SONY

SIMD Math Library Specification for Cell Broadband Engine™ Architecture

Version 1.0

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About This Document

This document contains specifications for a math library that takes advantage of the Single Instruction, Multiple Data (SIMD) instructions provided by the PowerPC Processor Unit (PPU) and the Synergistic Processor Unit (SPU) hardware of the Cell Broadband Engine™. By computing multiple results at one time, SIMD math functions allow programmers to obtain much higher performance from their PPU and SPU programs than would be possible from a corresponding traditional scalar math library.

Audience

This document is intended for system and application programmers who are interested in writing high-performance programs for the Cell Broadband Engine™.

Version History

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

Version Number & Date	Changes
v. 1.0 November 6, 2006	Created the initial document.

Related Documentation

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

Document Title	Version	Date
C/C++ Language Extensions for the Cell Broadband Engine™ Architecture	2.3	December 2006
ISO/IEC Standard 9899:1999 (C Standard)		
IEC Standard 60559:1989 (Standard for Binary Floating-Point Arithmetic)		
Synergistic Processor Unit Instruction Set Architecture	1.11	October 2006
PowerPC Microprocessor Family: Vector/SIMD Multimedia Extension Technology Programming Environments Manual, http://www-306.ibm.com/chips/techlib/techlib.nsf/techdocs/C40E4C6133B31EE8872570B500791108	2.06c	
PowerPC Architecture Book, http://www-128.ibm.com/developerworks/eserver/library/es-archguide-v2.html	2.02	

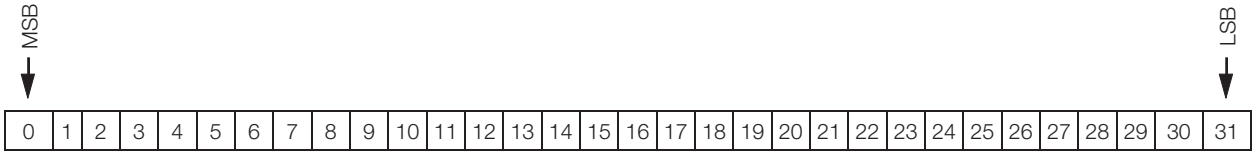
Document Structure

This document contains two chapters. The first is a SIMD math library overview, and the second is a specification describing the particular math functions that compose this library.

Bit Notation

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

As shown in Figure 1, byte ordering and element/slot numbering is always displayed in big endian order.

Figure 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 used only where it facilitates comprehension, especially in narrative descriptions.
`courier + italics`	Indicates arguments, parameters and variables, including variables of type `const`. This convention is used only 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 likely to be in italics.
blue	Indicates a hyperlink (color printers or online only).

1. Overview of the SIMD Math Library

The PPU and SPU instruction sets include Single Instruction, Multiple Data (SIMD) instructions, which are similar to normal instructions but operate on more than one input simultaneously. Traditional math functions operate on a single input and are unable to take advantage of the speed and power of SIMD instructions. The SIMD Math Library contains SIMD versions of the scalar math functions described in the C99 standard, or *ISO/IEC Standard 9899:1999 (C Standard)*. This chapter provides specifications for these special PPU and SPU SIMD libraries.

A. Library and Header Files

The name of the SIMD library will contain the string `simdmath`. For example. on GNU/Linux the library will be called `libsimdmath.a`, or `libsimdmath.so` (for the shared library version). The `simdmath.h` system header file will contain type declarations and prototypes for the SIMD math functions.

B. Functions Overview

The functions that comprise the PPU and SPU SIMD math libraries are listed in Table 1. The functions that are listed as “non-standard” have no C99 counterpart.

Names of the SIMD math functions are differentiated from their scalar counterparts by a vector type suffix appended to the standard scalar function name. For example, the SIMD version of `fabsf()`, which acts on a vector float, is called `fabsf4()`. Similarly, a SIMD version of a standard scalar function that acts on a vector double will have `d2` appended to the name.

Table 1: SIMD Math Functions

Function Name	C99 Name	Function Category	Precision	SPU/PPU
absi4	abs	integer	word	Both
acosd2	acos	trig	double	SPU
acosf4	acosf	trig	single	Both
acoshd2	acosh	trig	double	SPU
acoshf4	acoshf	trig	single	Both
asind2	asin	trig	double	SPU
asinf4	asinf	trig	single	Both
asinhd2	asinh	trig	double	SPU
asinhf4	asinhf	trig	single	Both
atan2d2	atan2	trig	double	SPU
atan2f4	atan2f	trig	single	Both
atand2	atan	trig	double	SPU
atanf4	atanf	trig	single	Both
atanhd2	atanh	trig	double	SPU
atanhf4	atanhf	trig	single	Both
cbrtd2	cbrt	power	double	SPU
cbrtf4	cbrtf	power	single	Both
ceild2	ceil	rounding	double	SPU
ceilf4	ceilf	rounding	single	Both
copysignd2	copysign	other	double	SPU
copysignf4	copysignf	other	single	Both
cosd2	cos	trig	double	SPU

Function Name	C99 Name	Function Category	Precision	SPU/PPU
cosf4	cosf	trig	single	Both
coshd2	cosh	trig	double	SPU
coshf4	coshf	trig	single	Both
divd2	non-standard	divide	double	SPU
divf4	non-standard	divide	single	Both
divi4	div	integer	word	Both
divu4	non-standard	integer	word	Both
erfcd2	erfc	error function	double	SPU
erfcf4	erfcf	error function	single	Both
erfd2	erf	error function	double	SPU
erff4	erff	error function	single	Both
exp2d2	exp2	exp	double	SPU
exp2f4	exp2f	exp	single	Both
expd2	exp	exp	double	SPU
expf4	expf	exp	single	Both
expm1d2	expm1	exp	double	SPU
expm1f4	expm1f	exp	single	Both
fabsd2	fabs	abs	double	SPU
fabsf4	fabsf	abs	single	Both
fdimd2	fdim	other	double	SPU
fdimf4	fdimf	other	single	Both
floord2	floor	rounding	double	SPU
floorf4	floorf	rounding	single	Both
fmad2	fma	other	double	SPU
fmaf4	fmaf	other	single	Both
fmaxd2	fmax	minmax	double	SPU
fmaxf4	fmaxf	minmax	single	Both
fmind2	fmin	minmax	double	SPU
fminf4	fminf	minmax	single	Both
fmodd2	fmod	modrem	double	SPU
fmodf4	fmodf	modrem	single	Both
fpclassifyd2	fpclassify	comparison	double	SPU
fpclassifyf4	fpclassify	comparison	single	Both
frexpd2	frexp	other	double	SPU
frexpf4	frexpf	other	single	Both
hypotd2	hypot	other	double	SPU
hypotf4	hypotf	other	single	Both
ilogbd2	ilogb	log	double	SPU
ilogbf4	ilogbf	log	single	Both
irintf4	non-standard	other	single	Both
iroundf4	non-standard	rounding	single	Both
is0denormf4	non-standard	comparison	single	Both
is0denormd2	non-standard	comparison	double	SPU
isequald2	non-standard	comparison	double	SPU
isequalf4	non-standard	comparison	single	Both

