



SPU Assembly Language Specification

Version 1.6

CBEA JSRE Series
Cell Broadband Engine Architecture
Joint Software Reference Environment
Series

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About This Document

This document describes the Synergistic Processor Unit (SPU) assembly-language syntax for a processor compliant with the Cell Broadband Engine™ Architecture (CBEA).

Audience

The document is intended for system and application programmers who desire to write assembly language programs for the SPU.

Version History

This section describes significant changes made to each version of this document.

Version Number & Date	Changes
v. 1.6 September 3, 2007	Corrected miscellaneous documentation errors (TWG_RFC00102-1: CORRECTION NOTICE).
v. 1.5 March 8, 2007	Added several new double precision floating-point instructions (TWG_RFC00071-0). Corrected document version numbers for related documentation (TWG_RGC00093-0).
v. 1.4 October 11, 2006	Changed several operands from <code>rt</code> to <code>rc</code> in the SPU Assembler Instructions table (TWG_RFC00049-0: CORRECTION NOTICE and jsre-tool messages 00468 and 00488). The description of the <code>wrch</code> instruction in the SPU Assembler Instructions table was corrected. Applied changes made in TWG_RFC00061-1 and TWG_RFC00062-0.
v. 1.3 October 20, 2005	Changed "Broadband Processor Architecture" to "Cell Broadband Engine Architecture", and changed "BPA" to "CBEA" (TWG_RFC00037-0: CORRECTION NOTICE). Deleted several references to BE revisions DD1.0 and DD2.0 (TWG_RFC00040-0: CORRECTION NOTICE).
v. 1.2 July 13, 2005	Deleted several sections in the "About This Document" chapter (TWG_RFC00032-0: CORRECTION NOTICE). Corrected several documentation errors; for example, in several descriptions in the SPU Assembler Instructions table, the phrase "halfword element <code>rt</code> " was changed to "halfword element 1 of register <code>rt</code> " (TWG_RFC00033-0: CORRECTION NOTICE).
v. 1.1 June 10, 2005	Changed "Broadband Engine" or "BE" to "a processor compliant with the Broadband Processor Architecture" or "a processor compliant with BPA"; and changed Synergistic Processing Unit to Synergistic Processor Unit. Defined a PPU as a PowerPC Processor Unit on first major instance. Corrected several book references and changed the copyright page so that trademark owners were specified. (All changes per TWG_RFC00031-0: CORRECTION NOTICE.) Made miscellaneous changes to the "About This Document" section.
v. 0.9 - 1.0	Not applicable. Version numbers were changed so that JSRE version numbers are in synchrony with those used by IBM in its public release.

Version Number & Date	Changes
v. 0.8 May 12, 2005	Changed PU to PPU; changed “PU-to-SPU” (mailboxes) and “SPU-to-PU” to “inbound” and “outbound” respectively (TWG_RFC00028-1: CORRECTION NOTICE). Updated channel names to coincide with BPA channel names (TWG_RFC00029-1).
v. 0.7 July 16, 2004	Removed all branch aliases from table of instruction aliases (TWG_RFC00009-0). Added an additional SPU instruction, <code>orx</code> (TWG_RFC00010-0). Added mnemonics for channels that support reading the event mask and tag mask (TWG_RFC00011-0). Removed operands from <code>hbrp</code> instruction and provided a new description of this instruction. Also removed it from a table (TWG_RFC00012-0). Made miscellaneous editorial changes.
v. 0.6 March 12, 2004	Made miscellaneous editorial changes.
v. 0.5 February 25, 2004	Changed formatting of document so that it reflects the typographic conventions mentioned in the “About This Document” section. Made minimal editorial changes.
v. 0.4 January 20, 2004	Changed document to new format, including front matter. Made miscellaneous editorial changes.
v. 0.3 August 31, 2003	Corrected PC-relative addressing style. Added low and high halfword address syntax. Added <code>stopd</code> instruction.
v. 0.2 May 13, 2003	Added isolation control channel. Replaced <code>aci</code> , <code>asc</code> , <code>sbi</code> , and <code>ssb</code> instructions with <code>addx</code> , <code>cg</code> , <code>cgx</code> , <code>sfx</code> , <code>bg</code> , and <code>bgx</code> .
v. 0.1 March 7, 2003	Initial release of this document.

Related Documentation

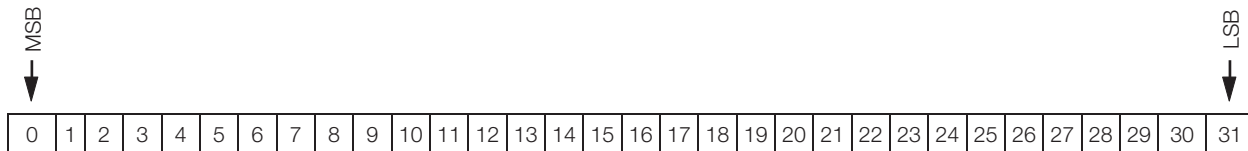
The following table provides a list of references and supporting materials for this document:

Document Title	Version	Date
<i>PowerPC User Instruction Set Architecture, Book I</i>	2.02	November 2005
<i>PowerPC Virtual Environment Architecture, Book II</i>	2.02	November 2005
<i>PowerPC Operating Environment Architecture, Book III</i>	2.02	November 2005
<i>PowerPC Microprocessor Family: The Programming Environments for 32-Bit Microprocessors (G522-0290-01)</i>	1.0	February 2000
<i>Cell Broadband Engine Architecture</i>	1.01	October 2006
<i>Synergistic Processor Unit Instruction Set Architecture</i>	1.2	January 2007

Conventions Used in This Document

Bit Notation

Standard bit notation is used throughout this document. Bits and bytes are numbered in ascending order from left to right. Thus, for a 4-byte word, bit 0 is the most significant bit and bit 31 is the least significant bit, as shown in the following figure:



MSB = Most significant bit

LSB = Least significant bit

Notation for bit encoding is as follows:

- Hexadecimal values are preceded by 0x. For example: 0x0A00.
- Binary values in sentences appear in single quotation marks. For example: '1010'.

Other Conventions

The following typographic conventions are used throughout this document:

Convention	Meaning
<code>courier</code>	Indicates programming code and literals, such as processing instructions, register names, data types, events, and file names. Also indicates function and macro names. This convention is only used where it facilitates comprehension, especially in narrative descriptions.
<i>courier + italics</i>	Indicates arguments, parameters, and variables. This convention is only used where it facilitates comprehension, especially in narrative descriptions.
<i>italics (without courier)</i>	Indicates emphasis. Except when hyperlinked, book references are in italics. When a term is first defined, it is often in italics.
blue	Indicates a hyperlink (color printers or online only).





1. Introduction

This specification describes SPU assembly-language syntax and machine-dependent features for the GNU assembler (as). Although this specification focuses on the GNU assembler, this document might also serve as an example specification for other SPU assemblers.





2. Instruction Set and Instruction Syntax

2.1. Notation and Conventions

In this specification, lower case is used for all instructions, register aliases, and channels names; however, these tokens may also be expressed in upper or mixed case. Table 2-1 describes notations used in this specification.

Table 2-1: Notations and Conventions

Notation/Convention	Meaning
ch	Channel number. Channels are specified as either <code>\$ch</code> followed by a channel number (for example, <code>\$ch3</code>) or a specific channel mnemonic. See section “2.4. Channel Mnemonics” for a complete list of channel mnemonics.
ra, rb, rc	Source register. Registers are specified as a dollar symbol (\$) followed by a register number from 0 to127. For example, <code>\$38</code> refers to register 38. See Table 2-3 for additional register aliases.
rt	Target register. Registers are specified as a dollar symbol (\$) followed by a register number from 0 to127. For example, <code>\$38</code> refers to register 38. See Table 2-3 for additional register aliases.
s3, s6	3-bit or 6-bit signed value, respectively. Encoded as a 7-bit signed immediate in which only a subset of the bits is used.
s7	7-bit sign-extended value.
s10	10-bit sign-extended value.
s11	11-bit sign-extended value.
s14	14-bit sign-extended value.
s16	16-bit sign-extended value.
s18	Relative address computations.
scale7	7-bit scale exponent. Values range from 0 to 127.
spr	Special purpose register.
u3, u5, u6	3-bit, 5-bit, or 6-bit unsigned value, respectively. Encoded as a 7-bit unsigned immediate in which only a subset of the bits is used.
u7	Unsigned 7-bit value.
u14	Unsigned 14-bit value.
u16	Unsigned 16-bit value.
u18	Unsigned 18-bit value.

2.2. Instruction Set

This section provides an overview of the SPU instruction set and its syntax, including:

- Supported instructions and their syntax
- Supported data types
- Supported ranges for instruction parameters

For details about the specific machine instructions, see the *Synergistic Processor Unit Instruction Set Architecture* specification.

