



OpenCL Extended Instruction Set Specification

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Contents

1	Introduction	4
2	Binary Form	4
2.1	Math extended instructions	6
2.2	Integer instructions	34
2.3	Common instructions	45
2.4	Geometric instructions	48
2.5	Relational instructions	51
2.6	Vector Data Load and Store instructions	52
2.7	Miscellaneous Vector instructions	57
2.8	Misc instructions	59
2.9	Image encoding	60
2.10	Sampler encoding	63
A	Changes and TBD	63
A.1	Changes from Version 0.99, Revision 1	63
A.2	Changes from Version 0.99, Revision 2	63
A.3	Changes from Version 0.99, Revision 3	63
A.4	Changes from Version 1.0, Revision 1	63
A.5	Changes from Version 1.0, Revision 2	64

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1 Introduction

This is the specification of **OpenCL.std** extended instruction set.

The library is imported into a SPIR-V module in the following manner:

```
<ext-inst-id> OpExtInstImport "OpenCL.std"
```

The library can only be imported when **Memory Model** is set to **OpenCL**

2 Binary Form

This section contains the semantics and exact form of execution of OpenCL extended instructions using the **OpExtInst** instruction.

In this section we use the following naming conventions:

- *void* denote an **OpTypeVoid**.
- *half*, *float* and *double* denote an **OpTypeFloat** with a width of 16, 32 and 64 bits respectively.
- *i8*, *i16*, *i32* and *i64* denote an **OpTypeInt** with a width of 8, 16, 32 and 64 bits respectively.
- *bool* denotes an **OpTypeBool**.
- *size_t* denotes an *i32* when the **Addressing Model** is **Physical32** and *i64* when the **Addressing Model** is **Physical64**.

- *vector*(n) denotes an **OpTypeVector** where n indicates the component count.
 - *vector*(n_1, n_2, \dots, n_i) abbreviates *vector*(n_1), *vector*(n_2), ... or *vector*(n_i).
- *integer* denotes *i8*, *i16*, *i32* or *i64*.
- *floating-point* denotes *half*, *float*, *double*.
- *pointer*(*storage*) denotes an **OpTypePointer** which points to *storage* **Storage Class**.
 - *pointer*(*constant*) denotes an OpTypePointer with **UniformConstant Storage Class**.
 - *pointer*(*generic*) denotes an OpTypePointer with **Generic Storage Class**.
 - *pointer*(*global*) denotes an OpTypePointer with **CrossWorkgroup Storage Class**.
 - *pointer*(*local*) denotes an OpTypePointer with **Workgroup Storage Class**.
 - *pointer*(*private*) denotes an OpTypePointer with **Function Storage Class**.
 - *pointer*(s_1, s_2, \dots, s_i) abbreviates *pointer*(s_1), *pointer*(s_2), ... or *pointer*(s_i).
- *image* defines all types of image memory objects (See [image encoding](#) section).
- *sampler* a SPIR-V sampler object (See [sampler encoding](#) section).

2.1 Math extended instructions

This section describes the list of external math instructions. The external math instructions are categorized into the following:

- A list of instructions that have scalar or vector argument versions, and,
- A list of instructions that only take scalar float arguments.

The vector versions of the math instructions operate component-wise. The description is per-component.

The math instructions are not affected by the prevailing rounding mode in the calling environment, and always return the same value as they would if called with the round to nearest even rounding mode.

acos						
Compute the arc cosine of x .						
Result is an angle in radians						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<i><id></i> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <i><id></i>	0	<i><id></i> x

acosh						
Compute the inverse hyperbolic cosine of x .						
Result is an angle in radians						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<i><id></i> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <i><id></i>	1	<i><id></i> x

<p>acospi</p> <p>Compute $\text{acos}(x) / \pi$.</p> <p>Result is an angle in radians</p> <p><i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p>All of the operands, including the <i>Result Type</i> operand, must be of the same type.</p>						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	2	<id> x

<p>asin</p> <p>Compute the arc sine of x.</p> <p>Result is an angle in radians</p> <p><i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p>All of the operands, including the <i>Result Type</i> operand, must be of the same type.</p>						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	3	<id> x

<p>asinh</p> <p>Compute the inverse hyperbolic sine of x.</p> <p>Result is an angle in radians</p> <p><i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p>All of the operands, including the <i>Result Type</i> operand, must be of the same type.</p>						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	4	<id> x

asinpi						
Compute $\text{asin}(x) / \pi$.						
Result is an angle in radians						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	5	<id> x

atan						
Compute the arc tangent of x .						
Result is an angle in radians						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	6	<id> x

atan2							
Compute the arc tangent of y / x .							
Result is an angle in radians							
<i>Result Type</i> , y and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	7	<id> y	<id> x

atanh

Compute the hyperbolic arc tangent of x .

Result is an angle in radians

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	8	<id> x
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atanpi

Compute $\text{atan}(x) / \pi$.

Result is an angle in radians

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	9	<id> x
---	----	----------------------------	--------------------	--------------------------------------	---	-------------

atan2pi

Compute $\text{atan2}(y, x) / \pi$.

Result is an angle in radians

Result Type, y and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	10	<id> y	<id> x
---	----	----------------------------	--------------------	--------------------------------------	----	-------------	-------------

cbrt						
Compute the cube-root of x .						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	11	<id> x

ceil						
Round x to integral value using the round to positive infinity rounding mode.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	12	<id> x

copysign							
Returns x with its sign changed to match the sign of y .							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	13	<id> x	<id> y

cos						
Compute the cosine of x radians.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	14	<id> x

cosh						
Compute the hyperbolic cosine of x radians.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	15	<id> x

cospi						
Compute $\cos(x) / \pi$ radians.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	16	<id> x

erfc						
Complementary error function of x .						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	17	<id> x

erf						
Error function of x encountered in integrating the normal distribution.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	18	<id> x

exp						
Compute the base-e exponential of x . (i.e. e^x)						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	19	<id> x

exp2						
Computes 2 raised to the power of x . (i.e. 2^x)						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	20	<id> x

exp10						
Computes 10 raised to the power of x . (i.e. 10^x)						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	21	<id> x

expm1						
Computes $e^x - 1.0$.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	22	<id> x

fabs

Compute the absolute value of x .

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	23	<id> x
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fdim

Compute $x - y$ if $x > y$, $+0$ if x is less than or equal to y .

Result Type, x and y must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	24	<id> x	<id> y
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floor

Round x to the integral value using the round to negative infinity rounding mode.

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	25	<id> x
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fma

Compute the correctly rounded floating-point representation of the sum of c with the infinitely precise product of a and b . Rounding of intermediate products shall not occur. Edge case behavior is per the IEEE 754-2008 standard.

