Mentor®
A Siemens Business

Algorithmic C (AC) Math Release Notes

Software Version v3.2.0

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Release 3.1.2

The following topics describes the changes that were made to the *ac_math* library since the last release. This release provides new functionality and bug fixes. This version of ac_math was included in Catapult release 10.3a.

Improved Bitwidth Calculation

The following PWL functions had the calculations for parameterized bitwidths of ac_fixed variables improved in order to eliminate redundant bits and reduce area:

- ac_inverse_sqrt_pwl.h
- ac_log_pwl.h
- ac_pow_pwl.h
- ac_reciprocal_pwl.h
- ac_sqrt_pwl.h
- ac_tan_pwl.h

Cleanup Sine/Cosine Cordic

The ac_sincos_cordic.h file was updated to rename a typedef so as to avoid a redeclaration conflict.

Removed Direct Access to AC Float Member Data

The ac_reciprocal_pwl(), ac_inverse_sqrt_pwl() and ac_sqrt_pwl() functions now no longer directly access the mantissa and exponent data members in the ac_float class for inputs. Instead, the functions use the .mantissa() and .exp() member functions to indirectly access (read-only) the data members of the input floating point variables.

Added New Power Function

A generic ac_pow_pwl() function was which accepted variable bases as well as exponents.

Default Template Parameter Changed

ac_exp_pwl() function now uses more fractional bits by default for an intermediate variable, to minimize error.

Corrected Issues

The following user-reported problems were fixed in this release:

- **(no bug #)**: File: ac_matrix.h – Transpose() member function was incorrect.
- **(no bug #)**: File ac_sqrt_pwl.h – Fixed bug in output near normalized 1 by adding extra bit to account for upward shifting of segments against the direction of concavity for ac_float types.
- **(no bug #)**: File ac_sincos_cordic.h – Renamed the typedef to avoid redeclaration conflict with ac_atan2_cordic.h

Release 3.1.0

The following topics describes the changes that were made to the *ac_math* library since the last release. This release provides new functionality and bug fixes. This version of ac_math was included in Catapult release 10.3.

Hyperbolic Tangent File Renamed

The file ac_hyperbolic_tan_pwl.h was renamed to ac_tanh_pwl.h for consistency with the other header files.

Improved AC Complex Support

The file ac_reciprocal_pwl.h was changed to use better bitwidth calculation for intermediate variables in the ac_complex<ac_float> version.

Corrected Issues

The following user-reported problems were fixed in this release:

- **(bug #51400):** File: ac_abs.h – Function for ac_int values results in hardware that uses an XW + 1 bit adder instead of an XW + 2 bit adder, where XW is the input bitwidth, thereby reducing area and improving QofR.
- **(bug #51145)**: Files: ac_inverse_sqrt_pwl.h, ac_reciprocal_pwl.h and ac_sqrt_pwl.h – Fixed expressions that directly manipulated the mantissa and exponent for ac_float outputs, replacing it with an ac_float constructor that performed normalization first and then modified the mantissa and exponent.
- **(no bug #)**: File: ac_sqrt.h – Fixed expression that could cause overflow.
- **(no bug #)**: Files: ac_arccos_cordic.h and ac_arcsin_cordic.h – Used different names for the class, function and variable in both the files to avoid name conflicts.

Release 2.0.10

This is the first official open-source release of the *ac_math* library. The following table lists the functions available in this release. For details about how to use the ac_math library consult the AC Math Reference Manual. This version of ac_math was included in Catapult release 10.2d.

