



SPIR-V Extended Instructions for GLSL

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1 Introduction

This specifies the GLSL.std.450 extended instruction set. It provides instructions for the GLSL built-in functions that do not directly map to native SPIR-V instructions.

Import this extended instruction set using an **OpExtInstImport** "GLSL.std.450" instruction.

2 Binary Form

Documentation form for each extended instruction:

Extended Instruction Name Instruction description. <i>Result Type</i> will describe the <i>Result Type</i> for the OpExtInst instruction. <i>Number</i> is the extended instruction number to use in the OpExtInst instruction. <i>Operand 1</i> , <i>Operand 2</i> , ... are the operands listed for the OpExtInst instruction. Any Capability restrictions.			
<i>Number</i>	<i>Operand 1</i>	<i>Operand 2</i>	...

Extended instructions:

Round Result is the value equal to the nearest whole number to x . The fraction 0.5 will round in a direction chosen by the implementation, presumably the direction that is fastest. This includes the possibility that Round x is the same value as RoundEven x for all values of x . The operand x must be a scalar or vector whose component type is floating-point. <i>Result Type</i> and the type of x must be the same type. Results are computed per component.	
1	<i><id></i> x

RoundEven Result is the value equal to the nearest whole number to x . A fractional part of 0.5 will round toward the nearest even whole number. (Both 3.5 and 4.5 for x will be 4.0.) The operand x must be a scalar or vector whose component type is floating-point. <i>Result Type</i> and the type of x must be the same type. Results are computed per component.	
2	<i><id></i> x

Trunc

Result is the value equal to the nearest whole number to x whose absolute value is not larger than the absolute value of x .

The operand x must be a scalar or vector whose component type is floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

3	$\langle id \rangle$ x
---	-----------------------------

FAbs

Result is $+0.0$ if x is ± 0.0 , x if $x > 0.0$, and $-x$ if $x < 0.0$.

The operand x must be a scalar or vector whose component type is floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

4	$\langle id \rangle$ x
---	-----------------------------

SAbs

Result is x if $x \geq 0$; otherwise result is $-x$, where x is interpreted as a signed integer.

Result Type and the type of x must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

This instruction can be decorated with **NoSignedWrap**.

5	$\langle id \rangle$ x
---	-----------------------------

FSign

Result is 1.0 if $x > 0$, -1.0 if $x < 0$, $+0.0$ if $x = +0.0$, and ± 0.0 if $x = -0.0$. When $x = \pm NaN$, the result can be any of ± 1.0 or ± 0.0 , regardless of whether `shader_float_controls` is in use.

The operand x must be a scalar or vector whose component type is floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

6	$\langle id \rangle$ x
---	-----------------------------

SSign

Result is 1 if $x > 0$, 0 if $x = 0$, or -1 if $x < 0$, where x is interpreted as a signed integer.

Result Type and the type of x must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

7	<i><id></i> <i>x</i>
---	-------------------------------

Floor

Result is the value equal to the nearest whole number that is less than or equal to *x*.

The operand *x* must be a scalar or vector whose component type is floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

8	<i><id></i> <i>x</i>
---	-------------------------------

Ceil

Result is the value equal to the nearest whole number that is greater than or equal to *x*.

The operand *x* must be a scalar or vector whose component type is floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

9	<i><id></i> <i>x</i>
---	-------------------------------

Fract

Result is *x* - **floor** *x*.

The operand *x* must be a scalar or vector whose component type is floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

10	<i><id></i> <i>x</i>
----	-------------------------------

Radians

Converts *degrees* to radians, i.e., *degrees* * π / 180.

The operand *degrees* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *degrees* must be the same type. Results are computed per component.

11	<i><id></i> <i>degrees</i>
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Degrees

Converts *radians* to degrees, i.e., $radians * 180 / \pi$.

The operand *radians* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *radians* must be the same type. Results are computed per component.

