- Designed for low power ASIC microcontroller and FPGA soft-core implementations.
- Integrated 8Kbytes instructions cache and 8Kbytes data cache.
- A Platform-Level Interrupt Controller (PLIC) can support up to 31 programmable interrupts with a single priority level.
- Supports the RISC-V standard RV32IMAF ISA.
- On-Chip debug unit with a JTAG interface.
- Two external AHB interfaces for IO and memory.

2.3 Core Version

This Handbook applies to MiV_RV32IMAF_L1_AHB version 2.0.

Note: There are two accompanying manuals for this core:

- The RISC-V Instruction Set Manual, Volume 1, User Level ISA, Version 2.1
- The RISC-V Instruction Set Manual, Volume 2, Privileged Architecture, Version 1.10

2.4 Supported Families

- PolarFire®
- RTG4™
- IGLOO®2
- SmartFusion®2

2.5 Device Utilization and Performance

Utilization and performance data is listed in [Table 1](#) for the supported device families. The data listed in this table is indicative only. The overall device utilization and performance of the core is system dependent.

Table 1 Device Utilization and Performance

Family	Sequential	Combinatorial	uSRAM	LSRAM	Math	Frequency (MHz)
SmartFusion2	6066	19073	34	8	2	58.38
IGLOO2	6626	18902	34	8	2	35.64
RTG4	6066	19076	46	8	2	44.27
PolarFire	6051	18973	67	10	2	91.46

Notes:

Performance numbers are for standard speed devices, except for PolarFire which uses the -1 speed.

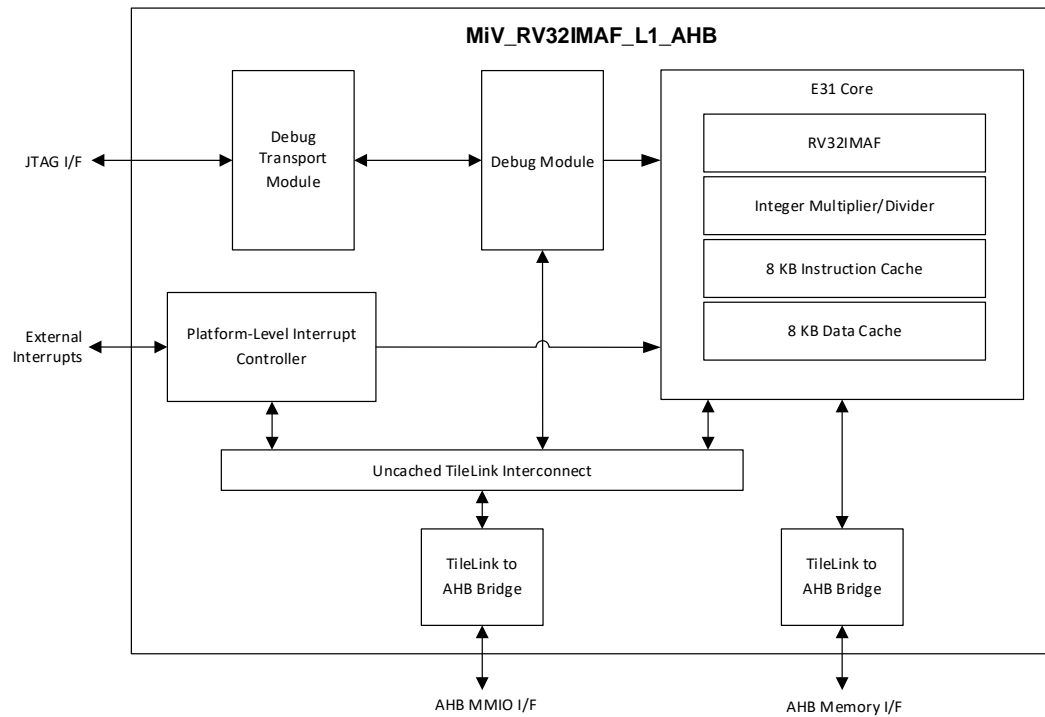
Multi-pass place-and-route setting used set to 5.

