GYRO2 TESTER FPGA

Design Specification

Revision 3.0

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Prepared for



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# Description

The Gyro tester FPGA device is a validation platform specifically designed to test the features of the Gyro2 ASIC by CSS. The device should be able to source and capture data on the high speed serial interface of the Gyro2 ASIC. Both sourced and captured data should be kept in the on board DDR3 of the Gyro tester system. It should also interface the custom SPI like programming interface of the Gyro2 ASIC.

# Features

* Provides a 48K by 16bit word transmit buffer for sourcing data into the Gyro2 ASIC
* Provides a 48K by 16bit word capture buffer for receiving back data from the Gyro2 ASIC
* Provides a simple Register to SPI interface for both sourcing and capturing SPI communications to the Gyro2 ASIC.
* Uses the standard Xilinx AXI-DMA IP in direct memory access mode.
* Ability to turn off the outputs to avoid damaging the device under test during power up.
* Uses the Xilinx Zynq Processor for all communications and DMA access.
* All internal data interfaces are AXI-S (AMBA Streaming interface)
* All internal register access is controlled via the Zynq Processor over AXI4 interfaces
* Implements various loopbacks for testing
* Implements various internal test pattern for testing
* Sample C code for various types of tests is provided.

# Block Diagram

Figure 1 Gyro Tester Block Diagram



# Transmit Data Path

The Transmit data path is responsible for fetching data from the DDR to the TX fifo buffer. Once the buffer is filled with 48K 16bit words it is then sent to the serializer found within the Bidir block. Serial data is sent out on the divided down MCK output clock.

Serial TX data should look like the timing diagram below:

Figure 2 Serial TX data timing diagram



For the actual implementation internally, the data must go through a few transforms to work with the different IP and as a matter of convenience for loop back testing. The data is stored on the DDR as 16bit words, then the data is DMA packed at 32bit words. Also, the required output serial data is 48bit (3x16bit) words. For this reason, the TX fifo buffer will output 48bit words. The following diagram illustrates the required transforms on the data.

It should be noted that the memory requirement for the TX fifo buffer will be 2 instances of 24Kx16bit memories. The Xilinx compiler will most likely use its own block ram types to achieve this.

Figure 3 TX Data Transformations



# Receive Data Path

The receive data path is responsible for capturing the incoming high-speed serial data. Then storing it internally in the RX fifo buffer. Once the buffer indicated it is ready to the DMA, it will pack and transmit the data to the DDR in the form of 48K 16bit data. Serial data is captured out on the divided down MCK output clock.

Serial RX data should look like the timing diagram below

Figure 4 Serial RX data timing diagram



Much like the transmit side the receiver also must do a few transforms on the data to facilitate both the delivery across a packed 32bit DMA interface as well as implement testing loopbacks from the 48bit transmit path. The data flow will look like the following diagram:

Figure 5 RX Data Transformations



From this we can see that the actual memory requirements of the RX path are 8 instances of 8K x 16bit memories. It is assumed that Xilinx compiler will choose its own block memory devices for these elements. Although it would not matter if it decided to use a sea of flops either.

# SPI Register Interface

The SPI interface is a custom implementation of the SPI protocol. It should follow the below timing diagram:

Figure 6 SPI serial register interface



Data is directly written via the register interface from the Zynq processor over AXI Lite. See the register description later in this document for more info.

# Loopbacks

The Gyro Tester design has been equipped with 3 functional loopback modes for help in testing the FPGA and the board before the ASIC is delivered. These implemented via internal AXI Switches provided by Xilinx IP. They can be turned on and off with their register interfaces accessed by AXI Lite with the Zynq processor. See the register description and sample code for more information on how to turn on and off the loopbacks.