12	<i><id></i> <i>radians</i>
----	-------------------------------------

Sin

The standard trigonometric sine of *x* radians.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

13	<i><id></i> <i>x</i>
----	-------------------------------

Cos

The standard trigonometric cosine of *x* radians.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

14	<i><id></i> <i>x</i>
----	-------------------------------

Tan

The standard trigonometric tangent of *x* radians.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

15	<i><id></i> <i>x</i>
----	-------------------------------

Asin

Arc sine. Result is an angle, in radians, whose sine is *x*. The range of result values is $[-\pi / 2, \pi / 2]$. Result is undefined if **abs** *x* > 1.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

16	<i><id></i> <i>x</i>
----	-------------------------------

Acos

Arc cosine. Result is an angle, in radians, whose cosine is x . The range of result values is $[0, \pi]$. Result is undefined if **abs** $x > 1$.

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

17	$\langle id \rangle$ x
----	-----------------------------

Atan

Arc tangent. Result is an angle, in radians, whose tangent is y_over_x . The range of result values is $[-\pi / 2, \pi / 2]$.

The operand y_over_x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of y_over_x must be the same type. Results are computed per component.

18	$\langle id \rangle$ y_over_x
----	--------------------------------------

Sinh

Hyperbolic sine of x radians.

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

19	$\langle id \rangle$ x
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Cosh

Hyperbolic cosine of x radians.

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

20	$\langle id \rangle$ x
----	-----------------------------

Tanh

Hyperbolic tangent of x radians.

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

21	<i><id></i> <i>x</i>
----	-------------------------------

Asinh

Arc hyperbolic sine; result is the inverse of **sinh**.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

22	<i><id></i> <i>x</i>
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Acosh

Arc hyperbolic cosine; Result is the non-negative inverse of **cosh**. Result is undefined if $x < 1$.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

23	<i><id></i> <i>x</i>
----	-------------------------------

Atanh

Arc hyperbolic tangent; result is the inverse of tanh. Result is undefined if **abs** $x \geq 1$.

The operand *x* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of *x* must be the same type. Results are computed per component.

24	<i><id></i> <i>x</i>
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Atan2

Arc tangent. Result is an angle, in radians, whose tangent is y / x . The signs of *x* and *y* are used to determine what quadrant the angle is in. The range of result values is $[-\pi, \pi]$. Result is undefined if *x* and *y* are both 0.

The operand *x* and *y* must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

25	<i><id></i> <i>y</i>	<i><id></i> <i>x</i>
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Pow

Result is x raised to the y power; x^y . Result is undefined if $x < 0$. Result is undefined if $x = 0$ and $y \leq 0$.

The operand x and y must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

26	<id> x	<id> y
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Exp

Result is the natural exponentiation of x ; e^x .

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

27	<id> x
----	-------------

Log

Result is the natural logarithm of x , i.e., the value y which satisfies the equation $x = e^y$. Result is undefined if $x \leq 0$.

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

28	<id> x
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Exp2

Result is 2 raised to the x power; 2^x .

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

29	<id> x
----	-------------

Log2

Result is the base-2 logarithm of x , i.e., the value y which satisfies the equation $x = 2^y$. Result is undefined if $x \leq 0$.

The operand x must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

30	<id> x
----	-------------

Sqrt

Result is the square root of x . Result is undefined if $x < 0$.

The operand x must be a scalar or vector whose component type is floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

31

<id>

 x **InverseSqrt**

Result is the reciprocal of **sqrt** x . Result is undefined if $x \leq 0$.

The operand x must be a scalar or vector whose component type is floating-point.

Result Type and the type of x must be the same type. Results are computed per component.

32

<id>

 x **Determinant**

Result is the determinant of x .

The operand x must be a square matrix.

Result Type must be the same type as the component type in the columns of x .

33

<id>

 x **MatrixInverse**

Result is a matrix that is the inverse of x . The values in the result are undefined if x is singular or poorly conditioned (nearly singular).