Function Name	C99 Name	Function Category	Precision	SPU/PPU
isfinited2	isfinite	comparison	double	SPU
isfinitef4	isfinite	comparison	single	Both
isgreaterd2	isgreater	comparison	double	SPU
isgreaterf4	isgreater	comparison	single	Both
isgreaterequald2	isgreaterequal	comparison	double	SPU
isgreaterequalf4	isgreaterequal	comparison	single	Both
islessd2	isless	comparison	double	SPU
islessf4	isless	comparison	single	Both
islessequald2	islessequal	comparison	double	SPU
islessequalf4	islessequal	comparison	single	Both
islessgreaterd2	islessgreater	comparison	double	SPU
islessgreaterf4	islessgreater	comparison	single	Both
isunorderedd2	isunordered	comparison	double	SPU
isunorderedf4	isunordered	comparison	single	Both
isinfd2	isinf	comparison	double	SPU
isinff4	isinf	comparison	single	Both
isnand2	isnan	comparison	double	SPU
isnanf4	isnan	comparison	single	Both
isnormald2	isnormal	comparison	double	SPU
isnormalf4	isnormal	comparison	single	Both
ldexpd2	ldexp	other	double	SPU
ldexpf4	ldexpf	other	single	Both
lgammad2	lgamma	gamma	double	SPU
lgammaf4	lgammaf	gamma	single	Both
llabsi2	llabs	integer	double word	SPU
lldivi2	lldiv	integer	double word	SPU
lldivu2	non-standard	integer	double word	SPU
llrintd2	llrint	rounding	double	SPU
llrintf4	llrintf	rounding	single	SPU
llroundd2	llround	rounding	double	SPU
llroundf4	llroundf	rounding	single	SPU
log10d2	log10	log	double	SPU
log10f4	log10f	log	single	Both
log1pd2	log1p	log	double	SPU
log1pf4	log1pf	log	single	Both
log2d2	log2	log	double	SPU
log2f4	log2f	log	single	Both
logbd2	logb	log	double	SPU
logbf4	logbf	log	single	Both
logd2	log	log	double	SPU
logf4	logf	log	single	Both
modfd2	modf	modrem	double	SPU
modff4	modff	modrem	single	Both
nearbyintd2	nearbyint	rounding	double	SPU
nearbyintf4	nearbyintf	rounding	single	Both

Function Name	C99 Name	Function Category	Precision	SPU/PPU
negated2	non-standard	other	double	SPU
negatef4	non-standard	other	single	Both
negatei4	non-standard	integer	word	Both
negatell2	non-standard	integer	double word	SPU
nextafterd2	nextafter	rounding	double	SPU
nextafterf4	nextafterf	rounding	single	Both
powd2	pow	power	double	SPU
powf4	powf	power	single	Both
recipd2	non-standard	recip	double	SPU
recipf4	non-standard	recip	single	Both
remainderd2	remainder	modrem	double	SPU
remainderf4	remainderf	modrem	single	Both
remquod2	remquo	modrem	double	SPU
remquof4	remquof	modrem	single	Both
rintd2	rint	rounding	double	SPU
rintf4	rintf	rounding	single	Both
roundd2	round	rounding	double	SPU
roundf4	roundf	rounding	single	Both
rsqrtd2	non-standard	sqrt	double	SPU
rsqrtf4	non-standard	sqrt	single	Both
scalbllnd2	non-standard	other	double	SPU
scalbnf4	scalbnf	other	single	Both
signbitf4	signbit	comparison	single	Both
signbitd2	signbit	comparison	double	SPU
sincosd2	non-standard	trig	double	SPU
sincosf4	non-standard	trig	single	Both
sind2	sin	trig	double	SPU
sinf4	sinf	trig	single	Both
sinhd2	sinh	trig	double	SPU
sinhf4	sinhf	trig	single	Both
sqrtd2	sqrt	sqrt	double	SPU
sqrtf4	sqrtf	sqrt	single	Both
tand2	tan	trig	double	SPU
tanf4	tanf	trig	single	Both
tanhd2	tanh	trig	double	SPU
tanhf4	tanhf	trig	single	Both
tgammad2	tgamma	gamma	double	SPU
tgammaf4	tgammaf	gamma	single	Both
truncd2	trunc	rounding	double	SPU
truncf4	truncf	rounding	single	Both

C. Special Cases

Unless otherwise specified, each element of a SIMD result will adhere to either the C99 standard or the *IEC 60559:1989* standard.

1. Rounding

On the SPU, the full range of IEEE rounding modes is supported for double precision, but only round-toward-zero is supported for single precision. On the PPU, SIMD operations always use IEEE round-to-nearest mode.

The mathematical accuracy of the SIMD functions assumes the default rounding mode. Accuracy may be compromised if the functions are called in another rounding mode.

2. Special Operands

On the PPU , `NaN` and `Inf` are recognized as special operands.

On the SPU, all values passed to single-precision functions are treated as ordinary operands. `NaN` and `Inf` are not recognized as special single-precision operands; however, they are recognized as special double-precision operands, and SIMD functions check for them, as described in C99, *IEC 60559:1989* and the SIMD function specifications. See *Synergistic Processor Unit Instruction Set Architecture* for details.

On both the PPU and the SPU, single precision floating-point denormal inputs are coerced to zero unless otherwise noted.

3. Error Conditions

A *domain error* occurs if an input argument is outside the domain over which the mathematical function is defined. The description of each function lists any required domain errors. The resulting vector element is undefined for all corresponding element input arguments which contain a domain error and no exception or error is reported.

A *range error* occurs when the mathematical result cannot be represented in an object of the specified type. When a range error occurs, the resulting vector element is either `HUGE_VAL` (for double precision results) or `HUGE_VALF` (for single precision results). Integer arithmetic function results are undefined when they cannot be represented.

4. Exceptions

The SIMD library functions have an undefined effect on the exception flags in the SPU floating-point status and control register (FPSCR). SPU functions on double precision arguments set exception bits in the FPSCR that can be tested by calling the routine `fegetexcept`, as documented in `fenv.h`.

The SPU does not raise hardware traps for single-precision fp exceptions; PPU SIMD operations do have hardware support for a subset of the C99 fp exceptions.

2. SIMD Function Specifications

This chapter contains descriptions of the SIMD math functions, their arguments, and their return values. Where necessary, accuracy information is provided to clarify expected specific behavior. All functions are available on both the PPU and SPU unless otherwise noted.

A. Type Definitions

The following type definitions are used for function return values:

divi4_t: Remainder/Quotient Struct for Vector Signed Int

```
typedef struct divi4_s {
   vector signed int quot;
   vector signed int rem;
} divi4_t;
```

Structures of this type are used to hold the return value of `divi4()`. The member *`quot`* contains the quotient and the member *`rem`* contains the remainder of the division.

divu4_t: Remainder/Quotient Struct for Vector Unsigned Int

```
typedef struct divu4_s {
   vector unsigned int quot;
   vector unsigned int rem;
} divu4_t;
```

Structures of this type are used to hold the return value of `divu4()`.The member *`quot`* contains the quotient and the member *`rem`* contains the remainder of the division.

lldivi2_t: Remainder/Quotient Struct for Vector Signed Long Long (SPU Only)

```
typedef struct lldivi2_s {
   vector signed long long quot;
   vector signed long long rem;
} lldivi2_t;
```

Structures of this type are used to hold the return value of `lldivi2()`.The member *`quot`* contains the quotient and the member *`rem`* contains the remainder of the division.

lldivu2_t: Remainder/Quotient Struct for Vector Unsigned Long Long (SPU Only)

```
typedef struct lldivu2_s {
   vector unsigned long long quot;
   vector unsigned long long rem;
} lldivu2_t;
```

Structures of this type are used to hold the return value of `lldivu2()`.The member *`quot`* contains the quotient and the member *`rem`* contains the remainder of the division.

llroundf4_t: Vector of Four Long Long (SPU Only)

```
typedef struct llroundf4_s {
   vector signed long long vll[2];
} llroundf4_t;
```

Structures of this type are used to hold signed long long data corresponding to a vector of four elements.

B. Function Descriptions

In the function descriptions that follow, a subscript is used to indicate a vector element. For example, element *i* of vector x is shown as x_i.

absi4: Absolute Value of Integer

```
(vector signed int) absi4 (vector signed int x)
```

A vector signed int is returned that contains the absolute value of each corresponding element of vector signed int x.

If the absolute value of x_i cannot be represented, the corresponding result is undefined and no error is reported.

acosd2: Arccosine of Double (SPU Only)

```
(vector double) acosd2 (vector double x);
```

A vector double is returned that contains the angles whose cosines correspond to the respective elements in vector double x. Each element in the result is in the range [0, pi] radians.

If the absolute value of x_i is greater than 1, the corresponding result is undefined and no error is reported.

acosf4: Arccosine of Float

```
(vector float) acosf4 (vector float x);
```

A vector float is returned that contains the angles whose cosines correspond to the respective elements in vector float x. Each element in the result is in the range [0, pi] radians.

If the absolute value of x_i is greater than 1, the corresponding result is undefined and no error is reported.

acoshd2: Hyperbolic Arccosine of Double (SPU Only)

```
(vector double) acoshd2 (vector double x)
```

A vector double is returned that contains the nonnegative hyperbolic arccosines of the corresponding elements of vector double x.

