C/C++ Language Extensions for Cell Broadband Engine Architecture

Version 2.4

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About This Document

This document describes language extension specifications that allow software developers to access hardware features that are not easily accessible from a high level language, such as C or C++, in order to obtain the best performance from a Synergistic Processor Unit (SPU) and a Power Processing Unit (PPU) of the Cell Broadband Engine™ (CBE). This document also includes function specifications to facilitate communication between SPUs and PPU, and it lists a minimal set of standard library functions that must be provided as part of a standard SPU programming environment.

Audience

This document is intended for system and application programmers who want to write SPU and PPU programs for a CBEA-compliant processor.

Version History

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

Version Number & Date	Changes
v 2.4 March 8, 2007	Added support for enhanced double precision SPU instructions (TWG_RFC00071-0). Specified use of vector data types with standard C/C++ operators (TWG_RFC00082-1). Made it explicit that the vector keyword n the SPU is the same as the vector keyword on the PPU (TWG_RFC00096-0). Provided a predefined macro for use by compilers that are targeted to a processor that supports the SPU's optional enhanced double precision instructions (TWG_RFC00097-0). Attached "volatile" with *dmalist* arguments in intrinsics (TWG_RFC00100-0). Corrected various organizational, grammatical, and spelling issues (TWG_RFC00093-0: CORRECTION NOTICE and TWG_RFC00094-0: CORRECTION NOTICE). Specified the kinds of variables to which the aligned attribute applies (TWG_RFC00098-0). Corrected the specification of `isnan()` so that it applies only to single precision (TWG_RFC00099-0: CORRECTION NOTICE). Corrected various minor errors (TWG_RFC00101-0: CORRECTION NOTICE).
v. 2.3 December 4, 2006	Corrected the function parameter ordering of the PPU `__stwbrx` instrinsic (TWG_RFC00074-0: CORRECTION NOTICE) Corrected the type of element initializers used to initialize a vector of `signed/unsigned char` (TWG_RFC00075-0: CORRECTION NOTICE) Changed to note that the use of double-precision contracted operations is permitted by default unless prohibited by the `FP_CONTRACT` pragma or the no-fast-double compiler option (TWG_RFC00076-0). Added PPU data types and programming directives to Chapter 1, and changed title from "SPU Data Types and Program Directives" to "Data Types and Programming Directives" (TWG_RFC00077-1). Removed the `__fre`, `__frsqrtes`, and `__popcntb` intrinsics, and added the `__frsqrte` intrinsic (TWG_RFC00078-3). Added that support is provided in the floating-point environment for both double-precision elements and all four single-precision elements. Also, updated information for `FLT_ROUNDS` (TWG_RFC00079-1).

Version Number & Date	Changes
	Added a new chapter, “PPU VMX Intrinsics”, that specifies a set of intrinsic functions making the underlying PPU VMX instruction set accessible from the C programming language (TWG_RFC00081-1 and TWG_RFC00092-0). Added 32-bit ABI support to the PPU intrinsic functions, changed function arguments to provide a consistent high-level interface, and corrected several typographical errors (TWG_RFC00083-1). Changed the return type of the `__fctiw` and `__fctiwx` PPU intrinsic functions , changed the descriptive names of these and other similar conversion intrinsics, and removed the `__stfiwx` intrinsic function (TWG_RFC00089-1). Identified deprecated PPU VMX operations and recommendations for suitable PPU intrinsic function alternatives (TWG_RFC00090-0). Identified non-supported language features and specified that C++ exception handling is not supported on the SPU (TWG_RFC00091-0).
v. 2.2 October 11, 2006	Applied the changes made in the following requests: TWG_RFC00056-0, TWG_RFC00057-0, TWG_RFC00058-2, TWG_RFC00061-1, TWG_RFC00060-1, TWG_RFC00062-0, TWG_RFC00066-2, TWG_RFC00067-2, TWG_RFC00068-0, TWG_RFC00070-1, TWG_RFC00072-0, and TWG_RFC00073-0. Changed document title because its contents are no longer limited to the SPU. Changed the sections “About this Document” and “Audience” accordingly. Applied TWG_RFC00053-0, TWG_RFC00054-1, and TWG_RFC00055-0. Replaced uses of a protected name by references to the document *Altivec Technology Programming Interface Manual* per TWG_RFC00050-1 and TWG_RFC00052-0. Corrected several operand errors related to `spu_sub`, which is the arithmetic intrinsic for vector subtraction (TWG_RFC00046-0: CORRECTION NOTICE). Corrected various documentation errors; for example, changed sample code demonstrating how to restore the Stack Pointer Information register as a result of invoking the longjmp function (TWG_RFC00047-0: CORRECTION NOTICE). Specified that alternate vector syntax for vector literals is optional rather than mandatory (TWG_RFC00050).
v. 2.1 October 20, 2005	Added a sub-section called “Malloc Heap” to the C library section of the “C and C++ Standard Libraries” chapter. This section is related to an attempt to define a standard process for memory heap initialization and stack management (TWG_RFC00024-3). In the “SPU and Vector Multimedia Extension Intrinsics” chapter, clarified which intrinsic mappings are required according to this specification and which are not because a straightforward mapping does not exist. Provided additional explanations regarding the intrinsics that are difficult to map (TWG_RFC00034-1: CORRECTION NOTICE). Corrected the description of the `si_stqx` instruction (TWG_RFC00035-0: CORRECTION NOTICE). Corrected various documentation errors; for example, changed several descriptions in the “Alternate Vector Literal Format and Description” table. (TWG_RFC00036-0: CORRECTION NOTICE, TWG_RFC00041-0: CORRECTION NOTICE, TWG_RFC00045-0: CORRECTION NOTICE). 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). Added a new chapter describing MFC I/O intrinsics; these intrinsics facilitate MFC programming by defining a common set of utility functions (TWG_RFC00043-2).

Version Number & Date	Changes
v. 2.0 July 11, 2005	Deleted several sections in the “About This Document” chapter. Changed two entries in the Write Word Channel table from `si_wrch(channel, si_to_int(a))` to `si_wrch(channel, si_from_int(a))`. Clarified that the syntax for vector type specifiers does not allow the use of a typedef name as a type specifier. (All changes per TWG_RFC00032-0: CORRECTION NOTICE.)
v. 1.9 June 10, 2005	Added new chapter describing C and C++ Libraries (TWG_RFC00018-5). Added new chapter describing SPU floating-point arithmetic (TWG_RFC00027-1). Changed “Broadband Engine” or “BE” to “a processor compliant with the Broadband Processor Architecture” or “a processor compliant with BPA”; changed VMX to Vector Multimedia Extension; changed Synergistic Processing Element to Synergistic Processor Element; 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 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. 1.8 May 12, 2005	Added new channel number for multisource synchronization requests (TWG_RFC00023-1). Corrected example describing loading of misaligned vectors. Changed PU to PPU and SPC to SPE; changed “PU-to-SPU” (mailboxes) and “SPU-to-PU” to “inbound” and “outbound” respectively (TWG_RFC00028-1: CORRECTION NOTICE). Changed the name of `spu_mulhh` to `spu_mule` (TWG_RFC00021-0). Updated channel names to coincide with BPA channel names (TWG_RFC00029-1).
v. 1.7 July 16, 2004	Clarified that channel intrinsics must not be reordered with respect to other channel commands or volatile local-storage memory accesses (TWG_RFC00007-1). Warned that compliant compilers may ignore `__align_hint` intrinsics (TWG_RFC00008-1). Added an additional SPU instruction, `orx` (TWG_RFC00010-0). Added mnemonics for channels that support reading the event mask and tag mask (TWG_RFC00011-0). Specified that `spu_ienable` and `spu_idisable` intrinsics do not have return values (TWG_RFC00013-0). Moved paragraph beginning “This intrinsic is considered volatile...” from `spu_mfspr` intrinsic to `spu_mtfpscr` (TWG_RFC00014-0). Changed the descriptions for `si_lqd` and `si_stqd` intrinsics (TWG_RFC00015-1). Provided new descriptions of various rotation-and-mask intrinsics, specifically: `spu_rlmask`, `spu_rlmaska`, `spu_rlmaskqw`, `spu_rlmaskqwbyte`, and `spu_rlmaskqwbytebc`. These descriptions include pseudo-code examples (TWG_RFC00016-1). Made miscellaneous editorial changes.
v. 1.6 March 12, 2004	Made miscellaneous editorial changes.
v. 1.5 February 25, 2004	Changed formatting of document so that it reflects the typographic conventions described on page xviii. Made miscellaneous editorial changes. Changed some of the parameter types for `spu_mfcdma32` and `spu_mfcdma64`, as requested in TWG_RFC00002. Inserted new specifications for the vector literal format, as requested in TWG_RFC00003.
v. 1.4	Changed document to new format, including front matter. Made miscellaneous

Version Number & Date	Changes
January 20, 2004	editorial changes.
v. 1.3 November 4, 2003	Added enable/disable interrupt intrinsics.
v. 1.2 September 2, 2003	Changed parameter types of `spu_sel` intrinsic to be compatible with Vector Multimedia Extension's `vec_sel`. Added `si_stopd` specific intrinsic. Corrected tables for `spu_genb` and `spu_genc` generic intrinsics.
v. 1.1 June 15, 2003	Made changes to support RFC 24. Added isolation control channel 64. Made changes to support RFC 33. Removed `spu_addc`, `spu_addsc`, `spu_subb`, and `spu_subsb`. Added `spu_addx`, `spu_subx`, `spu_genc`, `spu_gencx`, `spu_genb`, and `spu_genbx`.
v. 1.0 April 28, 2003	Made minor corrections.
v. 0.9 March 7, 2003	Added new intrinsics to support new or modified instructions. These include: `fscrrd`, `fscrwr`, `stop`, `dfma`, `mpyhhau`, `mpyhhu`, `rotqmbybi`, `iret`, `lqr`, and `stqr`. Also added intrinsics to support new feature bits for `iret`, `bisled`, `bihnz`, and `sync`.
v. 0.8 January 23, 2003	Improved documentation of specific intrinsics. Completely defined parameter ordering and immediate sizes. Defined new global (`spu_intrinsics.h`) and compiler specific (`spu_internals.h`) header files. Specified that single token vector types and channel enumerants are declared in `spu_intrinsics.h`. Added specific pointer casting intrinsics. Added standardized `__SPU__` conditional compilation control. Changed specific convert intrinsics to unbiased scale parameters, such as generic intrinsics. Specified that the bisled target function does not observe the standard calling convention with respect to volatile registers.
v. 0.7 November 18, 2002	Specified that gcc-style inline assembly is required. Specified that `__builtin_expect` is required. Added `bisled` specific and generic intrinsics. Added `__align_hint` intrinsic. Specified that the `restrict` type qualifier is required. Specified that out-of-range scale factors on generic conversion intrinsics return an error.
v. 0.6 September 24, 2002	Changed document title to include C++. Made miscellaneous clarifications and typing corrections. Changed `spu_eqv` to return the same vector type as its inputs. Changed `spu_and`, `spu_or`, and `spu_xor` to accept immediate values of the same type as the elements of parameter *a*. Added specific casting intrinsics. Changed default action on out-of-range immediate values for specific intrinsics to issuing an error. Added documentation of the `__builtin_expect` builtin. Completed SPU-to-Vector Multimedia Extension intrinsic mapping section.
v. 0.5 August 27, 2002	Edited discussion of Vector Multimedia Extension-to-SPU intrinsic mapping. Removed appendices. Added support for 32-bit read and write channel intrinsics. Renamed quadword channel read and write to `readchqw` and `writechqw`.

Version Number & Date	Changes
v. 0.4 August 5, 2002	Corrected the instruction mapping for `spu_promote` and `spu_extract`. Specified that instruction mapping for generic intrinsics `spu_re` and `spu_rsqrte` include the `FI` (floating-point interpolate) instruction. Renamed `spu_splat` to `spu_splats` (scalar splat) to avoid confusion with `vec_splat`. Added documentation about the size of the immediate intrinsic forms. Changed all `vector signed long` to `vector signed long long`. Changed *`count`* to unsigned for `spu_sl`, `spu_slqw`, `spu_slqwbyte`, and `spu_slqwbytebc`. Changed *`count`* to signed for `spu_rl`, `spu_rlmask` and `spu_rlmaska`. Specified that the return value of `spu_cntlz` is an unsigned value. Corrected description of `spu_gather` intrinsic. Edited mapping documentation of scalars for `spu_and`, `spu_or`, and `spu_xor`. Removed vector input forms of `spu_hcmpeq` and `spu_hcmpgt`.
v. 0.3 July 16, 2002	Added `fsmbi` to literal constructor instructions. Added `fsmbi` (immediate form) to `spu_maskb` intrinsic. Added vector forms to compare and halt (`spu_hcmpeq` and `spu_hcmpgt`) intrinsics. Added `qword` data type as the only vector type accepted by specific intrinsics. Added typedefs for the vector types as the basic types used for code portability. Merged all `spu_splat` generic intrinsics into a single intrinsic. Dropped `spu_load`, `spu_store`, and `spu_insertctl` generic intrinsics.
v. 0.2 July 9, 2002	Incorporated changes and suggestions from Peng. Changed `vector long` types to `vector long long`.
v. 0.1 June 21, 2002	First version of the language extension specification. Initial specification based on the Tobey compiler intrinsics specification.

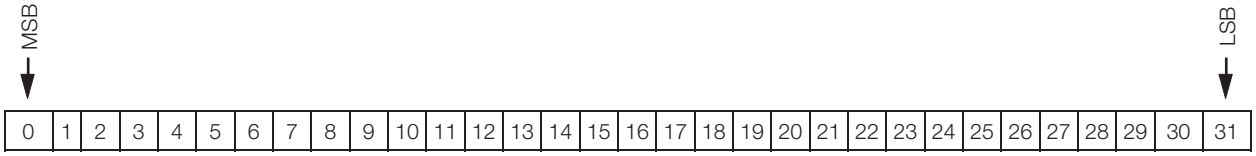
Related Documentation

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

Document Title	Version	Date
ISO/IEC Standard 9899:1999 (C Standard)		
ISO/IEC Standard 14882:1998 (C++ Standard)		
IEEE-754 (Standard for Binary Floating-Point Arithmetic)		
Synergistic Processor Unit Instruction Set Architecture	1.2	January 2007
Cell Broadband Engine Architecture	1.01	October 2006
Tool Interface Standard (TIS), Executable and Linking Format (ELF) Specification	1.2	May 1995
Tool Interface Standard (TIS), DWARF Debugging Information Format Specification	2.0	May 1995
PowerPC Architecture Book, Book II: PowerPC Virtual Environment Architecture	2.02	January 2005

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’.

Byte Ordering and Element Numbering

Byte ordering and element numbering is always displayed in big endian order, as shown in Figure 1-1,

Figure 1-1: Big-Endian Byte/Element Ordering for Vector Types

Byte 0 (MSB)	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8	Byte 9	Byte 10	Byte 11	Byte 12	Byte 13	Byte 14	Byte 15 (LSB)
doubleword 0								*doubleword 1*							
word 0				*word 1*				*word 2*				*word 3*			
halfword 0		*halfword 1*		*halfword 2*		*halfword 3*		*halfword 4*		*halfword 5*		*halfword 6*		*halfword 7*	
char 0	*char 1*	*char 2*	*char 3*	*char 4*	*char 5*	*char 6*	*char 7*	*char 8*	*char 9*	*char 10*	*char 11*	*char 12*	*char 13*	*char 14*	*char 15*

Typographic Conventions

In addition to bit notation, the following typographic conventions are used throughout this document:

Convention	Meaning
`courier`	Indicates programming code, processing instructions, register names, data types, events, file names, and other literals. Also indicates function and macro names. This convention is only used where it facilitates comprehension, especially in narrative descriptions.
`courier + italics`	Indicates arguments, parameters and variables, including variables of type `const`. This convention is only used where it facilitates comprehension, especially in narrative descriptions.
italics (without courier)	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. Data Types and Programming Directives

This chapter specifies PPU Vector Multimedia eXtension™ (VMX) and SPU vector data types, operations on these data types, programming directives, and predefined macro target definitions.

Any confict between the requirements described here for PPU Vector Multimedia eXtension (VMX) data types and the *Altivec Technology Programming Interface Manual* is unintentional.

The `vector` keyword and the `__vector` keyword have the same properties, defined in the *Altivec Technology Programming Interface Manual*. The `__vector` keyword is preferred for code portability because it is always defined.

1.1. Data Types

In this section, a set of fundamental vector data types are introduced to the C language, and several mappings are described which relate PPU and SPU data types to one another.

1.1.1. Fundamental Data Types

The fundamental vector data types that are supported by the PPU and SPU are shown in Table 1-1. All of these data types are 128-bits long and contain from 2 to 16 elements, depending on the corresponding element data type.

Table 1-1: Vector Data Types

Vector Data Type	Content	SPU/PPU
vector unsigned char	16 8-bit unsigned chars	Both
vector signed char	16 8-bit signed chars	Both
vector unsigned short	8 16-bit unsigned halfwords	Both
vector signed short	8 16-bit signed halfwords	Both
vector unsigned int	4 32-bit unsigned words	Both
vector signed int	4 32-bit signed words	Both
vector unsigned long long	2 64-bit unsigned doublewords	SPU
vector signed long long	2 64-bit signed doublewords	SPU
vector float	4 32-bit single-precision floats	Both
vector double	2 64-bit double-precision floats	SPU
qword	quadword (16-byte), used exclusively as an input/output to a specific intrinsic function. See section "2.1. Specific Intrinsics"	SPU
vector bool char	16 8-bit bools – 0 (false) 255 (true)	PPU
vector bool short	8 16-bit bools – 0 (false) 65535 (true)	PPU
vector bool int	4 32-bit bools – 0 (false) $2^{32} - 1$ (true)	PPU
vector pixel	8 16-bit unsigned halfword, 1/5/5/5 pixel	PPU

The syntax for vector type specifiers does not allow the use of a typedef name as a type specifier. For example, the following declaration is not allowed:

```
typedef signed short int16;
vector int16 data;
```

1.1.2. Mapping of PPU Data Types to SPU Data Types

Not all PPU vector data types are supported on the SPU. The PPU vector data types that do not map identically to SPU data types are shown in Table 1-2.

Table 1-2: Non-identical Mapping of VMX Data Types to SPU Data Types

VMX Data Type	Maps to SPU Data Type
vector bool char	vector unsigned char
vector bool short	vector unsigned short
vector bool int	vector unsigned int
vector pixel	vector unsigned short[1]

[1] Because `vector pixel` and `vector bool short` are mapped to the same base vector type (`vector unsigned short`), the overloaded functions for `vec_unpackh` and `vec_unpackl` cannot be uniquely resolved.

1.1.3. Mapping of SPU Data Types to PPU Data Types

Not all SPU data types are supported by the PPU VMX. The SPU data types that do not map identically to PPU vector data types are shown in Table 1-3.

Table 1-3: Non-identical Mapping of SPU Data Types to VMX Data Types

SPU Data Type	Maps to VMX Data Type
vector unsigned long long	vector bool char
vector signed long long	vector bool short
vector double	vector bool int

1.2. Header Files

There are separate system header files for the SPU and PPU that include typedefs and other information required by this specification.

1.2.1. Header File Contents

The SPU system header file, `spu_intrinsics.h`, defines common enumerations and typedefs. These include the single token vector types and MFC channel mnemonic enumerations (see Table 1-4 and Table 2-91, respectively). In addition, `spu_intrinsics.h` will include a compiler specific header file, `spu_internals.h`, that contains any implementation specific definitions.

The PPU system header file, `altivec.h`, defines typedefs and keywords and also includes any implementation specific definitions. The PPU system header file, `vec_types.h`, defines typedefs required by the language extension features defined in this specification.

1.2.2. Single Token Typedefs

To improve code portability, single token typedefs are provided for the vector keyword data types. These typedefs, which are shown in Table 1-4 are defined in `spu_intrinsics.h` on the SPU and in `vec_types.h` on the PPU. Besides simplifying type declarations, the single token types serve as class names for extending generic intrinsics or for mapping between PPU VMX intrinsics and/or SPU intrinsics.

Table 1-4: Single Token Vector Data Types

Vector Keyword Data Type	Single Token Typedef	SPU/PPU
vector unsigned char	vec_uchar16	Both
vector signed char	vec_char16	Both
vector unsigned short	vec_ushort8	Both
vector signed short	vec_short8	Both
vector unsigned int	vec_uint4	Both
vector signed int	vec_int4	Both
vector unsigned long long	vec_ullong2	SPU

Vector Keyword Data Type	Single Token Typedef	SPU/PPU
vector signed long long	vec_llong2	SPU
vector float	vec_float4	Both
vector double	vec_double2	SPU
vector bool char	vec_bchar16	PPU
vector bool short	vec_bshort8	PPU
vector bool int	vec_bint4	PPU
vector pixel	vec_pixel8	PPU

1.3. Alignment

1.3.1. Default Data Type Alignments

Table 1-5 shows the size and default alignment of the various data types.

Table 1-5: Default Data Type Alignments

Data Type	Size	Alignment
char	1	byte
short	2	halfword
int	4	word
long	4	word/doubleword
long long	8	doubleword
float	4	word
double	8	doubleword
pointer	4	word
vector	16	quadword

The aligned attribute will be provided by implementations to align static, global, and local variables, as well as static and non-static data members. The aligned attribute will not guarantee alignment of variables allocated using `malloc` or `operator new`. Implementations will support at least 128-byte alignment.

In the following declaration statement, the floating-point scalar *`factor`* will be aligned on a quadword boundary:

```
float factor __attribute__ ((aligned (16)));
```

1.3.2. __align_hint

The `__align_hint` intrinsic is provided to improve data access through pointers and to provide compilers the additional information that is needed to support auto-vectorization. This built-in function is available only on the SPU.

Although `__align_hint` is defined as an intrinsic, it behaves like a directive, because no code is ever specifically generated. For example:

```
__align_hint(ptr, base, offset)
```

The `__align_hint` intrinsic informs the compiler that the pointer *`ptr`* points to data with a base alignment of *`base`* and with an offset from *`base`* of *`offset`*. The base alignment has to be a power of 2. A base address of zero implies that the pointer has no known alignment. The alignment offset has to be less than *`base`* or zero.

The `__align_hint` intrinsic is not intended to specify pointers that are not naturally aligned. Specifying pointers that are not naturally aligned results in data objects straddling quadword boundaries. If a programmer specifies alignment incorrectly, incorrect programs might result.

Programming Note: Although compliant compiler implementations must provide the `__align_hint` intrinsic, compilers may ignore these hints.

1.4. Operating on Vector Types

This section describes the C/C++ operators and operations that are required to act on vector data types. These operators are the `sizeof()` operator, the assignment operator (=), and the address operator (&). Many other standard C/C++ operators are also extended for vector data types. The overloading of these operators for vector data types is described in "10. Operator Overloading for Vector Data Types".

The operations on vector data types are pointer operations and type casting operations.

1.4.1. sizeof() Operator

The operation `sizeof()` on a vector type always returns 16.

1.4.2. Assignment Operator

If either the left or right side of an expression has a vector type, both sides of the expression has to be of the same vector type. Thus, the expression a = *b* is valid and represents assignment if *a* and *b* are of the same type or if neither variable is a vector type. Otherwise, the expression is invalid, and the compiler reports the inconsistency as an error.

1.4.3. Address Operator

The operation &a is valid when *a* is a vector type. The result of the operation is a pointer to vector *a*.

1.4.4. Pointer Arithmetic and Pointer Dereferencing

The usual pointer arithmetic involving a pointer to a vector type can be performed. For example, assuming *p* is a pointer to a vector type, *p+1* is the pointer to the next vector following *p*.

Dereferencing the vector pointer *p* implies a 128-bit vector load from or store to the address obtained by masking the 4 least significant bits of *p*. When a vector is misaligned, the 4 least significant bits of its address are nonzero. Although vectors are 16-byte aligned (see section "1.3. Alignment"), it nevertheless might be desirable to load or store a vector that is misaligned. A misaligned vector can be loaded in several ways using generic intrinsics (see section "2.2. Generic Intrinsics and Built-ins").

The following code shows one example of how to load a misaligned floating-point vector on the SPU:

```
vector float load_misaligned_vector_float (vector float *ptr)
{
       vector float qw0, qw1;
       int shift;

       qw0 = *ptr;
       qw1 = *(ptr+1);
       shift = (unsigned) ptr & 15;

       return spu_or(
                    spu_slqwbyte(qw0, shift),
                    spu_rlmaskqwbyte(qw1, shift-16));
}
```

Similarly, this next example shows how to store to a misaligned floating-point vector on the SPU.

```
void store_misaligned_vector_float (vector float flt, vector float *ptr)
{
       vector float qw0, qw1;
       vector unsigned int mask;
```

```
        int shift;

        qw0 = *ptr;
        qw1 = *(ptr+1);
        shift = (unsigned)(ptr) & 15;
        mask = (vector unsigned int)
               spu_rlmaskqwbyte((vector unsigned char)(0xFF), -shift);

        flt = spu_rlqwbyte(flt, -shift);

        *ptr = spu_sel(qw0, flt, mask);
        *(ptr+1) = spu_sel(flt, qw1, mask);
}
```

1.4.5. Type Casting

Pointers to vector types and non-vector types may be cast back and forth to each other. For the purpose of aliasing, a vector type is treated as an array of its corresponding element type, as shown in Table 1-6. If a pointer is cast to the address of a vector type, it is the programmer's responsibility to ensure that the address is 16-byte aligned. Vector types that are applicable only on the PPU do not have an underlying scalar type.

Table 1-6: Vector Pointer Types and Matching Base Element Pointer Types

Vector Pointer Type (vector T*)	Base Element Pointer Type (T*)	SPU/PPU
vector unsigned char*	unsigned char*	Both
vector signed char*	signed char*	Both
vector unsigned short*	unsigned short*	Both
vector signed short*	signed short*	Both
vector unsigned int*	unsigned int*	Both
vector signed int*	signed int*	Both
vector unsigned long long*	unsigned long long*	SPU
vector signed long long*	signed long long*	SPU
vector float*	float*	Both
vector double*	double*	SPU

Casts from one vector type to another vector type has to be explicit and are done using normal C-language casts. None of these casts performs any data conversion. Thus, the bit pattern of the result is the same as the bit pattern of the argument that is cast.

Casts between vector types and scalar types are illegal. On the SPU, the `spu_extract`, `spu_insert`, and `spu_promote` generic intrinsics or the specific casting intrinsics may be used to efficiently achieve the same results (see section "2.1.1. Specific Casting Intrinsics"). On the PPU, the `vec_lde` and `vec_ste` intrinsics may be used to copy between scalar and vector types.

1.4.6. Vector Literals

As shown in Table 1-7, a vector literal is written as a parenthesized vector type followed by a curly braced set of constant expressions. If a vector literal is used as an argument to a macro, the literal has to be enclosed in parentheses. In all other cases, the literal can be used without enclosing parentheses. The elements of the vector are initialized to the corresponding expression. Elements for which no expressions are specified default to 0. Vector literals may be used either in initialization statements or as constants in executable statements. The syntax for vector initialization and for vector compound literals is the same as the corresponding array syntax except designators which do not exist for vector elements. The initializer should act as an array of either 2, 4, 8, or 16 elements depending on the size of the underlying type. For example the following two initializations are valid and equivalent:

```
vector signed int v1[] = {{0, 1, 2, 3},{4, 5, 6, 7}};
vector signed int v2[] = {0, 1, 2, 3, 4, 5, 6, 7};
```

The following two struct initializers are also valid and equivalent:

```
struct stypy {
       int i;
       vector signed int t;
} v3 = {1, {0, 1, 2, 3}}, v4 = {1, 0, 1, 2, 3};
```

The following types on both the SPU and PPU cannot be initialized using a vector literal: `qword`, `vector bool char`, `vector bool short`, `vector bool int`, and `vector pixel`. They can be created by using the intrinsics or by casting to these vector types.

Table 1-7: Vector Literal Format and Description

Notation	Represents	SPU/PPU
(vector unsigned char) {unsigned char, ...}	A set of 16 unsigned 8-bit quantities.	Both
(vector signed char) {signed char, ...}	A set of 16 signed 8-bit quantities.	Both
(vector unsigned short) {unsigned short, ...}	A set of 8 unsigned 16-bit quantities.	Both
(vector signed short) {signed short, ...}	A set of 8 signed 16-bit quantities.	Both
(vector unsigned int) {unsigned int, ...}	A set of 4 unsigned 32-bit quantities.	Both
(vector signed int) {signed int, ...}	A set of 4 signed 32-bit quantities.	Both
(vector unsigned long long) {unsigned long long, ...}	A set of 2 unsigned 64-bit quantities.	SPU
(vector signed long long) {signed long long, ...}	A set of 2 signed 64-bit quantities.	SPU
(vector float) {float, ...}	A set of 4 32-bit floating-point quantities.	Both
(vector double) {double, ...}	A set of 2 64-bit floating-point quantities.	SPU

An alternate format may also be supported which corresponds to the syntax specified in the *Altivec Technology Programming Interface Manual*. This format consists of a parenthesized vector type followed by a parenthesized set of constant expressions. See Table 1-8.

Table 1-8: Alternate Vector Literal Format and Description

Notation	Represents	SPU/PPU
(vector unsigned char)(unsigned int)	A set of 16 unsigned 8-bit quantities that all have the value specified by the integer.	Both
(vector unsigned char)(unsigned int, ..., unsigned int)	A set of 16 unsigned 8-bit quantities specified by the 16 integers.	Both
(vector signed char)(signed int)	A set of 16 signed 8-bit quantities that all have the value specified by the integer.	Both
(vector signed char)(signed int, ..., signed int)	A set of 16 signed 8-bit quantities specified by the 16 integers.	Both
(vector unsigned short)(unsigned int)	A set of 8 unsigned 16-bit quantities that all have the value specified by the integer.	Both
(vector unsigned short)(unsigned int, ..., unsigned int)	A set of 8 unsigned 16-bit quantities specified by the 8 integers.	Both
(vector signed short)(signed int)	A set of 8 signed 16-bit quantities that all have the value specified by the integer.	Both
(vector signed short)(signed int, ..., signed int)	A set of 8 signed 16-bit quantities specified by the 8 integers.	Both
(vector unsigned int)(unsigned int)	A set of 4 unsigned 32-bit quantities that all have the value specified by the integer.	Both
(vector unsigned int)(unsigned int, ..., unsigned int)	A set of 4 unsigned 32-bit quantities specified by the 4 integers.	Both
(vector signed int)(signed int)	A set of 4 signed 32-bit quantities that all have the value specified by the integer.	Both

Notation	Represents	SPU/PPU
(vector signed int)(signed int, ..., signed int)	A set of 4 signed 32-bit quantities specified by the 4 integers.	Both
(vector unsigned long long)(unsigned long long)	A set of 2 unsigned 64-bit quantities that all have the value specified by the long integer.	SPU
(vector unsigned long long)(unsigned long long, unsigned long long)	A set of 2 unsigned 64-bit quantities specified by the 2 long integers.	SPU
(vector signed long long)(signed long long)	A set of 2 signed 64-bit quantities that all have the value specified by the long integer.	SPU
(vector signed long long)(signed long long, signed long long)	A set of 2 signed 64-bit quantities specified by the 2 long integers.	SPU
(vector float)(float)	A set of 4 32-bit floating-point quantities that all have the value specified by the float.	Both
(vector float)(float, float, float, float)	A set of 4 32-bit floating-point quantities specified by the 4 floats.	Both
(vector double)(double)	A set of 2 64-bit double-precision quantities that all have the value specified by the double.	SPU
(vector double)(double, double)	A set of 2 64-bit quantities specified by the 2 doubles.	SPU

1.5. Restrict Type Qualifier

The `restrict` type qualifier, which is specified in the C99 language specification, is intended to help the compiler generate better code by ensuring that all access to a given object is obtained through a particular pointer. When a pointer uses the `restrict` type qualifier, the pointer is `restrict`-qualified. For example:

```
void *memcpy(void * restrict s1, const void * restrict s2, size_t n);
```

In the above prototype, both pointers, *s1* and *s2*, are `restrict`-qualified. Therefore, the compiler can safely assume that the source and destination objects will not overlap, allowing for a more efficient implementation.

