



Lattice Nexus 2 sysDSP User Guide

Preliminary Technical Note

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Abbreviations in This Document

A list of abbreviations used in this document.

Abbreviation	Definition
CNN	Convolutional Neural Network
DSP	Digital Signal Processing
FFT	Fast Fourier Transform
FIR	Finite Impulse Response
GEMM	General Matrix Multiplication
HDL	Hardware Description Language
IIR	Infinite Impulse Response
MSB	Most Significant Bit
RHU	Round Half Up
RRH	Remote Radio Head
RTI	Round to Infinity
RTZ	Round to Zero
VHDL	Very-High-Speed Integrated Circuit Hardware Description Language

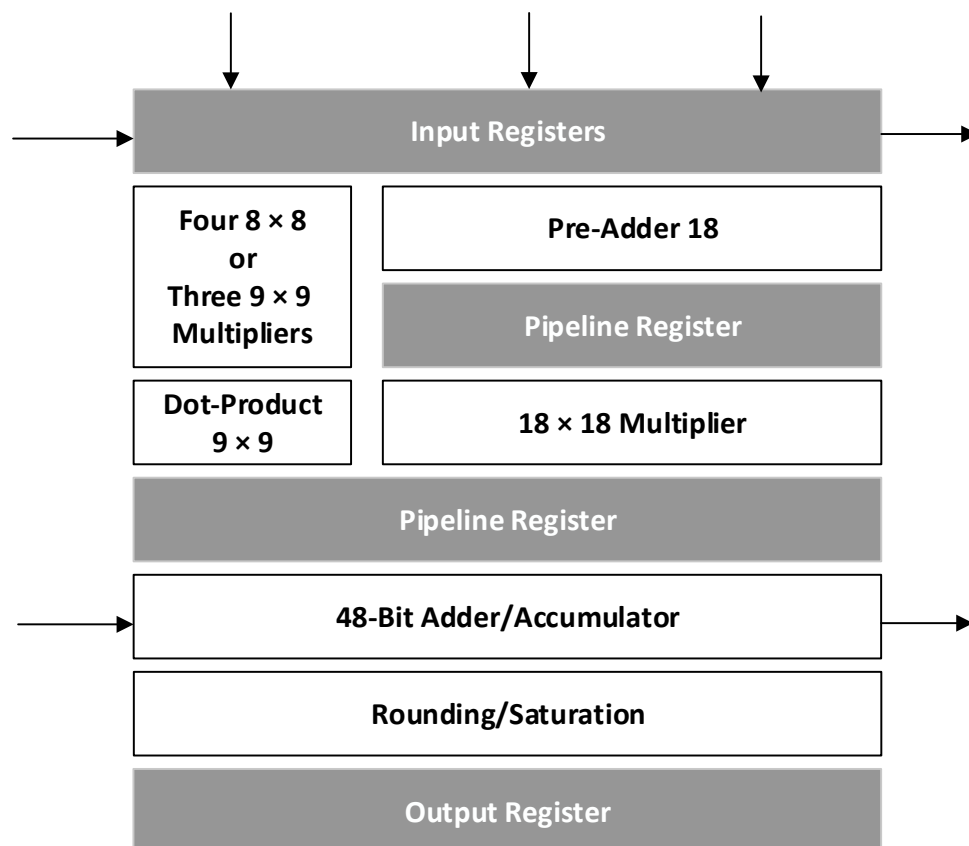
1. Introduction

This technical note discusses how to access the features of the Lattice sysDSP™ (Digital Signal Processing) block for the Lattice Nexus™ 2 platform.

Lattice Nexus 2 devices are optimized to support high-performance sysDSP applications, such as wireless base station channel cards, remote radio head (RRH) systems, video and imaging applications, and fast Fourier transform (FFT) functions. These applications can be easily built by cascading multiple sysDSP instances with minimal fabric or routing resources to form the core of those operations, such as different finite impulse response (FIR) filters, 9 bits or 18 bits precision dot product operation that are widely used in general matrix multiplication (GEMM) and convolutional neural network (CNN), as well as high-precision floating-point multiplier.

2. sysDSP Overview

Figure 2.1 shows the sysDSP block diagram. The Lattice Nexus 2 sysDSP block consists of pre-adder, multiplier, pipeline register, and wide accumulator with saturation. The multiplier can be configured to different modes, 8 × 8 multiplier, 9 × 9 multiplier, 18 × 18 multiplier, and 9 × 9 dot product. The sysDSP block contains an 18-bit pre-adder that works with the 18 × 18 multiplier mode, and a 48-bit adder/accumulator to support multiply-add or multiply-accumulate operation. The input, output, and pipeline registers in the sysDSP block can be bypassed.



Note: All the four 8 × 8 multipliers or three 9 × 9 multipliers must share the same clock enable (CE) and reset (RST) ports.

Figure 2.1. sysDSP Block Diagram

The Lattice Nexus 2 sysDSP block has strong multiplication support and dedicated architectural features that enable efficient implementation of machine learning, wearable, mobile, video, and other sysDSP-intensive applications.

The architectural features include:

- Dedicated input shift registers, bypassable pipeline registers, and dedicated cascade connections to implement multi-tap FIR, matrix dot product, and higher precision multiplier.
- 2-depth input shift registers with separate clock enable (CE) that enable one register to perform as shift register and the other as update register.
- Configured multipliers that can implement 8×8 , 9×9 , or 18×18 multiplications natively.
- Rounding support with rounding constant from operand C input that enables rounding point anywhere in the 48-bit accumulator output.
- Configurable width (N=3 to 48 bits) overflow and saturation logic.

3. Targeting the sysDSP Block by Instantiating Primitives

The sysDSP block can be targeted by instantiating the sysDSP primitive into a design. The advantage of instantiating primitives is that it provides access to all the available ports and parameters. The disadvantage of this flow is that the customization requires extra coding and knowledge. This section details the primitives supported by Lattice Nexus 2 devices. See the [Instantiating sysDSP Primitives in HDL](#) section that shows an HDL example on how to instantiate sysDSP primitives.

The Lattice Nexus 2 sysDSP supports primitives, such as MULT8×8, MULT9×9A, MULT18×18A, MULTADDSUB18×18A, and DOTPRODADDSUB9×9(A). In addition, several other library primitives are defined to take advantage of the features of the Lattice Nexus 2 sysDSP.

The following sections discuss various primitives along with the port definitions and attributes of the primitives.

3.1. MULT8×8 – 8×8 Multiplier with Optional Input/Output Registers

MULT8×8 implements the function $Z = A * B$. [Figure 3.1](#) shows the MULT8×8 primitive available in Lattice Nexus 2 devices. The functional diagram of the multiplier is shown in [Figure 3.2](#).