Figure 7 Loopbacks for testing



# Test Patterns

Test patterns are internally generated counting patterns to prefill the tx rx buffers or prefill the Shift Registers. This if for testing and debug. For the Transmit side if the test pattern is active the incoming tx data from the DMA in ignored and the tx buffer fifo is filled with a simple counting pattern. For the receive side the captured serial stream on the DRX is ignored and the rx buffer fifo is filled with a similar fixed counting pattern. Similarly, for the shift registers the rx serial stream is ignored and patterns are injected at either the rx or tx. For more information on how to turn these on see the register descriptions for the TX, RX buffers and Bidir shift register interface.

# Vivado Functional Testbench

The rtl was fully tested inside vivado using their generated functional models and system Verilog api function calls. These functions which interact with the Zynq processor BFM can be found in the document ds941-zynq-ultra-ps-e-vip.pdf found within the “docs” section of the project. The goal is too fully cover most of the features of the design with directed tests. Then each of these system Verilog directed tests should have a corresponding C-code directed test for validation on the actual zedboard unit. The provided xsim within the Vivado tool is free and works well enough to accomplish full functional testing without any extra licenses required.

Table 1 Functional Test Cases

|  |  |  |
| --- | --- | --- |
| System Verilog test | Corresponding C code test | Description |
| test\_case\_loop1.sv | test\_case\_loop1.c | Fills the DDR with a pattern uses DMA TX/RX to send it through Loop1 |
| test\_case\_loop2.sv | test\_case\_loop2.c | Uses both the TX ad RX Buffer memories to loop DMA data over the internal 48bit interface. |
| test\_case\_loop2\_txpattern.sv | test\_case\_loop2\_txpattern.c | Counting pattern is generated inside the TX Buffer and looped internally over the 48bit interface to RX buffer and then to the RX DMA path. |
| test\_case\_rx\_pattern.sv | test\_case\_rx\_pattern.c | A counting pattern is generated inside the RX Buffer and sent out the RX DMA path. |
| test\_case\_loop3\_txpattern.sv | test\_case\_loop3\_txpattern.c | A counting pattern is generated inside the TX Buffer and sent to the serial output, looped over to the Full RX path including the RX Buffer memory. |
| test\_case\_loop3\_srtx\_pattern.sv | test\_case\_loop3\_srtx\_pattern.c | A reverse counting pattern is generated inside the TX shift register and looped across the serial interface to the Full RX path including the RX Buffer memory. |
| test\_case\_srrx\_pattern.sv | test\_case\_srrx\_pattern.c | A counting pattern is generated inside the RX shift register and sent down the full RX path including the RX buffer memory. |
| test\_case\_loop3.sv | test\_case\_loop3.c | A full serial loop back of the entire system. Uses both Buffer memories. |
| test\_case\_spi.sv | test\_case\_spi.c | A simple test of write and reads of external SPI registers |
| test\_case\_loop2\_rxbyp.sv | test\_case\_loop2\_rxbyp.c | DMA data is again looped over across the 48bit internal interface; however, this time the RX buffer memory is bypassed. |
| test\_case\_loop3\_rxbyp.sv | test\_case\_loop3\_rxbyp.c | DMA data is sent through the full external serial loop of the system; however, this time the RX buffer memory is bypassed. |

# Standalone Functional Testbench

A full functional framework was created so that the main features of the gyro2 tester fpga could be simulated in standard Verilog. The testbench does not using any of the Xilinx IP so more flexibility, less complexity when developing new features or testing using different simulation tools. For this first revision NCSIM tools by cadence were used, although there is no reason it would not function well with either VCS or modelsim as well.

Figure 8 Standalone testbench block diagram



The main original rtl code to the gyro2 design is shown above in blue. This code needs to be fully covered in a functional testbench platform. Wrappers and stubs were written to ease integration using system Verilog standard interfaces. This will emulate how vivado visually hooks the blocks up in its tool.

For the DMA emulation a simple file reader and writer were written for streaming 32bit hex data from a file. The receiver is writing the data out to a file in the same format. This allows us to compare the files and ensure data continuity in all the loopback modes.

For the Zynq processor we only require a flexible AXI lite functional model. This will handle all the AXI write commands written into the registers. It will also be able to perform AXI lite reads to any of the internal registers.