Table 2-2: SPU Assembler Instructions

Instruction/Usage	Description
a rt, ra, rb	Add word. Each word element of register <i>ra</i> is added to the corresponding word element of register <i>rb</i> , and the results are placed in the corresponding word elements of register <i>rt</i> .
absdb rt, ra, rb	Absolute difference of bytes. Each byte element of register <i>ra</i> is subtracted from the corresponding byte element of register <i>rb</i> . The absolute values of the results are placed in the corresponding elements of register <i>rt</i> .
addx rt, ra, rb	Add word extended. Each word element of register <i>ra</i> , the corresponding word element of register <i>rb</i> , and the least significant bit of the corresponding word element of register <i>rt</i> are added, and the results are placed in the corresponding word elements of register <i>rt</i> .
ah rt, ra, rb	Add halfword. Each halfword element of register <i>ra</i> is added to the corresponding halfword element of register <i>rb</i> , and the results are placed in the corresponding halfword elements of register <i>rt</i> .
ahi rt, ra, s10	Add halfword immediate. The sign-extended immediate value <i>s10</i> is added to each halfword element of register <i>ra</i> , and the results are placed in the corresponding halfword elements of register <i>rt</i> .
ai rt, ra, s10	Add word immediate. The sign-extended immediate value <i>s10</i> is added to each word elements of register <i>ra</i> , and the results are placed in the corresponding word elements of register <i>rt</i> .
and rt, ra, rb	And. The value of register <i>ra</i> is logically ANDed with register <i>rb</i> , and the result is placed in register <i>rt</i> .
andbi rt, ra, s10	And byte immediate. The eight least significant bits of <i>s10</i> are logically ANDed with each byte element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
andc rt, ra, rb	And with complement. The value of register <i>ra</i> is logically ANDed with the complement of register <i>rb</i> , and the result is placed in register <i>rt</i> .
andhi rt, ra, s10	And halfword immediate. The sign-extended immediate value <i>s10</i> is logically ANDed with each halfword element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
andi rt, ra, s10	And word immediate. The sign-extended immediate value <i>s10</i> is logically ANDed with each word element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
avgb rt, ra, rb	Average bytes. The corresponding byte elements of registers <i>ra</i> and <i>rb</i> are averaged ($((a+b+1) \gg 1)$), and the results are placed in the corresponding byte elements of register <i>rt</i> .
bg rt, ra, rb	Borrow generate word. Each unsigned word element of register <i>ra</i> is compared to the corresponding unsigned word element of <i>rb</i> . If the value of <i>ra</i> is greater than that of <i>rb</i> , a 0 is placed in the corresponding element of <i>rt</i> ; otherwise, a 1 is placed there.
bgx rt, ra, rb	Borrow generate word extended. Each word element of register <i>ra</i> is subtracted from the corresponding word element of register <i>rb</i> . An additional 1 is subtracted from the result if the least significant bit of word element <i>rt</i> is 0. If the result is less than 0, a 0 is placed in the corresponding element of register <i>rt</i> ; otherwise, a 1 is placed there.
bi ra	Branch indirect. Execution proceeds with the instruction at the address specified by word element 0 of register <i>ra</i> . The two least significant bits of the address are ignored.

Instruction/Usage	Description
bid ra	Branch indirect, disable. Execution proceeds with the instruction at the address specified by word element 0 of register <i>ra</i> , and interrupts are disabled. The two least significant bits of this address are ignored.
bie ra	Branch indirect, enable. Execution proceeds with the instruction at the address specified by word element 0 of register <i>ra</i> , and interrupts are enabled. The two least significant bits of the address are ignored.
bihnz rc, ra	Branch indirect if not zero halfword. If halfword element 1 of register <i>rc</i> is 0, execution proceeds with the next sequential instruction; otherwise, execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored.
bihnzd rc, ra	Branch indirect if not zero halfword, disable. If halfword element 1 of register <i>rc</i> is 0, execution proceeds with the next sequential instruction; otherwise, the branch is taken, and execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the branch is taken, interrupts are disabled; otherwise, the interrupt enable state remains unchanged.
bihnze rc, ra	Branch indirect if not zero halfword, enable. If halfword element 1 of register <i>rc</i> is 0, execution proceeds with the next sequential instruction; otherwise, the branch is taken, and execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the branch is taken, interrupts are enabled; otherwise, the interrupt enable state remains unchanged.
bihz rc, ra	Branch indirect if zero halfword. If halfword element 1 of register <i>rc</i> is 0, execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. Otherwise, the element <i>rc</i> is nonzero, and execution proceeds with the next sequential instruction.
bihzd rc, ra	Branch indirect if zero halfword, disable. If halfword element 1 of register <i>rc</i> is 0, the branch is taken, and execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. Otherwise, execution proceeds with the next sequential instruction. If the branch is taken, interrupts are disabled; otherwise, the interrupt enable state remains unchanged.
bihze rc, ra	Branch indirect if zero halfword, enable. If halfword element 1 of register <i>rc</i> is 0, the branch is taken, and execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. Otherwise, the element <i>rc</i> is nonzero, and execution proceeds with the next sequential instruction. If the branch is taken, interrupts are enabled; otherwise, the interrupt enable state remains unchanged.
binz rc, ra	Branch indirect if not zero word. If word element 0 of register <i>rc</i> is 0, execution proceeds with the next sequential instruction; otherwise, execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored.
binzd rc, ra	Branch indirect if not zero word, disable. If word element 0 of register <i>rc</i> is 0, execution proceeds with the next sequential instruction; otherwise, the branch is taken, and execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the branch is taken, interrupts are disabled; otherwise, the interrupt enable state remains unchanged.
binze rc, ra	Branch indirect if not zero word, enable. If word element 0 of register <i>rc</i> is 0, execution proceeds with the next sequential instruction; otherwise, the branch is taken, and execution proceeds at the address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the branch is taken, interrupts are enabled; otherwise, the interrupt enable state remains

Instruction/Usage	Description
	unchanged.
bisl rt, ra	Branch indirect and set link. The effective address of the next instruction is taken from word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. The address of the instruction following this instruction is placed into word element 0 of register <i>rt</i> , and all other word elements of <i>rt</i> are assigned a value of zero.
bisld rt, ra	Branch indirect and set link, disable. The effective address of the next instruction is taken from word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. The address of the instruction following this instruction is placed into word element 0 of register <i>rt</i> , and all other word elements of <i>rt</i> are assigned a value of zero. Interrupts are also disabled.
bisle rt, ra	Branch indirect and set link, enable. The effective address of the next instruction is taken from word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. The address of the instruction following this instruction is placed into word element 0 of register <i>rt</i> , and all other word elements of <i>rt</i> are assigned a value of zero. Interrupts are also enabled.
bisled rt, ra	Branch indirect and set link on external data. The address of the instruction following this instruction is placed in word element 0 of register <i>rt</i> , and all other elements of register <i>rt</i> are assigned a value of zero. If the count of channel 0 is nonzero, execution continues at the effective address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the count of channel 0 is zero, execution continues with the next sequential instruction.
bisledd rt, ra	Branch indirect and set link on external data, disable. The address of the instruction following this instruction is placed in word element 0 of register <i>rt</i> , and all other elements of register <i>rt</i> are assigned a value of zero. If the count of channel 0 is nonzero, the branch is taken, and execution continues at the effective address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the count of channel 0 is zero, execution continues with the next sequential instruction. If the branch is taken, interrupts are disabled; otherwise, the interrupt enable state remains unchanged.
bislede rt, ra	Branch indirect and set link on external data, enable. The address of the instruction following this instruction is placed in word element 0 of register <i>rt</i> , and all other elements of register <i>rt</i> are assigned a value of zero. If the count of channel 0 is nonzero, the branch is taken, and execution continues at the effective address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If the count of channel 0 is zero, execution continues with the next sequential instruction. If the branch is taken, interrupts are enabled; otherwise, the interrupt enable state remains unchanged.
biz rc, ra	Branch indirect if zero word. If word element 0 of register <i>rc</i> is zero, execution proceeds at the effective address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If word element 0 of <i>rc</i> is nonzero, execution proceeds with the next sequential instruction.
bizd rc, ra	Branch indirect if zero word, disable. If word element 0 of register <i>rc</i> is zero, the branch is taken, and execution proceeds at the effective address in word element 0 of register <i>ra</i> . The two least significant bits of this address are ignored. If word element 0 of <i>rc</i> is nonzero, execution proceeds with the next sequential instruction. If the branch is taken, interrupts are disabled; otherwise, the interrupt enable state remains unchanged.
bize rc, ra	Branch indirect if zero word, enable. If word element 0 of register <i>rc</i> is zero, the branch is taken, and execution proceeds at the effective address in word element 0 of register <i>ra</i> . The two least significant bits of this address are