3 Functional Description

3.1 MiV_RV32IMAF_L1_AHB Architecture

Table 2 MiV_RV32IMAF_L1_AHB Architecture

Parameter	Value	Units	Notes
ISA Support	RV32IMAF		
Cores	1		
Harts/Cores	1		
Branch prediction	None		Static Not Taken
Multiplier occupancy	16	cycles	2-bit/cycles iterative multiply
I-cache size	8	KiB	direct-mapped
I-cache associativity	1	way	
I-cache line-size	64	bytes	
D-cache size	8	KiB	direct-mapped
D-cache associativity	1	way	
D-cache line-size	64	bytes	
Reset Vector	configurable		
External interrupts	31		Fixed priorities
PLIC Interrupt priorities	1		
External memory bus	AHB		
External I/O bus	AHB		
JTAG debug transport address width	5	bits	
Hardware breakpoints	2		

Figure 2 MiV_RV32IMAF_L1_AHB Block Diagram

3.2 MiV_RV32IMAF_L1_AHB Processor Core

MiV_RV32IMAF_L1_AHB is based on the E31 Coreplex Core by SiFive. The core provides a single hardware thread (or hart) supporting the RISC-V standard RV32IMAF ISA and machine-mode privileged architecture.

3.3 Pipelined Architecture

MiV_RV32IMAF_L1_AHB provides a high-performance single-issue in-order 32-bit execution pipeline, with a peak sustainable execution rate of one instruction per clock cycle. The RISC-V ISA standard M extensions add hardware multiply and divide instructions. MiV_RV32IMAF_L1_AHB has a range of performance options including a fully pipelined multiply unit. An example of the pipeline and its timing is as shown below.

