MATLAB for Synthesis

Style Guide

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Preface

About This Guide

The AccelDSP™ Synthesis Tool is a product that allows you to transform a MATLAB floating-point design into a hardware module that can be implemented in a Xilinx FPGA This document describes the AccelDSP coding sytle guidelines for the MATLAB floating-point model.

Guide Contents

This manual contains the following chapters:

- [“Chapter, comma” cross-reference to chapter 1] [explain chapter content here]
- [List each additional chapter in a separate bulleted item.]
- [“Appendix, comma” cross-reference to the first appendix], [explain appendix content here]
- [List each additional appendix in a separate bulleted item.]
- [Do not list the glossary in this bulleted list.]

Additional Resources

To find additional documentation, see the Xilinx website at:

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To search the Answer Database of silicon, software, and IP questions and answers, or to create a technical support WebCase, see the Xilinx website at:

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Conventions

This document uses the following conventions. An example illustrates each convention.

Typographical

The following typographical conventions are used in this document:

Convention	Meaning or Use	Example
`Courier font`	Messages, prompts, and program files that the system displays	`speed grade: - 100`
`Courier bold`	Literal commands that you enter in a syntactical statement	**`ngdbuild`** *design_name*
Helvetica bold	Commands that you select from a menu	**File →Open**
	Keyboard shortcuts	**Ctrl+C**
Italic font	Variables in a syntax statement for which you must supply values	**`ngdbuild`** *design_name*
	References to other manuals	See the *Development System Reference Guide* for more information.
	Emphasis in text	If a wire is drawn so that it overlaps the pin of a symbol, the two nets are *not* connected.
Square brackets [ ]	An optional entry or parameter. However, in bus specifications, such as **`bus[7:0]`**, they are required.	**`ngdbuild`** `[`*`option_name`*`]` *`design_name`*
Braces { }	A list of items from which you must choose one or more	**`lowpwr`** `={`**`on`**`|`**`off`**`}`
Vertical bar |	Separates items in a list of choices	**`lowpwr`** `={`**`on`**`|`**`off`**`}`

Vertical ellipsis
.
.
.
	Repetitive material that has been omitted	`IOB #1: Name = QOUT'`
		`IOB #2: Name = CLKIN'`
		.
		.
		.

Horizontal ellipsis . . .	Repetitive material that has been omitted	**`allow block`** *block_name loc1 loc2 ... locn;*

Online Document

The following conventions are used in this document:

Convention	Meaning or Use	Example
Blue text	Cross-reference link to a location in the current document	See the section "Additional Resources" for details. Refer to "Title Formats" in Chapter 1 for details.

Convention	Meaning or Use	Example
Red text	Cross-reference link to a location in another document	See Figure 2-5 in the *Virtex-II Platform FPGA User Guide.*
Blue, underlined text	Hyperlink to a website (URL)	Go to http://www.xilinx.com for the latest speed files.

Chapter 1

Design File Structure

The following information provides guidelines for structuring the constructs within your MATLAB floating-point files.

A Synthesizable MATLAB Design

Figure 1-1 illustrates the basic structure of a MATLAB design that can be synthesized by the AccelDSP™ Synthesis Tool. The design must be represented by a minimum of two M-files, a *script* M-file and a *function* M-file. These two basic files may also reference other related function files.

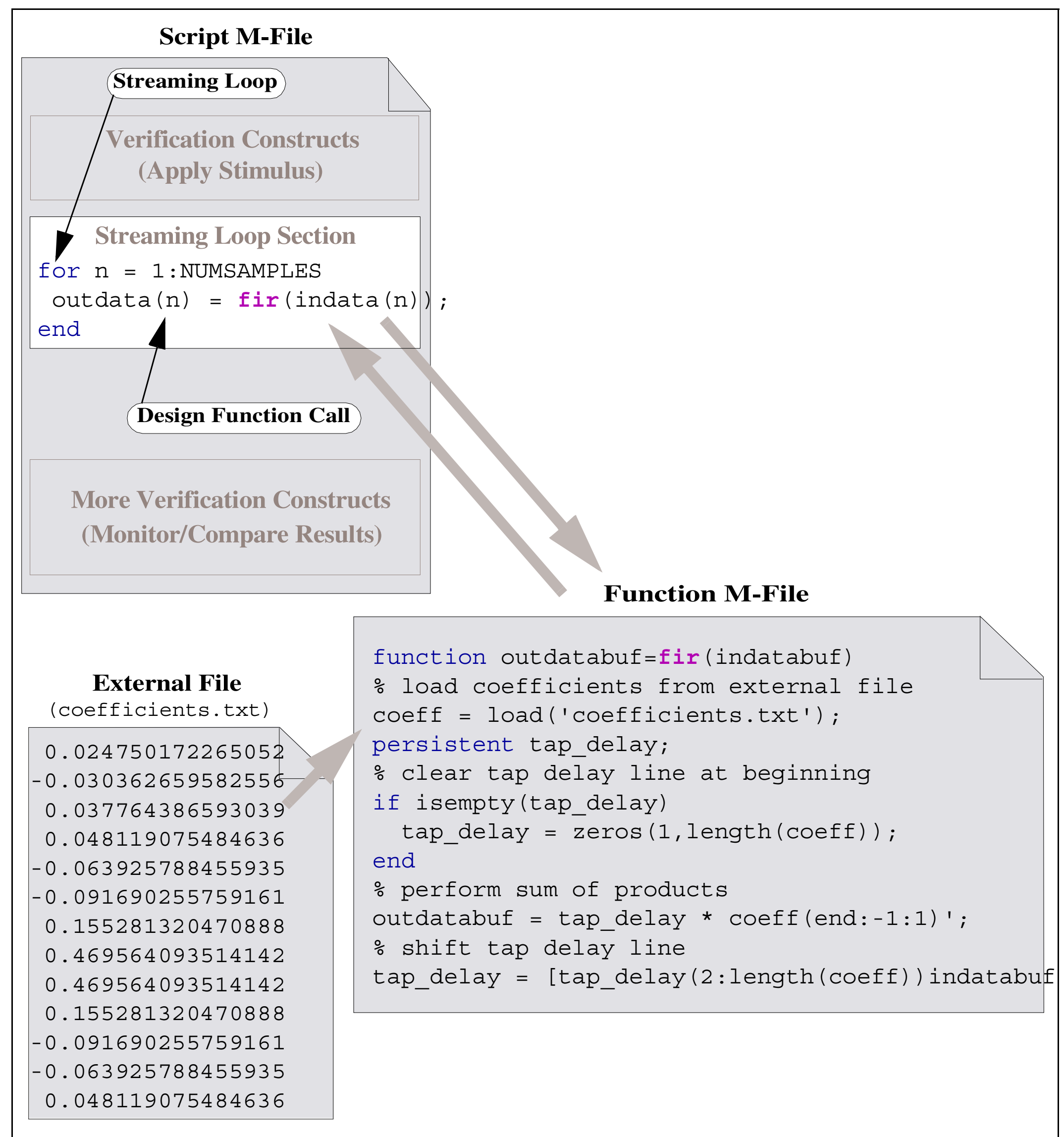

Figure 1-1: **The Basic Files of a Synthesizable MATLAB Design**

The two main elements of the script file are (1) the streaming loop and (2) the top-level design function call. Other constructs may be intermixed with these basic elements, but are not recognized by the AccelDSP Synthesis Tool for hardware synthesis. These secondary constructs are typically used for design verification.