Instruction/Usage	Description
	ignored. If word element 0 of <code>rc</code> is nonzero, execution proceeds with the next sequential instruction. If the branch is taken, interrupts are enabled; otherwise, the interrupt enable state remains unchanged.
<code>br s18</code>	Branch relative. Execution proceeds with the instruction addressed by the sum of the current instruction address and the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored.
<code>bra s18</code>	Branch absolute. Execution proceeds with the instruction addressed by the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored.
<code>brasl rt, s18</code>	Branch absolute and set link. Execution proceeds with the instruction addressed by the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored. The instruction following the current instruction is placed in word element 0 of register <code>rt</code> , and all other elements of <code>rt</code> are assigned a value of zero.
<code>brhnc rc, s18</code>	Branch if not zero halfword. If the halfword element 1 of register <code>rc</code> is nonzero, execution proceeds with the instruction addressed by the sum of the current instruction address and the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored. If halfword element 1 of <code>rc</code> is zero, execution proceeds with the next sequential instruction.
<code>brhz rc, s18</code>	Branch if zero halfword. If the halfword element 1 of register <code>rc</code> is zero, execution proceeds with the instruction addressed by the sum of the current instruction address and the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored. If the halfword element 1 of register <code>rc</code> is nonzero, execution proceeds with the next sequential instruction.
<code>brnz rc, s18</code>	Branch if not zero word. If the word element 0 of register <code>rc</code> is nonzero, execution proceeds with the instruction addressed by the sum of the current instruction address and the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored. If word element 0 of register <code>rc</code> is zero, execution proceeds with the next sequential instruction.
<code>brsl rt, s18</code>	Branch relative and set link. Execution proceeds with the instruction addressed by the sum of the current instruction address and the sign-extended value of <code>s18</code> . The two least significant bits of <code>s18</code> are ignored. The instruction following the current instruction is placed in word element 0 of register <code>rt</code> , and all other elements of <code>rt</code> are assigned a value of zero.
<code>brz rc, s18</code>	Branch if zero word. If the word element 0 of register <code>rc</code> is zero, execution proceeds with the instruction addressed by the sum of the current instruction address and the sign-extended value of <code>s18</code> . The two least significant bit of <code>s18</code> are ignored. If word element 0 of register <code>rc</code> is nonzero, execution proceeds with the following instruction.
<code>cbd rt, u7(ra)</code>	Generate controls for byte insertion (d-form). A control mask is generated that can be used by the <code>shufb</code> instruction to insert a byte at the effective address computed by the sum of register <code>ra</code> and the unsigned value <code>u7</code> . The control mask is placed in register <code>rt</code> .
<code>cbx rt, ra, rb</code>	Generate controls for byte insertion (x-form). A control mask is generated that can be used by the <code>shufb</code> instruction to insert a byte at the effective address computed by the sum of registers <code>ra</code> and <code>rb</code> . The control mask is placed in register <code>rt</code> .
<code>cdd rt, u7(ra)</code>	Generate controls for doubleword insertion (d-form). A control mask is generated that can be used by the <code>shufb</code> instruction to insert a doubleword at the effective address computed by the sum of register <code>ra</code> and unsigned value <code>u7</code> . The control mask is placed in register <code>rt</code> .
<code>cdx rt, ra, rb</code>	Generate controls for doubleword insertion (x-form). A control mask is generated that can be used by the <code>shufb</code> instruction to insert a doubleword at the effective address computed by the sum of registers <code>ra</code> and <code>rb</code> . The control

Instruction/Usage	Description
	mask is placed in register <i>rt</i> .
<i>ceq rt, ra, rb</i>	Compare equal word. Each word element of register <i>ra</i> is compared with the corresponding word element of register <i>rb</i> . If the two elements are equal, all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the two elements are not equal, and zero is placed in the corresponding word element of register <i>rt</i> .
<i>ceqb rt, ra, rb</i>	Compare equal byte. Each byte element of register <i>ra</i> is compared with the corresponding byte element of register <i>rb</i> . If the two elements are equal, all ones are placed in the corresponding byte element of register <i>rt</i> . Otherwise, the elements are not equal, and zero is placed in the corresponding byte element of register <i>rt</i> .
<i>ceqbi rt, ra, s10</i>	Compare equal byte immediate. Each byte element of register <i>ra</i> is compared with the eight least significant bits of <i>s10</i> . If the two values are equal, all ones are placed in the corresponding byte element of register <i>rt</i> . Otherwise, the values are not equal, and zero is placed in the corresponding byte element of register <i>rt</i> .
<i>ceqh rt, ra, rb</i>	Compare equal halfword. Each halfword element of register <i>ra</i> is compared with the corresponding halfword element of register <i>rb</i> . If the two elements are equal, all ones are placed in the corresponding halfword element of register <i>rt</i> . Otherwise, the elements are not equal, and zero is placed in the corresponding halfword element of register <i>rt</i> .
<i>ceqhi rt, ra, s10</i>	Compare equal halfword immediate. Each halfword element of register <i>ra</i> is compared with the 16-bit sign-extended value <i>s10</i> . If the two values are equal, all ones are placed in the corresponding halfword element of register <i>rt</i> . Otherwise, the values are not equal, and zero is placed in the corresponding halfword element of register <i>rt</i> .
<i>ceqi rt, ra, s10</i>	Compare equal word immediate. Each word element of register <i>ra</i> is compared with the 32-bit sign-extended value <i>s10</i> . If the two values are equal, all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the values are not equal, and zero is placed in the corresponding word element of register <i>rt</i> .
<i>cflts rt, ra, scale7</i>	Convert floating to signed integer. Each floating-point element of register <i>ra</i> is multiplied by 2^{scale7} , converted to a signed 32-bit integer, and placed in the corresponding word element of register <i>rt</i> . Values outside of the range from -2^{31} to $2^{31}-1$ are clamped (saturated to the nearest bound).
<i>cfltu rt, ra, scale7</i>	Convert floating to unsigned integer. Each floating-point element of register <i>ra</i> is multiplied by 2^{scale7} , converted to an unsigned 32-bit integer, and placed in the corresponding word elements of register <i>rt</i> . Values outside of the range from 0 to $2^{32}-1$ are clamped (saturated to the nearest bound).
<i>cg rt, ra, rb</i>	Carry generate word. Each word element of register <i>ra</i> is added to the corresponding word element of register <i>rb</i> . The carry out is placed in the least significant bit of the corresponding word element of register <i>rt</i> , and 0 is placed in the remaining bits of <i>rt</i> .
<i>cgt rt, ra, rb</i>	Compare greater than word. Each word element of register <i>ra</i> is compared with the corresponding word element of register <i>rb</i> . If the word in <i>ra</i> is greater than the corresponding word in <i>rb</i> , all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the word in <i>ra</i> is less than or equal to the corresponding word in <i>rb</i> , and zeros are placed in the corresponding word element of register <i>rt</i> .

Instruction/Usage	Description
cgtb rt, ra, rb	Compare greater than byte. Each byte element of register <i>ra</i> is compared with the corresponding byte element of register <i>rb</i> . If the byte in <i>ra</i> is greater than the corresponding byte in <i>rb</i> , all ones are placed in the corresponding byte element of register <i>rt</i> . Otherwise, the byte in <i>ra</i> is less than or equal to the corresponding byte in <i>rb</i> , and zeros are placed in the corresponding byte element of register <i>rt</i> .
cgtbi rt, ra, s10	Compare greater than byte immediate. Each byte element of register <i>ra</i> is compared with the eight least significant bits of <i>s10</i> . If the byte in <i>ra</i> is greater than the corresponding byte in <i>s10</i> , all ones are placed in the corresponding byte element of register <i>rt</i> . Otherwise, the byte in <i>ra</i> is less than or equal to the corresponding byte in <i>s10</i> , and zeros are placed in the corresponding byte element of register <i>rt</i> .
cgth rt, ra, rb	Compare greater than halfword. Each halfword element of register <i>ra</i> is compared with the corresponding halfword element of register <i>rb</i> . If the halfword in <i>ra</i> is greater than the corresponding halfword in <i>rb</i> , all ones are placed in the corresponding halfword element of register <i>rt</i> . Otherwise, the halfword in <i>ra</i> is less than or equal to the corresponding halfword in <i>rb</i> , and zeros are placed in the corresponding halfword element of register <i>rt</i> .
cgthi rt, ra, s10	Compare greater than halfword immediate. Each halfword element of register <i>ra</i> is compared with the 16-bit sign-extended value <i>s10</i> . If the halfword in <i>ra</i> is greater than <i>s10</i> , all ones are placed in the corresponding halfword element of register <i>rt</i> . Otherwise, the halfword in <i>ra</i> is less than or equal to <i>s10</i> , and zeros are placed in the corresponding halfword element of register <i>rt</i> .
cgti rt, ra, s10	Compare greater than word immediate. Each word element of register <i>ra</i> is compared with the 32-bit sign-extended value <i>s10</i> . If the word in <i>ra</i> is greater than <i>s10</i> , all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the word in <i>ra</i> is less than or equal to <i>s10</i> , and zeros are placed in the corresponding word element of register <i>rt</i> .
cgx rt, ra, rb	Carry generate word extended. For each word element in registers <i>ra</i> and <i>rb</i> , a carry out is generated by summing the element of register <i>ra</i> , the corresponding element of <i>rb</i> , and the least significant bit of <i>rt</i> . The carry out is placed in the least significant bit of the corresponding word element of <i>rt</i> , and zeros are placed in the remaining bits.
chd rt, u7(ra)	Generate controls for halfword insertion (d-form). A control mask is generated that can be used by the <i>shufb</i> instruction to insert a halfword at the effective address computed by the sum of register <i>ra</i> and the unsigned value <i>u7</i> . The control mask is placed in register <i>rt</i> .
chx rt, ra, rb	Generate controls for halfword insertion (x-form). A control mask is generated that can be used by the <i>shufb</i> instruction to insert a halfword at the effective address computed by the sum of registers <i>ra</i> and <i>rb</i> . The control mask is placed in register <i>rt</i> .
clgt rt, ra, rb	Compare logical greater than word. Each word element of register <i>ra</i> is logically compared with the corresponding word element of register <i>rb</i> . If the word in <i>ra</i> is greater than the corresponding word in <i>rb</i> , all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the word in <i>ra</i> is less than or equal to the corresponding word in <i>rb</i> , and zeros are placed in the corresponding word element of register <i>rt</i> .