Figure 3 Example Five Stage Pipelined Architecture

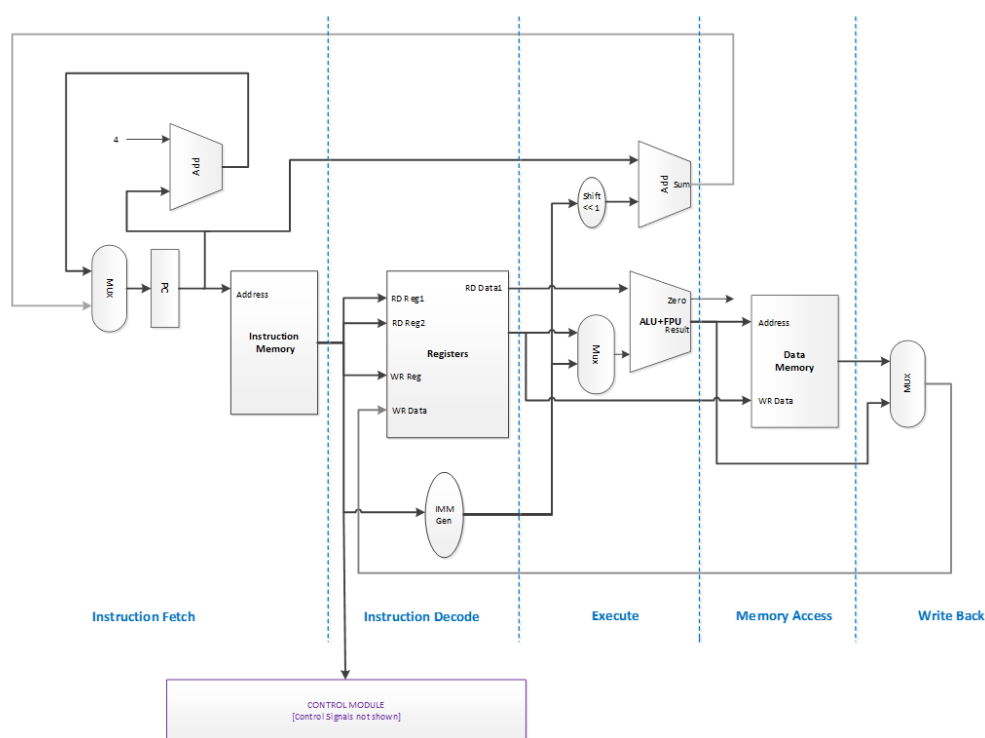


Table 3 Example Pipeline Timing

Clock Cycle	1	2	3	4	5	6	.....	n
Fetch	Instruction 1	Instruction 2	Instruction 3	Instruction 4	Instruction 5	Instruction 6	.....	Instruction n
Decode		Decode Instruction 1	Decode Instruction 2	Decode Instruction 3	Decode Instruction 4	Decode Instruction 5	.....	Decode Instruction n-1
Execute			Execute Instruction 1	Execute Instruction 2	Execute Instruction 3	Execute Instruction 4	.....	Execute Instruction n-2
Mem access				RD/WR Memory 1	Memory Access 2	Memory Access 3	.....	Memory Access n-3
Writeback					Write Back Result 1	Write Back 2	.....	Write Back n-4

3.4 Memory System

MiV_RV32IMAF_L1_AHB memory system supports configurable split first-level instruction and data caches with full support for hardware cache flushing, as well as uncached memory accesses. External connections are provided for both cached and uncached TileLink fabrics.

3.5 Platform-Level Interrupt Controller

MiV_RV32IMAF_L1_AHB includes a RISC-V standard platform-level interrupt controller (PLIC) configured to support up to 31 inputs with a single priority level.

3.6 Debug support through JTAG

MiV_RV32IMAF_L1_AHB includes full external debugger support over an industry-standard JTAG port, supporting two hardware breakpoints.

3.7 External AHB Interfaces

MiV_RV32IMAF_L1_AHB includes two external AHB interfaces, bridged from the internal TileLink interfaces. The AHB memory interface is used by the cache controller to refill the instruction and data caches. The AHB I/O interface is used for uncached accesses to I/O peripherals.

4 Interface

4.1 Configuration Parameters

4.1.1 MiV_RV32IMAF_L1_AHB Configurable Options

There are two configurable options that apply to MiV_RV32IMAF_L1_AHB as shown in [Table 4](#). If a configuration other than the default is required, use the configuration dialog box in SmartDesign to select appropriate values for the configurable options.

Table 4 MiV_RV32IMAF_L1_AHB Configuration Options

Parameter	Valid Range	Default	Description
RESET_VECTOR_ADDR (high halfword)	0x6000 - 0x8FFF	0x6000	This is the address the processor will start executing from after a reset. This address is byte aligned.
RESET_VECTOR_ADDR (low halfword)	0x0000 – 0xFFFC	0x0	

4.1.2 Signal Descriptions

Signal descriptions for MiV_RV32IMAF_L1_AHB are defined in [Table 5](#).

Table 5 MiV_RV32IMAF_L1_AHB I/O Signals

Port Name	Width	Direction	Description
Global Signals			
CLK	1	In	System clock. All other I/Os are synchronous to this clock.
RESETN	1	In	Synchronous reset signal. Active Low.
JTAG Interface Signals			
TDI	1	In	Test Data In (TDI). This signal is used by the JTAG device for downloading and debugging programs. Sampled on the rising edge of TCK.
TCK	1	In	Test Clock (TCK). This signal is used by the JTAG device for downloading and debugging programs.
TMS	1	In	Test Mode Select (TMS). This signal is used by the JTAG device when downloading and debugging programs. It is sampled on the rising edge of TCK to determine the next state.
TRST	1	In	Test Reset (TRST). This is an optional signal used to reset the TAP controllers state machine.
TDO	1	Out	Test Data Out (TDO). This signal is the data which is shifted out of the device during debugging. It is valid on FALLING/RISING edge of TCK.
DRV_TDO	1	Out	Drive Test Data Out (DRV_TDO). This signal is used to drive a tristate buffer.