The Streaming Loop

For hardware synthesis, the infinite streams of data entering and leaving the design must be partitioned into manageable groups or “slices” in order to properly process the data. A streaming loop (a **for** loop or **while** loop) is the construct that performs this task. A MATLAB script file must have a streaming loop.

The Top-Level Design Function Call

The top-level design function call represents the hardware to be synthesized. This function must reside inside the streaming loop. During the pre-analyze phase, the AccelDSP Synthesis Tool attempts to automatically identify the top-level design function. If it can not, the tool prompts you to manually identify the design function call in the AccelDSP Project Explorer window.

Input and Output Data Types

Each input and output to the top-level design function must be a variable that represents a **scalar**, a **row vector**, or a **column vector**. *All other argument types are not supported.* For example, array elements a(i), sub-expressions (a+b), and function calls like (abs(x)*2) are not allowed in the top-level design function argument list.

The Function M-File

Figure 1-2 shows a top-level design function file for a floating-point low-pass FIR filter. This function will be synthesized into the hardware block. In this design, the coefficients are maintained in a separate external file that is called within the body of the function. A basic rule for defining a design function is that that a variable in the function input list cannot be specified in the function output list.

You may include calls to other functions within the body of this block, as long as the constructs of the other functions are supported by AccelDSP Synthesis. Each call to a sub-function must be on its own line. For example, the following line is not allowed:

```
a = my_func1(indata1,indata2) + my_func2(indata1,indata2);
```

The equivalent code is allowed:

```
tmp1 = my_func1(indata1,indata2);
tmp2 = my_func2(indata1,indata2);
a = tmp1 + tmp2;
```

Inputs and Outputs to Function Calls within the Design Body

The I/O restrictions that apply to the top-level design function do not apply to function calls within the design body. For example, an argument may be an array element a(i), a sub-expression (a+b), or include a function call like (abs(x)*2). For example, the following line is allowed within the body of the top-level design function:

```
tmp_out(i) = abs(5*indatabuf(i))
```

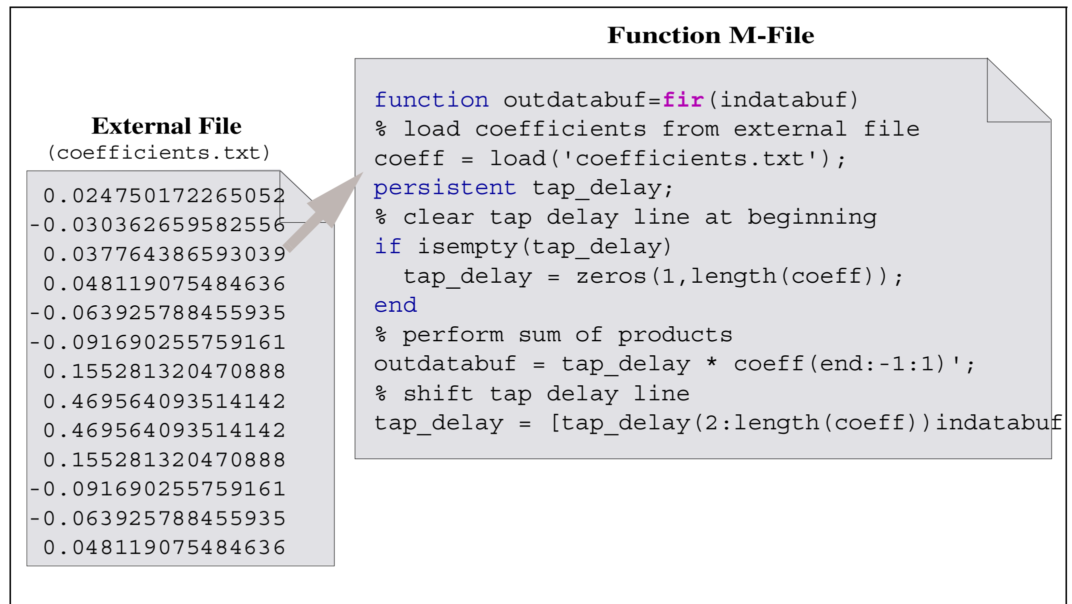

Figure 1-2: **A Design Function File**

How the Design is Mapped to Hardware

Figure 1-3 shows how the constructs surrounding the top-level design function are synthesized into hardware. The name of the hardware block matches the name of the *design function* call. The names of the input and output ports are derived from the MATLAB variables used to move data into and out of the design function.