Result Type, a , b and c must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	26	<id> a	<id> b	<id> c
---	----	----------------------------	--------------------	--------------------------------------	----	-------------	-------------	-------------

fmax

Returns y if $x < y$, otherwise it returns x . If one argument is a NaN, *Fmax* returns the other argument. If both arguments are NaNs, *Fmax* returns a NaN.

Result Type, x and y must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

Note: *fmax* behave as defined by C99 and may not match the IEEE 754-2008 definition for *maxNum* with regard to signaling NaNs. Specifically, signaling NaNs may behave as quiet NaNs

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	27	<id> x	<id> y
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fmin

Returns y if $y < x$, otherwise it returns x . If one argument is a NaN, *Fmin* returns the other argument. If both arguments are NaNs, *Fmin* returns a NaN.

Result Type, x and y must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

Note: *fmin* behave as defined by C99 and may not match the IEEE 754-2008 definition for *minNum* with regard to signaling NaNs. Specifically, signaling NaNs may behave as quiet NaNs

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	28	<id> x	<id> y
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fmod

Modulus. Returns $x - y * \text{trunc}(x/y)$.

Result Type, x and y must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	29	<id> x	<id> y
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fract

Returns $fmin(x - floor(x), 0x1.ffffep-1f \cdot floor(x))$ is returned in *ptr*.

Result Type and *x* must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

ptr must be a *pointer(global, local, private, generic)* to *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type, or must be a pointer to the same type.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	30	<id> <i>x</i>	<id> <i>ptr</i>
---	----	----------------------------	--------------------------	--------------------------------------	----	------------------	--------------------

frexp

Extract the mantissa and exponent from *x*. The *Result Type* holds the mantissa, and *exp* points to the exponent. For each component the mantissa returned is a *floating-point* with magnitude in the interval $[1/2, 1)$ or 0. Each component of *x* equals mantissa returned * 2^{exp} .

Result Type and *x* must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

exp must be a *pointer(global, local, private, generic)* to *i32* or *vector(2,3,4,8,16)* of *i32* values.

Result Type and *x* operands must be of the same type. *exp* operand must point to an *i32* with the same component count as *Result Type* and *x* operands.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	31	<id> <i>x</i>	<id> <i>exp</i>
---	----	----------------------------	--------------------------	--------------------------------------	----	------------------	--------------------

hypot

Compute the value of the square root of $x^2 + y^2$ without undue overflow or underflow.

Result Type, *x* and *y* must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	32	<id> <i>x</i>	<id> <i>y</i>
---	----	----------------------------	--------------------------	--------------------------------------	----	------------------	------------------

ilogb							
Return the exponent of x as an $i32$ value.							
<i>Result Type</i> must be $i32$ or $vector(2,3,4,8,16)$ of $i32$ values.							
x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
<i>Result Type</i> and x operands must have the same component count.							
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	33	<id> x	

ldexp							
Multiply x by 2 to the power k .							
k must be $i32$ or $vector(2,3,4,8,16)$ of $i32$ values.							
<i>Result Type</i> and x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
<i>Result Type</i> and x operands must be of the same type. k operand must have the same component count as <i>Result Type</i> and x operands.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	34	<id> x	<id> k

lgamma							
Log gamma function of x . Returns the natural logarithm of the absolute value of the gamma function.							
<i>Result Type</i> and x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	35	<id> x	

lgamma_r

Log gamma function of x . Returns the natural logarithm of the absolute value of the gamma function. The sign of the gamma function is returned in the *signp* operand

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

signp must be a *pointer(global, local, private, generic)* to *i32* or *vector(2,3,4,8,16)* of *i32* values.

Result Type and x operands must be of the same type. *signp* operand must point to an *i32* with the same component count as *Result Type* and x operands.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	36	<id> x	<id> <i>signp</i>
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log

Compute natural logarithm of x .

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	37	<id> x
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log2

Compute a base 2 logarithm of x .

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	38	<id> x
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log10

Compute a base 10 logarithm of x .

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	39	<id> x
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log1p						
Compute $\log_e(1.0 + x)$.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	40	<id> x

logb						
Compute the exponent of x , which is the integral part of $\log_r x $.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	41	<id> x

mad								
mad approximates $a * b + c$. Whether or how the product of $a * b$ is rounded and how supernormal or subnormal intermediate products are handled is not defined. mad is intended to be used where speed is preferred over accuracy								
<i>Result Type</i> , a , b and c must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
Note: For some usages, e.g. $\text{mad}(a, b, -a*b)$, the definition of mad() is loose enough that almost any result is allowed from mad() for some values of a and b .								
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	42	<id> a	<id> b	<id> c

maxmag							
Returns x if $ x > y $, y if $ y > x $, otherwise $\text{fmax}(x, y)$.							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	43	<id> x	<id> y

minmag							
Returns x if $ x < y $, y if $ y < x $, otherwise $fmin(x, y)$.							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	44	<id> x	<id> y

modf							
Decompose a <i>floating-point</i> number. The <code>modf</code> function breaks the argument x into integral and fractional parts, each of which has the same sign as the argument. It stores the integral part in the object pointed to by <i>iptr</i>							
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
<i>iptr</i> must be a <i>pointer(global, local, private, generic)</i> to <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type, or must be a pointer to the same type.							
7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	45	<id> x	<id> <i>iptr</i>

nan							
Returns a quiet NaN. The <i>nancode</i> may be placed in the significand of the resulting NaN.							
<i>Result Type</i> must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
<i>nancode</i> must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
<i>Result Type</i> and <i>nancode</i> operands must have the same component count. The primitive data type size of <i>nancode</i> and <i>Result Type</i> must be equal.							
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	46	<id> <i>nancode</i>	

nextafter							
Computes the next representable <i>floating-point</i> value following x in the direction of y . Thus, if y is less than x , <i>nextafter()</i> returns the largest representable floating-point number less than x .							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	47	<id> x	<id> y

pow							
Compute x to the power y .							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	48	<id> x	<id> y

pown							
Compute x to the power y , where y is an <i>i32</i> integer.							
y must be <i>i32</i> or <i>vector(2,3,4,8,16)</i> of <i>i32</i> values.							
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
<i>Result Type</i> and x operands must be of the same type. y operand must have the same component count as <i>Result Type</i> and x operands.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	49	<id> x	<id> y

powr							
Compute x to the power y , where x is ≥ 0 .							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	50	<id> x	<id> y

remainder

Compute the value r such that $r = x - n*y$, where n is the integer nearest the exact value of x/y . If there are two integers closest to x/y , n shall be the even one. If r is zero, it is given the same sign as x .