1.6. SPU Programmer Directed Branch Prediction

Branch prediction can be significantly improved by using feedback-directed optimization. However, feedback-directed optimization is not always practical in situations where typical data sets do not exist. Instead, on the SPU, programmer-directed branch prediction is provided using an enhanced version of GCC's `__builtin_expect` function.

```
int __builtin_expect(int exp, int value)
```

Programmers can use `__builtin_expect` to provide the compiler with branch prediction information. The return value of `__builtin_expect` is the value of the *exp* argument, which has to be an integral expression. For dynamic prediction, the *value* argument can be either a compile-time constant or a variable. The `__builtin_expect` function assumes that `exp` equals `value`.

```
Static Prediction Example
      if (__builtin_expect(x, 0)) {
            foo();       /* programmer doesn't expect foo to be called */
      }

Dynamic Prediction Example
      cond2 = ...               /* predict a value for cond1 */
      ...
      cond1 = ...
      if (__builtin_expect(cond1, cond2)) {
            foo();
      }
```

```
cond2 = cond1;      /* predict that next branch is the same as the
                    previous */
```

Compilers may require limiting the complexity of the expression argument because multiple branches could be generated. When this situation occurs, the compiler has to issue a warning if the program's branch expectations are ignored.

Implementation of this extension is not required for the PPU because the PPU only supports static prediction for branches

1.7. Inline Assembly

Occasionally, a programmer might not be able to achieve the desired low-level programming result by using only C/C++ language constructs and intrinsic functions. To handle these situations, the use of inline assembly might be necessary, and therefore, it has to be provided. The inline assembly syntax have to match the AT&T assembly syntax implemented by GCC.

The `.balignl` directive may be used within the inline assembly to ensure the known alignment that is needed to achieve effective dual-issue by the hardware.

1.8. Target Definitions

Compilers must define `__SPU__` when code is being compiled for the SPU, and `__PPU__` when code is being compiled for the PPU. The availability of these definitions enables the development of code that can be conditionally compiled for either target.

As an example, the following code supports misaligned quadword loads. The `__SPU__` and `__PPU__` defines are used to conditionally select which code to use. The code that is selected will be different depending on the processor target.

```
vector unsigned char load_qword_unaligned(vector unsigned char *ptr)
{
       vector unsigned char qw0, qw1, qw;
#ifdef __SPU__
       unsigned int shift;
#endif
       qw0 = *ptr;
       qw1 = *(ptr+1);
#ifdef __SPU__
       shift = (unsigned int)(ptr) & 15;
       qw = spu_or(spu_slqwbyte(qw0, shift),
                   spu_rlmaskqwbyte(qw1, (signed)(shift - 16)));
#elif defined(__PPU__) /* PPU */
       qw = vec_perm(qw0, qw1, vec_lvsl(0, ptr));
#else
# error “This code can only be compiled for PPU or the SPU”
#endif
       return (qw);
}
```

When compiling for an SPU implementation that supports the optional enhanced double-precision instructions, `__SPU_EDP__` will also be defined. The enhanced double-precision instructions include `DFCEQ`, `DFCGT`, `DFMCEQ`, `DFMCGT`, and `DFTSV`.

2. SPU Low-Level Specific and Generic Intrinsics

This chapter describes the minimal set of basic intrinsics and built-ins that make the underlying Instruction Set Architecture (ISA) and Synergistic Processor Element (SPE) hardware accessible from the C programming language. There are three types of intrinsics:

- Specific
- Generic
- Built-ins

Intrinsics may be implemented either internally within the compiler or as macros. However, if an intrinsic is implemented as a macro, restrictions apply with respect to vector literals being passed as arguments. For more details, see section "1.4.6. Vector Literals".

The instruction set may vary among SPU implementations. If an instruction is not supported by the SPU implementation for which the intrinsic is being compiled, special handling shall occur. For specific intrinsics, an error is generated if the targeted SPU does not support the corresponding instruction. For generic intrinsics, an alternate instruction mapping will be generated that achieves an equivalent operation.

Throughout this section, intrinsics which may generate special handling are indicated by a dagger (†).

2.1. Specific Intrinsics

Specific intrinsics are *specific* in the sense that they have a one-to-one mapping with a single SPU assembly instruction. All specific intrinsics are named using the SPU assembly instruction prefixed by the string `si_`. For example, the specific intrinsic that implements the `stop` assembly instruction is named `si_stop`.

A specific intrinsic exists for nearly every assembly instruction. However, the functionality provided by several of the assembly instructions is better provided by the C/C++ language; therefore, for these instructions no specific intrinsic has been provided. Table 2-9 describes the assembly instructions that have no corresponding specific intrinsic.

Table 2-9: Assembly Instructions for which No Specific Intrinsic Exists

Instruction Type	SPU Instructions
Branch instructions	br, bra, brsl, brasl, bi, bid, bie, bisl, bisld, bisle, brnz, brz, brhnz, brhz, biz, bizd, bize, binz, binzd, binze, bihz, bihzd, bihze, bihnz, bihnzd, and bihnze (excluding bisled, bisledd, bislede)
Branch Hint instructions	hbr, hbrp, hbra, and hbrr
Interrupt Return Instructions	iret, iretd, and irete

All specific intrinsics are accessible through generic intrinsics, except for the specific intrinsics shown in Table 2-10. The intrinsics that are not accessible fall into three categories:

- Instructions that are generated using basic variable referencing (that is, using vector and scalar loads and stores)
- Instructions that are used for immediate vector construction
- Instructions that have limited usefulness and are not expected to be used except in rare conditions

Table 2-10: Specific Intrinsics Not Accessible Through Generic Intrinsics

Instruction/Description	Usage	Assembly Mapping
Generate Controls for Sub-Quadword Insertion		
si_cbd: Generate Controls for Byte Insertion (d-form) An effective address is computed by adding the value in the signed 7-bit immediate *imm* to word element 0 of *a*. The rightmost 4 bits of the effective address are used to determine the position of the addressed byte within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a byte (byte element 3) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_cbd(*a*, *imm*)	CBD d, imm(a)
si_cbx: Generate Controls for Byte Insertion (x-form) An effective address is computed by adding the value of word element 0 of *a* to word element 0 of *b*. The rightmost 4 bits of the effective address are used to determine the position of the addressed byte within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a byte (byte element 3) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_cbx(*a*, *b*)	CBX d, a, b
si_cdd: Generate Controls for Doubleword Insertion (d-form) An effective address is computed by adding the value in the signed 7-bit immediate *imm* to word element 0 of *a*. The rightmost 4 bits of the effective address are used to determine the position of the addressed doubleword within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a doubleword (doubleword element 0) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_cdd(*a*, *imm*)	CDD d, imm(a)
si_cdx: Generate Controls for Doubleword Insertion (x-form) An effective address is computed by adding the value of word element 0 of *a* to word element 0 of *b*. The rightmost 4 bits of the effective address are used to determine the position of the addressed doubleword within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a doubleword (doubleword element 3) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_cdx(*a*, *b*)	CDX d, a, b
si_chd: Generate Controls for Halfword Insertion (d-form) An effective address is computed by adding the value in the signed 7-bit immediate *imm* to word element 0 of *a*. The rightmost 4 bits of the effective address are used to determine the position of the addressed halfword within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a halfword (halfword element 1) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_chd(*a*, *imm*)	CHD d, imm(a)
si_chx: Generate Controls for Halfword Insertion (x-form) An effective address is computed by adding the value of word element 0 of *a* to word element 0 of *b*. The rightmost 4 bits of the effective address are used to determine the position of the addressed halfword within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a halfword (halfword element 1) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_chx(*a*, *b*)	CHX d, a, b

Instruction/Description	Usage	Assembly Mapping
si_cwd: Generate Controls for Word Insertion (d-form) An effective address is computed by adding the value in the signed 7-bit immediate *imm* to word element 0 of *a*. The rightmost 4 bits of the effective address are used to determine the position of the addressed word within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a word (word element 0) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_cwd(*a*, *imm*)	CWD d, imm(a)
si_cwx: Generate Controls for Word Insertion (x-form) An effective address is computed by adding the value of word element 0 of *a* to word element 0 of *b*. The rightmost 4 bits of the effective address are used to determine the position of the addressed word within a quadword. Based on the position, a pattern is generated that can be used with the `si_shufb` intrinsic to insert a word (element 0) at the indicated position within a quadword. The pattern is returned in quadword *d*.	*d* = si_cwx(*a*, *b*)	CWX d, a, b
Constant Formation Intrinsics		
si_il: Immediate Load Word The 16-bit signed immediate value *imm* is sign-extended to 32 bits and placed into each of the 4 word elements of quadword *d*.	*d* = si_il(*imm*)	IL d, imm
si_ila: Immediate Load Address The 18-bit immediate value *imm* is placed in the rightmost bits of each of the 4 word elements of quadword *d*. The upper 14 bits of each word is set to 0.	*d* = si_ila(*imm*)	ILA d, imm
si_ilh: Immediate Load Halfword The 16-bit signed immediate value *imm* is placed in each of the 8 halfword elements of quadword *d*.	*d* = si_ilh(*imm*)	ILH d, imm
si_ilhu: Immediate Load Halfword Upper The 16-bit signed immediate value *imm* is placed into the leftmost 16 bits each of the 4 word elements of quadword *d*. The rightmost 16 bits are set to 0.	*d* = si_ilhu(*imm*)	ILHU d, imm
si_iohl: Immediate Or Halfword Lower The 16-bit immediate value *imm* is prepended with zeros and ORed with each of the 4 word elements of quadword *a*. The result is returned in quadword *d*.	*d* = si_iohl(*a*, *imm*)	rt <--- a IOHL rt, imm d <--- rt
No Operation Intrinsics		
si_lnop: No Operation (load) A no-operation is performed on the load pipeline.	si_lnop()	LNOP
si_nop: No Operation (execute) A no-operation is performed on the execute pipeline.	si_nop()	NOP rt[1]
Memory Load and Store Intrinsics		
si_lqa: Load Quadword (a-form) An effective address is determined by the sign-extended 18-bit value *imm*, with the 4 least significant bits forced to zero. The quadword at this effective address is returned in quadword *d*.	*d* = si_lqa(*imm*)	LQA d, imm
si_lqd: Load Quadword (d-form) An effective address is computed by zeroing the 4 least significant bits of the sign-extended 14-bit immediate value *imm*, adding *imm* to word element 0 of quadword *a*, and forcing the 4 least significant bits of the result to zero. The quadword at this effective address is then returned in quadword *d*.	*d* = si_lqd(*a*, *imm*)	LQD d, imm(a)

Instruction/Description	Usage	Assembly Mapping
si_lqr: Load Quadword Instruction Relative (a-form) An effective address is computed by forcing the 2 least significant bits of the signed 18-bit immediate value *imm* to zero, adding this value to the address of the instruction, and forcing the 4 least significant bits of the result to zero. The quadword at this effective address is then returned in quadword *d*.	*d* = si_lqr(*imm*)	LQR, d, imm
si_lqx: Load Quadword (x-form) An effective address is computed by adding word element 0 of quadword *a* to word element 0 of quadword *b* and forcing the 4 least significant bits to zero. The quadword at this effective address is then returned in quadword *d*.	*d* = si_lqx(*a*, *b*)	LQX d, a, b
si_stqa: Store Quadword (a-form) An effective address is determined by the sign-extended 18-bit value *imm*, with the 4 least significant bits forced to zero. The quadword *a* is stored at this effective address.	si_stqa(*a*, *imm*)	STQA a, imm
si_stqd: Store Quadword (d-form) An effective address is computed by zeroing the 4 least significant bits of the sign-extended 14-bit immediate value *imm*, adding *imm* to word element 0 of quadword *b*, and forcing the 4 least significant bits to zero. The quadword *a* is then stored at this effective address.	si_stqd(*a*, *b*, *imm*)	STQD a, imm(b)
si_stqr: Store Quadword Instruction Relative (a-form) An effective address is computed by forcing the 2 least significant bits of the signed 18-bit immediate value *imm* to zero, adding this value to the address of the instruction, and forcing the 4 least significant bits of the result to zero. The quadword *a* is then stored at this effective address.	si_stqr(*a*, *imm*)	STQR, a, imm
si_stqx: Store Quadword (x-form) An effective address is computed by adding word element 0 of quadword *b* to word element 0 of quadword *c* and forcing the 4 least significant bits to zero. The quadword *a* is then stored at this effective address.	si_stqx(*a*, *b*, *c*)	STQX a, b, c
Control Intrinsics		
si_stopd: Stop and Signal with Dependencies Execution of the SPU is stopped and a signal type of `0x3FFF` is delivered after all register dependencies are met. This intrinsic is considered volatile with respect to all instructions and will not be reordered with any other instructions.	si_stopd(*a*, *b*, *c*)	STOPD a, b, c

[1] The false target parameter *rt* is optimally chosen depending on the register usage of neighboring instructions.

Specific intrinsics accept only the following types of arguments:

- Immediate literals, as an explicit constant expression or as a symbolic address
- Enumerations
- `qword` arguments

Arguments of other types must be cast to `qword`.

For complete details on the specific instructions, see the *Synergistic Processor Unit Instruction Set Architecture*.

2.1.1. Specific Casting Intrinsics

When using specific intrinsics, it may be necessary to cast from scalar types to the `qword` data type, or from the `qword` data type to scalar types. Similar to casting between vector data types, specific cast intrinsics have no effect on an argument that is stored in a register. All specific casting intrinsics are of the following form:

```
d=casting_intrinsic(a)
```

See Table 2-11 for additional details about the specific casting intrinsics.

Table 2-11: Specific Casting Intrinsics

Casting Intrinsic	Return/Argument Types		Description
	d	a	
si_to_char	signed char	qword	Cast byte element 3 of qword *a* to signed char *d*.
si_to_uchar	unsigned char		Cast byte element 3 of qword *a* to unsigned char *d*.
si_to_short	short		Cast halfword element 1 of qword *a* to short *d*.
si_to_ushort	unsigned short		Cast halfword element 1 of qword *a* to unsigned short *d*.
si_to_int	int		Cast word element 0 of qword *a* to int *d*.
si_to_uint	unsigned int		Cast word element 0 of qword *a* to unsigned int *d*.
si_to_ptr	void *		Cast word element 0 of qword *a* to a void pointer *d*.
si_to_llong	long long		Cast doubleword element 0 of qword *a* to long long *d*.
si_to_ullong	unsigned long long		Cast doubleword element 0 of qword *a* to unsigned long long *d*.
si_to_float	float		Cast word element 0 of qword *a* to float *d*.
si_to_double	double		Cast doubleword element 0 of qword *a* to double *d*.
si_from_char	qword	signed char	Cast signed char *a* to byte element 3 of qword *d*.
si_from_uchar		unsigned char	Cast unsigned char *a* to byte element 3 of qword *d*.
si_from_short		short	Cast short *a* to halfword element 1 of qword *d*.
si_from_ushort		unsigned short	Cast unsigned short *a* to halfword element 1 of qword *d*.
si_from_int		int	Cast int *a* to word element 0 of qword *d*.
si_from_uint		unsigned int	Cast unsigned int *a* to word element 0 of qword *d*.
si_from_ptr		void *	Cast void pointer *a* to word element 0 of qword *d*.
si_from_llong		long long	Cast long long *a* to doubleword element 0 of qword *d*.
si_from_ullong		unsigned long long	Cast unsigned long long *a* to doubleword element 0 of
si_from_float		float	Cast float *a* to word element 0 of qword *d*.
si_from_double		double	Cast double *a* to doubleword element 0 of qword *d*.

Because the casting intrinsics do not perform data conversion, casting from a scalar type to a `qword` type results in portions of the quadword being undefined.

2.2. Generic Intrinsics and Built-ins

Generic intrinsics are operations that map to one or more specific intrinsics. The mapping of a generic intrinsic to a specific intrinsic depends on the input arguments to the intrinsic. Built-ins are similar to generic intrinsics; however, unlike generic intrinsics, built-ins map to more than one SPU instruction. All generic intrinsics and built-ins are prefixed by the string `spu_`. For example, the generic intrinsic that implements the `stop` assembly instruction is named `spu_stop`.

2.2.1. Mapping Intrinsics with Scalar Operands

Intrinsics with scalar arguments are introduced for SPU instructions with immediate fields. For example, the intrinsic function `vector signed int spu_add(vector signed int, int)` will translate to an `AI` assembly instruction.

Depending on the assembly instruction, immediate values are either 7, 10, 16, or 18 bits in length. The action performed for out-of-range immediate values depends on the type of intrinsic. By default, immediate-form specific intrinsics with an out-of-range immediate value are flagged as an error. Compilers may provide an option to issue a warning for out-of-range immediate values and use only the specified number of least significant bits for the out-of-range argument.

Generic intrinsics support a full range of scalar operands. This support is not dependent on whether the scalar operand can be represented within the instruction's immediate field. Consider the following example:

```
d = spu_and (vector unsigned int a, int b);
```

Depending on argument *b*, different instructions are generated:

- If *b* is a literal constant within the range supported by one of the immediate forms, the immediate instruction form is generated. For example, if *b* equals 1, then `ANDI d, a, 1` is generated.
- If *b* is a literal constant and is out-of-range but can be folded and implemented using an alternate immediate instruction form, the alternate immediate instruction is generated. For example, if *b* equals `0x30003`, then `ANDHI d, a, 3` is generated. In this context, "alternate immediate instruction form" means an immediate instruction form having a smaller data element size.
- If *b* is a literal constant that can be constructed using one or two immediate load instructions followed by the non-immediate form of the instruction, the appropriate instructions will be used. Immediate load instructions include `IL`, `ILH`, `ILHU`, `ILA`, `IOHL`, and `FSMBI`. Table 2-12 shows possible uses of the immediate load instructions for various constants *b*.

Table 2-12: Possible Uses of Immediate Load Instructions for Various Values of Constant b

Constant *b*	Generates Instructions
-6000	IL b, -6000 AND d, a, b
131074 (0x20002)	ILH b, 2 AND d, a, b
131072 (0x20000)	ILHU b, 2 AND d, a, b
134000 (0x20B70)	ILA b, 134000 AND d, a, b
262780 (0x4027C)	ILHU b, 4 IOHL b, 636 AND d, a, b
(0xFFFFFFFF, 0x0, 0x0, 0xFFFFFFFF)	FSMBI b, 0xF00F AND d, a, b

- If *b* is a variable (non-literal) integer, code to splat the integer across the entire vector is generated followed by the non-immediate form of the instruction. For example, if *b* is an integer of unknown value, the constant area is loaded with the shuffle pattern (`0x10203`, `0x10203`, `0x10203`, `0x10203`) at "`CONST_AREA, offset`" and the following instructions are generated:

```
LQD    pattern, CONST_AREA, offset
SHUFB  b, b, b, pattern
AND    d, a, b
```

2.2.2. Implicit Conversion of Arguments of Intrinsics

There is no implicit conversion of arguments that have a vector type. Arguments of scalar type are converted according to the rules specified in the C/C++ standards. Consider, for example,

```
d = spu_insert(a, b, element);
```

Scalar *a* is inserted into the element of vector *b* that is specified by the *`element`* parameter. When *b* is a `vector double`, *a* must be converted to `double`, *`element`* must be converted to `int`, and *d* must be a `vector double`.

2.2.3. Notations and Conventions

The remaining documentation describing the generic intrinsics uses the following rules and naming conventions:

- The table associated with each generic intrinsic specifies the supported input types.

- For intrinsics with scalar operands, only the immediate form of the instruction is shown. The other forms can be deduced in accordance with the rules discussed in section "2.2.1. Mapping Intrinsics with Scalar Operands".
- Some intrinsics, whether specific or generic, map to assembly instructions that do not uniquely specify all input and output registers. Instead, an input register also serves as the output register. Examples of these assembly instructions include `ADDX`, `DFMS`, `MPYHHA`, and `SFX`. For these intrinsics, the notation `rt <--- c` is used to imply that a register-to-register copy (copy *c* to *rt*) might be required to satisfy the semantics of the intrinsic, depending on the inputs and outputs. No copies will be generated if input *c* is the same as output *d*.
- Generic intrinsics that do not map to specific intrinsics are identified by the acronym "N/A" (not applicable) in the Specific Intrinsics column of the respective table.

2.3. Constant Formation Intrinsics

spu_splats: Splat Scalar to a Vector

```
d = spu_splats(a)
```

A single scalar value is replicated across all elements of a vector of the same type. The result is returned in vector *d*.

Table 2-13: Splat Scalar to a Vector

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned char	unsigned char	N/A	SHUFB d, a, a, pattern
vector signed char	signed char		
vector unsigned short	unsigned short		
vector signed short	signed short		
vector unsigned int	unsigned int		
vector signed int	signed int		
vector unsigned long long	unsigned long long		
vector signed long long	signed long long		
vector float	float		
vector double	double		
vector unsigned char	unsigned char (literal)	N/A	IL d, a *or* ILA d, a *or* ILH d, a&0xFFFF *or* ILHU d, a>>16 *or* ILHU d, a>>16; IOHL d, a *or* FSMBI d, a
vector signed char	signed char (literal)		
vector unsigned short	unsigned short (literal)		
vector signed short	signed short (literal)		
vector unsigned int	unsigned int (literal)		
vector signed int	signed int (literal)		
vector unsigned long long	unsigned long long (literal)		
vector signed long long	signed long long (literal)		
vector float	float (literal)		
vector double	double (literal)		

2.4. Conversion Intrinsics

spu_convtf: Convert Vector to Float

```
d = spu_convtf(a, scale)
```

Each element of vector *a* is converted to a floating-point value and divided by 2^{scale}. The allowable range for *scale* is 0 to 127. Values outside this range are flagged as an error and compilation is terminated. The result is returned in vector *d*.

Table 2-14: Convert an Integer Vector to a Vector Float

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	scale		
vector float	vector unsigned int	unsigned int (7-bit literal)	*d* = si_cuflt(*a*, *scale*)	CUFLT d, a, scale
vector float	vector signed int		*d* = si_csflt(*a*, *scale*)	CSFLT d, a, scale

spu_convts: Convert Floating-Point Vector to Signed Integer Vector

```
d = spu_convts(a, scale)
```

Each element of vector *a* is scaled by 2^{scale}, and the result is converted to a signed integer. If the intermediate result is greater than 2^{31}-1, the result saturates to 2^{31}-1. If the intermediate value is less than -2^{31}, the result saturates to -2^{31}. The allowable range for *scale* is 0 to 127. Values outside this range are flagged as an error and compilation is terminated. The results are returned in the corresponding elements of vector *d*.

Table 2-15: Convert a Vector Float to a Signed Integer Vector

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	scale		
vector signed int	vector float	unsigned int (7-bit literal)	*d* = si_cflts(*a*, *scale*)	CFLTS d, a, scale

spu_convtu: Convert Floating-Point Vector to Unsigned Integer Vector

```
d = spu_convtu(a, scale)
```

Each element of vector *a* is scaled by 2^{scale} and the result is converted to an unsigned integer. If the intermediate result is greater than 2^{32}-1, the result saturates to 2^{32}-1. If the intermediate value is negative, the result saturates to zero. The allowable range for *scale* is 0 to 127. Values outside this range are flagged as an error and compilation is terminated. The results are returned in the corresponding elements of vector *d*.

Table 2-16: Convert a Vector Float to an Unsigned Integer Vector

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	scale		
vector unsigned int	vector float	unsigned int (7-bit	*d* = si_cfltu(*a*, *scale*)	CFLTU d, a, scale

spu_extend: Sign Extend Vector

```
d = spu_extend(a)
```

For a fixed-point vector *a*, each odd element of vector *a* is sign-extended and returned in the corresponding element of vector *d*. For a floating-point vector, each even element of *a* is sign-extended and returned in the corresponding element of *d*.

Table 2-17: Sign Extend Vector

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector signed short	vector signed char	*d* = si_xsbh(*a*)	XSBH d, a
vector signed int	vector signed short	*d* = si_xshw(*a*)	XSHW d, a
vector signed long long	vector signed int	*d* = si_xswd(*a*)	XSWD d, a
vector double	vector float	*d* = si_fesd(*a*)	FESD d, a

spu_roundtf: Round Vector Double to Vector Float

```
d = spu_roundtf(a)
```

Each doubleword element of vector *a* is rounded to a single-precision floating-point value and placed in the even element of vector d. Zeros are placed in the odd elements of *d*.

Table 2-18: Round a Vector Double to a Float

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector float	vector double	*d* = si_frds(*a*)	FRDS d, a

2.5. Arithmetic Intrinsics

spu_add: Vector Add

```
d = spu_add(a, b)
```

Each element of vector *a* is added to the corresponding element of vector *b*. If *b* is a scalar, the scalar value is replicated for each element and then added to *a*. Overflows and carries are not detected, and no saturation is performed. The results are returned in the corresponding elements of vector *d*.

Table 2-19: Vector Add

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed int	vector signed int	*d* = si_a(*a*, *b*)	A d, a, b
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed short	vector signed short	vector signed short	*d* = si_ah(*a*, *b*)	AH d, a, b
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed int	vector signed int	10-bit signed int (literal)	*d* = si_ai(*a*, *b*)	AI d, a, b
vector unsigned int	vector unsigned int			
vector signed int	vector signed int	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned int	vector unsigned int	unsigned int		
vector signed short	vector signed short	10-bit signed short (literal)	*d* = si_ahi(*a*, *b*)	AHI d, a, b
vector unsigned short	vector unsigned short			
vector signed short	vector signed short	short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned short	vector unsigned short	unsigned short		

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector float	vector float	vector float	*d* = si_fa(*a*, *b*)	FA d, a, b
vector double	vector double	vector double	*d* = si_dfa(*a*, *b*)	DFA d, a, b

spu_addx: Vector Add Extended

```
d = spu_addx(a, b, c)
```

Each element of vector *a* is added to the corresponding element of vector *b* and to the least significant bit of the corresponding element of vector *c*. The result is returned in the corresponding element of vector *d*.

Table 2-20: Vector Add Extended

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector signed int	vector signed int	vector signed int	vector signed int	*d* = si_addx(*a*, *b*, *c*)	rt <--- c ADDX rt, a, b d <--- rt
vector unsigned int	vector unsigned int	vector unsigned int	vector unsigned int		

spu_genb: Vector Generate Borrow

```
d = spu_genb(a, b)
```

Each element of vector *b* is subtracted from the corresponding element of vector *a*. The resulting borrow out is placed in the least significant bit of the corresponding element of vector *d*. The remaining bits of d are set to 0.

Table 2-21: Vector Generate Borrow

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed int	vector signed int	*d* = si_bg(*b*, *a*)	BG rt, b, a
vector unsigned int	vector unsigned int	vector unsigned int		

spu_genbx: Vector Generate Borrow Extended

```
d = spu_genbx(a, b, c)
```

Each element of vector *b* is subtracted from the corresponding element of vector *b*. An additional 1 is subtracted from the result if the least significant bit of the corresponding element of vector *c* is 0. If the result is less than 0, a 1 is placed in the corresponding element of vector d; otherwise, a 0 is placed in the corresponding element of *d*.

Table 2-22: Vector Generate Borrow Extended

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector signed int	vector signed int	vector signed int	vector signed int	*d* = si_bgx(*b*, *a*, *c*)	rt <--- c BGX rt, b, a d <--- rt
vector unsigned int	vector unsigned int	vector unsigned int	vector unsigned int		

spu_genc: Vector Generate Carry

```
d = spu_genc(a, b)
```

Each element of vector *a* is added to the corresponding element of vector *b*. The resulting carry out is placed in the least significant bit of the corresponding element of vector *d*. The remaining bits of *d* are set to 0.

Table 2-23: Vector Generate Carry

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed int	vector signed int	*d* = si_cg(*a*, *b*)	CG rt, a, b
vector unsigned int	vector unsigned int	vector unsigned int		

spu_gencx: Vector Generate Carry Extended

```
d = spu_gencx(a, b, c)
```

Each element of vector *a* is added to the corresponding element of vector *b* and the least significant bit of the corresponding element of vector *c*. The resulting carry out is placed in the least significant bit of the corresponding element of vector *d*. The remaining bits of *d* are set to 0.

Table 2-24: Vector Generate Carry Extended

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector signed int	vector signed int	vector signed int	vector signed int	*d* = si_cgx(*a*, *b*, *c*)	rt <--- c CGX rt, a, b d <--- rt
vector unsigned int	vector unsigned int	vector unsigned int	vector unsigned int		

spu_madd: Vector Multiply and Add

```
d = spu_madd(a, b, c)
```

Each element of vector *a* is multiplied by vector *b* and added to the corresponding element of vector *c*. The result is returned to the corresponding element of vector *d*. For integer multiply-and-adds, the odd elements of vectors *a* and *b* are sign-extended to 32-bit integers prior to multiplication.

Table 2-25: Vector Multiply and Add

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector signed int	vector signed short	vector signed short	vector signed int	*d* = si_mpya(*a*, *b*, *c*)	MPYA d, a, b, c
vector float	vector float	vector float	vector float	*d* = si_fma(*a*, *b*, *c*)	FMA d, a, b, c
vector double	vector double	vector double	vector double	*d* = si_dfma(*a*, *b*, *c*)	rt <--- c DFMA rt, a, b d <--- rt

spu_mhhadd: Vector Multiply High High and Add

```
d = spu_mhhadd(a, b, c)
```

Each even element of vector *a* is multiplied by the corresponding even element of vector *b*, the 32-bit result is added to the corresponding element of vector *c*, and the result is returned in the corresponding element of vector *d*.

Table 2-26: Vector Multiply High High and Add

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector signed int	vector signed short	vector signed short	vector signed int	*d* = si_mpyhha(*a*, *b*, *c*)	rt <--- c MPYHHA rt, a, b d <--- rt
vector unsigned int	vector unsigned short	vector unsigned short	vector unsigned int	*d* = si_mpyhhau(*a*, *b*, *c*)	rt <--- c MPYHHAU rt, a, b d <--- rt

spu_msub: Vector Multiply and Subtract

```
d = spu_msub(a, b, c)
```

Each element of vector *a* is multiplied by the corresponding element of vector *b*, and the corresponding element of vector *c* is subtracted from the product. The result is returned in the corresponding element of vector *d*.