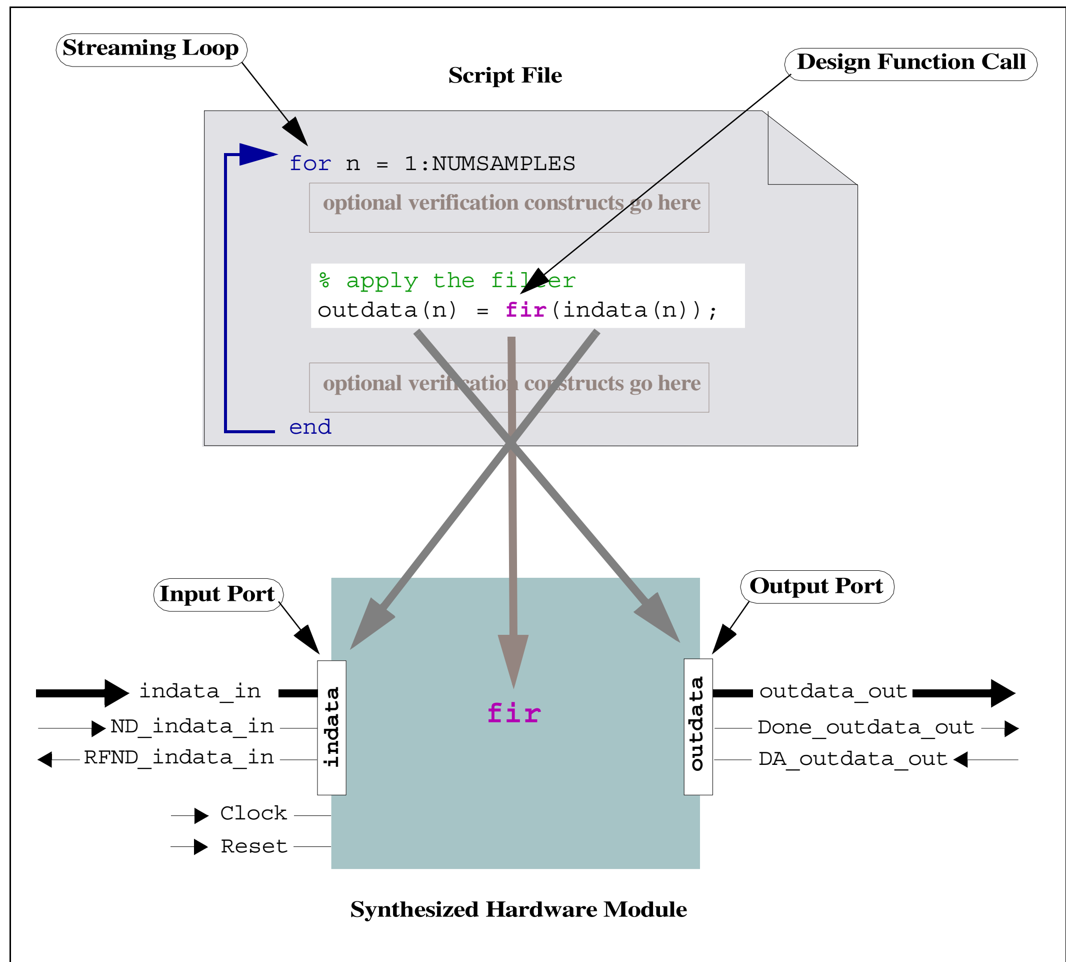

Figure 1-3: **Mapping MATLAB Constructs to Hardware Elements**

Chapter 2

Data Types

This chapter presents the data types and the associated MATLAB coding styles that are supported by the AccelDSP Synthesis Tool.

MATLAB Data Types

The MATLAB programming language supports the processing of several types of data. In terms of precision, MATLAB supports different data types: double precision floating-point (the default) both real and complex, integers, fixed-point quantized data (as provided with the Filter Design Tool Box), and others. In terms of simple and aggregate data, MATLAB supports: scalars, arrays, cells, structures, and combinations of these. The following sections describe the data types that AccelDSP Synthesis supports for effective hardware synthesis.

Constant and Variable Data

In the MATLAB programming language there is no explicit differentiation between data that is constant (constant variable) and data that is variable (non-constant variable) in a program. Scalars, vectors, and matrices can be assigned single or multiple values throughout the program with no need to differentiate between these cases. However, when a MATLAB program is used for hardware synthesis, it is important to differentiate between these types of data because of the distinct impact on the generated hardware.

The AccelDSP Synthesis Tool differentiates between constant and non-constant variable data by analyzing the number of times a variable is assigned values throughout the MATLAB program. Specifically, these are the rules followed by the AccelDSP Synthesis Tool to determine the type of variables present in a MATLAB function:

- If a variable is assigned a value only once in the program, the variable is recognized as a constant variable. A constant variable translates into a constant when the MATLAB program is synthesized into VHDL, and it translates into a parameter when synthesized to Verilog.
- If a variable has multiple assignments throughout the synthesizable constructs, and the first value assigned can be determined at analysis time, then the variable is recognized as a non-constant variable. The determined first assigned value of the variable is treated as an initialization value in the generated HDL RTL Model.
- If a variable has multiple assignments and no initial value is determined at analysis time, then the variable is recognized as a non-constant variable with no initial value in the HDL RTL Model.

Initializing Constant Variables

You can initialize a constant variable by assigning explicit values in the M-file or you can load the values from an external text file.

In the synthesizable code segment below, the constant variable coeff is initialized by the six numeric values on the right side of the assignment statement.

```
% define filter coefficients - numerator and denominator polynomials
coeff = [-2.4750172265052; -2.4750172265052; -3.0362659582556; ...
          3.7764386593039; 4.8119075484636; -6.3925788455935];
```

In the synthesizable code segment below, the constant variable coeff is initialized with values read from the external text file coefficients.txt:

```
% define filter coefficients
coeff = load('coefficients.txt');
```

Data Dimensions

The AccelDSP Synthesis Tool supports operands with fixed-point quantization parameters as described earlier for hardware synthesis. Only real-valued operands are supported of the following dimensions

- Scalar operands
- Single dimensional (row or column) vectors operands
- Two-dimensional matrix operands
- Data structures

'double' Data Type

The AccelDSP Synthesis Tool provides support for the MATLAB built-in data type '**double**' which is a 64-bit double-precision signed number with a fractional part. Both real and native complex numbers are supported.

'structure' Data Type

In MATLAB, a structure array allows you to create a single variable that holds any number of other variables via named “fields”. These fields can be any type of MATLAB variable that is supported by AccelDSP including a structure which yields a nested structure.

The AccelDSP Synthesis Tool provides the following support for the **structure** data type:

- Structures can be used in any way in the script file.
- Passing a whole structure into or out of a design function port is not allowed. However, an individual element of a structure can be passed into or out of a design function port as long as a real-valued scalar or vector is assigned to the element.
- Inside the design function and its sub-functions, structures are supported as described below.

Supported MATLAB Coding Styles for Structure Arrays

- The fields of a structure can be any data type that is supported for regular variables (e.g. double, gf, quantizer, structure).

- Structure fields may be constant or non-constant.
- Structure fields can be any shape that is supported for the structure field’s type (e.g. for a double structure field, that structure field can be a scalar, vector, or matrix).
- All operations on structure fields should be supported as per the structure field’s type (e.g. arithmetic operations are supported for structure fields that are of type double or gf).
- Structure fields that are the same name as other non-structure variables are allowed.
- A structure field that is named the same as its “parent” (or other “ancestor”) structure object is allowed (e.g. “a.a.b.a”).
- Structure objects may be declared persistent.
- Persistent structure objects may be initialized (within an “if isempty” statement) via:
  - A series of constant structure field assignments.
  - A struct function call that returns a structure object whose structure fields are all constant.
  - A combination of the above two assignments.
- Structure objects may be passed into and out of sub-functions.
- A structure object input argument may be used to auto-infer a function.
- Assigning a structure object to a variable (e.g. “a = b” where b is a structure object) is allowed if one of the following are true:
  - The left-hand side variable is previously undefined
  - The left-hand side variable is also a structure object and all structure fields that are common (e.g. the same name) between the left-hand side and right-hand side of the structure objects have the same type and shape. The left-hand side and right-hand side of a quantizer object must be exactly the same. Note that this is a recursive requirement for structure fields that are also structure objects.
  - The left-hand side and right-hand side variable names are the same (e.g. “a = a”).
- A new structure field may be added to a structure object at any time (including in a loop or conditional statement).
- Assigning a structure object to another structure object will cause every structure field that is common to both the left-hand side and right-hand side to be AutoQuantized as if they were directly assigned to each other (this includes if any structure field is in a feedback loop).
- Passing a structure object into or out of a sub-function will cause all the structure object's fields to be AutoQuantized as if they were passed individually into or out-of the sub-function (this includes if any structure field is in a feedback loop).