Instruction/Usage	Description
clgtb rt, ra, rb	Compare logical greater than byte. Each byte element of register <i>ra</i> is logically compared with the corresponding byte element of register <i>rb</i> . If the byte in <i>ra</i> is greater than the corresponding byte in <i>rb</i> , all ones are placed in the corresponding byte element of register <i>rt</i> . Otherwise, the byte in <i>ra</i> is less than or equal to the corresponding byte in <i>rb</i> , and zeros are placed in the corresponding byte element of register <i>rt</i> .
clgtbi rt, ra, s10	Compare logical greater than byte immediate. Each byte element of register <i>ra</i> is logically compared with the eight least significant bits of <i>s10</i> . If the byte in <i>ra</i> is greater than the value in <i>s10</i> , all ones are placed in the corresponding byte element of register <i>rt</i> . Otherwise, the byte in <i>ra</i> is less than or equal to the byte in <i>s10</i> , and zeros are placed in the corresponding byte element of register <i>rt</i> .
clgth rt, ra, rb	Compare logical greater than halfword. Each halfword element of register <i>ra</i> is logically compared with the corresponding halfword element of register <i>rb</i> . If the halfword in <i>ra</i> is greater than the corresponding halfword in <i>rb</i> , all ones are placed in the corresponding halfword element of register <i>rt</i> . Otherwise, the halfword in <i>ra</i> is less than or equal to the corresponding halfword in <i>rb</i> , and zeros are placed in the corresponding halfword element of register <i>rt</i> .
clgthi rt, ra, s10	Compare logical greater than halfword immediate. Each halfword element of register <i>ra</i> is logically compared with the 16-bit sign-extended value <i>s10</i> . If the halfword in <i>ra</i> is greater than the value in <i>s10</i> , all ones are placed in the corresponding halfword element of register <i>rt</i> . Otherwise, the halfword in <i>ra</i> is less than or equal to the value in <i>s10</i> , and zeros are placed in the corresponding halfword element of register <i>rt</i> .
clgti rt, ra, s10	Compare logical greater than word immediate. Each word element of register <i>ra</i> is logically compared with the 32-bit sign-extended value <i>s10</i> . If the word in <i>ra</i> is greater than the value in <i>s10</i> , all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the word element in <i>ra</i> is less than or equal to the value in <i>s10</i> , and zeros are placed in the corresponding word element of register <i>rt</i> .
clz rt, ra	Count leading zeros. The number of zeros to the left of the first 1 in each word element of register <i>ra</i> is counted, and the resulting count is placed in the corresponding element of register <i>rt</i> .
cntb rt, ra	Count ones in bytes. The number of ones in each byte element of register <i>ra</i> is counted, and the resulting count is placed in the corresponding element of register <i>rt</i> .
csflt rt, ra, scale7	Convert signed integer to floating. Each signed word element of register <i>ra</i> is converted to floating-point, multiplied by $2^{-\text{scale7}}$, and placed in the corresponding floating-point elements of register <i>rt</i> .
cufilt rt, ra, scale7	Convert unsigned integer to floating. Each unsigned word element of register <i>ra</i> is converted to floating-point, multiplied by $2^{-\text{scale7}}$, and placed in the corresponding floating point elements of register <i>rt</i> .
cwd rt, u7(ra)	Generate controls for word insertion (d-form). A control mask is generated that can be used by the <i>shufb</i> instruction to insert a word at the effective address computed by the sum of register <i>ra</i> and the unsigned value <i>u7</i> . The control mask is placed in register <i>rt</i> .
cwx rt, ra, rb	Generate controls for word insertion (x-form). A control mask is generated that can be used by the <i>shufb</i> instruction to insert a word at the effective address computed by the sum of registers <i>ra</i> and <i>rb</i> . The control mask is placed in register <i>rt</i> .

Instruction/Usage	Description
dfa rt, ra, rb	Double floating add. Each double floating-point element of register <i>ra</i> is added to the corresponding double floating-point element of register <i>rb</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
dfceq rt, ra, rb	Double floating compare equal. Each double floating-point element of register <i>ra</i> is compared with the corresponding double floating-point element of register <i>rb</i> . If the two elements are equal, all ones are placed in the corresponding double-word element of register <i>rt</i> . Otherwise, if they are not equal, zeros are placed in the corresponding double-word element of register <i>rt</i> .
dfcgt rt, ra, rb	Double floating compare greater than. Each double floating-point element of register <i>ra</i> is compared with the corresponding double floating-point element of register <i>rb</i> . If the element in <i>ra</i> is greater than the corresponding element of register <i>rb</i> , all ones are placed in the corresponding double-word element of register <i>rt</i> . Otherwise, if the element in <i>ra</i> is less than or equal to the corresponding element in <i>rb</i> , zeros are placed in the corresponding double-word element of register <i>rt</i> .
dfcmeq rt, ra, rb	Double floating compare magnitude equal. The absolute value of each double floating-point element of register <i>ra</i> is compared with the absolute value of the corresponding double floating-point element of register <i>rb</i> . If the two elements are equal, all ones are placed in the corresponding double-word element of register <i>rt</i> . Otherwise, if they are not equal, zeros are placed in the corresponding double-word element of register <i>rt</i> .
dfcmgt rt, ra, rb	Double floating compare magnitude greater than. The absolute value of each double floating-point element of register <i>ra</i> is compared with the absolute value of the corresponding double floating-point element of register <i>rb</i> . If the element in <i>ra</i> is greater than the corresponding element of register <i>rb</i> , all ones are placed in the corresponding double-word element of register <i>rt</i> . Otherwise, if the element in <i>ra</i> is less than or equal to the corresponding element in <i>rb</i> , zeros are placed in the corresponding double-word element of register <i>rt</i> .
dfm rt, ra, rb	Double floating multiply. Each double floating-point element of register <i>ra</i> is multiplied by the corresponding double floating-point element of register <i>rb</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
dfma rt, ra, rb	Double floating multiply and add. Each double floating-point element of register <i>ra</i> is multiplied by the corresponding double floating-point element of register <i>rb</i> , and the corresponding double floating-point element of register <i>rt</i> is then added to the product. The results are placed in the corresponding elements of register <i>rt</i> .
dfms rt, ra, rb	Double floating multiply and subtract. Each double floating-point element of register <i>ra</i> is multiplied by the corresponding double floating-point element of register <i>rb</i> , and the corresponding double floating-point element of register <i>rt</i> is subtracted from the product. The results are placed in the corresponding elements of register <i>rt</i> .
dfnma rt, ra, rb	Double floating negative multiply and add. Each double floating-point element of register <i>ra</i> is multiplied by the corresponding double floating-point element of register <i>rb</i> , and the corresponding double floating-point element of register <i>rt</i> is added to the product. Each result is negated and placed in the corresponding element of register <i>rt</i> .
dfnms rt, ra, rb	Double floating negative multiply and subtract. Each double floating-point element of register <i>ra</i> is multiplied by the corresponding double floating-point element of register <i>rb</i> , and the product is subtracted from the corresponding double floating-point element of register <i>rt</i> . The results are placed in corresponding elements of register <i>rt</i> .

