

# ANY-1 Instruction Set

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## Instruction Formats

Immediate Format:

59										28	27 24	23 16	15 8	7	0
											Sz <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		09h <sub>8</sub>

Register Format:

SR1 (one source register)

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>		0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		0Ch <sub>8</sub>	Func <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			03h <sub>8</sub>

SR2 (two source register)

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>		0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		Func <sub>8</sub>	Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			03h <sub>8</sub>

SR3 (three source register)

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	Func <sub>8</sub>		Sz <sub>4</sub>	m <sub>3</sub>	z		Rc <sub>8</sub>	Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			03h <sub>8</sub>

SR4 (four source register)

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	Rd <sub>8</sub>		Sz <sub>4</sub>	m <sub>3</sub>	z		Rc <sub>8</sub>	Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			03h <sub>8</sub>

z: 1 = zero vector element if mask bit clear, 0 = vector element unchanged (ignored for scalar ops)

m<sub>3</sub>: vector mask register (ignored for scalar operations).

Rm<sub>3</sub>: rounding mode

If any of Rt, Ra, Rb, Rc are vector registers, then the instruction is a vector instruction.

Rn<sub>8</sub>

0 to 63 scalar registers

64 to 127 vector registers

128 to 255 Rn is a seven-bit constant

U <sub>2</sub>	Execution Unit	Qualifier	
0	Integer	.int	
1	Floating-point	.fp	
2	Decimal floating-point	.dfp	
3	Posit	.pos	
Sz <sub>4</sub>	Size	Qualifier	Alt Qualifier
0	byte	.b	
1	wyde	.w	
2	tetra	.t	.s (single)
3	octa	.o	.d (double)
4	hexi	.h	.q (quad)
8	SIMD byte	.bp	

9	SIMD wyde	.wp	
10	SIMD tetra	.tp	.sp
11	SIMD octa	.op	.dp
12	SIMD hexi	.hp	.qp

## Example Instruction

add.int.o x1,x2,x3,x0 ; scalar add of integers x2,x3

add.int.o v1,v2,v3,v0 ; vector add of integers v2,v3

add.int.o v1,v2,v0,x4 ; vector add scalar integers v2,x4

add.fp.o v1,v2,v3,v0 ; vector add float-point double v2,v3

## Instructions

### Arithmetic / Logical

## ABS – Absolute Value

### Description:

This instruction takes the absolute value of a register and places the result in a target register.

### Instruction Format: SR1

59	5856	55	48	47 44	4341	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	0Ch <sub>8</sub>	4 <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			

### Operation:

```

If Ra < 0
    Rt = -Ra
else
    Rt = Ra

```

### Vector Operation

for x = 0 to VL - 1

if (Vm[x]) Rt[x] = Ra[x] < 0 ? -Ra[x] : Ra[x]

**Execution Units:** I, F, D, P

**Exceptions:** none

### Notes:

For sign-magnitude formats this instruction simply clears the MSB of the number. No rounding occurs.

# ADD - Addition

## Description:

Add two values. The first operand must be in a register. The second operand may be in a register or may be an immediate value specified in the instruction.

## Operation:

$$Rt = Ra + Imm$$

or

$$Rt = Ra + Rb + Rc$$

## Vector Operation

for  $x = 0$  to  $VL - 1$

if  $(Vm[x]) \quad Vt[x] = Va[x] + Vb[x] + Vc[x]$

else if  $(z) \quad Vt[x] = 0$

## Immediate Instruction Format

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		SZ <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		04h <sub>8</sub>

## Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>		4 <sub>8</sub>	SZ <sub>4</sub>	m <sub>3</sub>	z	RC <sub>8</sub>		Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		03h <sub>8</sub>

**Exceptions:** none



# ADDIS – Add Immediate Shifted

## Description:

Perform an addition operation between operands. The immediate constant is shifted left by a multiple of 32 bits and sign extended to the left and zero extended to the right before use.

## Immediate Instruction Format

59		28	27	24	23	16	15	8	7	0
	Constant <sub>32</sub>		Sh <sub>4</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		38h <sub>8</sub>	

## Operation

$$Rt = Ra + (\text{Immediate} \ll (32 * Sh))$$

**Exceptions:** none

# AND – Bitwise And

## Description:

Perform a bitwise ‘and’ operation between operands. The first operand must be in a register. The second operand may be in a register or may be an immediate value specified in the instruction. A third source operand must be in a register. The immediate constant is one extended before use.

## Immediate Instruction Format

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		SZ <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		08h <sub>8</sub>

## Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>		8 <sub>8</sub>	SZ <sub>4</sub>	m <sub>3</sub>	Z		Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		03h <sub>8</sub>

## Operation:

$Rt = Ra \& Imm$

or

$Rt = Ra \& Rb \& Rc$

## Vector Operation

for  $x = 0$  to  $VL - 1$

if  $(Vm[x]) \quad Vt[x] = Va[x] \& Vb[x] \& Vc[x]$

else if  $(z) \quad Vt[x] = 0$

**Exceptions:** none

# ANDIS – Bitwise And Immediate Shifted

## Description:

Perform a bitwise and operation between operands. The immediate constant is shifted left a multiple of 32 bits and one extended to the left and right before use.

## Immediate Instruction Format

59		28	2724	23	16	15	8	7	0
	Constant <sub>32</sub>		Sh <sub>4</sub>	Ra <sub>8</sub>		Rt <sub>8</sub>		39h <sub>8</sub>	

## Operation

$$Rt = Ra \& ((\text{Immediate} \ll (32 * Sh2)) \mid 0xFFFFFFFF)$$

**Exceptions:** none

## AISIP – Add Immediate Shifted to IP

### Description:

This instruction forms the sum of the instruction pointer and an immediate value shifted left a multiple of 32 times. The result is then placed in the target register. The low order 32 bits of the target register are zeroed out.

### Instruction Format

63		32	3128	2724	23	16	15	8	7	0
	Constant <sub>32</sub>		F <sub>4</sub>	Sh <sub>4</sub>		63 <sub>8</sub>		Rt <sub>8</sub>		Opcode <sub>8</sub>

**Exceptions:** none

## BLEND – Blend Colors

### Description:

This instruction blends two colors whose values are in Ra and Rb according to an alpha value in Rc. The resulting color is placed in register Rt. The alpha value is an eight-bit value assumed to be a binary fraction less than one. The color values in Ra and Rb are assumed to be RGB888 format colors. The result is a RGB888 format color. The high order eight bits of the result register are set to the high order eight bits of Ra. Note that a close approximation to  $1.0 - \alpha$  is used. Each component of the color is blended.

### Instruction Format: R3

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~ <sub>3</sub>	Rm <sub>3</sub>	30h <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

### Operation:

$$Rt.R = (Ra.R * \alpha) + (Rb.R * \sim\alpha)$$

$$Rt.G = (Ra.G * \alpha) + (Rb.G * \sim\alpha)$$

$$Rt.B = (Ra.B * \alpha) + (Rb.B * \sim\alpha)$$

**Clock Cycles:** 1

# BMM – Bit Matrix Multiply

BMM Rt, Ra, Rb

## Description:

The BMM instruction treats the bits of register Ra and register Rb as an 8x8 matrix and performs a bit matrix multiply of the two registers and stores the result in the target register. An alternate mnemonic for this instruction is MOR.

## Instruction Format: S2

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
Fn <sub>3</sub>	Rm <sub>3</sub>	03h <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	~ <sub>8</sub>			Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		03h <sub>8</sub>

Fn <sub>3</sub>	Function
0	MOR
1	MXOR
2	MORT (MOR transpose)
3	MXORT (MXOR transpose)
4 to 7	reserved

## Operation:

for I = 0 to 7  
 for j = 0 to 7  

$$Rt.bit[i][j] = (Ra[i][0] \& Rb[0][j]) \mid (Ra[i][1] \& Rb[1][j]) \mid \dots \mid (Ra[i][15] \& Rb[15][j])$$

**Clock Cycles:** 1

**Execution Units:** Integer ALU

**Exceptions:** none

## Notes:

The bits are numbered with bit 63 of a register representing I<sub>j</sub> = 0,0 and bit 0 of the register representing I<sub>j</sub> = 7,7.

## BYTNDX – Byte Index

### Description:

This instruction searches Ra, which is treated as an array of eight bytes, for a byte value specified by Rb or an immediate value and places the index of the byte into the target register Rt. If the byte is not found -1 is placed in the target register. A common use would be to search for a null byte. The index result may vary from -1 to +7. The index of the first found byte is returned (closest to zero).

The result tag type is set to integer.

### Instruction Format: SR2

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
0 <sub>3</sub>	Rm <sub>3</sub>	~ <sub>8</sub>		0 <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z		~ <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		1Ah <sub>8</sub>

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
1 <sub>3</sub>	Rm <sub>3</sub>	~ <sub>8</sub>		0 <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z		~ <sub>8</sub>	Imm <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		1Ah <sub>8</sub>

**R2 Supported Formats:** .w, .t, .o

**Clock Cycles:** 1

**Execution Units:** Integer ALU

### Operation:

Rt = Index of (Rb in Ra)

**Exceptions:** none

# CNTLZ – Count Leading Zeros

## Description:

Count the number of leading zeros (starting at the MSB) in Ra and place the count in the target register.

## Instruction Format: SR1

59	5856	55	48	47 44	4341	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	0Ch <sub>8</sub>	0 <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			

**R1 Supported Formats:** .b .w, .t, .o

**Clock Cycles:** 1

**Execution Units:** Integer ALU

**Exceptions:** none



# CNTPOP – Count Population

## Description:

Count the number of ones and place the count in the target register.