An AXI demux block was required to communicate between the one master and multiple slaves. This is shown as the axi\_demux.

A simple 4 register external SPI block was written for emulating the SPI interface on the Gyro2 design and ensuring the design would both properly write and readback registers.

# Register Map

Table 2 Register Map

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Address | Name | Access Type | Default | Description |
| 0x43C0\_0000 | AXI SW0 Control | R/W | 0000\_0000 | General Control |
| 0x43C0\_0040 | AXI SW0 M0 Addr | R/W | 8000\_0000 | M1 Selector value |
|  |  |  |  |  |
| 0x43C1\_0000 | SPI Control 0 | R/W | 0000\_0000 |  |
| 0x43C1\_0004 | SPI Address | R/W | 0000\_0000 |  |
| 0x43C1\_0008 | SPI Data | R/W | 0000\_0000 |  |
| 0x43C1\_000C | SPI Read Data | R |  |  |
|  |  |  |  |  |
| 0x43C2\_0000 | BiDir Control 0 | R/W | 0000\_0000 |  |
| 0x43C2\_0004 | BiDir Control 1 | R/W | 0000\_0000 |  |
| 0x43C2\_0008 | BiDir Control 2 | R/W | 0000\_0000 |  |
| 0x43C2\_000C | BiDir Status | R |  |  |
|  |  |  |  |  |
| 0x43C3\_0000 | RX FIFO Control 0 | R/W | 0000\_0000 |  |
| 0x43C3\_0004 | RX FIFO Control 1 | R/W | 0000\_0000 |  |
| 0x43C3\_0008 | RX FIFO Control 2 | R/W | 0000\_0000 |  |
| 0x43C3\_000C | RX FIFO Status | R |  |  |
|  |  |  |  |  |
| 0x43C4\_0000 | TX FIFO Control 0 | R/W | 0000\_0000 |  |
| 0x43C4\_0004 | TX FIFO Control 1 | R/W | 0000\_0000 |  |
| 0x43C4\_0008 | TX FIFO Control 2 | R/W | 0000\_0000 |  |
| 0x43C4\_000C | TX FIFO Status | R |  |  |
|  |  |  |  |  |
| 0x43C5\_0000 | AXI SW1 Control | R/W | 0000\_0000 | General Control |
| 0x43C5\_0040 | AXI SW1 M0 Addr | R/W | 8000\_0000 | M0 Selector value |
| 0x43C5\_0044 | AXI SW1 M1 Addr | R/W | 8000\_0000 | M1 Selector value |
|  |  |  |  |  |
|  |  |  |  |  |
| 0x43C6\_0000 | AXI SW2 Control | R/W | 0000\_0000 | General Control |
| 0x43C6\_0040 | AXI SW2 M0 Addr | R/W | 8000\_0000 | M0 Selector value |
| 0x43C6\_0044 | AXI SW2 M1 Addr | R/W | 8000\_0000 | M1 Selector value |
|  |  |  |  |  |
| 0x43C7\_0000 | AXI SW3 Control | R/W | 0000\_0000 | General Control |
| 0x43C7\_0040 | AXI SW3 M0 Addr | R/W | 8000\_0000 | M0 Selector value |
| 0x43C7\_0044 | AXI SW3 M1 Addr | R/W | 8000\_0000 | M1 Selector value |
|  |  |  |  |  |
| 0x4040\_0000 | MM2S\_DMACR | R/W | 0000\_0000 | MM2S DMA Control |
| 0x4040\_0004 | MM2S\_DMASR | R | 0000\_0000 | MM2S DMA Status |
| 0x4040\_0018 | MM2S\_SA | R/W | 0000\_0000 | MM2S Source Address. Lower 32 bits of  address. |
| 0x4040\_001C | MM2S\_SA\_MSB | R/W | 0000\_0000 | MM2S Source Address. Upper 32 bits of  address. |
| 0x4040\_0028 | MM2S\_LENGTH | R/W | 0000\_0000 | MM2S Transfer Length (Bytes) |
| 0x4040\_0030 | S2MM\_DMACR | R/W | 0000\_0000 | S2MM DMA Control |
| 0x4040\_0034 | S2MM\_DMASR | R | 0000\_0000 | S2MM DMA Status |
| 0x4040\_0048 | S2MM\_DA | R/W | 0000\_0000 | S2MM Destination Address. Lower 32 bit  address. |
| 0x4040\_004C | S2MM\_DA\_MSB | R/W | 0000\_0000 | S2MM Destination Address. Upper 32 bit  address. |
| 0x4040\_0058 | S2MM\_LENGTH | R/W | 0000\_0000 | S2MM Buffer Length Bytes |