Port Name	Width	Direction	Description
External Interrupts Signals			
IRQ	31	In	External interrupts from off-chip or peripheral sources. These are level-based interrupt signals.
AHB Cached Memory Bus Master Interface			
AHB_MST_MEM_HLOCK	1	Out	AHB Master interface for cached memory accesses.
AHB_MST_MEM_HTRANS	2	Out	
AHB_MST_MEM_HSEL	1	Out	
AHB_MST_MEM_HWRITE	1	Out	
AHB_MST_MEM_HADDR	32	Out	
AHB_MST_MEM_HSIZE	3	Out	
AHB_MST_MEM_HBURST	3	Out	
AHB_MST_MEM_HPROT	4	Out	
AHB_MST_MEM_HWDATA	32	Out	
AHB_MST_MEM_HREADY	1	In	
AHB_MST_MEM_HRESP	1	In	
AHB_MST_MEM_HRDATA	32	In	
AHB Non-cached Memory Bus Interface			
AHB_MST_MMIO_HLOCK	1	Out	AHB Master Interface for non-cached memory accesses.
AHB_MST_MMIO_HTRANS	2	Out	
AHB_MST_MMIO_HWRITE	1	Out	
AHB_MST_MMIO_HADDR	31	Out	
AHB_MST_MMIO_HSIZE	3	Out	
AHB_MST_MMIO_HBURST	3	Out	
AHB_MST_MMIO_HPROT	4	Out	
AHB_MST_MMIO_HWDATA	32	Out	
AHB_MST_MMIO_HREADY	1	In	
AHB_MST_MMIO_HRESP	1	In	
AHB_MST_MMIO_HRDATA	32	In	

5 Register Map and Descriptions

Table 6 Physical Memory Map (from E3 Coreplex Series)

Base	Top	Description	
0x0000_0000	0x0000_00FF	Reserved	Debug Area(4 KiB)
0x0000_0100		Clear debug interrupt to component	
0x0000_0104		Set debug interrupt to component	
0x0000_0108		Clear halt notification from component	
0x0000_010C		Set halt notification from component	
0x0000_0110	0x0000_03FF	Reserved	Debug Area(4 KiB)
0x0000_0400	0x0000_07FF	Debug RAM (≤1KiB)	
0x0000_0800	0x0000_0FFF	Debug ROM (≤1KiB)	
0x0000_1000	0x0000_XXXX	Reset	Small ROM Area (60 KiB)
0x0000_1004		NMI	
0x0000_1008		Reserved	
0x0000_100C		Configuration string address	
0x0000_1010		Trap vector table start	
0x0000_XXXX		Reset code	
		Interrupt handlers	
		Emulation routines	
		Register save/restore routines	
	0x0000_FFFF	User ROM	
0x0001_0000	0x3FFF_FFFF	Reserved	ROM/Misc./Reserved (≈1GiB)
0x4000_0000	0x43FF_FFFF	Platform-Level Interrupt Control (PLIC)	
0x4400_0000	0x47FF_FFFF	Power/Reset/Clock/Interrupt (PRCI)	
0x4800_0000	0x4800_0FFF	Device Bank 0:	On-Coreplex Devices (128 MiB)
...			
0x4800_F000	0x4800_FFFF	Device Bank 15:	
0x4801_0000	0x4FFF_FFFF	Reserved	
0x5000_0000	0x5FFF_FFFF	I/O	Off-Coreplex Devices (768 MiB)
0x6000_0000	0x7FFF_FFFF	AHB I/O Interface	
0x8000_0000	0x8FFF_FFFC	AHB Memory Interface	RAM Area (256 MiB)

6 Tool Flow

6.1 License

This core is being released under a modified Apache 2.0 license and is freely available through Libero. Technical support is only provided for Microsemi Products.

6.1.1 RTL

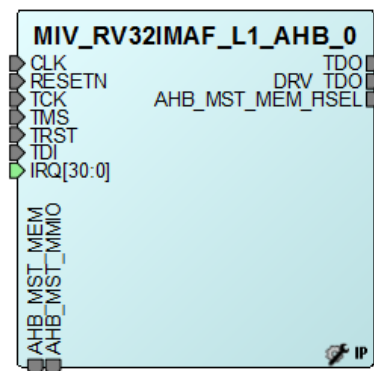
Complete Verilog source code is provided for the core. A VHDL wrapper is provided for use in VHDL projects. Allowing the core to be instantiated with SmartDesign. Simulation, Synthesis, and Layout can be performed within Libero SoC.