## Vector Operation

for  $x = 0$  to  $VL - 1$

if ( $Vm[x]$ )  $Vt[x] = \text{popcnt}(Va[x])$

## Instruction Format: SR1

59	5856	55	48	47 44	4341	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	0Ch <sub>8</sub>	2 <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			

**Execution Units:** integer ALU

**Exceptions:** none

# DEP – Deposit

## Description:

Insert to a bitfield. Rc specifies the bitfield offset, Rd specifies the width of the bitfield. Rb specifies the data to insert. Ra contains the original source data. The least significant Rd minus one bits of Rb are inserted into Ra at the position specified by Rc. The final result is placed into Rt.

This instruction may also be used to perform a left shift of a single register by specifying x0 for Ra.

## Formats Supported: SR3

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	Rd <sub>8</sub>		3 <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		1	Ch <sub>8</sub>

**Operation Size:** .w

**Execution Units:** integer ALU

**Exceptions:** none

**Example:**

## DIF – Difference

### Description:

This instruction computes the difference between two signed values in registers Ra and Rb and places the result in a target Rt register. The difference is calculated as the absolute value of Ra minus Rb.

**Instruction Format:** R2, R2S

**Supported Formats:** .b .w, .t, .o, .h, .bv, .wv, .tv, .ov, .hv

**Clock Cycles:** 1

**Execution Units:** Integer

### Operation:

$$Rt = \text{Abs}(Ra - Rb)$$

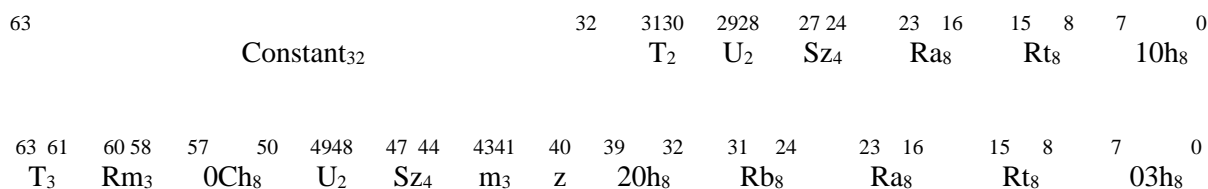
**Exceptions:** none

# DIV – Division

## Description:

Divide two operand values and place the result in the target register. The first operand must be in a register specified by the Ra field of the instruction. The second operand may be either a register specified by the Rb field of the instruction, an immediate value. Both operands are treated as signed values.

## Formats Supported: R2, RI



## Execution Units: ALU

## Clock Cycles: 67

## Exceptions: none

T2	Mnemonic	Trap
0	DIV	none
1	DIVZ	zero
2	DIVO	overflow
3	DIVZO	zero and overflow

## DIVR – Division

### Description:

This instruction is supplied as division is not commutative. Divide two operand values and place the result in the target register. The first operand must be an immediate value. The second operand must be a register specified by the Ra field of the instruction. Both operands are treated as signed values. This instruction allows a constant to be divided by a register value “reverse” to how the DIV instruction works.

### Formats Supported: RI

63			32	3130	2928	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>			T <sub>2</sub>	U <sub>2</sub>	Sz <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		21h <sub>8</sub>

### Execution Units: ALU

Clock Cycles: 67

Exceptions: none

## DIVU – Division Unsigned

### Description:

Divide two operand values and place the result in the target register. The first operand must be in a register specified by the Ra field of the instruction. The second operand may be either a register specified by the Rb field of the instruction, an immediate value. Both operands are treated as unsigned values.

### Formats Supported: R2, RI

59							28	27 24	23 16	15 8	7	0
		Constant <sub>32</sub>						Sz <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		11h <sub>8</sub>

59	58 56	55	48	47 44	4341	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>		Sz <sub>4</sub>	m <sub>3</sub>	Z		21h <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		03h <sub>8</sub>

### Execution Units: ALU

Clock Cycles: 67

Exceptions: none

## EXT –Extract Bitfield

### Description:

A bitfield is extracted from the source by shifting the source to the right and ‘and’ masking. The result is sign extended to the width of the machine. This instruction may be used to sign extend a value from an arbitrary bit position. The width specified should be one less than the desired width. The source is value is contained in the register pair Ra, Rb. The field width is specified by Rc and field offset by Rd.

### Instruction Format: SR4

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	Rd <sub>8</sub>	4 <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	1Ch <sub>8</sub>						

**Execution Units:** Integer ALU

**Exceptions:** none

**Notes:**

## EXTU –Extract Bitfield Unsigned

### Description:

A bitfield is extracted from the source by shifting the source to the right and ‘and’ masking. The result is zero extended to the width of the machine. This instruction may be used to zero extend a value from an arbitrary bit position. The width specified should be one less than the desired width. The source is a 128-bit value which is the concatenation of Rb and Ra. Rc contains the field offset, Rd the width.

### Instruction Format: SR4

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>		Rd <sub>8</sub>	5 <sub>4</sub>	m <sub>3</sub>	z		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		1Ch <sub>8</sub>

**Execution Units:** Integer ALU

**Exceptions:** none

**Notes:**

## FDP – Fused Dot Product

### Description:

Calculate the dot product  $x = (a * b) + (c * d)$ . The operations are fused together meaning no rounding occurs until the final product is produced.

### Instruction Format: SR4

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~ <sub>3</sub>	Rm <sub>3</sub>		Rd <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		37h <sub>8</sub>

## FFO –Find First One

### Description:

A bitfield contained in Ra is searched beginning at the most significant bit to the least significant bit for a bit that is set. The index into the bitfield of the bit that is set is stored in Rt. If no bits are set, then Rt is set equal to -1. The field offset is specified by Rc, the field width by Rd.

**Instruction Format:** BF

**Clock Cycles:**

**Execution Units:** Integer

**Exceptions:** none



## MAX – Maximum Value

### Description:

Determines the maximum of three values in registers Ra, Rb, Rc and places the result in the target register Rt.

### Instruction Format: R3

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	15h <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

### Operation:

IF Ra > Rb and Ra > Rc

Rt = Ra

else if Rb > Rc

Rt = Rb

else

Rt = Rc

## MIN – Minimum Value

### Description:

Determines the minimum of three values in registers Ra, Rb, Rc and places the result in the target register Rt.

### Instruction Format: R3

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	14h <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

### Operation:

IF Ra < Rb and Ra < Rc

Rt = Ra

else if Rb < Rc

Rt = Rb

else

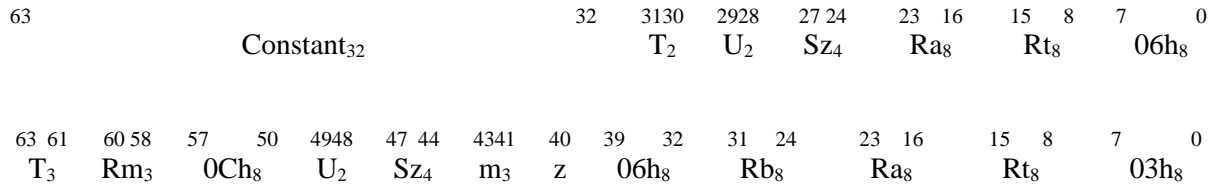
Rt = Rc

# MUL – Signed Multiply

## Description:

Multiply two values. The first operand must be in a register. The second operand may be in a register or may be an immediate value specified in the instruction. Both the operands are treated as signed values, the result is a signed result.

## Formats Supported: R2, RI



## Execution Units: ALU

## Vector Operation

for x = 0 to VL - 1

if (Vm[x]) Vt[x] = Va[x] \* Vb[x]

**Exceptions:** multiply overflow, if enabled

T2	Mnemonic	Trap
0	MUL	none
1		
2	MULO	overflow
3		

**Exceptions:** none

# MULU – Unsigned Multiply

## Description:

Multiply two values. The first operand must be in a register. The second operand may be in a register or may be an immediate value specified in the instruction. Both the operands are treated as unsigned values, the result is a unsigned result.

## Formats Supported: R2, RI

63		32	31 30	29 28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		T <sub>2</sub>	U <sub>2</sub>	Sz <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		0Eh <sub>8</sub>

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
T <sub>3</sub>	Rm <sub>3</sub>		0Ch <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		0Eh <sub>8</sub>	Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			03h <sub>8</sub>

## Vector Operation

for x = 0 to VL - 1

if (Vm[x]) Vt[x] = Va[x] \* Vb[x]

**Exceptions:** multiply overflow, if enabled

## MUX – Multiplex

### Description:

The MUX instruction performs a bit-by-bit copy of a bit of Rb to the target register if the corresponding bit in Ra is set, or a copy of a bit from Rc if the corresponding bit in Ra is clear.

### Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	1Bh <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z	Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>				03h <sub>8</sub>

**Exceptions:** none

**Execution Units:** integer ALU

# NEG - Negate

## Description:

This is an alternate mnemonic for the SUB instruction where the first register operand is R0.

## Instruction Format: SR2

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	5 <sub>8</sub>	Rb <sub>8</sub>	0 <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			

## Scalar Operation

$$Rt = 0 - Rb$$

## Vector Operation

for x = 0 to VL - 1

if (Vm[x]) Vt[x] = 0 - Vb[x]

else if (z) Vt[x] = 0

else Vt[x] = Vt[x]

## Notes

For sign-magnitude operations the sign bit is inverted, no subtract occurs. The result is not rounded.