Table 2-27: Vector Multiply and Subtract

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector float	vector float	vector float	vector float	*d* = si_fms(*a*, *b*, *c*)	FMS d, a, b, c
vector double	vector double	vector double	vector double	*d* = si_dfms(*a*, *b*, *c*)	rt <--- c DFMS rt, a, b d <--- rt

spu_mul: Vector Multiply

```
d = spu_mul(a, b)
```

Each element of vector *a* is multiplied by the corresponding element of vector *b* and returned in the corresponding element of vector *d*.

Table 2-28: Vector Multiply

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector float	vector float	vector float	*d* = si_fm(*a*, *b*)	FM d, a, b
vector double	vector double	vector double	*d* = si_dfm(*a*, *b*)	DFM d, a, b

spu_mulh: Vector Multiply High

```
d = spu_mulh(a, b)
```

Each even element of vector *a* is multiplied by the next (odd) element of vector *b*. The product is shifted left by 16 bits and stored in the corresponding element of vector *d*. Bits shifted out at the left are discarded. Zeros are shifted in at the right.

Table 2-29: Vector Multiply High

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed short	vector signed short	*d* = si_mpyh(*a*, *b*)	MPYH d, a, b

spu_mule: Vector Multiply Even

```
d = spu_mule(a, b)
```

Each even element of vector *a* is multiplied by the corresponding even element of vector *b*, and the 32-bit result is returned to the corresponding element of vector *d*.

Table 2-30: Vector Multiply Even

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed short	vector signed short	*d* = si_mpyhh(*a*, *b*)	MPYHH d, a, b
vector unsigned int	vector unsigned short	vector unsigned short	*d* = si_mpyhhu(*a*,	MPYHHU d, a, b

spu_mulo: Vector Multiply Odd

```
d = spu_mulo(a, b)
```

Each odd element of vector *a* is multiplied by the corresponding element of vector *b*. If *b* is a scalar, the scalar value is replicated for each element and then multiplied by *a*. The results are returned in vector *d*.

Table 2-31: Vector Multiply Odd

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed short	vector signed short	*d* = si_mpy (*a*, *b*)	MPY d, a, b
		10-bit signed short (literal)	*d* = si_mpyi(*a*, *b*)	MPYI d, a, b
		signed short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned int	vector unsigned short	vector unsigned short	*d* = si_mpyu(*a*, *b*)	MPYU d, a, b
		10-bit signed short (literal)	*d* = si_mpyui(*a*, *b*)	MPYUI d, a, b
		unsigned short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	

spu_mulsr: Vector Multiply and Shift Right

```
d = spu_mulsr(a, b)
```

Each odd element of vector *a* is multiplied by the corresponding odd element of vector *b*. The leftmost 16 bits of the resulting 32-bit product is sign-extended and returned in the corresponding 32-bit element of vector *d*.

Table 2-32: Vector Multiply and Shift Right

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	vector signed short	vector signed short	*d* = si_mpys(*a*, *b*)	MPYS d, a, b

spu_nmadd: Negative Vector Multiply and Add

```
d = spu_nmadd(a, b, c)
```

Each element of vector *a* is multiplied by the corresponding element in vector *b* and then added to the corresponding element of vector *c*. The result is negated and returned in the corresponding element of vector *d*.

Table 2-33: Negative Vector Multiply and Add

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector double	vector double	vector double	vector double	*d* = si_dfnma(*a*, *b*, *c*)	rt <-- c DFNMA rt, a, b d <-- rt

spu_nmsub: Negative Vector Multiply and Subtract

```
d = spu_nmsub(a, b, c)
```

Each element of vector *a* is multiplied by the corresponding element in vector *b*. The result is subtracted from the corresponding element in *c* and returned in the corresponding element of vector *d*.

Table 2-34: Negative Vector Multiply and Subtract

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector float	vector float	vector float	vector float	*d* = si_fnms(*a*, *b*, *c*)	FNMS d, a, b, c
vector double	vector double	vector double	vector double	*d* = si_dfnms(*a*, *b*, *c*)	rt <--- c DFNMS rt, a, b d <--- rt

spu_re: Vector Floating-Point Reciprocal Estimate

```
d = spu_re(a)
```

For each element of vector *a*, an estimate of its floating-point reciprocal is computed, and the result is returned in the corresponding element of vector *d*. The resulting estimate is accurate to 12 bits.

Table 2-35: Vector Floating-Point Reciprocal Estimate

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector float	vector float	t = si_frest(*a*) *d* = si_fi(*a*, *t*)	FREST d, a FI d, a, d

spu_rsqrte: Vector Floating-Point Reciprocal Square Root Estimate

```
d = spu_rsqrte(a)
```

For each element of vector *a*, an estimate of its floating-point reciprocal square root is computed, and the result is returned in the corresponding element of vector *d*. The resulting estimate is accurate to 12 bits.

Table 2-36: Vector Floating-Point Reciprocal Square Root Estimate

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector float	vector float	t = si_frsqest(*a*) *d* = si_fi(*a*, *t*)	FRSQEST d, a FI d, a, d

spu_sub: Vector Subtract

```
d = spu_sub(a, b)
```

Each element of vector *b* is subtracted from the corresponding element of vector *a*. If *a* is a scalar, the scalar value is replicated for each element of *a*, and then *b* is subtracted from the corresponding element of *a*. Overflows and carries are not detected. The results are returned in the corresponding elements of vector *d*.

Table 2-37: Vector Subtract

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed short	vector signed short	vector signed short	*d* = si_sfh(b, a)	SFH d, b, a
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed int	vector signed int	vector signed int	*d* = si_sf(b, a)	SF d, b, a
vector unsigned int	vector unsigned int	vector unsigned int		

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed int	10-bit signed int (literal)	vector signed int	*d* = si_sfi(b, a)	SFI d, b, a
vector unsigned int		vector unsigned int		
vector signed int	int	vector signed int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned int	unsigned int	vector unsigned int		
vector signed short	10-bit signed short (literal)	vector signed short	*d* = si_sfhi(b, a)	SFHI d, b, a
vector unsigned short		vector unsigned short		
vector signed short	short	vector signed short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned short	unsigned short	vector unsigned short		
vector float	vector float	vector float	*d* = si_fs(a, b)	FS d, a, b
vector double	vector double	vector double	*d* = si_dfs(a, b)	DFS d, a, b

spu_subx: Vector Subtract Extended

```
d = spu_subx(a, b, c)
```

Each element of vector *b* is subtracted from the corresponding element of vector *a*. An additional 1 is subtracted from the result if the least significant bit of the corresponding element of vector *c* is 0. The final result is returned in the corresponding element of vector *d*.

Table 2-38: Vector Subtract Extended

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	c		
vector signed int	vector signed int	vector signed int	vector signed int	*d* = si_sfx(*b*,*a*, *c*)	rt <--- c SFX rt, b, a d <--- rt
vector unsigned int	vector unsigned int	vector unsigned int	vector unsigned int		

2.6. Byte Operation Intrinsics

spu_absd: Element-Wise Absolute Difference

```
d = spu_absd(a, b)
```

Each element of vector *a* is subtracted from the corresponding element of vector *b*, and the absolute value of the result is returned in the corresponding element of vector *d*.

Table 2-39: Element-Wise Absolute Difference

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_absdb(*a*, *b*)	ABSDB d, a, b

spu_avg: Average of Two Vectors

```
d = spu_avg(a, b)
```

Each element of vector *a* is added to the corresponding element of vector *b* plus 1. The result is shifted to the right by 1 bit and placed in the corresponding element of vector *d*.

Table 2-40: Average of Two Vectors

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_avgb(*a*, *b*)	AVGB d, a, b

spu_sumb: Sum Bytes into Shorts

```
d = spu_sumb(a, b)
```

Each four elements of *b* are summed and returned in the corresponding even elements of vector *d*. Each four elements of *a* are summed and returned in the corresponding odd elements of *d*.

Table 2-41: Sum Bytes into Shorts

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned short	vector unsigned char	vector unsigned char	*d* = si_sumb(*a*, *b*)	SUMB d, a, b

2.7. Compare, Branch and Halt Intrinsics

spu_bisled: Branch Indirect and Set Link if External Data

```
(void) spu_bisled(func)
(void) spu_bisled_d(func)
(void) spu_bisled_e(func)
```

The count value of channel 0 (event status) is examined. If it is zero, execution continues with the next sequential instruction. If it is nonzero, the function *func* is called. The parameter *func* is the name of, or pointer to, a parameter-less function with no return value. If *func* is called, the `spu_bisled_d` and `spu_bisled_e` forms of the intrinsic do one of the following actions:

- Disable interrupts – use `spu_bisled_d`
- Enable interrupts – use `spu_bisled_e`

Because the bisled instruction is assumed to behave as a synchronous software interrupt, and because all volatile registers must be considered non-volatile by the bisled target function, `func`, standard calling conventions are not observed. See the *SPU Application Binary Interface Specification* for additional details about standard calling conventions.

With respect to branch prediction, it is assumed that `func` is not called. Therefore, a branch hint instruction will not be inserted as a result of the `spu_bisled()` intrinsic.

Table 2-42: Branch Indirect and Set Link if External Data

Generic Intrinsic Form	func	Specific Intrinsics	Assembly Mapping
spu_bisled	void (*func) ()	si_bisled(*func*)	BISLED $LR, func
spu_bisled_d		si_bisledd(*func*)	BISLEDD $LR, func
spu_bisled_e		si_bislede(*func*)	BISLEDE $LR, func

spu_cmpabseq: Element-Wise Compare Absolute Equal

```
d = spu_cmpabseq(a, b)
```

The absolute value of each element of vector *a* is compared with the absolute value of the corresponding element of vector *b*. If the absolute values are equal, all bits of the corresponding element of vector *d* are set to one; otherwise, all bits of the corresponding element of *d* are set to zero.

Table 2-43: Element-Wise Compare Absolute Equal

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned int	vector float	vector float	*d* = si_fcmeq(*a*, *b*)	FCMEQ d, a, b
vector unsigned long long	vector double	vector double	*d* = si_dfcmeq(*a*, *b*)	DFCMEQ d, a, b †

spu_cmpabsgt: Element-Wise Compare Absolute Greater Than

```
d = spu_cmpabsgt(a, b)
```

The absolute value of each element of vector *a* is compared with the absolute value of the corresponding element of vector *b*. If the element of *a* is greater than the element of *b*, all bits of the corresponding element of vector *d* are set to one; otherwise, all bits of the corresponding element of *d* are set to zero.

Table 2-44: Element-Wise Compare Absolute Greater Than

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned int	vector float	vector float	*d* = si_fcmgt(*a*, *b*)	FCMGT d, a, b
vector unsigned long long	vector double	vector double	*d* = si_dfcmgt(*a*, *b*)	DFCMGT d, a, b †

spu_cmpeq: Element-Wise Compare Equal

```
d = spu_cmpeq(a, b)
```

Each element of vector *a* is compared with the corresponding element of vector *b*. If *b* is a scalar, the scalar value is first replicated for each element, and then *a* and *b* are compared. If the operands are equal, all bits of the corresponding element of vector *d* are set to one. If they are unequal, all bits of the corresponding element of *d* are set to zero.

Table 2-45: Element-Wise Compare Equal

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector signed char	vector signed char	*d* = si_ceqb(*a*, *b*)	CEQb d, a, b
	vector unsigned char	vector unsigned char		
vector unsigned short	vector signed short	vector signed short	*d* = si_ceqh(*a*, *b*)	CEQH d, a, b
	vector unsigned short	vector unsigned short		
vector unsigned int	vector signed int	vector signed int	*d* = si_ceq(*a*, *b*)	CEQ d, a, b
	vector unsigned int	vector unsigned int		
	vector float	vector float	*d* = si_fceq(*a*, *b*)	FCEQ d, a, b
vector unsigned char	vector signed char	10-bit signed int (literal)	*d* = si_ceqbi(*a*, *b*)	CEQBI d, a, b
	vector unsigned char			
	vector signed char	signed char	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector unsigned char	unsigned char		
vector unsigned short	vector signed short	10-bit signed int (literal)	*d* = si_ceqhi(*a*, *b*)	CEQHI d, a, b
	vector unsigned short			
	vector signed short	signed short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector unsigned short	unsigned short		
vector unsigned int	vector signed int	10-bit signed int (literal)	*d* = si_ceqi(*a*, *b*)	CEQI d, a, b
	vector unsigned int			
	vector signed int	signed int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector unsigned int	unsigned int		
vector unsigned long long	vector double	vector double	*d* = si_dfceq(*a*, *b*)	DFCEQ d, a, b †

spu_cmpgt: Element-Wise Compare Greater Than

```
d = spu_cmpgt(a, b)
```

Each element of vector *a* is compared with the corresponding element of vector *b*. If *b* is a scalar, the scalar value is replicated for each element and then *a* and *b* are compared. If the element of *a* is greater than the corresponding element of *b*, all bits of the corresponding element of vector *d* are set to one; otherwise, all bits of the corresponding element of *d* are set to zero.

Table 2-46: Element-Wise Compare Greater Than

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector signed char	vector signed char	*d* = si_cgtb(*a*, *b*)	CGTB d, a, b
		10-bit signed int (literal)	*d* = si_cgtbi(*a*, *b*)	CGTBI d, a, b
		signed char	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector unsigned char	vector unsigned char	*d* = si_clgtb(*a*, *b*)	CLGTB d, a, b
		10-bit signed int (literal)	*d* = si_clgtbi(*a*, *b*)	CLGTBI d, a, b
		unsigned char	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned short	vector signed short	vector signed short	*d* = si_cgth(*a*, *b*)	CGTH d, a, b
		10-bit signed int (literal)	*d* = si_cgthi(*a*, *b*)	CGTHI d, a, b
		signed short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector unsigned short	vector unsigned short	*d* = si_clgth(*a*, *b*)	CLGTH d, a, b
		10-bit signed int (literal)	*d* = si_clgthi(*a*, *b*)	CLGTHI d, a, b
		unsigned short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector unsigned int	vector signed int	vector signed int	*d* = si_cgt(*a*, *b*)	CGT d, a, b
		10-bit signed int (literal)	*d* = si_cgti(*a*, *b*)	CGTI d, a, b
		signed int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector unsigned int	vector unsigned int	*d* = si_clgt(*a*, *b*)	CLGT d, a, b
		10-bit signed int (literal)	*d* = si_clgti(*a*, *b*)	CLGTI d, a, b
		unsigned int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
	vector float	vector float	*d* = si_fcgt(*a*, *b*)	FCGT d, a, b
vector unsigned long long	vector double	vector double	*d* = si_dfcgt(*a*, *b*)	DFCGT d, a, b †

spu_hcmpeq: Halt If Compare Equal

```
(void) spu_hcmpeq(a, b)
```

The contents of *a* and *b* are compared. If they are equal, execution is halted.

Table 2-47: Halt If Compare Equal

Return/Argument Types		Specific Intrinsics	Assembly Mapping[1,2]
a	b		
int	int (non-literal)	si_heq(*a*, *b*)	HEQ rt, a, b
unsigned int	unsigned int (non-literal)		
int	10-bit signed int (literal)	si_heqi(*a*, *b*)	HEQI rt, a, b
unsigned int			

[1] Immediate values that cannot be represented as a 10-bit signed value are constructed similar to the method described in section "2.2.1. Mapping Intrinsics with Scalar Operands".

[2] The false target parameter `rt` is optimally chosen depending on the register usage of neighboring instructions.

spu_hcmpgt: Halt If Compare Greater Than

```
(void) spu_hcmpgt(a, b)
```

The contents of *a* and *b* are compared. If *a* is greater than *b*, execution is halted.

Table 2-48: Halt If Compare Greater Than

Return/Argument Types		Specific Intrinsics	Assembly Mapping[1,2]
a	b		
int	int (non-literal)	si_hgt(*a*, *b*)	HGT rt, a, b
unsigned int	unsigned int (non-literal)	si_hlgt(*a*, *b*)	HLGT rt, a, b
int	10-bit signed int (literal)	si_hgti(*a*, *b*)	HGTI rt, a, b
unsigned int	10-bit signed int (literal)	si_hlgti(*a*, *b*)	HLGTI rt, a, b

[1] Immediate values that cannot be represented as 10-bit signed values are constructed in a way similar to the method described in section "2.2.1. Mapping Intrinsics with Scalar Operands".

[2] The false target parameter `rt` is optimally chosen depending on the register usage of neighboring instructions.

spu_testsv: Element-Wise Test Special Value

```
d = spu_testsv(a, values)
```

Each element of vector *a* is compared with the set of special values specified by `values`. If any one of the specified comparisons is true all ones are placed in the corresponding element of vector *d*. If none of the tests are true, zeros are placed in the corresponding element of vector *d*.

Table 2-49: Element-Wise Test Special Value

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	values		
vector unsigned long long	vector double	7-bit unsigned int (literal)	*d* = si_dftsv(*a*, `values`)	DFTSV d, a, values †

The set of bit flag mnemonics that can be used to specify a set of special values to be tested is shown in Table 2-50. These mnemonics are defined in spu_intrinsics.h.

Table 2-50: Special Value Bit Flag Mnemonics

Mnemonic	Value	Description

Mnemonic	Value	Description
SPU_SV_NEG_DENORM	0x01	Test for a negative denormalized number
SPU_SV_POS_DENORM	0x02	Test for a positive denormalized number
SPU_SV_NEG_ZERO	0x04	Test for a negative zero
SPU_SV_POS_ZERO	0x08	Test for a positive zero
SPU_SV_NEG_INFINITY	0x10	Test for a negative infinity
SPU_SV_POS_INFINITY	0x20	Test for a positive infinity
SPU_SV_NAN	0x40	Test for a Not a Number, both signalling and quiet

2.8. Bits and Mask Intrinsics

spu_cntb: Vector Count Ones for Bytes

```
d = spu_cntb(a)
```

For each element of vector *a*, the number of ones are counted, and the count is placed in the corresponding element of vector *d*.

Table 2-51: Vector Count Ones for Bytes

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned char	vector unsigned char	si_cntb	CNTB d, a
	vector signed char		

spu_cntlz: Vector Count Leading Zeros

```
d = spu_cntlz(a)
```

For each element of vector *a*, the number of leading zeros is counted, and the resulting count is placed in the corresponding element of vector *d*.

Table 2-52: Vector Count Leading Zeros

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned int	vector signed int	*d* = si_clz(*a*)	CLZ d, a
	vector unsigned int		
	vector float		

spu_gather: Gather Bits from Elements

```
d = spu_gather(a)
```

The rightmost bit (LSB) of each element of vector *a* is gathered, concatenated, and returned in the rightmost bits of element 0 of vector *d*. For a byte vector, 16 bits are gathered; for a halfword vector, 8 bits are gathered; and for a word vector, 4 bits are gathered. The remaining bits of element 0 of *d* and all other elements of that vector are zeroed.

Table 2-53: Gather Bits from Elements

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned int	vector unsigned char	*d* = si_gbb(*a*)	GBB d, a
	vector signed char		
	vector unsigned short	*d* = si_gbh(*a*)	GBH d, a
	vector signed short		
	vector unsigned int	*d* = si_gb(*a*)	GB d, a
	vector signed int		
	vector float		

spu_maskb: Form Select Byte Mask

```
d = spu_maskb(a)
```

For each of the least significant 16 bits of *a*, each bit is replicated 8 times, producing a 128-bit vector mask that is returned in vector *d*.

Table 2-54: Form Select Byte Mask

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned char	unsigned short	*d* = si_fsmb(*a*)	FSMB d, a
	signed short		
	unsigned int		
	signed int		
	16-bit unsigned int (literal)	*d* = si_fsmbi(*a*)	FSMBI d, a

spu_maskh: Form Select Halfword Mask

```
d = spu_maskh(a)
```

For each of the least significant 8 bits of *a*, each bit is replicated 16 times, producing a 128-bit vector mask that is returned in vector *d*.

Table 2-55: Form Select Halfword Mask

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned short	unsigned char	*d* = si_fsmh(*a*)	FSMH d, a
	signed char		
	unsigned short		
	signed short		
	unsigned int		
	signed int		

spu_maskw: Form Select Word Mask

```
d = spu_maskw(a)
```

For each of the least significant 4 bits of *a*, each bit is replicated 32 times, producing a 128-bit vector mask that is returned in vector *d*.

Table 2-56: Form Select Word Mask

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned int	unsigned char	*d* = si_fsm(*a*)	FSM d, a
	signed char		
	unsigned short		
	signed short		
	unsigned int		
	signed int		

spu_sel: Select Bits

```
d = spu_sel(a, b, pattern)
```

For each bit in the 128-bit vector *pattern*, the corresponding bit from either vector *a* or vector *b* is selected. If the bit is 0, the bit from *a* is selected; otherwise, the bit from *b* is selected. The result is returned in vector *d*.

Table 2-57: Select Bits

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	pattern		
vector unsigned char	vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_selb(*a*, *b*, *pattern*)	SELB d, a, b, pattern
vector signed char	vector signed char	vector signed char			
vector unsigned short	vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short			
vector unsigned int	vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int			
vector float	vector float	vector float			
vector unsigned long long	vector unsigned long long	vector unsigned long long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long			
vector double	vector double	vector double			

spu_shuffle: Shuffle Two Vectors of Bytes

```
d = spu_shuffle(a, b, pattern)
```

For each byte of *pattern*, the byte is examined, and a byte is produced, as shown in Figure 2-2. The result is returned in the corresponding byte of vector *d*.

Figure 2-2: Shuffle Pattern

Value in the Byte of Pattern (in binary)	Resulting Byte
10xxxxxx	0x00
110xxxxx	0xFF
111xxxxx	0x80
otherwise	the byte of (a | | b) addressed by the rightmost 5 bits of pattern

Table 2-58: Shuffle Two Vectors of Bytes

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	pattern		
vector unsigned char	vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_shufb(*a*, *b*, *pattern*)	SHUFB d, a, b, pattern
vector signed char	vector signed char	vector signed char			
vector unsigned short	vector unsigned short	vector unsigned short			
vector signed short	vector signed short	vector signed short			
vector unsigned int	vector unsigned int	vector unsigned int			
vector signed int	vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long	vector signed long long			
vector float	vector float	vector float			
vector double	vector double	vector double			

2.9. Logical Intrinsics

spu_and: Vector Bit-Wise AND

```
d = spu_and(a, b)
```

Each bit of vector *a* is logically ANDed with the corresponding bit of vector *b*. If *b* is a scalar, the scalar value is first replicated for each element, and then *a* and *b* are ANDed. The results are returned in the corresponding bit of vector *d*.

Table 2-59: Vector Bit-Wise AND

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_and(*a*, *b*)	AND d, a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		
vector double	vector double	vector double		
vector unsigned char	vector unsigned char	10-bit signed int (literal)	*d* = si_andbi(*a*, *b*)	ANDBI d, a, b
vector signed char	vector signed char			
vector unsigned char	vector unsigned char	unsigned char	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed char	vector signed char	signed char		
vector unsigned short	vector unsigned short	10-bit signed int	*d* = si_andhi(*a*,	ANDHI d, a, b

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector signed short	vector signed short	(literal)	*b*)	
vector unsigned short	vector unsigned short	unsigned short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short	signed short		
vector unsigned int	vector unsigned int	10-bit signed int (literal)	*d* = si_andi(*a*, *b*)	ANDI d, a, b
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	unsigned int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int	signed int		

spu_andc: Vector Bit-Wise AND with Complement

```
d = spu_andc(a, b)
```

Each bit of vector *a* is ANDed with the complement of the corresponding bit of vector *b*. The result is returned in the corresponding bit of vector *d*.

Table 2-60: Vector Bit-Wise AND with Complement

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_andc(*a*, *b*)	ANDC d, a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long	vector unsigned long	vector unsigned long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		
vector double	vector double	vector double		

spu_eqv: Vector Bit-Wise Equivalent

```
d = spu_eqv(a, b)
```

Each bit of vector *a* is compared with the corresponding bit of vector *b*. The corresponding bit of vector *d* is set to 1 if the bits in *a* and *b* are equivalent; otherwise, the bit is set to 0.

Table 2-61: Vector Bit-Wise Equivalent

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_eqv(*a*, *b*)	EQV d, a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long		

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector float	vector float	vector float		
vector double	vector double	vector double		

spu_nand: Vector Bit-Wise Complement of AND

```
d = spu_nand(a, b)
```

Each bit of vector *a* is ANDed with the corresponding bit of vector *b*. The complement of the result is returned in the corresponding bit of vector *d*.

Table 2-62: Vector Bit-Wise Complement of AND

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_nand(*a*, *b*)	NAND d, a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		
vector double	vector double	vector double		

spu_nor: Vector Bit-Wise Complement of OR

```
d = spu_nor(a, b)
```

Each bit of vector *a* is ORed with the corresponding bit of vector *b*. The complement of the result is returned in the corresponding bit of vector *d*.

Table 2-63: Vector Bit-Wise Complement of OR

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_nor(*a*, *b*)	NOR d,a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		
vector double	vector double	vector double		

spu_or: Vector Bit-Wise OR

```
d = spu_or(a, b)
```

Each bit of vector *a* is logically ORed with the corresponding bit of vector *b*. If *b* is a scalar, the scalar value is first replicated for each element, and then *a* and *b* are ORed. The result is returned in the corresponding bit of vector *d*.

Table 2-64: Vector Bit-Wise OR

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_or(*a*, *b*)	OR d, a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long long	vector unsigned long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		
vector double	vector double	vector double		
vector unsigned char	vector unsigned char	10-bit signed int (literal)	*d* = si_orbi(*a*, *b*)	ORBI d, a, b
vector signed char	vector signed char			
vector unsigned char	vector unsigned char	unsigned char	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed char	vector signed char	signed char		
vector unsigned short	vector unsigned short	10-bit signed int (literal)	*d* = si_orhi(*a*, *b*)	ORHI d, a, b
vector signed short	vector signed short			
vector unsigned short	vector unsigned short	unsigned short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short	signed short		
vector unsigned int	vector unsigned int	10-bit signed int (literal)	*d* = si_ori(*a*, *b*)	ORI d, a, b
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	unsigned int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int	signed int		

spu_orc: Vector Bit-Wise OR with Complement

```
d = spu_orc(a, b)
```

Each bit of vector *a* is ORed with the complement of the corresponding bit of vector *b*. The result is returned in the corresponding bit of vector *d*.

Table 2-65: Vector Bit-Wise OR with Complement

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_orc(*a*, *b*)	ORC d,a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		
vector double	vector double	vector double		

spu_orx: OR Word Across

```
d = spu_orx(a)
```

The four word elements of vector *a* are logically ORed. The result is returned in word element 0 of vector *d*. All other elements (1,2,3) of *d* are assigned a value of zero.

Table 2-66: OR Word Across

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	a		
vector unsigned int	vector unsigned int	*d* = si_orx(*a*)	ORX d, a
vector signed int	vector signed int		

spu_xor: Vector Bit-Wise Exclusive OR

```
d = spu_xor(a, b)
```

Each element of vector *a* is exclusive-ORed with the corresponding element of vector *b*. If *b* is a scalar, the scalar value is first replicated for each element. The result is returned in the corresponding bit of vector *d*.

Table 2-67: Vector Bit-Wise Exclusive OR

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector unsigned char	vector unsigned char	vector unsigned char	*d* = si_xor(*a*, *b*)	XOR d, a, b
vector signed char	vector signed char	vector signed char		
vector unsigned short	vector unsigned short	vector unsigned short		
vector signed short	vector signed short	vector signed short		
vector unsigned int	vector unsigned int	vector unsigned int		
vector signed int	vector signed int	vector signed int		
vector unsigned long long	vector unsigned long	vector unsigned long long		
vector signed long long	vector signed long long	vector signed long long		
vector float	vector float	vector float		

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	b		
vector double	vector double	vector double		
vector unsigned char	vector unsigned char	10-bit signed int (literal)	*d* = si_xorbi(*a*, *b*)	XORBI d, a, b
vector signed char	vector signed char			
vector unsigned char	vector unsigned char	unsigned char	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed char	vector signed char	signed char		
vector unsigned short	vector unsigned short	10-bit signed int (literal)	*d* = si_xorhi(*a*, *b*)	XORHI d, a, b
vector signed short	vector signed short			
vector unsigned short	vector unsigned short	unsigned short	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short	signed short		
vector unsigned int	vector unsigned int	10-bit signed int (literal)	*d* = si_xori(*a*, *b*)	XORI d, a, b
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	unsigned int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int	signed int		

2.10. Shift and Rotate Intrinsics

spu_rl: Element-Wise Rotate Left by Bits

```
d = spu_rl(a, count)
```

Each element of vector *a* is rotated left by the number of bits specified by the corresponding element in vector `count`. Bits rotated out of the left end of the element are rotated in at the right end. A limited number of `count` bits are used depending on the size of the element. For halfword elements, the 4 least significant bits of `count` are used. For word elements, the 5 least significant bits of `count` are used.

The results are returned in the corresponding elements of vector *d*.

Table 2-68: Element-Wise Rotate Left by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned short	vector unsigned short	vector signed short	*d* = si_roth(*a*, `count`)	ROTH d, a, count
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	vector signed int	*d* = si_rot(*a*, `count`)	ROT d, a, count
vector signed int	vector signed int			
vector unsigned short	vector unsigned short	7-bit signed int (literal)	*d* = si_rothi(*a*, `count`)	ROTHI d, a, count
vector signed short	vector signed short			
vector unsigned short	vector unsigned short	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	7-bit signed int (literal)	*d* = si_roti(*a*, `count`)	ROTI d, a, count
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int			

spu_rlmask: Element-Wise Rotate Left and Mask by Bits

```
d = spu_rlmask(a, count)
```

This function uses an element-wise rotate left and mask operation to perform a logical shift right (LSR) by bits of each element of vector *a*, where *count* represents the negated value, or values, of the desired corresponding right-shift amounts. (The *count* parameter can be either a vector or a scalar, as shown in Table 2-69.) For example, if scalar *count* is –5, each element of *a* is shifted right by 5 bits. The effect of this function is more precisely shown by the following code:

```
For (each halfword element h in vector a){
    int bitshift = -count & 0x1F;
    h = (shift & 0x10)? 0: LSR(h,bitshift);
}

For (each word element w in vector a){
    int bitshift = -count & 0x3F;
    w = (shift & 0x20)? 0: LSR(w,bitshift);
}
```

The results are returned in the corresponding elements of vector *d*.