Table 3 AXI SW0 Control Register (0x43C0\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Reserved | 0 | Reserved |
| REG\_UPDATE | 1 | Register Update. MUX registers are double buffered. Writing '1' updates the registers and issues a soft reset to the core (for approximately 16 cycles.) |
| Reserved | 31:2 | Reserved |

Table 4 AXI SW0 M0 Addr (0x43C0\_0040)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Mix\_MUX | 3:0 | Mux Value |
| MIx\_DISABLE | 31 | Set to 1 to explicitly disable |

Table 5 SPI Control 0 (0x43C1\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| SPI Update | 0 | SPI update. auto clearing pulse starts transaction. |
| SPI Direction | 1 | SPI direction 0=write ; 1=read |
| SPI clock Div | 3:2 | Div16,Div8,Div,4,Div2 |
| SPI Output en | 4 | 1 = enable the spi outputs 0 = disable all spi outputs |
| Reserved | 30:5 | Reserved |
| SPI Busy | 31 | SPI is currently shifting data. Should be polled for new transactions |

Table 6 SPI Address (0x43C1\_0004)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| SPI Address | 6:0 | SPI supports a 7 bit address field |
| Reserved | 31:7 | Reserved |

Table 7 SPI Data (0x43C1\_0008)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| SPI Data | 15:0 | SPI supports a 16 bit write data |
| Reserved | 31:16 | Reserved |

Table 8 SPI Read Data (0x43C1\_000C)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| SPI Read Data | 15:0 | SPI read back data |
| Reserved | 31:16 | Reserved |

Table 9 BiDir Control 0 (0x43C2\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Reserved | 15:0 | Reserved |
| Clock Div | 19:16 | values 0-7 change the output and txclk frequency 50Mhz – 12.5Mhz |
| Reserved | 23:20 | Reserved |
| Mode | 25:24 | 00 Normal; 01 Loopback DRX=DTX |
| Reserved | 28:26 | Reserved |
| RX\_testpattern | 29 | setting to 1 will inject test pattern at the input shift register |
| TX\_testpattern | 30 | setting to 1 will inject test pattern at the output shift register |
| Soft Reset | 31 | 1 will hold outputs into reset mode. |

Table 10 BiDir Control 1 (0x43C2\_0004)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Start Output | 0 | Enables the output serial stream |
| Start Input | 4 | Enables the input serial stream |

Table 11 BiDir Control 2 (0x43C2\_0008)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Enable | 0 | General purpose enable turns entire block on/off |
| Reserved | 31:1 | Reserved |

Table 12 BiDir Control 3 (0x43C2\_000C)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Reserved | 31:0 | Reserved |

Table 13 RX FIFO Control 0 (0x43C3\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Fifo Push En | 0 | Enables the Rx Fifo Push (filling of fifo). |
| Fifo Pop En | 1 | Enables the Draining of the RX fifo |
| Reserved | 3:2 | Reserved |
| rx\_byp\_en | 4 | Bypasses the Memory of the RX Buffer direct reading to DMA |
| Reserved | 11:5 | Reserved |
| rxfull\_irq\_en | 12 | Interrupt enable for the RX full |
| Reserved | 15:13 | Reserved |
| Test Pattern | 16 | Test fill pattern into the RX Buffer. Disables incoming data |
| Reserved | 31:17 | Reserved |