The operand x must be a square matrix.

Result Type and the type of x must be the same type.

34

<id>

 x

Modf

Result is the fractional part of x and stores through i the whole number part (as a whole-number floating-point value). Both the result and the output parameter will have the same sign as x .

The operand x must be a scalar or vector whose component type is floating-point.

The operand i must have a pointer type.

Result Type, the type of x , and the type i points to must all be the same type and have a floating-point component type. Results are computed per component.

35	$\langle id \rangle$ x	$\langle id \rangle$ i
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ModfStruct

Same semantics as in **Modf**, except that the entire result is in the instruction's result; there is not a pointer operand to write through.

Result Type must be an **OpTypeStruct** with two members. Member 0 holds the fractional part. Member 1 holds the whole number part. These two members, and x must all be the same type and have a floating-point component type.

36	$\langle id \rangle$ x
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FMin

Result is y if $y < x$, either x or y when both x and y are zeros, otherwise x . Which operand is the result is undefined if one of the operands is a NaN.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

37	$\langle id \rangle$ x	$\langle id \rangle$ y
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UMin

Result is y if $y < x$; otherwise result is x , where x and y are interpreted as unsigned integers.

Result Type and the type of x and y must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

38	$\langle id \rangle$ x	$\langle id \rangle$ y
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SMin

Result is y if $y < x$; otherwise result is x , where x and y are interpreted as signed integers.

Result Type and the type of x and y must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

39	<i><id></i> <i>x</i>	<i><id></i> <i>y</i>
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FMax

Result is *y* if $x < y$, either *x* or *y* when both *x* and *y* are zeros, otherwise *x*. Which operand is the result is undefined if one of the operands is a NaN.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

40	<i><id></i> <i>x</i>	<i><id></i> <i>y</i>
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UMax

Result is *y* if $x < y$; otherwise result is *x*, where *x* and *y* are interpreted as unsigned integers.

Result Type and the type of *x* and *y* must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

41	<i><id></i> <i>x</i>	<i><id></i> <i>y</i>
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SMax

Result is *y* if $x < y$; otherwise result is *x*, where *x* and *y* are interpreted as signed integers.

Result Type and the type of *x* and *y* must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

42	<i><id></i> <i>x</i>	<i><id></i> <i>y</i>
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FClamp

Result is $\min(\max(x, \text{minVal}), \text{maxVal})$. Result is undefined if $\text{minVal} > \text{maxVal}$. The semantics used by $\min()$ and $\max()$ are those of FMin and FMax.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

43	<i><id></i> <i>x</i>	<i><id></i> <i>minVal</i>	<i><id></i> <i>maxVal</i>
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UClamp

Result is $\min(\max(x, \text{minVal}), \text{maxVal})$, where x , minVal and maxVal are interpreted as unsigned integers. Result is undefined if $\text{minVal} > \text{maxVal}$.

Result Type and the type of the operands must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

44	<i><id></i> x	<i><id></i> minVal	<i><id></i> maxVal
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S Clamp

Result is $\min(\max(x, \text{minVal}), \text{maxVal})$, where x , minVal and maxVal are interpreted as signed integers. Result is undefined if $\text{minVal} > \text{maxVal}$.

Result Type and the type of the operands must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

45	<i><id></i> x	<i><id></i> minVal	<i><id></i> maxVal
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FMix

Result is the linear blend of x and y , i.e., $x * (1 - a) + y * a$.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

46	<i><id></i> x	<i><id></i> y	<i><id></i> a
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Step

Result is 0.0 if $x < \text{edge}$; otherwise result is 1.0.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

48	<i><id></i> edge	<i><id></i> x
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SmoothStep

Result is 0.0 if $x \leq \text{edge0}$ and 1.0 if $x \geq \text{edge1}$ and performs smooth Hermite interpolation between 0 and 1 when $\text{edge0} < x < \text{edge1}$. This is equivalent to:

$$t * t * (3 - 2 * t), \text{ where } t = \text{clamp}((x - \text{edge0}) / (\text{edge1} - \text{edge0}), 0, 1)$$

