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Thor2023

[Document subtitle]

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### Thor2023

# Nomenclature

The ISA refers to primitive object sizes following the convention suggested by Knuth of using Greek.

|  |  |  |  |
| --- | --- | --- | --- |
| Number of Bits |  | Instructions | Comment |
| 8 | byte | LDB, STB | UTF8 usage |
| 16 | wyde | LDW, STW |  |
| 24 | char | LDC, STC | UTF24 usage |
| 32 | tetra | LDT, STT |  |
| 40 | penta | LDP, STP | Instruction size |
| 64 | octa | LDO, STO |  |
| 96 |  | LDN, STN |  |

The register used to address instructions is referred to as the instruction pointer or IP register. The instruction pointer is a synonym for instruction pointer or PC register.

## Endian

Thor2023 is a little-endian machine. The difference between big endian and little endian is in the ordering of bytes in memory. Bits are also numbered from lowest to highest for little endian and from highest to lowest for big endian.

Shown is an example of a 32-bit word in memory.

Little Endian:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Address | 3 | 2 | 1 | 0 |
| Byte | 3 | 2 | 1 | 0 |

Big Endian:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Address | 3 | 2 | 1 | 0 |
| Byte | 0 | 1 | 2 | 3 |

For Thor2023 the root opcode is in byte zero of the instruction and bytes are shown from right to left in increasing order. As the following table shows.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Address 3 | Address 2 | Address 1 | | Address 0 | |
| Byte 3 | Byte 2 | Byte 1 | | Byte 0 | |
|  |  |  |  | ▼ | |
| 31 24 | 23 16 | 15 8 | | 7 5 | 4 0 |
| Constant8 | Raspec8 | Rtspec8 | | Sz3 | Opcode5 |

# Programming Model

## Register File

### Rn – General Purpose Registers

The register file contains 64 96-bit general purpose registers. The register file is *unified*; register may hold integer or floating-point values. The stack pointer is banked with a separate stack pointer for each operation mode.

|  |  |  |  |
| --- | --- | --- | --- |
| Regno | ABI | ABI Usage |  |
| 0 | 0 | Always zero |  |
| 1 | A0 | First argument / return value register |  |
| 2 | A1 | Second argument / return value register |  |
| 3 | T0 | Temporary register, caller save |  |
| 4 | T1 | Temporary register |  |
| 5 | T2 | Temporary register |  |
| 6 | T3 | Temporary register |  |
| 7 | T4 | Temporary register |  |
| 8 | T5 | Temporary register |  |
| 9 | T6 | Temporary register |  |
| 10 | T7 | Temporary register |  |
| 11 | T8 | Temporary register |  |
| 12 | T9 | Temporary register |  |
| 13 | S0 | Saved register, register variables |  |
| 14 | S1 | Saved register |  |
| 15 | S2 | Saved register |  |
| 16 | S3 | Saved register |  |
| 17 | S4 | Saved register |  |
| 18 | S5 | Saved register |  |
| 19 | S6 | Saved register |  |
| 20 | S7 | Saved register |  |
| 21 | S8 | Saved register |  |
| 22 | S9 | Saved register |  |
| 23 | A2 | Third argument register |  |
| 24 | A3 | Argument register |  |
| 25 | A4 | Argument register |  |
| 26 | A5 | Argument register |  |
| 27 | A6 | Argument register |  |
| 28 | A7 | Argument register |  |
| 29 | A8 | Argument register |  |
| 30 | A9 | Argument register |  |
| 31 |  |  |  |

|  |  |  |  |
| --- | --- | --- | --- |
| 32 | M0 | Vector mask |  |
| 33 | M1 | Vector mask |  |
| 34 | M2 | Vector mask |  |
| 35 | M3 | Vector mask |  |
| 36 | M4 | Vector mask |  |
| 37 | M5 | Vector mask |  |
| 38 | M6 | Vector mask |  |
| 39 | M7 | Vector mask |  |
| 40 |  |  |  |
| 41 |  |  |  |
| 42 |  |  |  |
| 43 |  |  |  |
| 44 |  |  |  |
| 45 |  |  |  |
| 46 |  |  |  |
| 47 |  |  |  |
| 48 |  |  |  |
| 49 |  |  |  |
| 50 |  |  |  |
| 51 |  |  |  |
| 52 |  |  |  |
| 53 | PC | Program counter / Status Register |  |
| 54 | SC | Stack canary; a LOAD does CCHK |  |
| 55 | LC | Loop counter |  |
| 56 | LR0 | Subroutine link register #0; branch subroutine specific |  |
| 57 | LR1 | Subroutine link register #1 |  |
| 58 | LR2 | Subroutine link register #2 |  |
| 59 | LR3 | Subroutine link register #3 |  |
| 60 | GP1 | Global Pointer #1 |  |
| 61 | GP0 | Global Pointer #0 |  |
| 62 | FP | Frame Pointer |  |
| 63 | SP | Stack Pointer |  |
| 63 | ASP | Application Stack pointer |  |
| 63 | SSP | System Stack pointer |  |

|  |  |  |  |
| --- | --- | --- | --- |
|  | AC | Application Control Register |  |

## Predicate Registers

The original Thor machine had 16 four-bit dedicated predicate registers. Thor2023 by contrast stores predicate conditions in general purpose registers. Any GPR may be used to hold values used in predication. Original Thor predicates were a prefix byte containing the predicate register and condition present for every instruction. This has been superseded by the use of the predicate instruction modifier, PRED, which allows up to eight following instructions to be predicated in the same manner.

## Mask Registers (m0 to m7)

Mask registers are used to mask off vector operations so that a vector instruction doesn’t perform the operation on all elements of the vector. Vector instructions (loads and stores) that don’t explicitly specify a mask register assume the use of mask register zero (m0).

|  |  |  |
| --- | --- | --- |
| Register | Tag | Usage |
| m0 | 88 | contains all ones by convention |
| m1 | 89 |  |
| m2 | 90 |  |
| m3 | 91 |  |
| m4 | 92 |  |
| m5 | 93 |  |
| m6 | 94 |  |
| m7 | 95 |  |

## Vector Length (VL register)

The vector length register controls how many elements of a vector are processed. The vector length register may not be set to a value greater than the number of elements supported by hardware. After the vector length is set a SYNC instruction should be used to ensure that following instructions will see the updated version of the length register.

Vector length has register tag #87.

|  |  |
| --- | --- |
| 15 8 | 7 0 |
| 0 | Elements7..0 |

### Code Address Registers

Many architectures have registers dedicated to addressing code. Almost every modern architecture has a program counter or instruction pointer register to identify the location of instructions. Many architectures also have at least one link register or return address register holding the address of the next instruction after a subroutine call. There are also dedicated branch address registers in some architectures. These are all code addressing registers.

*The original Thor lumped these registers together in a code address register array.*

#### LRn – Link Registers

There are four registers in the Thor2023 architecture reserved for subroutine linkage. These registers are used to store the address of the calling instruction. They may be used to implement fast returns for several levels of subroutines or to used to call milli-code routines. The jump to subroutine, [JSR](#_JSR_–_Jump), and branch to subroutine, [BSR](#_BSR_–_Branch), instructions update a link register. The return from subroutine,. [RTS](#_RTS_–_Return), instruction may reload the program counter with an offset from the value contained in a link register. Typically, this is used to return to the next instruction.

#### PC – Program Counter

This register points to the currently executing instruction. The program counter increments as instructions are fetched, unless overridden by another flow control instruction.

### LC - Loop Counter

The loop counter register is used in counted loops along the decrement and branch, [DBcc](#_DBcc_–_Decrement), instruction.

### SR - Status Register

The processor status register holds bits controlling the overall operation of the processor. The status register is not accessible in user mode.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 24 | 23 21 | 20 16 | 15 |  | 13 12 | 11 | 10 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
| CPL | ~ | ~ | T |  | OM |  | IPL |  |  | D | D | AR | | RT | |

CPL is the current privilege level the processor is operating at.

T indicates that trace mode is active.

S indicates the processor is in supervisor mode.