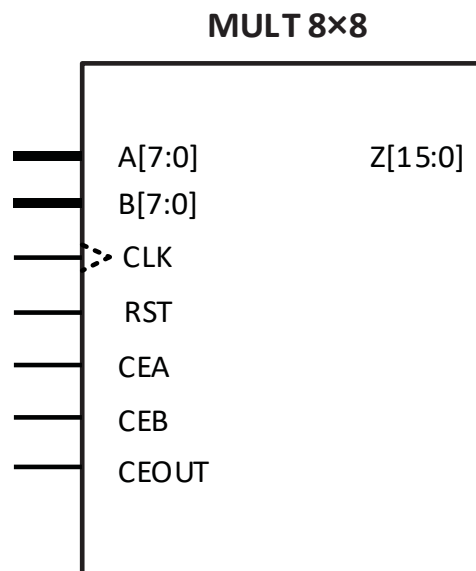


Figure 3.1. MULT8×8 Primitive

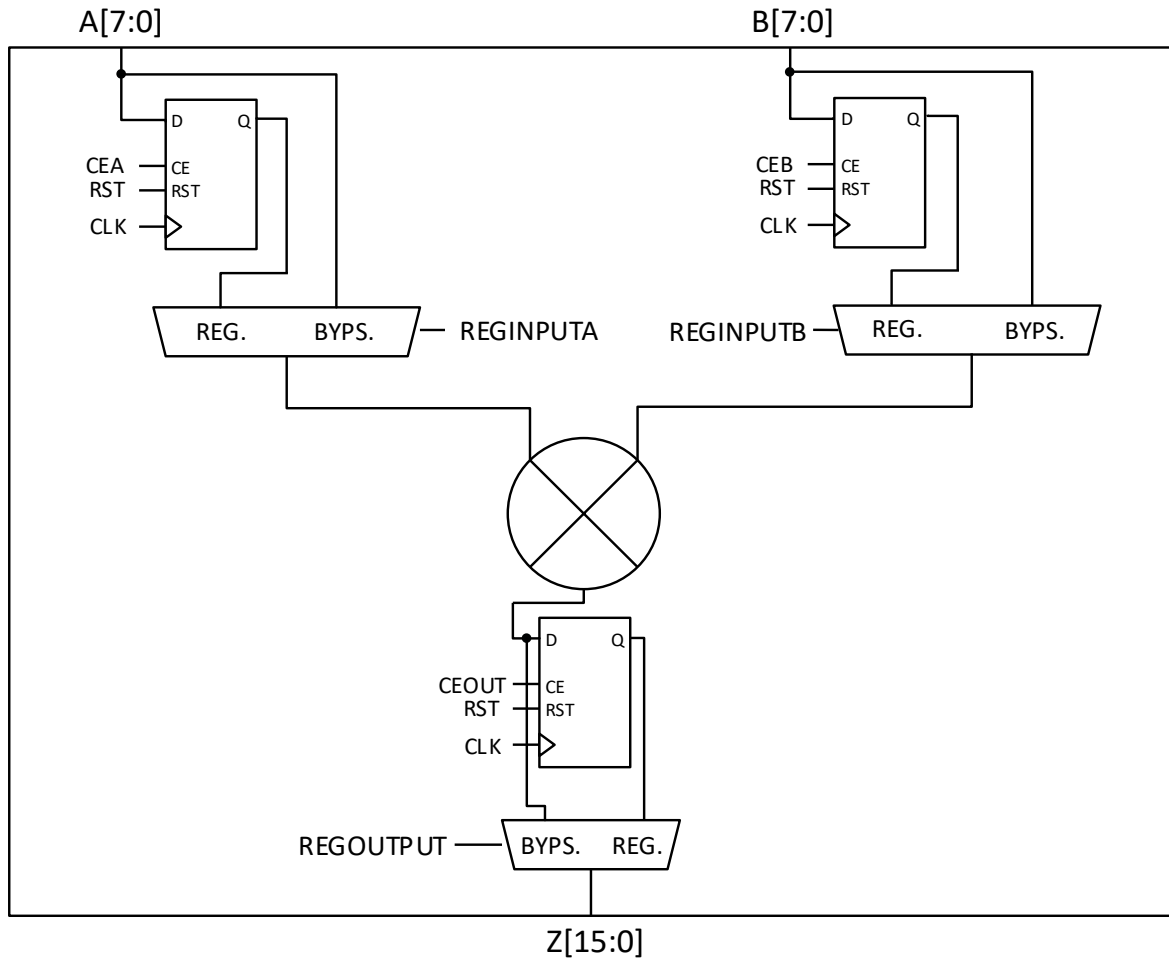


Figure 3.2. MULT8x8 Functional Diagram

3.1.1. MULT8x8 – I/O Ports

Table 3.1 describes the ports available for the primitive.

Table 3.1. MULT8x8 I/O Ports

Port	Input/Output	Description
A[7:0]	Input	Operand A (signed)
B[7:0]	Input	Operand B (signed)
CLK	Input	Clock
RST	Input	Reset
CEA	Input	Operand A register clock enable
CEB	Input	Operand B register clock enable
CEOOUT	Input	Output register clock enable
Z[15:0]	Output	Multiplication result

3.1.2. MULT8x8 – Attributes

Table 3.2 describes the attributes for the primitive.

Table 3.2. MULT8x8 Attributes

Attribute Name	Values	Default Value	Description
REGINPUTA	REGISTERED, BYPASSED	REGISTERED	Operand A register
REGINPUTB	REGISTERED, BYPASSED	REGISTERED	Operand B register
REGOUTPUT	REGISTERED, BYPASSED	REGISTERED	Output register
GSR	ENABLED, DISABLED	DISABLED	Enable global set/reset
RESETMODE	SYNC, ASYNC	SYNC	Synchronous/asynchronous reset control

3.2. MULT9X9A – 9×9 Multiplier with Optional Input/Output Registers

The 9 × 9 multiplier implements the function $Z = A * B$. Figure 3.3 shows the MULT9×9A primitive available in Lattice Nexus 2 devices. The functional diagram of the multiplier is shown in Figure 3.4.

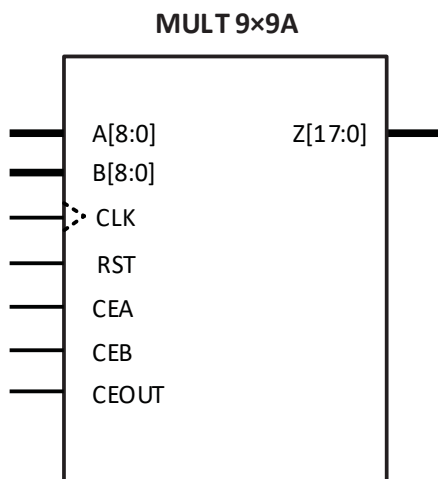


Figure 3.3. MULT9×9A Primitive

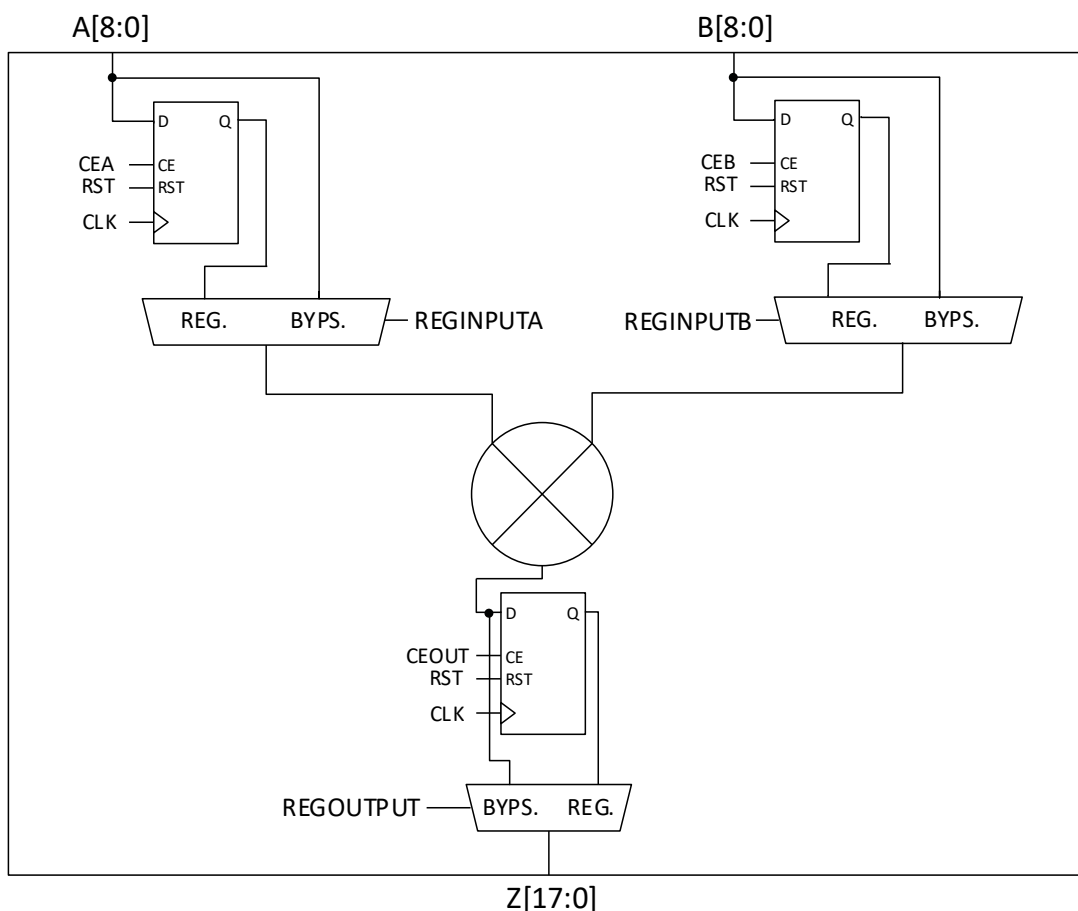


Figure 3.4. MULT9×9A Functional Diagram

3.2.1. MULT9x9A – I/O Ports

Table 3.3 describes the list of ports available for the primitive.

Table 3.3. MULT9x9A I/O Ports

Port	Input/Output	Description
A[8:0]	Input	Operand A (signed)
B[8:0]	Input	Operand B (signed)
CLK	Input	Clock
RST	Input	Reset
CEA	Input	Operand A register clock enable
CEB	Input	Operand B register clock enable
CEOUT	Input	Output register clock enable
Z[17:0]	Output	Multiplication result

3.2.2. MULT9x9A – Attributes

Table 3.4 describes the attributes for the primitive.

Table 3.4. MULT9x9A Attributes

Attribute Name	Values	Default Value	Description
REGINPUTA	REGISTERED, BYPASSED	REGISTERED	Operand A register
REGINPUTB	REGISTERED, BYPASSED	REGISTERED	Operand B register
REGOUTPUT	REGISTERED, BYPASSED	REGISTERED	Output register
GSR	ENABLED, DISABLED	DISABLED	Enable global set/reset
RESETMODE	SYNC, ASYNC	SYNC	Synchronous/asynchronous reset control

3.3. MULT18x18A – 18x18 Multiplier with Optional Input/Output Registers

The 18 × 18 multiplier implements the function $Z = A * B$. Figure 3.5 shows the MULT18X18A primitive available in Lattice Nexus 2 devices. The functional diagram of the multiplier is shown in Figure 3.6.