6.2 SmartDesign

MiV_RV32IMAF_L1_AHB is preinstalled in SmartDesign IP Deployment design environment.

For more information on using SmartDesign to instantiate and generate cores, refer to the [Using DirectCore in Libero® SoC User Guide](#).

Figure 4 SmartDesign MiV_RV32IMAF_L1_AHB Instance View

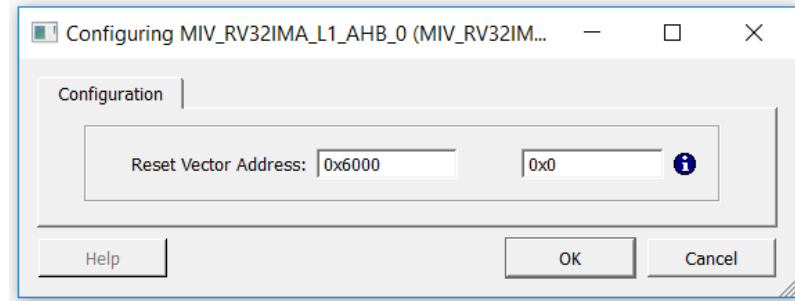


6.3 Configuring MiV_RV32IMAF_L1_AHB in SmartDesign

The core is configured using the configuration GUI within SmartDesign, as shown in [Figure 5](#).

Note: Leading zeros are suppressed, for example, 0x6000 0000 is displayed as 0x6000 0x0. The reset vector is byte aligned.

Figure 5 Configuring MiV_RV32IMAF_L1_AHB in SmartDesign



6.4 Debugging

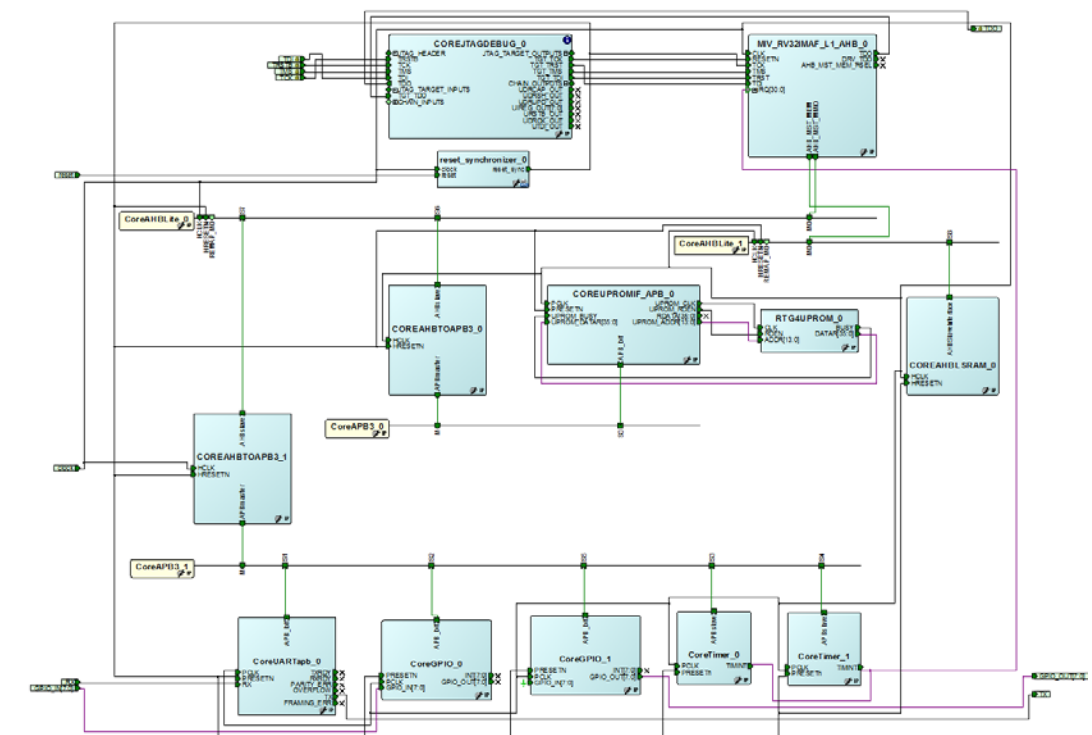
CoreJTAGDebug V2.0.100 or later, is used to enable debugging of MiV_RV32IMAF_L1_AHB. This is available in the Libero Catalog.