Table 14 RX FIFO Control 1 (0x43C3\_0004)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| clear | 0 | Write 1 to clear bit. Soft reset for the RXFIFO pointers. |
| Reserved | 31:1 | Reserved |

Table 15 RX FIFO Control 2 (0x43C3\_0008)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| rx\_max\_len | 31:0 | For use with the RX Buffer Bypass option. Need to know the transfer length in bytes for the DMA last flag. |

Table 16 RX FIFO Status (0x43C3\_000C)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| write pointer | 15:0 | value of the current fifo write pointer |
| Reserved | 29:16 | Reserved |
| RX Fifo Empty | 30 | The fifo is empty |
| RX Fifo Full | 31 | The fifo is full condition. |

Table 17 TX FIFO Control 0 (0x43C4\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Tx Fifo Enable | 0 | Tx Enable |
| Reserved | 15:1 | Reserved |
| Test Pattern | 16 | Test fill pattern into the TX Buffer. Disables incoming data |
| Reserved | 31:1 | Reserved |

Table 18 TX FIFO Control 1 (0x43C4\_0004)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| clear | 0 | Write 1 to clear bit. Soft reset for the TXFIFO pointers. |
| Reserved | 31:0 | Reserved |

Table 19 TX FIFO Status RevID (0x43C4\_0008)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Chip Rev | 31:0 | Revision ID of the FPGA RTL code |

Table 20 TX FIFO Status (0x43C4\_000C)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| write pointer | 15:0 | value of the current fifo write pointer |
| Reserved | 29:16 | Reserved |
| TX Fifo Empty | 30 | The fifo is empty |
| TX Fifo Full | 31 | The fifo is full condition. |

Table 21 AXI SW1 Control Register (0x43C5\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Reserved | 0 | Reserved |
| REG\_UPDATE | 1 | Register Update. MUX registers are double buffered. Writing '1' updates the registers and issues a soft reset to the core (for approximately 16 cycles.) |
| Reserved | 31:2 | Reserved |

Table 22 AXI SW1 M0 Addr (0x43C5\_0040)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Mix\_MUX | 3:0 | Mux Value |
| MIx\_DISABLE | 31 | Set to 1 to explicitly disable |

Table 23 AXI SW1 M1 Addr (0x43C5\_0044)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Mix\_MUX | 3:0 | Mux Value |
| MIx\_DISABLE | 31 | Set to 1 to explicitly disable |

Table 24 AXI SW2 Control Register (0x43C6\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Reserved | 0 | Reserved |
| REG\_UPDATE | 1 | Register Update. MUX registers are double buffered. Writing '1' updates the registers and issues a soft reset to the core (for approximately 16 cycles.) |
| Reserved | 31:2 | Reserved |

Table 25 AXI SW2 M0 Addr (0x43C6\_0040)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Mix\_MUX | 3:0 | Mux Value |
| MIx\_DISABLE | 31 | Set to 1 to explicitly disable |

Table 26 AXI SW2 M1 Addr (0x43C6\_0044)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Mix\_MUX | 3:0 | Mux Value |
| MIx\_DISABLE | 31 | Set to 1 to explicitly disable |

Table 27 AXI SW3 Control Register (0x43C7\_0000)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Reserved | 0 | Reserved |
| REG\_UPDATE | 1 | Register Update. MUX registers are double buffered. Writing '1' updates the registers and issues a soft reset to the core (for approximately 16 cycles.) |
| Reserved | 31:2 | Reserved |

Table 28 AXI SW3 M0 Addr (0x43C7\_0040)

|  |  |  |
| --- | --- | --- |
| Name | Bits | Description |
| Mix\_MUX | 3:0 | Mux Value |
| MIx\_DISABLE | 31 | Set to 1 to explicitly disable |

Table 29 DMA Registers (0x4040\_0000) - (0x4040\_0058)

\*\*See the DMA 7.1 specification page 13-37 for the register descriptions. Included In the documents folder as Xilinx\_axi\_dma\_rev71.pdf

# APPENDIX A - Direct Register Mode (Simple DMA)

Direct Register Mode (Scatter Gather Engine is disabled) provides a configuration for doing

simple 0, a DMASR.IOC\_Irq asserts

for the associated channel and if enabled generates an interrupt out.