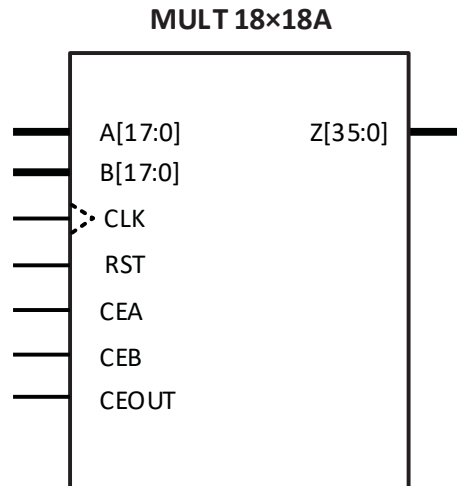


Figure 3.5. MULT18x18A Primitive

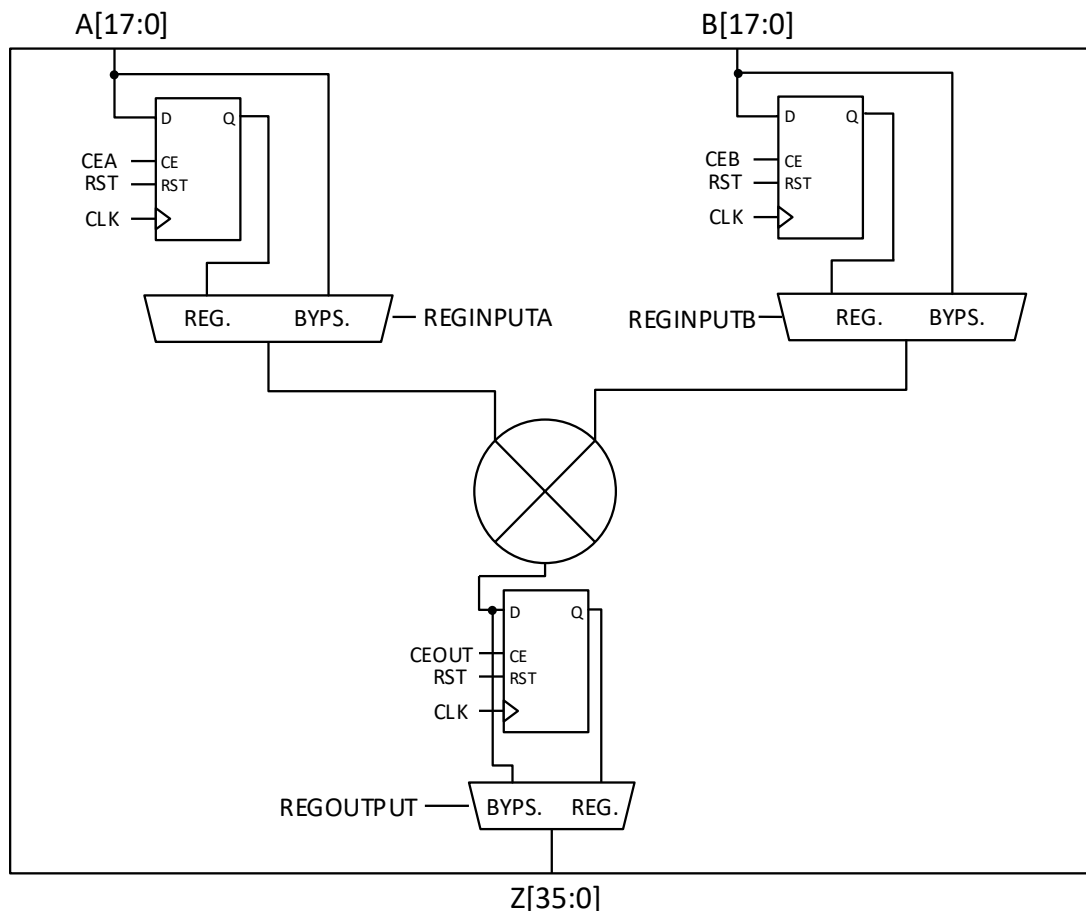


Figure 3.6 MULT18x18A Functional Diagram

3.3.1. MULT18x18A – I/O Ports

Table 3.5 describes the list of ports available for the primitive.

Table 3.5. MULT18x18A I/O Ports

Port	Input/Output	Description
A[17:0]	Input	Operand A (signed)
B[17:0]	Input	Operand B (signed)
CLK	Input	Clock
RST	Input	Reset
CEA	Input	Operand A register clock enable
CEB	Input	Operand B register clock enable
CEOUT	Input	Output register clock enable
Z[35:0]	Output	Multiplication result

3.3.2. MULT18x18A – Attributes

Table 3.6 describes the attributes for the primitive.

Table 3.6. MULT18x18A Attributes

Attribute Name	Values	Default Value	Description
REGINPUTA	REGISTERED, BYPASSED	REGISTERED	Operand A register
REGINPUTB	REGISTERED, BYPASSED	REGISTERED	Operand B register
REGOUTPUT	REGISTERED, BYPASSED	REGISTERED	Output register
GSR	ENABLED, DISABLED	DISABLED	Enable global set/reset
RESETMODE	SYNC, ASYNC	SYNC	Synchronous/asynchronous reset control

3.4. MULTADDSUB18×18A – 18×18 Multiplier with Pre-adder and Accumulator

MULTADDSUB18×18A implements an 18 × 18 multiplication with pre-adder and accumulator. The pre-adder and accumulator can be enabled or disabled to achieve different functions.

When pre-adder and accumulator are both enabled, it implements the function:

$$M_{INT} = A * (B \pm C)$$

$$Z_{out} = CAS_{INT} + C_{INT} + CIN_{INT} \pm M_{INT}$$

Note that the pre-adder and accumulator share the C input. If the pre-adder is used, typically ACCUM_C_EN must be set to DISABLED so that the accumulator ignores the value of the C port.

When pre-adder is enabled and accumulator is disabled, it implements the function:

$$Z_{out} = A * (B \pm C)$$

When pre-adder is disabled and accumulator is enabled, it implements the function:

$$M_{int} = A * B$$

$$Z_{out} = CAS_{INT} + C_{INT} + CIN_{INT} \pm M_{INT}$$

The output of the accumulator is fed to a saturation logic that is responsible for checking if the result exceeds a defined limit. Refer to [Appendix B. Rounding and Saturation for more details on saturation](#) for more details.

Figure 3.7 shows the MULTADDSUB18×18A primitive available in Lattice Nexus 2 devices. The functional diagram of the multiplier is shown in Figure 3.8.

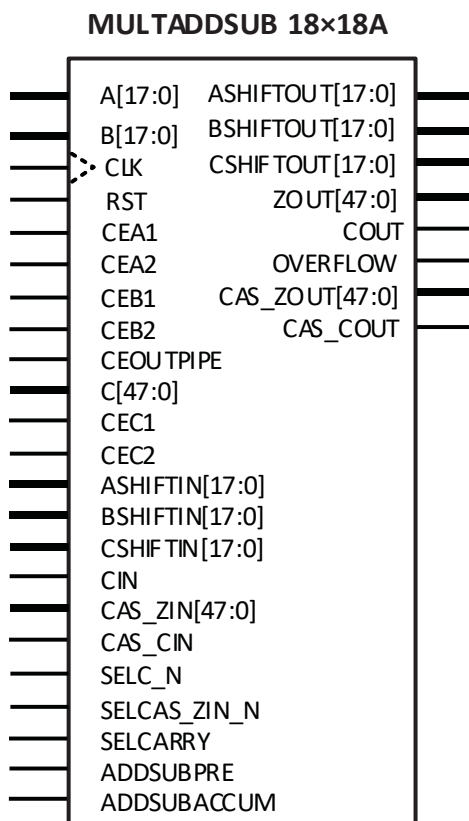


Figure 3.7. MULTADDSUB18×18A Primitive

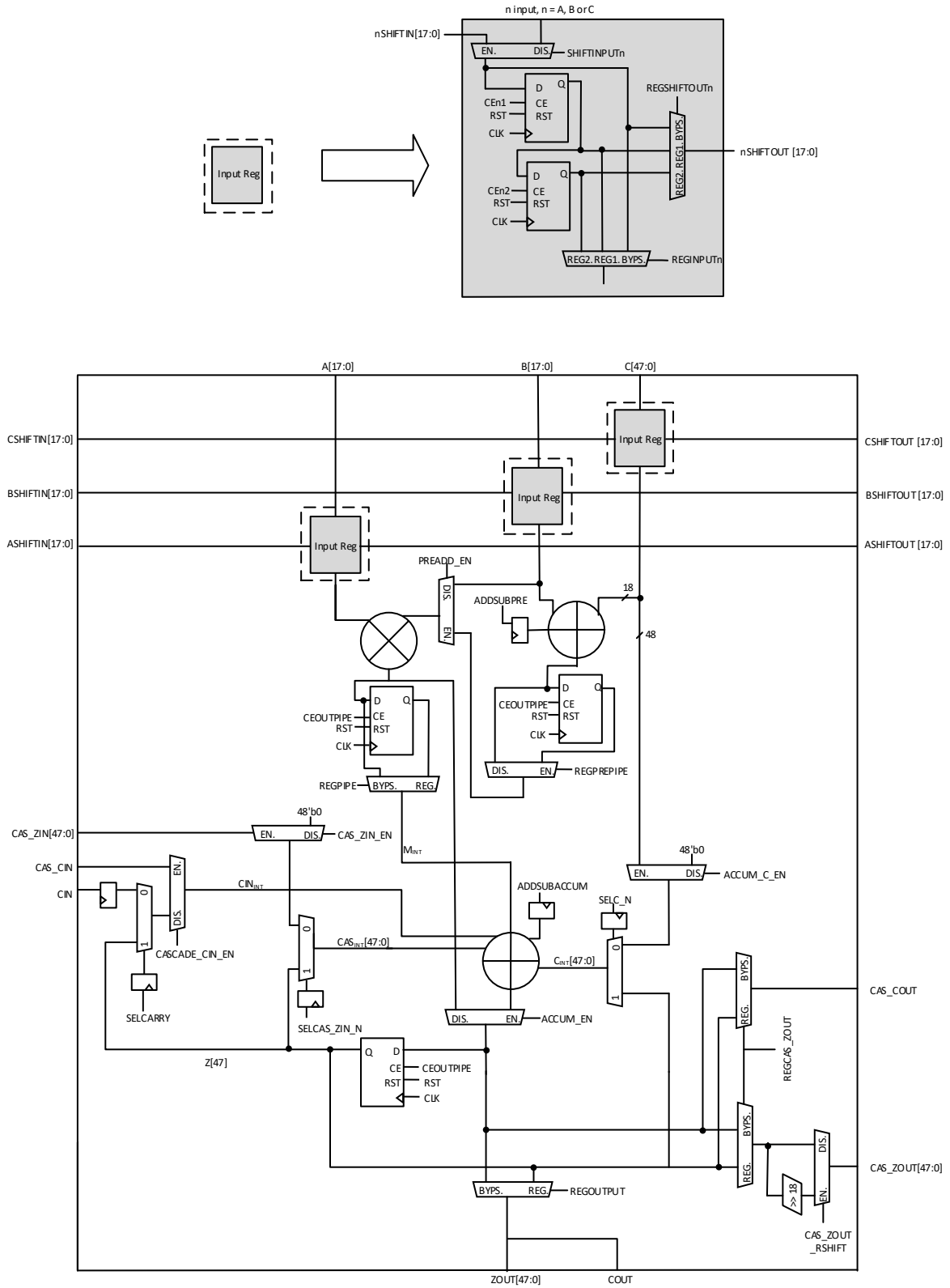


Figure 3.8. MULTADDSUB18x18A Functional Diagram

3.4.1. MULTADDSUB18x18A – I/O Ports

Table 3.7 describes the ports available for the primitive.

