Playstation 2 Vector Unit Instruction Manual

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Updates

1/7/2003 - Initial Version

Vector Units : Introduction

GENERAL

The VU0 is the first of two Vector Processing Units in PS2. It's designed to operate in two modes : as the second coprocessor for the 5900 core or independently as a microprocessor. Operating as a coprocessor the VU0 utilises either the upper or the lower instruction in each 64-bit microcode stored in it's instruction cache. Operating as an independent microprocessor the VU0 receives data fed from DMA to VIF0 and finally to the VU0 instruction or data cache. In
microprocessor mode the VU0 utilises both upper and lower microcode instructions.

The VU1 is an independent microproseccor operating in parallel to the CPU. It executes the program in its instruction cache on demand of a VIF1 program. VU1 programms use both upper and lower microcode instructions and and has additional commands to the VU0, because of the EPU and the path to the GIF.

REGISTERS

The VU0 has 32 128 bit floating point registers , 16 32 bit integer data registers and 16 control registers.

FLOATING POINT REGISTERS

The floating point registers are 128 bits wide and each is divided in 4 fields of 32 bits : x , y , z and w.

FLOATING POINT REGISTERS FIELD LAYOUT

Word 0	Word 1	Word 2	Word 3
31 … 0	63 … 32	95 … 64	127 … 96
x	y	z	w

VU0F00 AND VU1F00 REGISTERS

Word 0	Word 1	Word 2	Word 3
31 … 0	63 … 32	95 … 64	127 … 96
0.0	0.0	0.0	1.0

The Floating registers can be represented in 4 fixed point formats:

Mode	Meaning
Fixed 0	fixed point 0 bits
Fixed 4	fixed point 4 bits
Fixed 12	fixed point 12 bits
Fixed 15	fixed point 15 bits

INTEGER DATA REGISTERS

The Integer data registers are 32 bits wide but only the lower halfword is used as the integer registers work as pointers to the instruction or data cache.

INTEGER CONTROL REGISTERS

The Integer control registers are:

Status flag
MAC flag
clipping flag
reserved
R
I
Q
reserved
reserved
reserved
TPC
CMSAR0
FBRST
VPU_STAT
reserved
CMSAR1

Status Flag

```
Bits       : 32
Bits used  : lower 12
Instructions : FSAND    rt,12 bit immediate
               FSEQ     rt,12 bit immediate
               FSOR     rt,12 bit immediate
               FSSET    12 bit immediate
```

MAC flag

```
Bits         : 32
Bits used    : lower 16
Instructions : FMAND    rt,rs
               FMEQ     rt,rs
               FMOR     rt,rs
```

Clipping flag

```
Bits         : 32
Bits used    : lower 24
Instructions : FCAND    rt,24 bit immediate
               FCEQ     rt,24 bit immediate
               FCGET    rt
               FCOR     rt,24 bit immediate
               FCSET    24 bit immediate
```

R register

```
Bits         : 32
Bits used    : 32
Instructions : RINIT    R,Frs.e
               RGET     Frt,R
               RNEXT    Frt,R
               RXOR     R,Frs
```

I register

```
Bits         : 32
Bits used    : 32 (floating point)
Instructions : ADDI           Upper
               SUBI           Upper
               MULI           Upper
               MADDI          Upper
               MSUBI          Upper
               ADDAI          Upper
               SUBAI          Upper
               MULAI          Upper
               MADDAI         Upper
               MSUBAI         Upper
               MAXII          Upper
               MINII          Upper
```

Q register

```
Bits         : 32
Bits used    : 32 (floating point)
Instructions : ADDQ           Upper
               SUBQ           Upper
               MULQ           Upper
               MADDQ          Upper
               MSUBQ          Upper
               ADDAQ          Upper
               SUBAQ          Upper
               MULAQ          Upper
               MADDAQ         Upper
               MSUBAQ         Upper
               DIV    Q,rt,rs Lower
               SQRT   Q,rs    Lower
               RSQRT  Q,rs    Lower

TPC          ????? 2 Bytes used
FBRST        ????? sceGSreset sets the bits in this disabling break
VPU-STAT     ?????
CMSAR0       ?????
CMSAR1       ?????
```

Reading the manual

It can be quite confusing reading the manual for the first time so here is a quick introduction to understanding the manual and basics of VU.

First lets remember that there are 32 x 128 bit general purpose registers, each of these 128 bits registers is split into 4 x 32 bits (floats). These 32 bit parts of the 128 bit register is accessed by X,Y,Z,W (like a vector).

Register:

```
Bit: 128     96      64      32      0
     |   W   |   Z   |   Y   |   X   |
```

Register are named VF00 - VF31, VF00 is static and has the values; X = 0.0f, Y = 0.0f, Z = 0.0f, W = 1.0f

Now lets look at some documentation.

Add broadcast ADDx ADDy ADDz ADDw

```
 ____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |   ADDbc | bc  |
|              | 0| 0|    dest   |              |              |              |   0000  |     |
```

Format: ADDx.dest fd,fs,ft
ADDy.dest fd,fs,ft
ADDz.dest fd,fs,ft
ADDw.dest fd,fs,ft

Purpose:
To add up to 4 fields with the broadcast field

Description:
```
if dest & .x == true : fd.x <- fs.x + ft.bc
if dest & .y == true : fd.y <- fs.y + ft.bc
if dest & .z == true : fd.z <- fs.z + ft.bc
if dest & .w == true : fd.w <- fs.w + ft.bc
```

First, lets look at description, “if dest & .x == true”, this means that if we can do

addy.x $vf3x, $vf4x, $vf5y

This performs **$vf3.x** (x part of vf3**) = $vf4.x** (x part of vf4) **+ $vf5.y** (y part of vf5)

But what the description also saids, is that we can combine different dests

addy.xyzw $vf3xywz, $vf4xywz, $vf5y

This performs

$vf3.x = $vf4.x + $vf5.y
$vf3.y = $vf4.y + $vf5.y
$vf3.z = $vf4.z + $vf5.y
$vf3.w = $vf4.w + $vf5.y

Or ..

addz.xw $vf3xw, $vf4xw, $vf5z

Which performs

$vf3.x = $vf4.x + $vf5.z
$vf3.w = $vf4.w + $vf5.z

You can also just write this instruction like this and still make sense because of the last z on $vf5

addz.xw $vf3, $vf4, $vf5z

As you can see VU is very flexible and as you learn more and read others code you will learn quite a few tricks which will result in fast VU code.

VU0 INSTRUCTION NOTE
This manaul covers VU1 instructions, but the VU1 instructions which are avaliable on VU0 are noted on the following pages. Just remember that you need to add a **V** as the first letter of the instruction, like
VU1 Instruction: **addy.x $vf3x, $vf4x, $vf5y**
VU0 Instruction: **vaddy.x $vf3x, $vf4x, $vf5y**

UPPER INSTRUCTION AVAILABILITY IN VU UNITS

Instruction	VU0 coprocessor	VU0 microprocessor	VU1 microprocessor
ADD.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
ADDA.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
SUB.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
SUBA.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
MUL.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
MULA.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
MADD.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
MADDA.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes

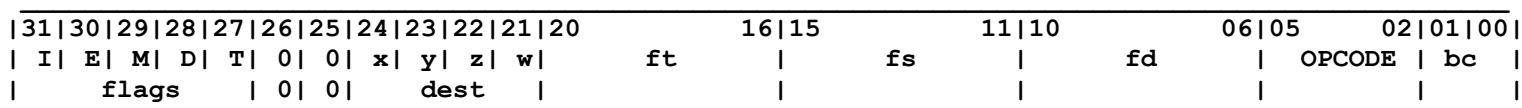
Instruction	VU0 coprocessor	VU0 microprocessor	VU1 microprocessor
MSUB.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
MSUBA.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
Q.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
OPMULA.xyz	Yes	Yes	Yes
OPMSUB.xyz	Yes	Yes	Yes
ABS.dest	Yes	Yes	Yes
MAX.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
MINI.dest	Yes	Yes	Yes
I.dest	Yes	Yes	Yes
e.dest	Yes	Yes	Yes
CLIPw.dest	Yes	Yes	Yes
ITOF0.dest	Yes	Yes	Yes
4.dest	Yes	Yes	Yes
12.dest	Yes	Yes	Yes
15.dest	Yes	Yes	Yes
FTOI0.dest	Yes	Yes	Yes
4.dest	Yes	Yes	Yes
12.dest	Yes	Yes	Yes
15.dest	Yes	Yes	Yes
NOP	Yes	Yes	Yes

LOWER INSTRUCTION AVAILABILITY IN VU UNITS

Instruction	VU0 coprocessor	VU0 microprocessor	VU1
IADD	Yes	Yes	Yes
IADDI	Yes	Yes	Yes
IADDIU	Yes	Yes	Yes
ISUB	Yes	Yes	Yes
ISUBIU	Yes	Yes	Yes
DIV	Yes	Yes	Yes
SQRT	Yes	Yes	Yes
RQSRT	Yes	Yes	Yes
IAND	Yes	Yes	Yes
IOR	Yes	Yes	Yes
B	Yes	Yes	Yes
BAL	Yes	Yes	Yes
IBEQ	Yes	Yes	Yes
IBNE	Yes	Yes	Yes
IBGTZ	Yes	Yes	Yes
IBLEZ	Yes	Yes	Yes
IBGEZ	Yes	Yes	Yes
JR	Yes	Yes	Yes
JALR	Yes	Yes	Yes
ILW.dest	Yes	Yes	Yes
ILWR.dest	Yes	Yes	Yes
ISW.dest	Yes	Yes	Yes
ISWR.dest	Yes	Yes	Yes
LQ.dest	Yes	Yes	Yes
LQI.dest	Yes	Yes	Yes
LQD.dest	Yes	Yes	Yes
SQ.dest	Yes	Yes	Yes
SQI.dest	Yes	Yes	Yes
SQD.dest	Yes	Yes	Yes
MOVE.dest	Yes	Yes	Yes
MFIR.dest	Yes	Yes	Yes
MTIR	Yes	Yes	Yes
MR32.dest	Yes	Yes	Yes
FCAND	Yes	Yes	Yes
FCOR	Yes	Yes	Yes
FCEQ	Yes	Yes	Yes
FCGET	Yes	Yes	Yes
FCSET	Yes	Yes	Yes
FSAND	Yes	Yes	Yes
FSOR	Yes	Yes	Yes
FSEQ	Yes	Yes	Yes
FSSET	Yes	Yes	Yes
FMAND	Yes	Yes	Yes
FMOR	Yes	Yes	Yes
FMEQ	Yes	Yes	Yes
RINIT	Yes	Yes	Yes
RGET.dest	Yes	Yes	Yes
RNEXT.dest	Yes	Yes	Yes
RXOR	Yes	Yes	Yes
WAITP	Yes	Yes	Yes
WAITQ	Yes	Yes	Yes
ESUM	No	No	Yes
ESQRT	No	No	Yes
ESADD	No	No	Yes
ERSQRT	No	No	Yes
ERSADD	No	No	Yes
EATAN	No	No	Yes
EATANxz	No	No	Yes
EATANxy	No	No	Yes
ELENG	No	No	Yes
ESIN	No	No	Yes
ERLENG	No	No	Yes
ERCPR	No	No	Yes
EEXP	No	No	Yes
MFP.dest	No	No	Yes
XTOP	No	No	Yes
XITOP	No	No	Yes
XGKICK	No	No	Yes

UPPER VU1 INSTRUCTION ENCODING

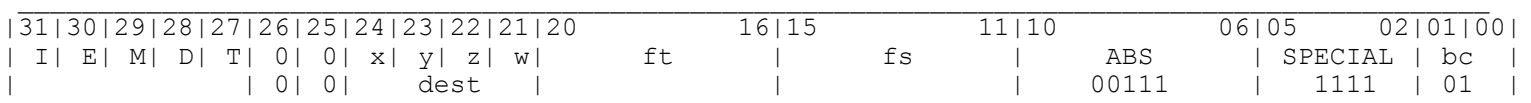
UPPER VU1 INSTRUCTION LAYOUT



UPPER VU1 INSTRUCTION FLAGS

FLAG	USAGE
i	Floating point value in lower microcode
e	Unknown
m	Unknown
d	Breakpoint. The code breaks after the current instruction executes
t	Unknown

Absolute ABS



Format: ABS.dest fs,ft

Purpose:
To calculate the absolute values of up to 4 fields

Description:
```
if dest & .x == true : fs.x <- abs(ft.x)
if dest & .y == true : fs.y <- abs(ft.y)
if dest & .z == true : fs.z <- abs(ft.z)
if dest & .w == true : fs.w <- abs(ft.w)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add ADD