Result Type, x and y must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	51	<id> x	<id> y
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remquo

The `remquo` function computes the value r such that $r = x - k*y$, where k is the integer nearest the exact value of x/y . If there are two integers closest to x/y , k shall be the even one. If r is zero, it is given the same sign as x . This is the same value that is returned by the `remainder` function. `remquo` also calculates the lower seven bits of the integral quotient x/y , and gives that value the same sign as x/y . It stores this signed value in the object pointed to by `quo`.

Result Type, x and y must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

`quo` must be a *pointer(global, local, private, generic)* to *i32* or *vector(2,3,4,8,16)* of *i32* values.

Result Type, x and y operands must be of the same type. `quo` operand must point to an *i32* with the same component count as *Result Type*, x and y operands.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	52	<id> x	<id> y	<id> <code>quo</code>
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rint

Round x to integral value (using round to nearest even rounding mode) in floating-point format.

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	53	<id> x
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rootn							
Compute x to the power $1/y$.							
y must be $i32$ or $vector(2,3,4,8,16)$ of $i32$ values.							
<i>Result Type</i> and x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
<i>Result Type</i> and x operands must be of the same type. y operand must have the same component count as <i>Result Type</i> and x operands.							
7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	54	<id> x	<id> y

round							
Return the integral value nearest to x rounding halfway cases away from zero, regardless of the current rounding direction.							
<i>Result Type</i> and x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	55	<id> x	

rsqrt							
Compute inverse square root of x .							
<i>Result Type</i> and x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	56	<id> x	

sin							
Compute sine of x radians.							
<i>Result Type</i> and x must be <i>floating-point</i> or $vector(2,3,4,8,16)$ of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	57	<id> x	

sincos							
<p>Compute sine and cosine of x radians. The computed sine is the return value and computed cosine is returned in <i>cosval</i>.</p> <p><i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p><i>cosval</i> must be a <i>pointer(global, local, private, generic)</i> to <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p>All of the operands, including the <i>Result Type</i> operand, must be of the same type, or must be a pointer to the same type.</p>							
7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	58	<id> x	<id> <i>cosval</i>

sinh							
<p>Compute hyperbolic sine of x radians.</p> <p><i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p>All of the operands, including the <i>Result Type</i> operand, must be of the same type.</p>							
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	59	<id> x	

sinpi							
<p>Compute $\sin(\pi x)$ radians.</p> <p><i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.</p> <p>All of the operands, including the <i>Result Type</i> operand, must be of the same type.</p>							
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	60	<id> x	

sqrt						
Compute square root of x .						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	61	<id> x

tan						
Compute tangent of x radians.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	62	<id> x

tanh						
Compute hyperbolic tangent of x radians.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	63	<id> x

tanpi						
Compute $\tan(\pi x)$ radians.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	64	<id> x

tgamma						
Compute the gamma function of x .						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	65	<id> x

trunc						
Round x to integral value using the round to zero rounding mode.						
<i>Result Type</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	66	<id> x

half_cos						
Compute cosine of x radians, where x must be in the range $-2^{16} \dots +2^{16}$.ha						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	67	<id> x

half_divide							
Compute x / y .							
<i>Result Type</i> , x and y must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	68	<id> x	<id> y

half_exp						
Compute the base-e exponential of x .						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	69	<id> x

half_exp2						
Compute the base- 2 exponential of x .						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	70	<id> x

half_exp10						
Compute the base- 10 exponential of x .						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	71	<id> x

half_log						
Compute natural logarithm of x .						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	72	<id> x

half_log2

Compute a base 2 logarithm of x .

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	73	<id> x
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half_log10

Compute a base 10 logarithm of x .

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	74	<id> x
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half_powr

Compute x to the power y , where x is ≥ 0 .

Result Type, x and y must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	75	<id> x	<id> y
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half_recip

Compute reciprocal of x .

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	76	<id> x
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half_rsqrt						
Compute inverse square root of x .						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	77	<id> x

half_sin						
Compute sine of x radians, where x must be in the range $-2^{16} \dots +2^{16}$.						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	78	<id> x

half_sqrt						
Compute the square root of x .						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	79	<id> x

half_tan						
Compute tangent value of x radians, where x must be in the range $-2^{16} \dots +2^{16}$.						
<i>Result Type</i> and x must be <i>float</i> or <i>vector(2,3,4,8,16)</i> of <i>float</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	80	<id> x

native_cos

Compute cosine of x radians over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	81	<id> x
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native_divide

Compute x / y over an implementation-defined range. The maximum error is implementation-defined.

Result Type, x and y must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	82	<id> x	<id> y
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native_exp

Compute the base-e exponential of x over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	83	<id> x
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native_exp2

Compute the base- 2 exponential of x over an implementation-defined range. The maximum error is implementation-defined..

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	84	<id> x
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native_exp10

Compute the base- 10 exponential of x over an implementation-defined range. The maximum error is implementation-defined..

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	85	<id> x
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native_log

Compute natural logarithm of x over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	86	<id> x
---	----	----------------------------	--------------------	--------------------------------------	----	-------------

native_log2

Compute a base 2 logarithm of x over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	87	<id> x
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native_log10

Compute a base 10 logarithm of x over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	88	<id> x
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native_powr

Compute x to the power y , where x is ≥ 0 .

Result Type, x and y must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	89	<id> x	<id> y
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native_recip

Compute reciprocal of x over an implementation-defined range. The range of x and y are implementation-defined. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	90	<id> x
---	----	----------------------------	--------------------	--------------------------------------	----	-------------

native_rsqrt

Compute inverse square root of x over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	91	<id> x
---	----	----------------------------	--------------------	--------------------------------------	----	-------------

native_sin

Compute sine of x radians over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	92	<id> x
---	----	----------------------------	--------------------	--------------------------------------	----	-------------

native_sqrt

Compute the square root of x over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	93	<id> x
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native_tan

Compute tangent value of x radians over an implementation-defined range. The maximum error is implementation-defined.

Result Type and x must be *float* or *vector(2,3,4,8,16)* of *float* values.

All of the operands, including the *Result Type* operand, must be of the same type.