6.5 Simulation Flows

The user testbench for MiV_RV32IMAF_L1_AHB is not included in this release.

The MiV_RV32IMAF_L1_AHB RTL can be used to simulate the processor executing a program using a standard Libero generated HDL testbench. An example subsystem for RTG4 is as shown in Figure 6.

Figure 6 RTG4 Example Simulation Subsystem



6.6 Synthesis in Libero

To run synthesis on the core, set the SmartDesign sheet as the design root and click **Synthesis** in Libero SoC.

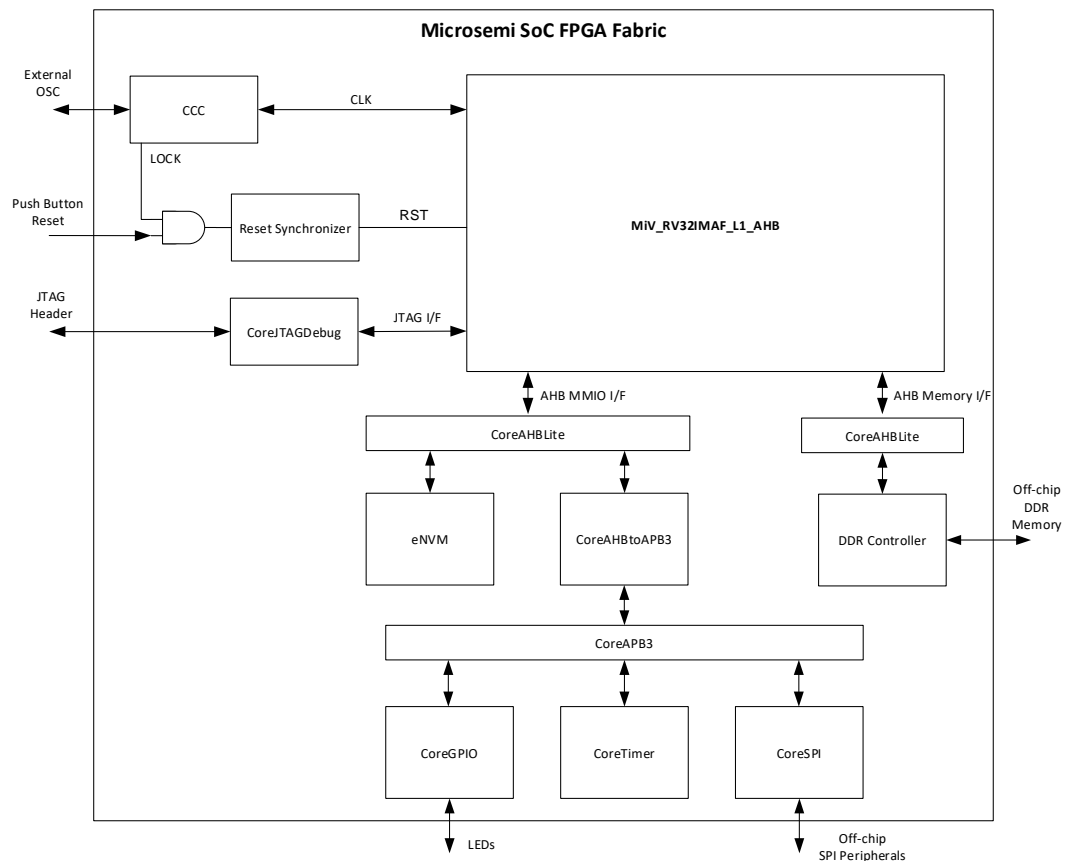
6.7 Place-and-Route in Libero

After the design is synthesized, run the compilation and the place and-route tools. Click **Layout** in the Libero SoC to invoke Designer. MiV_RV32IMAF_L1_AHB requires the place-and-route multi-seed settings set to 5.