Table 2-69: Element-Wise Rotate Left and Mask by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned short	vector unsigned short	vector signed short	*d* = si_rothm(*a*, *count*)	ROTHM d, a, count
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	vector signed int	*d* = si_rotm(*a*, *count*)	ROTM d, a, count
vector signed int	vector signed int			
vector unsigned short	vector unsigned short	7-bit signed int (literal)	*d* = si_rothmi(*a*, *count*)	ROTHMI d, a, count
vector signed short	vector signed short			
vector unsigned short	vector unsigned short	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	7-bit signed int (literal)	*d* = si_rotmi(*a*, *count*)	ROTMI d, a, count
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int			

spu_rlmaska: Element-Wise Rotate Left and Mask Algebraic by Bits

```
d = spu_rlmaska(a, count)
```

This function uses an element-wise rotate left and mask operation to perform an arithmetical shift right (ASR) of each element of vector *a*, where *count* represents the negated value, or values, of the desired corresponding right-shift amounts. (The *count* parameter can be either a vector or a scalar, as shown in Table 2-70.) For example, if scalar *count* is –5, each element of *a* is shifted right by 5 bits. The effect of this function is more precisely shown by the following code:

```
For (each halfword element h in vector a){
    int bitshift = -count & 0x1F;
    h = (shift & 0x10)? 0: ASR(h,bitshift);
}

For (each word element w in vector a){
    int bitshift = -count & 0x3F;
    w = (shift & 0x20)? 0: ASR(w,bitshift);
}
```

The results are returned in the corresponding elements of vector *d*.

Table 2-70: Element-Wise Rotate Left and Mask Algebraic by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned short	vector unsigned short	vector signed short	*d* = si_rotmah(*a*, *count*)	ROTMAH d, a, count
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	vector signed int	*d* = si_rotma(*a*, *count*)	ROTMA d, a, count
vector signed int	vector signed int			
vector unsigned short	vector unsigned short	7-bit signed int (literal)	*d* = si_rotmahi(*a*, *count*)	ROTMAHI d, a, count
vector signed short	vector signed short			
vector unsigned short	vector unsigned short	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	7-bit signed int (literal)	*d* = si_rotmai(*a*, *count*)	ROTMAI d, a, count
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int			

spu_rlmaskqw: Rotate Left and Mask Quadword by Bits

```
d = spu_rlmaskqw(a, count)
```

This function uses a rotate and mask quadword by bits operation to perform a quadword logical shift right (LSR) of up to 7 bits, where *count* represents the negated value of the desired right-shift amount. For example, if *count* is –5, vector *a* is shifted right by 5 bits. The effect of this function is more precisely shown by the following code:

```
qword spu_rlmaskqw(qword a, int count)
{   int bitshift = -count & 0x7;
    return LSR(a,bitshift);
}
```

The resulting quadword is returned in vector *d*.

Table 2-71: Rotate Left and Mask Quadword by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int (literal)	*d* = si_rotqmbii(*a*, *count*) (*count* = 7-bit immediate)	ROTQMBII d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int (non-literal)	*d* = si_rot qmbi(*a*, *count*)	ROTQMBI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_rlmaskqwbyte: Rotate Left and Mask Quadword by Bytes

```
d = spu_rlmaskqwbyte(a, count)
```

This function uses a rotate and mask quadword by bytes operation to perform a quadword logical shift right (LSR) by bytes, where *count* represents the negated value of the desired byte right-shift amount. For example, if *count* is –5, vector *a* is shifted right by 5 bytes. The effect of this function is more precisely shown by the following code:

```
qword spu_rlmaskqwbyte(qword a, int count)
{   int bitshift = (-count << 3) & 0xF8;
    return LSR(a,bitshift);
}
```

The resulting quadword is returned in vector *d*.

Table 2-72: Rotate Left and Mask Quadword by Bytes

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int (literal)	*d* = si_rotqmbyi(*a*, *count*) (*count* = 7-bit immediate)	ROTQMBYI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			
vector unsigned char	vector unsigned char	int (non-literal)	*d* = si_rotqmby(*a*, *count*)	ROTQMBY d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_rlmaskqwbytebc: Rotate Left and Mask Quadword by Bytes from Bit Shift Count

```
d = spu_rlmaskqwbytebc(a, count)
```

This function uses a rotate and mask quadword by bytes from bit shift count operation to perform a quadword logical shift right (LSR) by bytes, where bits 24-28 of *count* represent the negated value of the desired byte right-shift amount. For example, if the bit shift *count* is –10, vector *a* is shifted right by 2 bytes. The effect of this function is more precisely shown by the following code:

```
qword spu_rlmaskqwbytebc(qword a, int count)
{   int bitshift = -(count & 0xF8) & 0xF8;
    return LSR(a,bitshift);
}
```

The resulting quadword is returned in vector *d*.

The following example code shows typical usage of this function; it computes a vector *d* that is the value of vector *a* logically shifted right by *n* bits:

```
d = spu_rlmaskqwbytebc(a,7-n);
d = spu_rlmaskqw(d,-n);
```

Table 2-73: Rotate Left and Mask Quadword by Bytes from Bit Shift Count

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int	*d* = si_rotqmbybi(*a*, *count*)	ROTQMBYBI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_rlqw: Rotate Quadword Left by Bits

```
d = spu_rlqw(a, count)
```

Vector *a* is rotated to the left by the number of bits specified by the 3 least significant bits of *count*. Bits rotated out of the left end of the vector are rotated in on the right. The result is returned in vector *d*.

Table 2-74: Rotate Quadword Left by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int (literal)	*d* = si_rotqbii(*a*, *count*) (*count* = 7-bit immediate)	ROTQBII d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector double	vector double			
vector unsigned char	vector unsigned char	int (non-literal)	*d* = si_rotqbi(*a*, *count*)	ROTQBI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_rlqwbyte: Quadword Rotate Left by Bytes

```
d = spu_rlqwbyte(a, count)
```

Vector *a* is rotated to the left by the number of bytes specified by the 4 least significant bits of *count*. Bytes rotated out of the left end of the vector are rotated in on the right. The result is returned in vector *d*.

Table 2-75: Quadword Rotate Left by Bytes

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int (literal)	*d* = si_rotqbyi(*a*, *count*) (*count* = 7-bit immediate)	ROTQBYI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			
vector unsigned char	vector unsigned char	int (non-literal)	*d* = si_rotqby(*a*, *count*)	ROTQBY d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_rlqwbytebc: Rotate Left Quadword by Bytes from Bit Shift Count

```
d = spu_rlqwbytebc(a, count)
```

Vector *a* is rotated to the left by the number of bytes specified by bits 24-28 of `count`. Bytes rotated out of the left end of the vector are rotated in at the right. The result is returned in vector *d*.

Table 2-76: Rotate Left Quadword by Bytes from Bit Shift Count

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	int	*d* = si_rotqbybi(*a*, `count`)	ROTQBYBI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_sl: Element-Wise Shift Left by Bits

```
d = spu_sl(a, count)
```

Each element of vector *a* is shifted left by the number of bits specified by the corresponding element in vector `count`. If `count` is a scalar, the scalar value is first replicated for each element, and then *a* is shifted.

Bits shifted out of the left end of the element are discarded, and zeros are shifted in at the right. A limited number of `count` bits are used depending on the size of the element. For halfword elements, the 5 least significant bits of `count` are used, and for word elements, the 6 least significant bits are used. The result is returned in the corresponding bit of vector *d*.

Table 2-77: Element-Wise Shift Left by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned short	vector unsigned short	vector unsigned short	*d* = si_shlh(*a*, `count`)	SHLH d, a, count
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	vector unsigned int	*d* = si_shl(*a*, `count`)	SHL d, a, count
vector signed int	vector signed int			
vector unsigned short	vector unsigned short	7-bit unsigned int (literal)	*d* = si_shlhi(*a*, `count`)	SHLHI d, a, count
vector signed short	vector signed short			
vector unsigned short	vector unsigned short	unsigned int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed short	vector signed short			
vector unsigned int	vector unsigned int	7-bit unsigned int (literal)	*d* = si_shli(*a*, `count`)	SHLI d, a, count
vector signed int	vector signed int			
vector unsigned int	vector unsigned int	unsigned int	See section "2.2.1. Mapping Intrinsics with Scalar Operands".	
vector signed int	vector signed int			

spu_slqw: Shift Quadword Left by Bits

```
d = spu_slqw(a, count)
```

Vector *a* is shifted left by the number of bits specified by the 3 least significant bits of *count*. Bits shifted out of the left end of the vector are discarded, and zeros are shifted in at the right. The result is returned in vector *d*.

Table 2-78: Shift Quadword Left by Bits

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	unsigned int (literal)	*d* = si_shlqbii(*a*, *count*) (*count* = 7-bit immediate)	SHLQBII d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			
vector unsigned char	vector unsigned char	unsigned int (non-literal)	*d* = si_shlqbi(*a*, *count*)	SHLQBI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_slqwbyte: Shift Left Quadword by Bytes

```
d = spu_slqwbyte(a, count)
```

Vector *a* is shifted left by the number of bytes specified by the 5 least significant bits of *count*. Bytes shifted out of the left end of the vector are discarded, and zeros are shifted in at the right. The result is returned in vector *d*.

Table 2-79: Shift Left Quadword by Bytes

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	unsigned int (literal)	*d* = si_shlqbyi(*a*, *count*) (*count* = 7-bit immediate)	SHLQBYI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	unsigned int (non-literal)	*d* = si_shlqby(*a*, `count`)	SHLQBY d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

spu_slqwbytebc: Shift Left Quadword by Bytes from Bit Shift Count

```
d = spu_slqwbytebc(a, count)
```

Vector *a* is shifted left by the number of bytes specified by bits 24-28 of `count`. Bytes shifted out of the left end of the vector are discarded, and zeros are shifted in at the right. The result is returned in vector *d*.

Table 2-80: Shift Left Quadword by Bytes from Bit Shift Count

Return/Argument Types			Specific Intrinsics	Assembly Mapping
d	a	count		
vector unsigned char	vector unsigned char	unsigned int	*d* = si_shlqbybi(*a*, `count`)	SHLQBYBI d, a, count
vector signed char	vector signed char			
vector unsigned short	vector unsigned short			
vector signed short	vector signed short			
vector unsigned int	vector unsigned int			
vector signed int	vector signed int			
vector unsigned long long	vector unsigned long long			
vector signed long long	vector signed long long			
vector float	vector float			
vector double	vector double			

2.11. Control Intrinsics

spu_idisable: Disable Interrupts

```
(void) spu_idisable()
```

Asynchronous interrupts are disabled.

This intrinsic is considered volatile with respect to all other instructions; thus, the BID instruction will not be reordered with any other instructions.

Table 2-81: Disable Interrupts

Specific Intrinsics	Assembly Mapping
N/A	**position dependent:** ILA t, *next_inst* BID t *next_inst:* **position independent:** BRSL t, *next_inst* *next_inst:* AI t, t, 8 BID t

spu_ienable: Enable Interrupts

```
(void) spu_ienable()
```

Asynchronous interrupts are enabled.

This intrinsic is considered volatile with respect to all other instructions; thus, the BIE instruction will not be reordered with any other instructions.

Table 2-82: Enable Interrupts

Specific Intrinsics	Assembly Mapping
N/A	**position dependent:** ILA t, *next_inst* BIE t *next_inst:* **position independent:** BRSL t, *next_inst* *next_inst:* AI t, t, 8 BIE t

spu_mffpscr: Move from Floating-Point Status and Control Register

```
d = spu_mffpscr()
```

The floating-point status and control register (FPSCR) Special Purpose Register is read, and the contents are returned in *d*. Unused bits of the FPSCR are forced to zero.

This intrinsic is considered volatile with respect to the floating-point instructions and will not be reordered with respect to these instructions. The floating-point instructions include: `cflts`, `cfltu`, `csflt`, `cuflt`, `dfa`, `dfm`, `dfma`, `dfms`, `dfnma`, `dfnms`, `dfs`, `fa`, `fceq`, `fcgt`, `fcmeq`, `fcmgt`, `fesd`, `fi`, `fm`, `fma`, `fms`, `fnms`, `frds`, `frest`, `frsqest`, and `fscrwr`.

Table 2-83: Move from Floating-Point Status and Control Register

Return/Argument Types	Specific Intrinsics	Assembly Mapping
d		
vector unsigned int	*d* = si_fscrrd()	FSCRRD d

spu_mfspr: Move from Special Purpose Register

```
d = spu_mfspr(register)
```

The Specal Purpose Register specified by enumeration constant *`register`* is read, and the contents are returned in *d*.

Table 2-84: Move from Special Purpose Register

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	register		
unsigned int	enumeration	*d* = si_to_uint(si_mfspr(`register`))	MFSPR d, register

spu_mtfpscr: Move to Floating-Point Status and Control Register

```
(void) spu_mtfpscr(a)
```

The argument *a* is written to the floating-point status and control register (FPSCR).

This intrinsic is considered volatile with respect to the floating-point instructions, and it will not be reordered with respect to these instructions.

Table 2-85: Move to Floating-Point Status and Control Register

Return/Argument Types	Specific Intrinsics	Assembly Mapping
a		
vector unsigned int	si_fscrwr(*a*)	FSCRWR rt[1], a

[1] The false target parameter *`rt`* is optimally chosen depending on register usage of neighboring instructions.

spu_mtspr: Move to Special Purpose Register

```
(void) spu_mtspr(register, a)
```

The argument *a* is written to the Special Purpose Register specified by the enumeration constant `register`.

Table 2-86: Move to Special Purpose Register

Return/Argument Types		Specific Intrinsics	Assembly Mapping
register	a		
enumeration	unsigned int	si_mtspr(`register`, si_from_uint(*a*))	MTSPR register, a

spu_dsync: Synchronize Data

```
(void) spu_dsync()
```

All earlier store instructions are forced to complete before proceeding. This function ensures that all stores to local storage are visible to the MFC or PPU.

This intrinsic is considered volatile with respect to the store and MFC write instructions, and it will not be reordered with respect to these instructions. The store and MFC instructions include: `stqa`, `stqd`, `stqr`, `stqx`, and `wrch`.

Table 2-87: Synchronize Data

Specific Intrinsics	Assembly Mapping
si_dsync()	DSYNC

spu_stop: Stop and Signal

```
(void) spu_stop(type)
```

Execution of the SPU program is stopped. The address of the `stop` instruction is placed into the least significant bits of the SPU NPC register. The signal *`type`* is written to the SPU status register, and the PPU is interrupted.

This intrinsic is considered volatile with respect to all instructions, and it will not be reordered with any other instructions.

Table 2-88: Stop and Signal

Specific Intrinsics	type	Assembly Mapping
si_stop(type)	unsigned int (14-bit literal)	STOP type

spu_sync: Synchronize

```
(void) spu_sync()
(void) spu_sync_c()
```

The processor waits until all pending store instructions have been completed before fetching the next sequential instruction. The `spu_sync_c` form of the intrinsic also performs channel synchronization prior to the instruction synchronization. This operation must be used following a store instruction that modifies the instruction stream.

These synchronization intrinsics are considered volatile with respect to all instructions, and they will not be reordered with any other instructions.

Table 2-89: Synchronize

Generic Intrinsic Form	Specific Intrinsics	Assembly Mapping
spu_sync	si_sync()	SYNC
spu_sync_c	si_syncc()	SYNCC

2.12. Channel Control Intrinsics

The channel control intrinsics each take a *`channel`* number as an input. Channel numbers are literal unsigned integer values in the range from 0 to 127. Table 2-90 and Table 2-91 show the respective SPU and MFC channel numbers and their associated mnemonics. For additional details on the channels, see the *Cell Broadband Engine Architecture*.

The channel intrinsics must never be reordered with respect to other channel commands or volatile local-storage memory accesses.

The MFC channels are only valid for SPUs within a CBEA-compliant system. MFC and SPU channel enumerants are defined in `spu_intrinsics.h`

Table 2-90: SPU Channel Numbers

Channel Number	Mnemonic	Description
0	SPU_RdEventStat	Read event status with mask applied.
1	SPU_WrEventMask	Write event mask.
2	SPU_WrEventAck	Write End of event processing.
3	SPU_RdSigNotify1	Signal notification 1.
4	SPU_RdSigNotify2	Signal notification 2.
7	SPU_WrDec	Write decrementer count.
8	SPU_RdDec	Read decrementer count.
11	SPU_RdEventMask	Read event mask.
13	SPU_RdMachStat	Read SPU run status.
14	SPU_WrSRR0	Write SPU machine state save/restore register 0 (SRR0).
15	SPU_RdSRR0	Read SPU machine state save/restore register 0 (SRR0).
28	SPU_WrOutMbox	Write outbound mailbox contents.
29	SPU_RdInMbox	Read inbound mailbox contents.
30	SPU_WrOutIntrMbox	Write outbound interrupt mailbox contents (interrupting PPU).

Table 2-91: MFC Channel Numbers

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

spu_readch: Read Word Channel

```
d = spu_readch(channel)
```

The word channel that is specified by *channel* is read, and the contents are placed in *d*. If the channel does not exist, a value of zero is returned.

Table 2-92: Read Word Channel

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	channel		
unsigned int	enumeration	*d* = si_to_uint(si_rdch(*channel*))	RDCH d, channel

spu_readchqw: Read Quadword Channel

```
d = spu_readchqw(channel)
```

The quadword channel that is specified by *channel* is read, and the contents are placed in vector *d*. If the channel does not exist, a value of zero is returned.

Table 2-93: Read Quadword Channel

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	channel		
vector unsigned int	enumeration	*d* = si_rdch(*channel*)	RDCH d, channel

spu_readchcnt: Read Channel Count

```
d = spu_readchcnt(channel)
```

A Read Count operation is performed on thes channel that is specified by *channel*, and the count is placed in *d*. If the channel does not exist, a value of zero is returned in *d*.

Table 2-94: Read Channel Count

Return/Argument Types		Specific Intrinsics	Assembly Mapping
d	channel		
unsigned int	enumeration	*d* = si_rchcnt(*channel*)	RCHCNT d, channel

spu_writech: Write Word Channel

```
(void) spu_writech(channel, a)
```

The contents of scalar *a* are written to the channel that is specified by the enumeration constant *channel*.

Table 2-95: Write Word Channel

Return/Argument Types		Specific Intrinsics	Assembly Mapping
channel	a		
enumeration	int	si_wrch(*channel*, si_from_int(*a*))	WRCH channel, a
	unsigned int	si_wrch(*channel*, si_from_uint(*a*))	

spu_writechqw: Write Quadword Channel

```
(void) spu_writechqw(channel, a)
```

The contents of vector *a* are written to the channel that is specified by the enumeration constant *channel*.

Table 2-96: Write Quadword Channel

Return/Argument Types		Specific Intrinsics	Assembly Mapping
channel	a		
enumeration	vector unsigned char	si_wrch(*channel*, *a*)	WRCH channel, a
	vector signed char		
	vector unsigned short		
	vector signed short		
	vector unsigned int		
	vector signed int		
	vector unsigned long long		
	vector signed long long		
	vector float		

Return/Argument Types		Specific Intrinsics	Assembly Mapping
channel	a		
	vector double		

2.13. Scalar Intrinsics

All of the previous intrinsic functions perform operations only on vector data types. This section describes special utility intrinsics that allow programmers to efficiently coerce scalars to vectors, or vectors to scalars. With the aid of these intrinsics, programmers can use intrinsic functions to perform operations between vectors and scalars without having to revert to assembly language. This is especially important when there is a need is to perform an operation that cannot be conveniently expressed in C, such as shuffling bytes.

spu_extract: Extract Vector Element from Vector

```
d = spu_extract(a, element)
```

The element that is specified by *element* is extracted from vector *a* and returned in *d*. Depending on the size of the element, only a limited number of the least significant bits of the *element* index are used. For 1-, 2-, 4-, and 8-byte elements, only 4, 3, 2, and 1 of the least significant bits of the element index are used, respectively.

Table 2-97: Extract Vector Element from Vector

Return/Argument Types			Specific Intrinsics	Assembly Mapping[1]
d	a	element		
unsigned char	vector unsigned char	int (non-literal)	N/A	ROTQBY d, a, element
signed char	vector signed char		N/A	ROTQBY d, a, element
unsigned short	vector unsigned short		N/A	SHLI t, element, 1
signed short	vector signed short		N/A	SHLI t, element, 1
unsigned int	vector unsigned int		N/A	SHLI t, element, 2
signed int	vector signed int		N/A	SHLI t, element, 2
unsigned long long	vector unsigned long long		N/A	SHLI t, element, 3
signed long long	vector signed long long		N/A	SHLI t, element, 3
float	vector float		N/A	SHLI t, element, 2
double	vector double		N/A	SHLI t, element, 3
unsigned char	vector unsigned char	int (literal)	N/A	ROTQBYI d, a, element-3
signed char	vector signed char		N/A	
unsigned short	vector unsigned short		N/A	ROTQBYI d, a, 2*(element-1)
signed short	vector signed short		N/A	
unsigned int	vector unsigned int		N/A	ROTQBYI d, a, 4*element
signed int	vector signed int		N/A	
unsigned long long	vector unsigned long long		N/A	ROTQBYI d, a, 8*element
signed long long	vector signed long long		N/A	
float	vector float		N/A	ROTQBYI d, a, 4*element
double	vector double		N/A	ROTQBYI d, a, 8*element

[1] If the specified element is a known value (literal) and specifies the preferred (scalar) element, no instructions are produced. For 1 byte elements, the scalar element is 3. For 2 byte elements, the scalar element is 1. For 4 and 8 byte elements, the scalar element is 0. Sign extension may still be performed if a subsequent operation requires the resulting scalar to be cast to a larger data type. This sign extension may be deferred until the subsequent operation.

spu_insert: Insert Scalar into Specified Vector Element

```
d = spu_insert(a, b, element)
```

Scalar *a* is inserted into the element of vector *b* that is specified by the *element* parameter, and the modified vector is returned. All other elements of *b* are unmodified. Depending on the size of the element, only a limited number of the least significant bits of the *element* index are used. For 1-, 2-, 4-, and 8-byte elements, only 4, 3, 2, and 1 of the least significant bits of the *element* index are used, respectively.

Table 2-98: Insert Scalar into Specified Vector Element

Return/Argument Types				Specific Intrinsics	Assembly Mapping
d	a	b	element		
vector unsigned char	unsigned char	vector unsigned char	int (non-literal)	N/A	CBD t, 0(element) SHUFB d, a, b, t
vector signed char	signed char	vector signed char		N/A	
vector unsigned short	unsigned short	vector unsigned short		N/A	SHLI t, element, 1 CHD t, 0(t) SHUFB d, a, b, t
vector signed short	signed short	vector signed short		N/A	
vector unsigned int	unsigned int	vector unsigned int		N/A	SHLI t, element, 2 CWD t, 0(t) SHUFB d, a, b, t
vector signed int	signed int	vector signed int		N/A	
vector float	float	vector float		N/A	
vector unsigned long long	unsigned long long	vector unsigned long long		N/A	SHLI t, element, 3 CDD t, 0(t) SHUFB d, a, b, t
vector signed long long	signed long long	vector signed long long		N/A	
vector double	double	vector double		N/A	
vector unsigned char	unsigned char	vector unsigned char	int (literal)	N/A	LQD pat, CONST_AREA SHUFB d, a, b, pat
vector signed char	signed char	vector signed char		N/A	
vector unsigned short	unsigned short	vector unsigned short		N/A	LQD pat, CONST_AREA SHUFB d, a, b, pat
vector signed short	signed short	vector signed short		N/A	
vector unsigned int	unsigned int	vector unsigned int		N/A	LQD pat, CONST_AREA SHUFB d, a, b, pat
vector signed int	signed int	vector signed int		N/A	
vector float	float	vector float		N/A	
vector unsigned long long	unsigned long long	vector unsigned long long		N/A	LQD pat, CONST_AREA SHUFB d, a, b, pat
vector signed long long	signed long long	vector signed long long		N/A	
vector double	double	vector double		N/A	

[1] If the specified element is a known value (literal), a shuffle pattern can be loaded from the constant area. The contents of the pattern depend on the size of the element and the element being replaced.

spu_promote: Promote Scalar to a Vector

```
d = spu_promote(a, element)
```

Scalar *a* is promoted to a vector containing *a* in the element that is specified by the *element* parameter, and the vector is returned in *d*. All other elements of the vector are undefined. Depending on the size of the element/scalar, only a limited number of the least significant bits of the *element* index are used. For 1-, 2-, 4-, and 8-byte elements, only 4, 3, 2, and 1 of the least significant bits of the *element* index are used, respectively.

Table 2-99: Promote Scalar to a Vector

Return/Argument Types			Specific Intrinsics	Assembly Mapping[1]
d	a	element		
vector unsigned char	unsigned char	int (non-literal)	N/A	SFI t, element, 3 ROTQBY d, a, t
vector signed char	signed char		N/A	
vector unsigned short	unsigned short		N/A	SFI t, element, 1 SHLI t, t, 1 ROTQBY d, a, t
vector signed short	signed short		N/A	
vector unsigned int	unsigned int		N/A	SFI t, element, 0 SHLI t, t, 2 ROTQBY d, a, t
vector signed int	signed int		N/A	
vector float	float		N/A	
vector unsigned long long	unsigned long long		N/A	SHLI t, element, 3 ROTQBY d, a, t
vector signed long long	signed long long		N/A	
vector double	double		N/A	
vector unsigned char	unsigned char	int (literal)	N/A	ROTQBYI d, a, (3-element)
vector signed char	signed char		N/A	
vector unsigned short	unsigned short		N/A	ROTQBYI d, a, 2* (1-element)
vector signed short	signed short		N/A	
vector unsigned int	unsigned int		N/A	ROTQBYI d, a, -4*element
vector signed int	signed int		N/A	
vector float	float		N/A	
vector unsigned long long	unsigned long long		N/A	ROTQBYI d, a, -8*element
vector signed long long	signed long long		N/A	
vector double	double		N/A	

[1] If the specified element is of known value (literal) and specifies the preferred (scalar) element, no instructions are produced. For 1 byte elements, the scalar element is 3. For 2 byte elements, the scalar element is 1. For 4 and 8 byte elements, the scalar element is 0.

3. Composite Intrinsics

This chapter describes several composite intrinsics that have practical use for a wide variety of SPU programs. Composite intrinsics are those intrinsics that can be constructed from a series of low-level intrinsics. In this context, “low-level” means generic or specific. Because of the complexity of these operations, frequency of use, and scheduling constraints, the particular services are provided as intrinsics.

Composite intrinsics are DMA intrinsics. The DMA intrinsics rely heavily on the channel control intrinsics.

spu_mfcdma32: Initiate DMA to/from 32-Bit Effective Address

```
spu_mfcdma32(ls, ea, size, tagid, cmd)
```

A DMA transfer of *size* bytes is initiated from local to system memory or from system memory to local storage. The effective address that is specified by *ea* is a 32-bit virtual memory address. The local-storage address is specified by the *ls* parameter. The DMA request is issued using the specified *tagid*. The type and direction of DMA, bandwidth reservation, and class ID are encoded in the *cmd* parameter. For additional details about the commands and restrictions on the size of supported DMA operations, see the *Cell Broadband Engine Architecture.*

Table 3-100: Initiate DMA to/from 32-Bit Effective Address

Return/Argument Types					Assembly Mapping
ls	ea	size	tagid	cmd	
volatile void *	unsigned int	unsigned int	unsigned int	unsigned int	spu_writech(MFC_LSA, *ls*) spu_writech(MFC_EAL, *ea*) spu_writech(MFC_Size, *size*) spu_writech(MFC_TagID, *tagid*) spu_writech(MFC_Cmd, *cmd*)

spu_mfcdma64: Initiate DMA to/from 64-Bit Effective Address

```
spu_mfcdma64(ls, eahi, ealow, size, tagid, cmd)
```

A DMA transfer of *size* bytes is initiated from local to system memory or from system memory to local storage. The effective address that is specified by the concatenation of *eahi* and *ealow* is a 64-bit virtual memory address. The local-storage address is specified by the *ls* parameter. The DMA request is issued using the specified *tagid*. The type and direction of DMA, bandwidth reservation, and class ID are encoded in the *cmd* parameter. For additional details about the commands and restrictions on the size of supported DMA operations, see the *Cell Broadband Engine Architecture*.

Table 3-101: Initiate DMA to/from 64-Bit Effective Address

Return/Argument Types						Assembly Mapping
ls	eahi	ealow	sh	tagid	cmd	
volatile void *	unsigned int	unsigned int	unsigned int	unsigned int	unsigned int	spu_writech(MFC_LSA, *ls*) spu_writech(MFC_EAH, *eahi*) spu_writech(MFC_EAL, *ealow*) spu_writech(MFC_Size, *size*) spu_writech(MFC_TagID, *tagid*) spu_writech(MFC_CMD, *cmd*)

spu_mfcstat: Read MFC Tag Status

```
d = spu_mfcstat(type)
```

The current MFC tag status is read and logically ANDed with the current tag mask, and the result is returned in *d*. The type of read to be performed is specified by the *type* parameter. If the *type* is 0, the function reads and immediately returns the current MFC tag status. If the *type* is 1, the function reads and blocks for any outstanding MFC tags to complete, and if the *type* is 2, the function reads and blocks for all outstanding MFC tags to complete.

Table 3-102: Read MFC Tag Status

Return/Argument Types		Assembly Mapping
d	type	
unsigned int	unsigned int	spu_writech(MFC_WrTagUpdate, *type*) *d* = spu_readch(MFC_RdTagStat)

4. Programming Support for MFC Input and Output

Several MFC utility functions are described in this chapter. These functions may be provided as a programming convenience; none of them are required. The functions that are described can be implemented either as macro definitions or as built-in functions within the compiler. To access these functions, programmers must include the header file `spu_mfcio.h`.

For each function listed in the sections below, the function usage is shown, followed by a brief description and the function implementation.

4.1. Structures

A principal data structure is the MFC List DMA. The elements in this list are described below.

mfc_list_element: DMA List Element for MFC List DMA

```
typedef struct mfc_list_element {
   uint64_t notify     : 1;
   uint64_t reserved   : 16;
   uint64_t size       : 15;
   uint64_t eal        : 32;
} mfc_list_element_t;
```

The `mfc_list_element` is an element in the array MFC List DMA. The structure is comprised of several bit-fields: *`notify`* is the stall-and-notify bit, *`reserved`* is set to zero. *`size`* is the list element transfer size, and *`eal`* is the low word of the 64-bit effective address.

4.2. Effective Address Utilities

A frequent requirement for MFC programming is to manipulate effective addresses. This section describes several functions for performing the most common operations.

mfc_ea2h: Extract Higher 32 Bits from Effective Address

```
(uint32_t) mfc_ea2h(uint64_t ea)
```

The higher 32 bits are extracted from the 64-bit effective address *`ea`*.

Implementation

```
(uint32_t)((uint64_t)(ea)>>32)
```

mfc_ea2l: Extract Lower 32 Bits from Effective Address

```
(uint32_t) mfc_ea2l(uint64_t ea)
```

The lower 32 bits are extracted from the 64-bit effective address *`ea`*.

Implementation

```
(uint32_t)(ea)
```

mfc_hl2ea: Concatenate Higher 32 Bits and Lower 32 Bits

```
(uint64_t) mfc_hl2ea(uint32_t high, uint32_t low)
```

The higher 32 bits of a 64-bit address *high* and the lower 32 bits *low* are concatenated.