## NOT – Logical Not

### Description:

This instruction takes the logical ‘not’ value of a register and places the result in a target register. If the source register contains a non-zero value, then a zero is loaded into the target. Otherwise, if the source register contains a zero a one is loaded into the target register.

### Instruction Format: SR2

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	0Ch <sub>8</sub>	4 <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

### Operation:

Rt = !Ra

**Exceptions:** none

# OR – Bitwise Or

## Description:

Perform a bitwise or operation between operands. The immediate constant is zero extended before use.

## Instruction Format: RI

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		SZ <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		09h <sub>8</sub>

## Instruction Format: R3

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>		09h <sub>8</sub>	SZ <sub>4</sub>	m <sub>3</sub>	Z		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		03h <sub>8</sub>

## Operation

$$Rt = Ra \mid \text{Immediate}$$

OR

$$Rt = Ra \mid Rb \mid Rc$$

## Vector Operation

for  $x = 0$  to  $VL-1$

if  $(Vm[x]) \quad Vt[x] = Va[x] \mid Vb[x] \mid Vc[x]$

**Exceptions:** none



## ORIS – Bitwise Or Immediate Shifted

## PTRDIF – Difference Between Pointers

### Description:

Subtract two values then shift the result right. Both operands must be in a register. The right shift is provided to accommodate common object sizes. It may still be necessary to perform a divide operation after the PTRDIF to obtain an index into odd sized or large objects. Rc may vary from zero to thirty-one.

The result tag is forced to integer.

### Instruction Format: R3

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	30h <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			

### Operation:

$$Rt = \text{Abs}(Ra - Rb) \gg Rc$$

### Clock Cycles: 1

### Execution Units: Integer

### Exceptions:

None

## SEQ – Set if Equal

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is equal to a second operand in register (Rb) or an immediate constant then the target register is set to a one, otherwise the target register is set to a zero.

The set operation sets the result tag to BOOL.

For floating-point operations positive and negative zero are considered equal.

If a vector operation is taking place then the target register is one of the vector mask registers.

### Immediate Instruction Format

59						28	27 24	23 16	15 8	7	0
Constant <sub>32</sub>							Sz <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	26h <sub>8</sub>	

### Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
----	-------	----	----	-------	-------	----	----	----	-------	-------	------	---	---

~ Rm<sub>3</sub> 0Ch<sub>8</sub> Sz<sub>4</sub> m<sub>3</sub> z 46h<sub>8</sub> Rb<sub>8</sub> Ra<sub>8</sub> Rt<sub>8</sub> 03h<sub>8</sub>

# SGE – Set if Greater Than or Equal

## Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is greater than or equal to a second operand in register (Rb) then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as signed values.

There is no immediate form to this instruction. An immediate equivalent may be achieved using the SGT instruction and adjusting the constant by one.

The set operation sets the result tag to BOOL.

## Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	2Dh <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

## SGEU – Set if Greater Than or Equal Unsigned

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is greater than or equal to a second operand in register (Rb) then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as signed values.

There is no immediate form to this instruction. An immediate equivalent may be achieved using the SGTU instruction and adjusting the constant by one.

The set operation sets the result tag to BOOL.

### Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	2Fh <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

## SGT – Set if Greater Than

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is greater than a second operand which is a constant supplied in the instruction, then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as signed values.

There is no register form of this instruction. The register equivalent operation may be performed using the SLT instruction and swapping the registers.

The set operation sets the result tag to BOOL.

### Immediate Instruction Format

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		SZ <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		29h <sub>8</sub>

## SGTU – Set if Greater Than Unsigned

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is greater than a second operand which is a constant supplied in the instruction, then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as signed values.

There is no register form of this instruction. The register equivalent operation may be performed using the SLTU instruction and swapping the registers.

## SIGN – Sign

### Synopsis

Take sign of value.  $R_t = R_a < 0 ? -1 : R_a = 0 ? 0 : 1$

### Description

The sign of a register is placed in the target register Rt.

### Vector Operation

for  $x = 0$  to  $VL - 1$

if (Vm[x])  $V_t[x] = V_a[x] < 0 ? -1 : V_a[x] = 0 ? 0 : 1$

## SLL –Shift Left Logical Pair

### Description:

Left shift a pair of operand values by an operand value and place the result in the target register. The upper 64 bits of the result are placed in the target register. Zeros are shifted into the least significant bits. The operand pair must be in registers specified by the Ra and Rb field of the instruction. The third operand may be either a register specified by the Rc field of the instruction, or an immediate value.

This instruction may also be used to perform a left rotate of a single register by specifying the same register for Ra and Rb.

### Formats Supported: SR3

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	10h <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			

**Operation Size:** .o, .t, .w, .b

**Execution Units:** integer ALU

**Exceptions:** none

**Example:**

## SLT – Set if Less Than

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is less than a second operand in either a register (Rb) or a constant supplied in the instruction, then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as signed values.

The register form of the instruction may also be used to test for greater than by swapping the operands around.

### Instruction Format: R2

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	2Ch <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>			



## SLE – Set if Less Than or Equal

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is less than or equal to a second operand in register (Rb) then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as signed values.

There is no immediate form to this instruction. An immediate equivalent may be achieved using the SLT instruction and adjusting the constant by one.

## SLEU – Set if Less Than or Equal

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is less than or equal to a second operand in register (Rb) then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as unsigned values.

There is no immediate form to this instruction. An immediate equivalent may be achieved using the SLTU instruction and adjusting the constant by one.

## SLTU – Set if Less Than Unsigned

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is less than a second operand in either a register (Rb) or a constant supplied in the instruction, then the target register is set to a one, otherwise the target register is set to a zero. The operands are treated as unsigned values.

The register form of the instruction may also be used to test for greater than by swapping the operands around.

### Instruction Format: R2

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>		Sz <sub>4</sub>	m <sub>3</sub>	Z		2Eh <sub>8</sub>	Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			03h <sub>8</sub>

## SNE – Set if Not Equal

### Description:

The set instruction places a 1 or 0 in the target register based on the relationship between the two source operands. If operand Ra is not equal to a second operand in register (Rb) or an immediate constant then the target register is set to a one, otherwise the target register is set to a zero.

For floating-point operations positive and negative zero are considered equal.

### Immediate Instruction Format

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		Sz <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		27h <sub>8</sub>

### Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		27h <sub>8</sub>		Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		03h <sub>8</sub>

## SRA –Shift Right Arithmetic Pair

### Description:

This is an alternate mnemonic for the signed field extract [EXT](#) instruction.

Right shift a pair of operand values by an operand value and place the result in the target register. The lower 64 bits of the result are placed in the target register. The sign bit is shifted into the most significant bits. The operand pair must be in registers specified by the Ra and Rb field of the instruction. The third operand may be either a register specified by the Rc field of the instruction, or an immediate value.

### Instruction Format: SR4

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	BFh <sub>8</sub>	4 <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	2Ch <sub>8</sub>						

**Operation Size:** .w

**Execution Units:** integer ALU

**Exceptions:** none

**Example:**

# SRL –Shift Right Logical Pair

## Description:

This is an alternate mnemonic for the unsigned field extract [EXTU](#) instruction.

Right shift a pair of operand values by an operand value and place the result in the target register. The lower 64 bits of the result are placed in the target register. Zeros are shifted into the most significant bits. The operand pair must be in registers specified by the Ra and Rb field of the instruction. The third operand may be either a register specified by the Rc field of the instruction, or an immediate value.

This instruction may also be used to perform a right rotate of a single register by specifying the same register for Ra and Rb.

## Instruction Format: SR4

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	BFh <sub>8</sub>	5 <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	2Ch <sub>8</sub>						

**Operation Size:** .w

**Execution Units:** integer ALU

**Exceptions:** none

**Example:**

# SUB - Subtract

## Description:

Subtract two values. Both operands must be in a register or small immediates.

## Instruction Format: SR2

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	0Ch <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	5 <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

## Scalar Operation

$$Rt = Ra - Rb$$

## Vector Operation

for  $x = 0$  to  $VL - 1$

if ( $Vm[x]$ )  $Vt[x] = Va[x] - Vb[x]$

else if ( $z$ )  $Vt[x] = 0$

else  $Vt[x] = Vt[x]$

## SUBF – Subtract From

### Description:

Subtract two values. The first operand must be in a register. The second operand must be an immediate value specified in the instruction. There is no register form for this instruction.

### Immediate Instruction Format

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		SZ <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		05h <sub>8</sub>

### Operation:

$$Rt = Imm - Ra$$

**Exceptions:** none

## U20NDX – UTF20 Index

### Description:

This instruction searches Ra, which is treated as an array of three UTF20 values, for a value specified by Rb or an immediate value and places the index of the value into the target register Rt. If the UTF20 value is not found -1 is placed in the target register. A common use would be to search for a null. The index result may vary from -1 to +2. The index of the first found value is returned (closest to zero).

The result is tagged as an integer.

### Instruction Format: SR2

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>		~ <sub>8</sub>	0 <sub>4</sub>	m <sub>3</sub>	z		~ <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		23h <sub>8</sub>

59	58 56	55	48	47 44	43 41	40	39		24	23 16	15 8	7	0
~	Rm <sub>3</sub>	Imm <sub>23..16</sub>		l <sub>4</sub>	m <sub>3</sub>	z			Imm <sub>15..0</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		23h <sub>8</sub>

**R2 Supported Formats:** .w

**Clock Cycles:** 1

**Execution Units:** Integer ALU

### Operation:

Rt = Index of (Rb in Ra)

**Exceptions:** none

## WYDNDX – Wyde Index

### Description:

This instruction searches Ra, which is treated as an array of four wydes, for a wyde value specified by Rb or an immediate value and places the index of the wyde into the target register Rt. If the wyde is not found -1 is placed in the target register. A common use would be to search for a null wyde. The index result may vary from -1 to +3. The index of the first found wyde is returned (closest to zero).

