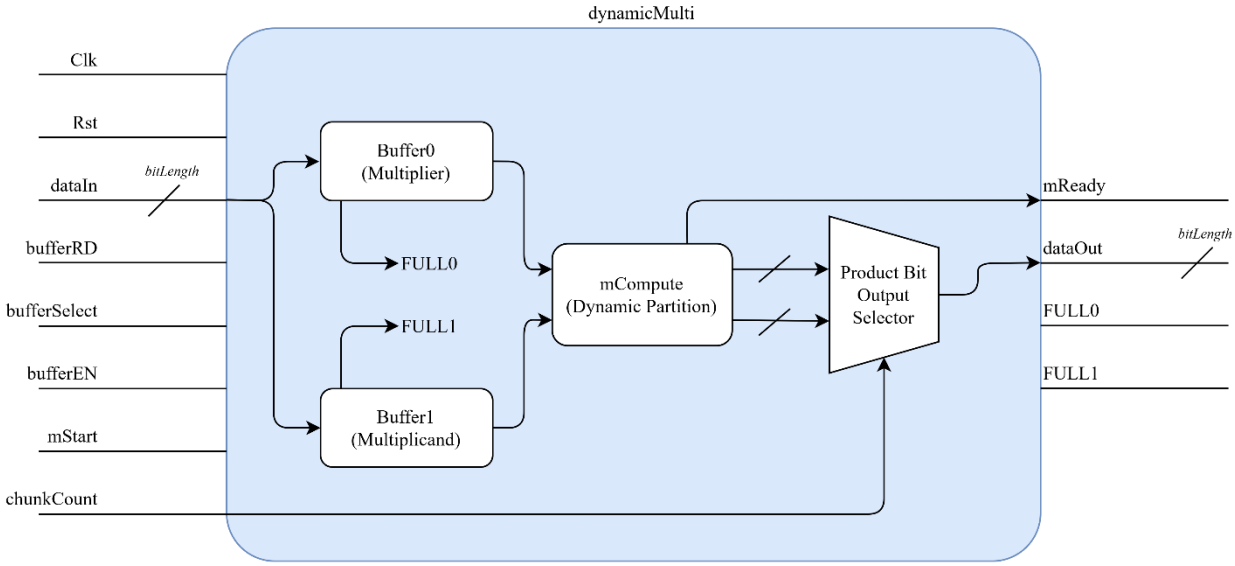
Multiplier Benchmark

Overview

Internal Block Diagram:



- The only portion of the multiplier that changes between data type is the “Multiply Compute” block.
- The block can be adjusted to n-bit data input. This benchmark will demonstrate n-bit inputs of n = 8-16-32.
- To ensure all signals are zeroed and set properly, there will be a 1 clock period reset delay at the beginning of each simulation. The period after this delay is when cycles to complete will begin to be counted, up until the last period necessary for all needed values to be extracted.
- Input vectors used will be the same bit patterns, except for fixed point to accommodate overflow. Due to notation structure difference, they will represent different numbers.
- Error is not a focus of the simulation but is monitored. Calculated with the following formula. Error is not a focus of the simulation but is monitored. Calculated with the following formula.
    - $Percent\ Error = \left|\frac{Calculated - Expected}{Expected}\right| * 100\%$

Data Structure and Example Data

Integer Representation

Data Structure

Simple base conversion from decimal to binary.

Example Data

$22 = (1*16) + (0*8) + (1*4) + (1*2) + (0*1) = (1*2^4) + (0*2^3) + (1*2^2) + (1*2^1) + (1*2^0) = 10110_{BINARY}$

Floating Point Representation

Data Structure:

N-Bit Count	*Sign Bits*	*Bias Bits (Bias Value)*	*Mantissa Bits*
8	1	4 (-7)	3
16	1	5 (-15)	10
32	1	8 (-127)	23

Example Data:

N-Bit Count	*Decimal Value*	*Bit Representation*			*Expanded Form*
		Sign	*Bias*	*Mantissa*	
8-bit	+48.0	0	1100	100	$+2^{12-7} * (1 + \frac{1}{2})$
16-bit	-48.0	1	10100	10000000000	$-2^{20-15} * (1 + \frac{1}{2})$
32-bit	+48.0	0	10000100	10000000000000000000000	$+2^{132-127} * (1 + \frac{1}{2})$