Implementation

```
si_to_ullong(si_selb(si_from_uint(high),
     si_from_si_rotqbyi(si_from_uint(low), -4), si_fsmbi(0x0f0f)))
```

mfc_ceil128: Round Up Value to Next Multiple of 128

```
(uint32_t) mfc_ceil128(uint32_t value)
(uint64_t) mfc_ceil128(uint64_t value)
(uintptr_t) mfc_ceil128(uintptr_t value)
```

The argument *value* is rounded to the next higher multiple of 128.

Implementation

```
(value + 127) & ~127
```

Example

```
volatile char buf[256];
volatile void *ptr = (volatile void*)mfc_ceil128((uintptr_t)buf);
```

4.3. MFC DMA Commands

This section describes functions that implement the various MFC DMA commands. See the *Cell Broadband Engine Architecture f*or a description of the DMA commands, including restrictions on the size of the supported operations.

MFC DMA command mnemonics are listed in Table 4-103. MFC command enumerants are defined in `spu_mfcio.h`.

Table 4-103: MFC DMA Command Mnemonics

Mnemonic	Opcode	Command
MFC_PUT_CMD	0x0020	put
MFC_PUTB_CMD	0x0021	putb
MFC_PUTF_CMD	0x0022	putf
MFC_GET_CMD	0x0040	get
MFC_GETB_CMD	0x0041	getb
MFC_GETF_CMD	0x0042	getf

mfc_put: Move Data from Local Storage to Effective Address

```
(void) mfc_put(volatile void *ls, uint64_t ea, uint32_t size, uint32_t tag,
     uint32_t tid, uint32_t rid)
```

Data is moved from local storage to system memory. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *ls* is the local-storage address, *ea* is the effective address in system memory, *size* is the DMA transfer size, *tag* is the DMA tag, *tid* is the transfer class identifier, and *rid* is the replacement class identifier.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), size, tag,
     ((tid<<24)|(rid<<16)|MFC_PUT_CMD))
```

mfc_putb: Move Data from Local Storage to Effective Address with Barrier

```
(void) mfc_putb(volatile void *ls, uint64_t ea, uint32_t size, uint32_t tag,
     uint32_t tid, uint32_t rid)
```

Data is moved from local storage to system memory. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`size`* is the DMA transfer size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command and all subsequent commands with the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), size, tag,
     ((tid<<24)|(rid<<16)|MFC_PUTB_CMD))
```

mfc_putf: Move Data from Local Storage to Effective Address with Fence

```
(void) mfc_putf(volatile void *ls, uint64_t ea, uint32_t size, uint32_t tag,
     uint32_t tid, uint32_t rid)
```

Data is moved from local storage to system memory. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`size`* is the DMA transfer size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command is locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), size, tag,
     ((tid<<24)|(rid<<16)|MFC_PUTF_CMD))
```

mfc_get: Move Data from Effective Address to Local Storage

```
(void) mfc_get(volatile void *ls, uint64_t ea, uint32_t size, uint32_t tag,
     uint32_t tid, uint32_t rid)
```

Data is moved from system memory to local storage. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`size`* is the DMA transfer size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), size, tag,
     ((tid<<24)|(rid<<16)|MFC_GET_CMD))
```

mfc_getf: Move Data from Effective Address to Local Storage with Fence

```
(void) mfc_getf(volatile void *ls, uint64_t ea, uint32_t size, uint32_t tag,
     uint32_t tid, uint32_t rid)
```

Data is moved from system memory to local storage. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`size`* is the DMA transfer size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command is locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), size,
     tag,((tid<<24)|(rid<<16)|MFC_GETF_CMD))
```

mfc_getb: Move Data from Effective Address to Local Storage with Barrier

```
(void) mfc_getb (volatile void *ls, uint64_t ea, uint32_t size, uint32_t tag,
     uint32_t tid, uint32_t rid)
```

Data is moved from system memory to local storage. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`size`* is the DMA transfer size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command and all subsequent commands with the same tag ID as this command are locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), size,tag,
     ((tid<<24)|(rid<<16)|MFC_GETB_CMD))
```

4.4. MFC List DMA Commands

This section describes utility functions that can be used to manage the MFC List DMA. See the *Cell Broadband Engine Architecture f*or a description of the DMA commands, including restrictions on the size of the supported operations.

MFC List DMA command mnemonics are listed in Table 4-104. MFC command enumerants are defined in `spu_mfcio.h`.

Table 4-104: MFC List DMA Command Mnemonics

Mnemonic	Opcode	Command
MFC_PUTL_CMD	0x0024	putl
MFC_PUTLB_CMD	0x0025	putlb
MFC_PUTLF_CMD	0x0026	putlf
MFC_GETL_CMD	0x0044	getl
MFC_GETLB_CMD	0x0045	getlb
MFC_GETLF_CMD	0x0046	getlf

mfc_putl: Move Data from Local Storage to Effective Address Using MFC List

```
(void) mfc_putl(volatile void *ls, uint64_t ea, volatile mfc_list_element_t *list,
     uint32_t list_size, uint32_t tag, uint32_t tid, uint32_t rid)
```

Data is moved from local storage to system memory using the MFC list. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`list`* is the DMA list address, *`list_size`* is the DMA list size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), (unsigned int)(list), list_size, tag,
     ((tid<<24)|(rid<<16)|MFC_PUTL_CMD))
```

mfc_putlb: Move Data from Local Storage to Effective Address Using MFC List with Barrier

```
(void) mfc_putlb(volatile void *ls, uint64_t ea, volatile mfc_list_element_t *list,
     uint32_t list_size, uint32_t tag, uint32_t tid, uint32_t rid)
```

Data is moved from local storage to system memory using the MFC list. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`list`* is the DMA list address, *`list_size`* is the DMA list size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command and all subsequent commands with the same tag ID as this command are locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls,mfc_ea2h(ea),(unsigned int)(list), list_size, tag,
     ((tid<<24)|(rid<<16)|MFC_PUTLB_CMD))
```

mfc_putlf: Move Data from Local Storage to Effective Address Using MFC List with Fence

```
(void) mfc_putlf(volatile void *ls, uint64_t ea, volatile mfc_list_element_t *list,
     uint32_t list_size, uint32_t tag, uint32_t tid, uint32_t rid)
```

Data is moved from local storage to system memory using the MFC list. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`list`* is the DMA list address, *`list_size`* is the DMA list size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command is locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea),(unsigned int)(list), list_size, tag,
     ((tid<<24)|(rid<<16)|MFC_PUTLF_CMD))
```

mfc_getl: Move Data from Effective Address to Local Storage Using MFC List

```
(void) mfc_getl (volatile void *ls, uint64_t ea, volatile mfc_list_element_t *list,
     uint32_t list_size, uint32_t tag, uint32_t tid, uint32_t rid)
```

Data is moved from system memory to local storage using the MFC list. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`list`* is the DMA list address, *`list_size`* is the DMA list size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier.

Implementation

```
spu_mfcdma64(ls,mfc_ea2h(ea),(unsigned int)(list), list_size, tag,
     ((tid<<24)|(rid<<16)|MFC_GETL_CMD))
```

mfc_getlb: Move Data from Effective Address to Local Storage Using MFC List with Barrier

```
(void) mfc_getlb(volatile void *ls, uint64_t ea, volatile mfc_list_element_t *list,
     uint32_t list_size, uint32_t tag, uint32_t tid, uint32_t rid)
```

Data is moved from system memory to local storage using the MFC list. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`list`* is the DMA list address, *`list_size`* is the DMA list size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command and all subsequent commands with the same tag ID as this command are locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls,mfc_ea2h(ea),(unsigned int)(list), list_size, tag,
     ((tid<<24)|(rid<<16)|MFC_GETLB_CMD))
```

mfc_getlf: Move Data from Effective Address to Local Storage Using MFC List with Fence

```
(void) mfc_getlf(volatile void *ls, uint64_t ea, volatile mfc_list_element_t *list,
     uint32_t list_size, uint32_t tag, uint32_t tid, uint32_t rid)
```

Data is moved from system memory to local storage using the MFC list. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the local-storage address, *`ea`* is the effective address in system memory, *`list`* is the DMA list address, *`list_size`* is the DMA list size, *`tag`* is the DMA tag, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier. This command is locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls,mfc_ea2h(ea),(unsigned int)(list), list_size, tag,
     ((tid<<24)|(rid<<16)|MFC_GETLF_CMD))
```

4.5. MFC Atomic Update Commands

This section describes utility functions that can be used to manage the MFC Atomic DMA. See the *Cell Broadband Engine Architecture f*or a description of the DMA commands, including restrictions on the size of the supported operations.

MFC Atomic DMA command mnemonics are listed in Table 4-105. MFC command enumerants are defined in `spu_mfcio.h`.

Table 4-105: MFC Atomic Update Command Mnemonics

Mnemonic	Opcode	Command
MFC_GETLLAR_CMD	0x00D0	getllar
MFC_PUTLLC_CMD	0x00B4	putllc
MFC_PUTLLUC_CMD	0x00B0	putlluc
MFC_PUTQLLUC_CMD	0x00B8	putqlluc

mfc_getllar: Get Lock Line and Create Reservation

```
(void) mfc_getllar(volatile void *ls, uint64_t ea, uint32_t tid, uint32_t rid)
```

The lock line is obtained and a reservation is created. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the 128-byte-aligned local-storage address, *`ea`* is the effective address in system memory, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier.

The `mfc_getllar` command does not have a tag ID. The command is immediately executed by the MFC. The transfer size is fixed at 128 bytes. An `mfc_read_atomic_status()` must follow this function to verify completion of the command.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea),128, 0,
     ((tid<<24)|(rid<<16)|MFC_GETLLAR_CMD))
```

mfc_putllc: Put Lock Line if Reservation for Effective Address Exists

```
(void) mfc_putllc(volatile void *ls, uint64_t ea, uint32_t tid, uint32_t rid)
```

The lock line is put if a reservation for effective address exists. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the 128-byte-aligned local-storage address, *ea* is the effective address in system memory, *`tid`* is the transfer class identifier, and *`rid`* is the replacement class identifier.

The `mfc_putllc` command does not have a tag ID and is immediately executed by MFC. Transfer size is fixed at 128 bytes. An `mfc_read_atomic_status()` must follow this command to verify completion of the command.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea),128, 0,
     ((tid<<24)|(rid<<16)|MFC_PUTLLC_CMD))
```

mfc_putlluc: Put Lock Line Unconditional

```
(void) mfc_putlluc(volatile void *ls, uint64_t ea, uint32_t tid, uint32_t rid)
```

The lock line is put regardless of the existence of a previously made reservation. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *`ls`* is the 128-byte-aligned local-storage address,

ea is the effective address in system memory, *tid* is the transfer class identifier, and *rid* is the replacement class identifier.

This command does not have a tag ID and is immediately executed by MFC. The transfer size is fixed at 128 bytes. The `mfc_read_atomic_status()` must follow this function to verify completion of the command.

Implementation

```
spu_mfcdma64(ls,mfc_ea2h(ea),mfc_ea2l(ea), 128, 0,
     ((tid<<24)|(rid<<16)|MFC_PUTLLUC_CMD))
```

mfc_putqlluc: Put Queued Lock Line Unconditional

```
(void) mfc_putqlluc(volatile void *ls, uint64_t ea, uint32_t tag, uint32_t tid,
     uint32_t rid)
```

The lock line is put in the queue regardless of the existence of a previously made reservation. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *ls* is the 128-byte-aligned local-storage address, *ea* is the effective address in system memory, *tid* is the transfer class identifier, and *rid* is the replacement class identifier.

Transfer size is fixed at 128 bytes. This command is functionally equivalent to the `mfc_putlluc` command. The difference between the two commands is the order in which the commands are executed and the way that completion is determined. `mfc_putlluc` is performed immediately; in contrast, `mfc_putqlluc` is placed into the MFC command queue, along with other MFC commands. Because this command is queued, it is executed independently of any pending immediate `mfc_getllar`, `mfc_putllc`, or `mfc_putlluc` commands. To determine if this command has been performed, a program must wait for a tag-group completion.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), 128, tag,
     ((tid<<24)|(rid<<16)|MFC_PUTQLLUC_CMD))
```

4.6. MFC Synchronization Commands

This section describes functions that implement the MFC synchronization commands, including signal notification and storage ordering. See the *Cell Broadband Engine Architecture f*or a description of the DMA commands, including restrictions on the size of the supported operations.

MFC synchronization command mnemonics are listed in Table 4-106. MFC command enumerants are defined in `spu_mfcio.h`.

Table 4-106: MFC Synchronization Command Mnemonics

Mnemonic	Opcode	Command
MFC_SNDSIG_CMD	0x00A0	sndsig
MFC_SNDSIGB_CMD	0x00A1	sndsigb
MFC_SNDSIGF_CMD	0x00A2	sndsigf
MFC_BARRIER_CMD	0x00C0	barrier
MFC_EIEIO_CMD	0x00C8	mfceieio
MFC_SYNC_CMD	0x00CC	mfcsync

mfc_sndsig: Send Signal

```
(void) mfc_sndsig(volatile void *ls, uint64_t ea, uint32_t tag, uint32_t tid,
     uint32_t rid)
```

An `mfc_sndsig` command is enqueued into the DMA queue, or is stalled when the DMA queue is full. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *ls* is the local-storage

address, *ea* is the effective address in system memory, *tag* is the DMA tag, *tid* is the transfer class identifier, and *rid* is the replacement class identifier. Transfer size is fixed at 4 bytes.

Implementation

```
spu_mfcdma64(ls,mfc_ea2h(ea),mfc_ea2l(ea),4,tag,
     ((tid<<24)|(rid<<16)|MFC_SNDSIG_CMD))
```

mfc_sndsigb: Send Signal with Barrier

```
(void) mfc_sndsigb(volatile void *ls, uint64_t ea, uint32_t tag, uint32_t tid,
     uint32_t rid)
```

An `mfc_sndsigb` command is enqueued into the DMA queue, or is stalled when the DMA queue is full. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *ls* is the local-storage address, *ea* is the effective address in system memory, *tag* is the DMA tag, *tid* is the transfer class identifier, and *rid* is the replacement class identifier. Transfer size is fixed at 4 bytes. This command and all subsequent commands with the same tag ID as this command are locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), 4, tag,
     ((tid<<24)|(rid<<16)|MFC_SNDSIGB_CMD))
```

mfc_sndsigf: Send Signal with Fence

```
(void) mfc_sndsigf(volatile void *ls, uint64_t ea, uint32_t tag, uint32_t tid,
     uint32_t rid)
```

An `mfc_sndsigf` command is enqueued into the DMA queue, or is stalled when the DMA queue is full. The arguments to this function correspond to the arguments of the `spu_mfcdma64` command: *ls* is the local-storage address, *ea* is the effective address in system memory, *tag* is the DMA tag, *tid* is the transfer class identifier, and *rid* is the replacement class identifier. Transfer size is fixed at 4 bytes. This command is locally ordered with respect to all previously issued commands within the same tag group and command queue.

Implementation

```
spu_mfcdma64(ls, mfc_ea2h(ea), mfc_ea2l(ea), 4, tag,
     ((tid<<24)|(rid<<16)|MFC_SNDSIGF_CMD))
```

mfc_barrier: Enqueue mfc_barrier Command into DMA Queue or Stall When Queue is Full

```
(void) mfc_barrier(uint32_t tag)
```

An `mfc_barrier` command is enqueued into the DMA queue, or the command is stalled when the DMA queue is full. *tag* is the DMA tag. An `mfc_barrier` command guarantees that MFC commands preceding the barrier will be executed before the execution of MFC commands following it, regardless of the *tag* of preceding or subsequent MFC commands.

Implementation

```
spu_mfcdma32(0, 0, 0,  tag, MFC_BARRIER_CMD)
```

mfc_eieio: Enqueue mfc_eieio Command into DMA Queue or Stall When Queue is Full

```
(void) mfc_eieio (uint32_t tag, uint32_t tid, uint32_t rid)
```

An `mfc_eieio` command is enqueued into the DMA queue, or the command is stalled when the DMA queue is full. *tag* is the DMA tag, *tid* is the transfer class identifier, and *rid* is the replacement class identifier. Do not use this command to maintain the order of commands immediately inside a single SPE. The `mfc_eieio` command is designed to use inter-processor/device synchronization. This command creates a large load on the memory system.

Implementation

```
spu_mfcdma32(0, 0, 0, tag, ((tid<<24)|(rid<<16)|MFC_EIEIO_CMD))
```

mfc_sync: Enqueue mfc_sync Command into DMA Queue or Stall When Queue is Full

```
(void) mfc_sync (uint32_t tag)
```

An `mfc_sync` command is enqueued into the DMA queue, where *`tag`* is the DMA tag, or the command is stalled when the DMA queue is full. This function must not be used to maintain the order of commands immediately inside a single SPE. The `mfc_sync` command is designed to use inter-processor/device synchronization. This command creates a large load on the memory system.

Implementation

```
spu_mfcdma32(0, 0, 0, tag, MFC_SYNC_CMD)
```

4.7. MFC DMA Status

This section describes functions that can be used to check the completion of MFC commands or the status of entries in the MFC DMA queue.

mfc_stat_cmd_queue: Check the Number of Available Entries in the MFC DMA Queue

```
(uint32_t) mfc_stat_cmd_queue(void)
```

The number of available entries in the MFC DMA queue is checked. This information can be used to avoid stalling the execution of an SPU program if a DMA command is issued to a full queue. A full queue is 16 entries.

Implementation

```
spu_readchcnt(MFC_Cmd)
```

mfc_write_tag_mask: Set Tag Mask to Select MFC Tag Groups to be Included in Query Operation

```
(void) mfc_write_tag_mask (uint32_t mask)
```

A tag mask is set to select the MFC tag groups to be included in the query operation, where *`mask`* is the DMA tag-group query mask. Each bit of *`mask`* indicates each tag group; tag 0 is mapped to LSB.

Implementation

```
spu_writech(MFC_WrTagMask, mask)
```

mfc_read_tag_mask: Read Tag Mask Indicating MFC Tag Groups to be Included in Query Operation

```
(uint32_t) mfc_read_tag_mask(void)
```

The tag mask is read to identify MFC tag groups to be included in the query operation. Each bit of the mask indicates each tag group; tag 0 is mapped to LSB. The result represents a DMA tag-group query mask.

Implementation

```
spu_readch(MFC_RdTagMask)
```

mfc_write_tag_update: Request That Tag Status be Updated

```
(void) mfc_write_tag_update(uint32_t ts)
```

A request is sent to the MFC to update tag status, where *`ts`* specifies a tag-status update condition shown in Table 4-107. Condition enumerants are defined in `spu_mfcio.h`.

This function must precede a tag-status read with the `mfc_read_tag_status()` function. A tag-status update request should be performed after setting the tag-group mask with the `mfc_write_tag_mask()` function.

Table 4-107: MFC Write Tag Update Conditions

Number	Mnemonic	Description
0	MFC_TAG_UPDATE_IMMEDIATE	Update immediately, unconditionally.
1	MFC_TAG_UPDATE_ANY	Update tag status if or when any enabled tag group has “no outstanding operation” status.
2	MFC_TAG_UPDATE_ALL	Update tag status if or when all enabled tag groups have “no outstanding operation” status.

Implementation

```
spu_writech(MFC_WrTagUpdate, ts)
```

mfc_write_tag_update_immediate: Request That Tag Status be Immediately Updated

```
(void) mfc_write_tag_update_immediate(void)
```

A request is sent to immediately update tag status.

Implementation

```
spu_writech(MFC_WrTagUpdate, MFC_TAG_UPDATE_IMMEDIATE)
```

mfc_write_tag_update_any: Request That Tag Status be Updated for Any Enabled Completion with No Outstanding Operation

```
(void) mfc_write_tag_update_any(void)
```

A request is sent to update tag status when any enabled MFC tag-group completion has a “no operation outstanding” status.

Implementation

```
spu_writech(MFC_WrTagUpdate, MFC_TAG_UPDATE_ANY)
```

mfc_write_tag_update_all: Request That Tag Status be Updated When All Enabled Tag Groups Have No Outstanding Operation

```
(void) mfc_write_tag_update_all(void)
```

A request is sent to update tag status when all enabled MFC tag groups have a “no operation outstanding” status.

Implementation

```
spu_writech(MFC_WrTagUpdate, MFC_TAG_UPDATE_ALL)
```

mfc_stat_tag_update: Check Availability of Tag Update Request Status Channel

```
(uint32_t) mfc_stat_tag_update(void)
```

The availability of the Tag Update Request Status channel is checked. The result has one of the following values:

- 0: The Tag Update Request Status channel is not yet available.
- 1: The Tag Update Request Status channel is available.

Implementation

```
spu_readchcnt(MFC_WrTagUpdate)
```

mfc_read_tag_status: Wait for an Updated Tag Status

```
(uint32_t) mfc_read_tag_status(void)
```

The status of the tag groups is requested. Unless the tag update is set to `MFC_TAG_UPDATE_IMMEDIATE`, this call could be blocked. Each bit of a returned value indicates the status of each tag group; tag 0 is mapped to LSB. If set, the tag group has no outstanding operation (that is, commands completed) and is not masked by the query.

Only the status of the enabled tag groups at the time of the tag-group status update are valid. The bit positions that correspond to the tag groups that are disabled at the time of the tag-group status update are set to 0.

Implementation

```
spu_readch(MFC_RdTagStat)
```

mfc_read_tag_status_immediate: Wait for the Updated Status of Any Enabled Tag Group

```
(uint32_t) mfc_read_tag_status_immediate(void)
```

A request is sent to immediately update tag status. The processor waits for the status to be updated.

Implementation

```
spu_mfcstat(MFC_TAG_UPDATE_IMMEDIATE)
```

mfc_read_tag_status_any: Wait for No Outstanding Operation of Any Enabled Tag Group

```
(uint32_t) mfc_read_tag_status_any(void)
```

A request is sent to update tag status when any enabled MFC tag-group completion has a “no operation outstanding” status. The processor waits for the status to be updated.

Implementation

```
spu_mfcstat(MFC_TAG_UPDATE_ANY)
```

mfc_read_tag_status_all: Wait for No Outstanding Operation of All Enabled Tag Groups

```
(uint32_t) mfc_read_tag_status_all(void)
```

A request is sent to update tag status when all enabled MFC tag groups have a “no operation outstanding” status. The processor waits for the status to be updated.

Implementation

```
spu_mfcstat(MFC_TAG_UPDATE_ALL)
```

mfc_stat_tag_status: Check Availability of MFC_RdTagStat Channel

```
(uint32_t) mfc_stat_tag_status(void)
```

The availability of `MFC_RdTagStat` channel is checked, and one of the following values is returned:

- 0: The status is not yet available.
- 1: The status is available.

This function is used to avoid a channel stall caused by reading the `MFC_RdTagStat` channel when a status is not available.

Implementation

```
spu_readchcnt(MFC_RdTagStat)
```

mfc_read_list_stall_status: Read List DMA Stall-and-Notify Status

```
(uint32_t) mfc_read_list_stall_status(void)
```

The List DMA stall-and-notify status is read and returned, or the program is stalled until the status is available.

Implementation

```
spu_readch(MFC_RdListStallStat)
```

mfc_stat_list_stall_status: Check Availability of List DMA Stall-and-Notify Status

```
(uint32_t) mfc_stat_list_stall_status(void)
```

The availability of the List DMA stall-and-notify status is checked, and one of the following values is returned:

- 0: The status is not yet available.
- 1: The status is available.

Implementation

```
spu_readchcnt(MFC_RdListStallStat)
```

mfc_write_list_stall_ack: Acknowledge Tag Group Containing Stalled DMA List Commands

```
(void) mfc_write_list_stall_ack(uint32_t tag)
```

An acknowledgement is sent with respect to a prior stall-and-notify event. (See `mfc_read_list_status` and `mfc_stat_list_stall_status`.) The argument *`tag`* is the DMA tag.

Implementation

```
spu_writech(MFC_WrListStallAck, tag)
```

mfc_read_atomic_status: Read Atomic Command Status

```
(uint32_t) mfc_read_atomic_status(void)
```

The atomic command status is read, or the program is stalled until the status is available. As shown in Table 4-108, one of the following atomic command status results (binary value of bits 29 through 31) is returned. Status enumerants are defined in `spu_mfcio.h`.

Table 4-108: Read Atomic Command Status or Stall Until Status Is Available

Status	Mnemonic	Description
1	MFC_PUTLLC_STATUS	The `mfc_putllc` command failed (reservation lost).
2	MFC_PUTLLUC_STATUS	The `mfc_putlluc` command was completed successfully.
4	MFC_GETLLAR_STATUS	The `mfc_getllar` command was completed successfully.

Implementation

```
spu_readch(MFC_RdAtomicStat)
```

mfc_stat_atomic_status: Check Availability of Atomic Command Status

```
(uint32_t) mfc_stat_atomic_status(void)
```

The availability of the atomic command status is checked, and one of the following values is returned:

- 0: An atomic DMA command has not yet completed.
- 1: An atomic DMA command has completed and the status is available.

Implementation

```
spu_readchcnt(MFC_RdAtomicStat)
```

4.8. MFC Multisource Synchronization Request

The *Cell Broadband Engine Architecture* describes the MFC Multisource Synchronization Facility. In that document, a cumulative ordering is broadly defined as an ordering of storage accesses performed by multiple processors or units with respect to another processor or unit. In this section, several functions are described that can be used to achieve a cumulative ordering across local and main storage address domains.

mfc_write_multi_src_sync_request: Request Multisource Synchronization

```
(void) mfc_write_multi_src_sync_request(void)
```

A request is sent to start tracking outstanding transfers sent to the associated MFC. When the requested synchronization is complete, the channel count of the MFC Multisource Synchronization Request channel is reset to one.

Implementation

```
spu_writech(MFC_WrMSSyncReq,0)
```

mfc_stat_multi_src_sync_request: Check the Status of Multisource Synchronization

```
(uint32_t) mfc_stat_multi_src_sync_request(void)
```

The channel count of the MFC Multisource Synchronization Request channel is read, and one of the following values is returned:

- 0: Outstanding transfers are being tracked.
- 1: The synchronization requested by `mfc_write_multi_src_sync_request` is complete.

Implementation

```
spu_readchcnt(MFC_WrMSSyncReq)
```

4.9. SPU Signal Notification

In this section, functions are described that can be used to read signals from other processors and other devices in the system.

spu_read_signal1: Atomically Read and Clear Signal Notification 1 Channel

```
(uint32_t) spu_read_signal1(void)
```

The Signal Notification 1 channel is read, and any bits that are set are atomically reset. A signal is returned. If no signals are pending, this function will stall the SPU until a signal is issued.

Implementation

```
spu_readch(SPU_RdSigNotify1)
```

spu_stat_signal1: Check if Pending Signals Exist on Signal Notification 1 Channel

```
(uint32_t) spu_stat_signal1(void)
```

A check is made to determine whether any pending signals exist on the Signal Notification 1 channel. One of the following values is returned:

- 0: No signals are pending.
- 1: Signals are pending.

Implementation

```
spu_readchcnt(SPU_RdSigNotify1)
```

spu_read_signal2: Atomically Read and Clear Signal Notification 2 Channel

```
(uint32_t) spu_read_signal2(void)
```

The Signal Notification 2 channel is read, and any bits that are set are atomically reset. A signal is returned. If no signals are pending, a call of this function stalls the SPU until a signal is issued.

Implementation

```
spu_readch(SPU_RdSigNotify2)
```

spu_stat_signal2: Check if Any Pending Signals Exist on Signal Notification 2 Channel

```
(uint32_t) spu_stat_signal2(void)
```

A check is made to determine whether any pending signals exist on the Signal Notification 2 channel. One of the following values is returned:

- 0: No signals are pending.
- 1: Signals are pending.

Implementation

```
spu_readchcnt(SPU_RdSigNotify2)
```

4.10. SPU Mailboxes

This section describes functions that can be used to manage SPU Mailboxes.

spu_read_in_mbox: Read Next Data Entry in SPU Inbound Mailbox

```
(uint32_t) spu_read_in_mbox(void)
```

The next data entry in the SPU Inbound Mailbox queue is read. The command stalls when the queue is empty. The application-specific mailbox data is returned. Each application can uniquely define the mailbox data.

Implementation

```
spu_readch(SPU_RdInMbox)
```

spu_stat_in_mbox: Get the Number of Data Entries in SPU Inbound Mailbox

```
(uint32_t) spu_stat_in_mbox(void)
```

The number of data entries in the SPU Inbound Mailbox is returned. If the returned value is non-zero, the mailbox contains data entries that have not been read by the SPU.

Implementation

```
spu_readchcnt(SPU_RdInMbox)
```

spu_write_out_mbox: Send Data to SPU Outbound Mailbox

```
(void) spu_write_out_mbox (uint32_t data)
```

Data is sent to the SPU Outbound Mailbox, where *`data`* is application-specific mailbox data, or the command stalls when the SPU Outbound Mailbox is full.

Implementation

```
spu_writech(SPU_WrOutMbox, data)
```

spu_stat_out_mbox: Get Available Capacity of SPU Outbound Mailbox

```
(uint32_t) spu_stat_out_mbox(void)
```

The available capacity of the SPU Outbound Mailbox is returned. A value of zero indicates that the mailbox is full.

Implementation

```
spu_readchcnt(SPU_WrOutMbox)
```

spu_write_out_intr_mbox: Send Data to SPU Outbound Interrupt Mailbox

```
(void) spu_write_out_intr_mbox (uint32_t data)
```

Data is sent to the SPU Outbound Interrupt Mailbox, where *`data`* is application-specific mailbox data. The command stalls when the SPU Outbound Interrupt Mailbox is full.

Implementation

```
spu_writech(SPU_WrOutIntrMbox, data)
```

spu_stat_out_intr_mbox: Get Available Capacity of SPU Outbound Interrupt Mailbox

```
(uint32_t) spu_stat_out_intr_mbox(void)
```

The available capacity of the SPU Outbound Interrupt Mailbox is returned. A value of zero indicates that the mailbox is full.

Implementation

```
spu_readchcnt(SPU_WrOutIntrMbox)
```

4.11. SPU Decrementer

This section describes functions that use the SPU 32-bit decrementer.

spu_read_decrementer: Read Current Value of Decrementer

```
(uint32_t) spu_read_decrementer(void)
```

The current value of the decrementer is read and returned.

Implementation

```
spu_readch(SPU_RdDec)
```

spu_write_decrementer: Load a Value to Decrementer

```
(void) spu_write_decrementer (uint32_t count)
```

A `count` is loaded to the decrementer.

Implementation