```
_____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05           00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |      ADD      |
|              | 0| 0|    dest   |              |              |              |     101000    |
```

Format: ADD.dest fd,fs,ft

Purpose:
To add up to 4 matching fields

Description:
```
if dest & .x == true : fd.x <- fs.x + ft.x
if dest & .y == true : fd.y <- fs.y + ft.y
if dest & .z == true : fd.z <- fs.z + ft.z
if dest & .w == true : fd.w <- fs.w + ft.w
```

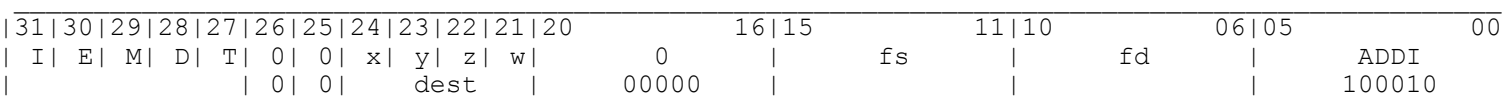
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add I ADDI



Format: ADD**I**.dest fd,fs,I

Purpose:
To add up to 4 fields with the I register

Description:
```
if dest & .x == true : fd.x <- fs.x + I
if dest & .y == true : fd.y <- fs.y + I
if dest & .z == true : fd.z <- fs.z + I
if dest & .w == true : fd.w <- fs.w + I
```

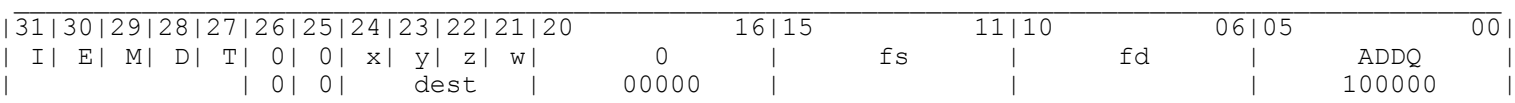
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add Q ADDQ



Format: ADD**Q**.dest fd,fs,Q

Purpose:
To add up to 4 fields with the Q register

Description:
```
if dest & .x == true : fd.x <- fs.x + Q
if dest & .y == true : fd.y <- fs.y + Q
if dest & .z == true : fd.z <- fs.z + Q
if dest & .w == true : fd.w <- fs.w + Q
```

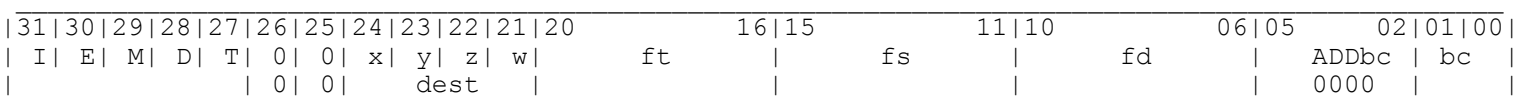
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add broadcast ADDx ADDy ADDz ADDw



Format: ADDx.dest fd,fs,ft
ADDy.dest fd,fs,ft
ADDz.dest fd,fs,ft
ADDw.dest fd,fs,ft

Purpose:
To add up to 4 fields with the broadcast field

Description:
```
if dest & .x == true : fd.x <- fs.x + ft.bc
if dest & .y == true : fd.y <- fs.y + ft.bc
if dest & .z == true : fd.z <- fs.z + ft.bc
if dest & .w == true : fd.w <- fs.w + ft.bc
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add accumulator ADDA

```
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |    ADDA      | SPECIAL | bc  |
|              | 0| 0|    dest   |              |              |    01010     |   1111  | 00  |
```

Format: ADDA.dest ACC,fs,ft

Purpose:
To add up to 4 matching fields

Description:
```
if dest & .x == true : ACC.x <- fs.x + ft.x
if dest & .y == true : ACC.y <- fs.y + ft.y
if dest & .z == true : ACC.z <- fs.z + ft.z
if dest & .w == true : ACC.w <- fs.w + ft.w
```

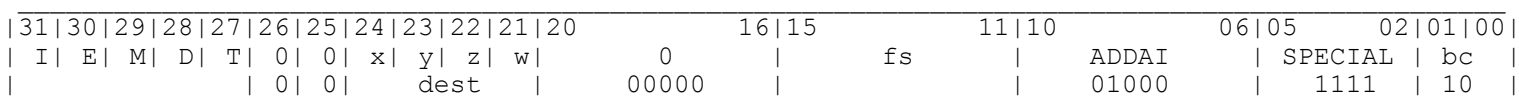
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add accumulator I ADDAI



Format: ADDAI.dest ACC,fs,I

Purpose:
To add up to 4 fields with the I register

Description:
```
if dest & .x == true : ACC.x <- fs.x + I
if dest & .y == true : ACC.y <- fs.y + I
if dest & .z == true : ACC.z <- fs.z + I
if dest & .w == true : ACC.w <- fs.w + I
```

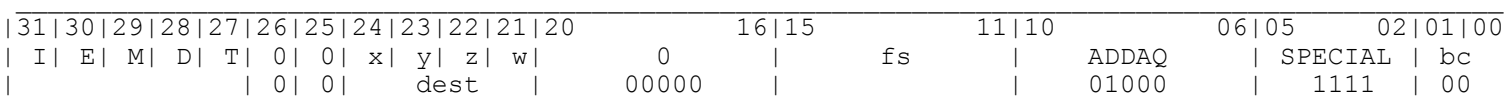
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add accumulator Q — ADDAQ



Format: ADDAQ.dest ACC,fs,Q

Purpose:
To add up to 4 fields with the Q register

Description:
```
if dest & .x == true : ACC.x <- fs.x + Q
if dest & .y == true : ACC.y <- fs.y + Q
if dest & .z == true : ACC.z <- fs.z + Q
if dest & .w == true : ACC.w <- fs.w + Q
```

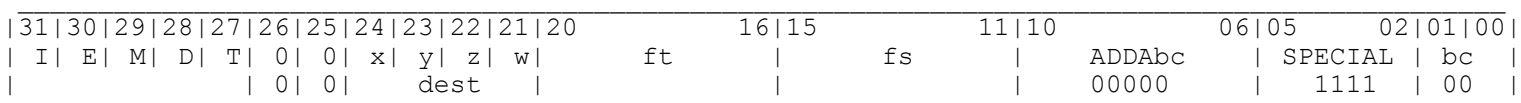
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Add accumulator broadcast ADDAx ADDAy ADDAz ADDAw



Format: ADDAx.dest ACC,fs,ft
ADDAy.dest ACC,fs,ft
ADDAz.dest ACC,fs,ft
ADDAw.dest ACC,fs,ft

Purpose:
To add up to 4 fields with the broadcast field

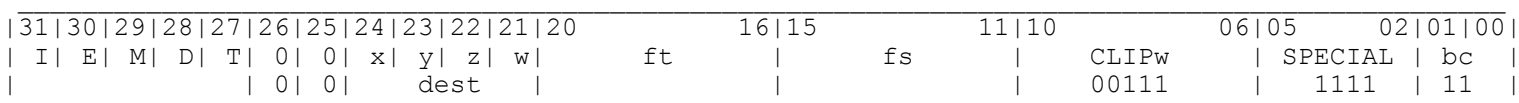
Description:
```
if dest & .x == true : ACC.x <- fs.x + ft.bc
if dest & .y == true : ACC.y <- fs.y + ft.bc
if dest & .z == true : ACC.z <- fs.z + ft.bc
if dest & .w == true : ACC.w <- fs.w + ft.bc
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1



Format: CLIPw.dest ft,fs

Purpose:
To update the status flag about the clipping condition of the destination values

Description:

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Floating to integer FTOI0 FTOI4 FTOI12 FTOI15

```
_____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |    FTOI      | SPECIAL | bc  |
|              | 0| 0|    dest   |              |              |    00101     |   1111  |     |
```

Format: FTOI0.dest It,fs
FTOI4.dest It,fs
FTOI12.dest It,fs
FTOI15.dest It,fs

Purpose:
To convert a floating point value to a fixed point (integer) number of 0, 4, 12 or 15 decimal digits

Description:
```
if     dest & .x == true : ft <- FixedPoint0/4/12/15(fs.x)
elseif dest & .y == true : ft <- FixedPoint0/4/12/15(fs.y)
elseif dest & .z == true : ft <- FixedPoint0/4/12/15(fs.z)
elseif dest & .w == true : ft <- FixedPoint0/4/12/15(fs.w)
```

Restrictions:

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1. It is primarily used with the Random number generator
The broadcast field specifies the number of decimal digits

Broadcast field	Meaning
00	0 decimal digits
01	4 decimal digits
10	12 decimal digits
11	15 decimal digits

Integer to floating point

ITOF0 ITOF4 ITOF12 ITOF15

```
_____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |    ITOF      | SPECIAL | bc  |
|              | 0| 0|    dest   |              |              |    00100     |   1111  |     |
```

Format: ITOF0.dest ft,fs
ITOF4.dest ft,fs
ITOF12.dest ft,fs
ITOF15.dest ft,fs

Purpose:
To convert a fixed point (integer) value of 0, 4, 12 or 15 decimal digits to a floating point number

Description:
```
if     dest & .x == true : ft.x <- FixedPoint0/4/12/15(fs)
elseif dest & .y == true : ft.y <- FixedPoint0/4/12/15(fs)
elseif dest & .z == true : ft.z <- FixedPoint0/4/12/15(fs)
elseif dest & .w == true : ft.w <- FixedPoint0/4/12/15(fs)
```

Restrictions:

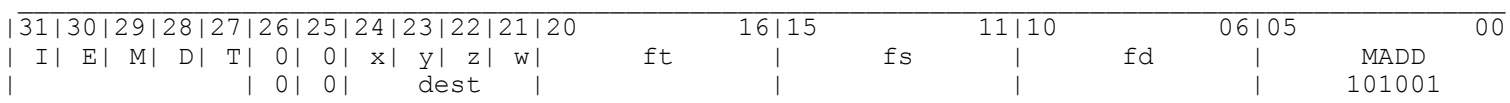
Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1. It is primarily used with the Random number generator
The broadcast field specifies the number of decimal digits

Broadcast field	Meaning
00	0 decimal digits
01	4 decimal digits
10	12 decimal digits
11	15 decimal digits

Multiply and add MADD



Format: MADD.dest fd,fs,ft

Purpose:
To multiply up to 4 matching fields and add the products with matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x + (fs.x * ft.x)
if dest & .y == true : fd.y <- ACC.y + (fs.y * ft.y)
if dest & .z == true : fd.z <- ACC.z + (fs.z * ft.z)
if dest & .w == true : fd.w <- ACC.w + (fs.w * ft.w)
```

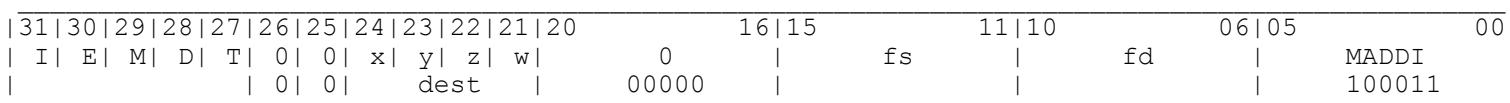
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add I — MADDI



Format: MADDI.dest fd,fs,I

Purpose:
To multiply up to 4 fields with the I register and add the products with matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x + (fs.x * I)
if dest & .y == true : fd.y <- ACC.y + (fs.y * I)
if dest & .z == true : fd.z <- ACC.z + (fs.z * I)
if dest & .w == true : fd.w <- ACC.w + (fs.w * I)
```

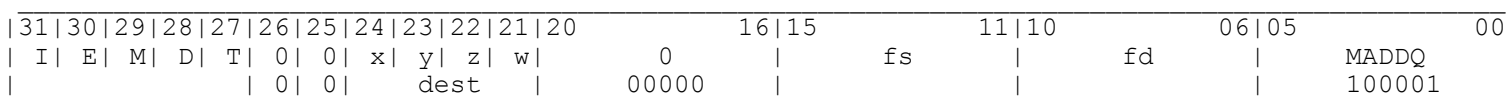
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add Q — MADDQ



Format: MADDQ.dest fd,fs,Q

Purpose:
To multiply up to 4 fields with the Q register and add the products with matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x + (fs.x * Q)
if dest & .y == true : fd.y <- ACC.y + (fs.y * Q)
if dest & .z == true : fd.z <- ACC.z + (fs.z * Q)
if dest & .w == true : fd.w <- ACC.w + (fs.w * Q)
```

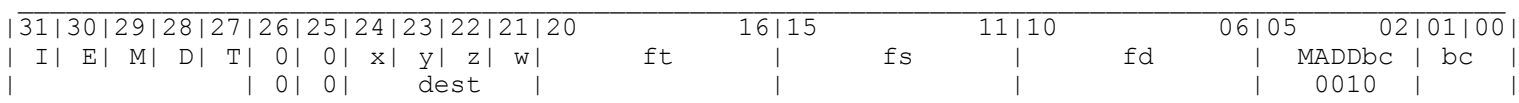
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add broadcast MADDx MADDy MADDz MADDw