Result is undefined if $\text{edge0} \geq \text{edge1}$.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

49	<id> <i>edge0</i>	<id> <i>edge1</i>	<id> <i>x</i>
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Fma

Computes $a * b + c$. In uses where this operation is decorated with **NoContraction**:

- **fma** is considered a single operation, whereas the expression $a * b + c$ is considered two operations.
- The precision of **fma** can differ from the precision of the expression $a * b + c$.
- **fma** will be computed with the same precision as any other **fma** decorated with **NoContraction**, giving invariant results for the same input values of a , b , and c .

Otherwise, in the absence of a **NoContraction** decoration, there are no special constraints on the number of operations or difference in precision between **fma** and the expression $a * b + c$.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

50	<id> <i>a</i>	<id> <i>b</i>	<id> <i>c</i>
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Frexp

Splits x into a floating-point significand in the range $(-1.0, 0.5]$ or $[0.5, 1.0)$ and an integral exponent of 2, such that:

$$x = \text{significand} * 2^{\text{exponent}}$$

The *significand* is the instruction result. An x of -0.0 results in a significand -0.0 , while an x of 0.0 results in 0.0 . For a floating-point value that is an infinity or is not a number, the significand is undefined.

The operand x must be a scalar or vector whose component type is floating-point.

The exponent is returned through the pointer-parameter *exp*. The *exp* operand must be a pointer to a scalar or vector with integer component type, with 32-bit component width. The number of components in x and what *exp* points to must be the same. When x is a zero, the exponent will be 0.0. When x is an infinity or a NaN, the exponent is undefined.

Result Type must be the same type as the type of x . Results are computed per component.

51	$\langle id \rangle$ x	$\langle id \rangle$ exp
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FrexpStruct

Same semantics as in **Frexp**, except that the entire result is in the instruction's result; there is not a pointer operand to write through.

Result Type must be an **OpTypeStruct** with two members. Member 0 must have the same type as the type of x . Member 0 holds the *significand*. Member 1 must be a scalar or vector with integer component type, with 32-bit component width. Member 1 holds *exponent*. These two members must have the same number of components.

52	$\langle id \rangle$ x	
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Ldexp

Builds a floating-point number from x and the corresponding integral exponent of two in exp :

$$significand * 2^{exponent}$$

If this product is too large to be represented in the floating-point type, the result is undefined. If exp is greater than +128 (single precision) or +1024 (double precision), the result undefined. If exp is less than -126 (single precision) or -1022 (double precision), the result may be flushed to zero. Additionally, splitting the value into a significand and exponent using **frexp** and then reconstructing a floating-point value using **ldexp** should yield the original input for zero and all finite non-denormalized values.

The operand x must be a scalar or vector whose component type is floating-point.

The exp operand must be a scalar or vector with integer component type. The number of components in x and exp must be the same.

Result Type must be the same type as the type of x . Results are computed per component.

53	$\langle id \rangle$ x	$\langle id \rangle$ exp
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PackSnorm4x8

First, converts each component of the normalized floating-point value v into 8-bit integer values. These are then packed into the result.

The conversion for component c of v to fixed point is done as follows:

$$\text{round}(\text{clamp}(c, -1, +1) * 127.0)$$

The first component of the vector will be written to the least significant bits of the output; the last component will be written to the most significant bits.

The v operand must be a vector of 4 components whose type is a 32-bit floating-point.

Result Type must be a 32-bit integer type.

54	<i><id></i> <i>v</i>
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PackUnorm4x8

First, converts each component of the normalized floating-point value *v* into 8-bit integer values. These are then packed into the result.

The conversion for component *c* of *v* to fixed point is done as follows:

$\text{round}(\text{clamp}(c, 0, +1) * 255.0)$

The first component of the vector will be written to the least significant bits of the output; the last component will be written to the most significant bits.