7 System Integration

7.1 Example System

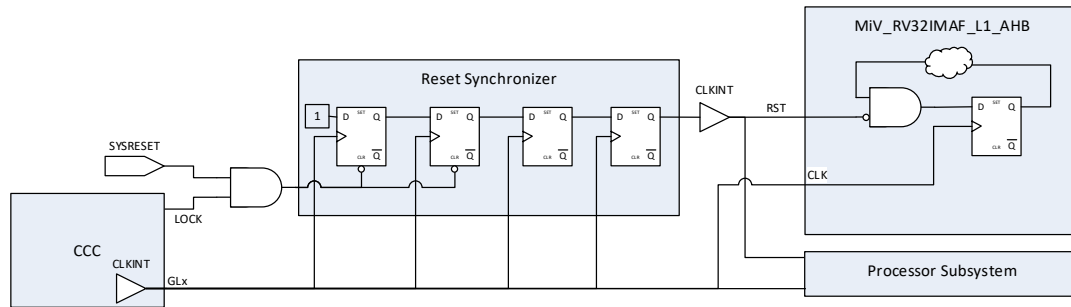
Figure 7 MiV_RV32IMAF_L1_AHB Example System



7.2 Reset Synchronization

7.2.1 RST

All sequential elements clocked by *CLK* within **MiV_RV32IMAF_L1_AHB**, which require a reset employ a synchronous reset topology. Since, most designs source *CLK* from a CCC/PLL, it is common practice to AND the *LOCK* output of the CCC with the push button reset to generate the *RST* input for **MiV_RV32IMAF_L1_AHB**. However, this results in the reset being deasserted when the *CLK* comes up, hence the reset assertion is not clocked through the sequential reset elements and goes unnoticed most commonly leading to the processor locking-up. To guarantee that the *RST* assertion is seen by all sequential elements, a reset synchronizer is required on the *RST* input, as shown in Figure 8.

Figure 8 RST Reset Synchronization

The Verilog code snippet below implements the reset synchronizer block as shown in [Figure 8](#). The function of this block is to make the reset assertion and deassertion synchronous to CLK whilst guaranteeing that the reset will be seen asserted for one or more CLK cycles within MiV_RV32IMAF_L1_AHB to ensure that it is registered by all sequential elements.

```
module reset_synchronizer (
    input  clock,
    input  reset,
    output reset_sync
);
    reg [1:0]  sync_deassert_reg;
    reg [1:0]  sync_asert_reg;

    always @ (posedge clock or negedge reset)
    begin
        if (!reset)
            begin
                sync_deassert_reg[1:0] <= 2'b00;
            end
        else
            begin
                sync_deassert_reg[1:0] <= {sync_deassert_reg[0], 1'b1};
            end
    end

    always @ (posedge clock)
    begin
        sync_asert_reg[1:0] <= {sync_asert_reg[0], sync_deassert_reg[1]};
    end
    assign reset_sync = sync_asert_reg[1];
endmodule
```

To include this synchronizer in your Libero design, select Create HDL from the Design Flow tab in your Libero project. In the popup window, name the HDL file accordingly and select Verilog as the HDL type whilst unchecking the option to Initialize file with standard template. Copy and paste the Verilog code snippet above into this file and save the changes. From the Design Hierarchy tab drag and drop the file into the SmartDesign sheet containing the MiV_RV32IMAF_L1_AHB instance and connect up the pins as shown above.

7.2.2 TRST

No reset synchronization is required on this reset input as all sequential elements in the debug logic within MiV_RV32IMAF_L1_AHB use an asynchronous reset topology.