Format: MADDx.dest fd,fs,ft
MADDy.dest fd,fs,ft
MADDz.dest fd,fs,ft
MADDw.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the broadcast field and add the products with matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x + (fs.x * ft.bc)
if dest & .y == true : fd.y <- ACC.y + (fs.y * ft.bc)
if dest & .z == true : fd.z <- ACC.z + (fs.z * ft.bc)
if dest & .w == true : fd.w <- ACC.w + (fs.w * ft.bc)
```

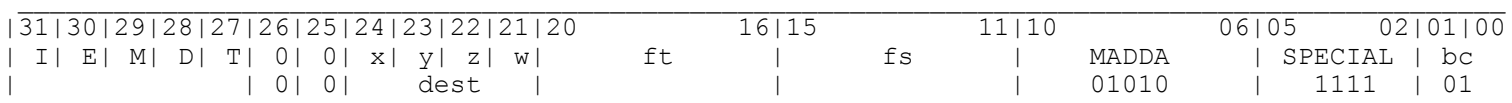
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add accumulator MADDA



Format: MADDA.dest ACC,fs,ft

Purpose:
To multiply up to 4 fields and add the products with matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x + (fs.x * ft.x)
if dest & .y == true : ACC.y <- ACC.y + (fs.y * ft.y)
if dest & .z == true : ACC.z <- ACC.z + (fs.z * ft.z)
if dest & .w == true : ACC.w <- ACC.w + (fs.w * ft.w)
```

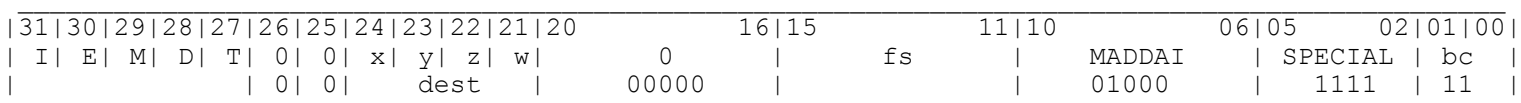
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add accumulator I MADDAI



Format: MADDAI.dest ACC,fs,I

Purpose:
To multiply up to 4 fields with the I register and add the products with matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x + (fs.x * I)
if dest & .y == true : ACC.y <- ACC.y + (fs.y * I)
if dest & .z == true : ACC.z <- ACC.z + (fs.z * I)
if dest & .w == true : ACC.w <- ACC.w + (fs.w * I)
```

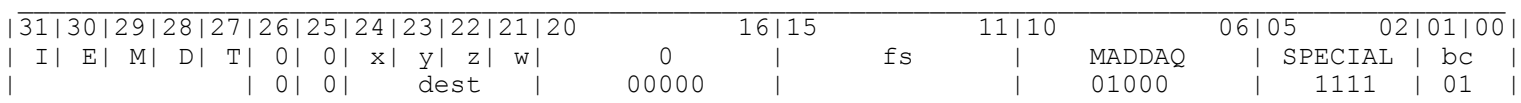
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add accumulator Q MADDAQ



Format: MADDAI.dest ACC,fs,Q

Purpose:
To multiply up to 4 fields with the Q register and add the products with matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x + (fs.x * Q)
if dest & .y == true : ACC.y <- ACC.y + (fs.y * Q)
if dest & .z == true : ACC.z <- ACC.z + (fs.z * Q)
if dest & .w == true : ACC.w <- ACC.w + (fs.w * Q)
```

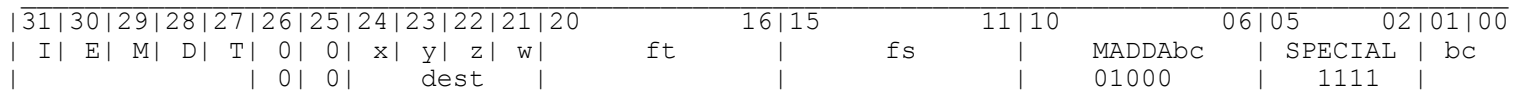
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and add accumulator broadcast MADDAx MADDAy MADDAz MADDAw



Format: MADDAx.dest ACC,fs,ft
MADDAy.dest ACC,fs,ft
MADDAz.dest ACC,fs,ft
MADDAw.dest ACC,fs,ft

Purpose:
To multiply up to 4 fields with the broadcast field and add the products with matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x + (fs.x * ft.x)
if dest & .y == true : ACC.y <- ACC.y + (fs.y * ft.y)
if dest & .z == true : ACC.z <- ACC.z + (fs.z * ft.z)
if dest & .w == true : ACC.w <- ACC.w + (fs.w * ft.w)
```

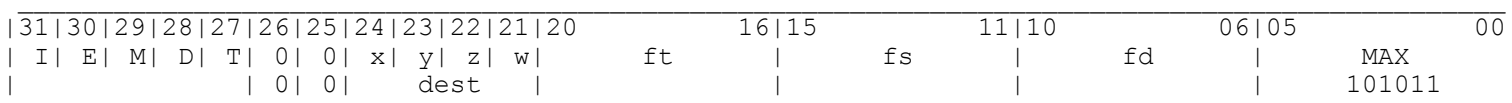
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Maximum MAX



Format: MAX.dest fd,fs,ft

Purpose:
To find the maximum value between up to 4 matching fields

Description:
```
if dest & .x == true : fd.x <- max(fs.x : ft.bc)
if dest & .y == true : fd.y <- max(fs.y : ft.bc)
if dest & .z == true : fd.z <- max(fs.z : ft.bc)
if dest & .w == true : fd.w <- max(fs.w : ft.bc)
```

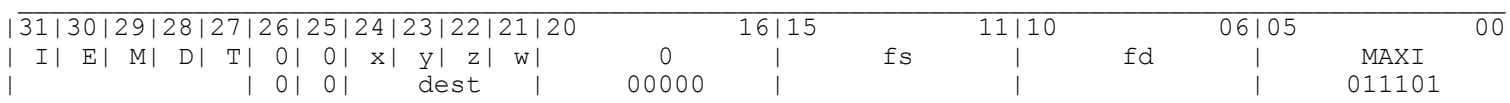
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Maximum I MAXI



Format: MAXI.dest fd,fs,I

Purpose:
To find the maximum value between up to 4 fields and the I register

Description:
```
if dest & .x == true : fd.x <- max(fs.x : I)
if dest & .y == true : fd.y <- max(fs.y : I)
if dest & .z == true : fd.z <- max(fs.z : I)
if dest & .w == true : fd.w <- max(fs.w : I)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Maximum broadcast MAXx MAXy MAXz MAXw

```
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |  MAXbc  | bc  |
|              | 0| 0|    dest   |              |              |              |   0100  |     |
```

Format: MAXx.dest fd,fs,ft
MAXy.dest fd,fs,ft
MAXz.dest fd,fs,ft
MAXw.dest fd,fs,ft

Purpose:
To find the maximum value between up to 4 fields and the I register

Description:
```
if dest & .x == true : fd.x <- max(fs.x : ft.bc)
if dest & .y == true : fd.y <- max(fs.y : ft.bc)
if dest & .z == true : fd.z <- max(fs.z : ft.bc)
if dest & .w == true : fd.w <- max(fs.w : ft.bc)
```

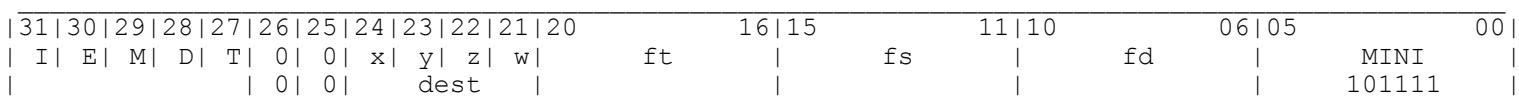
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Minimum MINI



Format: MINI.dest fd,fs,ft

Purpose:
To find the minimum value between up to 4 matching fields

Description:
```
if dest & .x == true : fd.x <- mini(fs.x : ft.x)
if dest & .y == true : fd.y <- mini(fs.y : ft.y)
if dest & .z == true : fd.z <- mini(fs.z : ft.z)
if dest & .w == true : fd.w <- mini(fs.w : ft.w)
```

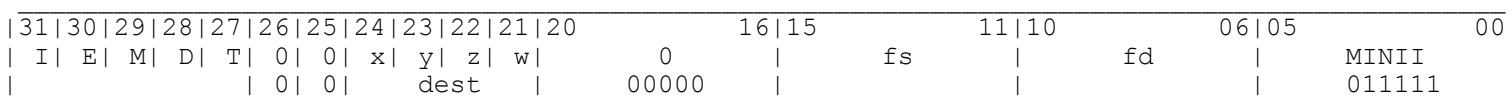
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Minimum I MINII



Format: MINII.dest fd,fs,ft

Purpose:
To find the minimum value between up to 4 fields and the I register

Description:
```
if dest & .x == true : fd.x <- mini(fs.x : I)
if dest & .y == true : fd.y <- mini(fs.y : I)
if dest & .z == true : fd.z <- mini(fs.z : I)
if dest & .w == true : fd.w <- mini(fs.w : I)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Minimum broadcast MINIx MINIy MINIz MINIw

```
 _____________________________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |  MINIbc | bc  |
|              | 0| 0|    dest   |              |              |              |   0101  |     |
```

Format: MINIx.dest fd,fs,ft
MINIy.dest fd,fs,ft
MINIz.dest fd,fs,ft
MINIw.dest fd,fs,ft

Purpose:
To find the minimum value between up to 4 fields and the I register

Description:
```
if dest & .x == true : fd.x <- mini(fs.x : ft.bc)
if dest & .y == true : fd.y <- mini(fs.y : ft.bc)
if dest & .z == true : fd.z <- mini(fs.z : ft.bc)
if dest & .w == true : fd.w <- mini(fs.w : ft.bc)
```

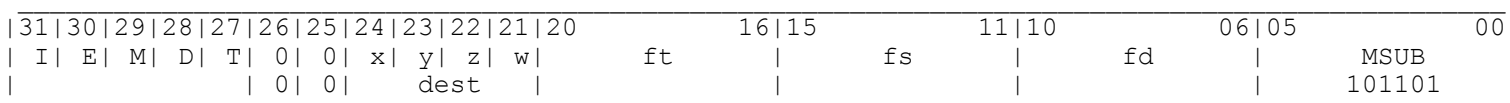
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract MSUB



Format: MSUB.dest fd,fs,ft

Purpose:
To multiply up to 4 matching fields and substract the products from matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x - (fs.x * ft.x)
if dest & .y == true : fd.y <- ACC.y - (fs.y * ft.y)
if dest & .z == true : fd.z <- ACC.z - (fs.z * ft.z)
if dest & .w == true : fd.w <- ACC.w - (fs.w * ft.w)
```

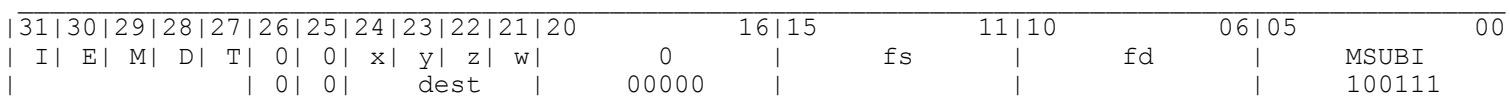
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract I — MSUBI



Format: MSUBI.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the I register and substract the products from matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x - (fs.x * I)
if dest & .y == true : fd.y <- ACC.y - (fs.y * I)
if dest & .z == true : fd.z <- ACC.z - (fs.z * I)
if dest & .w == true : fd.w <- ACC.w - (fs.w * I)
```

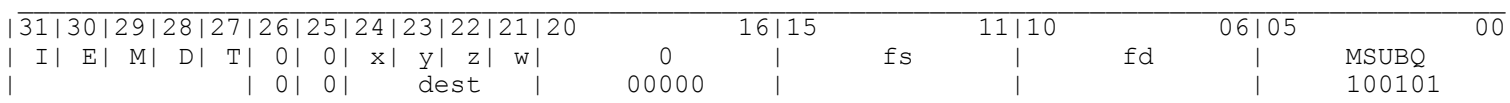
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract Q — MSUBQ



Format: MSUBQ.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the Q register and substract the products from matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x - (fs.x * Q)
if dest & .y == true : fd.y <- ACC.y - (fs.y * Q)
if dest & .z == true : fd.z <- ACC.z - (fs.z * Q)
if dest & .w == true : fd.w <- ACC.w - (fs.w * Q)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract broadcast MSUBx MSUBy MSUBz MSUBw