A DMA operation for the MM2S channel is set up and started by the following sequence:

1. Start the MM2S channel running by setting the run/stop bit to 1 (MM2S\_DMACR.RS =1). The halted bit (DMASR.Halted) should deassert indicating the MM2S channel is

running.

2. If desired, enable interrupts by writing a 1 to MM2S\_DMACR.IOC\_IrqEn and

MM2S\_DMACR.Err\_IrqEn. The delay interrupt, delay count, and threshold count are not

used when the AXI DMA is configured for Direct Register Mode.

3. Write a valid source address to the MM2S\_SA register. If AXI DMA is configured for an

address space greater than 32, then program the MM2S\_SA MSB register. If the AXI DMA

is not configured for Data Re-Alignment, then a valid address must be aligned or

undefined results occur. What is considered aligned or unaligned is based on the stream

data width. When AXI\_DMA is configured in Micro Mode, it is your responsibility to

specify the correct address. Micro DMA does not take care of the 4K boundary.

For example, if Memory Map Data Width = 32, data is aligned if it is located at word

offsets (32-bit offset), that is 0x0, 0x4, 0x8, 0xC, and so forth. If DRE is enabled and

Streaming Data Width < 128, then the Source Addresses can be of any byte offset.

4. Write the number of bytes to transfer in the MM2S\_LENGTH register. A value of zero

written has no effect. A non-zero value causes the MM2S\_LENGTH number of bytes to

be read on the MM2S AXI4 interface and transmitted out of the MM2S AXI4-Stream

interface. The MM2S\_LENGTH register must be written last. All other MM2S registers

can be written in any order. In the case of Micro DMA, this value cannot exceed

[Burst\_length \* (Memory Mapped Data Width)/8].

A DMA operation for the S2MM channel is set up and started by the following sequence:

1. Start the S2MM channel running by setting the run/stop bit to 1 (S2MM\_DMACR.RS =

1). The halted bit (DMASR.Halted) should deassert indicating the S2MM channel is

running.

2. If desired, enable interrupts by writing a 1 to S2MM\_DMACR.IOC\_IrqEn and S2MM\_DMACR.Err\_IrqEn. The delay interrupt, delay count, and threshold count are not used when the AXI DMA is configured for Direct Register Mode.

3. Write a valid destination address to the S2MM\_DA register. If AXI DMA is configured for an address space greater than 32, program the S2MM\_DA MSB register.

4. If the AXI DMA is not configured for Data Re-Alignment then a valid address must be

aligned or undefined results occur. What is considered aligned or unaligned is based on

the stream data width. For example, if Memory Map Data Width= 32, data is aligned if it is located at word offsets (32-bit offset), that is, 0x0, 0x4, 0x8, 0xC, and so forth. If DRE is enabled and Streaming Data Width < 128 then the Destination Addresses can be of any byte offset.

# APPENDIX B - LOOPBACK C code Settings

1. Normal Mode

XAxi\_WriteReg(SW0\_REG1, 0x00000001);

XAxi\_WriteReg(SW0\_REG0, 0x00000002);

XAxi\_WriteReg(SW1\_REG1, 0x80000000);

XAxi\_WriteReg(SW1\_REG2, 0x00000000);

XAxi\_WriteReg(SW1\_REG0, 0x00000002);

XAxi\_WriteReg(SW2\_REG1, 0x00000000);

XAxi\_WriteReg(SW2\_REG2, 0x80000000);

XAxi\_WriteReg(SW2\_REG0, 0x00000002);

XAxi\_WriteReg(SW3\_REG1, 0x00000000);

XAxi\_WriteReg(SW3\_REG0, 0x00000002);