The *v* operand must be a vector of 4 components whose type is a 32-bit floating-point.

Result Type must be a 32-bit integer type.

55	<i><id></i> <i>v</i>
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PackSnorm2x16

First, converts each component of the normalized floating-point value *v* into 16-bit integer values. These are then packed into the result.

The conversion for component *c* of *v* to fixed point is done as follows:

$\text{round}(\text{clamp}(c, -1, +1) * 32767.0)$

The first component of the vector will be written to the least significant bits of the output; the last component will be written to the most significant bits.

The *v* operand must be a vector of 2 components whose type is a 32-bit floating-point.

Result Type must be a 32-bit integer type.

56	<i><id></i> <i>v</i>
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PackUnorm2x16

First, converts each component of the normalized floating-point value v into 16-bit integer values. These are then packed into the result.

The conversion for component c of v to fixed point is done as follows:

$\text{round}(\text{clamp}(c, 0, +1) * 65535.0)$

The first component of the vector will be written to the least significant bits of the output; the last component will be written to the most significant bits.

The v operand must be a vector of 2 components whose type is a 32-bit floating-point.

Result Type must be a 32-bit integer type.

57	<i><id></i> v
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PackHalf2x16

Result is the unsigned integer obtained by converting the components of a two-component floating-point vector to the 16-bit **OpTypeFloat**, and then packing these two 16-bit integers into a 32-bit unsigned integer. The first vector component specifies the 16 least-significant bits of the result; the second component specifies the 16 most-significant bits.

The v operand must be a vector of 2 components whose type is a 32-bit floating-point.

Result Type must be a 32-bit integer type.

58	<i><id></i> v
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PackDouble2x32

Result is the double-precision value obtained by packing the components of v into a 64-bit value. If an IEEE 754 Inf or NaN is created, it will not signal, and the resulting floating-point value is unspecified. Otherwise, the bit-level representation of v is preserved. The first vector component specifies the 32 least significant bits; the second component specifies the 32 most significant bits.

The v operand must be a vector of 2 components whose type is a 32-bit integer.

Result Type must be a 64-bit floating-point scalar.

Use of this instruction requires declaration of the **Float64** capability.

59	<i><id></i> v
----	--------------------------

UnpackSnorm2x16

First, unpacks a single 32-bit unsigned integer p into a pair of 16-bit signed integers. Then, each component is converted to a normalized floating-point value to generate the result. The conversion for unpacked fixed-point value f to floating point is done as follows:

$$\text{clamp}(f / 32767.0, -1, +1)$$

The first component of the result will be extracted from the least significant bits of the input; the last component will be extracted from the most significant bits.

The p operand must be a scalar with 32-bit integer type.

Result Type must be a vector of 2 components whose type is 32-bit floating point.

60	$\langle id \rangle$ p
----	-----------------------------

UnpackUnorm2x16

First, unpacks a single 32-bit unsigned integer p into a pair of 16-bit unsigned integers. Then, each component is converted to a normalized floating-point value to generate the result. The conversion for unpacked fixed-point value f to floating point is done as follows:

$$f / 65535.0$$

The first component of the result will be extracted from the least significant bits of the input; the last component will be extracted from the most significant bits.

The p operand must be a scalar with 32-bit integer type.

Result Type must be a vector of 2 components whose type is 32-bit floating point.

61	$\langle id \rangle$ p
----	-----------------------------

UnpackHalf2x16

Result is the two-component floating-point vector with components obtained by unpacking a 32-bit unsigned integer into a pair of 16-bit values, interpreting those values as 16-bit floating-point numbers according to the OpenGL Specification, and converting them to 32-bit floating-point values. Subnormal numbers are either preserved or flushed to zero, consistently within an implementation.

The first component of the vector is obtained from the 16 least-significant bits of v ; the second component is obtained from the 16 most-significant bits of v .