Basic Math Functions

Function Type	Function Call	Approximation Method	Supported Data Types		
			ac_fixed	ac_float	ac_complex
Absolute Value	*ac_abs()*	N/A	Yes	Yes	No
Division	*ac_div()*	N/A	Yes	Yes	Yes
Normalization	*ac_normalize()*	N/A	Yes	No	Yes
Reciprocal	*ac_reciprocal_pwl()*	PWL	Yes	Yes	Yes
Logarithm Base e	*ac_log_pwl()*	PWL	Yes	No	No
	ac_log_cordic()	CORDIC	Yes	No	No
Logarithm Base 2	*ac_log2_pwl()*	PWL	Yes	No	No
	ac_log2_cordic()	CORDIC	Yes	No	No
Exponent Base e	*ac_exp_pwl()*	PWL	Yes	No	No
	ac_exp_cordic()	CORDIC	Yes	No	No
Exponent Base 2	*ac_pow2_pwl()*	PWL	Yes	No	No
	ac_exp2_cordic()	CORDIC	Yes	No	No
Generic Exponent	*ac_pow_pwl()*	PWL	Yes	No	No
	ac_pow_cordic()	CORDIC	Yes	No	No
Square Root	*ac_sqrt_pwl()*	PWL	Yes	Yes	Yes
	ac_sqrt()	N/A	Yes	No	No
Inverse Square Root	*ac_inverse_sqrt_pwl()*	PWL	Yes	Yes	Yes
Sine/Cosine	*ac_sincos()*	LUT	Yes	No	No
	ac_cos_cordic()	CORDIC	Yes	No	No
	ac_sin_cordic()	CORDIC	Yes	No	No
	ac_sincos_cordic()	CORDIC	Yes	No	No
Tangent	*ac_tan_pwl()*	PWL	Yes	No	No
Inverse Trig	*ac_atan_pwl()*	PWL	Yes	No	No
	ac_arccos_cordic()	CORDIC	Yes	No	No

Function Type	Function Call	Approximation Method	Supported Data Types		
			ac_fixed	ac_float	ac_complex
	ac_arcsin_cordic()	CORDIC	Yes	No	No
	ac_arctan_cordic()	CORDIC	Yes	No	No
Shift Left/Right	*ac_shift_left*	N/A	Yes	No	Yes
	ac_shift_right	N/A	Yes	No	Yes
Hyperbolic Tangent	*ac_tanh_pwl*	PWL	Yes	No	No
Sigmoid	*ac_sigmoid_pwl*	PWL	Yes	No	No
Softmax	*ac_softmax_pwl*	PWL	Yes	No	No

AC Matrix Class

The class ac_matrix implements a 2-D container class with a template parameter to specify the data type of the internal storage.

The class has member functions to implement some common operations including

- Assignment: operator=()
- Read-Only and Read-Write Element Access: *this(<row>,<col>)
- Comparison: operator!=(), operator==()
- Piecewise Addition: operator+(), operator+=()
- Piecewise Subtraction: operator-(), operator-=()
- Piecewise Multiplication: pwisemult()
- Matrix Multiplication (nested loops): operator*()
- Matrix Transpose: transpose()
- Sum All Elements: sum()
- Scale All Elements: scale(value)
- Formatted Stream Output: ostream &operator<<()

When using the computational functions with AC Datatypes, the form that returns a value is designed in such a way as to determine the full precision required in the output type in order to preserve accuracy during the operation. So using operator+ between two 10 bit ac_fixed matrices will return an 11 bit ac_fixed matrix. If you wish to prevent the bit growth and accept the truncation, you can use the compound operators +=,-=, etc. so that the target object receives the truncated values.

In addition to the built-in member functions, the ac_math library also includes stand-alone functions for more complicated linear algebra operations as described in the next section.

Linear Algebra Functions

The ac_math library includes several linear algebra functions that operate on either ac_matrix or plain C-style arrays. These functions, when used with AC Datatypes, are designed to give the user greater control over the bit precision of internal variables and the return value.

- Matrix Multiplication
- Matrix Determinant
- Cholesky Decomposition
- Cholesky Inverse
- QR Decomposition

Supported Compilers

The PWL functions use default template arguments. This requires using a C++ compiler that support the C++11 or newer standard.