### Instruction Format: SR2

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
0 <sub>3</sub>	Rm <sub>3</sub>	~ <sub>8</sub>	0 <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z	~ <sub>8</sub>		Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	1Bh <sub>8</sub>		

63 61	60 58	57	50	49 48	47 44	43 41	40	39		24	23 16	15 8	7	0
1 <sub>3</sub>	Rm <sub>3</sub>	~ <sub>8</sub>	0 <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z			Imm <sub>16</sub>		Ra <sub>8</sub>	Rt <sub>8</sub>	1Bh <sub>8</sub>	

**R2 Supported Formats:** .t, .o

**Clock Cycles:** 1

**Execution Units:** Integer ALU

### Operation:

Rt = Index of (Rb in Ra)

**Exceptions:** none



# XOR – Bitwise Exclusive Or

## Description:

Perform a bitwise exclusive or operation between operands. The first operand must be in a register. The second operand may be a register or immediate value. A third operand must be in a register. The immediate constant is zero extended before use.

## Immediate Instruction Format

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		SZ <sub>4</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		0Ah <sub>8</sub>

## Register Instruction Format

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>		0Ah <sub>8</sub>	SZ <sub>4</sub>	m <sub>3</sub>	z		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		03h <sub>8</sub>

## Operation

$Rt = Ra \wedge \text{Immediate}$

OR

$Rt = Ra \wedge Rb \wedge Rc$

## Vector Operation

for  $x = 0$  to  $VL-1$

if  $(Vm[x]) \quad Vt[x] = Va[x] \wedge Vb[x] \wedge Vc[x]$

else if  $(z) \quad Vt[x] = 0$

else  $Vt[x] = Vt[x]$

**Exceptions:** none

## ZXB –Zero Extend Byte

### Description:

This is an alternate mnemonic for the bitfield extract (EXTU) operation.

### Instruction Format: EXT

A bitfield in the source specified by Ra is extracted, the result is copied to the target register. Rc specifies the bit offset. Rd specifies the bit width.

### Clock Cycles: 1

### Execution Units: Integer ALU

### Exceptions: none

### Notes:

## ZXW –Zero Extend Wyde

### Description:

This is an alternate mnemonic for the bitfield extract (EXTU) operation.

### Instruction Format: BFI

A bitfield in the source specified by Ra is extracted, the result is copied to the target register. Rc specifies the bit offset. Rd specifies the bit width.

### Clock Cycles: 1

### Execution Units: Integer ALU

### Exceptions: none

### Notes:

## **ZXT –Zero Extend Tetra**

### **Description:**

This is an alternate mnemonic for the bitfield extract (EXTU) operation.

### **Instruction Format:** EXT

A bitfield in the source specified by Ra is extracted, the result is copied to the target register. Rc specifies the bit offset. Rd specifies the bit width.

### **Clock Cycles:** 1

### **Execution Units:** Integer ALU

### **Exceptions:** none

### **Notes:**

# Memory Operations

## LDx – Load

### Description:

Load a value from memory into a register.

### Formats Supported:

#### Scalar Indexed Form (LD)

The effective address (EA) is calculated as the sum of Ra plus Rb multiplied by a scale and a constant.

63                      50    4948    47 44    4341    40    39    32    31    24    23    16    15    8    7    0  
           Const<sub>21..8</sub>            U<sub>2</sub>    SZ<sub>4</sub>    SC<sub>3</sub>    Z    Const<sub>7..0</sub>    Rb<sub>8</sub>    Ra<sub>8</sub>    Rt<sub>8</sub>    60h<sub>8</sub>  
 z: 1= zero extend, 0 = sign extend

Sc <sub>3</sub>	Multiplier
0	1
1	2
2	4
3	8
4	16

#### Operation:

$Rt = \text{Memory}[d + Ra + Rb * Sc]$

#### Vector forms

#### Stridden Form (LDS)

63                      50    4948    47 44    4341    40    39    32    31    24    23    16    15    8    7    0  
           Const<sub>21..8</sub>            U<sub>2</sub>    SZ<sub>4</sub>    m<sub>3</sub>    Z    Const<sub>7..0</sub>    Rb<sub>8</sub>    Ra<sub>8</sub>    Rt<sub>8</sub>    62h<sub>8</sub>

Data is loaded from memory addresses separated by the stride amount specified by register field Rb, beginning with the sum of Ra and an immediate value. If the vector mask bit is clear and the 'z' bit is set in the instruction then the corresponding element of the vector register is loaded with zero. If the vector mask bit is clear and the 'z' bit is clear in the instruction then the corresponding element of the vector register is left unchanged (no value is loaded from memory).

Elements are loaded only up to the length specified in the vector length register.

Vm[x]	z	Result
0	0	Vt[x] = Vt[x] (unchanged)
0	1	Vt[x] = 0 (set to zero)
1	0	Vt[x] = memory, sign extended

1      1       $Vt[x] = \text{memory, zero extended}$

$U_2$     Unit  
 0      integer  
 1      floating-point  
 2      decimal-float  
 3      posit

$Sz_4$     Operation Size  
 0      byte  
 1      wyde  
 2      tetra  
 3      octa  
 4      hexi (double octa)  
 5      quad octa  
 6      reserved  
 7      pointer

**Operation:**

```
for x = 0 to vector length
  if (Vm[x])
     $Vt[x] = \text{Memory}[d + Ra + Rb * x]$ 
  else
     $Vt[x] = z ? 0 : Vt[x]$ 
```

**Indexed Form**

Data is loaded from memory addresses beginning with the sum of Ra and a vector element from Vb.

63		50	4948	47 44	4341	40	39	32	31	24	23	16	15	8	7	0
	Const <sub>21..8</sub>		$U_2$	$Sz_4$	$m_3$	$z$	Const <sub>7..0</sub>		$Vb_8$		$Ra_8$		$Rt_8$			63h <sub>8</sub>

**Operation:**

```
n = 0
for x = 0 to vector length
  if (Vm[x])
     $Vt[x] = \text{Memory}[d + Ra + Vb[x]]$ 
  else
     $Vt[x] = z ? 0 : Vt[x]$ 
```

**Exceptions:** none

## LDB – Load Byte (8 bits)

### Description:

Data is loaded from the memory address which is the sum of an immediate value and the sum of Ra and Rb times a scale. The value loaded is sign extended from bit 7 to the machine width.

**Formats Supported:** LD

### Operation:

$$Rd = \text{Memory}_8[d + Ra + Rb * Sc]$$

**Exceptions:** none

## LDBZ – Load Byte, Zero Extend (8 bits)

### Description:

Data is loaded from the memory address which is the sum of an immediate value and the sum of Ra and Rb times a scale. The value loaded is zero extended from bit 8 to the machine width.

**Formats Supported:** LD

### Operation:

$$Rd = \text{Memory}_8[d + Ra + Rb * Sc]$$

**Exceptions:** none

## LDO – Load Octa (64 bits)

### Description:

Data is loaded into Rt from the memory address which is the sum of an immediate value and the sum of Ra and Rb scaled.

**Formats Supported:** RR,RI

### Operation:

$$Rt = \text{Memory}_{64}[d + Ra + Rb * Sc]$$

**Execution Units:** Mem

**Exceptions:** none

## LDT – Load Tetra (32 bits)

### Description:

Data is loaded from the memory address which is the sum of Ra and an immediate value or the sum of Ra and Rb scaled. The value loaded is sign extended from bit 31 to the machine width.

**Formats Supported:** RR,RI

### Operation:

$$R_t = \text{Memory}_{32}[d + R_a + R_b * S_c]$$

**Execution Units:** Mem

**Exceptions:** none

## LDTZ – Load Tetra, Zero Extend (32 bits)

### Description:

Data is loaded from the memory address which is the sum of Ra and an immediate value or the sum of Ra and Rb scaled. The value loaded is zero extended from bit 8 to the machine width.

**Formats Supported:** RR,RI

### Operation:

$$R_t = \text{Memory}_{32}[d + R_a + R_b * S_c]$$

**Execution Units:** Mem

**Exceptions:** none



## LDW – Load Wyde (16 bits)

### Description:

Data is loaded from the memory address which is the sum of Ra and an immediate value or the sum of Ra and Rb scaled. The value loaded is sign extended from bit 15 to the machine width.

**Formats Supported:** LD

### Operation:

$$Rt = \text{Memory}_{16}[d + Ra + Rb * Sc]$$

**Execution Units:** Mem

**Exceptions:** none

## LDWZ – Load Wyde, Zero Extend (16 bits)

### Description:

Data is loaded from the memory address which is the sum of Ra and an immediate value or the sum of Ra and Rb scaled. The value loaded is zero extended from bit 16 to the machine width.

**Formats Supported:** LD

### Operation:

$$Rt = \text{Memory}_{16}[d + Ra + Rb * Sc]$$

**Execution Units:** Mem

**Exceptions:** none

# LEA – Load Effective Address

## Description:

This instruction computes the effective address for a load/store operation. The data type tag for the target register is set to indicate it contains a pointer.