AR: Address Range indicates the number of address bits in use. 0 = near or short (32-bit) addressing is in use. When short addressing is in use only the low order 32-bit are significant and stored or loaded to or from the stack.

IPL is the interrupt mask level

RT specifies the return type for an [RTI](#_RTI_–_Return) instruction.

#### Decimal Mode

Setting the ‘D’ flag bit 5 in the SR register sets the processor in decimal operating mode. Arithmetic operations will use BCD numbers for both source and destination operands.

Decimal mode, ‘D’ flag bit 4, may also be applied to floating-point which will use decimal floating-point operations instead of binary.

### Special Purpose Registers

#### SC - Stack Canary

This special purpose register is available in the general register file as register 54. The stack canary register is used to alleviate issues resulting from buffer overflows on the stack. The canary register contains a random value which remains consistent throughout the run-time of a program. In the right conditions, the canary register is written to the stack during the function’s prolog code. In the function’s epilog code, the value of the canary on stack is checked to ensure it is correct, if not a check exception occurs.

#### AV – Application Vector Table Address

This register holds the address of the applications vector table. The vector table must be 16-byte aligned.

|  |  |
| --- | --- |
| 63 4 | 3 0 |
| App Vector Table Address63..4 | 0 |

#### VB – Vector Base Register

The vector base register provides the location of the vector table. The vector table must be octa aligned. On reset the VBR is loaded with zero. There is a separate vector base register for each operating mode.

|  |  |  |
| --- | --- | --- |
| 63 3 | 2 | 1 0 |
| Vector Table Address63..3 | ~ | ~ |

# Operating Modes

The core operates in one of four basic modes: application/user mode, supervisor mode, hypervisor mode or machine mode. Machine mode is switched to when an interrupt or exception occurs, or when debugging is triggered. On power-up the core is running in machine mode. An RTI instruction must be executed to leave machine mode after power-up.

A subset of instructions is limited to machine mode.

|  |  |
| --- | --- |
| Mode Bits | Mode |
| 0 | User / App |
| 1 | Supervisor |
| 2 | Hypervisor |
| 3 | Machine |

Tags

|  |  |
| --- | --- |
| Tag |  |
| 0 | Untagged |
| 1 | Address Pointer – 20 bit size + 64 bit pointer   |  |  | | --- | --- | | Subtype |  | | 0 | Unused | | 1 | Return address | | 2 | Frame Pointer | | 3 | Pointer | | 4 to 7 | Unassigned | |  |  | |
| 2 | Integer 96 bits |
| 3 | Integer 64 - bits |
| 4 | Integer 32 - bits |
| 5 | Integer 16 - bits |
| 6 | Integer 8 - bits |
| 8 | Float 96 bits |
| 9 | Float 64 bits |
| 10 | Float 32 bits |
| 11 | Float 16-bits |
| 12 | Float 8-bits |
| 16 | String Descriptor – 24 bit length, 64 bit virtual address pointer |
| 17 | Character data, three 32-bit characters |
| 18 | Character data, four 24-bit characters |
| 19 | Character data, 12 8-bit characters |
|  |  |
| 63 | Instructions 40-bit parcels |

# Exceptions

## External Interrupts

There is little difference between an externally generated exception and an internally generated one. An externally caused exception will set the exception cause code for the currently fetched instruction.

There are eight priority interrupt levels for external interrupts. When an external interrupt occurs the mask level is set to the level of the current interrupt. A subsequent interrupt must exceed the mask level to be recognized.

## Effect on Machine Status

The operating mode is always switched to machine mode on exception. It is up to the machine mode code to redirect the exception to a lower operating mode when desired. Further exceptions at the same or lower interrupt level are disabled automatically. Machine mode code must enable interrupts at some point.

## Exception Stack

The status register, program counter, and predicate group register are pushed onto an internal stack when an exception occurs. This stack is at least 16 entries deep to allow for nested interrupts and multiply nested traps and exceptions.

Exception Table

|  |  |
| --- | --- |
| Vector | Usage |
| 0 | Reset value for system stack pointer |
| 1 | Reset value for program counter |
| 2 | Bus Error |
| 3 | Address Error |
| 4 | Unimplemented Instruction |
| 5 |  |
| 6 |  |
| 7 |  |
| 8 | Privilege Violation |
| 9 | Instruction trace |
| 10 |  |
| 11 | Stack Canary |
| 12 to 23 | reserved |
| 24 | Spurious interrupt |
| 25 | Auto vector #1 |
| 26 | Auto vector #2 |
| 27 | Auto vector #3 |
| 28 | Auto vector #4 |
| 29 | Auto vector #5 |
| 30 | Auto vector #6 |
| 31 | Auto vector #7 |
| 32 | Breakpoint (BRK) |
| 33 to 63 | Trap #1 to 31 |
|  | Applications Usage |
| 64 | Divide by zero |
| 65 | Overflow |
| 65 to 511 | Unassigned usage |
|  |  |

## Reset

Reset is treated as an exception. The reset routine should exit using an RTI instruction. The status register should be setup appropriately for the return.

The core begins executing instructions at address $00…00. All registers are in an undefined state.

## Precision

Exceptions in Thor2023 are precise. They are processed according to program order of the instructions. If an exception occurs during the execution of an instruction, then an exception field is set in the pipeline buffer. The exception is processed when the instruction commits which happens in program order. If the instruction was executed in a speculative fashion, then no exception processing will be invoked unless the instruction makes it to the commit stage.

# Instruction Set

## Overview

Thor was a variable length instruction set with instructions varying in length from one to eight bytes. Thor2023 is primarily a fixed length instruction with provision for additional instruction words used for constants. Reducing the variety of instruction sizes makes implementation of decoders more economical.

# Instruction Descriptions

### Major Opcode

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0x | 0  TRAP | 1 | 2  {R2} | 3  {CSR} | 4  ADDI | 5  CMPI | 6  MULI | 7  DIVI |
|  | 8  AND | 9  OR | 10  XOR | 11 | 12  {FLT2} | 13  {BIT} | 14  SHIFT | 15  FMA |
| 1x | 16  LOAD | 17 | 18  STORE | 19 | 20  FADDI | 21  FCMPI | 22  FMULI | 23  FDIVI |
|  | 24  JSR, JMP | 25 | 26  LOADG | 27  STOREG | 28  Bcc | 29  DBcc | 30 | 31  PFX / NOP |

### {R2} Operations

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0x | 0  CNTLZ | 1  CNTLO | 2  CNTPOP | 3  ABS | 4  ADD | 5  CMP | 6  MUL | 7  DIV |
|  | 8  AND | 9  OR | 10  EOR | 11  CHRNDX | 12 | 13 | 14 | 15 |
| 1x | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|  | 24  JMP / JSR | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| 2x | 32  PRED | 33  CARRY | 34  VMASK |  |  |  |  |  |
|  | 40  V2BITS | 41  BITS2V |  |  |  |  |  |  |
| 3x | 48 |  |  |  |  |  |  |  |
|  | 56 |  |  |  |  |  |  |  |

### {FLT2} Operations

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0x | 0  FSCALEB | 1  {FLT1} | 2  FMIN | 3  FMAX | 4  FADD | 5  FCMP | 6  FMUL | 7  FDIV |
|  | 8  FSEQ | 9  FSLT | 10  FSLE | 11  FSNE | 12 | 13 | 14  FNXT | 15  FREM |

### {FLT1} Operations

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 0x | 0 | 1 | 2  FOTI | 3  ITOF | 4 | 5 | 6  FSIGN | 7  FSIG |
|  | 8  FSQRT | 9  FS2D | 10  FS2T | 11  FD2T | 12 | 13 | 14  ISNAN | 15  FINITE |
| 1x | 16 | 17 | 18 | 19 | 20 | 21  FTRUNC | 22 | 23  FRES |
|  | 24 | 25  FD2S | 26  FT2S | 27  FT2D | 28 | 29 | 30  FCLASS | 31 |
| 2x | 32  FABS | 33 | 34  FNEG | 35 | 36 | 37 | 38 | 39 |
|  | 40 |  |  |  |  |  |  |  |
| 3x | 48 |  |  |  |  |  |  |  |
|  | 56 |  |  |  |  |  |  |  |

Operand Swapping

Many instructions allow first and second source operands to be swapped. This is indicated by the swap ‘S’ bit in the instruction. This is particularly useful for instructions that are non-commutative like SUB and DIV.

