Notes on IEEE 754 Floating-Point Number Format. Further details and examples can be found at http://weitz.de/ieee/ and https://en.wikipedia.org/wiki/IEEE_754

float16

The float16 library uses the IEEE 754 binary16 format for storing floating-point numbers:

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
+ -	exponent (+15)					mantissa (10 bits stored)									

The exponent is stored with a bias of +15.

Number	Binary Float	float16
0	0.0 x 2 ^ 0	0000 0000000000000000
1	1.0 x 2 ^ 0	3C00 0011110000000000
2	1.0 x 2 ^ 1	4000 0100000000000000
3.14	1.57 x 2 ^ 1	4248 0100001001001000
-100	-1.5625 x 2 ^ 6	D640 1101011001000000
inf	inf	7C00 0111110000000000
NaN	NaN	FFFF 1111111111111111

float32

The float32 library uses the IEEE 754 binary32 format for storing floating-point numbers:

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
+ -	exponent (+127)								mantissa (23 bits stored)																						

The exponent is stored with a bias of +127.

Number	Binary Float	float16
0	0.0 x 2 ^ 0	00000000 00000000000000000000000000000000
1	1.0 x 2 ^ 0	3F800000 00111111100000000000000000000000
2	1.0 x 2 ^ 1	40000000 01000000000000000000000000000000
3.1415927	1.5707964 x 2 ^ 1	40490FDB 01000000010010010000111111011011
-100	-1.5625 x 2 ^ 6	C2C80000 11000010110010000000000000000000
inf	inf	7F800000 01111111100000000000000000000000
NaN	NaN	FFFFFFFF 11111111111111111111111111111111

Each library provides routines for conversion between floating-point and integers (float16 only provides signed conversions), addition/subtraction, multiplication, division, square root and basic comparisons.

Numbers that are too large to store in the relevant format return the largest possible number in the relevant format, and too small to store return zero. Errors, such as divide by zero, return INF or NaN as appropriate.

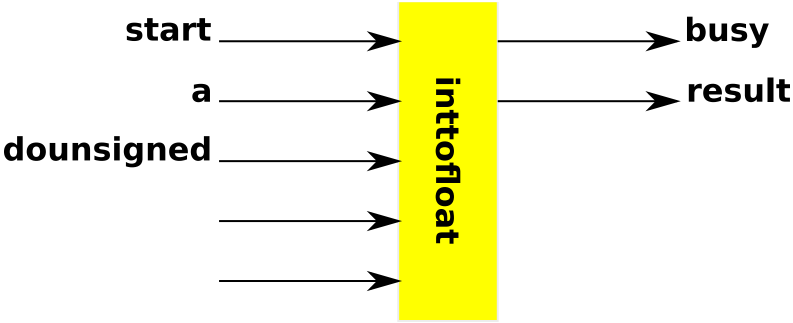
Usage

For all algorithms in the library, hold “start” to 1 for 1 clock, and wait for “busy” to return to 0. “a” represents the first operand, “b” the second operand, and “result” is the result in the appropriate format. “addsub” and “dounsigned” are explained in the appropriate section when used.

For the comparison circuits, there is a single output that is the result of the comparison, 1 for true, 0 for false, and two inputs, the two floating point numbers to compare.

inttofloat

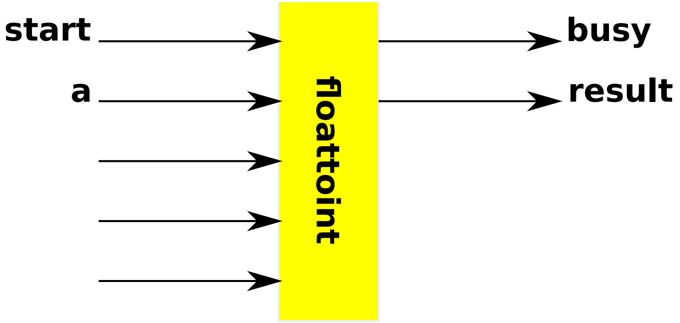
Converts integers (16 bit for float16, 32 bit for float32) to floating-point. NB: In float16 this is only for signed integers.