Unsupported MATLAB Coding Styles for Structures

- Structure objects that are non-scalar will cause an error in Analyze (e.g. “a(2).b”).
- Any operations on a whole structure (e.g. arithmetic, logical, etc.) will cause an error in Analyze.
- Dynamic field names are not supported (e.g. using parenthesis around a field name “a.(b)”) and will cause an error in Analyze.
- Assigning a structure object to another structure object will result in an error if the left-hand side and right-hand side structure object have a common structure field (or nested structure field) whose left-hand side type or shape is different than the

corresponding right-hand side structure field's type or shape. Also, the left-hand side and right-hand side of a quantizer object must be exactly the same or an error will result.

Supported Forms of structure-related Functions

- **struct** returns a scalar structure with any number of fields and initial values. The field names must be constant strings.
- **accel_probe** allows a structure field argument if it is a class 'double'.
- **quantize** allows a structure field argument if it is a class 'double' or 'gf'.

Unsupported Forms of structure-related Functions

- **struct** will error if a field name argument is not a constant string.
- **accel_probe** will error if it is passed a structure object.
- **quantize** will error if it is passed a structure object.
- **structfun** is not supported.

'char' Data Type

The AccelDSP Synthesis Tool provides native support for MATLAB string constants. String constants are declared using single quote marks surrounding a list of characters. For example:

```
a = 'This is a string.';
```

A MATLAB string is of type 'char'. The AccelDSP Synthesis Tool provides the following support for **char**:

- char data can be used in any way in the script file.
- Passing data of type char into or out of a design function port is not allowed.
- Inside the design function and its sub-functions, constant strings are supported as described below.

Supported MATLAB Coding Styles for String Constants

- You can pass constant strings into and out of sub-functions.
- A constant string can be assigned to a symbol (e.g. “a = 'my string';”) which then becomes a char type.
- A symbol with char type can only be assigned a value once.
- The right-hand side of a char symbol assignment must be a constant string.
- The left-hand side of a char symbol assignment may be a structure field.
- A char type symbol must be used as a whole (e.g. not indexed into).
- The equals and not equals (== and ~=) operators are support for char types if both operands are constant strings.
- Row-vector shaped char types are supported.
- Scalar shaped char types are supported.

Unsupported MATLAB Coding Styles for Constant Strings

- All operators other that equals and not equals that have an operand of char type.
- The equals and not equals operators that have one char type operand and one non-char type operand.
- Square brackets cannot be used around char types (this performs a string concatenation).
- You cannot index into a char type symbol (e.g. “mystringvar(1)”).
- Multi-dimensionally shaped char types are not supported.

Supported Forms of string-related Functions

- **length** allows a char type as the first input argument.
- **size** allows a char type as the first input argument.
- **struct** allows a char type for field name and value input arguments.

Unsupported Forms of string-related Functions

- **accel_probe** will error if passed a char type.
- **quantize** will error if passed a char type.
- **str* functions** All string manipulation functions are not be supported.

'gf' Data Type

The AccelDSP Synthesis Tool provides native support for the MATLAB Galois Field class '**gf**' which is part of the MATLAB Communications Toolbox. The gf class is a special structural class that is a matrix (representing the Galois Field) and a .x structure field that holds the current gf value as **uint16**. Galois Fields have applications in Forward Error Correction (FEC) - Encoders / Decoders and Encryption

Galois Field Basics

A Galois field is a finite field with p^n elements where p is a prime integer. The set of nonzero elements in the field is a cyclic group under multiplication. A generator of this cyclic group is called a primitive element of the field. The Galois field can be generated as the set of polynomials with coefficients in Z_p modulo an irreducible polynomial of degree n.

1. A Galois field has 2^m numbers in it.
2. Any number operated on by any other number is a Galois field results in a number in that field.

Creating a Galois Field in MATLAB

Galois field functions in MATLAB are part of the Communications Toolbox. You will need this toolbox to take full advantage of the AccelDSP Synthesis Tool’s support of these functions.

Syntax:

```
<variable> = gf(<input>,<order>, [primitive-polynomial])
```

Primitive Polynomials

The optional primitive polynomial (the third argument) is always represented with an integer.

```
C = gf(indata,4,25); % Use D^4+D^3+1
```

In a Galois Field of order 'm' the primitive polynomial will be represented by an integer having m +1 bits.

The integer is converted to a polynomial as follows:

```
25 = 11001b = 1*D^4 + 1*D^3 + 0*D^2 + 0*D^1 + 1*D^0
```

In MATLAB, primpoly(4) will list the default primitive polynomials for a Galois Field with an order of 4. primpoly(4,'all') will list all primitive polynomials for a Galois Field with m=4.

Galois Field Type Propagation

Data must have the same order and primitive polynomial to be operated on in Galois math. MATLAB assumes this in many cases to avoid the need to repeatedly use the gf() function.

```
A = gf(indata,4);
B = A + 1;  % B = A + gf(1,4);
C = double(B.x);
```

In the example above, the constant 1 is typecast to the same Galois Field as A. B is also of the same Galois Field type.

Using the gf Class in AccelDSP Synthesis

Figure 2-1 illustrates how the gf class can be used in the design function.

```
function [outdata] = SimpleGalois (indata1, indata2)

% Store indata1 in a Galois Field of order 8 using the primitve
% polynomial D^8+D^7+D^6+D^5+D^4+D^2+1 which is represented by
% the integer 501 from the coefficents of the primitve
% polynomial 111110101b = 501.  See the MATLAB function primpoly() for
% more information.
A = gf(indata1,8,501);

% Store indata2 in the same Galois Field.  Data must be in the same fiel
% to operate on each other.
B = gf(indata2,8,501);

% Since the constant 3 is not defined to be in any Galois field, it is
% assumed to be in the same field so the operation can be performed.
C = A * 3; % This is the same as C = A * gf(3,8,501);

% AccelDSP fully supports +, - , *, .* , /
D = (B + 2) / 5;
E = C .* D

% Extract the .x data field from the Galois array and
% convert it from UINT16 to type double.  This conversion
% is required.
outdata = double(E.x);
```

Figure 2-1: **Mapping MATLAB Constructs to Hardware Elements**

Rules for using the 'gf' class in AccelDSP Synthesis are as follows:

- Data entering and leaving the design function cannot be of class gf
- After double precision data enters the design function, it must be converted to class 'gf' using the gf() function in a manner similar to the following: A = gf(indata1,8,501). Class 'gf ' data leaving the design function must first be converted to double precision data in a manner similar to the following: outdata = double(E.x);
- Data used in the gf function or used in gf operations cannot have a fractional part.
- If specified, the optional primitive polynomial (the third argument) must be represented by an integer.
- The supported gf operators are: add, subtract, divide, multiply, constant power (i.e. x^3), equals, and not equals. (x^y is only supported when y is a constant.)