Operand Swap

|  |  |
| --- | --- |
| **Operand Order** | **S** |
| Normal | 0 |
| 1st and 2nd Swapped | 1 |

### Operand Sizes

Many instructions support four different operand sizes: byte, wyde, tetra and octa. The operand size is selected by suffixing the mnemonic with ‘b’ for byte, ‘w’ for wyde, ‘t’ for tetra and ‘o’ for octa.

|  |  |  |
| --- | --- | --- |
| Sz3 | Ext. | Operand |
| 0 | .b | 8-bit Byte |
| 1 | .w | 16-bit Wyde |
| 2 | .t | 32-bit Tetra |
| 3 | .o | 64-bit Octa |
| 4 | .c | 24-bit |
| 5 | .p | 40-bit Penta |
| 6 | .n | 96-bit |
| 7 |  | reserved |

## Arithmetic Operations

### Representations

#### Int:96

|  |
| --- |
| 95 0 |
| 96 bits |

#### Int:64

|  |
| --- |
| 63 0 |
| 64 bits |

#### Int:40

|  |
| --- |
| 39 0 |
| 40 bits |

#### Int:32

|  |
| --- |
| 31 0 |
| 32 bits |

#### Int:16

|  |
| --- |
| 15 0 |
| 16 bits |

#### Int:8

|  |
| --- |
| 7 0 |
| 8 bits |

### ABS – Absolute Value

**Description:**

This instruction computes the absolute value of the contents of the source operand and places the result in Rt.

**Supported Operand Sizes:** .b, .w, .t, .o

**Integer Instruction Format: R1**

**ADD Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 36 | ~ | 0 | 0 | 0 | 06 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**Operation:**

If Ra < 0

Rt = -Ra

else

Rt = Ra

**Execution Units:** Integer ALU #0

**Clock Cycles: 1**

**Exceptions:** none

**Notes:**

### ADD - Addition

**Description:**

Add two source operands and place the sum in the target register. All registers are treated as integer registers. Arithmetic is signed twos-complement values unless the decimal mode flag is set in which case values are treated as BCD numbers. This instruction may be used with the [CARRY](#_CARRY) modifier to perform extended precision addition.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra + Rb or Rt = Ra + Imm

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**ADD Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 46 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**ADD Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..8 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 45 |

**Clock Cycles: 1**

### AND – Bitwise And

**Description:**

Bitwise ‘and’ two source operands and place the result in the target register. The one’s complement of operands may be used by setting the appropriate ‘S’ bit in the instruction.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Clock Cycles: 1**

**Operation:**

Rt = Ra & Rb or Rt = Ra & Imm

**Instruction Formats:**

**AND Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 86 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**AND Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 85 |

**Clock Cycles: 1**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### CMP - Comparison

**Description:**

Compare two source operands and place the result in the target register. The result is a vector identifying the relationship between the two source operands as signed and unsigned integers.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Operation:**

Rt = Ra ? Rb or Rt = Ra ? Imm or Rt = Imm ? Ra

**Clock Cycles:** 1

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**CMP Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 56 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**CMP Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 55 |

**Clock Cycles: 1**

|  |  |  |  |
| --- | --- | --- | --- |
| Rt bit | Mnem. | Meaning | Test |
|  |  | **Integer Compare Results** |  |
| 0 | EQ | = equal |  |
| 1 | LT | < less than |  |
| 2 | LE | <= less than or equal |  |
| 3 | LO / CS | < unsigned less than |  |
| 4 | LS | <= unsigned less than or equal |  |
| 5 | AND | And |  |
| 6 | OR | Or |  |
| 7 | T | 1 |  |
| 8 | NE | < > not equal |  |
| 9 | GE | >= greater than or equal |  |
| 10 | GT | > greater than |  |
| 11 | HS / CC | unsigned greater than or equal |  |
| 12 | HI | unsigned greater than |  |
| 13 | NAND | nand |  |
| 14 | NOR | Nor |  |
| 15 | SR | Branch subroutine |  |

### CNTLZ – Count Leading Zeros

**Description:**

This instruction counts the number of consecutive zero bits beginning at the most significant bit towards the least significant bit.

**Supported Operand Sizes:** .b, .w, .t, .o

**Integer Instruction Format: R1**

**CNTLZ Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 06 | ~ | 0 | 0 | 0 | 06 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**Operation:**

**Execution Units:** Integer ALU #0

**Clock Cycles: 1**

**Exceptions:** none

**Notes:**

### CNTPOP – Count Population

**Description:**

This instruction counts the number of bits set in a register.

**Supported Operand Sizes:** .b, .w, .t, .o

**Integer Instruction Format: R1**

**CNTPOP Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 26 | ~ | 0 | 0 | 0 | 06 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**Operation:**

**Execution Units:** Integer ALU #0

**Clock Cycles: 1**

**Exceptions:** none

**Notes:**

### CSR – Control and Special Registers Operations

**Description:**

Perform an operation on a CSR.

|  |  |  |
| --- | --- | --- |
| **Operation** | **Op3** |  |
| Read CSR | 0 |  |
| Write CSR | 1 |  |
| Or to CSR (set bits) | 2 |  |
| And complement to CSR (clear bits) | 3 |  |
| Exclusive Or to CSR (flip bits) | 4 |  |

**Supported Operand Sizes:** N/A

|  |  |  |
| --- | --- | --- |
| **Regno** |  |  |
| $000 | reserved | Not used |
| $002 | sr | Status register (privileged) |
| $120 | Tick | Tick count (read only) |
| $121 | Coreno | Core number ( read only) (privileged) |
| $127 |  |  |

**Instruction Formats:**

**OR Rt, Ra, CSR**

**ANDC Rt, Ra, CSR**

**EOR Rt, Ra, CSR**

**CSR Rt,Ra,#Regno12**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 38 37 | 36 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 03 | Regno11..7 | S | Regno7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Op3 | 35 |

**Clock Cycles: 1**

**CSR Rt, #Regno12, #Imm**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 38 37 | 36 33 | 32 | 31 24 | 23 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 13 | Regno11..7 | S | Regno7..0 | Imm8 | Vt | St | Rt6 | Op3 | 35 |

### DIVS – Signed Division

**Description:**

Divide source dividend operand by divisor operand and place the quotient in the target register. All registers are integer registers. Arithmetic is signed twos-complement values.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra / Rb or Rt = Ra / Imm or Rt = Imm / Ra

**Instruction Formats:**

**DIVS Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 76 | 0 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 100**

**DIVS Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 75 |

**Clock Cycles: 100**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### DIVU – Unsigned Division

**Description:**

Divide source dividend operand by divisor operand and place the sum in the target register. All registers are integer registers. Arithmetic is unsigned twos-complement values.

Immediate mode is not available for this instruction.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra / Rb or Rt = Ra / Imm or Rt = Imm / Ra

**Instruction Formats:**

**DIVU Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 76 | 1 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 100**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### EOR – Bitwise Exclusive Or

**Description:**

Bitwise exclusive ‘or’ two source operands and place the sum in the target register. All registers are integer registers. Arithmetic is signed twos-complement values.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Operation:**

Rt = Ra ^ Rb or Rt = Ra ^ Imm

**Instruction Formats:**

**EOR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 106 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**EOR Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 105 |

**Clock Cycles: 1**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### ENOR – Bitwise Exclusive Nor

**Description:**

Bitwise exclusive ‘nor’ two source operands and place the result in the target register.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Operation:**

Rt = ~(Ra ^ Rb) or Rt = ~(Ra ^ Imm)

**Instruction Formats:**

**ENOR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 106 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | 1 | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**ENOR Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | 1 | Rt6 | Sz3 | 105 |

**Clock Cycles: 1**

**Clock Cycles: 1**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### PFX – Constant Postfix

**Description:**

The PFX instruction postfix is used to build large constants for use in the preceding instruction as the immediate constant for the instruction. There are three postfix instructions which extend the constant from different bit locations. They should be used in the order PFX0, PFX1. A postfix may be omitted if the omitted bits match what would be included.

