



## **SPIR-V Extended Instructions for GLSL**

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Version 1.00, Revision 4

May 15, 2017



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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:

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

Extended instructions:

<b>Round</b>	
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 <b>Round</b> $x$ is the same value as <b>RoundEven</b> $x$ 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>&lt;id&gt;</i> $x$

<b>RoundEven</b>	
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>&lt;id&gt;</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

&lt;id&gt;

 $x$ **FAbs**

Result is  $x$  if  $x \geq 0$ ; otherwise result is  $-x$ .

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.

4

&lt;id&gt;

 $x$ **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.

5

&lt;id&gt;

 $x$ **FSign**

Result is 1.0 if  $x > 0$ , 0.0 if  $x = 0$ , or -1.0 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.

6

&lt;id&gt;

 $x$ **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

&lt;id&gt;

 $x$

**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

<id>  
 $x$

**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

<id>  
 $x$

**Fract**

Result is  $x - \mathbf{floor} x$ .

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

<id>  
 $x$

**Radians**

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

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

<id>  
*degrees*

**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

<id>  
*radians*

<b>Sin</b>	
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.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
13	<i>&lt;id&gt;</i> $x$

<b>Cos</b>	
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.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
14	<i>&lt;id&gt;</i> $x$

<b>Tan</b>	
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.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
15	<i>&lt;id&gt;</i> $x$

<b>Asin</b>	
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 <b>abs</b> $x > 1$ .	
The operand $x$ must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
16	<i>&lt;id&gt;</i> $x$

<b>Acos</b>	
Arc cosine. Result is an angle, in radians, whose cosine is $x$ . The range of result values is $[0, \pi]$ . Result is undefined if <b>abs</b> $x > 1$ .	
The operand $x$ must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	

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

<b>Atan</b>	
Arc tangent. Result is an angle, in radians, whose tangent is $y\_over\_x$ . The range of result values is $[-\pi, \pi]$ .	
The operand $y\_over\_x$ must be a scalar or vector whose component type is 16-bit or 32-bit floating-point.	
<i>Result Type</i> and the type of $y\_over\_x$ must be the same type. Results are computed per component.	
18	$\langle id \rangle$ $y\_over\_x$

<b>Sinh</b>	
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.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
19	$\langle id \rangle$ $x$

<b>Cosh</b>	
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.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
20	$\langle id \rangle$ $x$

<b>Tanh</b>	
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.	
<i>Result Type</i> and the type of $x$ must be the same type. Results are computed per component.	
21	$\langle id \rangle$ $x$



**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

<id>  
 $x$

**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

<id>  
 $x$

**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

<id>  
 $x$

**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

<id>  
 $y$

<id>  
 $x$

**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>  
 $y$

**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>  
 $x$

**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

&lt;id&gt;

 $x$ **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

&lt;id&gt;

 $x$ **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

&lt;id&gt;

 $x$ **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 Results are computed per component.

35

&lt;id&gt;

 $x$ 

&lt;id&gt;

 $i$

**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 the *Result Type* must all have the same type. This structure type must be explicitly declared by the module.

36	<id> x
----	-----------

**FMin**

Result is  $y$  if  $y < x$ ; otherwise result is  $x$ . 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	<id> x	<id> y
----	-----------	-----------

**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	<id> x	<id> y
----	-----------	-----------

**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	<id> x	<id> y
----	-----------	-----------

**FMax**

Result is  $y$  if  $x < y$ ; otherwise result is  $x$ . 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	<id> x	<id> y
----	-----------	-----------

**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	<id> $x$	<id> $y$
----	-------------	-------------

**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	<id> $x$	<id> $y$
----	-------------	-------------

**FClamp**

Result is  $\min(\max(x, \mathit{minVal}), \mathit{maxVal})$ . Result is undefined if  $\mathit{minVal} > \mathit{maxVal}$ . 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	<id> $x$	<id> $\mathit{minVal}$	<id> $\mathit{maxVal}$
----	-------------	---------------------------	---------------------------

**UClamp**

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

*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	<id> $x$	<id> $\mathit{minVal}$	<id> $\mathit{maxVal}$
----	-------------	---------------------------	---------------------------

**SClamp**

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

*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	<id> $x$	<id> $\mathit{minVal}$	<id> $\mathit{maxVal}$
----	-------------	---------------------------	---------------------------

**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	<id> $x$	<id> $y$	<id> $a$
----	-------------	-------------	-------------

**Step**

Result is 0.0 if  $x < edge$ ; 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	<id> $edge$	<id> $x$
----	----------------	-------------

**SmoothStep**

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

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

Result is undefined if  $edge0 \geq edge1$ .

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> $edge0$	<id> $edge1$	<id> $x$
----	-----------------	-----------------	-------------

**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> $a$	<id> $b$	<id> $c$
----	-------------	-------------	-------------

**Frexp**

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

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

The *significand* is the result and the exponent is returned through the pointer-parameter *exp*. For a floating-point value of zero, the significand and exponent are both zero. For a floating-point value that is an infinity or is not a number, the result is undefined.

If an implementation supports negative 0, **Frexp** -0 should result in -0; otherwise it will result in 0.

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

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.

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

51	<id> $x$	<id> $exp$
----	-------------	---------------

**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. This structure type must be explicitly declared by the module.

52	<id> $x$
----	-------------

**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

&lt;id&gt;

 $x$ 

&lt;id&gt;

 $exp$ **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

&lt;id&gt;

 $v$



**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

&lt;id&gt;

 $v$ **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

&lt;id&gt;

 $v$ **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	<id> <i>v</i>
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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	<id> <i>v</i>
----	------------------

**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	<id> <i>v</i>
----	------------------

**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	<id> <i>p</i>
----	------------------

**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	<id> $p$
----	-------------

**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.

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	<id> $v$
----	-------------

**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	<id> $p$
----	-------------

**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	<i>&lt;id&gt;</i> $p$
----	--------------------------

**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	<i>&lt;id&gt;</i> $v$
----	--------------------------

**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	<i>&lt;id&gt;</i> $x$
----	--------------------------

**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	<i>&lt;id&gt;</i> $p0$	<i>&lt;id&gt;</i> $p1$
----	---------------------------	---------------------------

**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	<id> $N$	<id> $I$	<id> $Nref$
----	-------------	-------------	----------------

**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	<id> $I$	<id> $N$
----	-------------	-------------

**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 16-bit or 32-bit floating-point scalar.

*Result Type*, the type of  $I$ , and the type of  $N$  must all be the same type.

72	<id> $I$	<id> $N$	<id> $eta$
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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.

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 of *interpolant* 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 of *interpolant* 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 of *interpolant* 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  $y < x$ ; otherwise result is *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  $x < y$ ; otherwise result is *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	<id> <i>x</i>	<id> <i>minVal</i>	<id> <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.