Fixed Point Representation

Data Structure:

N-Bit Count	*Integer Bits*	*Fractional Bits*
8	4	4
16	8	8
32	16	16

Example Data:

N-Bit Count	*Decimal Value*	*Bit Representation*		*Expanded Form*
		Integer	*Fractional*	
8-bit	12.875	1100	1110	$2^3 + 2^2 + 2^{-1} + 2^{-2} + 2^{-3}$
16-bit	100.00390625	1100100	00000001	$2^6 + 2^5 + 2^2 + 2^{-8}$
32-bit	4100.250244	1000000000100	0010000000001	$2^{12} + 2^2 + ^{-2} + 2^{-12}$

Benchmark Simulation Generation and Analysis Steps

The exact same code structure is used for all three simulation objects. These are the steps to setup, generate, and demonstrate the analysis of the data for the following tables.

Step 1. Set input parameters by adjusting the values in “definitions.h”. This is a breakdown of input parameters with corresponding purpose.

a. **inputWidth:** Defines the width of the input vector. i.e. N-Bit Count.
b. **myTimeScale:** Defines the unit time and precision for simulation.
c. **clkPerid:** Defines the period of clock used for simulation
d. **dataIn1:** Defines the input multiplier value. Note that this is dependent on the width of the input vector.
e. **dataIn2:** Defines the input multiplicand value. Note that this is dependent on the width of the input vector.
f. **multiplyIndex:** Defines the width of the product for integer multiplication.
g. **mantissaIndex:** Defines the highest index of the mantissa for floating point multiplication. Simply, this should be (Mantissa Bits – 1).
h. **expBias:** Defines the bias to remove from added exponents for floating point multiplication.
i. **expWide:** Define the width of the exponent bias.
j. **fracBitCount:** Defines the number of bits counted as fractional for fixed point multiplication.

Step 2. Click the “Run Implementation” option. The pop-up will ask to complete synthesis first, click OK. Once this completes, press OK to open the implemented design.

Step 3. Click “Run Simulation, then select “Run Post-Implementation Timing Simulation”

Step 4. As stated before, the first clock period will not be counted when analyzing simulation. This is an example screenshot counting 3 cycles to complete.

Integer Multiplier, Custom Multiply Operator

- Design Source File Name: “integercomputeBlock.v”
- Test Bench File Name: “integercomputeBlock_tb.v”

Simulation Data:

(Input)

N-Bit Count	*Multiplier Hex Representation*	*Multiplier Decimal Notation*	*Multiplicand Hex Representation*	*Multiplicand Decimal Representation*
8	0xfa	250	0x25	37
16	0xfafa	64250	0x25ff	9727
32	0xfafafafa	4210752250	0xa925ff	11085311

(Output)

N-Bit Count	*Calculated Output Hex Representation*	*Calculated Output Decimal Representation*	*Cycles to Complete*	*Expected Output Decimal Representation*	*Error (%)*
8	0x2422	9250	4	9250	0.00
16	0x25402106	624959750	4	624959750	0.00
32	0x00a5d4eff5502106	4.66774e16	4	4.66774e16	0.00

Integer Multiplier, Built-In Multiply Operator

- Design Source File Name: “integercomputeBlockPynq.v”
- Test Bench File Name: “integercomputeBlockPynq_tb.v”

Simulation Data:

(Input)

N-Bit Count	*Multiplier Hex Representation*	*Multiplier Decimal Notation*	*Multiplicand Hex Representation*	*Multiplicand Decimal Representation*
8	0xfa	250	0x25	37
16	0xfafa	64250	0x25ff	9727
32	0xfafafafa	4210752250	0xa925ff	11085311

(Output)

N-Bit Count	*Calculated Output Hex Representation*	*Calculated Output Decimal Representation*	*Cycles to Complete*	*Expected Output Decimal Representation*	*Error (%)*
8	0x2422	9250	4	9250	0.00
16	0x25402106	624959750	4	624959750	0.00
32	0x00a5d4eff5502106	4.66774e16	4	4.66774e16	0.00

Floating Point Multiplier, Custom Multiply Operator

- Design Source File Name: “floatcomputeBlock.v”
- Test Bench File Name: “floatcomputeBlock_tb.v”

Simulation Data:

(Input)