Postfixes are normally caught at the decode stage and do not progress further in the pipeline. They are treated as a NOP instruction.

**Supported Operand Sizes:** N/A

**Instruction Format:**

This format extends the constant from bit 8 with the 32 bits specified in the instruction and sign extends the value to the width of the constant prefix buffer.

|  |  |  |
| --- | --- | --- |
| 39 8 | 7 5 | 4 0 |
| Immediate32 | 03 | 315 |

**Instruction Format:**

This format extends the previous constant value by 32 bits beginning at bit 40 and sign extends the value to the width of the machine.

|  |  |  |
| --- | --- | --- |
| 39 8 | 7 5 | 4 0 |
| Immediate32 | 13 | 315 |

**Instruction Format:**

This format extends the previous constant value by 32 bits beginning at bit 72 and sign extends the value to the width of the machine. Only the low order 24 bits of the extension are used as registers are 96-bits wide.

|  |  |  |
| --- | --- | --- |
| 39 8 | 7 5 | 4 0 |
| Immediate32 | 23 | 315 |

### MULS – Multiply Signed

**Description:**

Multiply two source operands and place the sum in the target register. All registers are treated as integer registers. Arithmetic is signed twos-complement values. The ‘S’ flag indicates to perform an unsigned multiply.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra \* Rb or Rt = Ra \* Imm

**Instruction Formats:**

**MULS Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 66 | 0 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 12**

**MULS Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | 0 | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 65 |

**Clock Cycles: 12**

**Clock Cycles:** 12

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### MULU – Unsigned Multiplication

**Description:**

Multiply two source operands and place the product in the target register. All registers are treated as integer registers. Arithmetic is signed twos-complement values. The ‘S’ flag indicates to perform an unsigned multiply. Unsigned multiply can be used during index calculations.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra \* Rb or Rt = Ra \* Imm

**Instruction Formats:**

**MULU Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 66 | 0 | 1 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 12**

**MULU Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | 1 | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 65 |

**Clock Cycles: 12**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### NAND – Bitwise And and Invert

**Description:**

Bitwise ‘nand’ two source operands and place the result in the target register.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Clock Cycles: 1**

**Operation:**

Rt = ~(Ra & Rb)

**Instruction Formats:**

**NAND Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 86 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | 1 | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**NAND Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | 1 | Rt6 | Sz3 | 85 |

**Clock Cycles: 1**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### NOR – Bitwise Or and Invert

**Description:**

Bitwise ‘or’ two source operands invert the result and place the result in the target register. All registers are integer registers.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Operation:**

Rt = ~(Ra | Rb)

**Instruction Formats:**

**NOR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 96 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | 1 | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**NOR Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | 1 | Rt6 | Sz3 | 95 |

**Clock Cycles: 1**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### OR – Bitwise Or

**Description:**

Bitwise ‘or’ two source operands and place the sum in the target register. All registers are integer registers. Arithmetic is signed twos-complement values.

**Supported Operand Sizes:** .b, .w, .t, .o, .c, .p, .n

**Operation:**

Rt = Ra | Rb or Rt = Ra | Imm

**Instruction Formats:**

**OR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 96 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**OR Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 95 |

**Clock Cycles: 1**

**Clock Cycles:** 2

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

## Floating-Point Operations

### Precision

Floating point operations are always performed at the greatest precision available. Lower precision formats are available for storage.

For decimal floating-point three storage formats are supported. 96-bit triple precision, 64-bit double precision, and 32-bit single precision values.

### Representations

#### Binary Floats

Triple Precision, Float:96

The core uses a 96-bit triple precision binary floating-point representation.

*96-bit values are more compact than 128-bit ones which reduces the amount of hardware required and data being transferred. They have enough significant digits for a wide variety of applications. 64-bit values are not sufficient for some applications. The question then is how much larger of a representation to use. 80-bits is popular, offering about 19 significant digits which is good for a wide variety of applications. 96-bit floats offer about 24 significant digits.*

|  |  |  |
| --- | --- | --- |
| 95 | 94 80 | 79 0 |
| S | Exponent15 | Significand80 |

Double Precision, Float:64

|  |  |  |
| --- | --- | --- |
| 63 | 62 52 | 51 0 |
| S | Exponent11 | Significand52 |

Single Precision, Float:32

|  |  |  |
| --- | --- | --- |
| 31 | 30 23 | 22 0 |
| S | Exponent8 | Significand23 |

Half Precision, Float:16

|  |  |  |
| --- | --- | --- |
| 15 | 14 7 | 6 0 |
| S | Exponent8 | Significand7 |

#### Decimal Floats

The core uses a 96-bit densely packed decimal triple precision floating-point representation.

|  |  |  |  |
| --- | --- | --- | --- |
| 95 | 94 90 | 89 80 | 79 0 |
| S | Combo5 | Exponent10 | Significand80 |

The significand stores 25 densely packed decimal digits. One whole digit before the decimal point.

The exponent is a power of ten as a binary number with an offset of 1535. Range is 10-1535 to 101536

64-bit double precision decimal floating point:

|  |  |  |  |
| --- | --- | --- | --- |
| 63 | 62 58 | 57 50 | 49 0 |
| S | Combo5 | Exponent8 | Significand50 |

The significand stores 16 DPD digits. One whole digit before the decimal point.

32-bit single precision decimal floating point:

|  |  |  |  |
| --- | --- | --- | --- |
| 31 | 30 26 | 25 20 | 19 0 |
| S | Combo5 | Exponent6 | Significand20 |

The significand store 7 DPD digits. One whole digit before the decimal point.

### Rounding Modes

#### Binary Float Rounding Modes

|  |  |
| --- | --- |
| R,Rm2 | Rounding Mode |
| 000 | Round to nearest ties to even |
| 001 | Round to zero (truncate) |
| 010 | Round towards plus infinity |
| 011 | Round towards minus infinity |
| 100 | Round to nearest ties away from zero |
| 101 | Reserved |
| 110 | Reserved |
| 111 | Use rounding mode in float control register |

#### Decimal Float Rounding Modes

|  |  |
| --- | --- |
| R,Rm2 | Rounding Mode |
| 000 | Round ceiling |
| 001 | Round floor |
| 010 | Round half up |
| 011 | Round half even |
| 100 | Round down |
| 101 | Reserved |
| 110 | Reserved |
| 111 | Use rounding mode in float control register |

### FABS – Absolute Value

**Description:**

This instruction computes the absolute value of the contents of the source operand and places the result in Rt. The sign bit of the value is cleared. No rounding occurs.

**Integer Instruction Format: R1**

**FABS Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 14 | ~3 | 0 | 0 | 0 | 326 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 1**

**Operation:**

FPt = Abs(FPa)

**Execution Units:** FPU #0

**Clock Cycles: 1**

**Exceptions:** none

**Notes:**

### FADD –Float Addition

**Description:**

Add two source operands and place the sum in the target register. All registers values are treated as 88-bit floating-point values.

**Supported Operand Sizes:**

**Operation:**

Rt = Ra + Rb or Rt = Ra + Imm

**Clock Cycles:** 8

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**FADD Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 44 | Rm3 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 8**

**FADD Rt,Ra,Imm12**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm11..8 | Rm3 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 205 |

**Clock Cycles: 8**

### FCMP - Comparison

**Description:**

Compare two source operands and place the result in the target register. The result is a vector identifying the relationship between the two source operands as floating-point values. This instruction may compare against lower precision immediate values to conserve code space.