If the value of x_i is less than 1, the corresponding result is undefined and no error is reported.

acoshf4: Hyperbolic Arccosine of Float

```
(vector float) acoshf4 (vector float x)
```

A vector float is returned that contains the nonnegative hyperbolic arccosines of the corresponding elements of vector float x.

If the value of x_i is less than 1, the corresponding result is undefined and no error is reported.

asind2: Arcsine of Double (SPU Only)

```
(vector double) asind2 (vector double x);
```

A vector double is returned that contains the angles whose sines correspond to the respective elements in vector double x. Each element in the result is in the range [-pi/2, +pi/2] radians.

If the absolute value of x_i is greater than 1, the corresponding result is undefined and no error is reported.

asinf4: Arcsine of Float

```
(vector float) asinf4 (vector float x);
```

A vector float is returned that contains the angles whose sines correspond to the respective elements in vector float x. Each element in the result is in the range [-pi/2, +pi/2] radians.

If the absolute value of x_i is greater than 1, the corresponding result is undefined and no error is reported.

asinhd2: Hyperbolic Arcsine of Double (SPU Only)

```
(vector double) asinhd2 (vector double x)
```

A vector double is returned that contains the nonnegative hyperbolic arcsines of the corresponding elements of vector double x.

asinhf4: Hyperbolic Arcsine of Float

```
(vector float) asinhf4 (vector float x)
```

A vector float is returned that contains the nonnegative hyperbolic arcsines of the corresponding elements of vector float x.

atand2: Tangent of Double (SPU Only)

```
(vector double) atand2 (vector double x);
```

A vector double is returned that contains the angles whose tangents correspond to the respective elements of vector double x. Each element in the result is in the range [-pi/2, +pi/2] radians.

atanf4: Tangent of Float

```
(vector float) atanf4 (vector float x);
```

A vector float is returned that contains the angles whose tangents correspond to the respective elements of vector float x. Each element in the result is in the range [-pi/2, +pi/2] radians.

atanhd2: Hyperbolic Arctangent of Double (SPU Only)

```
(vector double) atanhd2 (vector double x)
```

A vector double is returned that contains the nonnegative hyperbolic arctangents of the corresponding elements of vector double x.

If the absolute value of x_i is greater than 1, the corresponding result is undefined and no error is reported.

atanhf4: Hyperbolic Arctangent of Float

```
(vector float) atanhf4 (vector float x)
```

A vector float is returned that contains the nonnegative hyperbolic arctangents of the corresponding elements of vector float x.

If the absolute value if x_i is greater than 1, the corresponding result is undefined and no error is reported.

On the SPU, if the absolute value of x_i is equal to 1, the corresponding element of the result will be returned as `HUGE_VALF` and no error is reported.

atan2d2: Arctangent of Double Quotient (SPU Only)

```
(vector double) atan2d2 (vector double y, vector double x);
```

A vector double is returned that contains the angles whose tangents are y_i / x_i for corresponding elements of vector double y and vector double x. Each element in the result is within the range [-pi, +pi] radians.

If x_i and y_i are zero, the corresponding element of the result is undefined and no error is reported.

atan2f4: Arctangent of Float Quotient

```
(vector float) atan2f4 (vector float y, vector float x);
```

A vector float is returned that contains the angles whose tangents are y_i / x_i for corresponding elements of vector float y and vector float x. Each element in the result is within the range [-pi, +pi] radians.

If x_i and y_i are zero, the corresponding element of the result is undefined, and no error is reported.

cbrtd2: Cube Root of Double (SPU Only)

```
(vector double) cbrtd2 (vector double x);
```

A vector double is returned that contains the real cube roots, $x_i^{1/3}$ of the corresponding elements of vector double x.

cbrtf4: Cube Root of Float

```
(vector float) cbrtf4 (vector float x);
```

A vector float is returned that contains the real cube roots, $x_i^{1/3}$ of the corresponding elements of vector float x.

ceild2: Ceiling of Double (SPU Only)

```
(vector double) ceild2 (vector double x);
```

A vector double is returned that contains the smallest integer values, expressed as floating-point numbers, that are not less than the corresponding elements of vector double x.

ceilf4: Ceiling of Float

```
(vector float) ceilf4 (vector float x);
```

A vector float is returned that contains the smallest integer values, expressed as floating-point numbers, that are not less than the corresponding elements of vector float x.

copysignd2: Copy Sign of Double (SPU Only)

```
(vector double) copysignd2 (vector double x, vector double y);
```

A vector double is returned that contains the magnitude of the corresponding element of vector double x and the sign of the corresponding element of vector double y.

copysignf4: Copy Sign of Float

```
(vector float) copysignf4 (vector float x, vector float y);
```

A vector float is returned that contains the magnitude of the corresponding element of vector float x and the sign of the corresponding element of vector float y.

cosd2: Cosine of Double (SPU Only)

```
(vector double) cosd2 (vector double x);
```

A vector double is returned that contains the cosines of the corresponding elements of vector double x.

The results of `cosd2()` may not be accurate for very large values of x, but no error is reported. Implementations should document the point at which accuracy is lost.

cosf4: Cosine of Float

```
(vector float) cosf4 (vector float x);
```

A vector float is returned that contains the cosines of the corresponding elements of vector float x.

The results of `cosf4()` are may not be accurate for very large values, but no error is reported. Implementations should document the point at which accuracy is lost.

coshd2: Hyperbolic Cosine of Double (SPU Only)

```
(vector double) coshd2 (vector double x)
```

A vector double is returned that contains the hyperbolic cosines of the corresponding elements of vector double x.

coshf4: Hyperbolic Cosine of Float

```
(vector float) coshf4 (vector float x)
```

A vector float is returned that contains the hyperbolic cosines of the corresponding elements of vector float x.

On the SPU, element values of the result that are greater than `HUGE_VALF` are returned as `HUGE_VALF`, and no error is reported.

divd2: Divide Doubles (SPU Only)

```
(vector double) divd2 (vector double x, vector double y);
```

A vector double is returned that contains the quotient x_i / y_i, for the corresponding elements of vector double x and vector double y. This function handles special cases as follows:

- If either input is `NaN`, the result is `NaN`
- For `Inf`/`Inf` or 0/0, the result is `NaN`
- For finite/0, the result is `Inf` with sign = sign(x)/sign(y)
- For finite/±`Inf`, the result is 0 with sign = sign(x)/sign(y)

divf4: Divide Floats

```
(vector float) divf4 (vector float x, vector float y);
```

A vector float is returned that contains the quotients x_i / y_i, for the corresponding elements of vector float x and vector float y. This function handles special cases as follows:

- If either input is `NaN`, the result is `NaN`
- For `Inf`/`Inf` or 0/0, the result is `NaN`
- For finite/0, the result is `Inf` with sign = sign(x)/sign(y)
- For finite/±`Inf`, the result is 0 with sign = sign(x)/sign(y)

On the SPU, if y_i is zero, the result is `HUGE_VALF` with sign = sign(x)/sign(y).

divi4: Divide Integer

```
(divi4_t) divi4 (vector signed int x, vector signed int y)
```

Each element of vector signed int x is divided by the corresponding element of vector signed int y, and the result is returned in a structure of type `divi4_t()` that contains a vector of corresponding quotients and a vector of corresponding remainders.

Each element in the structure member *quot* is the algebraic quotient truncated towards zero. Each element in the structure member *rem* is the corresponding remainder, such that $x_i == quot * y_i + rem$.

If y_i is zero, the corresponding element of the resulting quotient is zero.

divu4: Divide Unsigned Integer

```
(divu4_t) divu4 (vector unsigned int x, vector unsigned int y)
```

Each element of vector unsigned int x is divided by the corresponding element of vector unsigned int y, and the result is returned in a structure of type `divu4_t()` that contains a vector of corresponding quotients and a vector of corresponding remainders.

Each element in the structure member *quot* is the algebraic quotient truncated towards zero. Each element in the structure member *rem* is the corresponding remainder, such that $x_i == quot * y_i + rem$.