```
spu_writech(SPU_WrDec, count)
```

4.12. SPU Event

This section describes several functions that can be used to monitor SPU events. See the *Cell Broadband Engine Architecture f*or a description of the SPU Event Facility.

The bit-fields of the Event Status, the Event Mask, and the Event Ack are shown in Table 4-109. Bit-field names are defined in `spu_mfcio.h`.

Table 4-109: MFC Event Bit-Fields

Bits	Field Name	Description
0x1000	MFC_MULTI_SRC_SYNC_EVENT	Multisource synchronization event
0x0800	MFC_PRIV_ATTN_EVENT	SPU privileged attention event
0x0400	MFC_LLR_LOST_EVENT	Lock-line reservation lost event
0x0200	MFC_SIGNAL_NOTIFY_1_EVENT	SPU Signal Notification 1 available event
0x0100	MFC_SIGNAL_NOTIFY_2_EVENT	SPU Signal Notification 2 available event
0x0080	MFC_OUT_MBOX_AVAILABLE_EVENT	SPU Outbound Mailbox available event
0x0040	MFC_OUT_INTR_MBOX_AVAILABLE_EVENT	SPU Outbound Interrupt Mailbox available event
0x0020	MFC_DECREMENTER_EVENT	SPU decrementer event
0x0010	MFC_IN_MBOX_AVAILABLE_EVENT	SPU Inbound Mailbox available event
0x0008	MFC_COMMAND_QUEUE_AVAILABLE_EVENT	MFC SPU command queue available event
0x0002	MFC_LIST_STALL_NOTIFY_EVENT	MFC DMA List command stall-and-notify event

Bits	Field Name	Description
0x0001	MFC_TAG_STATUS_UPDATE_EVENT	MFC tag-group status update event

spu_read_event_status: Read Event Status or Stall Until Status is Available

```
(uint32_t) spu_read_event_status(void)
```

The event status is read and returned. The command stalls until the status is available. Events that have been reported but not acknowledged will continue to be reported until acknowledged.

The return value is the value of the SPU Read Event Status channel.

Implementation

```
spu_readch(SPU_RdEventStat)
```

spu_stat_event_status: Check Availability of Event Status

```
(uint32_t) spu_stat_event_status(void)
```

The event status is checked, and one of the following values is returned:

- 0: No enabled events occurred.
- 1: Enabled events are pending.

Implementation

```
spu_readchcnt(SPU_RdEventStat)
```

spu_write_event_mask: Select Events to be Monitored by Event Status

```
(void) spu_write_event_mask (uint32_t mask)
```

Events are selected to be monitored by event status. The argument, *mask*, is the event mask.

Implementation

```
spu_writech(SPU_WrEventMask, mask)
```

spu_write_event_ack: Acknowledge Events

```
(void) spu_write_event_ack (uint32_t ack)
```

This function acknowledges that the corresponding events are being serviced by the software. The status of acknowledged events is reset, and the events are resampled. The argument, *ack*, represents events acknowledgment.

Implementation

```
spu_writech(SPU_WrEventAck, ack)
```

spu_read_event_mask: Read Event Status Mask

```
(uint32_t) spu_read_event_mask(void)
```

The current Event Status Mask is read, and the mask is returned.

Implementation

```
spu_readch(SPU_RdEventMask)
```

4.13. SPU State Management

This section describes functions that relate to interrupts. See the *Cell Broadband Engine Architecture* for a description of the SPU Machine Status channel and the SPU interrupt-related channels.

spu_read_machine_status: Read Current SPU Machine Status

```
(uint32_t) spu_read_machine_status(void)
```

The current SPU machine status is read, and the status is returned.

Implementation

```
spu_readch(SPU_RdMachStat)
```

spu_write_srr0: Write to SPU SRR0

```
(void) spu_write_srr0(uint32_t srr0)
```

The value of *srr0* is written to the SPU state save/restore register 0 (SRR0).

Implementation

```
spu_writech(SPU_WrSRR0,srr0)
```

spu_read_srr0: Read SPU SRR0

```
(uint32_t) spu_read_srr0(void)
```

The SPU state save/restore register 0 (SRR0) is read, and the state is returned.

Implementation

```
spu_readch(SPU_RdSRR0)
```

5. SPU and Vector Multimedia Extension Intrinsics

Function mapping techniques can be used to increase the portability of source code written with SPU intrinsics. One important set of intrinsic function mappings is between the SPU and PPU. This chapter describes a minimal mapping between SPU intrinsics and PPU Vector Multimedia Extension intrinsics.

For many intrinsic functions, an efficient one-to-one mapping between architectures will exist. For some functions, there could be a less efficient one-to-many instruction mapping; and for other functions, no straightforward mapping will exist because a mapping is either impractical or impossible to implement. In this document, only one-to-one mappings are identified for the SPU and PPU. For those SPU and PPU intrinsic functions for which there is no straightforward mapping, an explanation of the difficulty in mapping is provided.

The mappings between SPU and PPU intrinsics are defined in two header files: `vmx2spu.h` and `spu2vmx.h`. The former maps Vector Multimedia Extension intrinsics to generic SPU intrinsics, and the latter maps generic SPU intrinsics to Vector Multimedia Extension intrinsics. The functions that are defined in these two header files can be implemented as overloaded inline functions. To facilitate implementation, the vector data types must also be mapped.

The header file `vec_types.h` is provided to declare the single token vector data types for the Vector Multimedia Extension vector data types and to perform type mappings between the SPU and Vector Multimedia Extension. Programmers must similarly declare vector data using these single token data types. The single token vector data types for the Vector Multimedia Extension intrinsics are shown in Table 5-110.

Table 5-110: Vector Multimedia Extension Single Token Vector Data Types

Vector Keyword Data Type	Single Token Typedef
vector unsigned char	vec_uchar16
vector signed char	vec_char16
vector bool char	vec_bchar16
vector unsigned short	vec_ushort8
vector signed short	vec_short8
vector bool short	vec_bshort8
vector unsigned int	vec_uint4
vector signed int	vec_int4
vector bool int	vec_bint4
vector float	vec_float4
vector pixel	vec_pixel8

5.1. Mapping of Vector Multimedia Extension Intrinsics to SPU Intrinsics

This section lists the one-to-one mapping of Vector Multimedia Extension intrinsics to SPU intrinsics. It also lists those Vector Multimedia Extension intrinsics that are difficult to map to SPU intrinsics.

5.1.1. One-to-One Mapped Intrinsics

The Vector Multimedia Extension intrinsics that map one-to-one with the generic SPU intrinsics are shown in Table 5-111.

Table 5-111: Vector Multimedia Extension Intrinsics That Map One-to-One with SPU Intrinsics

Generic Vector Multimedia Extension Intrinsic	Maps to SPU Intrinsic	Applicable Data Type(s)
vec_add	spu_add	halfword, word, and float (not byte)
vec_addc	spu_genc	All

Generic Vector Multimedia Extension Intrinsic	Maps to SPU Intrinsic	Applicable Data Type(s)
vec_and	spu_and	All
vec_andc	spu_andc	All
vec_avg	spu_avg	unsigned char
vec_cmpeq	spu_cmpeq	All
vec_cmpgt	spu_cmpgt	All
vec_cmplt	spu_cmpgt	All (requires parameter reordering)
vec_ctf	spu_convtf	All
vec_cts	spu_convts	All
vec_ctu	spu_convtu	All
vec_madd	spu_madd	all
vec_mule	spu_mule	halfword (not byte)
vec_mulo	spu_mulo	halfword (not byte)
vec_nmusb	spu_nmsub	All
vec_nor	spu_nor	All
vec_or	spu_or	All
vec_re	spu_re	All
vec_rl	spu_rl	halfword, word (not byte)
vec_rsqrte	spu_rsqrte	All
vec_sel	spu_sel	All
vec_sub	spu_sub	halfword, word, float
vec_subc	spu_genb	All
vec_xor	spu_xor	all

5.1.2. Vector Multimedia Extension Intrinsics That Are Difficult to Map to SPU Intrinsics

The Vector Multimedia Extension intrinsics that are shown in Table 5-112 are not likely to be mapped to generic SPU intrinsics because a straightforward mapping does not exist.

Table 5-112: Vector Multimedia Extension Intrinsics That Are Difficult to Map to SPU Intrinsics

Generic Vector Multimedia Extension Intrinsic(s)	Explanation
vec_unpackh, vec_unpackl	These functions cannot be mapped without creating additional SPU data types. A mapping of `pixel` and `bool short` vector types to an `unsigned short` (as described in Table 1-2) will cause an overloaded function selection conflict.
vec_mfvscr, vec_mtvscr	Support of the VSCR register is difficult because the SPU does not support IEEE rounding modes on single-precision floating-point operations.
vec_step	Mapping requires specific compiler support that is not mandated by this specification.

5.2. Mapping of SPU Intrinsics to Vector Multimedia Extension Intrinsics

This section lists the one-to-one mapping of SPU intrinsics to Vector Multimedia Extension intrinsics. It also lists those SPU intrinsics that are difficult to map to Vector Multimedia Extension intrinsics.

5.2.1. One-to-One Mapped Intrinsics

Many of the generic SPU intrinsics map one-to-one with Vector Multimedia Extension intrinsics. These mappings are shown in Table 5-113.

Table 5-113: SPU Intrinsics That Map One-to-One with Vector Multimedia Extension Intrinsics

Generic SPU Intrinsic	Maps to Vector Multimedia Extension Intrinsic	Applicable Data Type(s)
spu_add	vec_add	vector/vector (no scalar operands)
spu_and	vec_and	vector/vector (no scalar operands)
spu_andc	vec_andc	All
spu_avg	vec_avg	All
spu_cmpeq	vec_cmpeq	vector/vector (no scalar operands)
spu_cmpgt	vec_cmpgt	vector/vector (no scalar operands)
spu_convtf	vec_ctf	Limited scale range (5 bits)
spu_convts	vec_cts	Limited scale range (5 bits)
spu_convtu	vec_ctu	Limited scale range (5 bits)
spu_genb	vec_subc	All
spu_genc	vec_addc	All
spu_madd	vec_madd	float
spu_mule	vec_mule	All
spu_mulo	vec_mulo	Halfword vector/vector (no scalar operands)
spu_nmsub	vec_nmsub	float
spu_nor	vec_nor	All
spu_or	vec_or	vector/vector (no scalar operands)
spu_re	vec_re	All
spu_rl	vec_rl	vector/vector (no scalar operands)
spu_rsqrte	vec_rsqrte	all
spu_sel	vec_sel	All
spu_sub	vec_sub	vector/vector (no scalar operands)
spu_xor	vec_xor	vector/vector (no scalar operands)

5.2.2. SPU Intrinsics That Are Difficult to Map to Vector Multimedia Extension Intrinsics

The generic SPU intrinsics that are shown in Table 5-114 are not likely to be mapped to Vector Multimedia Extension intrinsics because a straightforward mapping does not exist.

Table 5-114: SPU Intrinsics That Are Difficult to Map to Vector Multimedia Extension Intrinsics

Generic SPU Intrinsic(s)	Explanation
spu_bisled, spu_bislede, spu_bisledi	Event handling and interrupt handling on the SPU cannot be precisely mapped.
spu_idisable, spu_ienable	
spu_readch, spu_readchqw, spu_readchcnt	Specific channel functionality cannot be easily supported on the PPU, nor would it generally be desirable to do so. Whereas some channel sequences could be mapped, most would require special programmer insight and direction.
spu_writech, spu_writechqw	
spu_mfcdma32, spu_mfcdma64, spu_mfcstat	The mapping of DMA transactions typically is not needed because the PPU has full memory access. Nevertheless, these intrinsics could be used to perform memory synchronization that might not be precisely mappable.
spu_sync, spu_sync_c	These intrinsics could be mapped to one of the PPU sync instructions, but the results might not be what was intended.
spu_dsync	
spu_convts, spu_convtu, spu_convtf	The full dynamic range of scale factors is not easily supported. Vector Multimedia Extension provides a 5-bit scale factor; the SPU has an 8-bit scale factor. Some implementations might support only the 5-bit range provided by the direct mapping of the equivalent intrinsics.

Generic SPU Intrinsic(s)	Explanation
spu_hcmpeq, spu_hcmpgt	The halt instruction might be mappable to an exit function, but this will not work in all environments.
spu_stop, spu_stopd	It is not always appropriate to stop execution of the PPU.

6. PPU Intrinsics

This chapter specifies a minimal set of specific intrinsics to make the underlying PPU instruction set accessible from the C programming language. Except for `__setflm`, each of these intrinsics has a one-to-one assembly language mapping, unless compiled for a 32-bit ABI in which the high and low halves of a 64-bit doubleword are maintained in separate registers. In this latter situation, the corresponding 32-bit intrinsic might generate a sequence of instructions. In other instances, a corresponding 32-bit implementation cannot be supported.

The PPU intrinsics will be declared in the system header file, `ppu_intrinsics.h`. They may be either defined within this header as macros or implemented internally within the compiler.

Some intrinsics take a literal value of either 3, 4, 5, 6, 8, or 10 bits in length. By default, a call to an intrinsic with an out-of-range literal is reported by the compiler as an error. Compilers may provide an option to issue a warning for out-of-range literal values and use only the specified number of least significant bits for the out-of-range argument.

The intrinsics do not have a specific ordering unless otherwise noted. The intrinsics can be optimized by the compiler and be scheduled like normal operations.

__cctph: Change Thread Priority to High

```
(void) __cctph()
```

The current thread priority is changed to high priority. This intrinsic will not be reordered by the compiler.

Table 6-115: Change Thread Priority to High

Return/Argument Types	Assembly Mapping
none	cctph

__cctpl: Change Thread Priority to Low

```
(void) __cctpl()
```

The current thread priority is changed to low priority. This intrinsic will not be reordered by the compiler.

Table 6-116: Change Thread Priority to Low

Return/Argument Types	Assembly Mapping
none	cctpl

__cctpm: Change Thread Priority to Medium

```
(void) __cctpm()
```

The current thread priority is changed to medium priority. This intrinsic will not be reordered by the compiler.

Table 6-117: Change Thread Priority to Medium

Return/Argument Types	Assembly Mapping
none	cctpm

__cntlzd: Count Leading Doubleword Zeros

```
d = __cntlzd(a)
```

The number of leading zeros in the doubleword *a* is returned in *d*.

Table 6-118: Count Leading Doubleword Zeros

Return/Argument Types		Assembly Mapping	
d	a	64-bit ABI	32-bit ABI
unsigned int	unsigned long long	cntlzd d, a	cntlzw hi_cnt, a_hi cntlzw lo_cnt, a_lo rlwinm mask, hi_cnt, 26, 0, 5 srawi mask, mask, 31 and lo_cnt, lo_cnt, mask add d, hi_cnt, lo_cnt

__cntlzw: Count Leading Word Zeros

```
d = __cntlzw(a)
```

The number of leading zeros in the word *a* is returned in *d*.

Table 6-119: Count Leading Word Zeros

Return/Argument Types		Assembly Mapping
d	a	
unsigned int	unsigned int	cntlzw d, a

__db10cyc: Delay 10 Cycles at Dispatch

```
(void) __db10cyc()
```

The current thread is blocked at dispatch for 10 cycles. This intrinsic will not be reordered by the compiler.

Table 6-120: Delay 10 Cycles at Dispatch

Return/Argument Types	Assembly Mapping
none	db10cyc

__db12cyc: Delay 12 Cycles at Dispatch

```
(void) __db12cyc()
```

The current thread is blocked at dispatch for 12 cycles. This intrinsic will not be reordered by the compiler.

Table 6-121: Delay 12 Cycles at Dispatch

Return/Argument Types	Assembly Mapping
none	db12cyc

__db16cyc: Delay 16 Cycles at Dispatch

```
(void) __db16cyc()
```

The current thread is blocked at dispatch for 16 cycles. This intrinsic will not be reordered by the compiler.

Table 6-122: Delay 16 Cycles at Dispatch

Return/Argument Types	Assembly Mapping
none	db16cyc

__db8cyc: Delay 8 Cycles at Dispatch

```
(void) __db8cyc()
```

The current thread is blocked at dispatch for 8 cycles. This intrinsic will not be reordered by the compiler.

Table 6-123: Delay 8 Cycles at Dispatch

Return/Argument Types	Assembly Mapping
none	db8cyc

__dcbf: Data Cache Block Flush

```
(void) __dcbf(pointer)
```

The cache block that contains the argument *`pointer`* is flushed and removed from the cache.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

Table 6-124: Data Cache Block Flush

Return/Argument Types	Assembly Mapping
pointer	
void*	dcbf base, index

__dcbst: Data Cache Block Store

```
(void) __dcbst(pointer)
```

The cache block that contains the argument *`pointer`* is written to main memory. This intrinsic will not be reordered by the compiler.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

Table 6-125: Data Cache Block Store

Return/Argument Types	Assembly Mapping
pointer	
void*	dcbst base, index

__dcbt: Data Cache Block Touch

```
(void) __dcbt(pointer)
```

The processor receives a hint that the cache block which contains the argument *`pointer`* will soon be loaded. This intrinsic will not be reordered by the compiler.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

Table 6-126: Data Cache Block Touch

Return/Argument Types	Assembly Mapping
pointer	
void*	dcbt base, index

__dcbt_TH1000: Start Streaming Data

```
(void) __dcbt_TH1000(EATRUNC, D, UG, ID)
```

A stream is started with an id of *ID* and an effective address of EATRUNC. The argument *D* describes which direction the stream is going: `true` for forwards and `false` for backwards. The argument *UG* says if the stream is unlimited in bounds or not. This intrinsic will not be reordered by the compiler.

The effective address for this instruction is calculated as:

```
((unsigned long long) EATRUNC) & ~0x7F) | (((D & 1) << 6) | ((UG & 1) << 5) | (ID & 0xF)
```

The *base* and *index* arguments for the assembly mapping are calculated from the above effective address.

Table 6-127: Start Streaming Data

Return/Argument Types				Assembly Mapping
EATRUNC	D	UG	ID	
void*	bool	bool	int	dcbt base, index, 8

__dcbt_TH1010: Stop Streaming Data

```
(void) __dcbt_TH1010(G0, S, UNITCNT, T, U, ID)
```

The processor receives a hint that the stream identified by *ID* will no longer be needed. If *G0* is set then the program will soon load from all nascent data streams that have been completely described, and it will probably no longer load from any other nascent data streams; all the rest of the arguments are ignored in this case. If *S* is `10` then the stream associated with *ID* will stop and all other arguments except for *ID* are ignored. If *S* is `11` then all streams IDs are stopped and all other arguments are ignored. *UNITCNT* specifies the number of units in a data stream. *T* tells if the program's need for each block of the data stream is likely to be transient. *U* tells if the data stream is unlimited and the *UNITCNT* argument is ignored. This intrinsic will not be reordered by the compiler.

The effective address for this instruction is calculated as:

```
(((unsigned long long) G0 & 1) << 31)
  | ((S & 0x3) << 29)
  | ((UNITCNT & 0x3FF) << 7)
  | ((T & 1) << 6)
  | ((U & 1) << 5)
  | (ID & 0xF)
```

The *base* and *index* arguments for the assembly mapping are calculated from the above effective address.

Table 6-128: Stop Streaming Data

Return/Argument Types						Assembly Mapping
G0	S	UNITCNT	T	U	ID	
bool	int	int	bool	bool	int	dcbt base, index, 10

__dcbtst: Data Cache Block Touch for Store

```
(void) __dcbtst(pointer)
```

The processor receives a hint that the cache block that contains the argument *pointer* will soon be stored. This intrinsic will not be reordered by the compiler.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-129: Data Cache Block Touch for Store

Return/Argument Types	Assembly Mapping
pointer	
void*	dcbtst base, index

__dcbz: Data Cache Block Set to Zero

```
(void) __dcbz(pointer)
```

The cache block that contains the argument *pointer* is zeroed out. If the address is already in cache, the cache block containing it is zeroed. If the address was not already in a cache block, a cache block for it is created with all zeros. This intrinsic will not be reordered by the compiler.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-130: Data Cache Block Set to Zero

Return/Argument Types	Assembly Mapping
pointer	
void*	dcbz base, index

__eieio: Enforce In-Order Execution of I/O

```
(void) __eieio()
```

A memory barrier is created, which provides an ordering function for the storage accesses caused by *Load*, *Store*, `__dcbz()`, `__eciwx()`, and `__ecowx()` instructions executed by the processor executing the `__eieio()` instruction. The memory barrier and ordering function are described in section 1.7.1 of *PowerPC Architecture Book, Book II: PowerPC Virtual Environment Architecture, Version 2.02.*

Table 6-131: Enforce In-Order Execution of I/O

Return/Argument Types	Assembly Mapping
none	eieio

__fabs: Double Absolute Value

```
d = __fabs(a)
```

The absolute value of the argument *a* is returned in *d* with the sign bit set to zero.

Table 6-132: Double Absolute Value

Return/Argument Types		Assembly Mapping
d	a	
double	double	fabs d, a

__fabsf: Float Absolute Value

```
d = __fabsf(a)
```

The absolute value of the argument *a* is returned in *d* with the sign bit set to zero.

Table 6-133: Float Absolute Value

Return/Argument Types		Assembly Mapping
d	a	
float	float	fabs d, a

__fcfid: Convert Doubleword to Double

```
d = __fcfid(a)
```

The doubleword in *a* is converted to a floating-point and returned in *d*.

Table 6-134: Convert Doubleword to Double

Return/Argument Types		Assembly Mapping
d	a	
double	long long	fcfid d, a

__fctid: Convert Double to Doubleword

```
d = __fctid(a)
```

The `double` *a* is converted to a doubleword integer and returned in *d*. This function takes into account the current rounding mode.

Table 6-135: Convert Double to Doubleword

Return/Argument Types		Assembly Mapping
d	a	
long long	double	fctid d, a

__fctidz: Convert Double to Doubleword with Round Towards Zero

```
d = __fctidz(a)
```

The `double` *a* is converted to a doubleword integer and returned in *d*. This function always rounds towards zero.

Table 6-136: Convert Double to Doubleword with Round Towards Zero

Return/Argument Types		Assembly Mapping
d	a	
long long	double	fctidz d, a

__fctiw: Convert Double to Word

```
d = __fctiw(a)
```

The `double` *a* is converted to a word integer and returned in *d*. This function takes into account the current rounding mode.

Table 6-137: Convert Double to Word

Return/Argument Types		Assembly Mapping
d	a	

int	double	fctiw tmp, a stfiwx tmp, r1, tempspace lwzx d, r1, tempspace

__fctiwz: Convert Double to Word with Round Towards Zero

```
d = __fctiwz(a)
```

The `double` *a* is converted to a word integer and returned in *d*. This function always rounds towards zero.

Table 6-138: Convert Double to Word with Round Towards Zero

Return/Argument Types		Assembly Mapping
d	a	
int	double	fctiwz tmp, a stfiwx tmp, r1, tempspace lwzx d, r1, tempspace

__fmadd: Double Fused Multiply and Add

```
d = __fmadd(a, b, c)
```

The argument *a* is multiplied by the argument *b*, and the argument *c* is added to that product. The resulting value (*a*×*b*+*c*) is returned in *d*.

Table 6-139: Double Fused Multiply and Add

Return/Argument Types				Assembly Mapping
d	a	b	c	
double	double	double	double	fmadd d, a, b, c

__fmadds: Float Fused Multiply and Add

```
d = __fmadds(a, b, c)
```

The argument *a* is multiplied by the argument *b*, and the argument *c* is added to that product. The resulting value (*a*×*b*+*c*) is returned in *d*.

Table 6-140: Float Fused Multiply and Add

Return/Argument Types				Assembly Mapping
d	a	b	c	
float	float	float	float	fmadds d, a, b, c

__fmsub: Double Fused Multiply and Subtract

```
d = __fmsub(a, b, c)
```

The argument *a* is multiplied by the argument *b*, and the argument *c* is subtracted from that product. The resulting value (*a*×*b*-*c*) is returned in *d*.

Table 6-141: Double Fused Multiply and Subtract

Return/Argument Types				Assembly Mapping
d	a	b	c	
double	double	double	double	fmsub d, a, b, c

__fmsubs: Float Fused Multiply and Subtract

```
d = __fmsubs(a, b, c)
```

The argument *a* is multiplied by the argument *b*, and the argument *c* is subtracted from that product. The resulting value (*a*×*b*-*c*) is returned in *d*.

Table 6-142: Float Fused Multiply and Subtract

Return/Argument Types				Assembly Mapping
d	a	b	c	
float	float	float	float	fmsubs d, a, b, c

__fmul: Double Multiply

```
d = __fmul(a, b)
```

The doubles *a* and *b* are multiplied, and their product (*a*×*b*) is returned in *d*.

Table 6-143: Double Multiply

Return/Argument Types			Assembly Mapping
d	a	b	
double	double	double	fmul d, a, b

__fmuls: Float Multiply

```
d = __fmuls(a, b)
```

The floats *a* and *b* are multiplied, and their product (a×b) is returned in *d*.

Table 6-144: Float Multiply

Return/Argument Types			Assembly Mapping
d	a	b	
float	float	float	fmuls d, a, b

__fnabs: Double Negative

```
d = __fnabs(a)
```

The negative absolute value of the argument *a* is returned in *d*. The sign bit is set to 1.

Table 6-145: Double Negative

Return/Argument Types		Assembly Mapping
d	a	
double	double	fnabs d, a

__fnabsf: Float Negative

```
d = __fnabsf(a)
```

The negative absolute value of the argument *a* is returned in the *d*. The sign bit is set to 1.

Table 6-146: Float Negative

Return/Argument Types		Assembly Mapping
d	a	
float	float	fnabs d, a

__fnmadd: Double Fused Negative Multiply and Add

```
d = __fnmadd(a, b, c)
```

The arguments *a* and *b* are multiplied, and the argument *c* is added to their product. The sum is negated, and the resulting value -(*a*×*b*+*c*) is returned in *d*.

Table 6-147: Double Fused Negative Multiply and Add

Return/Argument Types				Assembly Mapping
d	a	b	c	
double	double	double	double	fnmadd d, a, b, c

__fnmadds: Float Fused Negative Multiply and Add

```
d = __fnmadds(a, b, c)
```

The arguments *a* and *b* are multiplied, and the argument *c* is added to their product. The sum is negated, and the resulting value -(*a*×*b*+*c*) is returned in *d*.

Table 6-148: Float Fused Negative Multiply and Add

Return/Argument Types				Assembly Mapping
d	a	b	c	
float	float	float	float	fnmadds d, a, b, c

__fnmsub: Double Fused Negative Multiply and Subtract

```
d = __fnmsub(a, b, c)
```

The arguments *a* and *b* are multiplied, and the argument *c* is subtracted from their product. The sum is negated, and the resulting value -(*a*×*b*-*c*) is returned in *d*.

Table 6-149: Double Fused Negative Multiply and Subtract

Return/Argument Types				Assembly Mapping
d	a	b	c	
double	double	double	double	fnmsub d, a, b, c

__fnmsubs: Float Fused Negative Multiply and Subtract

```
d = __fnmsubs(a, b, c)
```

The arguments *a* and *b* are multiplied, and the argument *c* is subtracted from their product. The sum is negated, and the resulting value -(*a*×*b*-*c*) is returned in *d*.

Table 6-150: Float Fused Negative Multiply and Subtract

Return/Argument Types				Assembly Mapping
d	a	b	c	
float	float	float	float	fnmsubs d, a, b, c

__fres: Float Reciprocal Estimate

```
d = __fres(a)
```

An estimate of the reciprocal of the argument *a* is returned in *d*. The estimate is correct to a precision of one part in 256 of the reciprocal.

Beyond this precision, the value is indeterminate; the results of executing this instruction may vary between implementations and between different executions on the same implementation.

Table 6-151: Float Reciprocal Estimate

Return/Argument Types		Assembly Mapping
d	a	
float	float	fres d, a

__frsp: Round to Single Precision

```
d = __frsp(a)
```

The argument *a* is rounded to single precision and returned in *d*.

Table 6-152: Round to Single Precision

Return/Argument Types		Assembly Mapping
d	a	
float	float	frsp d, a

__frsqrte: Double Reciprocal Square Root Estimate

```
d = __frsqrte(a)
```

An estimate of the reciprocal of the square root of the argument *a* is returned in *d*.

The estimate is correct to a precision of one part in 32 of the reciprocal of the square root. Beyond this precision, the value is indeterminate; the results of executing this instruction may vary between implementations and between different executions on the same implementation.

Table 6-153: Double Reciprocal Square Root Estimate

Return/Argument Types		Assembly Mapping
d	a	
float	double	frsqrte d, a

__fsel: Floating-Point Select of Double

```
d = __fsel(a, b, c)
```

The argument *b* is returned in *d* if the argument *a* is less than or equal to *0.0*; otherwise *c* is returned.

Table 6-154: Floating-Point Select of Double

Return/Argument Types				Assembly Mapping
d	a	b	c	
double	double	double	double	fsel d, a, b, c

__fsels: Floating-Point Select of Float

```
d = __fsels(a, b, c)
```

The argument *b* is returned in *d* if the argument *a* is less than or equal to *0.0*; otherwise *c* is returned.

Table 6-155: Floating-Point Select of Float

Return/Argument Types				Assembly Mapping
d	a	b	c	
float	float	float	float	fsel d, a, b, c

__fsqrt: Double Square Root

```
d = __fsqrt(a)
```

The square root of the argument *a* is returned in *d*.

Table 6-156: Double Square Root

Return/Argument Types		Assembly Mapping
d	a	
double	double	fsqrt d, a

__fsqrts: Float Square Root

```
d = __fsqrts(a)
```

The square root of the argument *a* is returned in *d*.

Table 6-157: Float Square Root

Return/Argument Types		Assembly Mapping
d	a	
float	float	fsqrts d, a

__icbi: Instruction Cache Block Invalidate

```
(void) __icbi(pointer)
```

The instruction cache block that contains the argument *`pointer`* is invalidated, if such a block is in the cache. This intrinsic will not be reordered by the compiler.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

Table 6-158: Instruction Cache Block Invalidate

Return/Argument Types	Assembly Mapping
pointer	
void*	icbi base, index

__isync: Instruction Sync

```
(void) __isync()
```

The processor waits until all previous instructions have finished. The `__isync()` function ensures that all `icbi` have been performed.

Table 6-159: Instruction Sync

Return/Argument Types	Assembly Mapping
none	isync

__ldarx: Load Doubleword with Reserved

```
d = __ldarx(pointer)
```

The reserved address of the processor is set to the value of *`pointer`*. A doubleword from the address in *`pointer`* is returned in *d*.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-160: Load Doubleword with Reserved

Return/Argument Types		Assembly Mapping
d	pointer	
unsigned long long	void*	ldarx d, base, index

__ldbrx: Load Reversed Doubleword

```
d = __ldbrx(pointer)
```

A doubleword from the address in *`pointer`* is loaded in reversed endian order into *`d`* and returned.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

Table 6-161: Load Reversed Doubleword

Return/Argument Types		Assembly Mapping	
d	pointer	64-bit ABI	32-bit ABI
unsigned long long	void*	ldbrx d, base, index	lwbrx d_lo, base, index lwbrx d_hi, base, index+4

__lhbrx: Load Reversed Halfword

```
d = __lhbrx(pointer)
```

A halfword from the address in *`pointer`* is loaded in reversed endian order into *d* and returned.

The *`base`* and *`index`* arguments for the assembly mapping are calculated from *`pointer`*.

Table 6-162: Load Reversed Halfword

Return/Argument Types		Assembly Mapping
d	pointer	
unsigned short	void*	lhbrx d, base, index

__lwarx: Load Word with Reserved