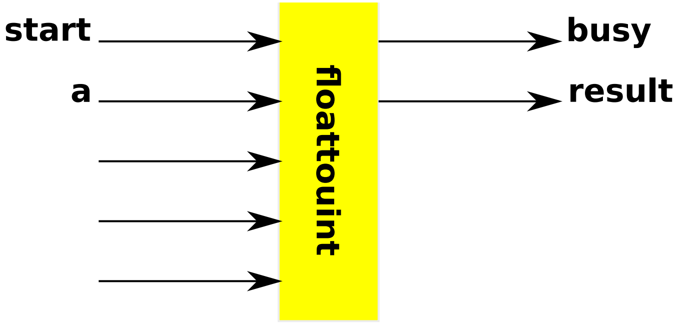


Signal	Meaning
“start”	Start the conversion by holding to 1 for 1 clock cycle.
“a”	Integer to convert to floating point (16 bit for float16, 32 bit for float32).
“dounsigned”	Set to 1 to treat a as an unsigned integer. **ONLY FOR float32.**
“busy”	Set to 1 whilst the conversion takes place.
“result”	Result of the conversion of a into floating point as float16 or float32.

floattoint and floattouint

Converts floating point numbers (16 bit for float16, 32 bit for float32) to integers. NB: In float16 this is only for signed numbers.

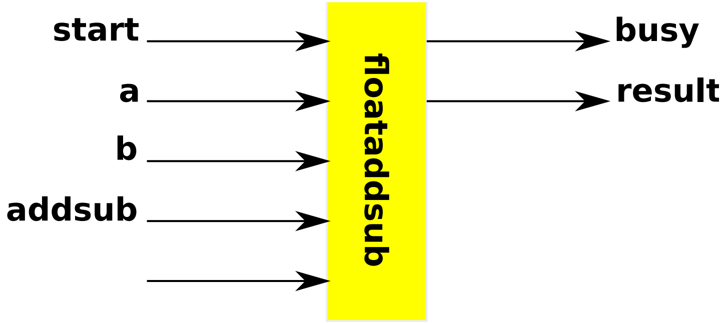




Signal	Meaning
“start”	Start the conversion by holding to 1 for 1 clock cycle.
“a”	Floating point number to convert to an integer.
“busy”	Set to 1 whilst the conversion takes place.
“result”	Result of the conversion of a into an integer.

floataddsub

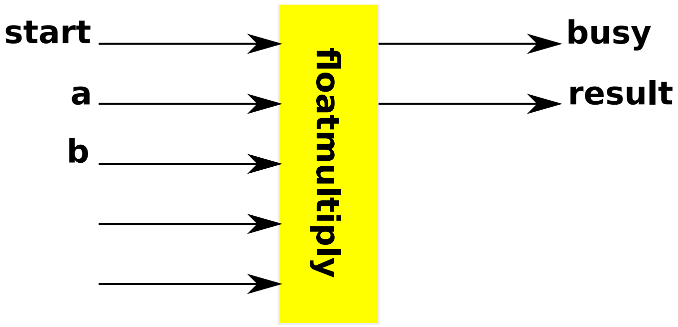
Performs addition or subtraction (16 bit for float16, 32 bit for float32) of two floating point numbers.



Signal	Meaning
“start”	Start the additiion or subtraction by holding to 1 for 1 clock cycle.
“a”	First floating point operand.
“b”	Second floating point operand.
“addsub”	Control when 0 do addition, or 1 do subtraction.
“busy”	Set to 1 whilst the operation takes place.
“result”	Result of the “addsub = 0” a +b, or “addsub = 1” a – b.

floatmultiply

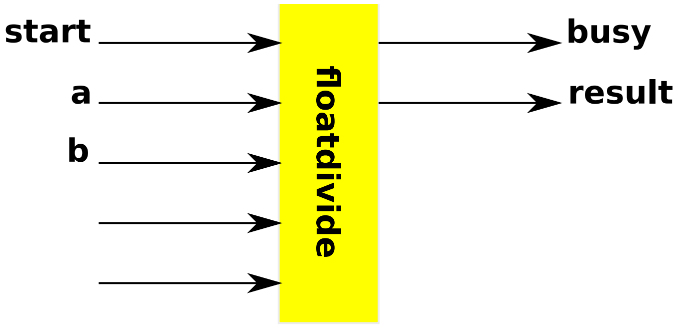
Performs multiplication (16 bit for float16, 32 bit for float32) of two floating point numbers. **NOTE uses 18 bit DSP multipliers (designed for ULX3S).**



Signal	Meaning
“start”	Start the multiplication by holding to 1 for 1 clock cycle.
“a”	First floating point operand.
“b”	Second floating point operand.
“busy”	Set to 1 whilst the operation takes place.
“result”	Result of the a * b.

floatdivide

Performs division (16 bit for float16, 32 bit for float32) of two floating point numbers.