Data Types Not Supported

The current version of the AccelDSP Synthesis Tool does not support hardware synthesis for operands of the following data types:

- Sparse matrices
- Cell arrays
- Empty arrays

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Chapter 3

MATLAB Construct Reference

Introduction

Setting Implementation Parameters

Some MATLAB functions within the AccelDSP Synthesis Tool have associated implementation parameters that you can change to customize the resulting hardware. Figure 3-1 illustrates how you can select a function in the Project Explorer window and change the associated parameters in the Proterties Viewer window.

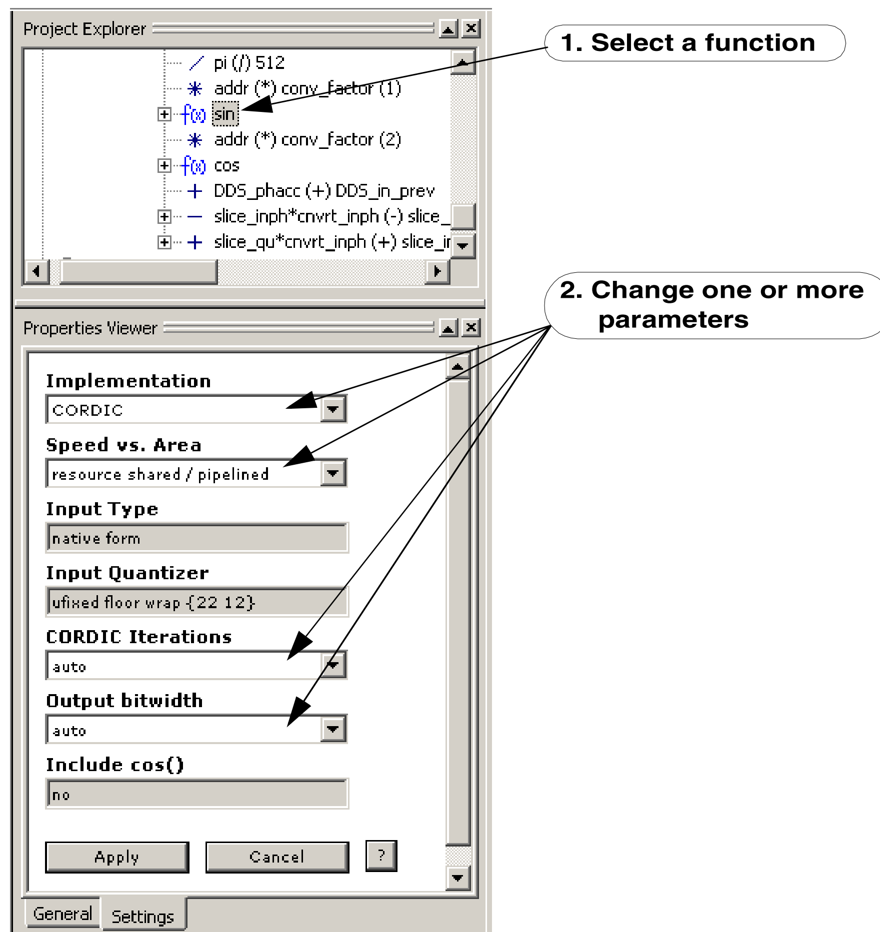


Figure 3-1: **Project Explorer window and Properties View window**

In Figure 3-1, the **sin** function is selected in the Project Explorer window and the associated parameters are displayed in the Properties Viewer window. Initially, heuristics are used to select the optimal hardware architecture for the function. As the designer, you can make manual adjustments to the parameter if necessary.

Parameters that you can change are displayed in white; parameters that you can't change are displayed in gray. Usually, these non-changeable parameters are inferred directly from the surrounding design environment. In this example, you can change the hardware implementation to either Bipartite Tables or Linerar Interpolated LUT, or leave it as CORDIC. You can also choose a Speed vs. Area tradeoff, adjust the number of CORDIC iterations, and adjust the Output bitwidth.

Bipartite Tables

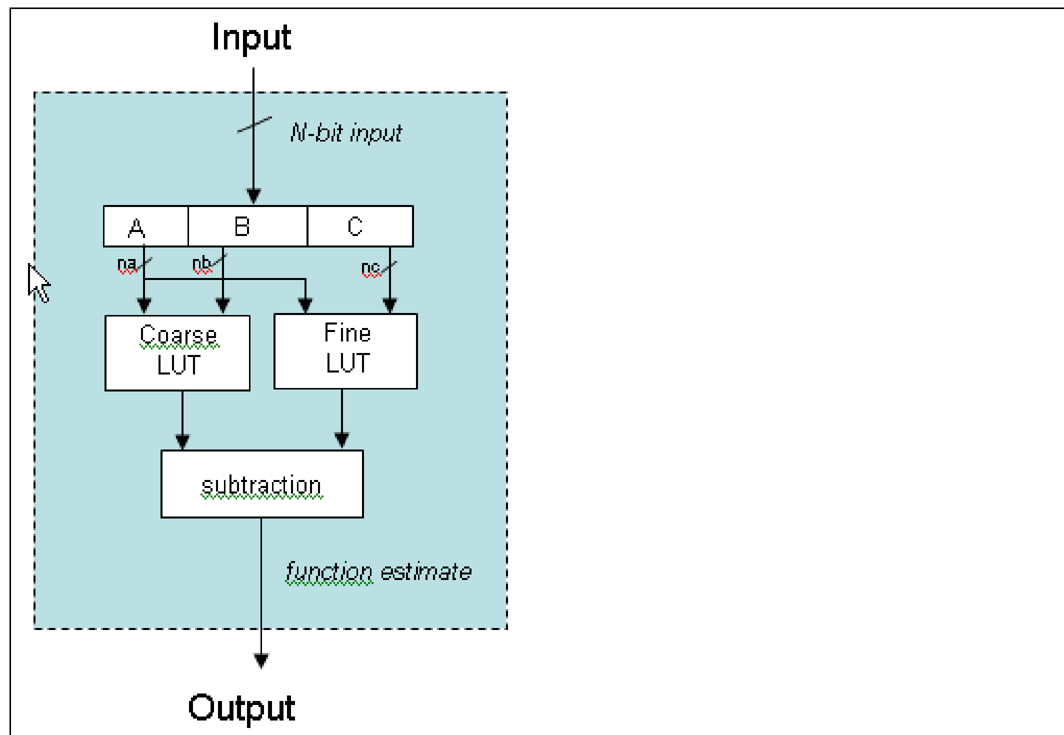


Figure 3-2: **Bipartite Table**

- N-bit Input word is divided input two smaller words [AB] and [AC].
- MSBs [AB] are used to look-up a coarse estimate of the function value.
- MSBs and LSBs [AC] are used to look-up a "correction" to the coarse estimate.
- Corrections factors are constant for each "region" as defined by the MSB [A].
- Regions should be selected such that the function within a region is as linear as possible.