The function may map to one or more native device instructions and will typically have better performance compared to the non native corresponding functions. Support for denormal values is implementation-defined for this function

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	94	<id> x
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2.2 Integer instructions

This section describes the list of integer instructions that take scalar or vector arguments. The vector versions of the integer functions operate component-wise. The description is per-component.

s_abs						
Returns $ x $, where x is treated as signed integer.						
<i>Result Type</i> and x must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	141	<id> x

s_abs_diff							
Returns $ x - y $ without modulo overflow, where x and y are treated as signed integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	142	<id> x	<id> y

s_add_sat							
Returns the saturated value of $x + y$, where x and y are treated as signed integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	143	<id> x	<id> y

u_add_sat							
Returns the saturated value of $x + y$, where x and y are treated as unsigned integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	144	<id> x	<id> y

s_hadd							
Returns the value of $(x + y) \gg 1$, where x and y are treated as signed integers. The intermediate sum does not modulo overflow.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	145	<id> x	<id> y

u_hadd							
Returns the value of $(x + y) \gg 1$, where x and y are treated as unsigned integers. The intermediate sum does not modulo overflow.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	146	<id> x	<id> y

s_rhadd							
Returns the value of $(x + y + 1) \gg 1$, where x and y are treated as signed integers. The intermediate sum does not modulo overflow.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	147	<id> x	<id> y

u_rhadd

Returns the value of $(x + y + 1) \gg 1$, where x and y are treated as unsigned integers. The intermediate sum does not modulo overflow.

Result Type, x and y must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	148	<id> x	<id> y
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s_clamp

Returns $s_min(s_max(x, minval), maxval)$, where x , $minval$, and $maxval$ are treated as signed integers. Results are undefined if $minval > maxval$.

Result Type, x , $minval$ and $maxval$ must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	149	<id> x	<id> $minval$	<id> $maxval$
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u_clamp

Returns $u_min(u_max(x, minval), maxval)$, where x , $minval$, and $maxval$ are treated as unsigned integers. Results are undefined if $minval > maxval$.

Result Type, x , $minval$ and $maxval$ must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	150	<id> x	<id> $minval$	<id> $maxval$
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clz

Returns the number of leading 0 bits in x , starting at the most significant bit position. If x is 0, returns the size in bits of the type of x or component type of x , if x is a vector.

Result Type and x must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	151	<id> x
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ctz							
Returns the count of trailing 0 bits in x . If x is 0, returns the size in bits of the type of x or component type of x , if x is a vector.							
<i>Result Type</i> and x must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	152	<id> x	

s_mad_hi								
Returns $mul_hi(a, b) + c$, where a, b and c are treated as signed integers.								
<i>Result Type</i> , a , b and c must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	153	<id> a	<id> b	<id> c

u_mad_sat								
Returns $x * y + z$ and saturates the result where x , y and z are treated as unsigned integers.								
<i>Result Type</i> , x , y and z must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	154	<id> x	<id> y	<id> z

s_mad_sat								
Returns $x * y + z$ and saturates the result where x , y and z are treated as signed integers.								
<i>Result Type</i> , x , y and z must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	155	<id> x	<id> y	<id> z

s_max							
Returns y if $x < y$, otherwise it returns x , where x and y are treated as signed integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	156	<id> x	<id> y

u_max							
Returns y if $x < y$, otherwise it returns x , where x and y are treated as unsigned integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	157	<id> x	<id> y

s_min							
Returns y if $y < x$, otherwise it returns x , where x and y are treated as signed integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	158	<id> x	<id> y

u_min							
Returns y if $y < x$, otherwise it returns x , where x and y are treated as unsigned integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	159	<id> x	<id> y

s_mul_hi							
Computes $x * y$ and returns the high half of the product of x and y , where x and y are treated as signed integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	160	<id> x	<id> y

rotate							
For each element in v , the bits are shifted left by the number of bits given by the corresponding element in i . Bits shifted off the left side of the element are shifted back in from the right.							
<i>Result Type</i> , v and i must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	161	<id> v	<id> i

s_sub_sat							
Returns the saturated value of $x - y$, where x and y are treated as signed integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	162	<id> x	<id> y

u_sub_sat							
Returns the saturated value of $x - y$, where x and y are treated as unsigned integers.							
<i>Result Type</i> , x and y must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	163	<id> x	<id> y

u_upsample

When *hi* and *lo* component type is i8:

$$\text{Result} = ((\text{upcast} \dots \text{ to i16})hi \ll 8) | lo$$

When *hi* and *lo* component type is i16:

$$\text{Result} = ((\text{upcast} \dots \text{ to i32})hi \ll 8) | lo$$

When *hi* and *lo* component i32:

$$\text{Result} = ((\text{upcast} \dots \text{ to i64})hi \ll 8) | lo$$

hi and *lo* are treated as unsigned integers.

hi and *lo* must be *i8*, *i16* or *i32* or *vector(2,3,4,8,16)* of *i8*, *i16* or *i32* values.

Result Type must be *i16*, *i32* or *i64* or *vector(2,3,4,8,16)* of *i16*, *i32* or *i64* values.

hi and *lo* operands must be of the same type. When *hi* and *lo* component type is i8, the *Result Type* component type must be i16. When *hi* and *lo* component type is i16, the *Result Type* component type must be i32. When *hi* and *lo* component type is i32, the *Result Type* component type must be i64. *Result Type* must have the same component count as *hi* and *lo* operands.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	164	<id> <i>hi</i>	<id> <i>lo</i>
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s_upsample							
When <i>hi</i> and <i>lo</i> component type is i8:							
Result = ((upcast... to i16) <i>hi</i> << 8) <i>lo</i>							
When <i>hi</i> and <i>lo</i> component type is i16:							
Result = ((upcast... to i32) <i>hi</i> << 8) <i>lo</i>							
When <i>hi</i> and <i>lo</i> component i32:							
Result = ((upcast... to i64) <i>hi</i> << 8) <i>lo</i>							
<i>hi</i> and <i>lo</i> are treated as signed integers.							
<i>hi</i> and <i>lo</i> must be <i>i8</i> , <i>i16</i> or <i>i32</i> or <i>vector(2,3,4,8,16)</i> of <i>i8</i> , <i>i16</i> or <i>i32</i> values.							
<i>Result Type</i> must be <i>i16</i> , <i>i32</i> or <i>i64</i> or <i>vector(2,3,4,8,16)</i> of <i>i16</i> , <i>i32</i> or <i>i64</i> values.							
<i>hi</i> and <i>lo</i> operands must be of the same type. When <i>hi</i> and <i>lo</i> component type is i8, the <i>Result Type</i> component type must be i16. When <i>hi</i> and <i>lo</i> component type is i16, the <i>Result Type</i> component type must be i32. When <i>hi</i> and <i>lo</i> component type is i32, the <i>Result Type</i> component type must be i64. <i>Result Type</i> must have the same component count as <i>hi</i> and <i>lo</i> operands.							
7	12	< <i>id</i> > <i>Result Type</i>	<i>Result</i> < <i>id</i> >	extended instructions set < <i>id</i> >	165	< <i>id</i> > <i>hi</i>	< <i>id</i> > <i>lo</i>

popcount							
Returns the number of non-zero bits in <i>x</i> .							
<i>Result Type</i> and <i>x</i> must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
6	12	< <i>id</i> > <i>Result Type</i>	<i>Result</i> < <i>id</i> >	extended instructions set < <i>id</i> >	166	< <i>id</i> > <i>x</i>	

s_mad24

Multiply two 24-bit integer values x and y and add the 32-bit integer result to the 32-bit integer z . Refer to definition of `s_mul24` to see how the 24-bit integer multiplication is performed.