**Supported Operand Sizes:**

**Operation:**

Rt = Ra ? Rb or Rt = Ra ? Imm or Rt = Imm ? Ra

**Clock Cycles:** 1

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**FCMP Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 54 | ~3 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 1**

**FCMP Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm11..8 | ~3 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 215 |

**Clock Cycles: 1**

|  |  |  |  |
| --- | --- | --- | --- |
| Rt bit | Mnem. | Meaning | Test |
|  |  | **Float Compare Results** |  |
| 0 | EQ | equal | !nan & eq |
| 1 | NE | not equal | !eq |
| 2 | GT | greater than | !nan & !eq & !lt & !inf |
| 3 | UGT | Unordered or greater than | Nan || (!eq & !lt & !inf) |
| 4 | GE | greater than or equal | Eq || (!nan & !lt & !inf) |
| 5 | UGE | Unordered or greater than or equal | Nan || (!lt || eq) |
| 6 | LT | Less than | Lt & (!nan & !inf & !eq) |
| 7 | ULT | Unordered or less than | Nan | (!eq & lt) |
| 8 | LE | Less than or equal | Eq | (lt & !nan) |
| 9 | ULE | unordered less than or equal | Nan | (eq | lt) |
| 10 | GL | Greater than or less than | !nan & (!eq & !inf) |
| 11 | UGL | Unordered or greater than or less than | Nan | !eq |
| 12 | ORD | Greater than less than or equal / ordered | !nan |
| 13 | UN | Unordered | Nan |
| 14 |  |  |  |
| 15 |  |  |  |

### FDIV –Float Division

**Description:**

Divide two source operands and place the quotient in the target register. All registers values are treated as 96-bit floating-point values.

**Supported Operand Sizes:**

**Operation:**

Rt = Ra / Rb or Rt = Ra / Imm or Rt = Imm / Ra

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**FDIV Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 74 | Rm3 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 150**

**FDIV Rt,Ra,Imm12**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm11..8 | Rm3 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 235 |

**Clock Cycles: 150**

### FMUL –Float Multiplication

**Description:**

Multiply two source operands and place the product in the target register. All registers values are treated as 96-bit floating-point values.

**Supported Operand Sizes:**

**Operation:**

Rt = Ra \* Rb or Rt = Ra \* Imm

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**FMUL Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 64 | Rm3 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 8**

**FMUL Rt,Ra,Imm12**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm11..8 | Rm3 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 225 |

**Clock Cycles: 8**

### FNEG – Negate Value

**Description:**

This instruction computes the negative value of the contents of the source operand and places the result in Rt. The sign bit of the value is inverted. No rounding occurs.

**Integer Instruction Format: R1**

**FNEG Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 14 | ~3 | 0 | 0 | 0 | 346 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 1**

**Operation:**

Rt = -Ra

**Execution Units:** FPU #0

**Clock Cycles: 1**

**Exceptions:** none

**Notes:**

### FSCALEB –Scale Exponent

**Description:**

Add the source operand to the exponent.

**Supported Operand Sizes:**

**Operation:**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**FSCALEB Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 04 | 03 | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 1**

**FSCALEB Rt, Ra, #Imm – Immediate**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 04 | 13 | 0 | Imm8 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

|  |  |  |  |
| --- | --- | --- | --- |
| ~24 | Immediate7..0 | 03 | 315 |

**Clock Cycles: 1**

### FSUB –Float Subtraction

**Description:**

Subtract two source operands and place the difference in the target register. All registers values are treated as 88-bit floating-point values. This is an alternate mnemonic for the [FADD](#_FADD_–Float_Addition) instruction where the second source operand, Rb is assumed negated.

**Supported Operand Sizes:**

**Operation:**

Rt = Ra + -Rb or Rt = Ra + -Imm

**Clock Cycles:** 8

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**FSUB Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 44 | Rm3 | 0 | Vb | 1 | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 1**

**FSUB Rt,Ra,Imm12**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm11..8 | Rm3 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 205 |

**Clock Cycles: 1**

### FTRUNC – Truncate Fraction

**Description:**

This instruction truncates off the fractional portion of the number leaving only the integer portion. No rounding occurs.

**Integer Instruction Format: R1**

**FTRUNC Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 36 | 35 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 14 | ~3 | 0 | 0 | 0 | 216 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 125 |

**Clock Cycles: 1**

**Operation:**

Rt = Trunc(Ra)

**Execution Units:** FPU #0

**Clock Cycles: 1**

**Exceptions:** none

**Notes:**

## String Operations

### Representations

#### Strings

|  |  |  |
| --- | --- | --- |
| 95 88 | 87 64 | 63 0 |
| Typ | Length24 | Pointer64 |

#### UTF8 Chars

|  |
| --- |
| 95 0 |
| 12 characters |

#### UTF24 Chars

|  |
| --- |
| 95 0 |
| 4 characters |

### CHRNDX – Character Index

**Description:**

This instruction searches Ra, which is treated as an array of characters, for a character value specified by Rb and places the index of the character into the target register Rt. If the character 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 +11 for UTF8 characters or -1 to +3 for UTF24 characters. The index of the first found byte is returned (closest to zero).

**Supported Operand Sizes:** .b, .c

**Instruction Formats:**

**CHRNDX Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 116 | ~ | 0 | Vb | Sb | Rb6 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**CHRNDX Rt,Ra,Imm15**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..7 | S | Imm7..0 | Va | Sa | Ra6 | Vt | St | Rt6 | Sz3 | 115 |

**Clock Cycles: 1**

**Operation:**

Rt = Index of (Rb in Ra)

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

## Bit Manipulation Operations

### BCLR – Clear Bit

**Description:**

A bit in the source operand is cleared and the result placed in the target register. The specified bit to clear is modulo the operand size.

**Supported Operand Sizes:** .b, .w, .t, .o

**Flag Updates:** none

**Operation:**

zf = Ra[Rb] or zf = Ra[Imm]

Rt = Ra &~bit Rb or Ra = Ra &~bit imm

**Instruction Formats:**

**BCLR Ct, Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 03 | ~2 | 0 | Rb5 | 01 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 1**

**BCLR Ct, Rt, Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 03 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### BCHG – Change Bit

**Description:**

A bit in the source operand is changed and placed in the target register. The specified bit to change is modulo the operand size.

**Supported Operand Sizes:** .b, .w, .t, .o

**Flag Updates: none**

**Operation:**

zf = Ra[Rb] or zf = Ra[Imm]

Rt[Rb] = ~Ra[Rb] or Rt[Imm] = ~Ra[Imm]

**Instruction Formats:**

**BCLR Ct, Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 23 | ~2 | 0 | Rb5 | 01 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 4**

**BCLR Ct, Rt, Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 23 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 4**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### BPCHG – Change Bit Pair

**Description:**

A bit pair in the source operand is changed and placed in the target register. The pair is exclusively or’d with 11b. There are four bit-pairs per byte indicated as pair #0 to #3. The bit pair specified is taken modulo the operand size.

|  |  |
| --- | --- |
| Bit Pair Value | Updated Value |
| 00 | 11 |
| 01 | 10 |
| 10 | 01 |
| 11 | 00 |

**Supported Operand Sizes:** .b, .w, .t, .o

**Flag Updates:** none

**Operation:**

zf = Ra[Rb] or zf = Ra[Imm]

Rt[Rb] = ~Ra[Rb] or Rt[Imm] = ~Ra[Imm]

**Instruction Formats:**

**BCLR Ct, Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 63 | ~2 | 0 | Rb5 | 01 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 1**

**BCLR Ct, Rt, Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 63 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### BPCLR – Clear Bit Pair

**Description:**

A pair of bits in the source operand is cleared and the result placed in the target register.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra &~bit Rb or Ra = Ra &~bit imm

**Instruction Formats:**

**BPCLR Ct, Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 43 | ~2 | 0 | Rb5 | 01 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 4**

**BPCLR Ct, Rt, Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 43 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 4**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### BPTST – Test Bit Pair

**Description:**

Test a bit pair in the source operand and place the bit status in the flags of the predicate register. The bit tested is modulo the operation size. All combinations of bit pair value may be detected via flags.

**Supported Operand Sizes:** .b, .w, .t, .o

**Flag Updates:**

Predicate Register Pt3 is always updated.

|  |  |
| --- | --- |
| Bit Pair Value | Flag Setting |
| 00 | Zero flag is set, cf, nf, and vf are cleared |
| 01 | Carry flag is set, zf, nf, and vf are cleared |
| 10 | Negative flag is set, zf, cf, and vf are cleared |
| 11 | Overflow flags is set, nf, zf and cf are cleared |

If the bit pair is zero the zero flag is set otherwise it is cleared.

If the bit pair is

The negative flag is set to the value of the high order bit of the pair.

The overflow flag is set to the exclusive or of the two bits in the pair.