Instruction/Usage	Description
dfs rt, ra, rb	Double floating subtract. Each double floating-point element of register <i>rb</i> is subtracted from the corresponding double floating-point element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
dftsv rt, ra, u7	Double floating test special value. Each double floating-point element of register <i>ra</i> is tested for the special values as specified by the immediate value <i>u7</i> . If one of the specified tests is true, all ones are placed in the corresponding double-word element of register <i>rt</i> . Otherwise, if none of the tests are true, zeros are placed in the corresponding double-word element of register <i>rt</i> .
dsync	Synchronize data. All pending store operations to local storage memory are completed before the processor proceeds to the next instruction.
eqv rt, ra, rb	Equivalent. The value in register <i>ra</i> is logically exclusive ORed with the value in register <i>rb</i> , and the complement of the result is placed in register <i>rt</i> .
fa rt, ra, rb	Floating add. Each floating-point element of register <i>ra</i> is added to the corresponding floating-point element of register <i>rb</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
fceq rt, ra, rb	Floating compare equal. Each floating-point element of register <i>ra</i> is compared with the corresponding floating-point element of register <i>rb</i> . If the two elements are equal, all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, they are not equal, and zeros are placed in the corresponding word element of register <i>rt</i> .
fcgt rt, ra, rb	Floating compare greater than. Each floating-point element of register <i>ra</i> is compared with the corresponding floating-point element of register <i>rb</i> . If the element in <i>ra</i> is greater than the corresponding element in <i>rb</i> , all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the element in <i>ra</i> is less than or equal to the corresponding element in <i>rb</i> , and zeros are placed in the corresponding word element of register <i>rt</i> .
fcmeq rt, ra, rb	Floating compare magnitude equal. The absolute value of each floating-point element of register <i>ra</i> is compared with the absolute value of the corresponding floating-point element of register <i>rb</i> . If the elements are equal, all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, they are not equal, and zeros are placed in the corresponding word elements of register <i>rt</i> .
fcmgt rt, ra, rb	Floating compare magnitude greater than. The absolute value of each floating-point element of register <i>ra</i> is compared with the absolute value of the corresponding floating-point element of register <i>rb</i> . If the value in <i>ra</i> is greater than the corresponding value in <i>rb</i> , all ones are placed in the corresponding word element of register <i>rt</i> . Otherwise, the value for <i>ra</i> is less than or equal to the corresponding value for <i>rb</i> , and zeros are placed in the corresponding word element of register <i>rt</i> .
fesd rt, ra	Floating extend single to double. Each even single precision floating-point element of register <i>ra</i> is converted to double precision and then placed in the corresponding element of register <i>rt</i> .
fi rt, ra, rb	Floating interpolate. Each floating-point element of register <i>ra</i> is interpolated to produce a more accurate estimate, using the base and step contained in the corresponding element of register <i>rb</i> , where <i>rb</i> is in the output format of a <i>frest</i> or <i>frsquest</i> instruction. The interpolated result is placed in the corresponding element of register <i>rt</i> .
fm rt, ra, rb	Floating multiply. Each floating-point element of register <i>ra</i> is multiplied by the corresponding floating-point element of register <i>rb</i> , and the products are placed in the corresponding elements of register <i>rt</i> .

Instruction/Usage	Description
fma rt, ra, rb, rc	Floating multiply and add. Each floating-point element of register <i>ra</i> is multiplied by the corresponding floating-point element of register <i>rb</i> , and the corresponding floating-point element of register <i>rc</i> is then added to the product. The results are placed in corresponding elements of register <i>rt</i> .
fms rt, ra, rb, rc	Floating multiply and subtract. Each floating-point element of register <i>ra</i> is multiplied by the corresponding floating-point element of register <i>rb</i> , and the corresponding floating-point element of register <i>rc</i> is subtracted from the product. The results are placed in the corresponding elements of register <i>rt</i> .
fnms rt, ra, rb, rc	Floating negative multiply and subtract. Each floating-point element of register <i>ra</i> is multiplied by the corresponding floating-point element of register <i>rb</i> , and the product is subtracted from the corresponding floating-point element of register <i>rc</i> . The results are placed in the corresponding elements of register <i>rt</i> .
frds rt, ra	Floating round double to single. Each double floating-point element of register <i>ra</i> is rounded to single precision and placed in the corresponding even element of register <i>rt</i> . At the same time, a zero is placed in the corresponding odd element of <i>rt</i> .
frest rt, ra	Floating reciprocal estimate. A base and step is computed for estimating the reciprocal of each floating-point element of register <i>ra</i> , and the result is placed in the corresponding element of register <i>rt</i> . The result returned by this instruction is intended as an operand to the <i>fi</i> instruction.
frsquest rt, ra	Floating reciprocal square root estimate. A base and step is computed for estimating the reciprocal of the square root for each floating-point element of register <i>ra</i> , and the result is placed in the corresponding element of register <i>rt</i> . The result returned by this instruction is intended as an operand to the <i>fi</i> instruction.
fs rt, ra, rb	Floating subtract. Each floating-point element of register <i>rb</i> is subtracted from the corresponding floating-point element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
fscrrd rt	Floating-point status control register read. The contents of the Floating-Point Status and Control Register (FPSCR) are read and placed in register <i>rt</i> .
fscrrw ra fscrrw rc, ra	Floating-point status control register write. The 128-bit register <i>ra</i> is written into the Floating-Point Status and Control Register (FPSCR). Register <i>rc</i> is a false target and no value is ever written to it. If register <i>rc</i> is not specified, register 0 is used as the false target.
fsm rt, ra	Form select mask for words. The four least significant bits of word element 0 of register <i>ra</i> are used to create a mask by replicating each bit 32 times. The 128-bit result is returned in register <i>rt</i> .
fsmb rt, ra	Form select mask for bytes. The 16 least significant bits of word element 0 of register <i>ra</i> are used to create a mask by replicating each bit eight times. The 128-bit result is returned in register <i>rt</i> .
fsmbi rt, u16	Form select mask for byte immediate. The 16 bits of <i>u16</i> are used to create a mask by replicating each bit eight times. The 128-bit result is returned in register <i>rt</i> .
fsmh rt, ra	Form select mask for halfwords. The eight least significant bits of word element 0 of register <i>ra</i> are used to create a mask by replicating each bit 16 times. The 128-bit result is returned in register <i>rt</i> .
gb rt, ra	Gather bits from words. A 4-bit value is formed by concatenating the least significant bit of each word element of register <i>ra</i> . The 4-bit value is then placed in the least significant bits of word element 0 of register <i>rt</i> , and zeros are placed in the remaining bits.

Instruction/Usage	Description
gbb rt, ra	Gather bits from bytes. A 16-bit value is formed by concatenating the least significant bit of each byte element of register <i>ra</i> . The 16-bit value is then placed in the least significant bits of word element 0 of register <i>rt</i> , and zeros are placed in the remaining bits.
gbh rt, ra	Gather bits from halfwords. An 8-bit value is formed by concatenating the least significant bit of each halfword element of register <i>ra</i> . The 8-bit value is then placed in the least significant bits of word element 0 of register <i>rt</i> , and zeros are placed in the remaining bits.
hbr s11, ra	Hint for branch (r-form). An instruction prefetch is allowed to occur at the branch target address contained in word element 0 of register <i>ra</i> , for the branch instruction that is addressed by the sum of the address of this instruction and the sign-extended value <i>s11</i> . The two least significant bits of <i>s11</i> are ignored.
hbra s11, s18	Hint for branch (a-form). An instruction prefetch is allowed to occur at the branch target address specified by the sign-extended value <i>s18</i> , for the branch instruction addressed by the sum of the address of this instruction and the sign-extended value <i>s11</i> . The two least significant bits of <i>s11</i> and <i>s18</i> are ignored.
hbrp	Hint for branch, prefetch (r-form). A slot in the fetch unit is reserved for an in-line prefetch. This instruction translates to an <i>hbr</i> instruction that has the <i>P</i> feature bit set. The field in the <i>hbr</i> instruction that contains the offset to the branch instruction is set to zero.
hbr s11, s18	Hint for branch relative. An instruction prefetch is allowed to occur at the branch target that is addressed by the sum of the address of this instruction and the sign-extended value <i>s18</i> , for the branch instruction that is addressed by the sum of the address of this instruction and the sign-extended value <i>s11</i> . The two least significant bits of <i>s18</i> and <i>s11</i> are ignored.
heq ra, rb heq rt, ra, rb	Halt if equal. If word element 0 of registers <i>ra</i> and <i>rb</i> are equal, the processor is halted. Register <i>rt</i> is a false target and is never written to. If register <i>rt</i> is not specified, register 0 is used as the false target.
heqi ra, s10 heqi rt, ra, s10	Halt if equal immediate. If word element 0 of register <i>ra</i> equals the sign-extended value of <i>s10</i> , the processor is halted. Register <i>rt</i> is a false target, and no value is ever written to it. If register <i>rt</i> is not specified, register 0 is used as the false target.
hgt ra, rb hgt rt, ra, rb	Halt if greater than. If signed word element 0 of register <i>ra</i> is greater than word element 0 of register <i>rb</i> , the processor is halted. Register <i>rt</i> is a false target, and no value is ever written to it. If register <i>rt</i> is not specified, register 0 is used as the false target.
hgti ra, s10 hgti rt, ra, s10	Halt if greater than immediate. If signed word element 0 of register <i>ra</i> is greater than the sign-extended value <i>s10</i> , the processor is halted. Register <i>rt</i> is a false target, and no value is ever written to it. If register <i>rt</i> is not specified, register 0 is used as the false target.
hlgt ra, rb hlgt rt, ra, rb	Halt if logically greater than. If unsigned word element 0 of register <i>ra</i> is greater than unsigned word element 0 of register <i>rb</i> , the processor is halted. Register <i>rt</i> is a false target, and no value is ever written to it. If register <i>rt</i> is not specified, register 0 is used as the false target.
hlgti ra, s10 hlgti rt, ra, s10	Halt if logically greater than immediate. If unsigned word element 0 of register <i>ra</i> is logically greater than the sign-extended value <i>s10</i> , the processor is halted. Register <i>rt</i> is a false target, and no value is ever written to it. If register <i>rt</i> is not specified, register 0 is used as the false target.
il rt, s16	Immediate load word. The sign-extended value <i>s16</i> is loaded into each of the word elements of <i>rt</i> .