The v operand must be a scalar with 32-bit integer type.

Result Type must be a vector of 2 components whose type is 32-bit floating point.

62	$\langle id \rangle$ v
----	-----------------------------

UnpackSnorm4x8

First, unpacks a single 32-bit unsigned integer p into four 8-bit signed integers. Then, each component is converted to a normalized floating-point value to generate the result. The conversion for unpacked fixed-point value f to floating point is done as follows:

$\text{clamp}(f / 127.0, -1, +1)$

The first component of the result will be extracted from the least significant bits of the input; the last component will be extracted from the most significant bits.

The p operand must be a scalar with 32-bit integer type.

Result Type must be a vector of 4 components whose type is 32-bit floating point.

63	$\langle id \rangle$ p
----	-----------------------------

UnpackUnorm4x8

First, unpacks a single 32-bit unsigned integer p into four 8-bit unsigned integers. Then, each component is converted to a normalized floating-point value to generate the result. The conversion for unpacked fixed-point value f to floating point is done as follows:

$f / 255.0$

The first component of the result will be extracted from the least significant bits of the input; the last component will be extracted from the most significant bits.

The p operand must be a scalar with 32-bit integer type.

Result Type must be a vector of 4 components whose type is 32-bit floating point.

64	$\langle id \rangle$ p
----	-----------------------------

UnpackDouble2x32

Result is the two-component unsigned integer vector representation of v . The bit-level representation of v is preserved. The first component of the vector contains the 32 least significant bits of the double; the second component consists of the 32 most significant bits.

The v operand must be a scalar whose type is 64-bit floating point.

Result Type must be a vector of 2 components whose type is a 32-bit integer.

Use of this instruction requires declaration of the **Float64** capability.

65	$\langle id \rangle$ v
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Length

Result is the length of vector x , i.e., $\text{sqrt}(x[0]^2 + x[1]^2 + \dots)$.

The operand x must be a scalar or vector whose component type is floating-point.

Result Type must be a scalar of the same type as the component type of x .

66

<id>

 x **Distance**

Result is the distance between $p0$ and $p1$, i.e., $\text{length}(p0 - p1)$.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type must be a scalar of the same type as the component type of the operands.

67

<id>

 $p0$

<id>

 $p1$ **Cross**

Result is the cross product of x and y , i.e., the resulting components are, in order:

$$x[1] * y[2] - y[1] * x[2]$$

$$x[2] * y[0] - y[2] * x[0]$$

$$x[0] * y[1] - y[0] * x[1]$$

All the operands must be vectors of 3 components of a floating-point type.

Result Type and the type of all operands must be the same type.

68

<id>

 x

<id>

 y **Normalize**

Result is the vector in the same direction as x but with a length of 1.

The operand x must be a scalar or vector whose component type is floating-point.

Result Type and the type of x must be the same type.

69

<id>

 x

FaceForward

If the dot product of $Nref$ and I is negative, the result is N , otherwise it is $-N$.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type.

70	<i><id></i> N	<i><id></i> I	<i><id></i> $Nref$
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Reflect

For the incident vector I and surface orientation N , the result is the reflection direction:

$$I - 2 * \text{dot}(N, I) * N$$

N must already be normalized in order to achieve the desired result.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type.

71	<i><id></i> I	<i><id></i> N
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Refract

For the incident vector I and surface normal N , and the ratio of indices of refraction eta , the result is the refraction vector. The result is computed by

$$k = 1.0 - eta * eta * (1.0 - \text{dot}(N, I) * \text{dot}(N, I))$$

if $k < 0.0$ the result is 0.0

otherwise, the result is $eta * I - (eta * \text{dot}(N, I) + \text{sqrt}(k)) * N$

The input parameters for the incident vector I and the surface normal N must already be normalized to get the desired results.

The type of I and N must be a scalar or vector with a floating-point component type.

The type of eta must be a floating-point scalar.