**Operation:**

**Instruction Formats:**

**BPTST Pt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 1110 | 9 7 | 6 5 | 4 0 |
| ~3 | 73 | ~2 | 0 | Rb5 | 01 | Ra5 | ~2 | Pt3 | Sz2 | 135 |

**Clock Cycles: 4**

**BPTST Pt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 1110 | 9 7 | 6 5 | 4 0 |
| ~3 | 73 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | ~2 | Pt3 | Sz2 | 135 |

**Clock Cycles: 4**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### BSET – Set Bit

**Description:**

A bit in the source operand is set and placed in the target register.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

zf = Ra[Rb] or zf = Ra[Imm]

Rt = Ra | bit Rb or Rt = Ra or Bit[Imm]

**Instruction Formats:**

**BSET Ct, Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 13 | ~2 | 0 | Rb5 | 01 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 1**

**BSET Ct, Rt, Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 11 7 | 6 5 | 4 0 |
| ~3 | 13 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | Rt5 | Sz2 | 135 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### BTST – Test Bit

**Description:**

Test a bit in the source operand and place the bit status in the zero flag of the predicate register. The bit tested is modulo the operation size.

**Supported Operand Sizes:** .b, .w, .t, .o

**Flag Updates:**

Predicate Register Pt3 is always updated.

If the bit is zero the zero flag is set otherwise it is cleared.

**Operation:**

zf = Ra[Rb] or zf = Ra[Imm]

**Instruction Formats:**

**BTST Pt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 2524 | 23 | 22 18 | 17 | 16 12 | 1110 | 9 7 | 6 5 | 4 0 |
| ~3 | 33 | ~2 | 0 | Rb5 | 01 | Ra5 | ~2 | Pt3 | Sz2 | 135 |

**Clock Cycles: 4**

**BTST Pt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 31 29 | 28 26 | 25 24 | 23 | 22 18 | 17 | 16 12 | 1110 | 9 7 | 6 5 | 4 0 |
| ~3 | 33 | Im6..5 | 0 | Imm4..0 | 11 | Ra5 | ~2 | Pt3 | Sz2 | 135 |

**Clock Cycles: 4**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

## Shift and Rotate Operations

### ASL – Arithmetic Shift Left

**Description:**

Shift the first source operand to the left by the number of bits specified by the second source operand and place the result in the target register. All registers are integer registers. Arithmetic is signed twos-complement values. The least significant bit is filled with the value of ‘N’ specified in the instruction.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra << Rb or Rt = Ra << Imm

**Instruction Formats:**

**ASL Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 06 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**ASL Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 326 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### ASR – Arithmetic Shift Right

**Description:**

Shift the first source operand to the right, preserving the sign bit, by the number of bits specified by the second source operand and place the result in the target register. All registers are integer registers. Arithmetic is signed twos-complement values.

**Supported Operand Sizes:** .b, .w, .l

**Operation:**

Rt = Ra >> Rb or Rt = Ra >> Imm

**Instruction Formats:**

**ASR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 16 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**ASR Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 336 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### SBX – Sign Bit Extend

**Description:**

Sign extend a value beginning at a specified bit to the width of the register and place the result in the target register. All registers are integer registers.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

**Instruction Formats:**

**SXB Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 96 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**SXB Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 416 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### LSL – Logical Shift Left

**Description:**

Shift the first source operand to the left by the number of bits specified by the second source operand and place the result in the target register. All registers are integer registers. Arithmetic is signed twos-complement values. Fill the least significant bit with the value specified by ‘N’ in the instruction.

**Supported Operand Sizes:** .b, .w, .l

**Operation:**

Rt = Ra << Rb or Rt = Ra << Imm

**Instruction Formats:**

**LSL Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 26 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**LSL Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 346 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### LSR – Logical Shift Right

**Description:**

Shift the first source operand to the right by the number of bits specified by the second source operand and place the result in the target register. All registers are integer registers. Arithmetic is signed twos-complement values. Fill the least significant bit with the value specified by ‘N’ in the instruction.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra >> Rb or Rt = Ra >> Imm

**Instruction Formats:**

**LSR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 36 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**LSR Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 356 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### ROL – Rotate Left

**Description:**

Rotate the first source operand to the left by the number of bits specified by the second source operand and place the result in the target register. All registers are integer registers. Arithmetic is signed twos-complement values. The least significant bit is set to the value of the most significant bit exclusively or’d with the value ‘N’ from the instruction.

**Supported Operand Sizes:** .b, .w, .t, .o

**Operation:**

Rt = Ra << Rb or Rt = Ra << Imm

**Instruction Formats:**

**ROL Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 46 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**ROL Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 366 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### ROR – Rotate Right

**Description:**

Rotate the first source operand through the carry to the right by the number of bits specified by the second source operand and place the result in the target register. All registers are integer registers. Arithmetic is signed twos-complement values. The most significant bit is set to the value of the least significant bit exclusively or’d with the value ‘N’ from the instruction.

**Supported Operand Sizes:** .b, .w, .l

**Operation:**

Rt = Ra >> Rb or Rt = Ra >> Imm

**Instruction Formats:**

**ROR Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 56 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**ROR Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 376 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

### ZBX – Zero Bit Extend

**Description:**

Zero extend a value beginning at a specified bit to the width of the register and place the result in the target register. All registers are integer registers.

**Supported Operand Sizes:** .b, .w, .l

**Operation:**

Rt = Zero Extend(Ra)

**Instruction Formats:**

**ZXB Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 86 | ~4 | N | 0 | Sb | Rb6 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**ZXB Rt,Ra,Imm7**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 30 | 29 | 28 | 27 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 406 | ~4 | N | 0 | Imm6..0 | Sa | Ra6 | St | Rt6 | Sz2 | 145 |

**Clock Cycles: 1**

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

## Flow Control Instructions

### Bcc – Conditional Branch

Bcc Pn, label

**Description:**

Branch if the predicate condition is met. The displacement is relative to the address of the branch instruction. The branch range is +/- 8MB.

**Instruction Format:**

|  |  |  |  |
| --- | --- | --- | --- |
| 39 16 | 15 10 | 9 5 | 4 0 |
| Disp23..0 | Rn6 | Cond5 | 285 |

|  |  |  |  |
| --- | --- | --- | --- |
| Cond5 | Mnem. | Meaning | Test |
|  |  | **Integer Compare Results** |  |
| 0 | EQ | = equal |  |
| 1 | LT | < less than |  |
| 2 | LE | <= less than or equal |  |
| 3 | LO / CS | < unsigned less than |  |
| 4 | LS | <= unsigned less than or equal |  |
| 5 | AND | And |  |
| 6 | OR | Or |  |
| 7 | T | 1 |  |
| 8 | NE | < > not equal |  |
| 9 | GE | >= greater than or equal |  |
| 10 | GT | > greater than |  |
| 11 | HS / CC | unsigned greater than or equal |  |
| 12 | HI | unsigned greater than |  |
| 13 | NAND | nand |  |
| 14 | NOR | Nor |  |
| 15 | SR | Branch subroutine |  |
| Cond5 | Mnem. | Meaning | Test |
|  |  | **Float Compare Results** |  |
| 16 | EQ | equal | !nan & eq |
| 17 | NE | not equal | !eq |
| 18 | GT | greater than | !nan & !eq & !lt & !inf |
| 19 | UGT | Unordered or greater than | Nan || (!eq & !lt & !inf) |
| 20 | GE | greater than or equal | Eq || (!nan & !lt & !inf) |
| 21 | UGE | Unordered or greater than or equal | Nan || (!lt || eq) |
| 22 | LT | Less than | Lt & (!nan & !inf & !eq) |
| 23 | ULT | Unordered or less than | Nan | (!eq & lt) |
| 24 | LE | Less than or equal | Eq | (lt & !nan) |
| 25 | ULE | unordered less than or equal | Nan | (eq | lt) |
| 26 | GL | Greater than or less than | !nan & (!eq & !inf) |
| 27 | UGL | Unordered or greater than or less than | Nan | !eq |
| 28 | ORD | Greater than less than or equal / ordered | !nan |
| 29 | UN | Unordered | Nan |
| 30 |  |  |  |
| 31 |  |  |  |

**Clock Cycles: 4**

### BRA – Unconditional Branch

**Description:**

Unconditionally branch to a new program address. The displacement is relative to the address of the branch instruction. The branch range is +/- 64MB.