Instruction/Usage	Description
ila rt, u18	Immediate load address. The unsigned value <code>u18</code> is loaded into each of the word elements of <code>rt</code> .
ilh rt, u16	Immediate load halfword. The value <code>u16</code> is loaded into each of the eight halfword elements of <code>rt</code> .
ilhu rt, u16	Immediate load halfword upper. The value <code>u16</code> is loaded into the 16 most significant bits of each of the 4 word elements of <code>rt</code> .
iohl rt, u16	Immediate OR halfword lower. Immediate OR the value <code>u16</code> with each of the word elements of <code>rt</code> .
iretd iretd ra	Interrupt return, disable. Execution proceeds with the instruction addressed by machine state save/restore register 0 (<code>SRR0</code>). Interrupts are disabled. Register <code>ra</code> is a false source, and its contents are ignored. If <code>ra</code> is not specified, register 0 is used as a false source.
irete irete ra	Interrupt return, enable. Execution proceeds with the instruction addressed by machine state save/restore register 0 (<code>SRR0</code>). Interrupts are enabled. Register <code>ra</code> is a false source, and its contents are ignored. If <code>ra</code> is not specified, register 0 is used as a false source.
iret iret ra	Interrupt return. Execution proceeds with the instruction addressed by machine state save/restore register 0 (<code>SRR0</code>). Register <code>ra</code> is a false source, and its contents are ignored. If <code>ra</code> is not specified, register 0 is used as a false source.
lnop	Nop operation (load). A no-operation is performed on the load pipeline.
lqa rt, s18	Load quadword (a-form). A quadword is loaded into register <code>rt</code> from the effective address specified by the sign-extended value <code>s18</code> . The two least significant bits of <code>s18</code> are ignored.
lqd rt, s14(ra)	Load quadword (d-form). A quadword is loaded into register <code>rt</code> from the effective address computed by the sum of register <code>ra</code> and the sign-extended value <code>s14</code> . The four least significant bits of <code>s14</code> are ignored.
lqr rt, s18	Load quadword instruction relative (a-form). A quadword is loaded into register <code>rt</code> from the effective address specified by the sum of the current instruction address and <code>s18</code> . The two least significant bits of <code>s18</code> are ignored.
lqx rt, ra, rb	Load quadword (x-form). A quadword is loaded into register <code>rt</code> from the effective address computed by the sum of registers <code>ra</code> and <code>rb</code> .
mfspr rt, spr	Move from special purpose register. The contents of the specified special purpose register <code>spr</code> are moved to the word element 0 of register <code>rt</code> .
mpy rt, ra, rb	Multiply. The signed 16 least significant bits of the corresponding word elements of registers <code>ra</code> and <code>rb</code> are multiplied, and the 32-bit products are placed in the corresponding word elements of register <code>rt</code> .
mpya rt, ra, rb, rc	Multiply and add. The signed 16 least significant bits of the corresponding word elements of registers <code>ra</code> and <code>rb</code> are multiplied, and the 32-bit products are then added to the corresponding word elements of register <code>rc</code> . The results are placed in the corresponding elements of register <code>rt</code> .
mpyh rt, ra, rb	Multiply high. The most significant 16 bits of the word elements of register <code>ra</code> are multiplied by the 16 least significant bits of the corresponding elements of register <code>rb</code> . The 32-bit products are then shifted left by 16 bits and placed in the corresponding word elements of register <code>rt</code> .
mpyhh rt, ra, rb	Multiply high high. The signed 16 most significant bits of the word elements of registers <code>ra</code> and <code>rb</code> are multiplied, and the 32-bit products are placed in the corresponding word elements of register <code>rt</code> .

Instruction/Usage	Description
mpyhha rt, ra, rb	Multiply high high and add. The signed 16 most significant bits of the word elements of registers <i>ra</i> and <i>rb</i> are multiplied. The 32-bit products are then added to the corresponding word elements of register <i>rt</i> , and the sums are placed in register <i>rt</i> .
mpyhau rt, ra, rb	Multiply high high unsigned and add. The unsigned 16 most significant bits of the word elements of registers <i>ra</i> and <i>rb</i> are multiplied, and the 32-bit products are then added to the corresponding word elements of register <i>rt</i> , and the sums are placed in register <i>rt</i> .
mpyhhu rt, ra, rb	Multiply high high unsigned. The unsigned 16 most significant bits of the word elements of registers <i>ra</i> and <i>rb</i> are multiplied, and the 32-bit products are then placed in the corresponding word elements of register <i>rt</i> .
mpyi rt, ra, s10	Multiply immediate. The 16 least significant bits of each of the word elements of register <i>ra</i> are multiplied by the sign-extended value <i>s10</i> . The 32-bit products are then placed in the corresponding word elements of register <i>rt</i> .
mpys rt, ra, rb	Multiply and shift right. The most significant 16 bits of corresponding word elements of registers <i>ra</i> and <i>rb</i> are multiplied, and the 16 most significant bits of the 32-bit products are placed in the least significant bits of the corresponding word elements of register <i>rt</i> .
mpyu rt, ra, rb	Multiply unsigned. The unsigned 16 least significant bits of the corresponding word elements of registers <i>ra</i> and <i>rb</i> are multiplied, and the 32-bit products are placed in the corresponding word elements of register <i>rt</i> .
mpyui rt, ra, s10	Multiply unsigned immediate. The 16 least significant bits of each of the word elements of register <i>ra</i> is multiplied by the sign-extended value <i>s10</i> . Both operands are treated as unsigned. The 32-bit products are placed in the corresponding word elements of register <i>rt</i> .
mtspr spr, ra	Move to special purpose register. The contents of word element 0 of register <i>ra</i> are moved to the special purpose register <i>spr</i> .
nand rt, ra, rb	Nand. The value of register <i>ra</i> is logically ANDed with register <i>rb</i> , and the complement of the result is placed in register <i>rt</i> .
nop nop rt	Nop operation (execute). A no-operation is performed on the execute pipeline. Register <i>rt</i> is a false target, and no value is ever written to it. If register <i>rt</i> is not specified, register 0 is used as the false target.
nor rt, ra, rb	Nor. The value of register <i>ra</i> is logically ORed with register <i>rb</i> , and the complement of the result is placed in register <i>rt</i> .
or rt, ra, rb	Or. The value of register <i>ra</i> is logically ORed with register <i>rb</i> , and the result is placed in register <i>rt</i> .
orbi rt, ra, s10	Or byte immediate. The eight least significant bits of <i>s10</i> are logically ORed with each byte element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
orc rt, ra, rb	Or with complement. The value of register <i>ra</i> is logically ORed with the complement of register <i>rb</i> , and the result is placed in register <i>rt</i> .
orhi rt, ra, s10	Or halfword immediate. The sign-extended value <i>s10</i> is logically ORed with each halfword element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
ori rt, ra, s10	Or word immediate. The sign-extended value <i>s10</i> is logically ORed with each word element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .

Instruction/Usage	Description
orx rt, ra	Or word across. The four word elements of register <i>ra</i> are logically ORed, and the result is placed in word element 0 of register <i>rt</i> . Word elements 1, 2, and 3 of register <i>rt</i> are assigned a value of zero.
rchcnt rt, ch	Read channel count. The channel count of the channel <i>ch</i> is read, and the count placed in register <i>rt</i> .
rdch rt, ch	Read channel. The contents of the channel <i>ch</i> are read, and the contents placed in register <i>rt</i> .
rot rt, ra, rb	Rotate word. The contents of each word element of register <i>ra</i> are rotated left according to the corresponding word element of register <i>rb</i> . The results are placed in the corresponding word elements of register <i>rt</i> .
roth rt, ra, rb	Rotate halfword. The contents of each halfword element of register <i>ra</i> are rotated left according to the corresponding halfword element of register <i>rb</i> . The results are placed in the corresponding halfword elements of register <i>rt</i> .
rothi rt, ra, s7	Rotate halfword immediate. The contents of each halfword element of register <i>ra</i> are rotated left according to the four least significant bits of <i>s7</i> . The results are placed in the corresponding halfword elements of register <i>rt</i> .
rothm rt, ra, rb	Rotate and mask halfword. The contents of each halfword element of register <i>ra</i> are right-shifted according to the two's complement of the five least significant bits of the corresponding halfword element of register <i>rb</i> . The results are placed in the corresponding halfword elements of register <i>rt</i> .
rothmi rt, ra, s6	Rotate and mask halfword immediate. The contents of each halfword element of register <i>ra</i> are right-shifted according to the two's complement of the signed value <i>s6</i> . The results are placed in the corresponding halfword elements of register <i>rt</i> .
roti rt, ra, s7	Rotate word immediate. The contents of each word element of register <i>ra</i> are rotated left according to the signed value <i>s7</i> . The results are placed in the corresponding word elements of register <i>rt</i> .
rotm rt, ra, rb	Rotate and mask word. The contents of each word element of register <i>ra</i> are right-shifted according to the two's complement of the six least significant bits of the corresponding word element of register <i>rb</i> . The results are placed in the corresponding word elements of register <i>rt</i> .
rotma rt, ra, rb	Rotate and mask algebraic word. The contents of each word element of register <i>ra</i> are right-shifted according to the two's complement of the six least significant bits of the corresponding word element of register <i>rb</i> . Copies of the sign bit are shifted in from the left. The results are placed in the corresponding word elements of register <i>rt</i> .
rotmah rt, ra, rb	Rotate and mask algebraic halfword. The contents of each halfword element of register <i>ra</i> are right-shifted according to the two's complement of the five least significant bits of the corresponding halfword element of register <i>rb</i> . Copies of the sign bit are shifted in from the left. The results are placed in the corresponding halfword element of register <i>rt</i> .
rotmahi rt, ra, s6	Rotate and mask algebraic halfword immediate. The contents of each halfword element of register <i>ra</i> are right-shifted according to the signed value <i>s6</i> . Copies of the sign bit are shifted in from the left. The results are placed in the corresponding halfword elements of register <i>rt</i> .
rotmai rt, ra, s7	Rotate and mask algebraic word immediate. The contents of each word element of register <i>ra</i> are right-shifted according to the two's complement of the signed value <i>s7</i> . Copies of the sign bit are shifted in from the left. The results are placed in the corresponding word elements of register <i>rt</i> .