Result Type, x , y and z must be *i32* or *vector(2,3,4,8,16)* of *i32* values.

All of the operands, including the *Result Type* operand, must be of the same type.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	167	<id> x	<id> y	<id> z
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u_mad24

Multiply two 24-bit integer values x and y and add the 32-bit integer result to the 32-bit integer z . Refer to definition of `u_mul24` to see how the 24-bit integer multiplication is performed.

Result Type, x , y and z must be *i32* or *vector(2,3,4,8,16)* of *i32* values.

All of the operands, including the *Result Type* operand, must be of the same type.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	168	<id> x	<id> y	<id> z
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s_mul24

Multiply two 24-bit integer values x and y , where x and y are treated as signed integers. x and y are 32-bit integers but only the low-order 24 bits are used to perform the multiplication. `s_mul24` should only be used when values in x and y are in the range $[-2^{23}, 2^{23}-1]$. If x and y are not in this range, the multiplication result is implementation-defined.

Result Type, x and y must be *i32* or *vector(2,3,4,8,16)* of *i32* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	169	<id> x	<id> y
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u_mul24

Multiply two 24-bit integer values x and y , where x and y are treated as unsigned integers. x and y are 32-bit integers but only the low-order 24 bits are used to perform the multiplication. `u_mul24` should only be used when values in x and y are in the range $[0, 2^{24}-1]$. If x and y are not in this range, the multiplication result is implementation-defined.

Result Type, x and y must be *i32* or *vector(2,3,4,8,16)* of *i32* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	170	<id> x	<id> y
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u_abs

Returns $|x|$, where x is treated as unsigned integer.

Result Type and x must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	201	<id> x	
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u_abs_diff

Returns $|x - y|$ without modulo overflow, where x and y are treated as unsigned integers.

Result Type, x and y must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	202	<id> x	<id> y
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u_mul_hi

Computes $x * y$ and returns the high half of the product of x and y , where x and y are treated as unsigned integers.

Result Type, x and y must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	203	<id> x	<id> y
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u_mad_hi

Returns $mul_hi(a, b) + c$, where a, b and c are treated as unsigned integers.

Result Type, a , b and c must be *integer* or *vector(2,3,4,8,16)* of *integer* values.

All of the operands, including the *Result Type* operand, must be of the same type.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	204	<id> a	<id> b	<id> c
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2.3 Common instructions

This section describes the list of common instructions that take scalar or vector arguments. The vector versions of the integer functions operate component-wise. The description is per-component. The common instructions are implemented using the round to nearest even rounding mode.

fclamp								
Returns $fmin(fmax(x, minval), maxval)$. Results are undefined if $minval > maxval$.								
<i>Result Type</i> , x , $minval$ and $maxval$ must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	95	<id> x	<id> $minval$	<id> $maxval$

degrees								
Converts <i>radians</i> to degrees, i.e. $(180 / \pi) * radians$.								
<i>Result Type</i> and <i>radians</i> must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	96	<id> $radians$		

fmax_common								
Returns y if $x < y$, otherwise it returns x . If x or y are infinite or NaN, the return values are undefined.								
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	97	<id> x	<id> y	

fmin_common							
Returns y if $y < x$, otherwise it returns x . If x or y are infinite or NaN, the return values are undefined.							
<i>Result Type</i> , x and y must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	98	<id> x	<id> y

mix								
Returns the linear blend of x & y implemented as:								
$x + (y - x) * a$								
<i>Result Type</i> , x , y and a must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
Note: This function can be implemented using contractions such as mad or fma								
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	99	<id> x	<id> y	<id> a

radians						
Converts <i>degrees</i> to radians, i.e. $(\pi / 180) * \textit{degrees}$.						
<i>Result Type</i> and <i>degrees</i> must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	100	<id> <i>degrees</i>

step							
Returns 0.0 if $x < \textit{edge}$, otherwise it returns 1.0.							
<i>Result Type</i> , <i>edge</i> and x must be <i>floating-point</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	101	<id> <i>edge</i>	<id> x

smoothstep

Returns 0.0 if $x \leq edge_0$ and 1.0 if $x \geq edge_1$ and performs smooth Hermite interpolation between 0 and 1, when $edge_0 < x < edge_1$.

This is equivalent to :

```
t = fclamp((x - edge0) / (edge1 - edge0), 0, 1);
```

```
return t * t * (3 - 2 * t);
```

Results are undefined if $edge_0 \geq edge_1$ or if x , $edge_0$ or $edge_1$ is a NaN.

Result Type, $edge_0$, $edge_1$ and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

Note: This function can be implemented using contractions such as mad or fma

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	102	<id> $edge_0$	<id> $edge_1$	<id> x
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sign

Returns 1.0 if $x > 0$, -0.0 if $x = -0.0$, +0.0 if $x = +0.0$, or -1.0 if $x < 0$. Returns 0.0 if x is a NaN.

Result Type and x must be *floating-point* or *vector(2,3,4,8,16)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	103	<id> x
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2.4 Geometric instructions

This section describes the list of geometric instructions. In this section x,y,z and w denote the first, second, third and fourth component respectively, of vectors with 3 and four components. The geometric instructions are implemented using the round to nearest even rounding mode.