```
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |  MSUBbc | bc  |
|              | 0| 0|    dest   |              |              |              |   0011  |     |
```

Format:
```
MSUBx.dest fd,fs,ft
MSUBy.dest fd,fs,ft
MSUBw.dest fd,fs,ft
MSUBw.dest fd,fs,ft
```

Purpose:
To multiply up to 4 fields with the broadcast field and substract the products from matching fields of the accumulator

Description:
```
if dest & .x == true : fd.x <- ACC.x - (fs.x * ft.bc)
if dest & .y == true : fd.y <- ACC.y - (fs.y * ft.bc)
if dest & .z == true : fd.z <- ACC.z - (fs.z * ft.bc)
if dest & .w == true : fd.w <- ACC.w - (fs.w * ft.bc)
```

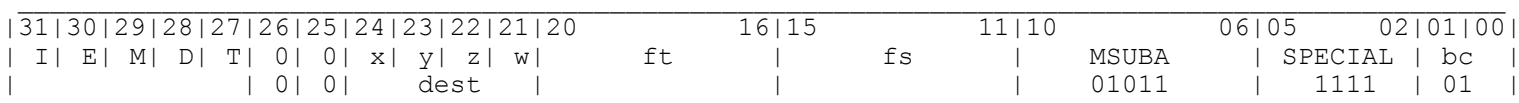
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract accumulator MSUBA



Format: MSUBA.dest fd,fs,ft

Purpose:
To multiply up to 4 fields and substract the products from matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x - (fs.x * ft.bc)
if dest & .y == true : ACC.y <- ACC.y - (fs.y * ft.bc)
if dest & .z == true : ACC.z <- ACC.z - (fs.z * ft.bc)
if dest & .w == true : ACC.w <- ACC.w - (fs.w * ft.bc)
```

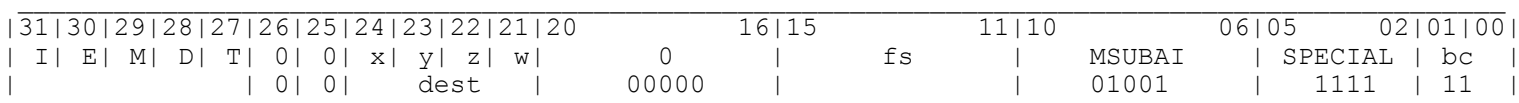
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract accumulator I MSUBAI



Format: MSUBAI.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the I register and substract the products from matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x - (fs.x * I)
if dest & .y == true : ACC.y <- ACC.y - (fs.y * I)
if dest & .z == true : ACC.z <- ACC.z - (fs.z * I)
if dest & .w == true : ACC.w <- ACC.w - (fs.w * I)
```

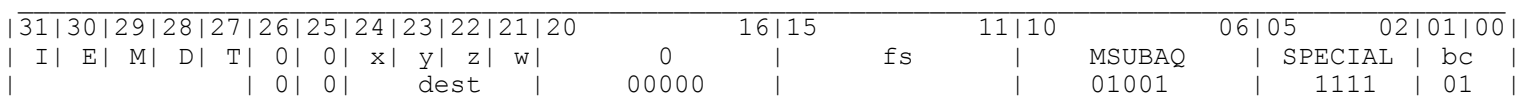
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract accumulator Q MSUBAQ



Format: MSUBAQ.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the Q register and substract the products from matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x - (fs.x * Q)
if dest & .y == true : ACC.y <- ACC.y - (fs.y * Q)
if dest & .z == true : ACC.z <- ACC.z - (fs.z * Q)
if dest & .w == true : ACC.w <- ACC.w - (fs.w * Q)
```

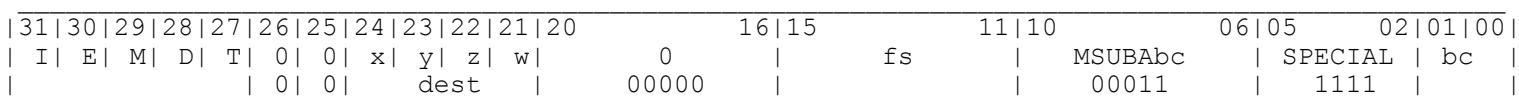
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply and substract accumulator broadcast MSUBAx MSUBAy MSUBAz MSUBAw



Format:
```
MSUBAx.dest fd,fs,ft
MSUBAy.dest fd,fs,ft
MSUBAz.dest fd,fs,ft
MSUBAw.dest fd,fs,ft
```

Purpose:
To multiply up to 4 fields with the broadcast field and substract the products from matching fields in the accumulator

Description:
```
if dest & .x == true : ACC.x <- ACC.x - (fs.x * ft.bc)
if dest & .y == true : ACC.y <- ACC.y - (fs.y * ft.bc)
if dest & .z == true : ACC.z <- ACC.z - (fs.z * ft.bc)
if dest & .w == true : ACC.w <- ACC.w - (fs.w * ft.bc)
```

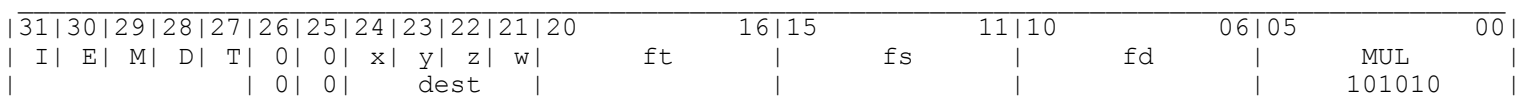
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply MUL



Format: MUL.dest fd,fs,ft

Purpose:
To multiply up to 4 matching fields

Description:
```
if dest & .x == true : fd.x <- fs.x * ft.x
if dest & .y == true : fd.y <- fs.y * ft.y
if dest & .z == true : fd.z <- fs.z * ft.z
if dest & .w == true : fd.w <- fs.w * ft.w
```

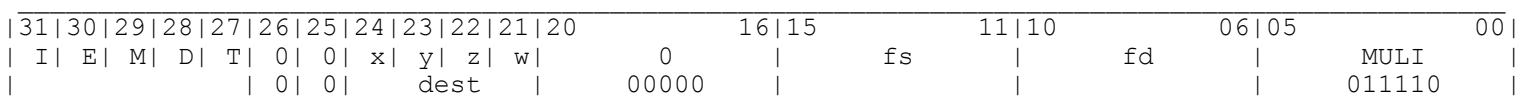
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply I MULI



Format: MULI.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the I register

Description:
```
if dest & .x == true : fd.x <- fs.x * I)
if dest & .y == true : fd.y <- fs.y * I)
if dest & .z == true : fd.z <- fs.z * I)
if dest & .w == true : fd.w <- fs.w * I)
```

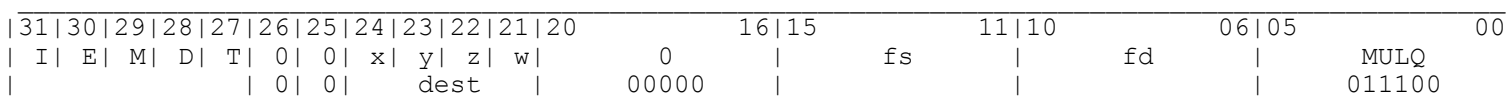
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply Q MULQ



Format: MULQ.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the Q register

Description:
```
if dest & .x == true : fd.x <- fs.x * Q)
if dest & .y == true : fd.y <- fs.y * Q)
if dest & .z == true : fd.z <- fs.z * Q)
if dest & .w == true : fd.w <- fs.w * Q)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Multiply broadcast

MULx MULy MULz MULw

```
 _____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |   MULbc | bc  |
|              | 0| 0|    dest   |              |              |              |   0110  |     |
```

Format: MULx.dest fd,fs,ft
MULy.dest fd,fs,ft
MULz.dest fd,fs,ft
MULw.dest fd,fs,ft

Purpose:
To multiply up to 4 fields with the broadcast field

Description: if dest & .x == true : fd.x <- fs.x * ft.bc)
if dest & .y == true : fd.y <- fs.y * ft.bc)
if dest & .z == true : fd.z <- fs.z * ft.bc)
if dest & .w == true : fd.w <- fs.w * ft.bc)

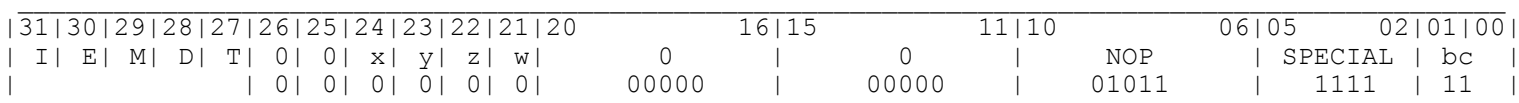
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

No operation NOP



Format: NOP

Purpose:
To perform no operation

Description:

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Outer product pre increment OPMULA

```
 _____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |    OPMULA    | SPECIAL | bc  |
|             | 0| 0| 1| 1| 1| 0|              |              |    01011     |   1111  | 10  |
```

Format: OPMULA.xyz ACC,fs,ft

Purpose:
To calculate the outer product pre increment

Description:
```
ACC.x <- (fs.y * ft.z) + (fs.z * ft.y)
ACC.y <- (fs.z * ft.x) + (fs.x * ft.z)
ACC.z <- (fs.x * ft.y) + (fs.y * ft.x)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Outer product post decrement OPMSUB

```
 ____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05           00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |     OPMSUB    |
|             | 0| 0| 1| 1| 1| 0|              |              |              |     011011    |
```

Format: OPMSUB.xyz fd,fs,ft

Purpose:
To calculate the outer product post decrement

Description:
```
fd.x <- (fs.y * ft.z) - (fs.z * ft.y)
fd.y <- (fs.z * ft.x) - (fs.x * ft.z)
fd.z <- (fs.x * ft.y) - (fs.y * ft.x)
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract SUB

```
 _____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05           00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |      SUB      |
|              | 0| 0|    dest   |              |              |              |     101100    |
```

Format: SUB.dest fd,fs,ft

Purpose:
To substract up to 4 matching fields

Description:
```
if dest & .x == true : fd.x <- fs.x - ft.x
if dest & .y == true : fd.y <- fs.y - ft.y
if dest & .z == true : fd.z <- fs.z - ft.z
if dest & .w == true : fd.w <- fs.w - ft.w
```

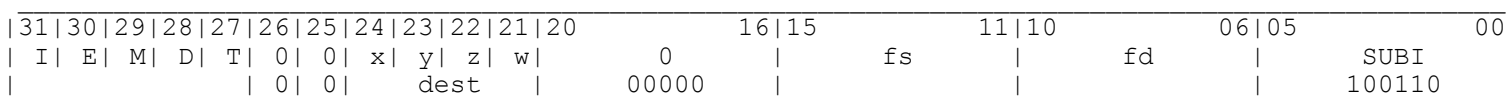
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract I SUBI



Format: SUBI.dest fd,fs,Q

Purpose:
To substract the I register from up to 4 fields

Description:
```
if dest & .x == true : fd.x <- fs.x - I
if dest & .y == true : fd.y <- fs.y - I
if dest & .z == true : fd.z <- fs.z - I
if dest & .w == true : fd.w <- fs.w - I
```

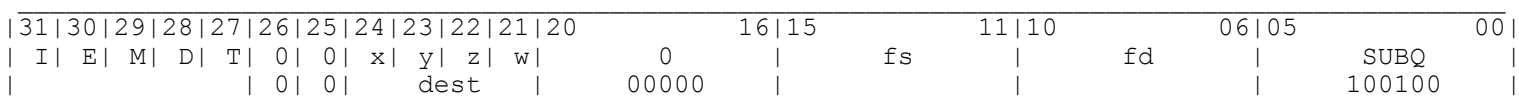
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract Q SUBQ



Format: SUBQ.dest fd,fs,Q

Purpose:
To substract the Q register from up to 4 fields

Description:
```
if dest & .x == true : fd.x <- fs.x - Q
if dest & .y == true : fd.y <- fs.y - Q
if dest & .z == true : fd.z <- fs.z - Q
if dest & .w == true : fd.w <- fs.w - Q
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract broadcast SUBx SUBy SUBz SUBw

```
 _____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |      fd      |   SUBbc | bc  |
|              | 0| 0|    dest   |              |              |              |   0001  |     |
```

Format: SUBx.dest fd,fs,ft
SUBy.dest fd,fs,ft
SUBz.dest fd,fs,ft
SUBw.dest fd,ft,fs

Purpose:
To substract the broadcast field from up to 4 fields

Description:
```
if dest & .x == true : fd.x <- fs.x - ft.bc
if dest & .y == true : fd.y <- fs.y - ft.bc
if dest & .z == true : fd.z <- fs.z - ft.bc
if dest & .w == true : fd.w <- fs.w - ft.bc
```

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract accumulator SUBA

```
_____________________________________________________________________________
|31|30|29|28|27|26|25|24|23|22|21|20          16|15          11|10          06|05     02|01|00|
| I| E| M| D| T| 0| 0| x| y| z| w|      ft      |      fs      |    SUBA      | SPECIAL | bc  |
|             | 0| 0|    dest   |              |              |    01011     |   1111  | 00  |
```