Table 3.7. MULTADDSUB18x18A I/O Ports

Port	Input/Output	Description
A[17:0]	Input	Operand A
B[17:0]	Input	Operand B
CLK	Input	Clock
RST	Input	Reset
CEA1	Input	Operand A register clock enable, stage one.
CEA2	Input	Operand A register clock enable, stage two.
CEB1	Input	Operand B register clock enable, stage one.
CEB2	Input	Operand B register clock enable, stage two.
CEOUTPIPE	Input	Output and pipeline register clock enable
C[47:0]	Input	Operand C
CEC1	Input	Operand C register clock enable, stage one.
CEC2	Input	Operand C register clock enable, stage two.
ASHIFTIN[17:0]	Input	Operand A shift chain input
BSHIFTIN[17:0]	Input	Operand B shift chain input
CSHIFTIN[17:0]	Input	Operand C shift chain input
CIN	Input	Carry in
CAS_ZIN[47:0]	Input	Cascade input from previous DSP block.
CAS_CIN	Input	Cascade carry input from previous DSP block.
SELC_N	Input	Select between C or accumulator output for input to accumulator.
SELCAS_ZIN_N	Input	Select between CAS_ZIN or accumulator output for input to accumulator.
SELCARRY	Input	Select between CIN or accumulator output Z[47] bit for input to accumulator.
ADDSUBPRE	Input	Pre-adder add/sub control 0: add 1: subtract
ADDSUBACCUM	Input	Accumulator add/sub control 0: add 1: subtract
ASHIFTOUT[17:0]	Output	Operand A shift chain output
BSHIFTOUT[17:0]	Output	Operand B shift chain output
CSHIFTOUT[17:0]	Output	Operand C shift chain output
ZOUT[47:0]	Output	Multiplication/accumulator result
COUT	Output	Carry out
OVERFLOW	Output	Overflow flag, asserted if accumulation result exceeds max/min limit set by SATURATION_BITS.
CAS_ZOUT[47:0]	Output	Cascade multiplication/accumulator result to next DSP block.
CAS_COUT	Output	Cascade carry out to next DSP block.

3.4.2. MULTADDSUB18x18A – Attributes

Table 3.8 describes the attributes for the primitive.

Table 3.8. MULTADDSUB18x18A Attributes

Attribute Name	Values	Default Value	Description
REGINPUTA	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A register
REGINPUTB	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B register
REGSHIFTOUTA	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A shift chain output register
REGSHIFTOUTB	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B shift chain output register
SHIFTINPUTA	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand A as input. ENABLED: Select Operand A shift chain input.
SHIFTINPUTB	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand B as input. ENABLED: Select Operand B shift chain input.
REGINPUTC	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand C register
SHIFTINPUTC	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand C as input. ENABLED: Select Operand C shift chain input.
REGSHIFTOUTC	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand C shift chain output register
REGPREPIPE	REGISTERED, BYPASSED	REGISTERED	Pre-adder output pipeline register
REGPIPE	REGISTERED, BYPASSED	REGISTERED	Multiplier output pipeline register
REGOUTPUT	REGISTERED, BYPASSED	REGISTERED	Accumulator output register
REGCAS_ZOUT	REGISTERED, BYPASSED	REGISTERED	CAS_COUT and CAS_ZOUT[47:0] output register
REGACCUMCONTROLS	REGISTERED, BYPASSED	REGISTERED	Accumulator control signals register, register for CIN, SELCARRY, SELCAS_ZIN, ADDSUBACCUM, and SELC
RESETMODE	SYNC, ASYNC	SYNC	Synchronous/asynchronous reset control
ACCUM_EN	ENABLED, DISABLED	DISABLED	Enable accumulator
CAS_ZOUT_RSHIFT	ENABLED, DISABLED	DISABLED	Cascade output 18 bits right shift
PREADD_EN	ENABLED, DISABLED	DISABLED	Enable pre-adder
REGADDSUBPRE	REGISTERED, BYPASSED	REGISTERED	ADDSUBPRE control signal register
ASIGNED	SIGNED, UNSIGNED	SIGNED	Operand A signed control (only used when cascading to build wider multipliers)
BSIGNED	SIGNED, UNSIGNED	SIGNED	Operand B signed control (only used when cascading to build wider multipliers)
ACCUM_C_EN	ENABLED, DISABLED	DISABLED	Enable C input to accumulator
CAS_ZIN_EN	ENABLED, DISABLED	DISABLED	Enable CAS_ZIN to accumulator
CAS_CIN_EN	ENABLED, DISABLED	DISABLED	Enable CAS_CIN for carry input

Attribute Name	Values	Default Value	Description
ROUNDMODE	ROUND_TO_ZERO, ROUND_TO_INFINITY	ROUND_TO_ZERO	Rounding mode
SATURATION	TO_NEG_MAX, TO_ZERO, DISABLED	DISABLED	Saturation mode
SATURATION_BITS	3 to 48	48	Set N-bit saturation
GSR	ENABLED, DISABLED	DISABLED	Enable global set/reset

3.5. DOTPRODADDSUB9X9 – 9×9 Multiply Add with Accumulator

DOTPRODADDSUB9×9 implements four 9 × 9 multiply-add function. The accumulator can be enabled or disabled to achieve different functions. Do note that C input is not available in this mode.

When the accumulator is enabled, it implements the following function:

$$M_{INT} = (A_0 * B_0) + (A_1 * B_1) + (A_2 * B_2) + (A_3 * B_3)$$

$$Z_{out} = CAS_{INT} + C_{INT} + CIN_{INT} \pm M_{INT}$$

The output of the accumulator is fed to a saturation logic that is responsible for checking if the result exceeds a defined limit. Refer to [Appendix B Rounding and Saturation](#) for more details on saturation.

When the accumulator is disabled, it implements the following function:

$$Z_{OUT} = (A_0 * B_0) + (A_1 * B_1) + (A_2 * B_2) + (A_3 * B_3)$$

Figure 3.9 shows the DOTPRODADDSUB9×9 primitive available in Lattice Nexus 2 devices. The functional diagrams of the multiplier are shown in [Figure 3.10](#) and [Figure 3.11](#).