Note: The geometric functions can be implemented using contractions such as mad or fma

cross							
Returns the cross product of $p_0.xyz$ and $p_1.xyz$.							
When the vector component count is 4, the w component returned will be 0.0.							
<i>Result Type</i> , p_0 and p_1 must be <i>vector(3,4)</i> of <i>floating-point</i> values.							
All of the operands, including the <i>Result Type</i> operand, must be of the same type.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	104	<id> p_0	<id> p_1

distance							
Returns the distance between p_0 and p_1 . This is calculated as $length(p_0 - p_1)$.							
<i>Result Type</i> must be <i>floating-point</i> .							
p_0 and p_1 must be <i>floating-point</i> or <i>vector(2,3,4)</i> of <i>floating-point</i> values.							
p_0 and p_1 operands must have the same type. <i>Result Type</i> , p_0 and p_1 operands must have the same component type							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	105	<id> p_0	<id> p_1

length							
Return the length of vector p , i.e. $sqrt(p.x^2 + p.y^2 + \dots)$							
<i>Result Type</i> must be <i>floating-point</i> .							
p must be <i>floating-point</i> or <i>vector(2,3,4)</i> of <i>floating-point</i> values.							
<i>Result Type</i> and p operands must have the same component type							
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	106	<id> p	

normalize						
Returns a vector in the same direction as p but with a length of 1.						
<i>Result Type</i> and p must be <i>floating-point</i> or <i>vector(2,3,4)</i> of <i>floating-point</i> values.						
All of the operands, including the <i>Result Type</i> operand, must be of the same type.						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	107	<id> p

fast_distance							
Returns $fast_length(p_0 - p_1)$.							
<i>Result Type</i> must be <i>floating-point</i> .							
p_0 and p_1 must be <i>floating-point</i> or <i>vector(2,3,4)</i> of <i>floating-point</i> values.							
p_0 and p_1 operands must have the same type. <i>Result Type</i> , p_0 and p_1 operands must have the same component type							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	108	<id> p_0	<id> p_1

fast_length						
Return the length of vector p computed as: $half_sqrt(p.x^2 + p.y^2 + \dots)$						
<i>Result Type</i> must be <i>floating-point</i> .						
p must be <i>vector(2,3,4)</i> of <i>floating-point</i> values.						
<i>Result Type</i> and p operands must have the same component type						
6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	109	<id> p

fast_normalize

Returns a vector in the same direction as p but with a length of 1 computed as:

$$p * \text{half_rsqrt}(p.x^2 + p.y^2 \dots)$$

The result shall be within 8192 ulps error from the infinitely precise result of:

```
if (all( p == 0.0f )) { result = p; }
```

```
else { result = p / sqrt(p.x^2 + p.y^2 + ...); }
```

with the following exceptions :

- 1) If the sum of squares is greater than FLT_MAX then the value of the floating-point values in the result vector are undefined.
- 2) If the sum of squares is less than FLT_MIN then the implementation may return back p .
- 3) If the device is in "denorms are flushed to zero" mode, individual operand elements with magnitude less than $\text{sqrt}(\text{FLT_MIN})$ may be flushed to zero before proceeding with the calculation.

Result Type and p must be *floating-point* or *vector(2,3,4)* of *floating-point* values.

All of the operands, including the *Result Type* operand, must be of the same type.

6	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	110	<id> p
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2.5 Relational instructions

This section describes the list of relational instructions that take scalar or vector arguments. The vector versions of the integer functions operate component-wise. The description is per-component.

bitselect								
Each bit of the result is the corresponding bit of <i>a</i> if the corresponding bit of <i>c</i> is 0. Otherwise it is the corresponding bit of <i>b</i> .								
<i>Result Type</i> , <i>a</i> , <i>b</i> and <i>c</i> must be <i>floating-point</i> or <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> or <i>integer</i> values.								
All of the operands, including the <i>Result Type</i> operand, must be of the same type.								
8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	186	<id> <i>a</i>	<id> <i>b</i>	<id> <i>c</i>

select								
For each component of a vector type, the result is <i>a</i> if the most significant bit of <i>c</i> is zero, otherwise it is <i>b</i> .								
For a scalar type, the result is <i>a</i> if <i>c</i> is zero, otherwise it is <i>b</i> .								
<i>c</i> must be <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>integer</i> values.								
<i>Result Type</i> , <i>a</i> and <i>b</i> must be <i>floating-point</i> or <i>integer</i> or <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> or <i>integer</i> values.								
<i>Result Type</i> , <i>a</i> and <i>b</i> must have the same type. <i>c</i> operand must have the same component count and component bit width as the rest of the operands.								
8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	187	<id> <i>a</i>	<id> <i>b</i>	<id> <i>c</i>

2.6 Vector Data Load and Store instructions

This section describes the list of instructions that allow reading and writing of vector types from a pointer to memory.

vloadn								
Return a vector value which is read from address $(p + (offset * n))$.								
The address computed as $(p + (offset * n))$ must be 8-bit aligned if p points to i8 value; 16-bit aligned if p points to i16 or half value; 32-bit aligned if p points to i32 or float value; 64-bit aligned if p points to i64 or double value.								
$offset$ must be $size_t$.								
p must be a <i>pointer(constant, generic)</i> to <i>floating-point, integer</i> .								
<i>Result Type</i> must be <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> or <i>integer</i> values.								
<i>Result Type</i> component count must be equal to n and its component type must be equal to the type pointed by p .								
n must be 2,3,4,8 or 16.								
8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	171	<id> <i>offset</i>	<id> p	Literal Number n

vstoren								
Write <i>data</i> vector value to the address $(p + (offset * compCountOf(data)))$, where $compCountOf(data)$ is equal to the component count of the vector <i>data</i> .								
The address computed as $(p + (offset * compCountOf(data)))$ must be 8-bit aligned if p points to i8 value; 16-bit aligned if p points to i16 or half value; 32-bit aligned if p points to i32 or float value; 64-bit aligned if p points to i64 or double value.								
$offset$ must be $size_t$.								
<i>Result Type</i> must be <i>void</i> .								
p must be a <i>pointer(generic)</i> to <i>floating-point, integer</i> .								
<i>data</i> must be <i>vector(2,3,4,8,16)</i> of <i>floating-point</i> or <i>integer</i> values.								
<i>data</i> component type must be equal to the type pointed by p .								
8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	172	<id> <i>data</i>	<id> <i>offset</i>	<id> p

vload_half

Reads a half value from the address ($p + (offset)$) and converts it to a float return value. The address computed as ($p + (offset)$) must be 16-bit aligned.

Result Type must be *float*.

offset must be *size_t*.

p must be a *pointer(global, local, private, constant, generic)* to *half*.

7	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	173	<id> <i>offset</i>	<id> <i>p</i>
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vload_halfn

Reads a half vector value from the address ($p + (offset * n)$) and converts it to a float vector return value. The address computed as ($p + (offset * n)$) must be 16-bit aligned.

offset must be *size_t*.

p must be a *pointer(global, local, private, constant, generic)* to *half*.

Result Type must be *vector(2,3,4,8,16)* of *float* values.

Result Type component count must be equal to *n*.

n must be 2,3,4,8 or 16.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	174	<id> <i>offset</i>	<id> <i>p</i>	Literal Number <i>n</i>
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vstore_half

Converts *data* float or double value to a half value and then write the converted value to the address ($p + offset$). The address computed as ($p + offset$) must be 16-bit aligned.

This function uses the default rounding mode when converting *data* to a half value. The default rounding mode is round to nearest even.

data must be *float* or *double*.

offset must be *size_t*.