Result Type, the type of I , the type of N , and the type of eta must all have the same component type.

72	<i><id></i> I	<i><id></i> N	<i><id></i> eta
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FindILsb

Integer least-significant bit.

Results in the bit number of the least-significant 1-bit in the binary representation of *Value*. If *Value* is 0, the result is -1.

Result Type and the type of *Value* must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

This instruction is currently limited to 32-bit width components.

73

<id>

*Value***FindSMsb**

Signed-integer most-significant bit, with *Value* interpreted as a signed integer.

For positive numbers, the result will be the bit number of the most significant 1-bit. For negative numbers, the result will be the bit number of the most significant 0-bit. For a *Value* of 0 or -1, the result is -1.

Result Type and the type of *Value* must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

This instruction is currently limited to 32-bit width components.

74

<id>

*Value***FindUMsb**

Unsigned-integer most-significant bit.

Results in the bit number of the most-significant 1-bit in the binary representation of *Value*. If *Value* is 0, the result is -1.

Result Type and the type of *Value* must both be integer scalar or integer vector types. *Result Type* and operand types must have the same number of components with the same component width. Results are computed per component.

This instruction is currently limited to 32-bit width components.

75

<id>

Value

InterpolateAtCentroid

Result is the value of the input *interpolant* sampled at a location inside both the pixel and the primitive being processed. The value obtained would be the same value assigned to the input variable if it were decorated as **Centroid**.

The operand *interpolant* must be a pointer to the **Input** Storage Class.

The operand *interpolant* must be a pointer to a scalar or vector whose component type is 32-bit floating-point.

This instruction is only valid in the **Fragment** execution model.

Result Type and the type that *interpolant* points to must be the same type.

Use of this instruction requires declaration of the **InterpolationFunction** capability.

76

<id>
interpolant

InterpolateAtSample

Result is the value of the input *interpolant* variable at the location of sample number *sample*. If multisample buffers are not available, the input variable will be evaluated at the center of the pixel. If sample *sample* does not exist, the position used to interpolate the input variable is undefined.

The operand *interpolant* must be a pointer to the **Input** Storage Class.

The operand *interpolant* must be a pointer to a scalar or vector whose component type is 32-bit floating-point.

This instruction is only valid in the **Fragment** execution model.

The *sample* operand must be a scalar 32-bit integer.

Result Type and the type that *interpolant* points to must be the same type.

Use of this instruction requires declaration of the **InterpolationFunction** capability.

77

<id>
interpolant

<id>
sample

InterpolateAtOffset

Result is the value of the input *interpolant* variable sampled at an offset from the center of the pixel specified by *offset*. The two floating-point components of *offset*, give the offset in pixels in the *x* and *y* directions, respectively. An *offset* of (0, 0) identifies the center of the pixel. The range and granularity of offsets supported are implementation-dependent.

The operand *interpolant* must be a pointer to the **Input** Storage Class.

The operand *interpolant* must be a pointer to a scalar or vector whose component type is 32-bit floating-point.

This instruction is only valid in the **Fragment** execution model.

The *offset* operand must be a vector of 2 components of 32-bit floating-point type.

Result Type and the type that *interpolant* points to must be the same type.

Use of this instruction requires declaration of the **InterpolationFunction** capability.

78	<id> <i>interpolant</i>	<id> <i>offset</i>
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NMin

Result is *y* if $y < x$, either *x* or *y* when both *x* and *y* are zeros, otherwise *x*. If one operand is a NaN, the other operand is the result. If both operands are NaN, the result is a NaN.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

79	<id> <i>x</i>	<id> <i>y</i>
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NMax

Result is *y* if $x < y$, either *x* or *y* when both *x* and *y* are zeros, otherwise *x*. If one operand is a NaN, the other operand is the result. If both operands are NaN, the result is a NaN.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

80	<id> <i>x</i>	<id> <i>y</i>
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NClamp

Result is $\min(\max(x, \text{minVal}), \text{maxVal})$. Result is undefined if $\text{minVal} > \text{maxVal}$. The semantics used by $\min()$ and $\max()$ are those of NMin and NMax.