Format: SUBA.dest ACC,fs,ft

Purpose:
To substract up to 4 matching fields to the accumulator

Description:
```
if dest & .x == true : ACC.x <- fs.x - ft.x
if dest & .y == true : ACC.y <- fs.y - ft.y
if dest & .z == true : ACC.z <- fs.z - ft.z
if dest & .w == true : ACC.w <- fs.w - ft.w
```

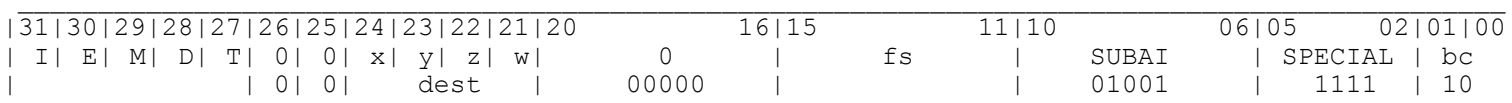
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract accumulator I SUBAI



Format: SUBAI.dest ACC,fs,I

Purpose:
To substract the I register from up to 4 matching fields to the accumulator

Description:
```
if dest & .x == true : ACC.x <- fs.x - I
if dest & .y == true : ACC.y <- fs.y - I
if dest & .z == true : ACC.z <- fs.z - I
if dest & .w == true : ACC.w <- fs.w - I
```

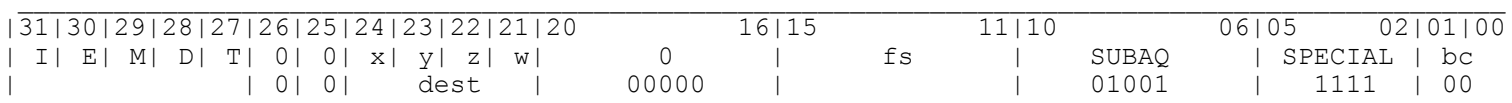
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract accumulator Q SUBAQ



Format: SUBAQ.dest ACC,fs,Q

Purpose:
To substract the Q register from up to 4 matching fields to the accumulator

Description:
```
if dest & .x == true : ACC.x <- fs.x - Q
if dest & .y == true : ACC.y <- fs.y - Q
if dest & .z == true : ACC.z <- fs.z - Q
if dest & .w == true : ACC.w <- fs.w - Q
```

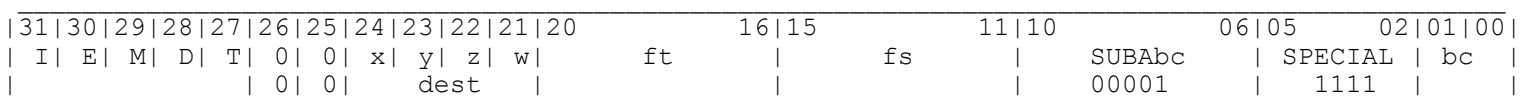
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Substract accumulator broadcast SUBAx SUBAy SUBAz SUBAw



Format: SUBAx.dest ACC,fs,ft
SUBAy.dest ACC,fs,ft
SUBAz.dest ACC,fs,ft
SUBAw.dest ACC,ft,fs

Purpose:
To substract up to matching 4 fields to the accumulator

Description:
```
if dest & .x == true : ACC.x <- fs.x - ft.bc
if dest & .y == true : ACC.y <- fs.y - ft.bc
if dest & .z == true : ACC.z <- fs.z - ft.bc
if dest & .w == true : ACC.w <- fs.w - ft.bc
```

Restrictions:
None

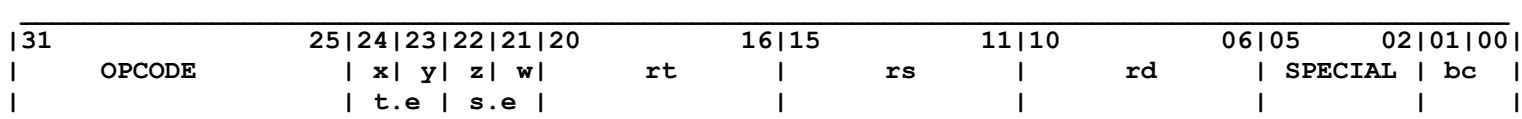
Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

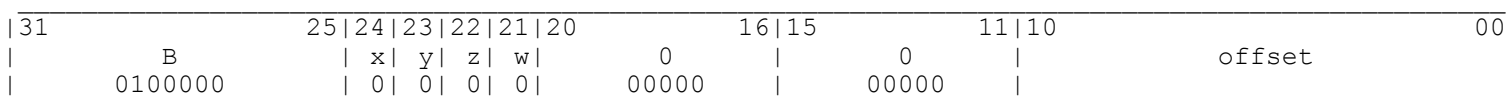
LOWER VU1 INSTRUCTION ENCODING

LOWER VU1 INSTRUCTION LAYOUT




```
ft.e and fs.e : 00 x
                01 y
                11 w
```

Branch B



Format: B offset

Purpose:
To unconditionally branch to a VU instruction address

Description: branch -> PC + offset + 8

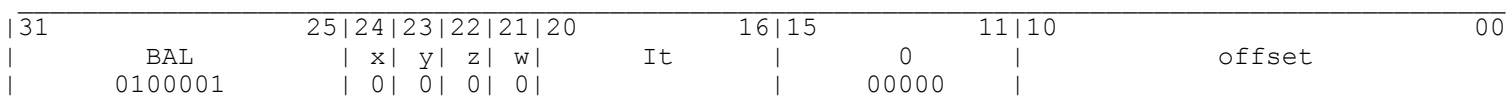
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Branch and link BAL



Format: BAL It, offset

Purpose:
To unconditionally branch to a VU instruction address and link to an IR

Description: branch -> PC + offset + 8
It -> PC + 16

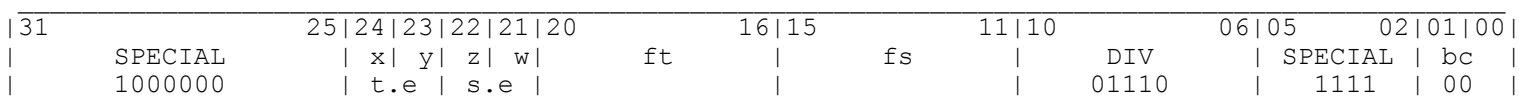
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Divide DIV



Format: DIV Q,ft.e,fs.e

Purpose:
To divide a field of a VU FPR with a field of a VU FPR and store the result in the Q register

Description: Q <- ft.e/fs.e

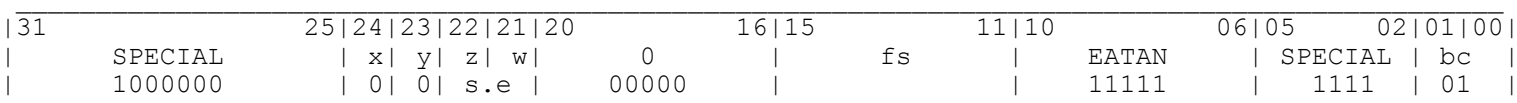
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Archtangent EATAN



Format: EATAN P, fs.e

Purpose:
To calculate the archtangent of a single field in a VU FPR and store it in the P register

Description: P <- arch(fs.e)

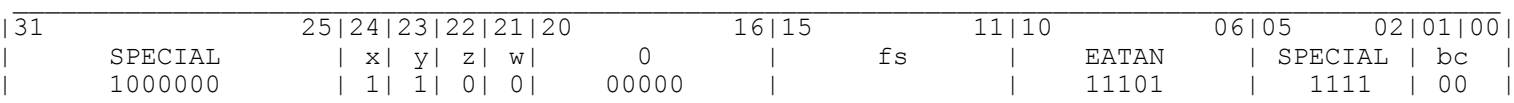
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Archtangent xy EATANxy



Format: EATANxy P, fs

Purpose:
To calculate the archtangent of two fields in a VU FPR and store it in the P register

Description: P <- arch(fs.x, fs.y)

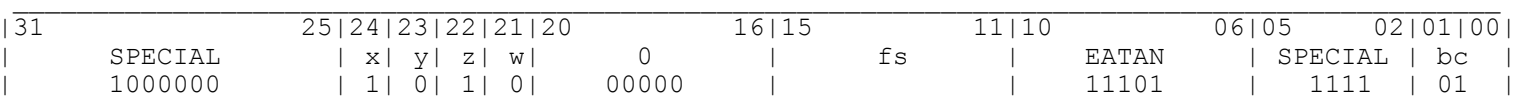
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Archtangent xz EATANxz



Format: EATANxy P, fs

Purpose:
To calculate the archtangent of two fields in a VU FPR and store it in the P register

Description: P <- arch(fs.x, fs.z)

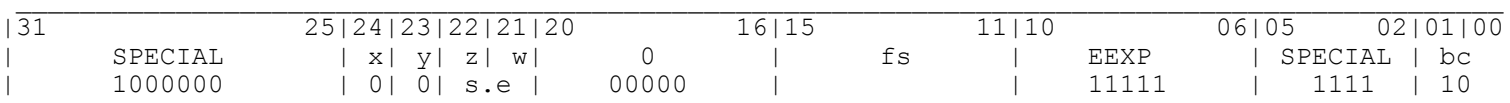
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Exponent EEXP



Format: EEXP P, fs.e

Purpose:
To calculate the exponent of a single field of a VU FPR and store it in the P register

Description: P <- exp(fs.e)

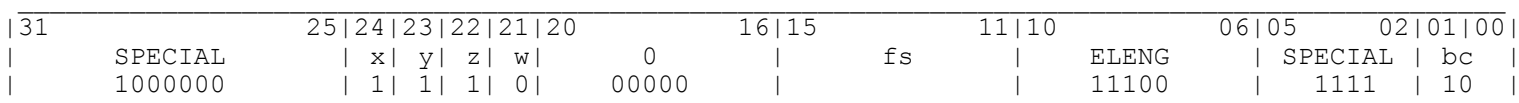
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Length ELENG



Format: ELENG P, fs

Purpose:
To calculate the length for the values in a VU FPR

Description: P <- len(fs)

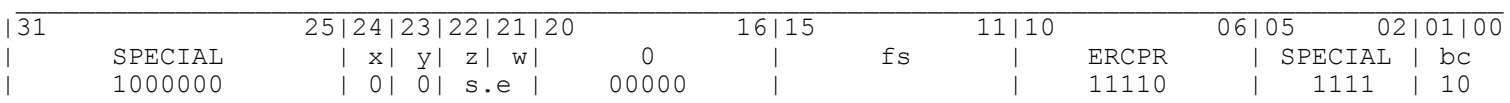
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Reciprocal root ERCPR



Format: ERCPR P, fs.e

Purpose:
To calculate the reciprocal root for a single field of a VU FPR and store it in the P register

Description: P <- rec.root(fs.e)

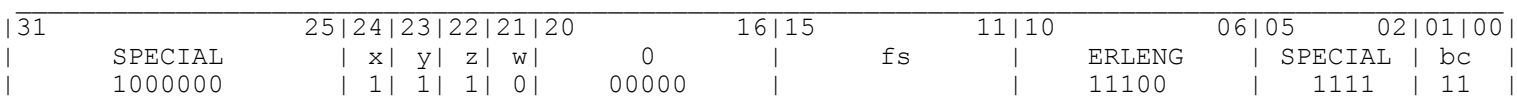
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Reverse length ERLENG



Format: ERLENG P, fs.xyz

Purpose:
To calculate the reverse length for the xyz fields of a VU FPR and store it in the P register

Description: P <- rev.len(fs.xyz)

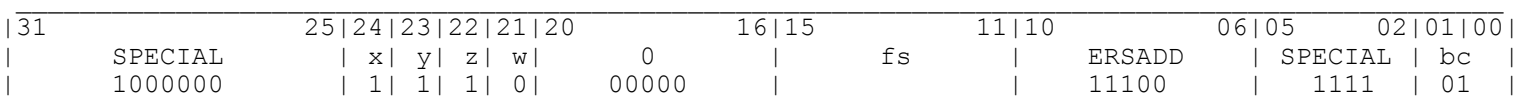
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Reverse square root add ERSADD



Format: ERSADD P,fs

Purpose:
To calculate the reverse square root of the addition of the xyz fields of a VU FPR and store it in the P register

Description: P <- rev.sq.root(fs.x + fs.y + fs.z)

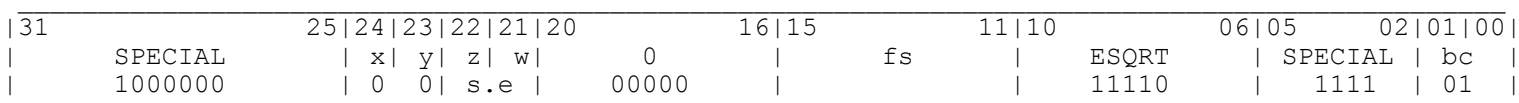
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Square root ESQRT



Format: ESQRT P, fs.e

Purpose:
To calculate the square root of a single field of a VU FPR and store it in the P register

Description: P <- sq.root(fs.e)

