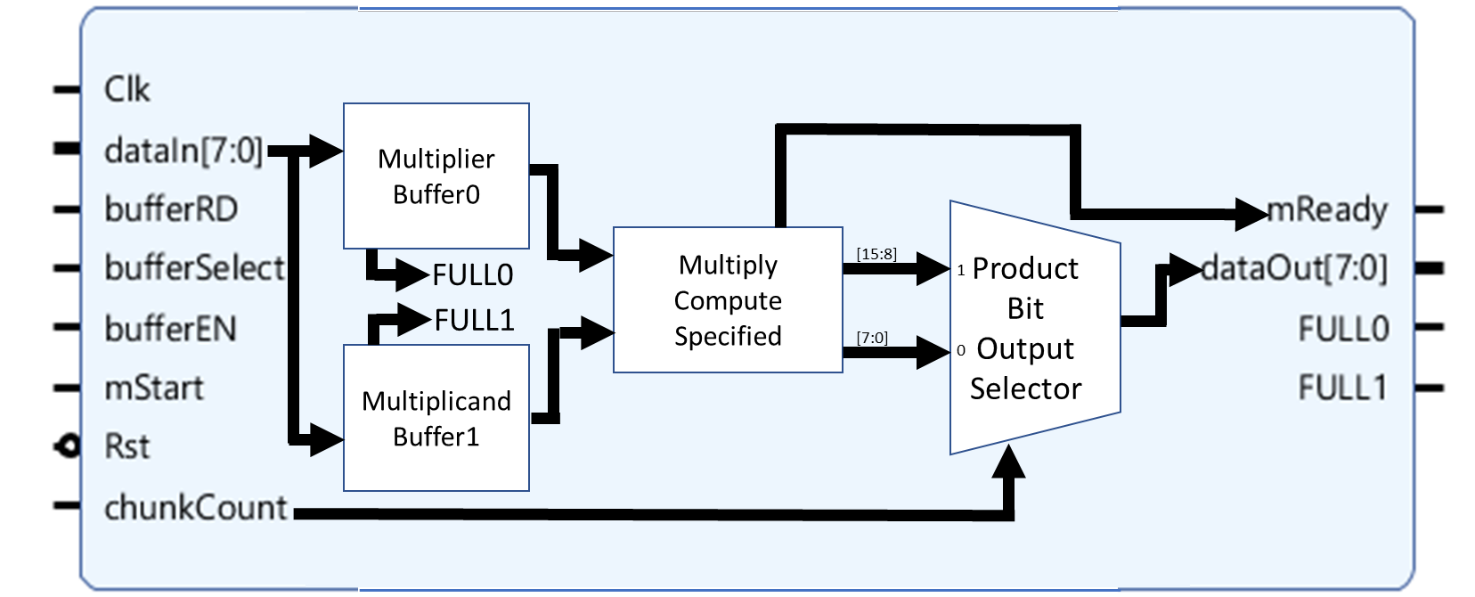
Multiplier Benchmark

# 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.
* For charts shown below, data will be represented in hexadecimal, using corresponding notation.
* When using lower n-bit representations, for fixed and floating point specifically, there will be error associated with the output values due to not being able to accurately represent the number with the given bit count. This error is calculated and shown below the output data.
* To ensure all signals are zeroed and set properly, there will be a 2.5ns reset delay at the beginning. The first positive edge after this delay is when cycles to complete will begin to be counted, up until the last positive edge when all needed values are extracted.
* Input vectors used will be the same bit patterns, but 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.

# Integer Multiplier

Data Structure:

Simple base conversion.

Example Data:

22 = 16 + 4 + 2 = 24 + 22 + 21 = 10110

Simulation Data:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *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 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *N-Bit Count* | *Calculated Output*  *Hex Representation* | *Calculated Output*  *Decimal Representation* | *Cycles to Complete* | *Expected Output*  *Decimal Representation* | *Error*  *(%)* |
| 8 | 0x2422 | 9250 | 5 | 9250 | 0.00 |
| 16 | 0x25402106 | 624959750 | 5 | 624959750 | 0.00 |
| 32 | 0x00a5d4eff5502106 | 4.66774e16 | 5 | 4.66774e16 | 0.00 |

# Floating Point Multiplier

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 | +212-7 \* (1 + ) |
| 16-bit | -48.0 | 1 | 10100 | 10000000000 | -220-15 \* (1 + ) |
| 32-bit | +48.0 | 0 | 10000100 | 10000000000000000000000 | +2132-127 \* (1 + ) |

Simulation Data:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *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 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *N-Bit Count* | *Calculated Output*  *Hex Representation* | *Calculated Output*  *Decimal Representation* | *Cycles to Complete* | *Expected Output*  *Decimal Representation* | *Error*  *(%)* |
| 8 | 0xe8 | -64 | 4 | -65 | 1.54 |
| 16 | 0xe66f | -1647 | 4 | -1339 | 18.70 |
| 32 | 0xbc4ba9d4 | -1.2430627e-2 | 4 | -0.01012156839 | 22.81 |

# Fixed Point Multiplier

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 | 23 + 22 + 2-1 + 2-2 + 2-3 |
| 16-bit | 100.00390625 | 1100100 | 00000001 | 26 + 25 + 22 + 2-8 |
| 32-bit | 4100.250244 | 1000000000100 | 0010000000001 | 212 + 22 + -2 + 2-12 |

Simulation Data:

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

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| *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 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| *N-Bit Count* | *Calculated Output*  *Hex Representation* | *Calculated Output*  *Decimal Representation* | *Cycles to Complete* | *Expected Output*  *Decimal Representation* | *Error*  *(%)* |
| 8 | 0xae | 10.875 | 4 | 10.890625 | 0.14 |
| 16 | 0xd2c8 | 210.78125 | 4 | 210.7850189 | 0.00 |
| 32 | 0x97c9 | 38903.78515625 | 4 | 68903.35597 | 0.00 |