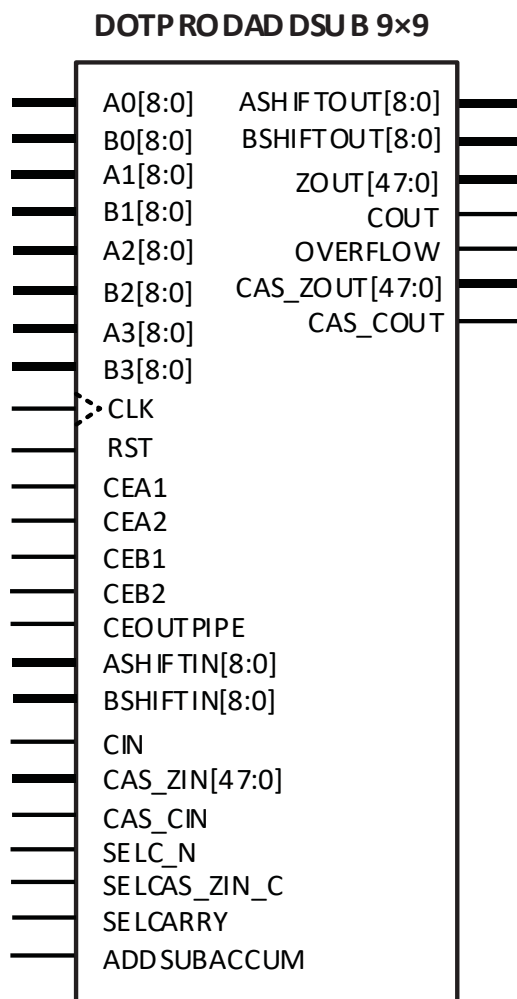


Figure 3.9. DOTPRODADDSUB9×9 Primitive

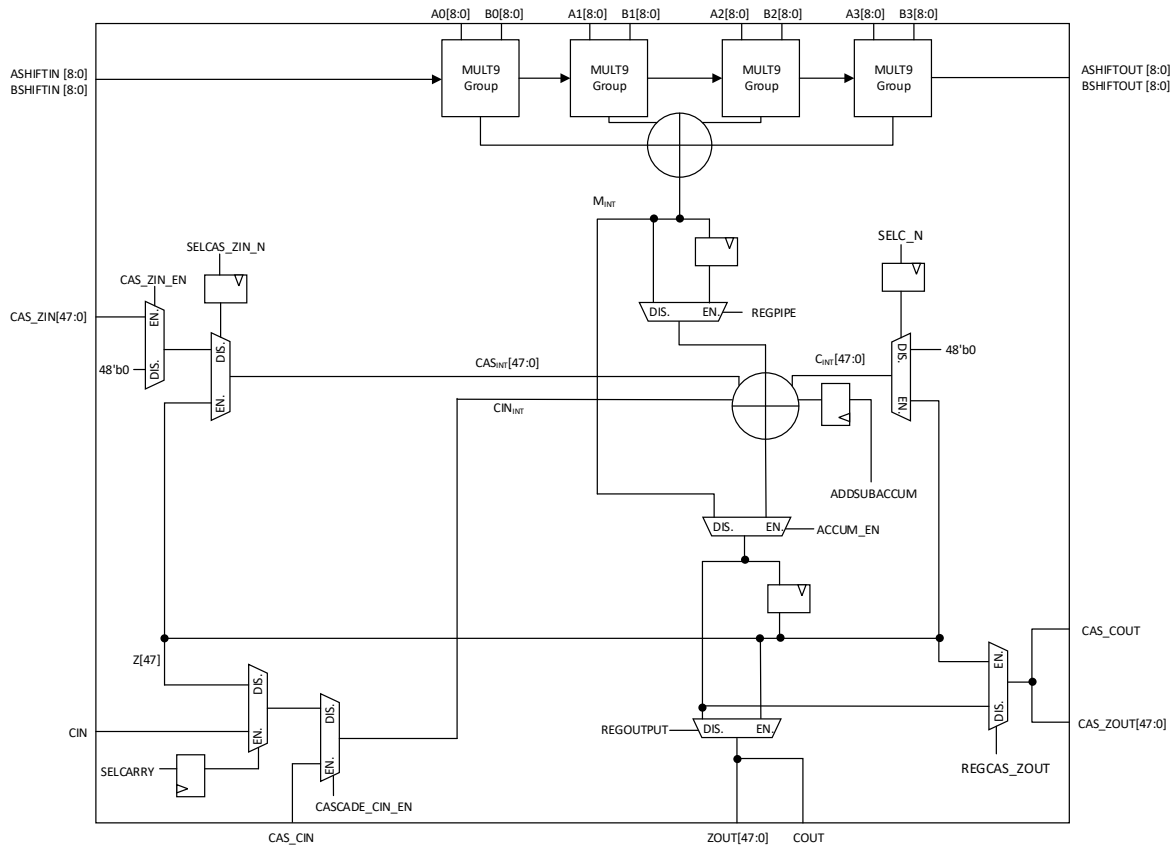


Figure 3.10. DOTPRODADDSUB9x9 Functional Diagram

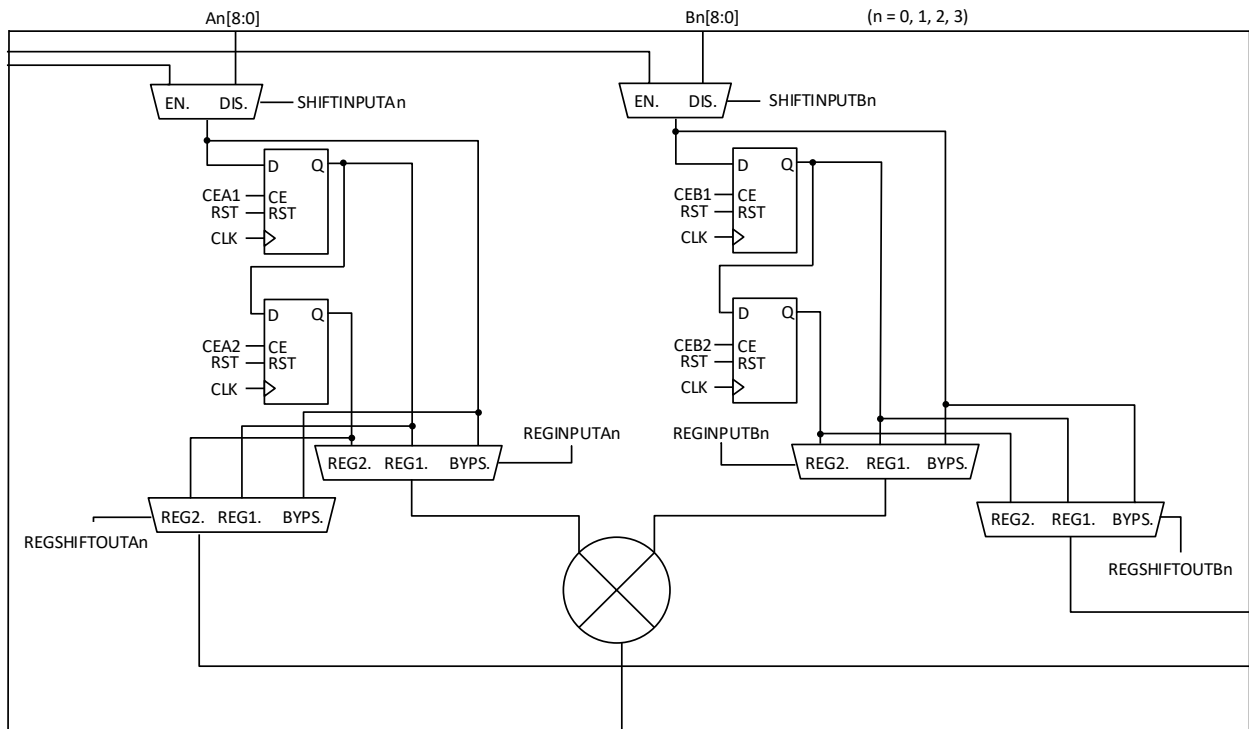


Figure 3.11. MULT9 Group Functional Diagram (1)

3.5.1. DOTPRODADDSUB9×9 – I/O Ports

Table 3.9 describes the ports available for the primitive.

Table 3.9. DOTPRODADDSUB9×9 I/O Ports

Port	Input/Output	Description
A0[8:0]	Input	Operand A0 (signed)
B0[8:0]	Input	Operand B0 (signed)
A1[8:0]	Input	Operand A1 (signed)
B1[8:0]	Input	Operand B1 (signed)
A2[8:0]	Input	Operand A2 (signed)
B2[8:0]	Input	Operand B2 (signed)
A3[8:0]	Input	Operand A3 (signed)
B3[8:0]	Input	Operand B3 (signed)
CLK	Input	Clock
RST	Input	Reset
CEA1	Input	Operand A register clock enable, stage one.
CEA2	Input	Operand A register clock enable, stage two.
CEB1	Input	Operand B register clock enable, stage one.
CEB2	Input	Operand B register clock enable, stage two.
CEOUTPIPE	Input	Output & pipeline register clock enable
ASHIFTIN[8:0]	Input	Operand A shift chain input
BSHIFTIN[8:0]	Input	Operand B shift chain input
CIN	Input	Carry in
CAS_ZIN[47:0]	Input	Cascade input from previous DSP block
CAS_CIN	Input	Cascade carry input from previous DSP block
SELC_N	Input	Select between C or accumulator output for input to accumulator.
SELCAS_ZIN_N	Input	Select between CAS_ZIN or accumulator output for input to accumulator.
SELCARRY	Input	Select between CIN or accumulator output Z[47] bit for input to accumulator.
ADDSUBACCUM	Input	Accumulator add/sub control 0: add 1: subtract
ASHIFTOUT[8:0]	Output	Operand A shift chain output
BSHIFTOUT[8:0]	Output	Operand B shift chain output
ZOUT[47:0]	Output	Multiplication/accumulator result
COUT	Output	Carry out
OVERFLOW	Output	Overflow flag, asserted if accumulation result exceeds max/min limit set by SATURATION_BITS.
CAS_ZOUT[47:0]	Output	Cascade multiplication/accumulator result to next DSP block.
CAS_COUT	Output	Cascade carry out to next DSP block.

3.5.2. DOTPRODADDSUB9×9 – Attributes

Table 3.10 shows the attributes for the primitive.

Table 3.10. DOTPRODADDSUB9×9 Attributes

Attribute Name	Values	Default Value	Description
REGINPUTA0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A0 register
REGINPUTB0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B0 register
REGSHIFTOUTA0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A0 shift chain output register
REGSHIFTOUTB0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B0 shift chain output register
SHIFTINPUTA0	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand A0 as input. ENABLED: Select Operand A0 shift chain input.
SHIFTINPUTB0	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand B0 as input. ENABLED: Select Operand B0 shift chain input.
REGINPUTA1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A1 register
REGINPUTB1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B1 register
REGSHIFTOUTA1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A1 shift chain output register
REGSHIFTOUTB1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B1 shift chain output register
SHIFTINPUTA1	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand A1 as input. ENABLED: Select Operand A1 shift chain input.
SHIFTINPUTB1	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand B1 as input. ENABLED: Select Operand B1 shift chain input.
REGINPUTA2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A2 register
REGINPUTB2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B2 register
REGSHIFTOUTA2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A2 shift chain output register

Attribute Name	Values	Default Value	Description
REGSHIFTOUTB2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B2 shift chain output register
SHIFTINPUTA2	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand A2 as input. ENABLED: Select Operand A2 shift chain input.
SHIFTINPUTB2	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand B2 as input. ENABLED: Select Operand B2 shift chain input.
REGINPUTA3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A3 register
REGINPUTB3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B3 register
REGSHIFTOUTA3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A3 shift chain output register
REGSHIFTOUTB3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B3 shift chain output register
SHIFTINPUTA3	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand A3 as input. ENABLED: Select Operand A3 shift chain input.
SHIFTINPUTB3	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand B3 as input. ENABLED: Select Operand B3 shift chain input.
REGPIPE	REGISTERED, BYPASSED	REGISTERED	Multiplier output pipeline register
REGOUTPUT	REGISTERED, BYPASSED	REGISTERED	Accumulator output register
REGCAS_ZOUT	REGISTERED, BYPASSED	REGISTERED	CAS_COUT and CAS_ZOUT[47:0] output register
REGACCUMCONTROLS	REGISTERED, BYPASSED	REGISTERED	Accumulator control signals register, register for CIN, SELCARRY, SELCAS_ZIN, ADDSUBACCUM, and SELC
RESETMODE	SYNC, ASYNC	SYNC	Synchronous/asynchronous reset control
ACCUM_EN	ENABLED, DISABLED	DISABLED	Enable accumulator.
CAS_ZIN_EN	ENABLED, DISABLED	DISABLED	Enable CAS_ZIN to accumulator.
CAS_CIN_EN	ENABLED, DISABLED	DISABLED	Enable CAS_CIN for carry input.
ROUNDMODE	ROUND_TO_ZERO, ROUND_TO_INFINITY	ROUND_TO_ZERO	Rounding mode
SATURATION	TO_NEG_MAX, TO_ZERO, DISABLED	DISABLED	Saturation mode
SATURATION_BITS	3 to 48	48	Set N-bit saturation
GSR	ENABLED, DISABLED	DISABLED	Enable global set/reset.