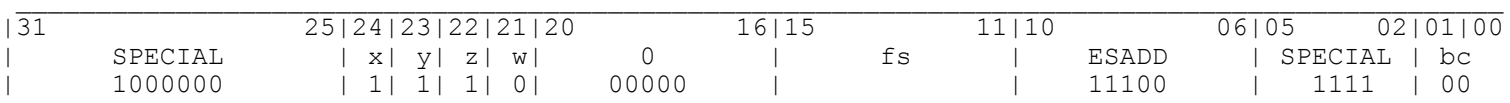
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Square root add ESADD



Format: ESADD P, fs.xyz

Purpose:
To calculate the square root of the sum of the xyz fields of a VU FPR and store it in the P register

Description: P <- sq.root(fs.x + fs.y + fs.z)

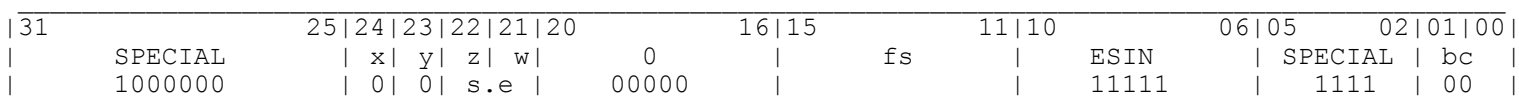
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Sin SIN



Format: ESIN P, fs.e

Purpose:
To calculate the sin of a single field of VU FPR and store it in the P register

Description: P <- sin(fs.e)

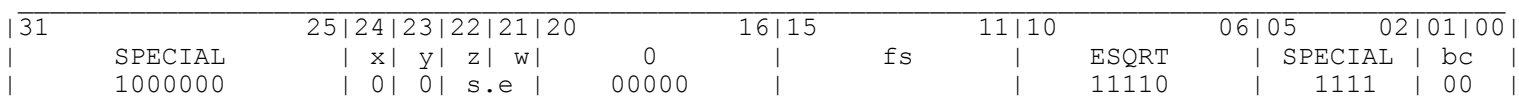
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Square root ESQRT



Format: ESQRT P, fs.e

Purpose:
To calculate the square root of a single field of VU FPR and store it in the P register

Description: P <- sq.root(fs.e)

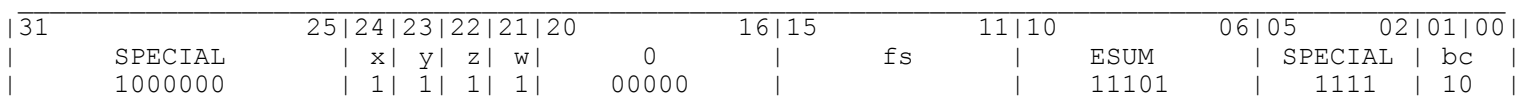
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Sum ESUM



Format: ESUM P,fs

Purpose:
To calculate the sum of all the fields of a VU FPR and store it in the P register

Description: P <- fs.x + fs.y + fs.z + fs.w

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable only to VU1

Clipping AND FCAND

Format: FCAND VI01,imm24

Purpose:
To perform a logical AND between the VI01 register and the 24 bit immediate and update the clipping flag

Description: clipping flag(VI01 AND imm24)

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Clipping equality FCEQ

Format: FCEQ VI01,imm24

Purpose:
To perform an equality check between the VI01 register and the 24 bit immediate and only update the clipping flag on equality

Description: clipping flag(VI01 EQ imm24)

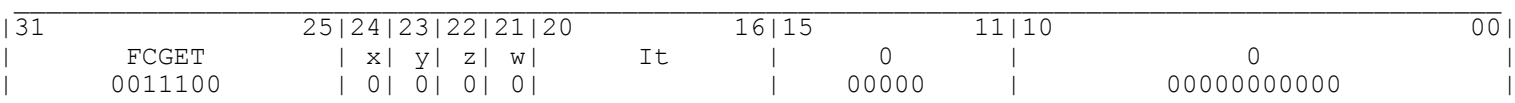
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Clipping transfer FCGET



31–25	24	23	22	21	20–16	15–11	10–00
FCGET	x	y	z	w	It	0	0
0011100	0	0	0	0		00000	00000000000

Format: FCGET It

Purpose:
To move the clipping flag to a VU IR

Description: It <- clipping flag

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Clipping OR FCOR

Format: FCOR VI01,imm24

Purpose:
To perform an OR between the VI01 register and the 24 bit immediate and update the clipping flag

Description: clipping flag(VI01 OR imm24)

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Clipping set FCSET

Format: FCSET imm24

Purpose:
To set the clipping flag to the value of the 24 bit immediate

Description: clipping flag = imm24

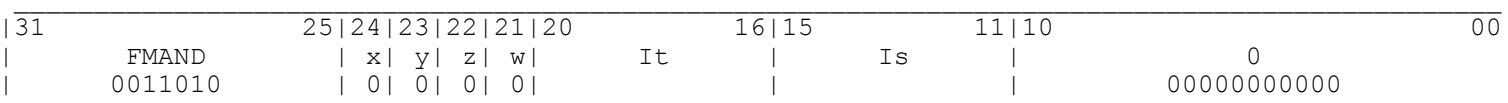
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

MAC AND FMAND



Format: FMAND It,Is

Purpose:
To AND the values in two VU IRs and move the result to the MAC flag

Description: MAC <- It AND Is

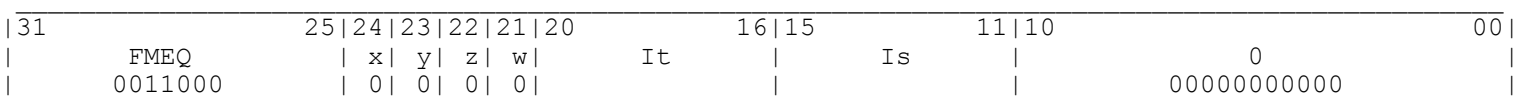
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

MAC equality FMEQ



31–25	24	23	22	21	20–16	15–11	10–00
FMEQ	x	y	z	w	It	Is	0
0011000	0	0	0	0			00000000000

Format: FMEQ It,Is

Purpose:
To compare the values in two VU IRs and only move the result to the MAC flag on eqauality

Description: MAC eq(It,Is)

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

MAC OR FMOR

31 25	24	23	22	21	20 16	15 11	10 00
FMOR	x	y	z	w	It	Is	0
0011011	0	0	0	0			00000000000

Format: FMOR It,Is

Purpose:
To OR the values two VU IRs and move the result to the MAC flag

Description: MAC == It OR Is

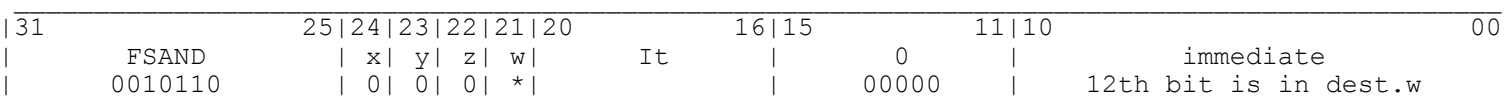
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Status AND FSAND



Format: FSAND It,imm12

Purpose:
To AND the value in a VU IR with a 12 bit immediate and move the result to the status flag

Description: STATUS == It OR imm12

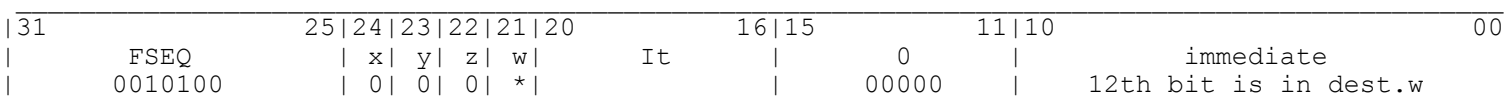
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Status equality FSEQ



Format: FSEQ It, imm12

Purpose:
To compare the value in a VU IR with a 12 bit immediate and only move the result to the status flag on equality

Description: STATUS eq(It, imm12)

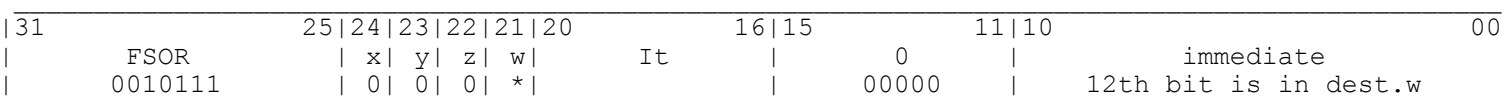
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Status OR FSOR



Format: FSOR It, imm12

Purpose:
To OR the value in a VU IR with a 12 bit immediate and move the result to the status flag

Description: STATUS == It OR imm12

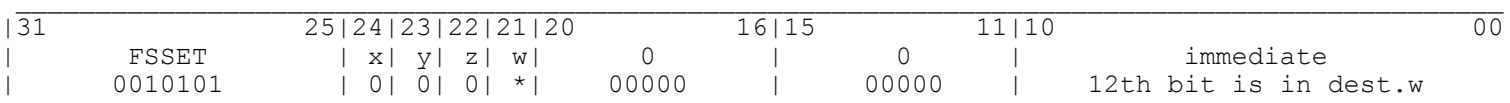
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Status set FSSET



Format: FSSET imm12

Purpose:
To set the status flag to the value of the 12bit immediate

Description: STATUS == imm12

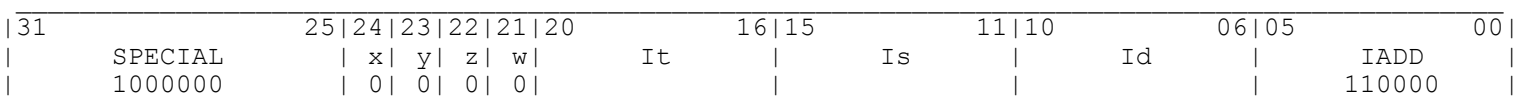
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer add IADD



Format: IADD Id, Is, It

Purpose:
To add two VU IRs and store the result in a VU IR

Description: Id = Is + It

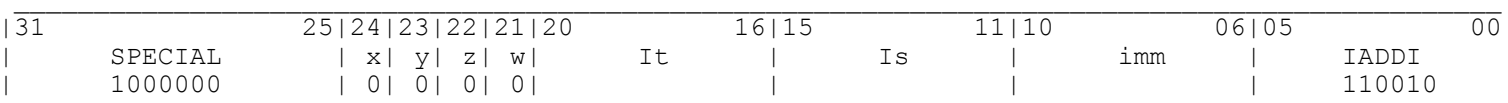
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer add immediate IADDI



Format: IADDI It, Is, imm5

Purpose:
To add a VU IRs with a 5 bit immediate and store the result in a VU IR

Description: It = Is + imm5

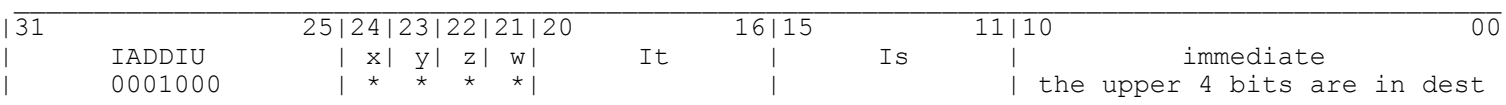
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer add immediate unsigned IADDIU



Format: IADDIU It, Is, imm12

Purpose:
To add a VU IRs with an unsigned 12 bit immediate and store the result in a VU IR

Description: It = Is + imm12

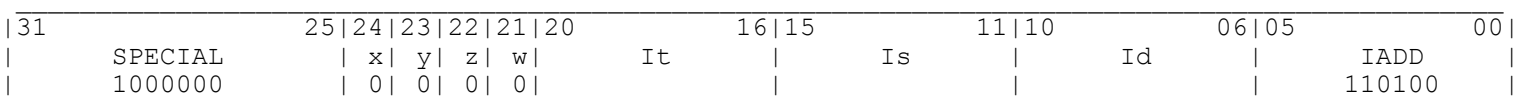
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer AND IAND



Format: IAND Id, Is, It

Purpose:
To AND two VU IRs and store the result in a VU IR

Description: Id = Is AND It

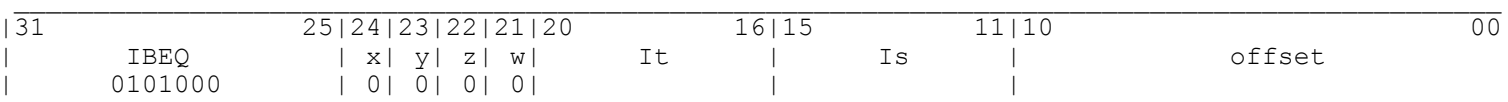
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer branch on equal IBEQ