Over-riding Default Values in AccelWare

You may over-ride the default setting while creating a bipartite table implementation by setting the LUT parameters as follows:

1. To fully specify the bipartite parameters set LUT parameters to {A B C}
   a. A+B+C must be equal to the number of input bits.
2. To partially specify the table the user may simply set the A value. This will determine the number of regions that will be used in the table (see detailed description below).
   a. C will be set via C=ceil((IBITS-A)/2)
   b. B will be set via B = IBITS-(A+C)

The parameters B and C will be alternately reduced (starting with B) when AccelWare recognizes that function symmetry may be used to the table size.

Bipartite Table Performance Summary

- Good performance for larger input word length with NO multipliers.
- Table Compression ratio (uncompressed table size/bipartite table size)
  - Increases with input bit width.
  - Increases as the number of regions decreases (A)

Linerly Interpolated Lookup Tables

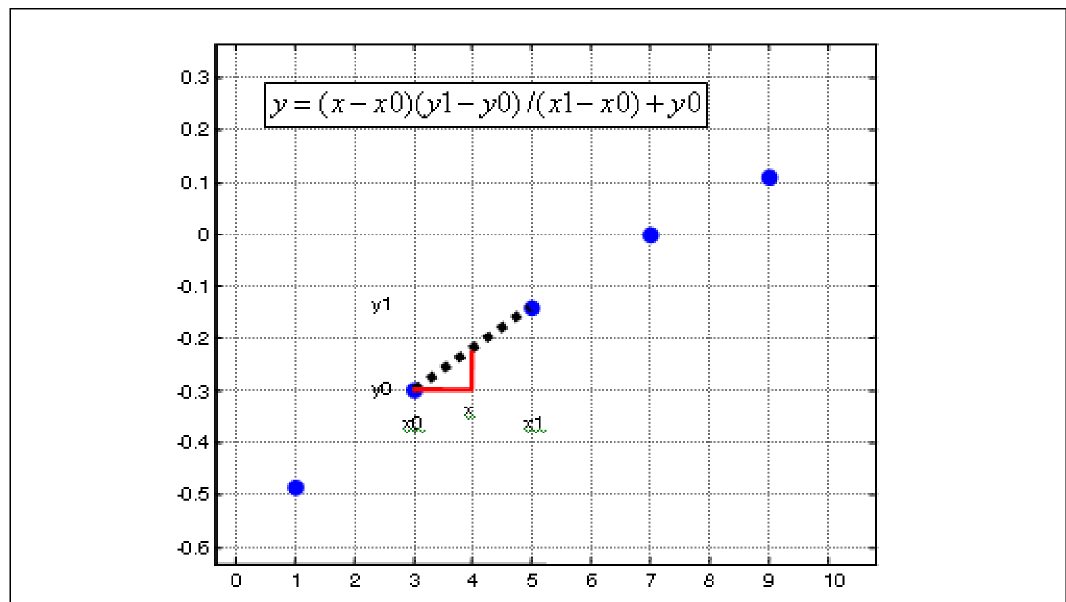


Figure 3-3: **Linerly Interpolated Lookup Tables**

You may over-ride the default setting while creating a LILT implementation by setting the LUT parameters to the desired compression factor:

1. To create an uncompressed table, set to '1'
2. Compression factor must be power of 2
3. Compression factor must be less than $2^{IBITS-1}$

InputType

One of the possible implementation parameters is called the 'input type' which can be specified as either 'native form' or 'scaled form'. The following text explains the meaning of these terms.

native form

Native form refers to the input type specified in MATLAB. The native form for sine and cosine is radians. Scaled form is a unit of measure defined by the number of bits in the input word. If the input word is 10 bits, the range of the input is 0 to 1024 (210) integer values. Figure 3-4 shows the relationship between the native form and scaled form.

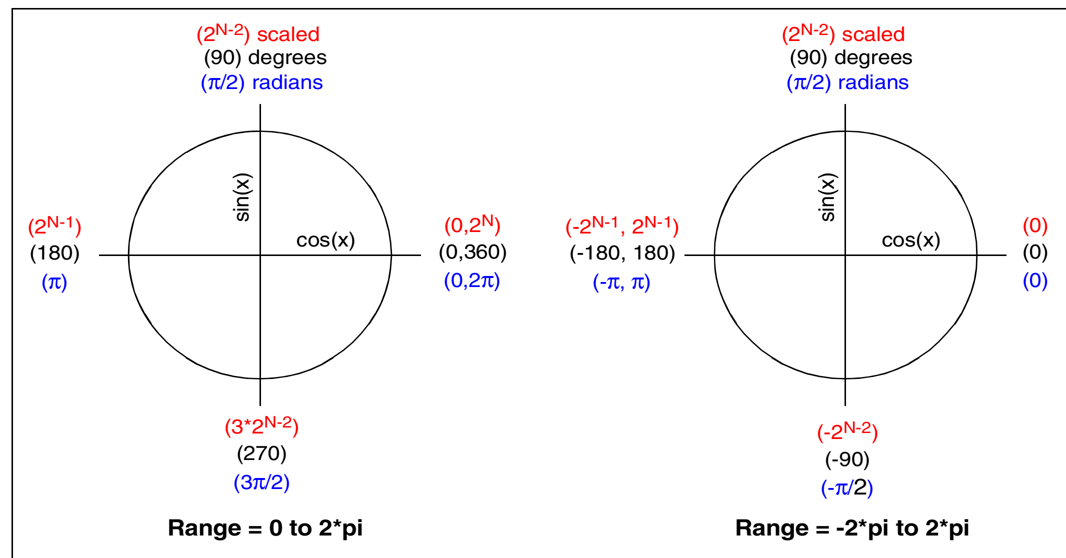


Figure 3-4: **InputType - Scaled Form vs. Native Form**

For sine and cosine, the native input form is assumed to be radians. If the Input Quantizer Sign Mode is 'ufixed', input range is inferred to be 0 to 2p. If the Input Quantizer Sign Mode is 'fixed', input range is inferred to be 0 to 2p.

scaled form

The input data must be integer values only with no fractional part. The unit of measure is defined by the number of bits in the input word. If the Input Quantizer Word Length is 10 and the Sign Mode is 'ufixed', then the range 0 to 2*p is inferred and it is assumed to be integers between 0 and 210. The only valid value for Fractional Length is 0. The input range is 0 to 1024. As shown in Figure 3-4, the unit circle is divided into 1024 units. If the Input Quantizer Word Length is 10 and the Sign Mode is 'fixed', then the range -p to p is inferred and the input range is -512 to +511. The scale naturally wraps, so the two's compliment number +512 is the same as
-512.