3.6. DOTPRODADDSUB9X9A – 9×9 Multiply Add with Accumulator and Cin

DOTPRODADDSUB9×9A implements four 9 × 9 multiply-add function. The accumulator can be enabled or disabled to achieve different functions. Operands are shifted in through the shift chain input in this mode, which enables operand C to be fed to the accumulator.

When the accumulator is enabled, it implements the function:

$$M_{INT} = (A_z * B_z) + (A_{z-1} * B_{z-1}) + (A_{z-2} * B_{z-2}) + (A_{z-3} * B_{z-3})$$

$$Z_{out} = CAS_{INT} + C_{INT} + CIN_{INT} \pm M_{INT}$$

The output of the accumulator is fed to a saturation logic that is responsible for checking if the result exceeds a defined limit. Refer to [Appendix B. Rounding and Saturation](#) for more details on saturation.

When the accumulator is disabled, it implements the following function:

$$Z_{OUT} = (A_z * B_z) + (A_{z-1} * B_{z-1}) + (A_{z-2} * B_{z-2}) + (A_{z-3} * B_{z-3})$$

Figure 3.12 shows the DOTPRODADDSUB9×9A primitive available in Lattice Nexus 2 devices. The functional diagrams of the multiplier are shown in [Figure 3.13](#) and [Figure 3.14](#).

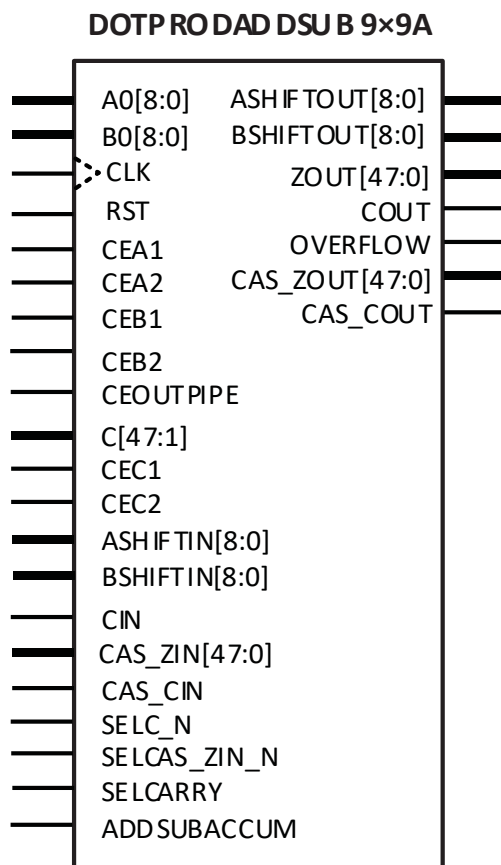


Figure 3.12. DOTPRODADDSUB9×9A Primitive

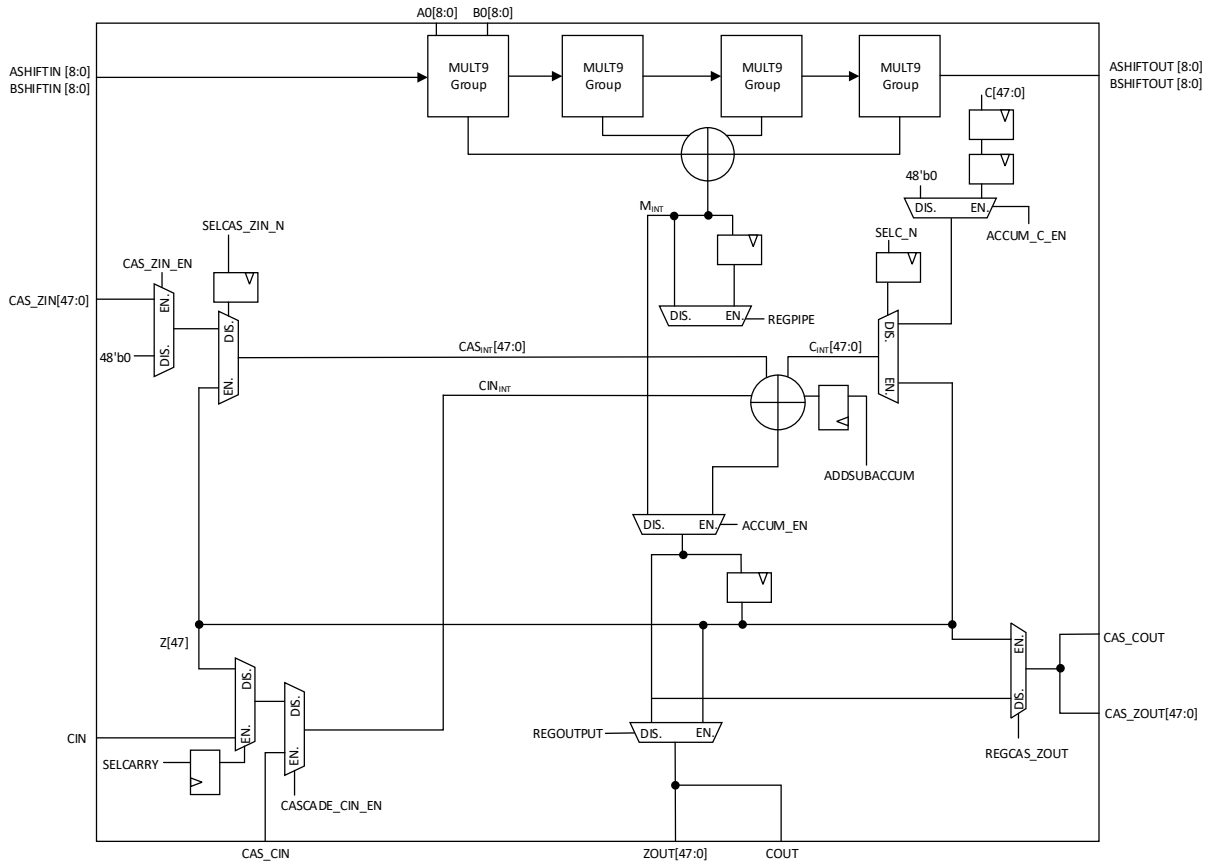


Figure 3.13. DOTPRODADDSUB9x9A Functional Diagram

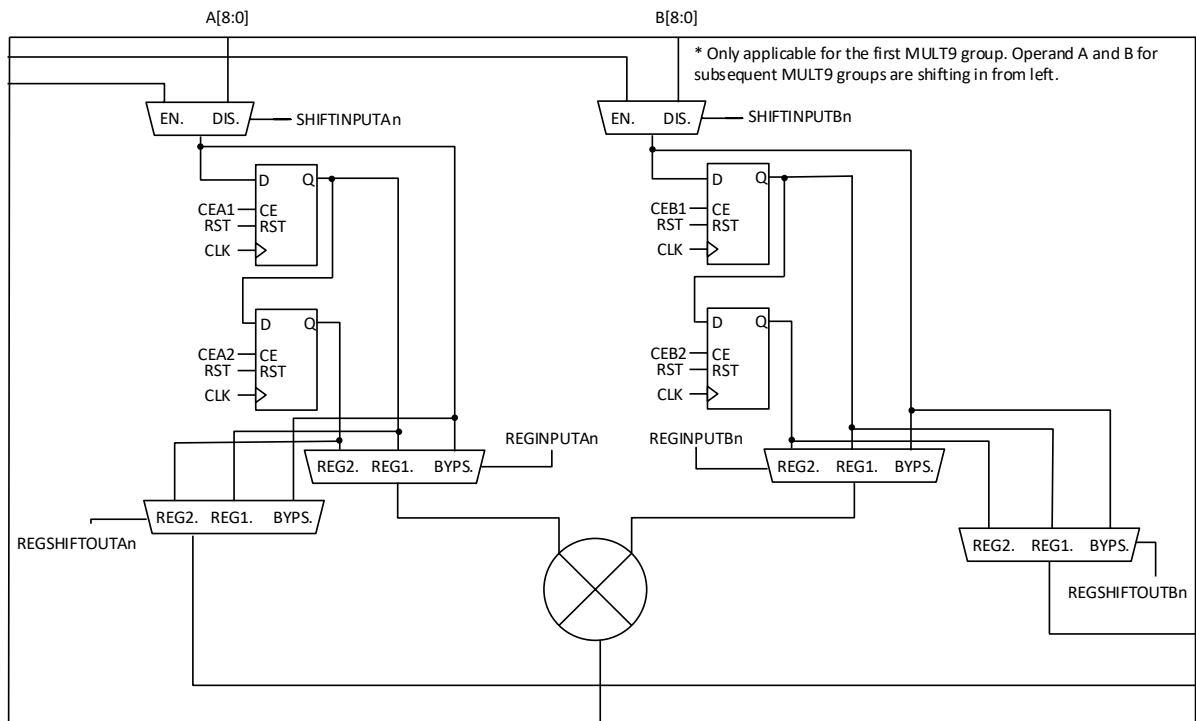


Figure 3.14. MULT9 Group Functional Diagram (2)

3.6.1. DOTPRODADDSUB9×9A – I/O Ports

Table 3.11 describes the ports available for the primitive.