If y_i is zero, the corresponding element of the resulting quotient is zero.

erfcd2: Complementary Error Function Double (SPU Only)

```
(vector double) erfcd2 (vector double x)
```

A vector double is returned that contains the complementary error functions of the corresponding elements of vector double x.

erfcf4: Complementary Error Function Float

```
(vector float) erfcf4 (vector float x)
```

A vector float is returned that contains the complementary error functions of the corresponding elements of vector float x.

erfd2: Error Function Double (SPU Only)

```
(vector double) erfd2 (vector double x)
```

A vector double is returned that contains the error functions of the corresponding elements of vector double x.

erff4: Error Function Float

```
(vector float) erff4 (vector float x)
```

A vector float is returned that contains the error functions of the corresponding elements of vector float x.

expd2: *e* Raised to the Power of Double (SPU Only)

```
(vector double) expd2 (vector double x);
```

A vector double is returned that contains the corresponding exponentials e^{x_i} for each element of vector double x.

expf4: *e* Raised to the Power of Float

```
(vector float) expf4 (vector float x);
```

A vector float is returned that contains the corresponding exponentials e^{x_i} for each element of vector float x.

On the SPU, element values of the result that are greater than `HUGE_VALF` are returned as `HUGE_VALF`, and no error is reported.

exp2d2: 2 Raised to the Power of Double (SPU Only)

```
(vector double) exp2d2 (vector double x);
```

A vector double is returned that contains the corresponding exponentials 2^{x_i}, for each element of vector double x.

exp2f4: 2 Raised to the Power of Float

```
(vector float) exp2f4 (vector float x);
```

A vector float is returned that contains the corresponding exponentials 2^{x_i}, for each element of vector float x.

On the SPU, element values of the result that are greater than `HUGE_VALF` are returned as `HUGE_VALF` and no error is reported.

expm1d2: *e* Raised to the Power of Double Minus 1 (SPU Only)

```
(vector double) expm1d2 (vector double x);
```

A vector double is returned that contains the exponential minus 1, $e^{x_i} - 1$, for corresponding elements of vector double x.

This function returns mathematically accurate values, even when x_i is near `0`, or when `exp (`x_i`)-1.0` would return bad values due to floating-point cancellation errors.

expm1f4: *e* Raised to the Power of Float Minus 1

```
(vector float) expm1f4 (vector float x);
```

A vector float is returned that contains the exponential minus 1, $e^{x_i} - 1$, for corresponding elements of vector float x.

This function returns mathematically accurate values, even when an element of x_i is near 0, or when `expf(`x_i`) - 1.0f` would return bad values due to floating-point cancellation errors.

fabsd2: Absolute Value Double (SPU Only)

```
(vector double) fabsd2 (vector double x);
```

A vector double is returned that contains the absolute values, $|x_i|$, for corresponding elements of vector double x.

fabsf4: Absolute Value Float

```
(vector float) fabsf4 (vector float x);
```

A vector float is returned that contains the absolute values, $|x_i|$, for corresponding elements of vector float x.

fdimd2: Subtract Staying Non-Negative Double (SPU Only)

```
(vector double) fdimd2 (vector double x, vector double y);
```

A vector double is returned that contains the larger of $(x_i - y_i)$ and zero, for corresponding elements of vector double x and vector double y.

fdimf4: Subtract Staying Non-Negative Float

```
(vector float) fdimf4 (vector float x, vector float y);
```

A vector float is returned that contains the larger of $(x_i - y_i)$ and zero, for corresponding elements of vector float x and vector float y.

floord2: Floor Double (SPU Only)

```
(vector double) floord2 (vector double x);
```

A vector double is returned that contains the largest integer values, expressed as floating-point numbers, that are not greater than the corresponding elements of vector double x.

floorf4: Floor Float

```
(vector float) floorf4 (vector float x);
```

A vector float is returned that contains the largest integer values, expressed as floating-point numbers, that are not greater than the corresponding elements of vector float x.

fmad2: Fused Multiply and Add Double (SPU Only)

```
(vector double) fmad2 (vector double x, vector double y, vector double z);
```

A vector double is returned that contains the results of the calculation of $(x_i * y_i + z_i)$, for the corresponding elements of vector double x, vector double y, and vector double z. Intermediate results are of arbitrary precision.

fmaf4: Fused Multiply and Add Float

```
(vector float) fmaf4 (vector float x, vector float y, vector float z);
```

A vector float is returned that contains the results of the calculation of $(x_i * y_i + z_i)$, for the corresponding elements of vector float x, vector float y, and vector float z. Intermediate results are of arbitrary precision.

fmaxd2: Maximum Double (SPU Only)

```
(vector double) fmaxd2 (vector double x, vector double y);
```

A vector double is returned that contains the larger (more positive) of x_i and y_i, for corresponding elements of vector double x and vector double y.

fmaxf4: Maximum Float

```
(vector float) fmaxf4 (vector float x, vector float y);
```

A vector float is returned that contains the larger (more positive) of x_i and y_i, for corresponding elements of vector float x and vector float y.

On the SPU, this function does not coerce denormals to zero. Instead, it compares them as normal values even though the SPU's floating-point instructions do not.

fmind2: Minimum Double (SPU Only)

```
(vector double) fmind2 (vector double x, vector double y);
```

A vector double is returned that contains the smaller (more negative) of x_i and y_i, for corresponding elements of vector double x and vector double y.

fminf4: Minimum Float

```
(vector float) fminf4 (vector float x, vector float y);
```

A vector float is returned that contains the smaller (more negative) of x_i and y_i, for corresponding elements of vector float x and vector float y.

On the SPU, this function does not coerce denormals to zero. Instead, it compares them as normal values even though the SPU's floating-point instructions do not.

fmodd2: Modulus Double (SPU Only)

```
(vector double) fmodd2 (vector double x, vector double y);
```

A vector double is returned that contains the remainder of x_i / y_i, for corresponding elements of vector double x and vector double y, as described below:

- If y_i is `0`, the result is `0`
- Otherwise, the function determines the unique signed integer value i such that the returned element is $x_i - i * y_i$ with the same sign as x_i and magnitude less than $|y_i|$

fmodf4: Modulus Float

```
(vector float) fmodf4 (vector float x, vector float y);
```

A vector float is returned that contains the remainder of x_i / y_i, for corresponding elements of vector float x and vector float y, as defined below:

- If y_i is `0`, the result is `0`
- Otherwise, `fmodf4()` determines the unique signed integer value i such that the returned element is $x_i - i * y_i$ with the same sign as x_i and magnitude less than $|y_i|$

fpclassifyd2: Classify Double (SPU Only)

```
(vector signed long long) fpclassifyd2 (vector double x)
```

A vector signed long long is returned that contains the floating-point classifications for corresponding elements of vector double x. The classifications, which are defined in `math.h`, are `FP_NAN`, `FP_INFINITE`, `FP_NORMAL`, `FP_SUBNORMAL`, and `FP_ZERO`.

fpclassifyf4: Classify Float

```
(vector signed int) fpclassifyf4 (vector float x)
```

A vector signed int is returned that contains the floating-point classifications for corresponding elements of vector float *x*. The classifications, which are defined in `math.h`, are `FP_NAN`, `FP_INFINITE`, `FP_NORMAL`, `FP_SUBNORMAL`, and `FP_ZERO`.

On the SPU, the resulting vector will never contain `FP_NAN` or `FP_INFINITE`.

frexpd2: Represent Double as Fraction and Exponent (SPU Only)

```
(vector double) frexpd2 (vector double x, vector signed long long *pexp);
```

A vector double is returned that contains normalized fractions, and a vector signed long long is stored in **pexp* that contains exponent integers. Each fraction element *frac* and each exponent integer element *exp* represents the value of the corresponding element of *x*, such that:

- Every element of |*frac*| is in the interval [1/2, 1) or is zero
- $x_i == frac * 2^{exp}$
- If x_i is `0`, the corresponding element of **pexp* is also zero
- If x_i is `NaN`, the corresponding result is `NaN` and the corresponding element of **pexp* is undefined.
- If x_i is `infinite`, the corresponding result is `infinite` and the corresponding element of **pexp* is undefined.

frexpf4: Represent Float as Fraction and Exponent

```
(vector float) frexpf4 (vector float x, vector signed int *pexp);
```

A vector float is returned that contains normalized fractions, and a vector signed int is stored in **pexp* that contains exponent integers. Each fraction element *frac* and each exponent integer element *exp* represents the value of the corresponding element of *x*, such that:

- Every element of |*frac*| is in the interval [1/2, 1) or is zero
- $x_i == frac * 2^{exp}$
- If x_i is `0`, the corresponding element of **pexp* is also zero
- If x_i is `NaN`, the corresponding result is `NaN` and the corresponding element of **pexp* is undefined.
- If x_i is `infinite`, the corresponding result is `infinite` and the corresponding element of **pexp* is undefined.

hypotd2: Hypotenuse Double (SPU Only)

```
(vector double) hypotd2 (vector double x, vector double y);
```

A vector double is returned that contains the square root of $x^2_i + y^2_i$ without undue overflow or underflow, for corresponding elements of vector double *x* and vector double *y*.

hypotf4: Hypotenuse Float

```
(vector float) hypotf4 (vector float x, vector float y);
```

A vector float is returned that contains the square root of $x^2_i + y^2_i$ without undue overflow or underflow, for corresponding elements of vector float *x* and vector float *y*.

ilogbd2: Integer Exponent of Double (SPU Only)

```
(vector signed long long) ilogbd2 (vector double x);
```

A vector signed long long is returned that contains the elements defined below, for corresponding elements of vector double *x*.