A scaled input is ideal for algorithms that are constructed in the "scaled" domain from the beginning. There is no need to convert the input data to radians. Also, since a scaled input is integer values only and naturally wraps, there is no need for extra rounding hardware.

Comparing Native Form to Scaled Form Plots in Range 0 to 2*pi

The sine and cosine plots in Figure 3-5 illustrate the difference between the native form and the scaled form input type when range 0 to 2π is inferred. In the native form plot on the right, the X axis scale is 0 to 2π radians (6.28). Notice that the quantization is ufixed [10 7], meaning three integer bits and 7 fractional bits.

In the scaled form plot on the right, the quantization is ufixed [10 0] so the X axis is a scale of integers from 0 to 2^{10} (1024). The scale naturally wraps so the 1024 point on the scale is the same as 0.

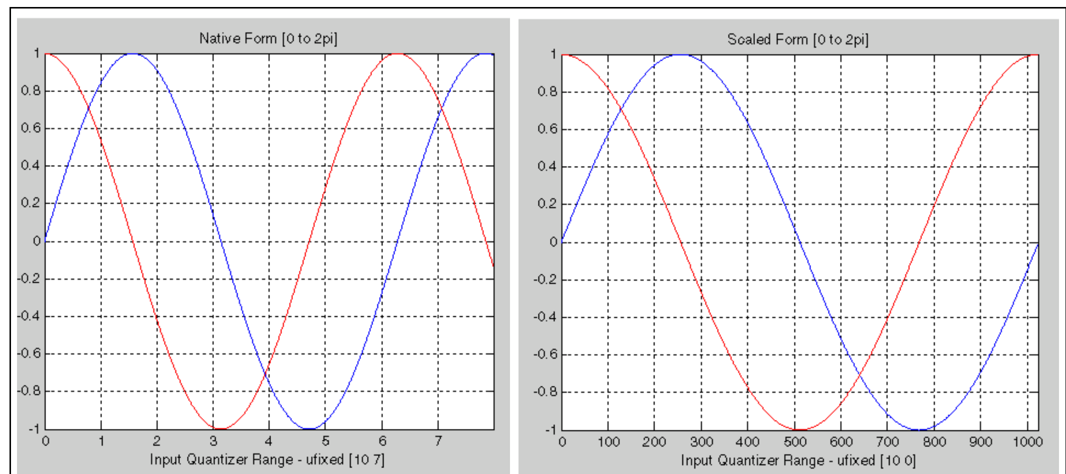


Figure 3-5: **Comparing Native Form to Scaled Form Plots in Range 0 to 2*pi**

Comparing Native Form to Scaled Form Plots in Range -2*pi to 2*pi

The sine and cosine plots in the Figure 3-6 illustrate the difference between the native form and the scaled form input type when range -2π to 2π is inferred. In the native form plot on the right, the X axis scale is -2π (-3.14) to 2π (3.14) radians. Notice that the quantization is fixed [10 7], meaning a sign bit, two integer bits and 7 fractional bits. Notice also that the native form does not naturally wrap.

In the scaled form plot on the right, the quantization is fixed [10 0], meaning a sign bit and 9 integer bits. The X axis is a scale of integers from -2^9 (-512) to 2^9 (+512). The scale naturally wraps so the +512 point on the scale is the same as -512 point.

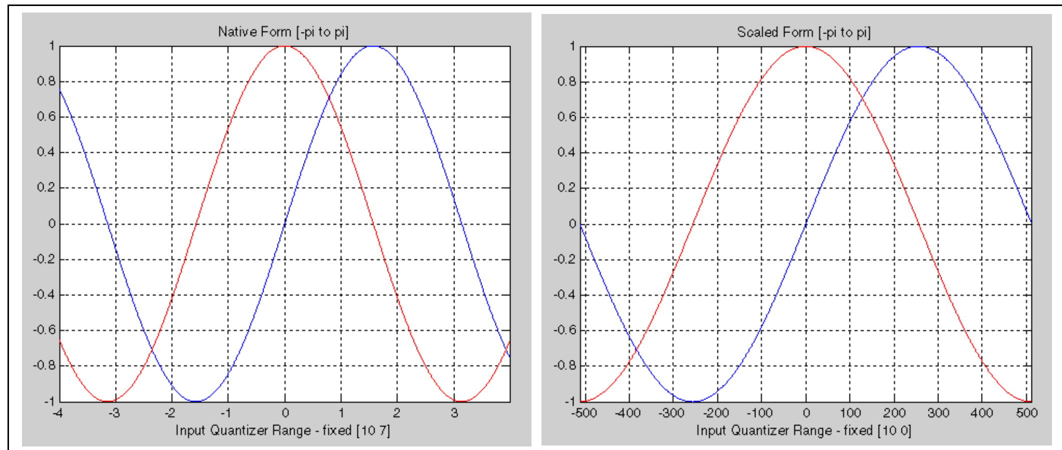


Figure 3-6: **Comparing Native Form to Scaled Form Plots in Range -2*pi to 2*pi**

InputType Conversion Factors

radians = scaled * p/$2^{(N-1)}$

radians = degrees * π/180

scaled = radians * $2^{(N-1)}$/π

scaled = degrees * $2^{(N-1)}$/180

degrees = scaled * 180 /$2^{(N-1)}$

degrees = radians * 180/π

AccelDSP Bitwise Functions

The AccelDSP Synthesis Tool provides specialized bitwise functions that you can use for advanced algorithmic design. These functions allow you to manipulate data at the bit level and are typically used to develop hardware addressing schemes. In general, each bitwise function provides extended capability beyond its equivalent MATLAB function. For example, the accel_bitand function allows you to input negative as well as positive integers and allows you to specify the quantization of each input and output port.

Before you can use the specialized AccelDSP functions, you must first add the AccelDSP .../lib/matlab folder (and subfolders) to the MATLAB search path. The folders should be added at a priority level that is higher than any of the MATLAB Tool Boxes. The procedure for adding the folder is described in the AccelDSP User Guide under the topic "Adding AccelDSP MATLAB Functions to the MATLAB Search Path".