Table 3.11. DOTPRODADDSUB9×9A I/O Ports

Port	Input/Output	Description
A0[8:0]	Input	Operand A0 (signed)
B0[8:0]	Input	Operand B0 (signed)
CLK	Input	Clock
RST	Input	Reset
CEA1	Input	Operand A register clock enable, stage one.
CEA2	Input	Operand A register clock enable, stage two.
CEB1	Input	Operand B register clock enable, stage one.
CEB2	Input	Operand B register clock enable, stage two.
CEOUTPIPE	Input	Output and pipeline register clock enable.
C[47:0]	Input	Operand C
CEC1	Input	Operand C register clock enable, stage one.
CEC2	Input	Operand C register clock enable, stage two.
ASHIFTIN[8:0]	Input	Operand A shift chain input.
BSHIFTIN[8:0]	Input	Operand B shift chain input.
CIN	Input	Carry in
CAS_ZIN[47:0]	Input	Cascade input from previous DSP block.
CAS_CIN	Input	Cascade carry input from previous DSP block.
SELC_N	Input	Select between C or accumulator output for input to accumulator.
SELCAS_ZIN_N	Input	Select between CAS_ZIN or accumulator output for input to accumulator.
SELCARRY	Input	Select between CIN or accumulator output Z[47] bit for input to accumulator.
ADDSUBACCUM	Input	Accumulator add/sub control, 0 = add, 1 = subtract
ASHIFTOUT[8:0]	Output	Operand A shift chain output
BSHIFTOUT[8:0]	Output	Operand B shift chain output
ZOUT[47:0]	Output	Multiplication/accumulator result
COUT	Output	Carry out
OVERFLOW	Output	Overflow flag, asserted if accumulation result exceeds max/min limit set by SATURATION_BITS.
CAS_ZOUT[47:0]	Output	Cascade multiplication/accumulator result to next DSP block.
CAS_COUT	Output	Cascade carry out to next DSP block.

3.6.2. DOTPRODADDSUB9x9A – Attributes

Table 3.12 describes the attributes for the primitive.

Table 3.12. DOTPRODADDSUB9x9A Attributes

Attribute Name	Values	Default Value	Description
REGINPUTA0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A0 register
REGINPUTB0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B0 register
REGSHIFTOUTA0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A0 shift chain output register
REGSHIFTOUTB0	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B0 shift chain output register
SHIFTINPUTA0	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand A0 as input. ENABLED: Select Operand A0 shift chain input
SHIFTINPUTB0	DISABLED, ENABLED	DISABLED	DISABLED: Select Operand B0 as input. ENABLED: Select Operand B0 shift chain input.
REGINPUTA1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A1 register
REGINPUTB1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B1 register
REGSHIFTOUTA1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A1 shift chain output register
REGSHIFTOUTB1	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B1 shift chain output register
REGINPUTA2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A2 register
REGINPUTB2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B2 register
REGSHIFTOUTA2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A2 shift chain output register
REGSHIFTOUTB2	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B2 shift chain output register
REGINPUTA3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A3 register
REGINPUTB3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B3 register

Attribute Name	Values	Default Value	Description
REGSHIFTOUTA3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand A3 shift chain output register
REGSHIFTOUTB3	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand B3 shift chain output register
REGINPUTC	REGISTERED_ONCE, REGISTERED_TWICE, BYPASSED	REGISTERED_ONCE	Operand C register
REGPIPE	REGISTERED, BYPASSED	REGISTERED	Multiplier output pipeline register
REGOUTPUT	REGISTERED, BYPASSED	REGISTERED	Accumulator output register
REGCAS_ZOUT	REGISTERED, BYPASSED	REGISTERED	CAS_COUT and CAS_ZOUT[47:0] output register
REGACCUMCONTROLS	REGISTERED, BYPASSED	REGISTERED	Accumulator control signals register, register for CIN, SELCARRY, SELCAS_ZIN, ADDSUBACCUM, and SELC
RESETMODE	SYNC, ASYNC	SYNC	Synchronous/asynchronous reset control
ACCUM_EN	ENABLED, DISABLED	DISABLED	Enable accumulator
ACCUM_C_EN	ENABLED, DISABLED	DISABLED	Enable C input to accumulator
CAS_ZIN_EN	ENABLED, DISABLED	DISABLED	Enable CAS_ZIN to accumulator
CAS_CIN_EN	ENABLED, DISABLED	DISABLED	Enable CAS_CIN for carry input
ROUNDMODE	ROUND_TO_ZERO, ROUND_TO_INFINITY	ROUND_TO_ZERO	Rounding mode
SATURATION	TO_NEG_MAX, TO_ZERO, DISABLED	DISABLED	Saturation mode
SATURATION_BITS	3 to 48	48	Set N-bit saturation
GSR	ENABLED, DISABLED	DISABLED	Enable global set/reset

4. Using sysDSP

The following sections describe the many ways you can use sysDSP blocks in Lattice Nexus 2 devices.

4.1. sysDSP Primitive Instantiation

Lattice sysDSP primitives can be directly instantiated in the design. Each of the primitives has a fixed set of attributes that can be customized to meet the design requirements. The Lattice Nexus 2 sysDSP supports the following primitives:

- MULT8X8 (8-bit multiplication)
- MULT9X9A (9-bit multiplication)
- MULT18X18A (18-bit multiplication)
- MULTADDSUB18X18A (18-bit multiplication with pre-adder and accumulator)
- DOTPRODADDSUB9X9/DOTPRODADDSUB9X9A (9 × 9 multiplication and addition with accumulator)

An example of the MULT18X18 primitive instantiation is provided in the [Instantiating sysDSP Primitives in HDL](#) section.

4.2. Instantiating sysDSP Primitives in HDL

This section illustrates how to instantiate Lattice Nexus 2 sysDSP primitives in both Verilog HDL and VHDL.

4.2.1. Verilog HDL Example Showing Snippet of the MULT18×18A Instantiation

```
defparam dsp_mult_0.REGINPUTA = "REGISTERED" ;
defparam dsp_mult_0.REGINPUTB = "REGISTERED" ;
defparam dsp_mult_0.REGOUTPUT = "REGISTERED" ;
defparam dsp_mult_0.GSR = "ENABLED" ;
defparam dsp_mult_0.RESETMODE = "SYNC" ;

MULT18X18A dsp_mult_0 (
  .CLK(clk_i),
  .RST(rst_i),
  .CEA(ce_a_i),
  .CEB(ce_b_i),
  .CEOUT(ce_o_i),
  .A(data_a_i[17:0]),
  .B(data_b_i[17:0]),
  .Z(result_o[35:0]));
```

4.2.2. VHDL Example Showing Snippet of the MULT18×18A Instantiation

```
dsp_mult_0 : MULT18X18A
  generic map (
    REGINPUTA => "REGISTERED",
    REGINPUTB => "REGISTERED",
    REGOUTPUT => "REGISTERED",
    GSR => "ENABLED",
    RESETMODE => "SYNC"
  )
  port map (
    CLK => clk_i,
    RST => rst_i,
    CEA => ce_a_i,
    CEB => ce_b_i,
    CEOUT=> ce_o_i,
    A => data_a_i,
```

```
        B => data_b_i,  
        Z => result_o  
    );
```

4.3. Inferencing sysDSP Block

The sysDSP can be inferred by synthesis tools. An example of the HDL inference for the sysDSP block is provided in [Appendix A. HDL Inference for sysDSP](#).

Appendix A. HDL Inference for sysDSP

Synthesis inference flow enables the design tools to infer sysDSP blocks from an HDL design. It is important to note that when using the inference flow, unless the code style matches the sysDSP block, results are not optimal. You can infer the sysDSP block with Synplify Pro® from Synopsys in the Lattice Radiant software if certain coding guidelines are followed. The following Verilog HDL and VHDL examples are for your reference only and do not have functional simulation support.

Verilog HDL Example to Infer Fully Pipelined Multiplier

```
module mult (dataout, dataax, dataay, clk, reset);
output signed [35:0] dataout;
input signed [17:0] dataax, dataay;
input clk,reset;

reg signed [35:0] dataout;
reg signed [17:0] dataax_reg, dataay_reg;
wire signed [35:0] dataout_node;

always @(posedge clk or posedge reset)
begin
if (reset) begin
dataax_reg <= 0;
dataay_reg <= 0;
end else begin
dataax_reg <= dataax;
dataay_reg <= dataay;
end
end

assign dataout_node = dataax_reg * dataay_reg;

always @(posedge clk or posedge reset)
begin
if (reset)
dataout <= 0;
else
dataout <= dataout_node;
end
endmodule
```

VHDL Example to Infer Fully Pipelined Multiplier

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;
use ieee.numeric_std.all;

entity mult is
port (reset, clk : in std_logic;
dataax, dataay : in signed (17 downto 0));
dataout : out signed (35 downto 0));
end;
```



```
architecture arch of mult is
    signal dataax_reg, dataay_reg : signed (17 downto 0);
begin
    process (clk, reset)
    begin
        if (reset='1') then
            dataax_reg <= (others => '0');
            dataay_reg <= (others => '0');
        elsif (clk'event and clk='1') then
            dataax_reg <= dataax;
            dataay_reg <= dataay;
        end if;
    end process;