- If x_i is not-a-number (`NaN`), the value is the macro `FP_ILOGBNAN`

- If x_i is equal to zero, the value is the macro `FP_ILOGB0`
- If x_i is equal to positive or negative `Inf`, the value is the macro `FP_ILOGB0`
- Otherwise, the result is `(int)logb(`x_i`)`

ilogbf4: Integer Exponent of Float

```
(vector signed int) ilogbf4 (vector float x);
```

A vector signed int is returned that contains the elements defined below, for corresponding elements of vector float x.

- If x_i is not-a-number (`NaN`), the value is the macro `FP_ILOGBNAN`
- If x_i is equal to `0`, the value is the macro `FP_ILOGB0`
- If x_i is equal to positive or negative `Inf`, the value is the macro `FP_ILOGB0`
- Otherwise, the result is `(int)logb(`x_i`)`

Because the SPU treats single-precision `Inf` and `NaN` codes as regular floating-point numbers, `ilogbf4` returns a result of 128 for these numbers. For compatibility with the double function `ilogb()`, `FP_ILOGBNAN` is set to `INT_MAX`.

irintf4: Nearest Integer Float

```
(vector signed int) irintf4 (vector float x)
```

A vector signed int is returned that contains the nearest integer to the corresponding element of vector float x, consistent with the current rounding mode. If the rounded value is outside the range of the return type, the numeric result is unspecified.

On the SPU, the rounding mode for floats is always towards zero.

iroundf4: Round Float to Nearest Integer

```
(vector signed int) iroundf4 (vector float x)
```

A vector signed int is returned that contains the rounded integer value of the corresponding element of vector float x.

Elements are rounded to the nearest value; halfway cases are rounded away from zero, regardless of the current rounding direction.

If the rounded value is outside the range of the return type, the numeric result is unspecified.

is0denormd2: 0 or Denormalized Double (SPU Only)

```
(vector unsigned long long) is0denormd2 (vector double x);
```

A vector unsigned long long is returned that contains the elements defined below for corresponding elements of vector double x.

- All bits of the resulting element are set to 1 if x_i is a denormalized value or zero
- Zero otherwise

is0denormf4: 0 or Denormalized Float

```
(vector unsigned int) is0denormf4 (vector float x);
```

`A vector unsigned int` is returned that contains the elements defined below for corresponding elements of vector float x.

- All bits of the resulting element are set to 1 if x_i is a denormalized value or zero
- Zero otherwise

isequald2: Compare Equal Double (SPU Only)

```
(vector unsigned long long) isequald2 (vector double x, vector double y);
```

A vector unsigned long long is returned that contains the elements defined below for corresponding elements of vector double `x` and vector double y.

- All bits of the resulting element are set to `1` if x_i and y_i are equal
- Zero otherwise

The function correctly compares denormalized numbers. If either input is `NaN`, the comparison result is false (zero). If both inputs are `Inf` with same sign, the inputs are considered equal. The values `0` and `-0` are considered equal.

isequalf4: Compare Equal Float

```
(vector unsigned int) isequalf4 (vector float x, vector float y);
```

A vector unsigned int is returned that contains the elements defined below for corresponding elements of vector float x and vectory float y.

- All bits of the resulting element are set to `1` if x_i and y_i are equal
- Zero otherwise

The function correctly compares denormalized numbers. If either input is `NaN`, the comparison is false (zero). If both inputs are `Inf` with same sign, the inputs are considered equal. The values `0` and `-0` are considered equal.

isfinited2: Double is Finite (SPU Only)

```
(vector unsigned long long) isfinited2 (vector double x)
```

A vector unsigned long long is returned that contains the elements defined below for corresponding elements of vector double x.

- All bits of the resulting element are set to `1` if x_i is finite
- Zero otherwise

isfinitef4: Float is Finite

```
(vector unsigned int) isfinitef4 (vector float x)
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float x.

- All bits of the resulting element are set to 1 if x_i is finite
- Zero otherwise

On the SPU, infinite values are not representable in single precision. Therefore, all bits of the resulting element are set to 1 regardless of the value of x_i.

isgreaterequald2: Greater or Equal Double (SPU Only)

```
(vector unsigned long long) isgreaterequald2 (vector double x, vector double y);
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double `x` and vector double y.

- All bits of the resulting element are set to 1 if x_i equals to or greater than y_i
- Zero otherwise

The function correctly compares denormalized numbers. If either element of the input is `NaN`, the comparison is false. If both elements of the inputs are `Inf` with the same sign, the inputs are considered equal. The values `0` and `-0` are considered equal.

isgreaterequalf4: Greater or Equal Float

```
(vector unsigned int) isgreaterequalf4 (vector float x, vector float y);
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float x and vector float y.

- All bits of the resulting element are set to 1 if x_i equals to or greater than y_i
- Zero otherwise

The function correctly compares denormalized numbers. If either element of the input is `NaN`, the comparison is false. If both elements of the inputs are `Inf` with the same sign, the inputs are considered equal. The values `0` and `-0` are considered equal.

isgreaterd2: Greater than Double (SPU Only)

```
(vector unsigned long long) isgreaterd2 (vector double x, vector double y);
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double x and vector double y.

- All bits of the resulting element are set to 1 if x_i greater than y_i
- Zero otherwise

The function correctly compares denormalized numbers.

isgreaterf4: Greater than Float

```
(vector unsigned int) isgreaterf4 (vector float x, vector float y);
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float x and vector float y.

- All bits of the resulting element are set to 1 if x_i greater than y_i
- Zero otherwise

The function correctly compares denormalized numbers.

isinfd2: Double is Infinity (SPU Only)

```
(vector unsigned long long) isinfd2 (vector double x)
```

A vector unsigned long long is returned that contains elements defined below, for corresponding elements of vector double x.

- All bits of the resulting element are set to 1 if x_i is infinite
- Zero otherwise

isinff4: Float is Infinity

```
(vector unsigned int) isinff4 (vector float x)
```

A vector unsigned long int is returned that contains elements defined below for corresponding elements of vector float `x`.

- All bits of the resulting element are set to 1 if x_i is infinite
- Zero otherwise

On the SPU, infinite values are not representable in single precision. Therefore, all bits of the resulting element are set to zero, regardless of the value of x_i.

islessd2: Double is Less Than (SPU Only)

```
(vector unsigned long long) islessd2 (vector double x, vector double y)
```

A vector unsigned long long is returned that contains elements defined below, for corresponding elements of vector double x and vector double y.

- All bits of the resulting element are set to 1 if x_i less than y_i
- Zero otherwise

The function correctly compares denormalized numbers.

islessequald2: Double is Less Than or Equal To (SPU Only)

```
(vector unsigned long long) islessequald2 (vector double x, vector double y)
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double x and vector double y.

- All bits of the resulting element are set to 1 if x_i less than or equal y_i
- Zero otherwise

The function correctly compares denormalized numbers.

islessequalf4: Float is Less Than or Equal To

```
(vector unsigned int) islessequalf4 (vector float x, vector float y)
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float x and vector float y.

- All bits of the resulting element are set to 1 if x_i less than or equal y_i
- Zero otherwise

The function correctly compares denormalized numbers.

islessf4: Float is Less Than

```
(vector unsigned int) islessf4 (vector float x, vector float y)
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float x and vector float y.