Result Type must be *void*.

p must be a *pointer(global, local, private, generic)* to *half*.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	175	<id> <i>data</i>	<id> <i>offset</i>	<id> <i>p</i>
---	----	----------------------------	--------------------------	--------------------------------------	-----	---------------------	-----------------------	------------------

vstore_half_r									
<p>Converts <i>data</i> float or double value to a half value and then write the converted value to the address ($p + offset$). The address computed as ($p + offset$) must be 16-bit aligned.</p> <p>This function uses <i>mode</i> rounding mode when converting <i>data</i> to a half value.</p> <p><i>data</i> must be <i>float</i> or <i>double</i>.</p> <p><i>offset</i> must be <i>size_t</i>.</p> <p><i>Result Type</i> must be <i>void</i>.</p> <p><i>p</i> must be a <i>pointer(global, local, private, generic)</i> to <i>half</i>.</p>									
9	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	176	<id> <i>data</i>	<id> <i>offset</i>	<id> <i>p</i>	FP Rounding Mode <i>mode</i>

vstore_halfn									
<p>Converts <i>data</i> vector of float or vector of double values to a vector of half values and then write the converted value to the address ($p + (offset * compCountOf(data))$), where $compCountOf(data)$ is equal to the component count of the vector <i>data</i>.</p> <p>The address computed as ($p + (offset * compCountOf(data))$) must be 16-bit aligned.</p> <p>This function uses the default rounding mode when converting <i>data</i> to a vector of half values. The default rounding mode is round to nearest even.</p> <p><i>offset</i> must be <i>size_t</i>.</p> <p><i>Result Type</i> must be <i>void</i>.</p> <p><i>p</i> must be a <i>pointer(global, local, private, generic)</i> to <i>half</i>.</p> <p><i>data</i> must be <i>vector(2,3,4,8,16)</i> of <i>float</i> or <i>double</i> values.</p>									
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	177	<id> <i>data</i>	<id> <i>offset</i>	<id> <i>p</i>	

vstore_halfn_r									
<p>Converts <i>data</i> vector of float or vector of double values to a vector of half values and then write the converted value to the address ($p + (offset * compCountOf(data))$), where $compCountOf(data)$ is equal to the component count of the vector <i>data</i>.</p> <p>The address computed as ($p + (offset * compCountOf(data))$) must be 16-bit aligned.</p> <p>This function uses <i>mode</i> rounding mode when converting <i>data</i> to a half value.</p> <p><i>offset</i> must be <i>size_t</i>.</p> <p><i>Result Type</i> must be <i>void</i>.</p> <p><i>p</i> must be a <i>pointer(global, local, private, generic)</i> to <i>half</i>.</p> <p><i>data</i> must be <i>vector(2,3,4,8,16)</i> of <i>float</i> or <i>double</i> values.</p>									
9	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	178	<id> <i>data</i>	<id> <i>offset</i>	<id> <i>p</i>	FP Rounding Mode <i>mode</i>

vloada_halfn									
<p>Reads a half vector value from the address ($p + (offset * n)$) and converts it to a float vector return value. The address computed as ($p + (offset * n)$) must be ($2 * n$) bytes aligned, when $n = 2,4,8,16$; For $n = 3$, the function returns a vector of 3 float values from the address ($p + (offset * 4)$). The address computed as ($p + (offset * 4)$) must be 8-bytes aligned</p> <p><i>offset</i> must be <i>size_t</i>.</p> <p><i>p</i> must be a <i>pointer(global, local, private, constant, generic)</i> to <i>half</i>.</p> <p><i>Result Type</i> must be <i>vector(2,3,4,8,16)</i> of <i>float</i> values.</p> <p><i>Result Type</i> component count must be equal to <i>n</i>.</p> <p><i>n</i> must be 2,3,4,8 or 16.</p>									
8	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	179	<id> <i>offset</i>	<id> <i>p</i>	Literal Number <i>n</i>	

vstorea_halfn									
<p>Converts <i>data</i> vector of float or vector of double values to a vector of half values and then write the converted value to the address $(p + (offset * compCountOf(data)))$, where $compCountOf(data)$ is equal to the component count of the vector <i>data</i>.</p> <p>The address computed as $(p + (offset * compCountOf(data)))$ must be $(2 * compCountOf(data))$ bytes aligned, when $n = 2,4,8,16$; For $n = 3$, the function returns a vector of 3 float values from the address $(p + (offset * 4))$. The address computed as $(p + (offset * 4))$ must be 8-bytes aligned.</p> <p>This function uses the default rounding mode when converting <i>data</i> to a vector of half values. The default rounding mode is round to nearest even.</p> <p><i>offset</i> must be <i>size_t</i>.</p> <p><i>Result Type</i> must be <i>void</i>.</p> <p><i>p</i> must be a <i>pointer(global, local, private, generic)</i> to <i>half</i>.</p> <p><i>data</i> must be <i>vector(2,3,4,8,16)</i> of <i>float</i> or <i>double</i> values.</p>									
8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	180	<id> <i>data</i>	<id> <i>offset</i>	<id> <i>p</i>	

vstorea_halfn_r									
<p>Converts <i>data</i> vector of float or vector of double values to a vector of half values and then write the converted value to the address $(p + (offset * compCountOf(data)))$, where $compCountOf(data)$ is equal to the component count of the vector <i>data</i>.</p> <p>The address computed as $(p + (offset * compCountOf(data)))$ must be $(2 * compCountOf(data))$ bytes aligned, when $n = 2,4,8,16$; For $n = 3$, the function returns a vector of 3 float values from the address $(p + (offset * 4))$. The address computed as $(p + (offset * 4))$ must be 8-bytes aligned.</p> <p>This function uses <i>mode</i> rounding mode when converting <i>data</i> to a vector of half values.</p> <p><i>offset</i> must be <i>size_t</i>.</p> <p><i>Result Type</i> must be <i>void</i>.</p> <p><i>p</i> must be a <i>pointer(global, local, private, generic)</i> to <i>half</i>.</p> <p><i>data</i> must be <i>vector(2,3,4,8,16)</i> of <i>float</i> or <i>double</i> values.</p>									
9	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	181	<id> <i>data</i>	<id> <i>offset</i>	<id> <i>p</i>	FP Rounding Mode <i>mode</i>

2.7 Miscellaneous Vector instructions

This section describes additional vector instructions.

shuffle							
Construct a permutation of components from x vector value, returning a vector value with the same component type as x and component count that is the same as <i>shuffle mask</i> .							
In this function, only the $\text{ilogb}(2m - 1)$ least significant bits of each mask element are considered, where m is equal to the component count of x .							
<i>shuffle mask</i> operand specifies, for each component in the result vector, which component of x it gets.							
The size of each component in <i>shuffle mask</i> must match the size of each component in <i>Result Type</i> .							
<i>Result Type</i> must have the same component type as x and component count as <i>shuffle mask</i> .							
<i>shuffle mask</i> must be <i>vector(2,4,8,16)</i> of <i>integer</i> values.							
<i>Result Type</i> and x must be <i>vector(2,4,8,16)</i> of <i>floating-point</i> or <i>integer</i> values.							
7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	182	<id> x	<id> <i>shuffle mask</i>

shuffle2

Construct a permutation of components from x and y vector values, returning a vector value with the same component type as x and y and component count that is the same as *shuffle mask*.