**Instruction Format:**

|  |  |  |  |
| --- | --- | --- | --- |
| 39 16 | 15 10 | 9 5 | 4 0 |
| Disp23..0 | ~6 | 75 | 285 |

**Clock Cycles: 3**

### BRK – Breakpoint

**Description:**

Execute the breakpoint exception. This is a form of the TRAP instruction.

**Instruction Format:**

|  |  |
| --- | --- |
| 39 5 | 4 0 |
| 0 | 05 |

### BSR – Branch to Subroutine

**Description:**

Branch to a subroutine placing the address of the next instruction in a register. The displacement is relative to the address of the branch instruction. The branch range is +/- 8MB.

**Instruction Format:**

|  |  |  |  |
| --- | --- | --- | --- |
| 39 16 | 15 10 | 9 5 | 4 0 |
| Disp23..0 | Rt6 | 155 | 285 |

**Clock Cycles: 3**

### DBcc – Decrement and Branch

DBcc Rn, label

**Description:**

Decrement the loop counter and branch if the condition is false and the loop counter is not equal to minus one. The displacement is relative to the address of the branch instruction. The branch range is +/- 8MB.

**Instruction Format:**

|  |  |  |  |
| --- | --- | --- | --- |
| 39 16 | 15 10 | 9 5 | 4 0 |
| Disp23..0 | Rn6 | Cond5 | 295 |

### FBcc – Float Conditional Branch

FBcc Pn, label

**Description:**

Branch if the condition is met. The displacement is relative to the address of the branch instruction. The branch range is +/- 8MB.

**Instruction Format:**

|  |  |  |  |
| --- | --- | --- | --- |
| 39 16 | 15 10 | 9 5 | 4 0 |
| Disp23..0 | Rn6 | Cond5 | 305 |

|  |  |  |
| --- | --- | --- |
| **Cond5** | **Mnemonic** | **Test** |
| 0 | F | 0 |
| 1 | EQ | Zf |
| 2 | OGT | !nanf && !zf && !vf && !nf |
| 3 | OGE | zf || (!nanf && !vf && !nf) |
| 4 | OLT | nf && (!nanf && !vf && !zf) |
| 5 | OLE | zf || (nf && !nanf) |
| 6 | OGL | !nanf && !vf && !zf |
| 7 | OR | !nanf |
| 8 | UN | nanf |
| 9 | UEQ | nanf || zf |
| A | UGT | nanf || (!nf && !vf && !zf) |
| B | UGE | nanf || zf || !nf |
| C | ULT | nanf || (nf && !zf) |
| D | ULE | nanf || zf || nf |
| E | NE | !zf |
| F | T | 1 |
| 10 | SF | 0 |
| 11 | SEQ | Zf |
| 12 | GT | !nanf && !zf && !vf && !nf |
| 13 | GE | zf || (!nanf && !vf && !nf) |
| 14 | LT | nf && (!nanf && !vf && !zf) |
| 15 | LE | zf || (nf && !nanf) |
| 16 | GL | !nanf && !vf && !zf |
| 17 | GLE | !nanf |
| 18 | NGLE | nanf |
| 19 | NGL | nanf || zf |
| 1A | NLE | nanf || (!nf && !vf && !zf) |
| 1B | NLT | nanf || (zf || !nf) |
| 1C | NGE | nanf || (nf && !zf) |
| 1D | NGT | nanf || zf || nf |
| 1E | SNE | !zf |
| 1F | ST | 1 |

**Clock Cycles: 4**

### JMP – Jump to Address

**Description:**

Compute the effective address and jump to it. If Ra=53 then the program counter is used.

**Flag Updates:**

None.

**Operation:**

PC = Ra + Rb or PC = Ra + Imm

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**JMP (Ra, Rb) – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 246 | ~5 | 0 | Sb | Rb6 | Sa | Ra6 | 0 | 06 | Sz2 | 25 |

**Clock Cycles: 1**

**JMP Imm18 (Ra)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| Imm17..7 | S | I6 | Imm5..0 | Sa | Ra6 | 0 | 06 | Sz2 | 245 |

**Clock Cycles: 1**

### JSR – Jump to Subroutine

**Description:**

Compute the effective address and jump to it. The address of the instruction is stored in a register. If Ra=53 then the program counter is used.

**Flag Updates:**

None.

**Operation:**

Rt = PC

PC = Ra + Rb or PC = Ra + Imm

**Clock Cycles:**

**Execution Units:** All Integer ALU’s

**Exceptions:** none

**Notes:**

**Instruction Formats:**

**JSR (Ra, Rb) – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 246 | ~5 | 0 | Sb | Rb6 | Sa | Ra6 | 0 | Rt6 | Sz2 | 25 |

**Clock Cycles: 1**

**JSR Imm18 (Ra)**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| Imm17..7 | S | I6 | Imm5..0 | Sa | Ra6 | 0 | Rt6 | Sz2 | 245 |

**Clock Cycles: 1**

### NOP – No Operation

NOP

**Description:**

This instruction does not perform any operation. Ty3 0 to 3 indicates a postfix instruction, and these codes should not be used for other NOPs.

**Instruction Format:**

|  |  |  |
| --- | --- | --- |
| 39 5 | 7 5 | 4 0 |
| Payload32 | Ty3 | 315 |

### RTE – Return From Exception

**Instruction Formats:**

**RTE #Rpt**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 31 | 3029 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 12 7 | 6 5 | 4 0 |
| 46 | ~3 | ~2 | 0 | ~ | ~6 | ~ | ~6 | R6 | Rpt6 | D2 | 15 |

**Field Description:**

Rpt7 is the number of bytes to skip past the return address. This is to allow inline subroutine arguments. Up to 128 bytes may be skipped over. For externally triggered interrupts this field should be zero.

D2 specifies the number of internal stack entries to unstack. It may be used to perform a multi-level return. Legal values for D are 1,2 or 3. In most cases a single entry is unstacked. If two entries are unstack a two-up level return will occur.

**Operation:**

Optionally pop the status register, condition code group register, and program counter from the internal stack. Add Rpt tetras to the program counter, and Arg tetras to the stack pointer. If returning from an application trap the status register is not popped from the stack.

### TRAP – Trap

**Description:**

Execute trap. The data field is loaded into the specified target register, Rt. The trap number to execute comes from the contents of register Ra or an immediate value encoded in the instruction. The trap number must be between 1 and 511. Trap numbers below 64 are reserved for the system. Trap numbers 64 and above may be used by applications.

Traps below 64 will use the vector base register to lookup the location of the service routine. Traps above 64 will use the application control register to lookup the location of the service routine.

**Instruction Format:**

**TRAP Rt, Ra, #Data**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| Imm14..8 | 0 | Imm7..0 | Va | Sa | Ra6 | 0 | 0 | Rt6 | 03 | 05 |

**TRAP Rt, #Vec, #Data**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 33 | 32 | 31 24 | 23 16 | 15 | 14 | 13 8 | 76 | 5 | 4 0 |
| Imm14..8 | 1 | Imm7..0 | Vec8 | 0 | 0 | Rt6 | ~2 | V9 | 05 |

**Clock Cycles: 1**

**Operation:**

The program counter and the status register are pushed on an internal stack. Next the vector is fetched from the exception vector table and jumped to.

## Memory Operations

|  |  |
| --- | --- |
| Sz2 |  |
| 0 | 8-bits |
| 1 | 32-bits |
| 2 | 96-bits |
| 3 | reserved |

### LOAD Rn,<ea>

**Description:**

Load register Rt from source. Loading register r54, the stack canary placeholder, will cause a check trap if the value loaded is not equal to the current value of the stack canary register.