- All bits of the resulting element are set to 1 if x_i less than y_i
- Zero otherwise

The function correctly compares denormalized numbers.

islessgreaterd2: Double is Less Than or Greater Than (SPU Only)

```
(vector unsigned long long) islessgreaterd2 (vector double x, vector double y)
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double x and vector double y.

- All bits of the resulting element are set to 1 if x_i less than or greater than y_i
- Zero otherwise

The function correctly compares denormalized numbers.

islessgreaterf4: Float is Less Than or Greater Than

```
(vector unsigned int) islessgreaterf4 (vector float x, vector float y)
```

A vector unsigned int is returned that contains elements defined below, for corresponding elements of vector float x and vector float y.

- All bits of the resulting element are set to 1 if x_i less than or greater than y_i
- Zero otherwise

The function correctly compares denormalized numbers.

isnand2: Double is NaN (SPU Only)

```
(vector unsigned long long) isnand2 (vector double x)
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double x.

- All bits of the resulting element are set to 1 if x_i is a `NaN`
- Zero otherwise

isnanf4: Float is NaN

```
(vector unsigned int) isnanf4 (vector float x)
```

A vector unsigned int is returned that contains elements defined below, for corresponding elements of vector float x.

- All bits of the resulting element are set to 1 if x_i is a `NaN`
- Zero otherwise

On the SPU, `NaN` is not representable in single precision. Therefore, all bits of the resulting element are set to zero, regardless of the value of x_i.

isnormald2: Double is Normal (SPU Only)

```
(vector unsigned long long) isnormald2 (vector double x)
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double x.

- All bits of the resulting element are set to 1 if x_i is normal, not a `NaN`, or an infinity
- Zero otherwise

isnormalf4: Float is Normal

```
(vector unsigned int) isnormalf4 (vector float x)
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float x.

- all bits of the resulting element are set to 1 if x_i is normal, not a `NaN`, or an infinity
- zero otherwise

isunorderedd2: Double is Unordered (SPU Only)

```
(vector unsigned long long) isunorderedd2 (vector double x, vector double y)
```

A vector unsigned long long is returned that contains elements defined below for corresponding elements of vector double x and vector double y.

- All bits of the resulting element are set to 1 if x_i is unordered to the element of y_i
- Zero otherwise

`NaN` is unordered to any operand, including `NaN` itself.

isunorderedf4: Float is Unordered

```
(vector unsigned int) isunorderedf4 (vector float x, vector float y)
```

A vector unsigned int is returned that contains elements defined below for corresponding elements of vector float `x` and vector float `y`.

- All bits of the resulting element are set to 1 if x_i is unordered to y_i
- Zero otherwise

`NaN` is unordered to any operand, including `NaN` itself. On the SPU, `NaN` does not exist in single precision. Therefore, this function will always return zero.

ldexpd2: Multiply Double by 2 Raised to its Power (SPU Only)

```
(vector double) ldexpd2 (vector double x, vector signed long long ex);
```

A vector double is returned that contains $x_i * 2^{ex_i}$ for the corresponding elements of vector double x and vector signed long long ex. For large elements of ex_i (overflow), the element in the result saturates to `HUGE_VAL` with an appropriate sign. For small elements of ex (underflow), the corresponding element of the result is `0`.

ldexpf4: Multiply Float by 2 Raised to its Power

```
(vector float) ldexpf4 (vector float x, vector signed int ex);
```

A vector float is returned that contains $x_i * 2^{ex_i}$ for the corresponding elements of vector float x and vector signed int ex. For large elements of ex (overflow), the element in the result saturates to `HUGE_VALF` with an appropriate sign. For small ex_i (underflow), the corresponding element of the result is `0`.

lgammad2: Natural Log of Gamma Function of Double (SPU Only)

```
(vector double) lgammad2 (vector double x)
```

A vector double is returned that contains the natural logarithm of the absolute value of the result of the gamma function for the corresponding elements of vector double x.

lgammaf4: Natural Log of Gamma Function of Float

```
(vector float) lgammaf4 (vector float x)
```

A vector float is returned that contains the natural logarithm of the absolute value of the result of the gamma function for the corresponding element of vector float x.

llabsi2: Absolute Value Long Long (SPU Only)

```
(vector long long) llabsi2 (vector signed long long x)
```

A vector long long is returned that contains the absolute value, $|x_i|$ of the corresponding element of vector signed long long x.

If the absolute value of x_i cannot be represented, the corresponding result is undefined and no error is reported.

lldivi2: Divide Long Long (SPU Only)

```
(lldivi2_t) lldivi2 (vector signed long long x, vector signed long long y)
```

Each element of vector signed long long x is divided by each element of vector signed long long y, and the result is returned in a structure of type `lldivi2_t()`, which contains a vector of quotients and a vector of remainders.

Each element of the vector in the structure member $quot$ is the algebraic quotient truncated towards zero. Each element of the vector in the structure member rem is the corresponding remainder, such that $x_i == quot * y_i + rem$.

If y_i is zero, the corresponding element of the resulting quotient is zero.

lldivu2: Divide Unsigned Long Long (SPU Only)

```
(lldivu2_t) lldivu2 (vector unsigned long long x, vector unsigned long long y)
```

Each element of vector unsigned long long x is divided by each element of vector unsigned long long y, and the result is returned in a structure of type `lldivu2_t()`, containing a vector of quotients and a vector of remainders.

Each element of the vector in the structure member *quot* is the algebraic quotient truncated towards zero. Each element of the vector in the structure member *rem* is the corresponding remainder, such that $x_i == quot * y_i + rem$.

If y_i is zero, the corresponding element of the resulting quotient is zero.

llrintd2: Find Nearest Long Long of Double (SPU Only)

```
(vector signed long long) llrintd2 (vector double x)
```

A vector signed long long is returned that contains the nearest long long integer to the corresponding element of vector double x consistent with the current rounding mode. If the rounded value is outside the range of the return type, the numeric result is unspecified.

llrintf4: Find Nearest Long Long of Float (SPU Only)

```
(llroundf4_t) llrintf4 (vector float x)
```

A structure of type `llroundf4_t()` is returned that contains the nearest long long integer to the corresponding element of vector float x consistent with the current rounding mode. If the rounded value is outside the range of the return type, the numeric result is unspecified.

On the SPU the rounding mode for floats is always towards zero.

llroundd2: Round Double to Nearest Long Long (SPU Only)

```
(vector signed long long) llroundd2 (vector double x)
```

A vector signed long long is returned that contains the corresponding elements of vector double x rounded to the nearest value, rounding halfway values away from `0` regardless of the current rounding direction. If the rounded value is outside the range of the return type, the numeric result is unspecified.

llroundf4: Round Float to Nearest Long Long (SPU Only)

```
(llroundf4_t) llroundf4 (vector float x)
```

A structure of type `llroundf4_t()` is returned that contains the corresponding elements of vector float x rounded to the nearest value, rounding halfway cases away from `0` regardless of the current rounding direction. If the rounded value is outside the range of the return type, the numeric result is unspecified.

logd2: Natural Log of Double (SPU Only)

```
(vector double) logd2 (vector double x);
```

A vector double is returned that contains the natural logarithms of the corresponding elements of vector double x.

If x_i is negative, the corresponding result is undefined and no error is reported.

logf4: Natural Log of Float

```
(vector float) logf4 (vector float x);
```

A vector float is returned that contains the natural logarithms of the corresponding elements of vector float x.

If x_i is negative, the corresponding result is undefined and no error is reported.

If x_i is zero, the result is `-HUGE_VALF`.

log10d2: Log Base 10 of Double (SPU Only)

```
(vector double) log10d2 (vector double x);
```

A vector double is returned that contains the base-10 logarithm of the corresponding elements of vector double x.

If x_i is negative, the corresponding result is undefined and no error is reported.

log10f4: Log Base 10 of Float

```
(vector float) log10f4 (vector float x);
```

A vector float is returned that contains the base-10 logarithm of the corresponding elements of vector float x.

If x_i is negative, the corresponding result is undefined and no error is reported.

If x_i is zero, the result is `-HUGE_VALF`.

log1pd2: Natural Log of Double Plus 1 (SPU Only)

```
(vector double) log1pd2 (vector double x);
```

A vector double is returned that contains the natural logarithm of $1 + x_i$ for the corresponding elements of vector double x.