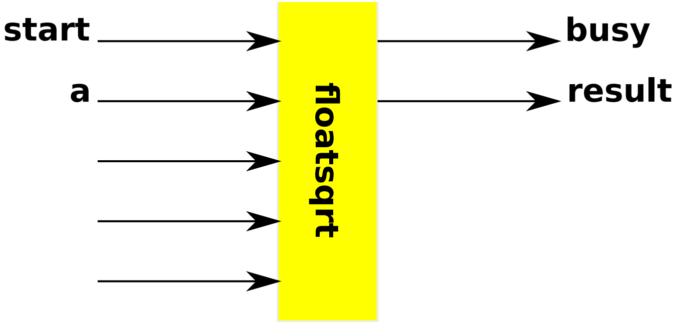


Signal	Meaning
“start”	Start the division by holding to 1 for 1 clock cycle.
“a”	First floating point operand.
“b”	Second floating point operand.
“busy”	Set to 1 whilst the operation takes place.
“result”	Result of the a / b.

floatsqrt

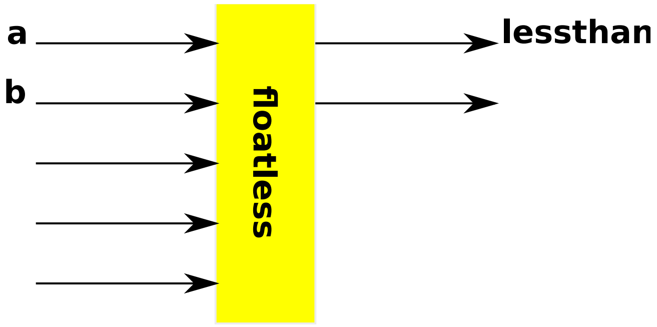
Adapted from https://projectf.io/posts/square-root-in-verilog/

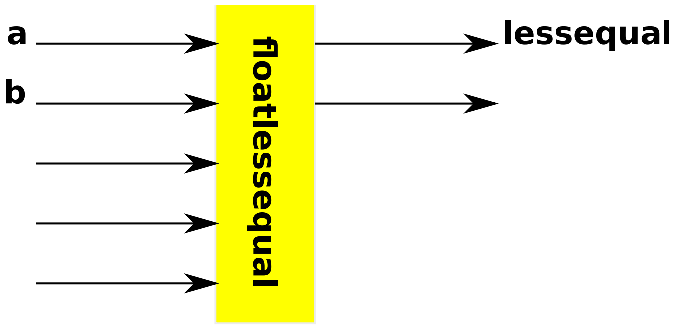
Performs square root (16 bit for float16, 32 bit for float32) of a floating point number.

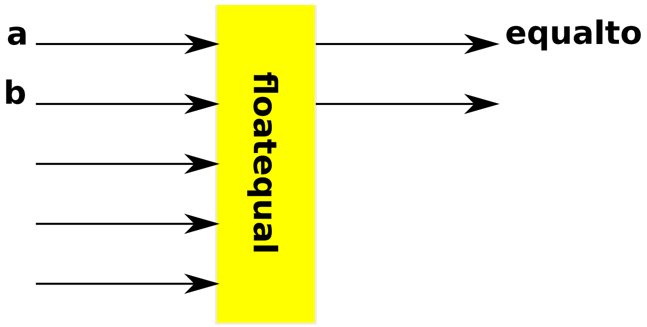


Signal	Meaning
“start”	Start the square root by holding to 1 for 1 clock cycle.
“a”	Floating point number to square root.
“busy”	Set to 1 whilst the operation takes place.
“result”	Result of the √a.

Comparisons: floatless floatequal floatlessequal







Adpated from Berkeley SoftFloat https://github.com/ucb-bar/berkeley-softfloat-3

Performs comparisons (16 bit for float16, 32 bit for float32) of two floating point numbers. These are provided as Silice circuits.

Signal	Meaning
“a”	First floating point operand.
“b”	Second floating point operand.
“lessthan”	Returns 1 if a < b.
“lessequal”	Returns 1 if a <= b.
“equalto”	Returns 1 if a == b.