Format: IBEQ It, Is, offset

Purpose:
To branch to a VU instruction memory offset if two VU IRs are equal

Description: PC <- PC + offset + 8

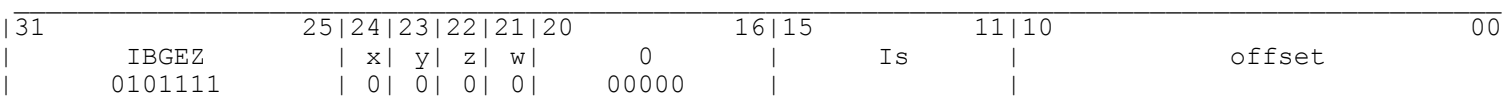
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Integer branch on greater or equal to zero IBGEZ



Format: IBGEZ Is, offset

Purpose:
To branch to a VU instruction memory offset if a VU IR is greater or equal to zero

Description: if Is >=0
PC <- PC + offset + 8

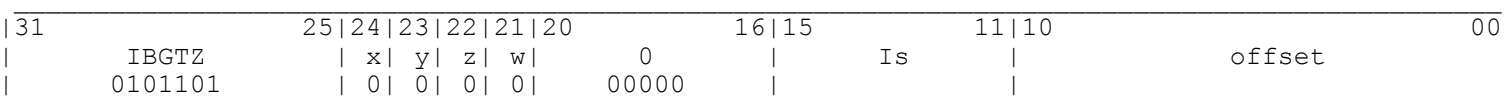
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Integer branch on greater than zero IBGTZ



Format: IBGEZ Is, offset

Purpose:
To branch to a VU instruction memory offset if a VU IR is greater than zero

Description: if Is >0
PC <- PC + offset + 8

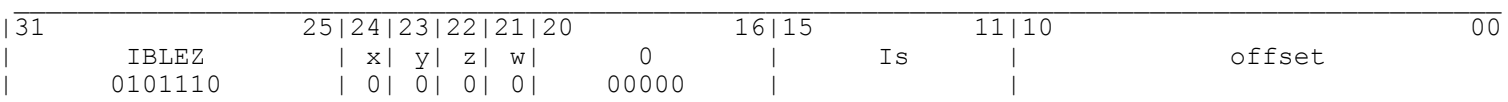
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Integer branch on less or equal to zero — IBLEZ



Format: IBLEZ Is, offset

Purpose:
To branch to a VU instruction memory offset if a VU IR is less or equal to zero

Description: if Is <=0
PC <- PC + offset + 8

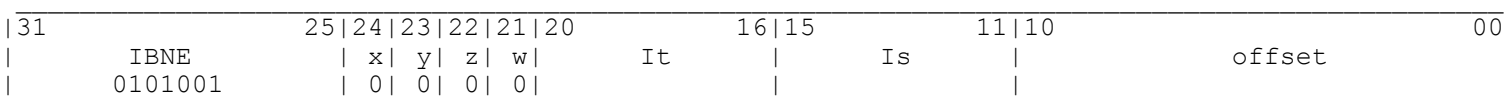
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Integer branch on not equal IBNE



Format: IBNE It, Is, offset

Purpose:
To branch to a VU instruction memory offset if two VU IR are not equal

Description: if Is =| It
PC <- PC + offset + 8

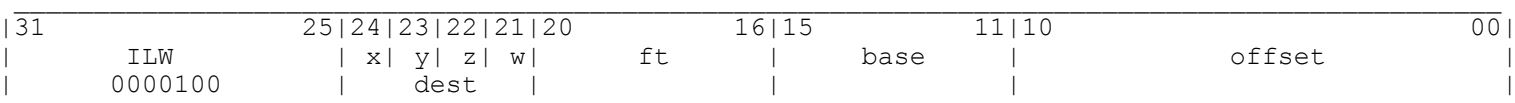
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU instruction memory.
This instruction is applicable to both VU0 and VU1

Integer load word ILW



Format: ILW.dest ft, offset(base)

Purpose:
To load up to 4 fields of a VU FPR with a word from the VU data cache

Description: fs.dest <- offset(base)

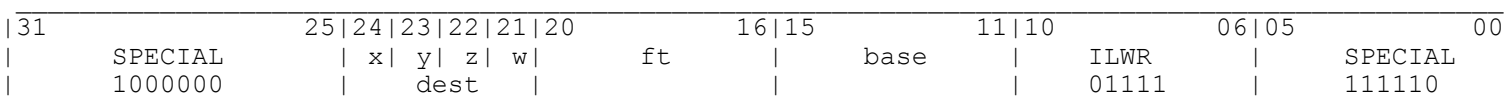
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU data memory.
This instruction is applicable to both VU0 and VU1

Integer load word register ILWR



Format: ILWR.dest ft, base

Purpose:
To load up to 4 fields of a VU FPR with a word from the VU data cache

Description: fs.dest <- [base]

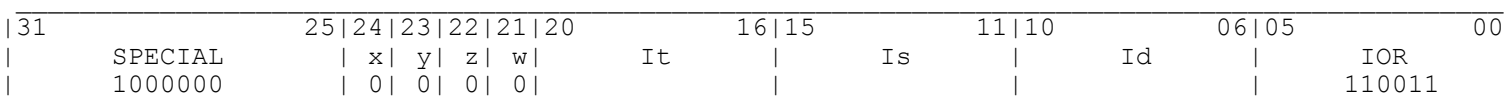
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer OR IOR



Format: IOR Id, Is, It

Purpose:
To OR two VU IRs and store the result in a VU IR

Description: Id = Is OR It

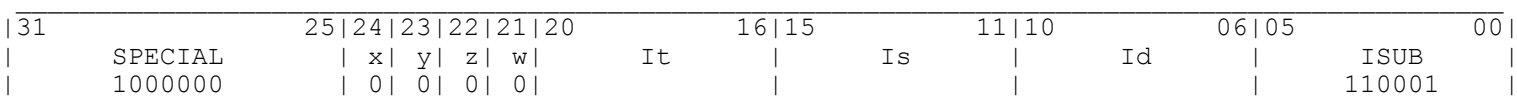
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer substract ISUB



Format: ISUB Id, Is, It

Purpose:
To substract two VU IRs and store the result in a VU IR

Description: Id = Is - It

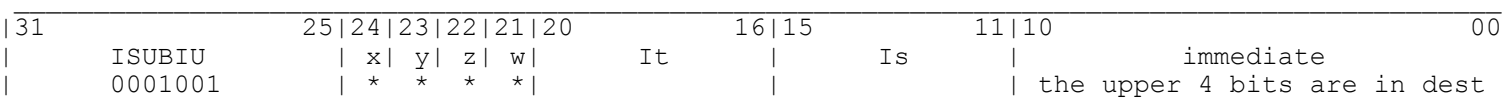
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer substract immediate unsigned ISUBIU



Format: IADDIU It, Is, imm12

Purpose:
To substract an unsigned 12 bit immediate from a VU IR and store the result in a VU IR

Description: It = Is + imm12

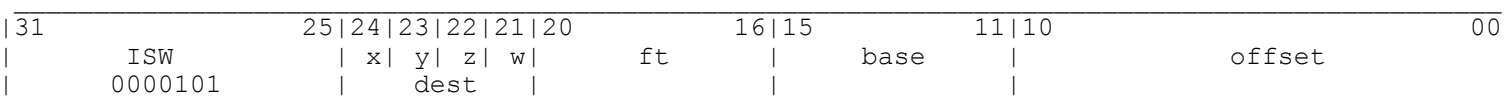
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Integer store word ISW



Format: ISW.dest ft, offset(base)

Purpose:
To store up to 4 fields of a VU FPR in the VU data cache

Description: offset(base) <- fs.dest

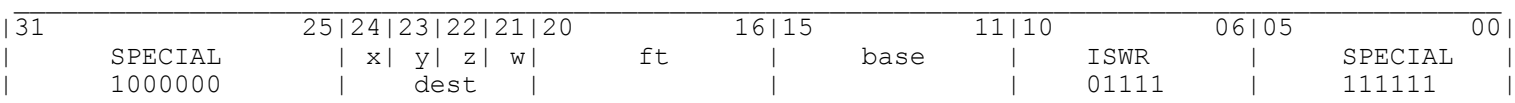
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU data memory.
This instruction is applicable to both VU0 and VU1

Integer store word register ISWR



Format: ISWR.dest ft, base

Purpose:
To store up to 4 fields of a VU FPR in the VU data cache

Description: [base] <- fs.dest

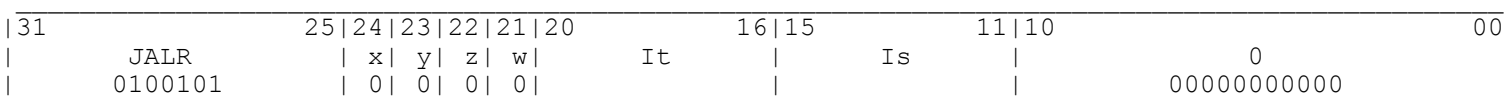
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Jump and link register JALR



Format: JALR It, Is

Purpose:
To branch to the VU instruction memory offset of a VU IR and link to a VU IR

Description: PC <- It
Is <- PC + 8

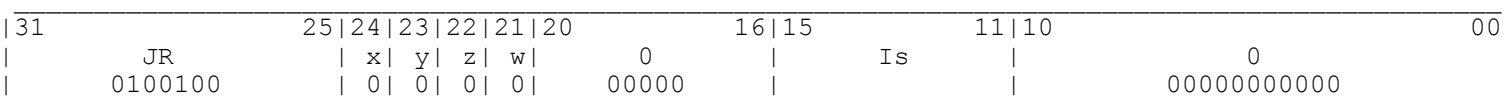
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Jump register JR



Format: JALR Is

Purpose:
To branch to the VU instruction memory offset of a VU IR

Description: PC <- Is

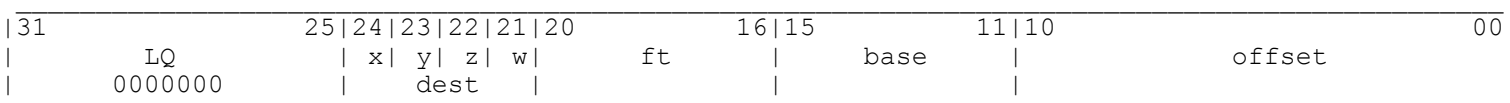
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Load quadraword LQ



Format: LQ.dest ft, offset(base)

Purpose:
To load up to 4 fields of a VU FPR with adjacent words in the VU data cache

Description: fs.dest <- offset(base)

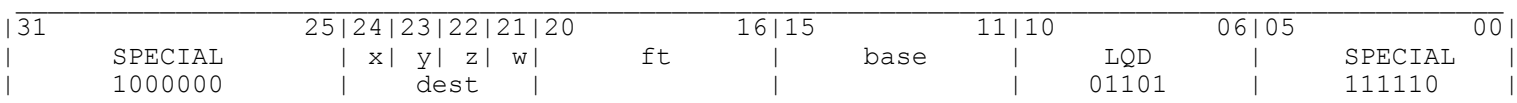
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU data memory.
This instruction is applicable to both VU0 and VU1

Load quadraword pre decrement LQD



Format: LQD.dest ft, --base

Purpose:
To load up to 4 fields of a VU FPR with VU data pre decrement

Description: base == base - 8
ft.dest <- [base]

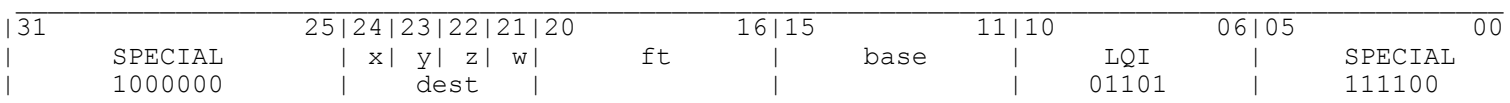
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Load quadraword post increment LQI



Format: LQI.dest ft, base++

Purpose:
To load up to 4 fields of a VU FPR with VU data post increment

Description: ft.dest <- [base]
base == base + 8

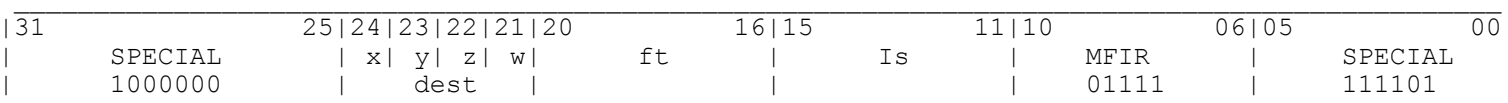
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Move from integer register MFIR



Format: MFIR.dest ft, Is

Purpose:
To load up to 4 fields of a VU FPR with the value of an IR

Description: ft.dest <- Is

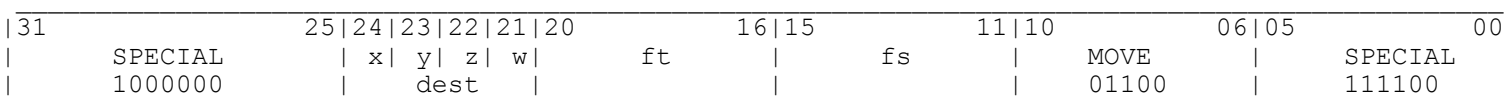
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Move floating point registers MOVE