## Formats Supported:

### Scalar Indexed Form (LD)

The effective address (EA) is calculated as the sum of Ra plus Rb multiplied by a scale and a constant and placed in target register Rt.

63		50		4948		47 44		4341		40		39 32		31 24		23 16		15 8		7		0
	Const <sub>21..8</sub>		U <sub>2</sub>	Sz <sub>4</sub>	Sc <sub>3</sub>	z	Const <sub>7..0</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	68h <sub>8</sub>											

z: 1= zero extend, 0 = sign extend

Sc <sub>3</sub>	Multiplier
0	1
1	2
2	4
3	8
4	16

### Operation:

$Rt = d + Ra + Rb * Sc$

## Vector forms

### Stridden Form (LDS)

63		50		4948		47 44		4341		40		39 32		31 24		23 16		15 8		7		0
	Const <sub>21..8</sub>		U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Const <sub>7..0</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	69h <sub>8</sub>											

Vm[x]	z	Result
0	0	Vt[x] = Vt[x] (unchanged)
0	1	Vt[x] = 0 (set to zero)
1	0	Vt[x] = memory address
1	1	Vt[x] = memory address

U <sub>2</sub>	Unit
0	integer
1	floating-point
2	decimal-float
3	posit

Sz <sub>4</sub>	Operation Size
0	byte
1	wyde
2	tetra
3	octa
4	hexi

**Operation:**

```

for x = 0 to vector length
  if (Vm[x])
    Vt[x] = d + Ra + Rb * x
  else
    Vt[x] = z ? 0 : Vt[x]

```

**Indexed Form**

63		48	47 44	43 41	40	39 32	31 24	23 16	15 8	7	0
Const <sub>23..8</sub>		Sz <sub>4</sub>	m <sub>3</sub>	z	Const <sub>7..0</sub>	Vb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	6Ah <sub>8</sub>		

**Operation:**

```

n = 0
for x = 0 to vector length
  if (Vm[x])
    Vt[x] = d + Ra + Vb[x]
  else
    Vt[x] = z ? 0 : Vt[x]

```

**Exceptions:** none

## LSM – Load or Store Multiple

### Description:

The LSM prefix instruction allows multiple registers or values to be loaded or stored using the following load / store instruction. Register x0 cannot be stored using this prefix. If the register spec field is zero then no load or store takes place at that position. Up to seven registers may be specified.

### Formats Supported: LSM

63	56	55	48	47	40	39	32	31	24	23	16	15	8	7	0
Rg <sub>8</sub>		Rf <sub>8</sub>		Re <sub>8</sub>		Rd <sub>8</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		6Fh <sub>8</sub>	

### Execution Units: Mem

### Exceptions: none

# STx – Store

## Description:

Store values to memory. Either the contents of a scalar or vector register or a seven-bit immediate constant may be stored. Both scalar and vector store operations are possible.

## Formats Supported:

### Scalar Indexed Form (ST)

The effective address (EA) is calculated as the sum of Ra plus Rb multiplied by a scale and a constant.

59                      48    47 44    43 41    40    39    32    31    24    23    16    15    8    7    0  
          Const<sub>19..8</sub>           Sz<sub>4</sub>    Sc<sub>3</sub>    z    Const<sub>7..0</sub>    Rb<sub>8</sub>           Ra<sub>8</sub>           Rs<sub>8</sub>           70h<sub>8</sub>

z: 1= zero extend, 0 = sign extend

Sc <sub>3</sub>	Multiplier
0	1
1	2
2	4
3	8
4	16

### Operation:

Memory[d+Ra + Rb \* Sc] = Rs

## Vector forms

### Stridden Form (STS)

63                      50    49 48    47 44    43 41    40    39    32    31    24    23    16    15    8    7    0  
          Const<sub>21..8</sub>           U<sub>2</sub>    Sz<sub>4</sub>    m<sub>3</sub>    z    Const<sub>7..0</sub>    Rb<sub>8</sub>           Ra<sub>8</sub>           Rs<sub>8</sub>           72h<sub>8</sub>

Data is stored to memory addresses separated by the stride amount specified by register field Rb, beginning with the sum of Ra and an immediate value. If the vector mask bit is clear and the 'z' bit is set in the instruction then memory for the corresponding element of the vector register is stored with zero. If the vector mask bit is clear and the 'z' bit is clear in the instruction then memory corresponding to the element of the vector register is left unchanged (no value is stored to memory).

Elements are loaded only up to the length specified in the vector length register.

Vm[x]	z	Result
0	0	Memory = Memory (unchanged)
0	1	Memory = 0 (set to zero)

1     0     memory = Vt[x]  
 1     1     memory = Vt[x]

U<sub>2</sub>     Unit  
 0     integer  
 1     floating-point  
 2     decimal-float  
 3     posit

Sz<sub>4</sub>     Operation Size  
 0     byte  
 1     wyde  
 2     tetra  
 3     octa  
 4     hexi  
 5,6     reserved  
 7     pointer

**Operation:**

```
for x = 0 to vector length
  if (Vm[x])
    Memory[d+Ra + Rb * x] = Vt[x]
  else
    Memory[d+Ra + Rb * x] = z ? 0 : Memory[d+Ra + Rb * x]
```

**Indexed Form**

Data is stored to memory addresses beginning with the sum of Ra and a vector element from Vb.

63		48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
	Const <sub>23..8</sub>		Sz <sub>4</sub>	m <sub>3</sub>	z	Const <sub>7..0</sub>	Vb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>				73h <sub>8</sub>

**Operation:**

```
n = 0
for x = 0 to vector length
  if (Vm[x])
    Memory[d + Ra + Vb[x]] = Vt[x]
  else
    Memory = z ? 0 : Memory
```

**Exceptions:** none

## STB – Store Byte (8 bits)

### Description:

This instruction stores a byte (8 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled.

### Instruction Format: ST

### Operation:

$$\text{Memory}_8[d + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

## STBZ – Store Byte and Zero (8 bits)

### Description:

This instruction stores a byte (8 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled. After the byte is stored to memory the register is zeroed out.

### Instruction Format: ST

### Operation:

$$\begin{aligned} \text{Memory}_8[d + \text{Ra} + \text{Rb} * \text{Sc}] &= \text{Rs} \\ \text{Rs} &= 0 \end{aligned}$$

## STO – Store Octa (64 bits)

### Description:

This instruction stores an octa-byte (64 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled.

### Instruction Format: ST

### Operation:

$$\text{Memory}_{64}[\text{d} + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

## STOZ – Store Octa and Zero (64 bits)

### Description:

This instruction stores an octa-byte (64 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled. After the octa is stored to memory the register is zeroed out.

### Instruction Format: ST

### Operation:

$$\text{Memory}_{64}[\text{d} + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

$$\text{Rs} = 0$$



## STPTR – Store Pointer (64 bits)

### Description:

This instruction stores an octa-byte (64 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled. STPTR begins a series of stores to memory addresses scaled by eight bits, until the address zero is reached. The first store proceeds normally, for the second and subsequent stores a byte store operation takes place with the value zero being to memory.

The purpose of the STPTR instruction is to allow a code dense implementation of a write barrier that indicates where in memory a pointer is stored with increasing resolution.

This instruction assumes that card memory used to record pointer locations is located at the low end of the memory system.

### Instruction Format: ST

### Operation:

```

ea = d + Ra + Rb*Sc
Memory64[ea] = Rs
while ea <> 0
    ea = ea >> 8
    Memory8[ea] = 0

```

## STT – Store Tetra (32 bits)

### Description:

This instruction stores a tetra-byte (32 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled.

### Instruction Format: ST

### Operation:

$$\text{Memory}_{32}[\text{d} + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

## STTZ – Store Tetra and Zero (32 bits)

### Description:

This instruction stores a tetra-byte (32 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled. After the tetra is stored to memory the register is zeroed out.

### Instruction Format: ST

### Operation:

$$\text{Memory}_{32}[\text{d} + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

$$\text{Rs} = 0$$

## STW – Store Wyde (16 bits)

### Description:

This instruction stores a byte (16 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled.

### Instruction Format: ST

### Operation:

$$\text{Memory}_{16}[\text{d} + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

## STWZ – Store Wyde and Zero (16 bits)

### Description:

This instruction stores a byte (16 bit) value to memory. The memory address is calculated as the sum of an immediate constant and the sum of Ra and Rb scaled. After the wyde is stored to memory the register is zeroed out.

### Instruction Format: ST

**Operation:**

$$\text{Memory}_{16}[\text{d} + \text{Ra} + \text{Rb} * \text{Sc}] = \text{Rs}$$

$$\text{Rs} = 0$$

## Flow Control (Branch Unit) Operations

### BEQ – Branch if Equal

#### Description:

This instruction branches to the target address if the contents of Ra and Rb are equal, otherwise program execution continues with the next instruction. The target address is formed as the sum of Rc and a displacement. If Rc is r63 then the instruction pointer value is used.

#### Formats Supported: BR

59	48	47 44	43 40	39 32	31 24	23 16	15 8	7 0
Displacement <sub>18..7</sub>	Sz <sub>4</sub>	Disp <sub>6..3</sub>	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	4Eh <sub>8</sub>	

#### Operation:

```

Rt = IP + 8
If (Ra = Rb)
    If (Rc = 63)
        IP = IP + Displacement
    Else
        IP = Rc + Displacement

```

#### Execution Units: Branch

#### Exceptions: none

#### Notes:

For a floating-point comparison positive and negative zero are considered equal.