N-Bit Count	*Multiplier Hex Representation*	*Multiplier Decimal Notation*	*Multiplicand Hex Representation*	*Multiplicand Decimal Representation*
8	0xfa	-320	0x25	+0.203125
16	0xfafa	-5.715e+4	0x25ff	2.342e-2
32	0xfafafafa	-6.51582312038e+35	0x00a925ff	+1.55338292809e-38

(Output)

N-Bit Count	*Calculated Output Hex Representation*	*Calculated Output Decimal Representation*	*Cycles to Complete*	*Expected Output Decimal Representation*	*Error (%)*
8	0xe8	-64	3	-65	1.54
16	0xe66f	-1647	3	-1339	18.70
32	0xbc4ba9d4	-1.2430627e-2	3	-1.012156839e-2	22.81

Floating Point Multiplier, Built-In Multiply Operator

- Design Source File Name: “floatcomputeBlockPynq.v”
- Test Bench File Name: “floatComputeBlockPynq_tb.v”

Simulation Data:

(Input)

N-Bit Count	*Multiplier Hex Representation*	*Multiplier Decimal Notation*	*Multiplicand Hex Representation*	*Multiplicand Decimal Representation*
8	0xfa	-320	0x25	+0.203125
16	0xfafa	-5.715e+4	0x25ff	2.342e-2
32	0xfafafafa	-6.51582312038e+35	0x00a925ff	+1.55338292809e-38

(Output)

N-Bit Count	*Calculated Output Hex Representation*	*Calculated Output Decimal Representation*	*Cycles to Complete*	*Expected Output Decimal Representation*	*Error (%)*
8	0xe8	-64	3	-65	1.54
16	0xe53a	-1338	3	-1339	0.00
32	0xbc25d4ef	-1.01215681061e-2	3	-1.012156839e-2	0.00

Fixed Point Multiplier

- Design Source File Name: “fixedcomputeBlock.v”
- Test Bench File Name: “fixedcomputeBlock_tb.v”

Simulation Data:

(Overflow occurred with the previous bit values, so they were substituted.)

(Input)

N-Bit Count	*Multiplier Hex Representation*	*Multiplier Decimal Notation*	*Multiplicand Hex Representation*	*Multiplicand Decimal Representation*
8	0x29	2.5625	0x44	4.25
16	0x2929	41.16015625	0x051f	5.12109375
32	0x027d1100	637.06640625	0x003d1100	61.06640625

(Output)

N-Bit Count	*Calculated Output Hex Representation*	*Calculated Output Decimal Representation*	*Cycles to Complete*	*Expected Output Decimal Representation*	*Error (%)*
8	0xae	10.875	3	10.890625	0.14
16	0xd2c8	210.78125	3	210.7850189	0.00
32	0x97c9	38903.78515625	3	68903.35597	0.00

Recourse Utilization

Utilization will be logged and exported as file. This list is the most current implementations.

Slice/DSP Utilization

N-Bit Count	*Multiplier Type*	*Slice LUTs*	*Slice LUT Utilization %*	*Slice*	*Slice Utilization %*	*DSP Use Count*
8	Integer Multiplier, Custom Multiply Operator	90	0.17	31	0.23	0
16	Integer Multiplier, Custom Multiply Operator	328	0.62	104	0.78	0
32	Integer Multiplier, Custom Multiply Operator	1187	2.23	342	2.57	0
8	Integer Multiplier, Built-In Multiply Operator	98	0.18	34	0.26	0
16	Integer Multiplier, Built-In Multiply Operator	46	0.09	18	0.14	1
32	Integer Multiplier, Built-In Multiply Operator	140	0.26	53	0.40	4
8	Floating Point Multiplier, Custom Multiply Operator	31	0.06	11	0.08	0
16	Floating Point Multiplier, Custom Multiply Operator	102	0.19	39	0.29	0
32	Floating Point Multiplier, Custom Multiply Operator	371	0.70	115	0.86	0
8	Floating Point Multiplier, Built-In Multiply Operator	36	0.07	16	0.12	0
16	Floating Point Multiplier, Built-In Multiply Operator	56	0.11	23	0.17	0
32	Floating Point Multiplier, Built-In Multiply Operator	101	0.19	43	0.32	0
8	Fixed Point Multiplier	91	0.17	32	0.24	0
16	Fixed Point Multiplier	181	0.34	57	0.43	0
32	Fixed Point Multiplier	1179	2.22	343	2.58	0

Notes

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