```
d = __lwarx(pointer)
```

The reserved address of the processor is set to the value of *pointer*. A word from the address in *pointer* is returned in *d*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-163: Load Word with Reserved

Return/Argument Types		Assembly Mapping
d	pointer	
unsigned	void*	lwarx d, base, index

__lwbrx: Load Reversed Word

```
d = __lwbrx(pointer)
```

A word from the address in *pointer* is loaded in reversed endian order into *d*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-164: Load Reversed Word

Return/Argument Types		Assembly Mapping
d	pointer	
unsigned	void*	lwbrx d, base, index

__lwsync: Light Weight Sync

```
(void) __lwsync()
```

A memory barrier is created, providing an ordering function for the storage accesses caused by prior *Load*, *Store*, and `__dcbz()` instructions that are executed by the processor executing `__lwsync()`. The memory barrier and ordering function are described in section 1.7.1 of *PowerPC Architecture Book, Book II: PowerPC Virtual Environment Architecture, Version 2.02.*

Table 6-165: Light Weight Sync

Return/Argument Types	Assembly Mapping
none	lwsync

__mffs: Move from Floating-Point Status and Control Register

```
d = __mffs()
```

The current Floating-Point Status and Control Register is returned in *d*. This intrinsic will not be reordered by the compiler.

Table 6-166: Move from Floating-Point Status and Control Register

Return/Argument Types	Assembly Mapping
d	
double	mffs d

__mfspr: Move from Special Purpose Register

```
d = __mfspr(spr)
```

The contents of the special purpose register specified by *spr* are returned in *d*. This intrinsic will not be reordered by the compiler.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-167: Move from Special Purpose Register

Return/Argument Types		Assembly Mapping
d	spr	
unsigned long long	10-bit literal unsigned int	mfspr d, spr

__mftb: Move from Time Base

```
d = __mftb()
```

The time base register is returned in *d*. This intrinsic will not be reordered by the compiler.

Table 6-168: Move from Time Base

Return/Argument Types	Assembly Mapping	
d	64-bit ABI	32-bit ABI
unsigned long long	mftb d	retry: mftbu d_hi mftb d_lo mftbu tmp cmp d_hi, tmp bne retry

__mtfsb0: Set Field of FPSCR

```
(void) __mtfsb0(bt)
```

Bit *bt* of Floating-Point Status and Control Register (FPSCR) is set to 0. This intrinsic will not be reordered by the compiler. It will also cause a barrier for floating-point operations.

Table 6-169: Set Field of FPSCR

Return/Argument Types	Assembly Mapping
bt	
5-bit unsigned int (literal)	mtfsb0 bt

__mtfsb1: Unset Field of FPSCR

```
(void) __mtfsb1(bt)
```

Bit *bt* of Floating-Point Status and Control Register is set to 1. This intrinsic will not be reordered by the compiler. It will also cause a barrier for floating-point operations.

Table 6-170: Unset Field of FPSCR

Return/Argument Types	Assembly Mapping
bt	
5-bit unsigned int (literal)	mtfsb1 bt

__mtfsf: Set Fields in FPSCR

```
(void) __mtfsf(flm, b)
```

The fields of Floating-Point Status and Control Register are set to *b* masked by the argument *flm*. This intrinsic will not be reordered by the compiler. It will also cause a barrier for floating-point operations.

Table 6-171: Set Fields in FPSCR

Return/Argument Types		Assembly Mapping
flm	b	
8-bit unsigned int (literal)	double	mtfsf flm, b

__mtfsfi: Set Field FPSCR from Other Field

```
(void) __mtfsfi(bf, u)
```

The *u* field of Floating-Point Status and Control Register is copied into the *bf* field of FPSCR. This intrinsic will not be reordered by the compiler. It will also cause a barrier for floating-point operations.

Table 6-172: Set Field FPSCR from Other Field

Return/Argument Types		Assembly Mapping
bf	u	
3-bit unsigned int (literal)	4-bit unsigned int (literal)	mtfsfi bf, u

__mtspr: Move to Special Purpose Register

```
(void) __mtspr(spr, value)
```

The special purpose register specified by *spr* is set to the argument *value*. This intrinsic will not be reordered by the compiler.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-173: Move to Special Purpose Register

Return/Argument Types		Assembly Mapping
spr	value	
10-bit unsigned int (literal)	unsigned long long	mtspr spr, value

__mulhd: Multiply Doubleword, High Part

```
d = __mulhd(a, b)
```

The high part of the signed product of the doubleword arguments *a* and *b* is returned in *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-174: Multiply Doubleword, High Part

Return/Argument Types			Assembly Mapping
d	a	b	
long long	long long	long long	mulhd d, a, b

__mulhdu: Multiply Double Unsigned Word, High Part

```
d = __mulhdu(a, b)
```

The high part of the unsigned product of the doubleword arguments *a* and *b* is returned in *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-175: Multiply Double Unsigned Word, High Part

Return/Argument Types			Assembly Mapping
d	a	b	
unsigned long long	unsigned long long	unsigned long long	mulhdu d, a, b

__mulhw: Multiply Word, High Part

```
d = __mulhw(a, b)
```

The high part of the signed product of the word arguments *a* and *b* is returned in *d*.

Table 6-176: Multiply Word, High Part

Return/Argument Types			Assembly Mapping
d	a	b	
int	int	int	mulhw d, a, b

__mulhwu: Multiply Unsigned Word, High Part

```
d = __mulhwu(a, b)
```

The high part of the unsigned product of the word arguments *a* and *b* is returned in *d*.

Table 6-177: Multiply Unsigned Word, High Part

Return/Argument Types			Assembly Mapping
d	a	b	
unsigned int	unsigned int	unsigned int	mulhwu d, a, b

__nop: No Operation

```
(void) __nop()
```

The preferred nop instruction is generated. This intrinsic will not be reordered by the compiler.

Table 6-178: No Operation

Return/Argument Types	Assembly Mapping
none	nop

__rldcl: Rotate Left Doubleword then Clear Left

```
d = __rldcl(a, b, mb)
```

The value in the argument *a* is rotated leftwards by the number of bits specified by the argument *b*. A mask is generated having 1-bits from bit *mb* through bit 63, and 0-bits elsewhere. The rotated data ANDed with the generated mask is returned into *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-179: Rotate Left Doubleword then Clear Left

Return/Argument Types				Assembly Mapping
d	a	b	mb	

unsigned long long	unsigned long long	unsigned long long	6-bit unsigned int (literal)	rldcl d, a, b, mb

__rldcr: Rotate Left Doubleword then Clear Right

```
d = __rldcr(a, b, me)
```

The value in the argument *a* is rotated leftwards by the number of bits specified by the argument *b*. A mask is generated having 1-bits from bit 0 though bit *me* and 0-bits elsewhere. The rotated data ANDed with the generated mask is returned in *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-180: Rotate Left Doubleword then Clear Right

Return/Argument Types				Assembly Mapping
d	a	b	me	
unsigned long long	unsigned long long	unsigned long long	6-bit unsigned int (literal)	rldcr d, a, b, me

__rldic: Rotate Left Doubleword Immediate then Clear

```
d = __rldic(a, sh, mb)
```

The value in the argument *a* is rotated leftwards by the number of bits specified by the argument *sh*. A mask is generated having 1-bits from bit *mb* through bit 63 - *sh* and 0-bits elsewhere. The rotated data ANDed with the generated mask is returned in *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-181: Rotate Left Doubleword Immediate then Clear

Return/Argument Types				Assembly Mapping
d	a	sh	mb	
unsigned long long	unsigned long long	6-bit unsigned int (literal)	6-bit unsigned int (literal)	rldic d, a, sh, mb

__rldicl: Rotate Left Doubleword Immediate then Clear Left

```
d = __rldicl(a, sh, mb)
```

The value in the argument *a* is rotated leftwards by the number of bits specified by the argument *sh*. A mask is generated having 1-bits from bit *mb* through bit 63 and 0-bits elsewhere. The rotated data ANDed with the generated mask is returned in *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-182: Rotate Left Doubleword Immediate then Clear Left

Return/Argument Types				Assembly Mapping
d	a	sh	mb	
unsigned long long	unsigned long long	6-bit unsigned int (literal)	6-bit unsigned int (literal)	rldicl d, a, sh, mb

__rldicr: Rotate Left Doubleword Immediate then Clear Right

```
d = __rldicr(a, sh, me)
```

The value in the argument *a* is rotated leftwards by the number of bits specified by the argument *sh*. A mask is generated having 1-bits from bit 0 though bit *me* and 0-bits elsewhere. The rotated data ANDed with the generated mask is returned in *d*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-183: Rotate Left Doubleword Immediate then Clear Right

Return/Argument Types				Assembly Mapping
d	a	sh	me	
unsigned long long	unsigned long long	6-bit unsigned int (literal)	6-bit unsigned int (literal)	rldicr d, a, sh, me

__rldimi: Rotate Left Doubleword Immediate then Mask Insert

```
d = __rldimi(a, b, sh, mb)
```

A mask is generated with 1-bits from bit *mb* through bit 63-*sh*, and 0-bits elsewhere. The value in *a* is ANDed with the complement of this mask, zeroing out just the bits inside the range *mb* through 63-*sh*. The argument *b* is rotated left by *sh* bits and ANDs the result with the mask, zeroing out all bits outside the range *mb* through 63-*sh*. The two masked values are combined together with inclusive OR, and returned in *c*.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-184: Rotate Left Doubleword Immediate then Mask Insert

Return/Argument Types					Assembly Mapping
d	a	b	sh	mb	
unsigned long long	unsigned long long	unsigned long long	6-bit unsigned int (literal)	6-bit unsigned int (literal)	mr d, a rldimi d, b, sh, mb

__rlwimi: Rotate Left Word Immediate then Mask Insert

```
d = __rlwimi(a, b, sh, mb, me)
```

A mask is generated with 1-bits from bit *mb* through bit *me*, and 0-bits elsewhere. The value in *a* is ANDed with the complement of this mask, zeroing out just the bits inside the range *mb* through me. The argument *b* is rotated left by *sh* bits and ANDs the result with the mask, zeroing out all bits outside the range *mb* through *me*. The two masked values are combined together with inclusive OR, and returned in *d*.

Table 6-185: Rotate Left Word Immediate then Mask Insert

Return/Argument Types						Assembly Mapping
d	a	b	sh	mb	me	
unsigned int	unsigned int	unsigned int	5-bit unsigned int (literal)	5-bit unsigned int (literal)	5-bit unsigned int (literal)	mr d, a rlwimi d, b, sh, mb, me

__rlwinm: Rotate Left Word Immediate then AND With Mask

```
d = __rlwinm(a, sh, mb, me)
```

A mask is generated with 1-bits from *mb* through bit *me*, and 0-bits elsewhere. The value in *a* is rotated left by *sh* bits, then ANDed with this mask, and returned in *d*.

Table 6-186: Rotate Left Word Immediate then AND With Mask

Return/Argument Types					Assembly Mapping
d	a	sh	mb	me	
unsigned int	unsigned int	5-bit unsigned int (literal)	5-bit unsigned int (literal)	5-bit unsigned int (literal)	rlwinm d, a, sh, mb, me

__rlwnm: Rotate Left Word then AND With Mask

```
d = __rlwnm(a, b, mb, me)
```

The argument *a* is rotated leftwards by the argument *b*. A mask is generated having 1-bits from bit *mb* through bit *me*, and 0-bits elsewhere. The rotated data ANDed with the generated mask is returned in *d*.

Table 6-187: Rotate Left Word then AND With Mask

Return/Argument Types					Assembly Mapping
d	a	b	mb	me	
unsigned int	unsigned int	unsigned int	5-bit unsigned int (literal)	5-bit unsigned int (literal)	rlwnm d, a, b, mb, me

__setflm: Save and Set the FPSCR

```
d = __setflm(a)
```

The Floating-Point Status and Control Register is set to *a*, and the context of that register is returned in *b*. This intrinsic will not be reordered by the compiler. It will also cause a barrier for floating-point operations.

Table 6-188: Save and Set the FPSCR

Return/Argument Types		Assembly Mapping
d	a	
double	double	mffs d; mtfst 0xFF, a

__stdbrx: Store Reversed Doubleword

```
(void) __stdbrx(pointer, b)
```

The argument *b* is stored in reversed endian order into the doubleword located at the argument *pointer*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-189: Store Reversed Doubleword

Return/Argument Types		Assembly Mapping	
pointer	b	64-bit ABI	32-bit ABI
void*	unsigned long long	stdbrx b, base, index	stwbrx b_lo, base, index stwbrx b_hi, base, index+4

__stdcx: Store Doubleword Conditional

```
d = __stdcx(pointer, b)
```

If the reserved address of the processor is the value in the argument *pointer*, *b* is stored into the doubleword at the argument *pointer*, and the value of 1 is returned in *d*. Otherwise, the store is not performed, and the value of 0 is returned in *d*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

The instruction `stdcx.` returns its value in `cr0.eq`, the `equals` field of conditional register 0.

This intrinsic might not be supported when compiling for 32-bit ABIs in which a 64-bit doubleword is maintained in two separate registers.

Table 6-190: Store Doubleword Conditional

Return/Argument Types			Assembly Mapping
d	pointer	b	
bool	void*	unsigned long long	stdcx. b, base, index; d = cr0.eq

__sthbrx: Store Reversed Halfword

```
(void) __sthbrx(pointer, b)
```

The argument *b* is stored in reversed endian order into the halfword located at the argument *pointer*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-191: Store Reversed Halfword

Return/Argument Types		Assembly Mapping
pointer	b	
void*	unsigned short	sthbrx b, base, index

__stwbrx: Store Reversed Word

```
(void) __stwbrx(pointer, b)
```

The argument *b* is stored in reversed endian order into the word located at the argument *pointer*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

Table 6-192: Store Reversed Word

Return/Argument Types		Assembly Mapping
pointer	b	
void*	unsigned	stwbrx b, base, index

__stwcx: Store Word Conditional

```
d = __stwcx(pointer, b)
```

If the reserved address of the processor is the value in the argument *pointer*, *b* is stored into the word at the argument *pointer*, and the value of 1 is returned in *d*. Otherwise, the store is not performed, and the value of 0 is returned in *d*.

The *base* and *index* arguments for the assembly mapping are calculated from *pointer*.

The instruction `stwcx.` returns its value in `cr0.eq`, the `equals` field of conditional register 0.

Table 6-193: Store Word Conditional

Return/Argument Types			Assembly Mapping
d	pointer	b	
bool	void*	unsigned	stwcx. b, base, index; d = cr0.eq

__sync: Sync

```
(void) __sync()
```

A memory barrier is created, providing an ordering function for all instructions executing on the same processor. The memory barrier and ordering function are described in section 1.7.1 of *PowerPC Architecture Book, Book II: PowerPC Virtual Environment Architecture, Version 2.02.*

Table 6-194: Sync

Return/Argument Types	Assembly Mapping
none	sync

7. PPU VMX Intrinsics

This chapter describes intrinsics which make the underlying PPU VMX instruction set accessible from the C and C++ programming languages. The *AltiVec Technology Programming Interface Manual*, Section 4.4, defines most of the generic intrinsics for the PPU VMX instruction set, except for a few new instructions which are specified in this chapter. The new intrinsics are in two different categories: intrinsics for extracting vector elements and intrinsics for inserting vector elements.

The PPU VMX intrinsics will be declared in the system header file `altivec.h`. These intrinsics may be either defined as macros within this header or implemented internally within the compiler.

For data prefetches, the `__dcbt`, `__dcbtst`, `__dcbt_TH1000`, and `__dcbt_TH1010` intrinsics should be used. The related stream control operations that are defined in the *AltiVec Technology Programming Interface Manual*, which are listed below, have been deprecated on the PPU and will execute as a NOP.

Table 7-195: Stream Control Operators That Have Been Deprecated on the PPU

Stream Control Operator	Description
vec_dss(a)	Vector Data Stream Stop
vec_dssall()	Vector Stream Stop All
vec_dst(a,b,c)	Vector Stream Touch
vec_dstst(a,b,c)	Vector Data Stream Touch for Store Transient

vec_extract: Extract Vector Element from Vector

```
d = vec_extract(a, element)
```

The element that is specified by *element* is extracted from vector *a* and returned in scalar *d*. Depending on the size of the element, only a limited number of the least significant bits of the *element* index are used. Specifically for 1-, 2-, and 4-byte elements, only four, three, and two of the least significant bits are used, respectively.

Table 7-196: Extract Vector Element from Vector

Return/Argument Types			Assembly Mapping[1]
d	a	element	
unsigned char	vector unsigned char	int	EA=memaddr + (element&0xF) stvebx a, 0, EA lbzx d, 0, EA
signed char	vector signed char		EA=memaddr + (element&0xF) stvebx a, 0, EA lbzx d, 0, EA extsb d, d
unsigned short	vector unsigned short		EA=memaddr + (element&0x7)<<2 stvehx a, 0, EA lhzx d, 0, EA
signed short	vector signed short		EA=memaddr + (element&0x7)<<2 stvehx a, 0, EA lhzx d, 0, EA extsh d, d
unsigned int	vector unsigned int		EA=memaddr + (element&0x3)<<3 stvewx a, 0, EA lwzx a, 0, EA
signed int	vector signed int		EA=memaddr + (element&0x3)<<3 stvewx a, 0, EA lwzx a, 0, EA extsw d, d [2]
float	vector float		EA=memaddr + (element&0x3)<<3 stvewx a, 0, EA lfsx a, 0, EA

[1] memaddr is the address of a temporary memory location which is 16-byte aligned.

[2] The sign extend from word to doubleword can be omitted if the processor is running in 32-bit mode.

vec_insert: Insert Scalar into Specified Vector Element

```
d = vec_insert(a, b, element)
```

Scalar *a* is inserted into the element of vector *b* that is specified by the *element* parameter, and the modified vector is returned. All other elements of *b* are unmodified. Depending on the size of the element, only a limited number of the least significant bits of the *element* index are used. Specifically for 1-, 2-, and 4-byte elements, only four, three, and two of the least significant bits are used, respectively.

Table 7-197: Insert Scalar into Specified Vector Element

Return/Argument Types				Assembly Mapping[1]
d	a	b	element	
vector unsigned char	unsigned char	vector unsigned char	int	EA=memaddr + (element&0xF) stbx a, 0, EA lvebx d, 0, EA vperm d, d, a, pattern
vector signed char	signed char	vector signed char		
vector unsigned short	unsigned short	vector unsigned short		EA=memaddr + (element&0x7)<<2 sthx a, 0, EA lvehx d, 0, EA vperm d, d, a, pattern
vector signed short	signed short	vector signed short		
vector unsigned int	unsigned int	vector unsigned int		EA=memaddr + (element&0x3)<<3 stwx a, 0, EA lvewx d, 0, EA vperm d, d, a, pattern
vector signed int	signed int	vector signed int		
vector float	float	vector float		EA=memaddr + (element&0x3)<<3 stfsx a, EA lvewx d, 0, EA vperm d, d, a, pattern

[1] memaddr is the address of a temporary memory location which is 16-byte aligned.

vec_lvlx: Load Vector Left Indexed

```
d = vec_lvlx(a, b)
```

Let EA be the effective address formed from the sum of the contents of *a* and the contents of *b* and let `eb` be the value of the four least significant bits of EA. The (16 - `eb`) bytes addressed by EA are loaded into the leftmost (16 - `eb`) byte elements of *d* and the rightmost `eb` byte of *d* are set to zero.

Table 7-198: Load Vector Left Indexed

Return/Argument Types			Assembly Mapping
d	a	b	
vector unsigned char	any integral type	unsigned char *	lvlx d, a, b
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_lvlxl: Load Vector Left Indexed Last

```
d = vec_lvlxl(a, b)
```

Let EA be the effective address formed from the sum of the contents of *a* and the contents of *b* and let eb be the value of the four least significant bits of EA. The (16 - eb) bytes addressed by EA are loaded into the leftmost (16 - eb) bytes of *d* and the rightmost eb bytes of *d* are set to zero. `vec_lvlxl` provides a hint that the quadword in memory addressed by EA will probably not be needed again by the program in the near future.

Table 7-199: Load Vector Left Indexed Last

Return/Argument Types			Assembly Mapping
d	a	b	
vector unsigned char	any integral type	unsigned char *	lvlxl d, a, b
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_lvrx: Load Vector Right Indexed

```
d = vec_lvrx(a, b)
```

Let EA be the effective address formed from the sum of the contents of *a* and the contents of *b* and let eb be the value of the four least significant bits of EA. If eb is not equal to zero (for example, EA is not quadword-aligned), then eb bytes in memory addressed by (EA - eb) are loaded into the rightmost eb bytes of *d* and the leftmost (16 - eb) bytes of *d* are set to zero. If eb is equal to zero (for example, EA is quadword-aligned), then the contents of *d* are set to zero.

Table 7-200: Load Vector Right Indexed

Return/Argument Types			Assembly Mapping
d	a	b	
vector unsigned char	any integral type	unsigned char *	lvrx d, a, b
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_lvrxl: Load Vector Right Indexed Last

```
d = vec_lvrxl(a,b)
```

Let EA be the effective address formed from the sum of the contents of *a* and the contents of *b* and let eb be the value of the four least significant bits of EA. If eb is not equal to zero (for example, EA is not quadword-aligned), then eb bytes in memory addressed by (EA - eb) are loaded into the rightmost eb bytes of *d* and the leftmost (16 - eb) bytes of *d* are set to zero. If eb is equal to zero (for example, EA is quadword-aligned), then the contents of *d* are set to zero. `vec_lvrxl` provides a hint that the quadword in memory addressed by EA will probably not be needed again by the program in the near future.

Table 7-201: Load Vector Right Indexed Last

Return/Argument Types			Assembly Mapping
d	a	b	
vector unsigned char	any integral type	unsigned char *	lvrxl d, a, b
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_stvlx: Store Vector Left Indexed

```
(void) vec_ stvlx(a, b, c)
```

Let EA be the effective address formed from the sum of the contents of *b* and the contents of *c*, and let eb be the value of the four least significant bits of EA. Store the (16 - eb) leftmost bytes of *a* into the memory addressed by EA.

Table 7-202: Store Vector Left Indexed

Return/Argument Types			Assembly Mapping
a	b	c	
vector unsigned char	any integral type	unsigned char *	stvlx a, b, c
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_ stvlxl: Store Vector Left Indexed Last

```
(void) vec_ stvlxl(a, b, c)
```

Let EA be the effective address formed from the sum of the contents of *b* and the contents of *c*, and let eb be the value of the four least significant bits of EA. Store the (16 - eb) leftmost bytes of *a* into the memory addressed by EA. `vec_stvlxl` provides a hint that the quadword in memory addressed by EA will probably not be needed again by the program in the near future.

Table 7-203: Store Vector Left Indexed Last

Return/Argument Types			Assembly Mapping
a	b	c	
vector unsigned char	any integral type	unsigned char *	stvlxl a, b, c
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_ stvrx: Store Vector Right Indexed

```
(void) vec_ stvrx(a, b, c)
```

Let EA be the effective address formed from the sum of the contents of *b* and the contents of *c*, and let eb be the value of the four least significant bits of EA. Store the eb rightmost bytes of *a* into the memory addressed by (EA - eb). If eb is zero, EA is 16-byte aligned, and no memory is stored.

Table 7-204: Store Vector Right Indexed

Return/Argument Types			Assembly Mapping
a	b	c	
vector unsigned char	any integral type	unsigned char *	stvrx a, b, c
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_ stvrxl: Store Vector Right Indexed Last

```
(void) vec_ stvrxl(a, b, c)
```

Let EA be the effective address formed from the sum of the contents of *b* and the contents of *c*, and let eb be the value of the four least significant bits of EA. Store the eb rightmost bytes of *a* into the memory addressed by (EA - eb). If eb is zero, EA is 16-byte aligned, no memory is stored. `vec_stvrxl` provides a hint that the quadword in memory addressed by EA will probably not be needed again by the program in the near future.

Table 7-205: Store Vector Right Indexed Last

Return/Argument Types			Assembly Mapping
a	b	c	
vector unsigned char	any integral type	unsigned char *	stvrxl a, b, c
		vector unsigned char *	
vector signed char	any integral type	signed char *	
		vector signed char *	
vector bool char	any integral type	vector bool char *	
vector unsigned short	any integral type	unsigned short *	
		vector unsigned short *	
vector signed short	any integral type	signed short *	
		vector signed short *	
vector bool short	any integral type	vector bool short *	
vector pixel	any integral type	vector pixel *	
vector unsigned int	any integral type	unsigned int *	
		vector unsigned int *	
vector signed int	any integral type	signed int *	
		vector signed int *	
vector bool int	any integral type	vector bool int *	
vector float	any integral type	float *	
		vector float *	

vec_promote: Promote Scalar to a Vector

```
d = vec_promote(a, element)
```

Scalar *a* is promoted to a vector containing *a* in the element that is specified by the `element` parameter, and the result is returned in vector *d*. All other elements of *d* are undefined. Depending on the size of *a*, only a limited number of the least significant bits of the `element` index are used. Specifically for 1-, 2-, and 4-byte elements, only four, three, and two of the least significant bits are used, respectively.

Table 7-206: Promote Scalar to a Vector

Return/Argument Types			Assembly Mapping[1]
d	a	element	
vector unsigned char	unsigned char	int	EA=memaddr + (element&0xF) stbx a, 0, EA lvebx d, 0, EA
vector signed char	signed char		
vector unsigned short	unsigned short		EA=memaddr + (element&0x7)<<2 sthx a, 0, EA lvehx d, 0, EA
vector signed short	signed short		
vector unsigned int	unsigned int		EA=memaddr + (element&0x3)<<3 stwx a, 0, EA lvewx d, 0, EA
vector signed int	signed int		
vector float	float		EA=memaddr + (element&0x3)<<3 stfsx a, EA lvewx d, 0, EA

[1] memaddr is the address of a temporary memory location which is 16-byte aligned.

vec_splats: Splat Scalar to a Vector

```
d = vec_splats(a)
```

The single scalar *a* value is replicated across all elements of a vector of the same type and the result is returned in vector *d*.

Table 7-207: Splat Scalar to a Vector

Return/Argument Types		Assembly Mapping
d	a	
vector unsigned char	unsigned char	store a into memory (EA) that 16-byte aligned lvebx/lvehx/lvewx tmp, 0, EA vspltb/vsplth/vspltw d, tmp, 0
vector signed char	signed char	
vector unsigned short	unsigned short	
vector signed short	signed short	
vector unsigned int	unsigned int	
vector signed int	signed int	
vector float	float	
vector unsigned char	unsigned char (5-bit unsigned literal)	vspltisb d, a *or* vspltish d, a *or* vspltisw d, a *or* vspltisw d, a
vector signed char	signed char (5-bit unsigned literal)	
vector unsigned short	unsigned short (5-bit unsigned literal)	
vector signed short	signed short (5-bit unsigned literal)	
vector unsigned int	unsigned int (5-bit unsigned literal)	
vector signed int	signed int (5-bit unsigned literal)	
vector float	float (5-bit unsigned literal)	

8. SPU C and C++ Standard Libraries and Language Support

This chapter describes differences between the implementations of the C and C++ standard libraries on the SPU and the corresponding IS0/IEC standards. It also identifies common language features that are specifically not supported on the SPU.

8.1. Standard Libraries

The C and C++ standard libraries that are required for the SPU are based on the Standard C Library described in ISO/IEC Standard 9899:1999 and the C++ Standard Library described in ISO/IEC Standard 14882:1998. However, neither library must be a fully compliant implementation of the respective ISO/IEC standard.

The proposed differences from ISO/IEC compliant implementations are due to two reasons: 1) The SPU does not have the same system resources and operating system support that are available to most stand-alone processors; and 2) the SPU hardware doesn't fully support the IEEE floating-point standard. Because of the SPU's limited operating system support, library functions that require system calls, thread facilities, and file input/output (I/0) may not be supported. Because of differences in floating-point behavior, the results of single-precision floating-point functions will probably be less accurate than defined by the Standard, and floating-point exceptions will be less reliable. Nevertheless, the standard library functions that are provided should execute fast, in most cases.

The minimum C and C++ library features that must be provided for the SPU are described in the following sections.

8.1.1. C Standard Library

This section describes the minimum requirements of a compliant C standard library implementation.

Library Contents

All of the entities required in the C standard library must be declared and defined within the library header files listed in Table 8-208. Differences between the contents of these header files and the header files that comprise the ISO Standard Library are identified in the table. For a detailed description of the particular entities, see the ISO/IEC C Standard listed in the "Related Documentation" section.

Table 8-208: C Library Header Files

Header Name	Description
assert.h	Enforce assertions when functions execute. The `assert` macro reports assertion failures using the special debug `printf` (described below).
complex.h	Perform complex arithmetic.
ctype.h	Classify characters. The functions declared in this header use only the "C" locale.
errno.h	Test error codes reported by library functions.
fenv.h	Control IEEE style floating-point arithmetic. Macros for single- and double-precision exceptions are described in "9.2.2. Floating-Point Exceptions".
float.h	Test floating-point type properties. These properties are specified in section "9.1. Properties of Floating-Point Data Type Representations".
inttypes.h	Convert various integer types.
iso646.h	Program in ISO 646 variant character sets.
limits.h	Test integer type properties. The macro `MB_LEN_MAX` is defined as 1.
locale.h	Not available.
math.h	Compute common mathematical functions. The floating-point behavior of these functions will adhere to the specifications described in section "9.3. Floating-Point Operations". Although not specified or required, corresponding vector versions of the math functions may be added to the library to take advantage of the many high-performance SIMD (single instruction, multiple data) instructions provided by the SPU hardware.
setjmp.h	Execute nonlocal goto statements.
signal.h	Not available.

Header Name	Description
stdarg.h	Access a varying number of arguments.
stdbool.h	Define a convenient Boolean type name and constants.
stddef.h	Define several useful types and macros. The `wchar_t` is not defined.
stdint.h	Define various integer types with size constraints. `SIG_ATOMIC_MAX` and `SIG_ATOMIC_MIN` are not defined, nor are any of the `WCHAR_MAX`, `WCHAR_MIN`, `WINT_MAX`, and `WINT_MIN`.
stdio.h	Not available, except for `printf`, which is provided for debugging. (See section "Debug printf()".)
stdlib.h	Perform a variety of operations. The functions `getenv`, `mblen`, `mbstowcs`, `mbtowc`, `system`, `wcstombs`, and `wctomb` are not defined. The type `wchar_t` and the macro `MB_CUR_MAX` are also not defined.
string.h	Manipulate several kinds of strings. The function `strxfrm` uses only the "C" locale.
tgmath.h	Declare various type-generic math functions. Single-precision functions declared in this header adhere to the same specifications described for the corresponding functions that are declared in `math.h`.
time.h	Not available.
wchar.h	Not available.
wctype.h	Not available.

Debug printf()

A `printf()` function will be provided for application debugging. The implementation of this function depends on the particular services provided by the underlying operating system. Although detailed specifications for this function are not mandated by this document, a full-featured implementation is recommended. Such an implementation would include all of the usual output format conversion specifiers required by the C standard. In addition, conversion specifiers of the type described in the *AltiVec Technology Programming Interface Manual* are recommended to handle vector output formatting. Output conversion specifiers take the following form:

```
%[<flags>][<width>][<precision>][<size>]<conversion>
```

where

```
<flags>             ::= <flag-char> | <flags><flag-char>
<flag-char>         ::= <std-flag-char> | <c-sep>
<std-flag-char>     ::= '-' | '+' | '0' | '#' | ' '
<c-sep>             ::= ',' | ';' | ':' | '_'
<width>             ::= <decimal-integer> | '*'
<precision>         ::= '.' <width> | '.' | '.*'
<size>              ::= 'hh' | 'h' | 'l' | 'll' | 'L' | <vector-size>
<vector-size>       ::= 'v' | 'vhh' | 'vh' | 'vl' | 'vll' | 'vL' | 'hhv'
                        | 'hv' | 'lv'| 'llv' | 'Lv'
<conversion>        ::= <char-conv> | <str_conv> | <fp-conv> | <int-conv>
                        | <byte-conv> | <misc-conv>
<char-conv>         ::= 'c'
<str-conv>          ::= 's'
<fp-conv>           ::= 'e' | 'E' | 'f' | 'F' | 'g' | 'G'
<int-conv>          ::= 'd' | 'i' | 'u' | 'p' | 'o' |'x' | 'X'
<byte-conv>         ::= 'uc' | 'co' | 'cx' | 'cX'
<misc-conv>         ::=  'n' | '%'
```

Extensions to the C standard output conversion specification are shown in bold for vector types. Vector types are formatted using the conversions shown in Table 8-209. String conversions (<str-conv>) and miscellaneous conversions (<misc-conv>) are not defined for vectors. The ‘p’ integer conversion (<int-conv>) is also not defined. The default separator (<c-sep>) is a space, except for character conversion (<char-conv>), which has no separator.

Table 8-209: Vector Formats

Vector Size	Conversion	Description
v	<char-conv>	A vector is printed as a vector char, consisting of 16 one-byte elements. The ‘c’ conversion prints contiguous ASCII characters.
v	<int-conv> <byte-conv>	With the ‘uc’ conversion, a vector is printed as a vector unsigned char, consisting of 16 one-byte elements. Similarly, the ‘co’, ‘cx’, and ‘cX’ conversions print either a vector unsigned char or a qword, in octal format or in hexadecimal format. For all other integer conversions, a vector is printed in the respective octal (o), integer (d, i, u) or hexadecimal (x, X) format, either as a vector unsigned int or as a vector signed int, consisting of 4 four-byte elements.
v	<fp-conv>	A vector is printed in a signed decimal fractional representation, either in standard decimal notation (f or F) or with a decimal power-of-ten exponent (e, E, g, G). The representation is printed as a vector float, containing 4 four-byte elements.
vhh or hhv	<int-conv>	A vector is printed in the respective octal (o), integer (d, i, u), or hexadecimal (x, X) format, either as a vector unsigned char or as a vector signed char, consisting of 16 one-byte elements.
vh or hv	<int-conv>	A vector is printed in the respective octal (o), integer (d, i, u), or hexadecimal (x, X) format, either as a vector unsigned short or as a vector signed short, consisting of 8 two-byte elements.
vl or lv	<int-conv>	A vector is printed in the respective octal (o), integer (d, i, u), or hexadecimal (x, X) format, as a vector unsigned int or as a vector signed int, consisting of 4 four-byte elements.
vll or llv	<int-conv>	A vector is printed in the respective octal (o), integer (d, i, u), or hexadecimal (x, X) format, as a vector unsigned long long or as a vector signed long long, consisting of 2 eight-byte elements.
vL or Lv	<fp-conv>	A vector is printed in a signed decimal fractional representation, either in standard decimal notation (f or F) or with a decimal power-of-ten exponent (e, E, g, G). The representation is printed as a vector double, consisting of 2 eight-byte elements.

Malloc Heap

The `malloc` heap is defined to begin at `_end` and to extend to the end of the stack. The memory heap may be enlarged by a heap-extending function. This function would negatively adjust the Available Stack Size element of the current Stack Pointer Information register and all Available Stack Sizes residing in the saved SP registers found in the sequence of Back Chain quadwords.

Whenever the `malloc` heap is enlarged, code should verify that the enlarged `malloc` heap does not extend into the currently used stack. If it does, the operation should fail.

Implementations of `setjmp`/`longjmp` are also affected by the use of heap-extending functions. When restoring the Stack Pointer Information register as a result of invoking the `longjmp` function, the function must detect any change to the Available Stack Size between `setjmp` and `longjmp`, and it must correct the saved Stack Pointer Information register. For example:

```
SP.avail_stack_size = SP_set.stack_ptr - SP.stack_ptr +
      SP.avail_stack_size;
```

where SP is the current Stack Pointer Information register, and `SP_set` is the Stack Pointer Information register saved at the last `setjmp` call.

8.1.2. C++ Standard Library

This section describes the minimum contents of the C++ standard library.

As with the C library, the C++ library header files declare or define the contents of the C++ library. Table 8-210 lists the header files that comprise the core of the C++ standard library. Differences between the contents of the C++ header files and the header files that comprise the ISO Standard Library are noted in this table.

Table 8-210: C++ Library Header Files

Header Name	Description
algorithm	Define numerous templates that implement useful algorithms.
bitset	Define a template class that administers sets of bits.
complex	Define a template class that supports complex arithmetic.
deque	Define a template class that implements a deque container.
exception	Not available.
fstream	Not available.
functional	Define several templates that help construct predicates for the templates defined in algorithm and numeric.
iomanip	Not available.
ios	Not available.
iosfwd	Not available.
iostream	Not available.
istream	Not available.
iterator	Define several templates that help define and manipulate iterators.
limits	Test numeric type properties.
list	Define a template class that implements a doubly linked list container.
locale	Not available.
map	Define template classes that implement associative containers that map keys to values.
memory	Define several templates that allocate and free storage for various container classes.
new	Declare several functions that allocate and free storage.
numeric	Define several templates that implement useful numeric functions.
ostream	Not available.
queue	Define a template class that implements a queue container.
set	Define template classes that implement associative containers.
slist	Define a template class that implements a singly linked list container.
sstream	Not available.
stack	Define a template class that implements a stack container.
stdexcept	Not available.
streambuf	Not available.
string	Define a template class that implements a string container.
strstream	Not available.
typeinfo	Not available.
utility	Define several templates of general utility.
valarray	Define several classes and template classes that support value-oriented arrays.
vector	Define a template class that implements a vector container.

The C++ standard library contains new-style C++ header files that correspond to 12 traditional C header files. Both the new-style and the traditional-style header files are included in the library. These header files are listed in Table 8-211.

Table 8-211: New and Traditional C++ Library Header Files

New-Style Header Name	Traditional Header Name	Description
cassert	assert.h	Enforce assertions when functions execute.[1]
cctype	ctype.h	Classify characters.[1]
cerrno	errno.h	Test error codes reported by library functions.[1]
cfloat	float.h	Test floating-point type properties.
ciso646	iso646.h	Program in ISO 646 variant character sets.
climits	limits.h	Test integer type properties.[1]
clocale	locale.h	Not available.
cmath	math.h	Compute common mathematical functions.[1]
csetjmp	setjmp.h	Execute nonlocal goto statements.
csignal	signal.h	Not available.
cstdarg	stdarg.h	Access a varying number of arguments.
cstddef	stddef.h	Define several useful types and macros.[1]
cstdio	stdio.h	Not available.
cstdlib	stdlib.h	Perform a variety of operations.[1]
cstring	string.h	Manipulate several kinds of strings.[1]
ctime	time.h	Not available.
cwchar	wchar.h	Not available.
cwctype	wctype.h	Not available.

[1] See Table 8-208: C Library Header Files, for specific implementation limitations.

8.2. Non-Supported Language Features

C and C++ implementations should comply with the language features prescribed in the respective ISO/IEC standards, as much as possible. However, certain features are specifically not supported because of SPU architecture limitations. Currently, the only non-supported feature is C++ exception handling.

9. Floating-Point Arithmetic on the SPU

Annex F of the C99 language standard (ISO/IEC 9899) specifies support for the IEC 60559 floating-point standard. This chapter describes differences from Annex F and ISO/IEC Standard 60559 that apply to SPU compilers and libraries.

Floating-point behavior is essentially dictated by the SPU hardware. For single precision, the hardware provides an extended single-precision number range. Denorm arguments are treated as 0, and `NaN` and Infinity are not supported. The only rounding mode that is supported is truncation (round towards 0), and exceptions apply only to certain extended range floating-point instructions). For double precision, the hardware provides the standard IEEE number range, but again, denorm arguments are treated as 0. IEEE exceptions are detected and accumulated in the FPSCR register, and the IEEE rules for propagation of `NaN`s are not implemented in the architecture. (For details, see the *Synergistic Processor Unit Instruction Set Architecture*.) These and other IEEE differences affect almost every aspect of floating-point computation, including data-type properties, rounding modes, exception status, error reporting, and expression evaluation. The particular effect of these differences on the compiler and libraries are described in the following sections.

9.1. Properties of Floating-Point Data Type Representations

The properties of floating-point data type representations are declared as macros in `float.h`. Table 9-212 lists these macros and the corresponding values that are applicable for the SPU.

Table 9-212: Values for Floating-Point Type Properties

Macro	Value
FLT_DIG	6
FLT_EPSILON	0x1p-23f (1.19209290E-07f)
FLT_MANT_DIG	24
FLT_MAX_10_EXP	38
FLT_MAX_EXP	129
FLT_MIN_10_EXP	-37
FLT_MIN_EXP	-125
FLT_MAX	0x1.FFFFFEp128f (6.80564694E+38f)
FLT_MIN	0x1p-126f (1.17549436E-38f)
FLT_ROUNDS	Initialized to 16 (to nearest for both elements)
FLT_EVAL_METHOD	0 (no promotions occur)
FLT_RADIX	2
DBL_DIG	15
DBL_EPSILON	0x1p-52 (2.2204460492503131E-016)
DBL_MANT_DIG	53
DBL_MAX_10_EXP	308
DBL_MAX_EXP	1024
DBL_MIN_10_EXP	-307
DBL_MIN_EXP	-1021
DBL_MAX	0x1.FFFFFFFFFFFFFp1023 (1.7976931348623157E+308)
DBL_MIN	0x1p-1022 (2.2250738585072014E-308)
DECIMAL_DIG	17

9.2. Floating-Point Environment

The macros defined within `fenv.h` control the directed-rounding control mode and floating-point exception status flags for floating-point operations.

9.2.1. Rounding Modes

Whereas the C language specification requires that all floating-point data types use the same rounding modes, the SPU hardware supports different rounding modes for single- and double-precision arithmetic. On the SPU, the rounding mode for single precision is round-towards-zero, and the default rounding mode for double precision is round-to-nearest.

According to the C99 standard, the rounding mode for floating-point addition is characterized by the implementation-defined value of `FLT_ROUNDS`. On the SPU, this macro is only used for double precision. Single-precision rounding mode is always truncation. (See Table 9-212.)

`FLT_ROUNDS` will return a 5-bit value which represents the rounding mode for both double precision elements. The highest bit is always 1. The next two bits are the rounding mode for element 0 and the two lowest bits are the rounding mode for element 1. Table 9-213 lists the rounding mode represented by the two bits for each element.

Table 9-213: Rounding Mode for Two Bits of FLT_ROUNDS

Last Two Bits	Rounding Mode
`00`	Round to nearest even
`01`	Round toward zero (truncate)
`10`	Round toward +infinity
`11`	Round towards -infinity

Because the SPU hardware only supports rounding towards zero for single precision, some single-precision math functions will necessarily deviate from the C99 standard. The standard library math functions and macros that deviate are described later, in section "9.3.2. Overall Behavior of C Operators and Standard Library Math Functions".

Table 9-214 lists the macros that can be used to set the double precision rounding modes for element 0 and element 1. The macros for element 0 and element 1 may be used together with a bitwise OR to set the rounding mode for both elements, or the macros can be used separately to set the rounding mode for only that element.

Table 9-214: Macros for Double Precision Rounding Modes

Macro	Comment
FE_TONEAREST	Set element 0 to round to nearest even
FE_TOWARDZERO	Set element 0 to round towards zero
FE_UPWARD	Set element 0 to round towards +infinity
FE_DOWNWARD	Set element 0 to round towards –infinity
FE_TONEAREST_1	Set element 1 to round to nearest even
FE_TOWARDZERO_1	Set element 1 to round towards zero
FE_UPWARD_1	Set element 1 to round towards +infinity
FE_DOWNWARD_1	Set element 1 to round towards -infinity

9.2.2. Floating-Point Exceptions

Table 9-215 and Table 9-216 list the macros for floating-point exceptions that will be defined in fenv.h. Because of the restricted behavior of the SPU floating-point hardware, single-precision library functions can have an undefined effect on these exception flags. Moreover, hardware traps will not result from any raised exception.

Table 9-215: Macros for Single Precision Floating-Point Exceptions

Macro	Comment
FE_OVERFLOW_SNGL	Overflow exception for element 0
FE_UNDERFLOW_SNGL	Underflow exception for element 0
FE_DIFF_SNGL	Different from IEEE exception for element 0
FE_DIVBYZERO_SNGL	Divide by zero exception for element 0
FE_OVERFLOW_SNGL_1	Overflow exception for element 1
FE_UNDERFLOW_SNGL_1	Underflow exception for element 1
FE_DIFF_SNGL_1	Different from IEEE exception for element 1
FE_DIVBYZERO_SNGL_1	Divide by zero exception for element 1
FE_OVERFLOW_SNGL_2	Overflow exception for element 2
FE_UNDERFLOW_SNGL_2	Underflow exception for element 2
FE_DIFF_SNGL_2	Different from IEEE exception for element 2
FE_DIVBYZERO_SNGL_2	Divide by zero exception for element 2
FE_OVERFLOW_SNGL_3	Overflow exception for element 3
FE_UNDERFLOW_SNGL_3	Underflow exception for element 3
FE_DIFF_SNGL_3	Different from IEEE exception for element 3
FE_DIVBYZERO_SNGL_3	Divide by zero exception for element 3
FE_ALL_EXCEPT_SNGL	Bitwise OR of all macros for element 0
FE_ALL_EXCEPT_SNGL_1	Bitwise OR of all macros for element 1
FE_ALL_EXCEPT_SNGL_2	Bitwise OR of all macros for element 2
FE_ALL_EXCEPT_SNGL_3	Bitwise OR of all macros for element 3

Table 9-216: Macros for Double Precision Floating-Point Exceptions

Macro	Comment
FE_OVERFLOW_DBL	Overflow exception for element 0
FE_UNDERFLOW_DBL	Underflow exception for element 0
FE_INEXACT_DBL	ISO/IEC inexact for element 0
FE_INVALID_DBL	ISO/IEC invalid for element 0
FE_NC_NAN_DBL	Possibly non-compliant NaN for element 0
FE_NC_DENORM_DBL	Possibly non-compliant denormal for element 0
FE_OVERFLOW_DBL_1	Overflow exception for element 1
FE_UNDERFLOW_DBL_1	Underflow exception for element 1
FE_INEXACT_DBL_1	ISO/IEC inexact for element 1
FE_INVALID_DBL_1	ISO/IEC invalid for element 1
FE_NC_NAN_DBL_1	Possibly non-compliant NaN for element 1
FE_NC_DENORM_DBL_1	Possibly non-compliant denormal for element 1
FE_ALL_EXCEPT_DBL	Bitwise OR of all macros for element 0
FE_ALL_EXCEPT_DBL_1	Bitwise OR of all macros for element 1
FE_ALL_EXCEPT	Bitwise OR of all macros from this table

The floating-point environment variables defined in the C99 specification only apply to double-precision.

The pragma FENV_ACCESS will be used to inform the compiler whether the program intends to control and test floating-point status. If the pragma is on, the compiler will take appropriate action to ensure that code transformations preserve the behavior specified in this document.

9.2.3. Other Floating-Point Constants in math.h

Several additional floating-point constants are defined in `math.h`. These constants are used by functions to report various domain and range errors. Many have a non-standard definition for the SPU. A description of these particular constants is shown in Table 9-217.

Table 9-217: Floating-Point Constants

Macro	Description
HUGE_VAL	Infinity
HUGE_VALF	`FLT_MAX`
HUGE_VALL	Infinity
INFINITY NAN	Double precision adheres to the IEEE definition. These macros are not used for single-precision operations.
FP_INFINITE FP_NAN FP_NORMAL FP_SUBNORMAL FP_ZERO	For single precision, the `fpclassify()` function will only return `FP_NORMAL` and `FP_ZERO` classes; `FP_NAN`, `FP_INFINITE`, and `FP_SUBNORMAL` are never generated.
FP_FAST_FMA FP_FAST_FMAF FP_FAST_FMAL	These are defined to indicate that the `fma` function executes more quickly than a multiply and an add of float and double operands.
FP_ILOGB0 FP_ILOGBNAN	`FP_ILOGB0` is the value returned by `ilogb(x)` and `ilogbf(x)` if `x` is zero or a denorm number. Its value is `INT_MIN`. `FP_ILOGBNAN` is the value returned by `ilogb(x)` if `x` is a `NaN`. This does not apply to the single-precision case of `ilogbf`. Its value is `INT_MAX`.
MATH_ERRNO MATH_ERREXCEPT	These will expand to the integer constants 1 and 2, respectively.
math_errhandling	Expands to an expression that has type `int` and the value `MATH_ERRNO`, `MATH_ERREXCEPT`, or the bitwise `OR` of both. The value of `math_errhandling` is constant for the duration of a program.

9.3. Floating-Point Operations

This section specifies floating-point data conversions, and it describes the overall behavior of C operators and standard library functions. It also describes several special cases where floating-point results might vary from the IEEE standard. Lastly, the section describes the specific behavior of several specific math functions.

9.3.1. Floating-Point Conversions

This section provides specifications for the four types of floating-point data conversions: 1) conversions from integers
to floating-point; 2) conversions from floating-point to integer; 3) conversion between floating-point precisions; and, 4) conversions between floating-point and string.

Integer to Floating-Point Conversions

Conversions from integers to floats will adhere to the following rules:

- A single-precision conversion from integer to float produces a result within the extended single-precision floating-point range. See Table 9-212 for details about this range.
- A single-precision conversion from integer to float rounds towards zero.
- A double-precision conversion from integer to float produces a result within the C99 standard double-precision floating-point range.
- A double-precision conversion from integer to float rounds according to the rounding mode indicated by the value of `FLT_ROUNDS`.

Floating-Point to Integer Conversions

Conversions from floats to integers will have the following behavior:

- When converting from a float to an integer, exceptions are raised for overflow, underflow, and IEEE non-compliant result.
- Overflow and underflow exceptions are raised when converting from a double to an integer. If a double-precision value is infinite or `NaN` or if the integral part of the floating value exceeds the range of the integer type, an “invalid” floating-point exception is raised, and the resulting value is unspecified. An “inexact” floating-point exception is raised by the hardware when a conversion involves an integral floating-point value that is outside the range of the integer data type.

Conversions between Floating-Point Precision

To achieve maximum performance, compilers only perform conversion from `float` to `double` and from `double` to `float` within the IEEE standard range. These conversions will comply with the IEEE standard, except for denormal inputs, which are forced to zero. Conversion of numbers outside of the IEEE standard range is unspecified. Conversions with `NaN`s, infinities, or denormal results are also unspecified.

Conversions between Floating-Point and Strings

Conversions between floating-point and string values will adhere to both the extended single-precision floating-point range and the IEEE standard double-precision floating-point range.

9.3.2. Overall Behavior of C Operators and Standard Library Math Functions

Library functions and compilers will obey the same general rules with respect to rounding and overflow. These rules differ, however, depending on whether the code is single precision or double precision.

Single-Precision Code

For single precision, the C operators (+, -, *, and /) and the standard library math functions will have the following behavior:

- If the operation produces a value with a magnitude greater than the largest positive representable extended-precision number, the result will be `FLT_MAX` with appropriate sign, and the overflow flag will be raised.
- For all operators and standard functions, except the negate operator and the `fabsf()` and `copysignf()` functions, an argument with a denormal value will be treated as `+0.0`.
- Except for the negate operator and the `fabsf()` and `copysignf()` functions, operators and standard functions will never return a denormal value or `-0.0`.
- The negate operator and the `fabsf()` and `copysignf()` functions must be implemented such that only the sign bit is changed.
- Expressions will be evaluated using the round-towards-zero mode. Implementations that depend on other rounding directions for algorithm correctness will produce incorrect results and therefore cannot be used.
- The overflow flag will be set when `FLT_MAX` is returned instead of a value whose magnitude is too large. Because infinity is undefined for single precision, `FLT_MAX` will be used to signal infinity in situations where infinity would otherwise be generated on an IEEE754-compliant system. This modification will enable common trig identities to work.
- `NaN` is not supported and does not need to be copied from any input parameter.
- By default, compilers may perform optimizations for single-precision floating-point arithmetic that assume 1) that `NaN`s are never given as arguments; and, 2) that `±Inf` will never be generated as a result.
- Compilers can assume that floating-point operations will not generate user-visible traps, such as division by zero, overflow, and underflow.
- Constant expressions that are evaluated at compile time will produce the same result as they would if they were evaluated at runtime. For example,

```
float x = 6.0e38f * 8.1e30f;
```

will be evaluated as FLT_MAX.

- Compilers may use single-precision contracted operations, such as Floating Reciprocal Absolute Square Root Estimate (frsqest) or Floating Multiply and Add (fma), unless explicitly prohibited by FP_CONTRACT pragma or a *no-fast-float* compiler option. When contracted operations are used, errno does not need to be set.

Double-Precision Code

For double-precision floating-point, the C operators and standard library math functions will be compliant with the IEEE standard, with the following exceptions:

- When a NaN is produced as a result of an operation, it will always be a QNaN.
- Except for the negate operator and the fabs() and copysign() functions, denormal values will only be supported as results. A denormal operand is treated as 0 with same sign as the denormal operand.
- The default rounding mode for double precision is rounding to nearest.
- Compilers may use double precision contracted operations, such as Double Floating Multiply and Add (dfma), unless explicitly prohibited by the FP_CONTRACT pragma or a *no-fast-double* compiler option. When contracted operations are used, errno does not need to be set.

9.3.3. Floating-Point Expression Special Cases

The C99 standard describes several standard expression transformations that might fail to produce the required effect on the SPU:

- x/2 -> x*0.5

  Valid for this particular value because the value is an exact power of 2, but it is invalid in general (for example, x/10 != x*0.1) because the floating-point constant is not exactly representable in any finite base-2 floating-point system.
- x*1 -> x and x/1 -> x

  Invalid when: 1) x is a SNaN or a non-default QNaN (double precision only); 2) x is a denormal number; or, 3) x is -0.0 (single precision only).
- x/x -> 1.0

  Invalid for single precision when x is zero or a denormal, and invalid for double precision when x is zero, or a denormal, Inf, or NaN.
- x-y -> -(y-x)

  Invalid for zero results which might have different signs, or, for double precision, round to +/- infinity, non-zero results might differ by 1 ULP.
- x-x -> 0.0

  Always valid for single precision, but the equivalence is invalid for double precision when x is either NaN or Inf. It is also invalid for double precision for round to –infinity, in which case the result will be –0.0.
- 0*x -> 0.0

  Always valid for single precision, but invalid for double precision when x is a NaN, Inf, negative number, or -0.
- x+0 -> x

  Invalid in single precision, if x is a denormal operand or -0. Invalid in double precision if x=-0 under round-to-nearest, round to +infinity and truncate. Also invalid in double precision if x is a SNaN or non-default QNaN and if x is a denormal number, in which case x+0 becomes a zero with appropriate sign.
- x-0 -> x

Valid for single precision, except if x is a denormal operand or -0. Invalid for double precision if x is an SNaN or non-default QNaN, if x is a denormal number, or if x is +0 and rounding mode is rounding to –infinity. In this last case, x-0 = +0-0 =-0. For any normalized operand the result is valid even with round to –infinity.

- -x -> 0-x
  Invalid for single precision when x is +0.0 or a denormal. Invalid for double precision in the following cases: 1) For NaNs the value of -x is undefined; the result will be different for all NaNs. 2) If x is +0 and the rounding mode is rounding to nearest-even, +infinity, or truncation, 0-x = +0 and -x = -0.
- x!=x -> false

  Always valid for single precision. For double precision, x=NaN always compares unordered, so x!=x -> true.
- x==x -> true

  Always valid for single precision. For double precision, x=NaN always compares unordered, so x==x -> false.
- x<y -> isless(x,y),
  x<=y -> islessequal(x,y),
  x>y -> isgreater(x,y), and
  x>=y -> isgreaterequal(x,y)

  Valid. Exceptions are due to flags that are set as side effects when x or y are NaN under double precision. The FENV_ACCESS pragma can change the invalid flag behavior.

9.3.4. Specific Behavior of Standard Math Functions

This section describes the specific behavior of various floating-point functions declared in math.h. As noted, the SPU hardware has a direct effect on the behavior of floating-point functions. Because of the many differences between strict IEEE behavior and the hardware behavior, the standard math functions do not need to provide rigorous checks for exception situations and out-of-range conditions. Consequently, the results of many functions are redefined. The following is a list of differences:

- The function nanf()will return 0.
- The isnan() macro will always return false for single precision.
- Unlike C99 standard specifications, single-precision versions of nearbyint, lrint, llrint, and fma round towards zero.
- Trig, hyperbolic, exponential, logarithmic, and gamma functions do not need to set the inexact flag when values are rounded.
- The boundary cases for frexp(NaN,exp) and modf(NaN,iptr) are not defined because these functions propagate and return NaN.
- nextafterf(subnormal,y) will never raise an underflow flag. The functions nextafterf() and nexttowardf() will succeed when incrementing past the IEEE maximal float value.
- The following boundary cases will not be supported for single precision because infinity is not a valid argument: atanf(±inf), atan2f(±y, ±inf), atan2f(±inf,x), atan2f(±inf,±inf), acoshf(+inf), asinhf(±inf), atanhf(±1), atanhf(±inf), coshf(±inf), sinhf(±inf), tanhf(±inf), expf(±inf), exp2f(±inf), expm1f(±inf), frexpf(±inf,&exp), ldexpf(±inf,exp), logf(+inf), log10f(+inf), log1pf(+inf), log2f(+inf), logbf(±inf), modff(±inf,iptr), scalbnf(±inf,n), cbrtf(±inf), fabsf(±inf), hypotf(±inf,y), powf(-1,±inf), powf(x,±inf), powf(±inf,y), sqrtf(±inf), erff(±inf), erfcf(±inf), lgammaf(±inf), tgammaf(+inf), ceilf(±inf), floorf(±inf), nearbyintf(±inf), roundf(±inf), rintf(±inf), lrintf(±inf), llrintf(±inf), lroundf(±inf), llroundf(±inf), truncf(±inf), fmodf(x,±inf), remainderf(±inf), remquof(±inf),and copysignf(±inf).

- For single precision, the following boundary cases will produce a non-IEEE-compliant result: `acosf(|x|>1)`, `asinf(|x|>1)`, `acoshf(x<1.0)`, `atanhf(|x|>1)`, `tgammaf(x<0)`, `fmodf(x,0)`, `ldexpf(x,BIG_INT), logf(±0)`, `logf(x<0)`, `log10f(±0)`, `log10f(x<0)`, `log1pf(-1)`, `log1pf(x<-1)`, `log2f(±0)`, `log2f(x<0)`, `logbf(±0)`, `powf(±0,y)`, and `tgammaf(±0)`
- For single precision, the following boundary cases will not return NaN,: `cosf(±inf)`, `sinf(±inf)`, `tanf(±inf)`, `tgammaf(-inf)`, `fmodf(±inf,y)`, `nextafterf(x,±inf)`, `fmaf(±inf|0,0|±inf,z)`, and `fmaf(±inf,0,-+inf)`.
- Section “9.3.1. Floating-Point Conversions” describes the behavior of implicit conversions when a single precision value is passed as an argument to a double precision function or when a single precision variable is assigned the result of a double-precision function.

10. Operator Overloading for Vector Data Types

Operator overloading is a syntactic feature in which common operators, such '+' or '-', have different implementations depending upon the type of their arguments. This section describes the vector data types that may be used with certain standard C/C++ operators and the behavior of these operators.

10.1. Supported Types

Operator overloading is valid on the vector data types listed in Table 10-218 and Table 10-219.

Table 10-218: Integer Vector Types

Type	SPU/PPU
vector signed char	Both
vector unsigned char	Both
vector signed short	Both
vector unsigned short	Both
vector signed int	Both
vector unsigned int	Both
vector signed long long	SPU
vector unsigned long long	SPU

Table 10-219: Floating-Point Vector Types

Type	SPU/PPU
vector float	Both
vector double	SPU

10.2. Vector Subscripting

Given `E1[E2]`, where `E1` has a vector type with base type `T` and `E2` has an integer type, the result is equivalent to:

```
(((T *)&(E1))[E2])
```

When the value of `E2` does not designate a valid element of `E1`, the behavior is undefined.

10.3. Unary Operators

Given `OP E1`, where `E1` is a vector type `T` with `N` elements and `OP` is one of the operators in Table 10-220, the result has a value equivalent to:

```
(T){ OP E1[0], ..., OP E1[N-1] }
```

Table 10-220: Valid Types for Specified Unary Operators

OP	Integer Vector Types	Floating-Point Vector Types
++	yes	yes
--	yes	yes
+	yes	yes
-	yes	yes
~	yes	no

10.4. Binary Operators

Given `E1 OP E2`, where `E1` and `E2` have equivalent vector types `T` with `N` elements and `OP` is one of the operators in Table 10-221, the result has a value equivalent to:

```
(T){ E1[0] OP E2[0], ..., E1[N-1] OP E2[N-1] }
```

For the assignment operators, `E1` shall be a modifiable lvalue, and the result value will be assigned to the object it designates.

Table 10-221: Valid Types for Specified Binary Operators

OP	Integer Vector Types	Floating-Point Vector Types
`+ +=`	yes	yes
`- -=`	yes	yes
`* *=`	yes	yes
`/ /=`	yes	yes
`% %=`	yes	no
`& &=`	yes	no
`| |=`	yes	no
`^ ^=`	yes	no
`<< <<=`	yes	no
`>> >>=`	yes	no

10.5. Relational Operators

Given `E1 OP E2`, where `E1` and `E2` have equivalent vector types `T` with `N` elements and `OP` is one of the operators in Table 10-222, the result has a value equivalent to:

```
((E1[0] OP E2[0]) & ... & (E1[N-1] OP E2[N-1]))
```

Table 10-222: Valid Types for Specified Relational Operators

OP	Integer Vector Types	Floating-Point Vector Types
`==`	yes	yes
`!=`	yes	yes
`<`	yes	yes
`>`	yes	yes
`<=`	yes	yes
`>=`	yes	yes

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