## BGE – Branch if Greater Than or Equal

### Description:

This instruction branches to the target address if the contents of Ra is greater than or equal to Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as signed values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the instruction pointer value is used.

### Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0
Displacement <sub>20..7</sub>		U <sub>2</sub>	SZ <sub>4</sub>	Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		49h <sub>8</sub>			

### Operation:

$$Rt = IP + 8$$

If (Ra >= Rb)

$$IP = Rc + \text{Displacement}$$

### Execution Units: Branch

### Exceptions: none

## BGEU – Branch if Greater Than or Equal Unsigned

### Description:

This instruction branches to the target address if the contents of Ra is greater than or equal to Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as unsigned values. The target address is formed as the sum of Rc and a displacement. If Rc is r63 then the program counter value is used.

### Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0
Displacement <sub>20..7</sub>				U <sub>2</sub>	SZ <sub>4</sub>	Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		4Bh <sub>8</sub>	

### Operation:

$Rt = IP + 8$

If (Ra >= Rb)

PC = Rc + Displacement

### Execution Units: Branch

### Exceptions: none

## BGT – Branch if Greater Than

### Description:

This instruction is an alternate mnemonic for the [BLT](#) instruction where the register operands have been swapped.

This instruction branches to the target address if the contents of Ra is less than Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as signed values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

### Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0
Displacement <sub>20..7</sub>				U <sub>2</sub>	SZ <sub>4</sub>	Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		48h <sub>8</sub>	

### Operation:

$Rt = IP + 8$

If (Ra < Rb)

PC = Rc + Displacement

### Execution Units: Branch

### Exceptions: none



# BGTU – Branch if Greater Than Unsigned

## Description:

This instruction is an alternate mnemonic for the [BLTU](#) instruction where the register operands have been swapped.

This instruction branches to the target address if the contents of Ra is less than Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as unsigned values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

## Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0
Displacement <sub>20..7</sub>		U <sub>2</sub>		Sz <sub>4</sub>		Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		4Ah <sub>8</sub>	

## Operation:

$$Rt = IP + 8$$

If (Ra < Rb)

$$PC = Rc + \text{Displacement}$$

## Execution Units: Branch

## Exceptions: none



# BNE – Branch if Not Equal

## Description:

This instruction branches to the target address if the contents of Ra and Rb are not equal, otherwise program execution continues with the next instruction. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

## Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0	
Displacement <sub>20..7</sub>				U <sub>2</sub>		SZ <sub>4</sub>		Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		4Fh <sub>8</sub>

## Operation:

$$Rt = IP + 8$$

If (Ra <> Rb)

$$PC = Rc + \text{Displacement}$$

## Execution Units: Branch

## Exceptions: none

## BLE – Branch if Less Than or Equal

### Description:

This is an alternate mnemonic for the BGE instruction, where the register operands have been swapped.

This instruction branches to the target address if the contents of Ra is greater than or equal to Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as signed values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

### Formats Supported: BR

### Operation:

If (Ra  $\geq$  Rb)  
PC = Rc + Displacement

### Execution Units: Branch

### Exceptions: none

## BLEU – Branch if Less Than or Equal Unsigned

### Description:

This is an alternate mnemonic for the BGEU instruction, where the register operands have been swapped.

This instruction branches to the target address if the contents of Ra is greater than or equal to Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as unsigned values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

### Formats Supported: BR

### Operation:

If (Ra  $\geq$  Rb)  
PC = Rc + Displacement

### Execution Units: Branch

### Exceptions: none

## BLT – Branch if Less Than

### Description:

This instruction branches to the target address if the contents of Ra is less than Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as signed values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

### Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0
Displacement <sub>20..7</sub>		U <sub>2</sub>	Sz <sub>4</sub>	Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		4Ah <sub>8</sub>			

### Operation:

$$Rt = IP + 8$$

If (Ra < Rb)

$$PC = Rc + \text{Displacement}$$

**Execution Units:** Branch

**Exceptions:** none

## BLTU – Branch if Less Than Unsigned

### Description:

This instruction branches to the target address if the contents of Ra is less than Rb, otherwise program execution continues with the next instruction. The values in Ra and Rb are treated as unsigned values. The target address is formed as the sum of Rc and a displacement. If Rc is x63 then the program counter value is used.

### Formats Supported: BR

63	50	49	48	47	44	43	40	39	32	31	24	23	16	15	8	7	0
Displacement <sub>20..7</sub>		U <sub>2</sub>	Sz <sub>4</sub>	Disp <sub>6..3</sub>		Rc <sub>8</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>		4Ah <sub>8</sub>			

### Operation:

$$Rt = IP + 8$$

If (Ra < Rb)

$$PC = Rc + \text{Displacement}$$

**Execution Units:** Branch

**Exceptions:** none



## BRA – Unconditional Branch

### Description:

This instruction is an alternate mnemonic for the [BEQ](#) instruction.

### Formats Supported: BR

59	48	47 44	43 40	39 32	31 24	23 16	15 8	7	0
Displacement <sub>18..7</sub>	Sz <sub>4</sub>	Disp <sub>6..3</sub>	Rc <sub>8</sub>	0 <sub>8</sub>	0 <sub>8</sub>	Rt <sub>8</sub>	4Eh <sub>8</sub>		

**Flags Affected:** none

### Operation:

$$Rt = IP + 8$$

$$IP = Rc + \text{Displacement}$$

**Execution Units:** Branch

**Exceptions:** none

**Notes:**

# CHK – Check Register Against Bounds

## Description:

A register is compared to two values. If the register is outside of the bounds then an exception will occur.

## Instruction Format: RI

59		28	27 24	23 16	15 8	7	0
	Constant <sub>32</sub>		Cn <sub>4</sub>	Ra <sub>8</sub>	Rs <sub>8</sub>		22h <sub>8</sub>

Cn <sub>2</sub>	Interpretation
0	Rs <= Ra <= Constant
1	Rs < Ra <= Constant
2	Rs <= Ra < Constant
3	Rs < Ra < Constant

## Instruction Format: S3

59	58 56	55	48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~	Rm <sub>3</sub>	Func <sub>8</sub>		Cn <sub>4</sub>	m <sub>3</sub>	z		Rc <sub>8</sub>	Rb <sub>8</sub>		Ra <sub>8</sub>		~ <sub>8</sub>			03h <sub>8</sub>

## Supported Formats: .o

## Clock Cycles: 1

**Execution Units:** Integer ALU, Float, Decimal Float, Posit

**Exceptions:** bounds check

## Notes:

The system exception handler will typically transfer processing back to a local exception handler.

# JAL – Jump and Link

## Description:

This instruction may be used to both call a subroutine and return from it. The address of the instruction after the JAL is stored in the specified return address register (Rt) then a jump to the address specified in the instruction plus an index register value is made. The address range is 39 bits or 512GB.

The return address register is assumed to be x1 if not otherwise specified. The JAL instruction does not require space in branch predictor tables.

If x63 is specified for Ra then the current instruction pointer value is used.

Note the branch instructions may also be used to return from a subroutine.

## Formats Supported: JAL

59		24	23	16	15	10	9	8	7	0
	Constant <sub>38..3</sub>			Ra <sub>8</sub>	Cnst <sub>6</sub>		Rt <sub>2</sub>			40h <sub>8</sub>

**Flags Affected:** none

## Operation:

$$Rt = IP + Cnst_6 * 8$$

If Ra=63

$$IP = IP + \text{displacement}$$

Else

$$IP = Ra + \text{Displacement}$$

**Execution Units:** Branch

**Exceptions:** none

**Notes:**

# JMP – Jump

## Description:

This instruction is an alternate mnemonic for the [JAL](#) instruction. It may be used to jump directly to a specific address. The address range is 39 bits or 512GB.

The return address register is assumed to be x0 (discarding the return address). The JMP instruction does not require space in branch predictor tables.

If r63 is specified for Ra then the current instruction pointer value is used.

## Formats Supported: JAL

59		24	23	16	15	10	9	8	7	0
	Constant <sub>38..3</sub>			Ra <sub>8</sub>	Cnst <sub>6</sub>		0 <sub>2</sub>			40h <sub>8</sub>

**Flags Affected:** none

## Operation:

If Ra=63

IP = IP + displacement

Else

IP = Ra + Displacement

**Execution Units:** Branch

**Exceptions:** none

**Notes:**



## RET – Return from Subroutine

### Description:

This instruction is an alternate mnemonic for the [JAL](#) instruction. Register Ra is assumed to be x1 and register Rt is assumed to be x0. The constant is assumed to be zero.

### Formats Supported: JAL

59		24	23	16	15	8	7	0
	Constant <sub>39,4</sub>			01 <sub>8</sub>		00 <sub>8</sub>		40h <sub>8</sub>

**Flags Affected:** none

**Operation:**

**Execution Units:** Branch

**Exceptions:** an unimplemented instruction exception may occur if a vector register is specified.

**Notes:**

Return address prediction hardware may make use of the RET instruction.

## System Instructions

### BRK – Break

#### Description:

This instruction initiates the processor debug routine. The processor enters debug mode. The cause code register is set to the value specified in the instruction. Interrupts are disabled. The instruction pointer is reset to the contents of tvec[4] and instructions begin executing. There should be a jump instruction placed at the break vector location. The address of the BRK instruction is stored in the EIP register.