1. Loop 1 Active

XAxi\_WriteReg(SW0\_REG1, 0x00000000);

XAxi\_WriteReg(SW0\_REG0, 0x00000002);

XAxi\_WriteReg(SW1\_REG1, 0x00000000);

XAxi\_WriteReg(SW1\_REG2, 0x80000000);

XAxi\_WriteReg(SW1\_REG0, 0x00000002);

1. Loop 2 Active

XAxi\_WriteReg(SW0\_REG1, 0x00000001);

XAxi\_WriteReg(SW0\_REG0, 0x00000002);

XAxi\_WriteReg(SW1\_REG1, 0x80000000);

XAxi\_WriteReg(SW1\_REG2, 0x00000000);

XAxi\_WriteReg(SW1\_REG0, 0x00000002);

XAxi\_WriteReg(SW2\_REG1, 0x80000000);

XAxi\_WriteReg(SW2\_REG2, 0x00000000);

XAxi\_WriteReg(SW2\_REG0, 0x00000002);

XAxi\_WriteReg(SW3\_REG1, 0x00000001);

XAxi\_WriteReg(SW3\_REG0, 0x00000002);

1. Loop 3 Active

XAxi\_WriteReg(BIDIR\_REG0, 0x01000000);

# APPENDIX C – Operation flow diagram



# APPENDIX D – Implementation results

Figure 9 Layout

# 

Table 30 Utilization

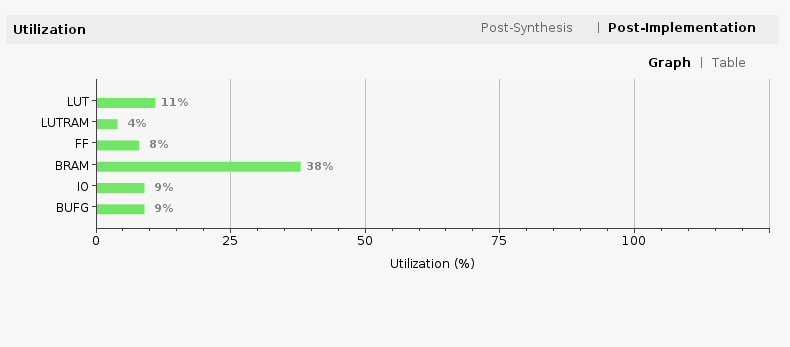
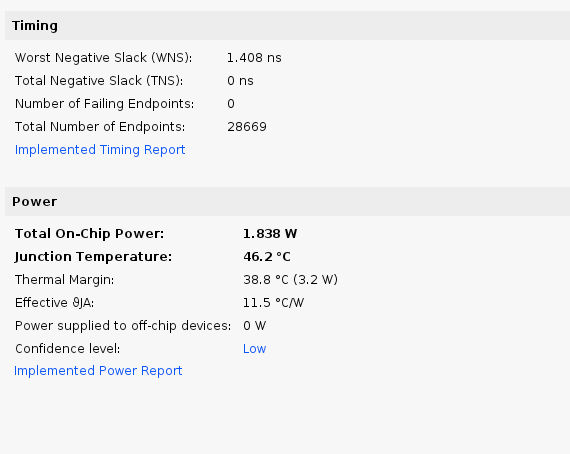


Table 31 Timing and Power



# APPENDIX E – code directory tree

All the C testcase sample code can be found here:

\*/gyro2tester/vitis/testcases\_src/

All the System Verilog testcase code can be found here:

\*/gyro2tester/vivado/ip\_repo/testbench

System Verilog design source are all under:

\*/gyro2tester/vivado/ip\_repo

Standalone Testbench can be found:

\*/ gyro2tester/funcsim

Additional Documentation can be found:

\*/ gyro2tester/docs

Vivado Project file:

\*/gyro2tester/vivado/project/gyro2\_tester.xpr

Vivado synthesis timing constraints:

\*/gyro2tester/vivado/project/gyro2\_tester.srcs/constrs\_1/imports/new/gyro\_constraints.vdc