Format: MOVE.dest ft, fs

Purpose:
To move up to 4 fields of a VU FPR to the corresponding fields of a VU FPR

Description:
```
if dest & .x == true : ft.x <- fs.x
if dest & .y == true : ft.y <- fs.y
if dest & .z == true : ft.z <- fs.z
if dest & .w == true : ft.w <- fs.w
```

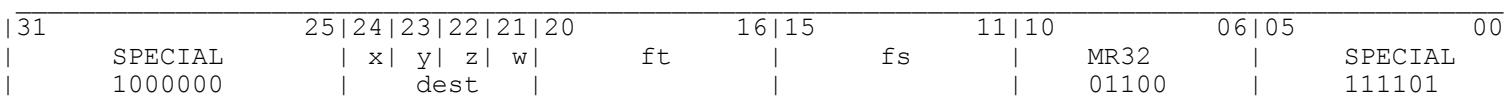
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Move and rotate per word MR32



Format: MOVE.dest ft, fs

Purpose:
To move up to 4 fields of a VU FPR to rotated fields of a VU FPR

Description:
```
if dest & .x == true : fs.x -> ft.y
if dest & .y == true : fs.y -> ft.z
if dest & .z == true : fs.z -> fs.w
if dest & .w == true : fs.w -> fs.x
```

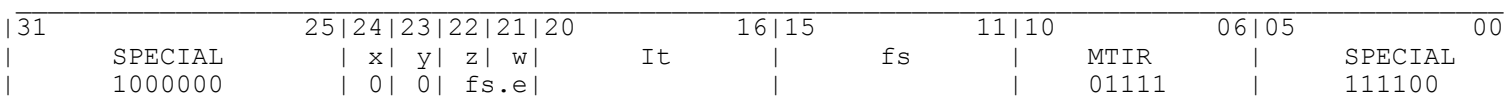
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Move to integer register MTIR



Format: MTIR.e It, fs.e

Purpose:
To move a field of a VU FPR to an IR

Description: It <- fs.dest

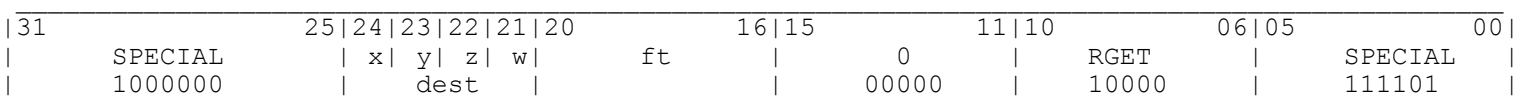
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

R move RGET



Format: RGET.dest ft, R

Purpose:
To load up to 4 fields of a VU FPR with the R register

Description: fs.dest <- R

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

R initialise RINIT

31 25	24	23	22	21	20 16	15 11	10 06	05 00
SPECIAL	x	y	z	w	0	fs	RINIT	SPECIAL
1000000	0	0	fs.e		00000		10000	111110

Format: RINIT.e R, fs.e

Purpose:
To initialise the random generator using a field of a VU FPR as matrix

Description: R <- Random(fs.e)

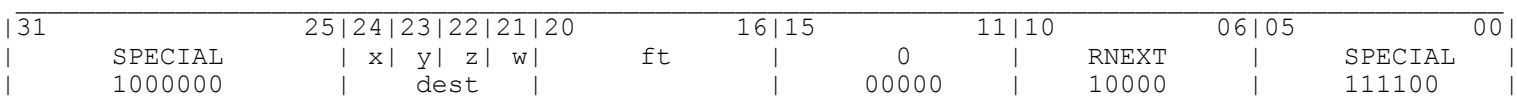
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

R next RNEXT



Format: RNEXT.dest ft, R

Purpose:
To load up to 4 fields of a VU FPR with the next random number from the R register

Description: ft.dest <- R

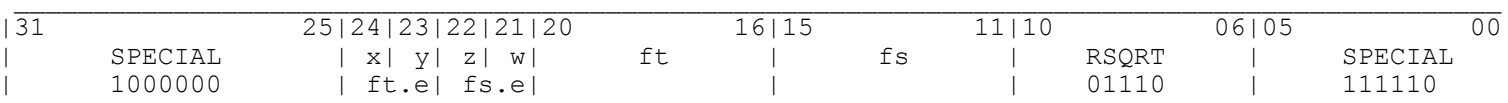
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Reverse square root RSQRT



Format: RSQRT Q, ft.e, fs.e

Purpose:
To calculate ft.e/sqrt(fs.e)

Description: Q <- ft.e/sqrt(fs.e)

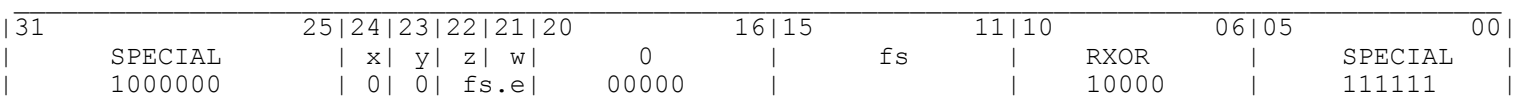
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

R XOR RXOR



Format: RXOR.e R, fs.e

Purpose:
To XOR the value in the R register and a field of a VU FPR and store the result in the R register

Description: R <- R XOR fs.e

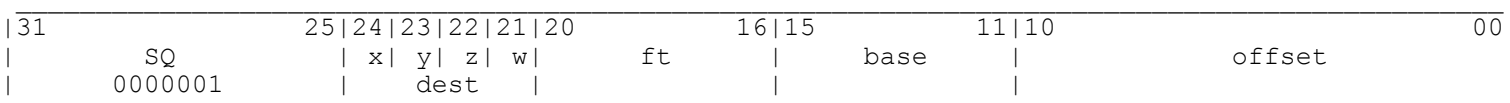
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Store quadraword SQ



Format: SQ.dest ft, offset(base)

Purpose:
To store up to 4 fields of a VU FPR to adjacent words in the VU data cache

Description: offset(base) <- fs.dest

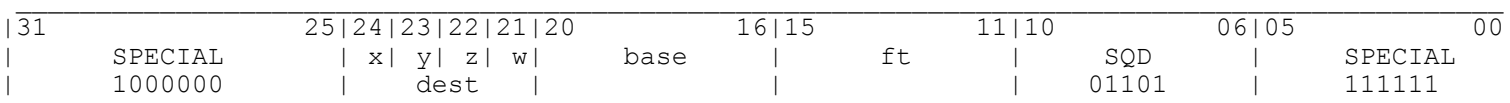
Restrictions:
None

Operation:

Exceptions:

Programming notes:
The offset refers to doublewords in the VU data memory.
This instruction is applicable to both VU0 and VU1

Store quadraword pre decrement SQD



Format: SQD.dest ft, --base

Purpose:
To store up to 4 fields of a VU FPR to the VU data cache pre decrement

Description: base == base - 8
[base] <- ft.dest

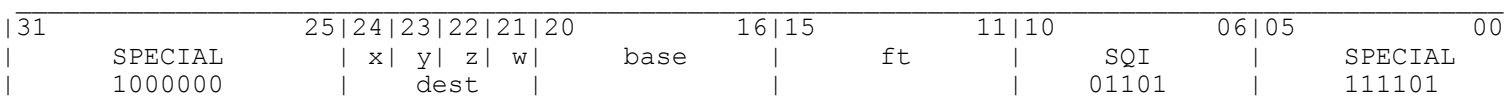
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Store quadraword post increment SQI



Format: SQI.dest ft, base++

Purpose:
To store up to 4 fields of a VU FPR to the VU data cache post increment

Description: [base] <- ft.dest
base == base + 8

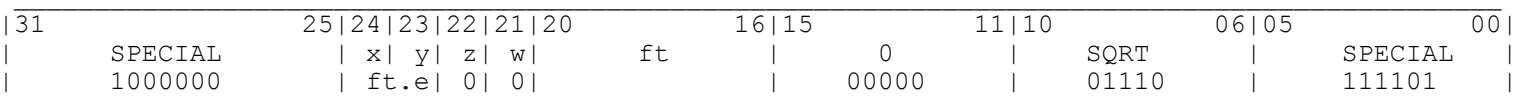
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Square root SQRT



Format: SQRT Q, ft.e

Purpose:
To calculate the square root of the value in a single field of a VU FPR

Description: Q <- sqrt(ft.e)

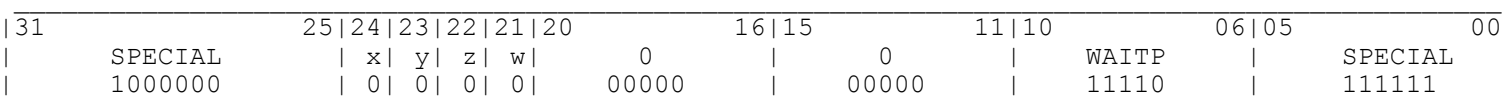
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Wait P operation WAITP



Format: WAITP

Purpose:
To postpone VU operation until the operation of the instruction that writes to the P register is concluded

Description:

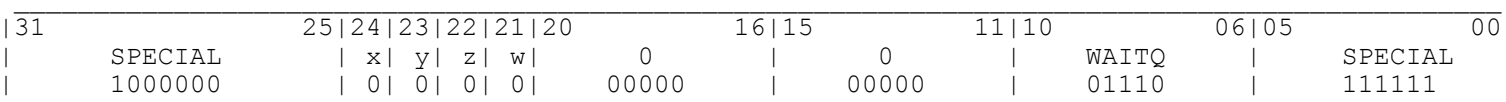
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Wait Q operation WAITQ



Format: WAITQ

Purpose:
To postpone VU operation untill the operation of the instruction that writes to the Q register is concluded

Description:

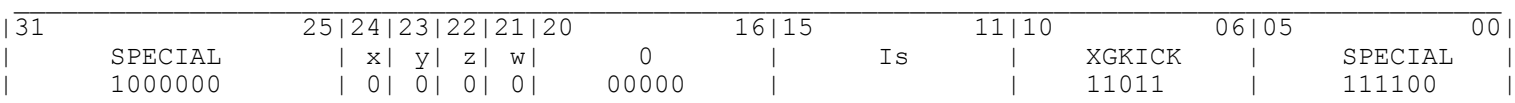
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is applicable to both VU0 and VU1

Initialise GIF path XGKICK



Format: XGKICK Is

Purpose:
To initialise the VU1 path to the GIF

Description:

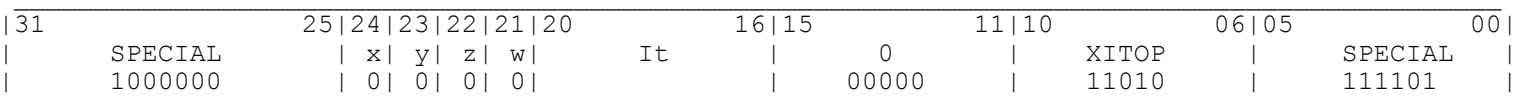
Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is only applicable to VU1

GIF path handling XITOP



31–25	24	23	22	21	20–16	15–11	10–06	05–00
SPECIAL	x	y	z	w	It	0	XITOP	SPECIAL
1000000	0	0	0	0		00000	11010	111101

Format: XITOP It

Purpose:
To control the VU1 path to the GIF

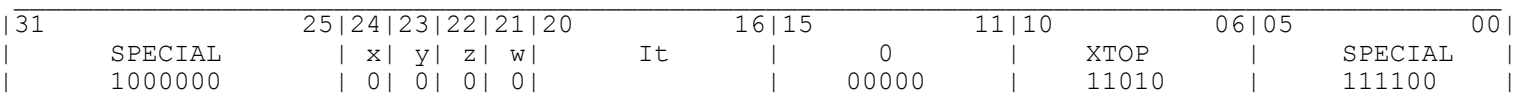
Description:

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is only applicable to VU1



31–25	24	23	22	21	20–16	15–11	10–06	05–00
SPECIAL	x	y	z	w	It	0	XTOP	SPECIAL
1000000	0	0	0	0		00000	11010	111100

Format: XTOP It

Purpose:
To control the VU1 path to the GIF

Description:

Restrictions:
None

Operation:

Exceptions:

Programming notes:
This instruction is only applicable to VU1

LEGEND

VU	Vector Unit
VU0	Vector Unit 0
VU1	Vector Unit 1
FPR	Floating point register
IR	Integer register
dest	destination fields
fs	floating point source register
ft	floating point target register
fd	floating point destination register
Is	integer source register
It	integer target register
Id	integer destination register
imm	immediate
bc	broadcast field
.e	field selector