**Supported Operand Sizes:** .b, .w, .t, .o, .p, .n

|  |  |  |
| --- | --- | --- |
| Sz3 | Ext. | Operand |
| 0 | .b | 8-bit Byte |
| 1 | .w | 16-bit Wyde |
| 2 | .t | 32-bit Tetra |
| 3 | .o | 64-bit Octa |
| 4 | .c | 24-bit |
| 5 | .p | 40-bit |
| 6 | .n | 96-bit |
| 7 |  | reserved |

**Instruction Formats: NDXL**

**LOAD Rt, d(Rb,Rc\*Sc) – indexed**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 | 38 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 8 | 7 5 | 4 0 |
| Vc | Rc6 | Sc | Vb | Sb | Rb6 | Vt | St | Rt6 | D7..0 | Sz3 | Opc5 |

**Clock Cycles:**

Notes:

### LOADG Gn,<ea>

**Description:**

Load group of five registers from source.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Gn | Registers |  | Gn | Registers |
| 0 | R0 to R4 |  | 8 | R40 to R44 |
| 1 | R5 to R9 |  | 9 | R45 to R49 |
| 2 | R10 to R14 |  | 10 | R50 to R54 |
| 3 | R15 to R19 |  | 11 | R55 to R59 |
| 4 | R20 to R24 |  | 12 | R60 to R64 |
| 5 | R25 to R29 |  | 13 | ASP, SSP, HSP, MSP |
| 6 | R30 to R34 |  |  |  |
| 7 | R35 to R39 |  |  |  |

**Supported Operand Sizes:** .b, .w, .l

**Instruction Formats: NDXL**

**LOADG Gt, d(Rb,Rc\*Sc) – indexed**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 35 | 34 29 | 28 | 27 | 26 21 | 20 | 19 14 | 13 | 1211 | 10 7 | 6 5 | 4 0 |
| D12..8 | Rc6 | Sc | Sb | Rb6 | D7 | D6..1 | D0 | ~2 | GRP4 | 22 | 265 |

**Clock Cycles:**

Notes:

### STORE Rt,<ea>

**Description:**

Store register Ra to destination.

**Supported Operand Sizes:** .b, .w, .t, .o, .p, .n

|  |  |  |
| --- | --- | --- |
| Sz3 | Ext. | Operand |
| 0 | .b | 8-bit Byte |
| 1 | .w | 16-bit Wyde |
| 2 | .t | 32-bit Tetra |
| 3 | .o | 64-bit Octa |
| 4 | .c | 24-bit |
| 5 | .p | 40-bit |
| 6 | .n | 96-bit |
| 7 |  | reserved |

**Instruction Formats: NDXS**

**STORE Ra, d(Rb, Rc\*Sc) – Indexed**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 | 38 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 8 | 7 5 | 4 0 |
| Vc | Rc6 | Sc | Vb | Sb | Rb6 | Va | Sa | Ra6 | D7..0 | Sz3 | Opc5 |

**Clock Cycles:**

Notes:

### STOREG Gt,<ea>

**Description:**

Store register group to destination. The destination is a 512 bit / 64 byte aligned region of memory.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Gn | Registers |  | Gn | Registers |
| 0 | R0 to R4 |  | 8 | R40 to R44 |
| 1 | R5 to R9 |  | 9 | R45 to R49 |
| 2 | R10 to R14 |  | 10 | R50 to R54 |
| 3 | R15 to R19 |  | 11 | R55 to R59 |
| 4 | R20 to R24 |  | 12 | R60 to R64 |
| 5 | R25 to R29 |  | 13 | ASP, SSP, HSP, MSP |
| 6 | R30 to R34 |  |  |  |
| 7 | R35 to R39 |  |  |  |

**Supported Operand Sizes:** .b, .w, .l

**Instruction Formats: NDXS**

**STOREG Ga, d(Rb, Rc\*Sc) – Indexed**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 35 | 34 29 | 28 | 27 | 26 21 | 20 | 1918 | 17 14 | 13 | 12 7 | 6 5 | 4 0 |
| D12..8 | Rc6 | Sc | Sb | Rb6 | D7 | ~2 | Ga4 | D6 | D5..0 | 22 | 275 |

**Clock Cycles: 1**

Notes:

## Vector Specific Instructions

### V2BITS

**Description**

Convert Boolean vector to bits. A bit specified by Rb or an immediate of each vector element is copied to the bit corresponding to the vector element in the target register. The target register is a scalar register. Usually, Rb would be zero so that the least significant bit of the vector is copied.

A typical use is in moving the result of a vector compare operation into a mask register.

**Instruction Format: R2**

**V2BITS Rt, Ra, Rb – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 | 29 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 406 | 0 | 0 | 0 | 0 | Rb6 | Va | Sa | Ra6 | 0 | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**V2BITS Rt, Ra, #bit – Register direct**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 | 32 | 31 | 30 24 | 23 | 22 | 21 16 | 15 | 14 | 13 8 | 7 5 | 4 0 |
| 406 | 1 | 0 | 0 | Imm7 | Va | Sa | Ra6 | 0 | St | Rt6 | Sz3 | 25 |

**Clock Cycles: 1**

**Operation**

For x = 0 to VL-1

Rt.bit[x] = Ra[x].bit[Rb]

**Exceptions:** none

**Example:**

|  |
| --- |
| cmp v1,v2,v3 ; compare vectors v2 and v3  v2bits m1,v1,#8 ; move NE status to bits in m1  vmask m1,m1,m1,m0,m0,m0,m0,m0  add v4,v5,v6 ; perform some masked vector operations  muls v7,v8,v9  add v7,v7,v4 |

## Modifiers

### CARRY

**Description:**

Apply the carry modifier to following instructions according to a bit mask. This modifier may be used to perform extended precision addition. It may also be used to retrieve the high order multiplier bits or the divide remainder. Note that carry input is not available for the first instruction under the modifier’s shadow.

|  |  |  |
| --- | --- | --- |
| Carry Modifier  Scope | Mask Bit |  |
| 0,1 | Instruction zero |
| 2,3 | Instruction one |
| 4,5 | Instruction two |
| 6,7 | Instruction three |
| 8,9 | Instruction four |
| 10,11 | Instruction five |
| 12,13 | Instruction six |
| 14,15 | Instruction seven |

|  |  |
| --- | --- |
| Mask Bit | Meaning |
| 00 | No carry in or out |
| 01 | Use carry in |
| 10 | Generate carry out |
| 11 | Use carry in and generate carry out |

**Instruction Format:**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 29 | 28 | 27 | 26 16 | 1514 | 13 | 12 7 | 6 5 | 4 0 |
| 336 | Imm15..11 | 0 | ~ | Imm10..0 | ~2 | 0 | Rn6 | ~2 | 25 |

### VMASK

**Description:**

Apply the vector masking to following instructions according to a bit mask.

|  |  |  |
| --- | --- | --- |
| MASK Modifier  Scope | Mask Bit |  |
| 0 to 2 | Instruction zero |
| 3 to 5 | Instruction one |
| 6 to 8 | Instruction two |
| 9 to 11 | Instruction three |
| 12 to 14 | Instruction four |
| 15 to 17 | Instruction five |
| 18 to 20 | Instruction six |
| 21 to 23 | Instruction seven |

**Instruction Format:**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 31 | 30 29 | 28 | 27 | 26 5 | 4 0 |
| 346 | ~3 | Imm23..22 | 1 | ~ | Imm21..0 | 25 |

### PRED

**Description:**

Apply the predicate to following instructions according to a bit mask.

|  |  |  |
| --- | --- | --- |
| Pred Modifier  Scope | Mask Bit |  |
| 0,1 | Instruction zero |
| 2,3 | Instruction one |
| 4,5 | Instruction two |
| 6,7 | Instruction three |
| 8,9 | Instruction four |
| 10,11 | Instruction five |
| 12,13 | Instruction six |
| 14,15 | Instruction seven |

|  |  |
| --- | --- |
| Mask Bit | Meaning |
| 00 | Always execute (ignore predicate) |
| 01 | Execute only if predicate is true |
| 10 | Execute only if predicate is false |
| 11 | Always execute (ignore predicate) |

**Instruction Format:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 39 34 | 33 29 | 28 | 27 | 26 16 | 15 10 | 9 5 | 4 0 |
| 326 | Imm15..11 | 1 | ~ | Imm10..0 | Rn6 | Cond5 | 25 |