In this function, only the $\text{ilogb}(2 m - 1) + 1$ least significant bits of each mask component are considered, where m is equal to the component count of x and y .

shuffle mask operand specifies, for each component in the result vector, which component of x or y it gets. Where component count begins with x and then proceeds to y .

x and y must be of the same type.

The size of each component in *shuffle mask* must match the size of each component in *Result Type*.

Result Type must have the same component type as x and component count as *shuffle mask*.

shuffle mask must be *vector(2,4,8,16)* of *integer* values.

Result Type, x and y must be *vector(2,4,8,16)* of *floating-point* or *integer* values.

8	12	<id> <i>Result Type</i>	<i>Result <id></i>	extended instructions set <id>	183	<id> x	<id> y	<id> <i>shuffle mask</i>
---	----	----------------------------	--------------------------	--------------------------------------	-----	-------------	-------------	---------------------------------

2.8 Misc instructions

This section describes additional miscellaneous instructions.

printf

The *printf* extended instruction writes output to an implementation-defined stream such as stdout under control of the string pointed to by *format* that specifies how subsequent arguments are converted for output. If there are insufficient arguments for the format, the behavior is undefined. If the format is exhausted while arguments remain, the excess arguments are evaluated (as always) but are otherwise ignored. The *printf* function returns when the end of the format string is encountered

printf returns 0 if it was executed successfully and -1 otherwise

Result Type must be *i32*.

format must be a *pointer(constant)* to *i8*.

6 + vari- able	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	184	<id> <i>format</i>	<id>, <id>, ... <i>additional arguments</i>
----------------------	----	----------------------------	--------------------	--------------------------------------	-----	-----------------------	---

prefetch

Prefetch *num_elements* * *size* in bytes of the type pointed by *p*, into the global cache. The prefetch instruction is applied to a work-item in a work-group and does not affect the functional behavior of the kernel.

num_elements must be *size_t*.

Result Type must be *void*.

ptr must be a *pointer(global)* to *floating-point*, *integer* or *vector(2,3,4,8,16)* of *floating-point*, *integer* values.

7	12	<id> <i>Result Type</i>	<i>Result</i> <id>	extended instructions set <id>	185	<id> <i>ptr</i>	<id> <i>num_elements</i>
---	----	----------------------------	--------------------	--------------------------------------	-----	--------------------	-----------------------------

2.9 Image encoding

The following list denotes the different valid **OpTypeImage** encodings of image objects.

image1d									
A 1D image									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 1D	<i>Depth</i> 0	<i>Arrayed</i> 0	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image1dBuffer									
A 1D image created from a buffer object.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> Buffer	<i>Depth</i> 0	<i>Arrayed</i> 0	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image1dArray									
A 1D image array.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 1D	<i>Depth</i> 0	<i>Arrayed</i> 1	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2d									
A 2D image.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 0	<i>Arrayed</i> 0	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dArray									
A 2D image array.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 0	<i>Arrayed</i> 1	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dDepth									
A 2D depth image.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 1	<i>Arrayed</i> 0	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dArrayDepth									
A 2D depth image array.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 1	<i>Arrayed</i> 1	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dMsaa									
A 2D multi-sample color image.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 0	<i>Arrayed</i> 0	<i>MS</i> 1	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dArrayMsaa									
A 2D multi-sample color image array.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 0	<i>Arrayed</i> 1	<i>MS</i> 1	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dMsaaDepth									
A 2D multi-sample depth image.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 1	<i>Arrayed</i> 0	<i>MS</i> 1	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image2dArrayMsaaDepth									
A 2D multi-sample depth image array.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 2D	<i>Depth</i> 1	<i>Arrayed</i> 1	<i>MS</i> 1	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

image3d									
A 3D image object.									
9	25	<i>Result</i> <id>	<i>Sampled</i> Type Op- TypeVoid	<i>Dim</i> 3D	<i>Depth</i> 0	<i>Arrayed</i> 0	<i>MS</i> 0	<i>Sampled</i> 0	<i>Image</i> <i>Format</i> Unknown

2.10 Sampler encoding

A SPIR-V *sampler* object is encoded via the **OpTypeSampler** instruction via a kernel function argument:

In addition, it is possible to define a constant (or inline) *sampler* using the **OpConstantSampler** instruction.

A Changes and TBD

- Fork the revision stream, changes section, TBD, etc. from the core specification, so this specification has its own, starting numbering at revision 1. This document now lives independently.

A.1 Changes from Version 0.99, Revision 1

- Move to use the updated image/texturing/sampling, instead of extended instructions. Also, see changes in core specification related to this.
 - 14241 Implement OpenCL Extended Instructions for images/samplers with core OpImageSample instructions
- Fixed internal bugs
 - 13455 Merged the OpenCL 1.2, 2.0, and 2.1 extended-instruction set into a single OpenCL extended-instruction set.
- Fixed public bugs

A.2 Changes from Version 0.99, Revision 2

- 14679 moved precision information to the OpenCL environment spec
- 14636 clarified trig functions to accept and return radians

A.3 Changes from Version 0.99, Revision 3

- Fixed internal bugs
 - 14862 removed remaining image instructions as core versions are sufficient
 - 14636 Fixed type-o's in several trig functions accepting radian inputs and/or producing radian results
 - Flattened opcode numbers

A.4 Changes from Version 1.0, Revision 1

- Fixed internal bugs
 - Issue 8 - order of parameters for prefetch was reversed; pointer operand should be first.
 - Issue 103 - typo: *singp* should be *signp*
- Fixed public bugs
 - 1469 - incorrect specification of "pow" and "pown"

A.5 Changes from Version 1.0, Revision 2

- Fixed internal bugs
 - Issue 261 - clarified that "s_mad24" and "u_mad24" only support 32-bit integers
 - Issue 262 - added scalars to the types supported by "length"
 - Issue 266 - fixed "shuffle" and "shuffle2" description
 - Issue 267 - fixed description of "ldexp" operands