The function returns mathematically accurate values even when the corresponding element of x_i is near zero.

If x_i is less than -1, the corresponding result is undefined and no error is reported.

log1pf4: Natural Log of Float Plus 1

```
(vector float) log1pf4 (vector float x);
```

A vector float is returned that contains the natural logarithms of $1 + x_i$, for corresponding elements of vector float x.

The function returns mathematically accurate values even when the corresponding element of x_i is near zero. If an element of x_i is -1, the result is `-HUGE_VALF`.

If x_i is less than -1, the corresponding result is undefined and no error is reported.

log2d2: Log Base 2 of Double (SPU Only)

```
(vector double) log2d2 (vector double x);
```

A vector double is returned that contains the base-2 logarithm of the corresponding elements of vector double x.

If x_i is less than 0, the corresponding result is undefined and no error is reported.

log2f4: Log Base 2 of Float

```
(vector float) log2f4 (vector float x);
```

A vector float is returned that contains the base-2 logarithm of the corresponding elements of vector float x.

If x_i is zero, the result is `-HUGE_VALF`.

If x_i is less than zero, the corresponding result is undefined and no error is reported.

logbd2: Represent Double as Fraction Greater Than 1 and Exponent (SPU Only)

```
(vector double) logbd2 (vector double x);
```

An integer exponent ex_i and a fraction $frac_i$ that represents the value of a finite element are determined for corresponding elements of vector double x. A vector double is returned that contains the value of ex_i for x_i, such that:

- $x_i == frac * FLT\_RADIX^{ex}$
- $|frac|$ is in the interval `[1, FLT_RADIX)`

If x_i is 0, the corresponding result is undefined and no error is reported.

On the SPU, if x_i is 0, the corresponding result is `-HUGE_VALF`. If x_i is infinite, the corresponding result is postive infinite. If x_i is a `NaN`, the corresponding result is also a `NaN`.

logbf4: Represent Float as Fraction Greater Than 1 and Exponent

```
(vector float) logbf4 (vector float x);
```

An integer exponent ex and a fraction $frac_i$ that represents the value of a finite element are determined for corresponding elements of vector float x. A vector float is returned that contains the values of ex_i for x_i, such that:

- $x_i == frac * FLT\_RADIX^{ex}$
- $|frac|$ is in the interval `[1, FLT_RADIX)`

If x_i is 0, the corresponding result is undefined and no error is reported.

modfd2: Represent Double as Proper Fraction and Exponent (SPU Only)

```
(vector double) modfd2 (vector double x, vector double *pint);
```

Each element of vector double x is split into an integral part i_i and a fractional part $frac_i$. A vector double is returned that contains the corresponding $frac_i$ elements, and another vector double is stored in $*pint$ that contains the corresponding i_i elements, such that:

- $x_i == frac + i$
- `|frac|` is in the interval `[0, 1)`
- both `frac` and i have the same sign as x_i

modff4: Represent Float as Proper Fraction and Exponent

```
(vector float) modff4 (vector float x, vector float *pint);
```

Each element of vector float x is split into an integral part i_i and a fractional part $frac_i$. A vector float is returned that contains the corresponding $frac_i$ elements, and another vector float is stored in $*pint$ that contains the corresponding i_i elements, such that:

- $x_i == frac + i$
- `|frac|` is in the interval `[0, 1)`
- both `frac` and i have the same sign as x_i

nearbyintd2: Find Nearest Integer for Double (SPU Only)

```
(vector double) nearbyintd2 (vector double x)
```

A vector double is returned that contains the corresponding elements of vector double x rounded to the nearest integer consistent with the current rounding mode, but without raising an inexact floating-point exception.

nearbyintf4: Find Nearest Integer for Float

```
(vector float) nearbyintf4 (vector float x)
```

A vector float is returned that contains the corresponding elements of vector float x rounded to the nearest integer, consistent with the current rounding mode, but without raising an inexact floating-point exception.

On the SPU, the rounding mode for a float is always towards zero.

negated2: Negate Double (SPU Only)

```
(vector double) negated2 (vector double x);
```

A vector double is returned that contains $-x_i$ for corresponding elements of vector double x.

negatef4: Negate Float

```
(vector float) negatef4 (vector float x);
```

A vector float is returned that contains $-x_i$ for corresponding elements of vector float x.

negatei4: Negate Signed Integer

```
(vector signed int) negatei4 (vector signed int x);
```

A vector signed int is returned that contains $-x_i$ for corresponding elements of vector signed int x.

If $-x_i$ cannot be represented, the corresponding result is undefined and no error is reported.

negatell2: Negate Signed Long Long Integer (SPU Only)

```
(vector signed long long) negatell2 (vector signed long long x);
```

A vector signed long long is returned that contains $-x_i$ for corresponding elements of vector signed long long x.

If $-x_i$ cannot be represented, the corresponding result is undefined and no error is reported.

nextafterd2: Find Next Integer After for Double (SPU Only)

```
(vector double) nextafterd2 (vector double x, vector double y)
```

A vector double is returned that contains the next representable value after x_i in the direction of y_i for corresponding elements of vector double x and vector double y. If x_i is equal to y_i the result is y_i.

If the magnitude x_i is the largest finite value representable, the result is undefined.

nextafterf4: Find Next Integer After for Float

```
(vector float) nextafterf4 (vector float x, vector float y)
```

A vector float is returned that contains the next representable value after x_i in the direction of y_i for corresponding elements of vector float x and vector float y. If the element of x_i is equal to y_i, the result is y_i.

If the magnitude of x_i is the largest finite value representable, the result is undefined.

powd2: Raise Double to Double Power (SPU Only)

```
(vector double) powd2 (vector double x, vector double y);
```

A vector double is returned that contains x_i raised to the power of y_i, ${x^y}_i$, for corresponding elements of vector double x and vector double y.

If x_i is finite and negative and y_i is finite and not a integer value, the corresponding result is undefined and no error is reported.

powf4: Raise Float to Float Power

```
(vector float) powf4 (vector float x, vector float y);
```

A vector float is returned that contains x_i raised to the power of y_i, ${x^y}_i$, for corresponding elements of vector float x and vector float y.

On the SPU, if the result would be greater than `HUGE_VALF`, the result is saturated to `HUGE_VALF` and no error is reported.

recipd2: Reciprocal of Double (SPU Only)

```
(vector double) recipd2 (vector double x);
```

A vector double is returned that contains the reciprocal of the corresponding elements of vector double x.

The function handles special cases as follows:

- When x_i is ±Inf, the result is 0 with the sign of x_i
- When x_i is 0, the result is Inf with the sign of x_i
- When x_i is NaN, the result is NaN

recipf4: Reciprocal of Float

```
(vector float) recipf4 (vector float x);
```

A vector float is returned that contains the reciprocal of the corresponding elements of vector float x.

The function handles special cases as follows:

- When x_i is ±Inf, the result is 0 with the sign of x_i
- When x_i is 0, the result is HUGE_VALF with the sign of x_i
- When an element of x_i is NaN, the result is NaN

remainderd2: Remainder of Doubles (SPU Only)

```
(vector double) remainderd2 (vector double x, vector double y);
```

A vector double is returned that contains the remainder x_i REM y_i for the corresponding elements of vector double x and vector double y.

If y_i is zero, the corresponding element of the result is undefined and no error is reported.

remainderf4: Remainder of Floats

```
(vector float) remainderf4 (vector float x, vector float y);
```

A vector float is returned that contains the remainder x_i REM y_i, for the corresponding elements of vector float x and vector float y.