8 Design Constraints

Designs containing MiV_RV32IMAF_L1_AHB require the application of the following constraints in the design flow to allow timing-driven placement and static timing analysis to be performed on MiV_RV32IMAF_L1_AHB. The procedure for adding the required constraints in the Enhanced Constraints flow in Libero v11.7 or later is as follows:

1. Double-click **Constraints > Manage Constraints** in the **Design Flow** window and click the **Timing** tab.

Assuming that the system clock used to clock MiV_RV32IMAF_L1_AHB is sourced from a PLL, select **Derive** to automatically create a constraints file containing the PLL constraints. Select **Yes** when prompted to allow the constraints to be automatically included for Synthesis, Place-and-Route, and Timing Verification stages.

If changes are made to the PLL configuration in the design, update the contents of this file by clicking **Derive**. Select **Yes** when prompted to allow the constraints to be overwritten.

2. In the **Timing** tab of the **Constraint Manager** window, select **New** to create a new SDC file, and name it. Design constraints other than the system clock source derived constraints can be entered in this blank SDC file. Keeping derived and manually added constraints in separate SDC files allows the **Derive** stage to be reperformed if changes are made to the PLL configuration, without deleting all manually added constraints in the process.
3. Calculate the TCK period and half period. TCK is typically 6 MHz when debugging with FlashPro, with a maximum frequency of 30 MHz supported by FlashPro5. After completion, enter the following constraints in the blank SDC file:

```
create_clock -name { TCK } \
  -period TCK_PERIOD \
  -waveform { 0 TCK_HALF_PERIOD } \
  [ get_ports { TCK } ]
```

For example, the following constraints need to be applied for a design that uses a TCK frequency of 6 MHz:

```
create_clock -name { TCK } \
  -period 166.67 \
  -waveform { 0 83.33 } \
  [ get_ports { TCK } ]
```

4. Next constraints must be applied to paths crossing the clock domain crossing between the TCK and system clock clock domains. MiV_RV32IMAF_L1_AHB implements two clock domain crossing FIFOs to handle the CDC and as such paths between the two clock domains may be declared as false paths to prevent min and max violations from being reported by SmartTime.

```
set_false_path -from [ get_clocks { TCK } ] \
  -to [ get_clocks { PLL_GEN_CLK } ]

set_false_path -from [ get_clocks { PLL_GEN_CLK } ] \
  -to [ get_clocks { TCK } ]
```

Where:

- PLL_GEN_CLK is the name applied to the create_generated_clock constraint derived in step 1 above.

5. Next constraints must be applied to the Floating Point Unit between the source clock and the following signals:

- i. MIV_RV32IMAF_L1_AHB_0/ChiselTop0/tile/rocket/fpuOpt/sfma/_T_28_data*
- ii. MIV_RV32IMAF_L1_AHB_0/ChiselTop0/tile/rocket/fpuOpt/sfma/_T_28_exc*

For example:

```
set_multicycle_path -setup_only 2 -through {
MIV_RV32IMAF_L1_AHB_0/ChiselTop0/tile/rocket/fpuOpt/sfma/_T_28_data* }

set_multicycle_path -setup_only 2 -through {
MIV_RV32IMAF_L1_AHB_0/ChiselTop0/tile/rocket/fpuOpt/sfma/_T_28_exc* }
```

6. Associate all constraints files with the Synthesis, Place-and-Route and Timing Verification stages in the **Constraint Manager > Timing** tab by selecting the related check boxes for the SDC files in which the constraints were entered in.

9 SoftConsole

SoftConsole Version 5.2 is required to use MiV_RV32IMAF_L1_AHB. Each SoftConsole project requires the Hardware Abstraction Layer (HAL) version 2.1 or greater. The SoftConsole Release Notes details how to set up a project for the MiV_RV32IMAF_L1_AHB core.

10 Known Issues

10.1 Reset/Power Cycle the Target Hardware before each Debug Session

At the moment, the debugger cannot effect a suitable Mi-V RISC-V CPU/SoC reset at the start of each debug session so one debug session may be impacted by what went before – for example, a previous debug session leaves the CPU in an ISR and a subsequent debug session does not behave as expected because of this. To mitigate this problem, it is recommended that the target hardware/board is power cycled or otherwise reset before each new debug session.