#### Formats Supported: BRK

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	~ <sub>8</sub>	Sz <sub>4</sub>	m <sub>3</sub>	Z	~ <sub>8</sub>	~ <sub>8</sub>	Cause <sub>8</sub>	0 <sub>8</sub>	00h <sub>8</sub>			

#### Operation:

PMSTACK = (PMSTACK << 4) | 10

CAUSE = Const<sub>8</sub>

EIP = IP

IP = tvec[4]

#### Execution Units: Branch

#### Clock Cycles:

#### Exceptions: none

#### Notes:

## CSRx – Control and Special / Status Access

### Description:

The CSR instruction group provides access to control and status registers in the core. For the read operation the current value of the CSR is placed in the target register Rt.

### Instruction Format: CSR

59 5856 55 48 47 44 4341 40 39 24 23 16 15 8 7 0  
 ~ Op<sub>3</sub> 0Fh<sub>8</sub> SZ<sub>4</sub> m<sub>3</sub> Z Regno<sub>16</sub> Ra<sub>8</sub> Rt<sub>8</sub> 44h<sub>8</sub>

Op <sub>3</sub>	Operation
0	CSRR Only read the CSR, no update takes place, Ra should be R0.
1	CSRW Write to CSR
2	CSRS Set CSR bits
3	CSRC Clear CSR bits
4 to 7	reserved

CSRS and CSRC operations are only valid on registers that support the capability.

The Regno<sub>[15..12]</sub> field is reserved to specify the operating mode. Note that registers cannot be accessed by a lower operating mode.

**Execution Units:** Integer, the instruction may be available on only a single execution unit (not supported on all available integer units).

**Clock Cycles:** 1

**Exceptions:** privilege violation attempting to access registers outside of those allowed for the operating mode.

## PFI – Poll for Interrupt

### Description:

The poll for interrupt instruction polls the interrupt status lines and performs an interrupt service if an interrupt is present. Otherwise, the PFI instruction is treated as a NOP operation. Polling for interrupts is performed by managed code. PFI provides a means to process interrupts at specific points in running software.

### Instruction Format:

6361	60 58	57 50	4948	47 44	4341	40	39 32	31 24	23 16	15 8	7	0
~ <sub>3</sub>	Op <sub>3</sub>	??h <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	0 <sub>8</sub>	0 <sub>8</sub>	0 <sub>8</sub>	0 <sub>8</sub>	44h <sub>8</sub>	

**Clock Cycles:**

**Execution Units: Branch**

# REX – Redirect Exception

## Description:

This instruction redirects an exception from an operating mode to a lower operating mode. This instruction if successful jumps to the target exception handler and does not return. If this instruction fails execution will continue with the next instruction.

This instruction may fail if exceptions are not enabled at the target level.

The location of the target exception handler is found in the trap vector register for that operating mode (tvec[xx]).

The cause (cause) and bad address (badaddr) registers of the originating mode are copied to the corresponding registers in the target mode.

## Instruction Format: REX

59	58 56	55	48	47 44	43 41	40	39	32	31 24	23 16	15 8	7	0
~	Rm <sub>3</sub>	7Ah <sub>8</sub>	Tm <sub>3</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Imm <sub>8</sub>	Ra <sub>8</sub>	0 <sub>8</sub>	44h <sub>8</sub>			

Tm<sub>3</sub>

- 0      redirect to user mode
- 1      redirect to supervisor mode
- 2      redirect to hypervisor mode
- 3      redirect to machine mode
- 4 to 7   not used

**Clock Cycles:** 4

**Execution Units:** Branch

Example:

```

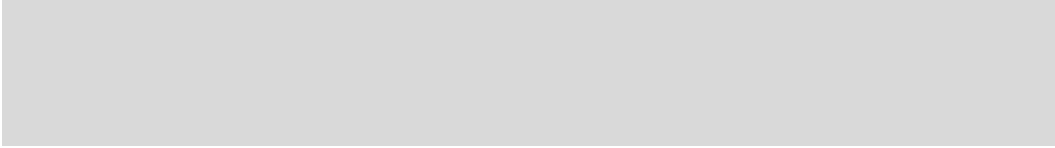
REX 1          ; redirect to supervisor handler

; If the redirection failed, exceptions were likely disabled at the target level.

; Continue processing so the target level may complete its operation.

RTE           ; redirection failed (exceptions disabled ?)

```

**Notes:**

Since all exceptions are initially handled in debug mode the debug handler must check for disabled lower mode exceptions.

## RTE – Return from Exception

### Description:

Restore the previous interrupt enable setting and operating level and transfer program execution back to the address in the exception address register (EIP). One of sixty-four semaphore registers specified by the Rb field of the instruction may also be cleared. Semaphore register zero is always cleared by this instruction.

This instruction may be encoded to return a short distance past the exception address point. This may be useful to return to the next instruction or return to a point past inline parameters. The Ra field specifies a return offset in terms of instruction words.

There is really only a single instruction to return from any mode for an exception. Although there are several additional mnemonics.

### Instruction Format:

6361	60 58	57 50	4948	47 44	4341	40	39 32	31 24	23 16	15 8	7 0
~ <sub>3</sub>	Op <sub>3</sub>	13h <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	0 <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	44h <sub>8</sub>

**Flags Affected:** none

### Operation:

PMSTACK = PMSTACK >> 4  
 Semaphore[0] = 0  
 Semaphore[Rb] = 0  
 IP = EIP + Ra

**Execution Units:** Branch

**Clock Cycles:**

**Exceptions:** none

**Notes:**

# SYNC -Synchronize

## Description:

All instructions for a particular unit before the SYNC are completed and committed to the architectural state before instructions of the unit type after the SYNC are issued. This instruction is used to ensure that the machine state is valid before subsequent instructions are executed.

## Instruction Format:

6361	60 58	57 50	4948	47 44	4341	40	39 32	31 24	23 16	15 8	7 0
~ <sub>3</sub>	Op <sub>3</sub>	??h <sub>8</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Rc <sub>8</sub>	Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	44h <sub>8</sub>





## TLBRW – Read / Write TLB

### Description:

This instruction both reads and writes the TLB. Which translation entry to update comes from the value in Rs1. The update value comes from the value in Rs2. Rs2 contains the virtual page number, ASID, and physical page number. The current value of the entry selected by Rs1 is copied to Rd. The TLB will be written only if bit 63 of Rs1 is set.

The entry number for Rs1 comes from virtual address bits 14 to 23.

Page numbers are in terms of a 16kB page size.

### Instruction Format:

63 61 60 58 57 50 49 48 47 44 43 41 40 39 32 31 24 23 16 15 8 7 0  
 ~<sub>3</sub> Op<sub>3</sub> 1Eh<sub>8</sub> U<sub>2</sub> Sz<sub>4</sub> m<sub>3</sub> z 0<sub>8</sub> 0<sub>8</sub> Ra<sub>8</sub> Rt<sub>8</sub> 44h<sub>8</sub>

Clock Cycles: 5

### Execution Units: Memory

Rs1 Value Format

63	62	12	11	10	9	0
w	~				way	entry no

Rs2/Rd Value Format

63	56	55	54	53	52	48	47	32	31	20	19	0
ASID	G	D	A	UCRWX	VPN			~		PPN		

Bits		Meaning
0 to 19	PPN	Physical page number
20 to 31	~	reserved (expansion of physical page number)
32 to 49	VPN	Virtual page number high address order bits 24 to 39
48	X	1 = page is executable
49	W	1 = page is writeable
50	R	1 = page is readable
51	C	1 = page is cachable
52	U	reserved for system usage
53	A	Accessed, set if translation was used
54	D	Dirty, set if a write occurred to the page
55	G	Global, global translation indicator
56 to 63	ASID	ASID address space identifier

### Instruction Format: OSR2

Exceptions: none

## Vector Specific Instructions

### Arithmetic / Logical

#### V2BITS

##### Synopsis

Convert Boolean vector to bits.

##### Description

The least significant bit of each vector element is copied to the corresponding bit in the target register. The target register is a scalar register.

##### Instruction Format

63 61	60 58	57	50	49 48	47 44	43 41	40	39	32	31	24	23	16	15	8	7	0
~ <sub>3</sub>	Rm <sub>3</sub>	0Ch <sub>8</sub>	U <sub>2</sub>	~ <sub>4</sub>	m <sub>3</sub>	Z	~ <sub>8</sub>	21h <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>	03h <sub>8</sub>						

##### Operation

For x = 0 to VL-1

if (Vm[x])

Rt[x] = Va[x].LSB

else if (z)

Rt[x] = 0

**Exceptions:** none

# VACC - Accumulate

## Synopsis

Register accumulation.  $R_t = V_a + R_b$

## Description

A vector register ( $V_a$ ) and scalar register ( $R_b$ ) are added together and placed in the target scalar register  $R_t$ .  $R_b$  and  $R_t$  may be the same register which results in an accumulation of the values in the register.

## Instruction Format: V2

## Operation

for  $x = 0$  to  $VL - 1$

if ( $V_m[x]$ )  $R_t = V_a[x] + R_b$

## Example

```
ldi    x1,#0           ; clear results
vfmul.s v1,v2,v3        ; multiply inputs (v2) times weights (v3)
vfacc.s x1,v1,x1        ; accumulate results
fadd.s  x1,x1,x2        ; add bias (r2 = bias amount)
fsigmoid.s    x1,x1     ; compute sigmoid
```

# VBITS2V

## Synopsis

Convert bits to Boolean vector.

## Description

Bits from a general register are copied to the corresponding vector target register.

## Operation

For  $x = 0$  to  $VL-1$

if ( $Vm[x]$ )  $Vt[x] = Ra[x]$

**Exceptions:** none

# VCIDX – Compress Index

## Synopsis

Vector compression.