Instruction/Usage	Description
rotmi rt, ra, s7	Rotate and mask word immediate. The contents of each word element of register <i>ra</i> are right-shifted according to the two's complement of the signed value <i>s7</i> . The results are placed in the corresponding word elements of register <i>rt</i> .
rotqbi rt, ra, rb	Rotate quadword by bits. The contents of register <i>ra</i> are rotated left by the number of bits specified by the three least significant bits of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
rotqbii rt, ra, u3	Rotate quadword by bits immediate. The contents of register <i>ra</i> are rotated left by the number of bits according to the value <i>u3</i> . The result is placed in register <i>rt</i> .
rotqby rt, ra, rb	Rotate quadword by bytes. The contents of register <i>ra</i> are rotated left by the number of bytes specified by the four least significant bits of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
rotqbybi rt, ra, rb	Rotate quadword by bytes from bit shift count. The contents of register <i>ra</i> are rotated left by the number of bytes specified by bits 25-28 of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
rotqbyi rt, ra, s7	Rotate quadword by bytes immediate. The contents of register <i>ra</i> are rotated left by the number of bytes according to the signed value <i>s7</i> . The result is placed in register <i>rt</i> .
rotqmbi rt, ra, rb	Rotate and mask quadword by bits. The contents of register <i>ra</i> are shifted right by the number of bits specified by the two's complement of the three least significant bits of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
rotqmbii rt, ra, s3	Rotate and mask quadword by bits immediate. The contents of register <i>ra</i> are shifted right by the number of bits specified by the two's complement of the signed value <i>s3</i> . The result is placed in register <i>rt</i> .
rotqmby rt, ra, rb	Rotate and mask quadword by bytes. The contents of register <i>ra</i> are shifted right by the number of bytes specified by the two's complement of the five least significant bits of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
rotqmbybi rt, ra, rb	Rotate and mask quadword by bytes from bit shift count. The contents of register <i>ra</i> are shifted right by the number of bytes specified by the two's complement of bits 24-28 of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
rotqmbyi rt, ra, s6	Rotate and mask quadword by bytes immediate. The contents of register <i>ra</i> are shifted right by the number of bytes specified by the two's complement of the signed value <i>s6</i> . The result is placed in register <i>rt</i> .
selb rt, ra, rb, rc	Select bits. Each bit of register <i>rc</i> whose value is 0 selects the corresponding bit from register <i>ra</i> . A bit whose value is 1 selects the corresponding bit from register <i>rb</i> . The quadword result is placed in register <i>rt</i> .
sf rt, ra, rb	Subtract from word. Each word element of register <i>ra</i> is subtracted from the corresponding word element of register <i>rb</i> , and the results are placed in the corresponding word elements of register <i>rt</i> .
sfh rt, ra, rb	Subtract from halfword. Each halfword element of register <i>ra</i> is subtracted from the corresponding halfword element of register <i>rb</i> , and the results are placed in the corresponding word elements of register <i>rt</i> .
sfhi rt, ra, s10	Subtract from halfword immediate. Each halfword element of register <i>ra</i> is subtracted from the sign-extended value <i>s10</i> , and the results are placed in the corresponding halfword elements of register <i>rt</i> .

Instruction/Usage	Description
sfi rt, ra, s10	Subtract from word immediate. Each word element of register <i>ra</i> is subtracted from the sign-extended value <i>s10</i> , and the results are placed in the corresponding word elements of register <i>rt</i> .
sfx rt, ra, rb	Subtract from word extended. Each word element of register <i>ra</i> is subtracted from the corresponding word element of register <i>rb</i> . An additional 1 is subtracted from the result if the least significant bit of word element <i>rt</i> is 0. The results are placed in the corresponding word elements of register <i>rt</i> .
shl rt, ra, rb	Shift left word. The contents of each word element of register <i>ra</i> are shifted left according to the six least significant bits of the corresponding word element of register <i>rb</i> . The results are placed in the corresponding word elements of register <i>rt</i> .
shlh rt, ra, rb	Shift left halfword. The contents of each halfword element of register <i>ra</i> are shifted left according to the five least significant bits of the corresponding halfword element of register <i>rb</i> . The results are placed in the corresponding halfword elements of register <i>rt</i> .
shli rt, ra, u5	Shift left halfword immediate. The contents of each halfword element of register <i>ra</i> are shifted left according to unsigned value <i>u5</i> . The results are placed in the corresponding halfword elements of register <i>rt</i> .
shli rt, ra, u6	Shift left word immediate. The contents of each word element of register <i>ra</i> are shifted left according to the unsigned value <i>u6</i> . The results are placed in the corresponding word element of register <i>rt</i> .
shlqbi rt, ra, rb	Shift left quadword by bits. The contents of register <i>ra</i> are shifted left by the number of bits specified by the three least significant bits of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
shlqbii rt, ra, u3	Shift left quadword by bits immediate. The contents of register <i>ra</i> are shifted left by the number of bits specified by the unsigned value <i>u3</i> . The result is placed in register <i>rt</i> .
shlqby rt, ra, rb	Shift left quadword by bytes. The contents of register <i>ra</i> are shifted left by the number of bytes specified by the five least significant bits of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
shlqbybi rt, ra, rb	Shift left quadword by bytes from bit shift count. The contents of register <i>ra</i> are shifted left by the number of bytes specified by bits 24-28 of word element 0 of register <i>rb</i> . The result is placed in register <i>rt</i> .
shlqbyi rt, ra, u5	Shift left quadword by bytes immediate. The contents of register <i>ra</i> are shifted left by the number of bytes specified by the unsigned value <i>u5</i> . The result is placed in register <i>rt</i> .
shufb rt, ra, rb, rc	Shuffle bytes. Each byte of register <i>rc</i> is used to select a byte from either register <i>ra</i> or register <i>rb</i> or a constant (0, 0x80, or 0xFF). The results are placed in the corresponding bytes of register <i>rt</i> .
stop u14	Stop and signal. Execution is stopped, the current address is written to the SPU NPC register, the value <i>u14</i> is written to the SPU status register, and an interrupt is sent to the PowerPC® Processor Unit (PPU).
stopd ra, rb, rc	Stop and signal with dependencies. Execution is stopped after register dependencies are met. This involves writing the current address to the SPU NPC register, writing the value 0x3FFF to the SPU status register, and interrupting the PPU.
stqa rc, s18	Store quadword (a-form). The quadword in register <i>rc</i> is stored at the effective address specified by the sign-extended value <i>s18</i> . The two least significant bits of <i>s18</i> are ignored.