    process (clk, reset)
    begin
        if (reset='1') then
            dataout <= (others => '0');
        elsif (clk'event and clk='1') then
            dataout <= dataax_reg * dataay_reg;
        end if;
    end process;
end arch;
```

Appendix B. Rounding and Saturation

Rounding operation is done by adding a round constant (Rconst) to the adder/accumulator result before truncating the less significant bits. For example, to round a 16-bit number to an 8-bit number, a rounding constant is added to the 16-bit number and the upper byte is retained as rounded 8-bit result, while the lower byte is discarded.

The Lattice Nexus 2 sysDSP block can support several rounding modes with rounding constant provided through the C input. This approach enables rounding to any bit position. This section discusses three rounding modes, namely Round-Half-Up (RHU), Round-to-Zero (RTZ), and Round-to-Infinity (RTI).

Round-Half-Up (RHU) is to round every half point to $+\infty$ and is done by adding a rounding constant of 0.5 to the number to be rounded and truncating the lower bits. In binary form, this is done by adding $Rconst=2^{(n-1)}$ where n is the LSB to rounded integer.

$$(5.5)_{10} = (0101.10)_2$$

Integer LSB
bit N
↓
↑
bit
N-1

The following examples show the rounding of a 6-bit signed binary number (xxxx.xx) to 4 bits (xxxx) with RHU where the rounding constant is $(0000.10)_2 = (0.10)_2$.

Binary	Decimal	Rounding by Adding Rconst = 0.10	Rounded Binary	Rounded Decimal
0101.01	5.25	0101.01 + 0.10 = 0101.11	0101	5
0101.10	5.5	0101.10 + 0.10 = 0110.00	0110	6
0101.11	5.75	0101.11 + 0.10 = 0110.01	0110	6
1010.11	-5.25	1010.11 + 0.10 = 1011.01	1011	-5
1010.10	-5.5	1010.10 + 0.10 = 1011.00	1011	-5
1010.01	-5.75	1010.01 + 0.10 = 1010.11	1010	-6

Round-to-Zero (RTZ) rounds every half-point toward zero. It can be done by adding all 1s from bit 0 to bit N-2 and sign of the number to round ($z[47]$); N is the rounding position or the LSB of the rounded number. In sysDSP, Rconst can be fed to the C input and $z[47]$ feedback provides the sign of the number to be rounded.

$$z[47] + \sum_{i=0}^{N-2} 2^i$$

The following table lists examples of rounding 7-bit 2's complement number to 4 bits with RTZ. The rounding constant is $(0000.011)_2$, with addition of signed bit $(0000.00x)_2$.

Binary	Decimal	Rounding by Adding Rconst = 0.011 and Signed Bit	Rounded Binary	Rounded Decimal
0101.001	5.125	0101.001 + 0.011 + 0.000 = 0101.100	0101	5
0101.010	5.25	0101.010 + 0.011 + 0.000 = 0101.101	0101	5
0101.100	5.5	0101.100 + 0.011 + 0.000 = 0101.111	0101	5
0101.101	5.625	0101.101 + 0.011 + 0.000 = 0110.000	0110	6
0101.110	5.75	0101.110 + 0.011 + 0.000 = 0110.001	0110	6
0101.111	5.875	0101.111 + 0.011 + 0.000 = 0110.010	0110	6
1010.111	-5.125	1010.111 + 0.011 + 0.001 = 1011.011	1011	-5
1010.110	-5.25	1010.110 + 0.011 + 0.001 = 1011.010	1011	-5
1010.100	-5.5	1010.100 + 0.011 + 0.001 = 1011.000	1011	-5
1010.011	-5.625	1010.011 + 0.011 + 0.001 = 1010.111	1010	-6
1010.010	-5.75	1010.010 + 0.011 + 0.001 = 1010.110	1010	-6
1010.001	-5.875	1010.001 + 0.011 + 0.001 = 1010.101	1010	-6

Round-to-Infinity (RTI) rounds every half point away from zero. This involves adding a rounding constant of all 1s from bit N-2 to bit 0 through the C input, as well as inverse of the signed bit to the result before truncating. The z[47] feedback to carry input mux can be used for this purpose.

For example, to round a 7-bit signed binary number (xxxx.xxx) to 4 bits (xxxx) with RTI, the rounding constant is $(0000.011)_2$, with addition of inverted signed bit $(0000.00x)_2$.

Binary	Decimal	Rounding by adding Rconst = 0.011 and Signed Bit	Rounded Binary	Rounded Decimal
0101.001	5.125	$0101.001 + 0.011 + 0.001 = 0101.101$	0101	5
0101.010	5.25	$0101.010 + 0.011 + 0.001 = 0101.110$	0101	5
0101.100	5.5	$0101.100 + 0.011 + 0.001 = 0110.000$	0110	6
0101.101	5.625	$0101.101 + 0.011 + 0.001 = 0110.001$	0110	6
0101.110	5.75	$0101.110 + 0.011 + 0.001 = 0110.010$	0110	6
0101.111	5.875	$0101.111 + 0.011 + 0.001 = 0110.011$	0110	6
1010.111	-5.125	$1010.111 + 0.011 + 0.000 = 1011.010$	1011	-5
1010.110	-5.25	$1010.110 + 0.011 + 0.000 = 1011.001$	1011	-5
1010.100	-5.5	$1010.100 + 0.011 + 0.000 = 1010.111$	1010	-6
1010.011	-5.625	$1010.011 + 0.011 + 0.000 = 1010.110$	1010	-6
1010.010	-5.75	$1010.010 + 0.011 + 0.000 = 1010.101$	1010	-6
1010.001	-5.875	$1010.001 + 0.011 + 0.000 = 1010.100$	1010	-6

Figure 4.1 shows carry input mux selection for z[47] to support rounding operation.

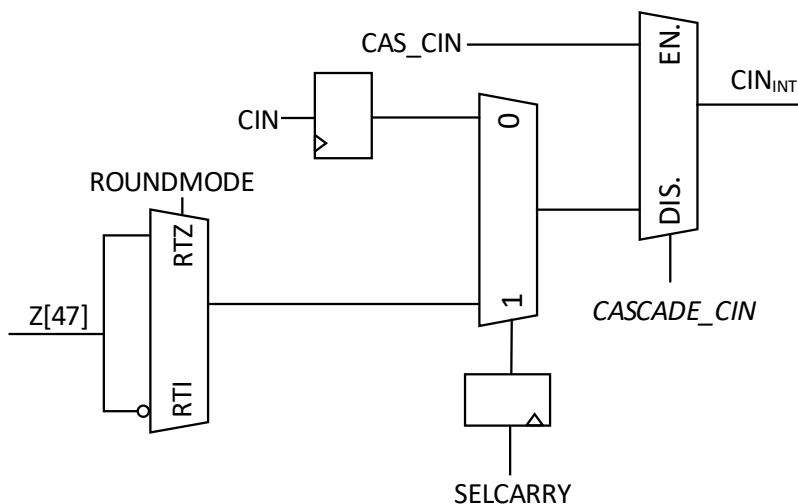


Figure 4.1. Carry Input Mux Selection

For saturation, the result of accumulator is fed to a saturation logic that is responsible for checking if the result exceeds the maximum or minimum limit defined by SATURATION_BITS. If the result exceeds the limit, the maximum or minimum value is chosen instead as accumulator output and overflow flags are asserted. The saturated values for a given N-bit saturation (“TO_NEG_MAX” mode) are:

$$-2^{N-1} \leq ZOUT < 2^{N-1}$$

For example, an eight-bit saturation has the range of (Min, Max) = $(-2^7, 2^7-1) = (-128, 127)$, which is the range of eight-bit 2’s complement number.

For saturation TO_ZERO mode, the output is saturated to zero every time the input is negative. In this mode, the positive value saturation and overflow flag behave the same way, but the negative overflow flag is asserted when the input is negative and the saturated value is zero. The saturated values for a given N-bit saturation (“TO_ZERO” mode) are:

$$0 \leq ZOUT < 2^{N-1}$$

When saturation is enabled, carryout output is no longer valid and must be ignored. Saturation logic only works in one sysDSP. When multiple sysDSPs are used to extend accumulator width or to form wider multiplier, the saturation logic must be disabled. Saturation logic is available in MULTADDSUB18 × 18A, DOTPRODADDSUB9 × 9, and DOTPRODADDBUS9 × 9A and requires ACCUM_EN = ENABLED. When SATURATION = DISABLED, overflow flag still reflects the overflow condition set by SATURATION_BITS but the output is not saturated.

References

- [Lattice Nexus 2](#) web page

A variety of technical notes for the Lattice Nexus 2 platform are available.

- [High-Speed PCB Design Considerations \(FPGA-TN-02178\)](#)
- [Lattice Nexus 2 Embedded Memory User Guide \(FPGA-TN-02366\)](#)
- [Lattice Nexus 2 Hardware Checklist \(FPGA-TN-02317\)](#)
- [Lattice Nexus 2 High-Speed I/O and External Memory Interface \(FPGA-TN-02372\)](#)
- [Lattice Nexus 2 Power User Guide \(FPGA-TN-02381\)](#)
- [Lattice Nexus 2 sysCLOCK PLL Design and User Guide \(FPGA-TN-02364\)](#)
- [Lattice Nexus 2 sysCONFIG User Guide \(FPGA-TN-02370\)](#)
- [Lattice Nexus 2 sysI/O User Guide \(FPGA-TN-02365\)](#)
- [Lattice Memory Mapped Interface and Lattice Interrupt Interface User Guide \(FPGA-UG-02039\)](#)
- [sub-LVDS Signaling Using Lattice Devices \(FPGA-TN-02028\)](#)
- [Thermal Management \(FPGA-TN-02044\)](#)
- [Using TraceID \(FPGA-TN-02084\)](#)

For more information on Lattice Nexus 2-related IP, reference designs, and board documents, refer to the following pages:

- [SGMII and Gb Ethernet PCS IP Core – Lattice Radiant Software \(FPGA-IPUG-02077\)](#)
- [IP and Reference Designs for Nexus 2 Devices](#)
- [Development Kits and Boards for Nexus 2 Devices](#)

For further information on interface standards refer to the following websites:

- JEDEC Standards (LVTTTL, LVCMOS, SSTL) – www.jedec.org
- PCI – www.pcisig.com

Other references:

- [Lattice Insights](#) for Lattice Semiconductor training courses and learning plans
- [Lattice Radiant](#) FPGA design software

Technical Support Assistance

Submit a technical support case through www.latticesemi.com/techsupport.

For frequently asked questions, refer to the Lattice Answer Database at <https://www.latticesemi.com/Support/AnswerDatabase>.

Revision History

Revision 0.81, November 2024

Section	Change Summary
All	<ul style="list-style-type: none">Changed the platform name from <i>Lattice Khronos</i> to <i>Lattice Nexus 2</i>.Made minor editorial fixes.
References	Updated the document list.

Revision 0.80, August 2024

Section	Change Summary
All	Preliminary release.



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