## Description

A value in a register Ra is multiplied by the element number and copied to elements of vector register Vt guided by a vector mask register.

## Operation

$y = 0$

for  $x = 0$  to  $VL - 1$

if ( $Vm[x]$ )

$Vt[y] = Ra * x$

$y = y + 1$

# VCMRSS – Compress Vector

## Synopsis

Vector compression.

## Description

Selected elements from vector register Va are copied to elements of vector register Vt guided by a vector mask register.

## Operation

y = 0

for x = 0 to VL - 1

if (Vm[x])

Vt[y] = Va[x]

y = y + 1

# VEINS / VMOVSV – Vector Element Insert

## Synopsis

Vector element insert.

## Description

A general-purpose register Rb is transferred into one element of a vector register Vt. The element to insert is identified by Ra.

## Operation

$$Vt[Ra] = Rb$$

Exceptions: none



## VEX / VMOVS – Vector Element Extract

### Synopsis

Vector element extract.

### Description

A vector register element from Vb is transferred into a general-purpose register Rt. The element to extract is identified by Ra.

### Operation

$$Rt = Vb[Ra]$$

**Exceptions:** none

# VSCAN

## Synopsis

.

## Description

Elements of  $V_t$  are set to the cumulative sum of a value in register  $R_a$ . The summation is guided by a vector mask register.

## Operation

sum = 0

for x = 0 to VL - 1

$V_t[x] = \text{sum}$

if ( $V_m[x]$ )

sum = sum +  $R_a$

# VSHLV – Shift Vector Left

## Synopsis

Vector shift left.

## Description

Elements of the vector are transferred upwards to the next element position. The first is loaded with the value zero. This is also called a slide operation.

## Operation

For  $x = VL-1$  to  $Amt$

$$Vt[x] = Va[x-amt]$$

For  $x = Amt-1$  to  $0$

$$Vt[x] = 0$$

**Exceptions:** none

# VSHRV – Shift Vector Right

## Synopsis

Vector shift right.

## Description

Elements of the vector are transferred downwards to the next element position. The last is loaded with the value zero. This is also called a slide operation.

## Operation

For  $x = 0$  to  $VL-Amt$

$$Vt[x] = Va[x+amt]$$

For  $x = VL-Amt + 1$  to  $VL-1$

$$Vt[x] = 0$$

**Exceptions:** none

## Memory Operations

### CVLDx – Compressed Vector Load

**Description:**

**Formats Supported:**

#### Stridden Form

63		50	4948	47 44	4341	40	39	32	31 24	23 16	15 8	7	0
	Const <sub>21..8</sub>		U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Const <sub>7..0</sub>		Rb <sub>8</sub>	Ra <sub>8</sub>	Rt <sub>8</sub>		65h <sub>8</sub>

Data is loaded from memory locations beginning at the sum of Ra and a constant and separated by the stride amount in the stride register Rb. Rb may also be a constant in the range -62 to 63. If Rb = -63 then the Sz<sub>4</sub> field is used to determine the stride.

#### Operation:

```

y = 0
for x = 0 to vector length
    if Rb is a constant
        if Rb = -63
            stride = Sz4
        else
            stride = Rb
    else
        stride = [Rb]
    n = stride * y
    if (Vm[x])
        Vt[y] = Memory[d+Ra + n]
        y = y + 1
for y = y to vector length
    Vt[y] = z ? 0 : Vt[y]

n = 0

```

If the vector mask bit is clear and the 'z' bit is set in the instruction then the corresponding element of the vector register is loaded with zero. If the vector mask bit is clear and the 'z' bit is clear in the instruction then the corresponding element of the vector register is left unchanged (no value is loaded from memory).

Elements are loaded only up to the length specified in the vector length register.

Vm[x]      z      Result

0	0	Vt[x] = Vt[x] (unchanged)
0	1	Vt[x] = 0 (set to zero)
1	0	Vt[x] = memory, sign extended
1	1	Vt[x] = memory, zero extended

**Operation:**

```

n = 0
y = 0
for x = 0 to vector length
    if (Vm[x])
        Vt[y] = Memory[d+Ra + n]
        n = n + sizeof precision
        y = y + 1
for y = y to vector length

    Vt[y] = z ? 0 : Vt[y]

```

**Indexed Form**

63		50	4948	47 44	4341	40	39	32	31	24	23	16	15	8	7	0
	Const <sub>21..8</sub>		U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Const <sub>7..0</sub>		Rb <sub>8</sub>		Ra <sub>8</sub>		Rt <sub>8</sub>			66h <sub>8</sub>

Data is loaded from memory addresses beginning with the sum of Ra and a vector element from Vb.

**Operation:**

```

y = 0
for x = 0 to vector length
    if (Vm[x])
        Vt[y] = Memory[d+Ra + Vb[x]]
        y = y + 1
for y = y to vector length

    Vt[y] = z ? 0 : Vt[y]

```

**Exceptions:** none

# CVSTx – Compressed Vector Store

## Description:

## Formats Supported:

### Register Indirect with Displacement

Data is stored to consecutive memory addresses beginning with the sum of Ra and an immediate

Elements are stored only up to the length specified in the vector length register.

47	42	4140	39 36	35 33	32	31		20	19 14	13 8	7	6	0
Const <sub>6</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		Constant <sub>12</sub>			Ra <sub>6</sub>	Vs <sub>6</sub>	1		74h <sub>7</sub>

Vm[x]	z	Result
1	0	memory = Vs[x]
1	1	memory = Vs[x], Vs[x] = 0

### Operation:

```

n = 0
for x = 0 to vector length
    if (Vm[x])
        Memory[d+Ra + n] = Vs[x]
        if (z) Vs[x] = 0
        n = n + sizeof precision

```

### Stridden Form

The stridden form works much the same as the register indirect form except that data is stored to memory locations separated by the stride amount in the stride register.

47	42	4140	39 36	35 33	32	31	26	25	20	19	14	13	8	7	6	0
Const <sub>6</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z		Const <sub>6</sub>		Rb <sub>6</sub>		Ra <sub>6</sub>		Vs <sub>6</sub>		1		75h <sub>7</sub>

### Operation:

```

y = 0
for x = 0 to vector length
    n = Rb * y
    if (Vm[x])
        Memory[d+Ra + n] = Vs[x]
        if (z) Vs[x] = 0
        y = y + 1

```

### Indexed Form

Data is stored to memory addresses beginning with the sum of Ra and a vector element from Vb.

47	42	4140	39 36	35 33	32	31	26	25	20	19	14	13	8	7	6	0
Const <sub>6</sub>	U <sub>2</sub>	Sz <sub>4</sub>	m <sub>3</sub>	z	Const <sub>6</sub>	Vb <sub>6</sub>	Ra <sub>6</sub>	Vs <sub>6</sub>	1	76h <sub>7</sub>						

**Operation:**

```

y = 0
for x = 0 to vector length
  if (Vm[x])
    Memory[d+Ra + Vb[y]] = Vs[x]
    if (z) Vs[x] = 0
    y = y + 1

```

**Exceptions:** none



## Root Opcode Map

	000	001	010	011	100	101	110	111
<b>ALU</b>								
00000	BRK			{R3}	ADD	SUBF	MUL	
00001	AND	OR	EOR			{SET}	MULU	CSR
00010	DIV	DIVU	DIVSU			MULF	MULSU	PERM
00011	REM	REMU	BYTNDX	WYDNDX	{BTFLD}			
00100	REMSU	DIVR	CHK	U21NDX	SAND	SOR	SEQ	SNE
00101	SLT	SGT	SLTU	SGTU				
00110	MADD	MSUB	NMADD	NMSUB				FDP
00111	ADDSI	ANDSI	ORSI	XORSI	ASIIP			NOP
<b>Branch Unit</b>								
01000	JAL				{SYS}			
01001	BLT	BGE	BLTU	BGEU			BEQ	BNE
01010								
01011								
<b>Memory Unit</b>								
01100	LDx		LDS	LDVX			CVLDS	CVLDVX
01101	LEA						CACHE	LSM
01110	STx		SDS	STVX			CVSTS	CVSTVX
01111								

## {SR3} Triadic Register Ops

	000	001	010	011	100	101	110	111
000	AND	OR	XOR		ADD	SUB		
001	NAND	NOR	XNOR		{R2}			
010	SLL				MIN	MAX		
011	PTRDIF							
100			CHK					
101								
110	BLEND							
111								

## {SR2} Dyadic Register Ops

	000	001	010	011	100	101	110	111
000				BMM			MUL	
001					{R1}	MULF	MULU	MULH
010	DIV	DIVU	DIVSU	REM	REMU	REMSU	MULSU	PERM
011	DIF				MULF	MULSUH	MULUH	RGF
100							SEQ	SNE
101					SLT	SGE	SLTU	SGEU
110								
111								

## {SR1} Monadic Register Ops

	000	001	010	011	100	101	110	111
00	CNTLZ	CNTLO	CNTPOP	COM	NOT	NEG		
01				TST				
10	PTRINC							
11								

## {OSR2} System Ops

	000	001	010	011	100	101	110	111
00	LLAL	LLAH			LPAL	LPAH		
01	PUSHQ	POPQ	PEEKQ	STATQ	SETKEY	GCCLR		
10	REX	PFI	WAI	RTE				
11	SETTO	GETTO	GETZL		MVMAP	MVSEG	TLBRW	SYNC