The operands must all be a scalar or vector whose component type is floating-point.

Result Type and the type of all operands must be the same type. Results are computed per component.

81	<i><id></i> <i>x</i>	<i><id></i> <i>minVal</i>	<i><id></i> <i>maxVal</i>
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A Changes

A.1 Changes from Version 0.99, Revision 1

- Fork the revision stream, changes section, etc. from the core specification, so this specification has its own, starting numbering at revision 1. This document now lives independently.
- Added integer versions of **abs**, **sign**, **min**, **max**, and **clamp**.
- Removed **floatBitsToInt**, **floatBitsToUint**, **intBitsToFloat**, and **uintBitsToFloat**; these can be handled with **OpBitcast**.
- Removed **fTransform**, not needed.
- Fixed internal bugs
 - 13721: Add **OpTypeStruct**-result versions of **Modf** and **Frexp**: **ModfStruct** and **FrexpStruct**.
- Fixed public bugs
 - 1322: GLSL.std.450 **frexp** wasn't saying the *exp* argument was a pointer to the result

A.2 Changes from Version 0.99, Revision 2

- Moved **AddCarry**, **SubBorrow**, and **MulExtended** type of instructions to the core specification.
- Added integer variant of **Mix**, creating **FMix** and **IMix** (14480).
- Modified spellings to be more regular (14614).

A.3 Changes from Version 0.99, Revision 3

- Add "N" version of **Min**, **Max**, and **Clamp**, creating a version that favors non-NaN operands over NaN operands.
- Bug 15452 Remove **IMix**.
- Bug 15300 Be more consistent that the **InterpolateAt** instructions take a pointer.
- Bug 14548 Document the **Capability** needed for **Double2x32** and **InterpolateAt** instructions.

A.4 Changes from Version 1.00, Revision 1

- Bug 14548 Document the **Capability** needed for **UnpackDouble2x32**.

A.5 Changes from Version 1.00, Revision 2

- Change **precise** to **NoContraction**

A.6 Changes from Version 1.00, Revision 3

- Allow both 16-bit and 32-bit floating-point types in most places where before only 32-bit floating-point types were allowed. This does not effect whether 16-bit floating point types are allowed, which is selected independently. Since 16-bit types were historically disallowed, this is a backward compatible change.
- Fix Khronos internal issue #109: be more clear for **NMin**/**NMax**: If both operands are NaN, the result is a NaN.

A.7 Changes from Version 1.00, Revision 4

- Be clear about **UnpackHalf2x16** denorm rules.

A.8 Changes from Version 1.00, Revision 5

Fixed:

- Khronos SPIR-V Issue #211: As with **FindSMsb** and **FindUMsb**, **FindILsb** needs 32-bit components.

A.9 Changes from Version 1.00, Revision 6

Fixed:

- Khronos SPIR-V Issue #337: The component types of the operands for **Refract** must all be the same.
- Khronos SPIR-V Issue #331: Correct the types in **ModfStruct**.

A.10 Changes from Version 1.00, Revision 7

Support SPV_KHR_no_integer_wrap_decoration, in the **SAbs** instruction.

A.11 Changes from Version 1.00, Revision 8

Fixed:

- Khronos SPIR-V Issue #466: **FAbs** of -0.0 is $+0.0$, **FSign** of -0.0 can be either ± 0.0 . **FMin**, **FMax**, **NMin**, and **NMax** are allowed to return either operand when both are zeros.
- Khronos SPIR-V Issue #458: For **Frexp**, be more clear about negative values, and also about which returned value is being discussed.

A.12 Changes from Version 1.00, Revision 9

- Corrected the output range of **Atan**.

A.13 Changes from Version 1.00, Revision 10

- State what **FSign** of $\pm NaN$ is.