If y_i is zero, the corresponding element of the result is undefined and no error is reported.

remquod2: Remainder Function of Double (SPU Only)

```
(vector double) remquod2 (vector double x, vector double y, vector signed long long
*pquo)
```

This function returns the same vector double result as `remainderd2()`. In addition a vector signed long long is stored in *pquo that contains the corresponding element values whose sign is the sign of x_i / y_i and whose magnitude is congruent modulo 2^n to the magnitude of the integral quotient of x_i / y_i, where *n* is an implementation-defined integer greater than or equal to 3.

remquof4: Remainder Function of Float

```
(vector float) remquof4 (vector float x, vector float y, vector signed int *pquo)
```

This function returns the same vector float result as `remainderf4()`. In addition a vector signed int is stored in *pquo that contains the corresponding element values whose sign is the sign of x_i / y_i and whose magnitude is congruent modulo 2^n to the magnitude of the integral quotient of x_i / y_i, where *n* is an implementation-defined integer greater than or equal to 3.

rintd2: Round Double to the Nearest Integer (SPU Only)

```
(vector double) rintd2 (vector double x);
```

A vector double is returned that contains the corresponding elements of vector double x rounded to the nearest integer, consistent with the current rounding mode.

rintf4: Round Float to the Nearest Integer

```
(vector float) rintf4 (vector float x);
```

A vector float is returned that contains the corresponding elements of vector float x rounded to the nearest integer, consistent with the current rounding model.

On the SPU, the rounding mode for float is always towards zero.

roundd2: Round Double (SPU Only)

```
(vector double) roundd2 (vector double x);
```

A vector double is returned that contains the rounded elements of vector double x. Rounding is done to the nearest integer value in floating-point format. Halfway cases are rounded away from zero regardless of the current rounding direction.

roundf4: Round Float

```
(vector float) roundf4 (vector float x);
```

A vector float is returned that contains the rounded elements of vector float x. Rounding is done to the nearest integer value in floating-point format. Halfway cases are rounded away from zero regardless of the current rounding direction.

rsqrtd2: Reciprocal Square Root of Double (SPU Only)

```
(vector double) rsqrtd2 (vector double x);
```

A vector double is returned that contains the reciprocal of the square root of x_i for the corresponding elements of vector double x. Special cases are handled as follows:

- When x_i is less than `0`, the result is `NaN`
- When x_i is `+Inf`, the result is `+0`
- When x_i is `0`, the result is `Inf` with the sign of x_i
- When x_i is `NaN`, the result is `NaN`

rsqrtf4: Reciprocal Square Root of Float

```
(vector float) rsqrtf4 (vector float x);
```

A vector float is returned that contains the reciprocal of the square root of x_i for the corresponding elements of vector float x. Special cases are handled as follows:

- When x_i is less than `0`, the result is `NaN`
- When x_i is `+Inf`, the result is `+0`
- When x_i is `0`, the result is `Inf` with the sign of x_i
- When x_i is `NaN`, the result is `NaN`

On the SPU, if x_i is less than zero, the corresponding result is undefined.

scalbllnd2: Scale Double by Long Long Integer (SPU Only)

```
(vector double) scalbllnd2 (vector double x, vector signed long long n)
```

A vector double is returned that contains x_i efficiently multiplied by 2^n for corresponding elements of vector double x and vector signed long long n.

scalbnf4: Scale Float by Integer

```
(vector float) scalbnf4 (vector float x, vector signed int n)
```

A vector float is returned that contains x_i efficiently multiplied by 2^n for corresponding elements of vector float x and vector signed int n.

signbitd2: Sign Bit of Double (SPU Only)

```
(vector unsigned long long) signbitd2 (vector double x)
```

A vector unsigned long long is returned that contains the elements defined below for corresponding elements of vector double `x`.

- All bits of the resulting element are set to 1 if the sign bit is set in x_i
- Zero otherwise

signbitf4: Sign Bit of Float

```
(vector unsigned int) signbitf4 (vector float x)
```

A vector unsigned int is returned that contains the elements defined below for corresponding elements of vector float x.

- All bits of the resulting element are set to 1 if the sign bit is set in x_i
- Zero otherwise

sincosd2: Sine and Cosine of Double (SPU Only)

```
(void) sincosd2 (vector double x, vector double *sx, vector double *cx);
```

A vector double is stored in $*sx$ and a vector double is stored in $*cx$ that contain the respective sines and cosines of the corresponding elements of vector double x.

The results of `sincosd2()` may not be accurate for very large values of x_i, and no error is reported. Implementations should document the point at which accuracy is lost.

sincosf4: Sine and Cosine of Float

```
(void) sincosf4 (vector float x, vector float *sx, vector float *cx);
```

A vector float is stored in $*sx$, and a vector float is stored in $*cx$, that contains the respective sines and cosines of the corresponding elements of vector float x.

The results of `sincosf4()` may not be accurate for very large values of x_i, and no error is reported. Implementations should document the point at which accuracy is lost.

sind2: Sine of Double (SPU Only)

```
(vector double) sind2 (vector double x);
```

A vector double is returned that contains the corresponding sines of the elements of vector double x.

The results of `sind2()` may not be accurate for very large values of x_i, and no error is reported. Implementations should document the point at which accuracy is lost.

sinf4: Sine of Float

```
(vector float) sinf4 (vector float x);
```

A vector float is returned that contains the corresponding sines of the elements of vector float x.

The results of `sinf4()` may not be accurate for very large values of x_i, and no error is reported. Implementations should document the point at which accuracy is lost.

sinhd2: Hyperbolic Sine of Double (SPU Only)

```
(vector double) sinhd2 (vector double x)
```

A vector double is returned that contains the corresponding hyperbolic sines of the elements of vector double x.

sinhf4: Hyperbolic Sine of Float

```
(vector float) sinhf4 (vector float x)
```

A vector float is returned that contains the corresponding hyperbolic sines of the elements of vector float x.

On the SPU, element values of the result that are greater than `HUGE_VALF` are returned as `HUGE_VALF`, and no error is reported.

sqrtd2: Square Root of Double (SPU Only)

```
(vector double) sqrtd2 (vector double x);
```

A vector double is returned that contains the real square roots ${x^{1/2}}_i$ for the corresponding elements of vector double x.

This function handles special cases as follows:

- When x_i is less than `0`, the result is `NaN`
- When x_i is `+Inf`, the result is `+Inf`
- When x_i is `0`, the result is `0` with the sign of x_i
- When x_i is `NaN`, the result is `NaN`

sqrtf4: Square Root of Float

```
(vector float) sqrtf4 (vector float x);
```

A vector float is returned that contains the real square roots $x^{1/2}$ for the corresponding elements of vector float x.

This function handles special cases as follows:

- When x_i is less than `0`, the result is `NaN`
- When x_i is `+Inf`, the result is `+Inf`
- When x_i is `0`, the result is `0` with the sign of x_i
- When x_i is `NaN`, the result is `NaN`

On the SPU, the result is undefined when x_i is negative.

tand2: Tangent of Double (SPU Only)

```
(vector double) tand2 (vector double x);
```

A vector double is returned containing the corresponding tangents of the elements of vector double x.

The results may not be accurate for very large values of x_i and no error is reported. Implementations should document the point at which accuracy is lost.

tanf4: Tangent of Float

```
(vector float) tanf4 (vector float x);
```

A vector float is returned containing the corresponding tangents of the elements of vector float x.

The results may not be accurate for very large values of x_i and no error is reported. Implementations should document the point at which accuracy is lost.

tanhd2: Hyperbolic Tangent of Double (SPU Only)

```
(vector double) tanhd2 (vector double x)
```

A vector double is returned that contains the corresponding hyperbolic tangents of the elements of vector double x.

tanhf4: Hyperbolic Tangent of Float

```
(vector float) tanhf4 (vector float x)
```

A vector float is returned that contains the corresponding hyperbolic tangents of the elements of vector float x.

tgammad2: Gamma of Double (SPU Only)

```
(vector double) tgammad2 (vector double x)
```

A vector double is returned that contains the corresponding results of the gamma function applied to the respective elements of vector double x.

If x_i is a negative integer, the corresponding element of the result is undefined and no error is reported.

tgammaf4: Gamma of Float

```
(vector float) tgammaf4 (vector float x)
```

A vector float is returned that contains the corresponding results of the gamma function applied to the respective elements of vector float x.

If x_i is a negative integer, the corresponding element of the result is undefined and no error is reported.

truncd2: Truncate Double (SPU Only)

```
(vector double) truncd2 (vector double x);
```

A vector double is returned that contains x_i rounded to the nearest integer n that is not larger in magnitude than x_i (rounded towards zero) for each corresponding element of vector double x.

truncf4: Truncate Float

```
(vector float) truncf4 (vector float x);
```

A vector float is returned that contains x_i rounded to the nearest integer n that is not larger in magnitude than x_i (rounded towards zero) for each corresponding element of vector float x.

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End of Document