Instruction/Usage	Description
stqd rc, s14(ra)	Store quadword (d-form). The quadword in register <i>rc</i> is stored at the effective address computed by the sum of register <i>ra</i> and the sign-extended value <i>s14</i> . The four least significant bits of <i>s14</i> are ignored.
stqr rc, s18	Store quadword instruction relative (a-form). The quadword in register <i>rc</i> is stored at the effective address specified by the sum of the current instruction address and <i>s18</i> . The two least significant bits of <i>s18</i> are ignored.
stqx rc, ra, rb	Store quadword (x-form). The quadword in register <i>rc</i> is stored at the effective address computed by the sum of registers <i>ra</i> and <i>rb</i> .
sumb rt, ra, rb	Sum bytes into halfword. The four bytes of each word element of register <i>ra</i> are summed and placed in the corresponding odd halfword elements of register <i>rt</i> , and the four bytes of each word element of register <i>rb</i> are summed and placed in the corresponding even halfword elements of register <i>rt</i> .
sync	Synchronize. The processor waits until all pending store instructions have been completed before it fetches the next sequential instruction.
syncc	Synchronize channel. The processor waits until the channel is ready and all pending store instructions have been completed before it fetches the next sequential instruction.
wrch ch, ra	Write channel. The contents of register <i>ra</i> are written to the channel <i>ch</i> .
xor rt, ra, rb	Xor. The value of register <i>ra</i> is logically exclusive ORed with register <i>rb</i> and the result is placed in register <i>rt</i> .
xorbi rt, ra, s10	Exclusive or byte immediate. The eight least significant bits of <i>s10</i> are logically exclusive ORed with each byte element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
xorhi rt, ra, s10	Exclusive or halfword immediate. The sign-extended 16 least significant bits of <i>s10</i> are logically exclusive ORed with each halfword element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
xori rt, ra, s10	Exclusive or word immediate. The sign-extended value of <i>s10</i> is logically exclusive ORed with each word element of register <i>ra</i> , and the results are placed in the corresponding elements of register <i>rt</i> .
xsbh rt, ra	Extend sign byte to halfword. The least significant eight bits of each halfword element of register <i>ra</i> are sign extended to 16 bits and placed in the corresponding halfword element of register <i>rt</i> .
xshw rt, ra	Extend sign halfword to word. The least significant 16 bits of each word element in register <i>ra</i> are sign extended to 32 bits and placed in the corresponding word element of register <i>rt</i> .
xswd rt, ra	Extend sign word to doubleword. The least significant 32 bits of each doubleword element in register <i>ra</i> are sign extended to 64 bits and placed in the corresponding doubleword element of register <i>rt</i> .

2.3. Aliases

For the programmer's convenience, the assembler supports the register and instruction aliases shown in Table 2-3.

Table 2-3: Register and Instruction Aliases

Alias	Is Equivalent To	Description
\$LR	\$0	Return address / link register
\$SP	\$1	Stack pointer
lr rt, ra	ori rt, ra, 0	Load register <i>rt</i> with the register <i>ra</i>

2.4. Channel Mnemonics

Table 2-4 and Table 2-5 specify the supported channel mnemonics. The assembler provides generic channel mnemonics of the form `$ch#` for all possible channels 0-127, where # indicates the channel number. For example, `$ch0` is the event status read channel.

All SPU channel mnemonics must be supported. In contrast, only target systems that support the MFC must support the MFC channel mnemonics.

Table 2-4: SPU Channels

Channel Number	Equivalent Mnemonic	Description
0 - 127	<code>\$ch0 - \$ch127</code>	Generic channel mnemonics
0	<code>\$SPU_RdEventStat</code>	Read event status with mask applied
1	<code>\$SPU_WrEventMask</code>	Write event mask
2	<code>\$SPU_WrEventAck</code>	Write end of event processing
3	<code>\$SPU_RdSigNotify1</code>	Signal notification 1
4	<code>\$SPU_RdSigNotify2</code>	Signal notification 2
7	<code>\$SPU_WrDec</code>	Write decremter count
8	<code>\$SPU_RdDec</code>	Read decremter count
11	<code>\$SPU_RdEventMask</code>	Read event mask
13	<code>\$SPU_RdMachStat</code>	Read SPU run status
14	<code>\$SPU_WrSRR0</code>	Write SPU machine state save/restore register 0 (SRR0)
15	<code>\$SPU_RdSRR0</code>	Read SPU machine state save/restore register 0 (SRR0)
28	<code>\$SPU_WrOutMbox</code>	Write outbound mailbox contents
29	<code>\$SPU_RdInMbox</code>	Read inbound mailbox contents
30	<code>\$SPU_WrOutIntrMbox</code>	Write outbound interrupt mailbox contents (interrupting PPU)

Table 2-5: MFC Channels

Channel Number	Equivalent Mnemonic	Description
9	<code>\$MFC_WrMSSyncReq</code>	Write multisource synchronization request
12	<code>\$MFC_RdTagMask</code>	Read tag mask
16	<code>\$MFC_LSA</code>	Write local memory address command parameter
17	<code>\$MFC_EAH</code>	Write high order DMA effective address command parameter
18	<code>\$MFC_EAL</code>	Write low order DMA effective address command parameter
19	<code>\$MFC_Size</code>	Write DMA transfer size command parameter
20	<code>\$MFC_TagID</code>	Write tag identifier command parameter
21	<code>\$MFC_Cmd</code>	Write and enqueue DMA command with associated class ID
22	<code>\$MFC_WrTagMask</code>	Write tag mask
23	<code>\$MFC_WrTagUpdate</code>	Write request for conditional or unconditional tag status update
24	<code>\$MFC_RdTagStat</code>	Read tag status with mask applied
25	<code>\$MFC_RdListStallStat</code>	Read DMA list stall-and-notify status
26	<code>\$MFC_WrListStallAck</code>	Write DMA list stall-and-notify acknowledge
27	<code>\$MFC_RdAtomicStat</code>	Read completion status of last completed immediate MFC atomic update command (see the Synergistic Processor Unit

Channel Number	Equivalent Mnemonic	Description
		Channels section of <i>Cell Broadband Engine Architecture</i>)

2.5. Immediate Values

Many instructions accept signed or unsigned immediate values of various lengths. These values can be encoded in the following ways:

- *An immediate constant value or expression.* For example, the instruction “ai \$3, \$3, -32” subtracts 32 from each of the word elements of register 3.
- *A PC relative address.* The current program counter is expressed by a dot (.) symbol. For example, the instruction “br . -4” branches to the instruction immediately prior to this instruction.
- *A symbolic label address.* These addresses are resolved during link edit, during which the appropriate instruction value is encoded in the symbol’s place. For example, relative addressing instructions are encoded with a relative address. Absolute address instructions are encoded with the address of the label or symbol. Halfword addresses are specified using the @h or @l to specify the high and lower halfwords, respectively. For example, the following instruction sequence loads the 32-bit address of *variable* into register 3:

```
ilhu $3, variable@h    # load high halfword address of variable
iohl $3, variable@l    # logically OR low halfword address of variable
```

2.6. Errors and Warnings

To assist in early identification of coding errors, the assembler will issue a warning or error whenever an immediate value is outside of the range expected by the respective instruction. For some instructions, it is inappropriate to issue a warning or an error for out-of-range values. Table 2-6 shows valid ranges for immediate operands, in addition to any special variances to the valid range of values.

Table 2-6: Valid Immediate Values

Immediate Value	Minimum Value	Maximum Value	Special Variances
s3	-4	3	No limits will be placed on the <code>rotqmbii</code> instruction. The seven least significant bits of the specified immediate value will be encoded in the instruction.
s6	-32	31	Warnings may optionally be issued for values outside the range [-31, 0] for the <code>rothmi</code> , <code>rotmahi</code> , and <code>rotqmbyi</code> instructions.
s7	-64	63	No limits will be placed on the <code>rothi</code> , <code>roti</code> , and <code>rotqbyi</code> instructions. The seven least significant bits of the specified immediate value will be encoded in the instructions. Warnings may optionally be issued for values outside the range [-63, 0] for the <code>rotmai</code> and <code>rotmi</code> instructions.
s10	-512	511	Warnings may optionally be issued for values outside the range [-128, 255] for the <code>andbi</code> , <code>ceqbi</code> , <code>cgtbi</code> , <code>clgtbi</code> , <code>orbi</code> , and <code>xorbi</code> instructions.
s11	-1024	1023	Warnings may optionally be issued for values whose least two significant bits are nonzero, for the <code>hbr</code> , <code>hbra</code> , and <code>hbrr</code> instructions.

Immediate Value	Minimum Value	Maximum Value	Special Variances
s14	-8192	8191	Warnings may optionally be issued for values whose least four significant bits are nonzero, for the <code>lqd</code> and <code>stqd</code> instructions.
s16	-32768	32767	
s18	-131072	131071	Warnings may optionally be issued for values whose least two significant bits are nonzero, for the <code>br</code> , <code>bra</code> , <code>brasl</code> , <code>brhnz</code> , <code>brhz</code> , <code>brnz</code> , <code>brsl</code> , <code>brz</code> , <code>hbra</code> , <code>hbrr</code> , <code>lqa</code> , <code>lqr</code> , <code>stqa</code> , and <code>stqr</code> instructions.
scale7	0	127	
u3	0	7	No limits will be placed on the <code>rotqbi</code> instruction. The seven least significant bits of the specified immediate value will be encoded in the instructions.
u5	0	31	
u6	0	63	
u7	0	127	No limits will be placed on the <code>cbd</code> , <code>cdd</code> , <code>chd</code> , and <code>cwd</code> instructions. The assembler will quietly encode the least significant bits of the immediate value as the <code>u7</code> parameter.
u14	0	16383	
u16	0	65535	For instructions in which no leading bits are appended, the minimum value will be extended to -32768. This includes the <code>fsmbi</code> , <code>ilh</code> , <code>ilhu</code> , and <code>iohl</code> instructions.
u18	0	262143	



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