The following table provides a summary and a link to each base function:

Table 3-1: **Alphabetical Function Summary**

Base Function	Description
accel_bitand	Returns the unsigned bit-wise AND of two integers.
accel_bitcmp	Returns the unsigned bit-wise complement of an integer.
accel_bitmerge	Concatenates two components, MSB (most-significant bits) and LSB (lease-significant bits) into one output word.
accel_bitnand	Returns the unsigned bit-wise NAND of two integers.
accel_bitnor	Returns the unsigned bit-wise NOR of two integers.
accel_bitor	Returns the unsigned bit-wise OR of two integers.
accel_bitpack	Returns a single value-representation of the bit-vector argument x quantized to quantizer q.
accel_bitrev2	Returns the unsigned digit reversal of the argument IN.
accel_bitrev	Returns the unsigned bit-wise reversal of the argument IN.
accel_bitshl	Returns the unsigned bit-wise shift-left of the argument IN shifted left by N bits.
accel_bitshr	Returns the unsigned bit-wise shift-right of the argument IN shifted right by N bits.
accel_bitsplit	Splits the input value into MSB (most-significant bits) and LSB (least-significant bits) components according to the bitwidths specified in the specified quantizers.
accel_bitunpack	Returns a row-vector bit-representation of the scalar argument x quantized to quantizer qout.
accel_bitunpackselect	Returns the i'th element from the output of accel_bitunpack(x, q).
accel_bitxor	Returns the unsigned bit-wise XOR of two integers.

+ (addition)

Addition is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

Generated Hardware

An RTL adder is generated.

Example 1

```
c = a + b;
```

- (subtraction)

Subtraction is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

Generated Hardware

An RTL subtractor is generated

Example 1

```
c = a - b;
```

* (multiplication)

Multiplication is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

Generated Hardware

An RTL shift register is generated if multiplying by a constant that is equivalent to 2^n (where n is a real integer). Otherwise, an RTL multiplier is generated.

Example 1

```
c = a * 4;  % This will generate a RTL shift register
```

Example 2

```
c = a * b;  % This will generate a RTL multiplier
```

/ (right division)

Right MatrixDivision.

Example

```
C = a / 4;  % This will generate an RTL shift register
```

Also supported through AccelWare.

\ (left division)

Left MatrixDivision.

^ (matrix power)

X ^ Y is supported when Y is a scalar integer. Same as the mpower() function.

Example

Z = X ^ Y;

Generated Hardware

X ^ 3 turns into X * X * X in hardware.

.^ (array power)

Power is computed element-by-element. X and Y must have the same dimensions unless one is a scalar. A scalar is expanded to an array of the same size as the other input. Same as the power() function.

Example

Z = X ^ Y;

./ (array right divide)

Array right divide.

.\ (array left divide)

Array left divide.

< (Less than)

Less than.

<= (Less than or equal)

Less than or equal.

> (Greater than)

Greater than.

>= (Greater than or equal)

Greater than or equal.

==, eq (equal)

Test for equality.

~=, ne (Not equal)

Not equal.

&& (Logical AND)

Logical AND.

|| (Logical OR)

Logical OR.

& (Logical AND for arrays)

Logical AND for arrays.

| (Logical OR for arrays)

Logical OR for arrays.

~ (Logical NOT)

Logical NOT.

false

False array.

true

True array.

% (comment)

Comment.

a_dsinccompensation

A/D Sinc Compensation filter. Supported with AccelWare.

abs/accel_abs

Description

Returns the absolue value of the input matrix.

Related MATLAB Functions

abs

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors and 2-D matrices.

Features of the accel_abs() Function

The accel_abs() function provides an abs() function with a complex input:

1. Accepts two values instead of a single complex value (x=a+jb).
2. Offers an optional angle() output with little additional hardware.
3. Offers a normalized output with range {-1 to 1} instead of {-π to π]}.

Syntax

AccelDSP abs() Function Call	Supported MATLAB Syntax
y = abs(x);	y = abs(x);
AccelDSP accel_abs() Function Calls	**Supported MATLAB Syntax**
y = accel_abs(a,b); [y,z] = accel_abs(a,b);	y = abs(x); z = angle(x);

Parameters

Input quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	{CORDIC}
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Implementation Parameters			
Name	**Description**	**Type**	**Range**
CORDIC Scaling	When a relative measure of the absolute value are sufficient, the CORDIC scaling may be removed to create a multiplier-free implementation.	String	{yes | no} Default = {yes}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB.	Integer	[4 to 100] Default = [auto]
Output bitwidth	Number of bits used to represent the abs() output y.	Positive Integer	Range = [4 to 32] Default = auto
Include angle() output	A angle() output can be created with little additional hardware. The angle can be returned in radians [-π to π] or normalized to [-1 to 1].	String	{no | Radians | Normalized} Default = {no}

Inputs / Outputs

abs() Input			
Name	**Description**	**Type**	**Range**
x	An input matrix representing real(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion.	Real	Range = $[-2^{IBITS-1}$ to $2^{IBITS-1}-1]/2^{IFBITS}$

accel_abs() Input(s)			
Name	**Description**	**Type**	**Range**
a	An input matrix representing real(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion.	Real	Range = $[-2^{IBITS-1}$ to $2^{IBITS-1}-1]/2^{IFBITS}$
b	An input matrix representing imag(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion.	Real	Range = $[-2^{IBITS-1}$ to $2^{IBITS-1}-1]/2^{IFBITS}$

abs() Output			
Name	**Description**	**Type**	**Range**
y	An output matrix with each element OBITS-bits wide.	Real	Function of the SigInQ parameters

Additional accel_abs() Output			
Name	**Description**	**Type**	**Range**
z	An optional output Angle OBITS-bits wide with (Angle OBITS-3)-bits representing the fractional portion.	Real	Range = [-π to π] or [-1 to 1] depending on the value of the IncludeAngle parameter.

accel_bitand

Returns the unsigned bit-wise AND of two integers.

Syntax

```
out = accel_bitand(a , b , qa, qb, qout )
out = accel_bitand(a , b , q, qout ) where qa=qb=q
out = accel_bitand(a , b , q ) where qa=qb=qout=q
```

Related MATLAB Function

bitand

Description

Returns the bit-wise AND of two integer arguments. To ensure that the arguments are integers, you can use the ceil, fix, floor, and round functions.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitand(13,11,q)
y =
  9
```

The four-bit binary representations of the integers 13 and 11 are 1101 and 1011, respectively. Doing a bit-wise AND on these two integers yields 1001, or 9.

	2^3	2^2	2^1	2^0	
	1	1	0	1	(13)
	1	0	1	1	(11)
AND	↓	↓	↓	↓	
	1	0	0	1	(9)

Related Commands

accel_bitcmp
accel_bitnand
accel_bitnor
accel_bitor
accel_bitxor

accel_bitcmp

Returns the unsigned bit-wise complement of an integer.

Syntax

```
out = accel_bitcmp( in, qin, qout)
```

Related MATLAB Function

bitcmp

Description

Returns the unsigned bit-wise complement of the argument IN.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitcmp(13,q)
y =
    2
```

The four-bit binary representation of the integer 13 is1101. Doing a bit-wise CMP on this integer yields 0010, or 2.

	2^3	2^2	2^1	2^0	
	1	1	0	1	(13)
	1	0	1	1	(11)
AND	↓	↓	↓	↓	
	1	0	0	1	(9)

Related Commands

accel_bitand
accel_bitnand
accel_bitnor
accel_bitor
accel_bitxor

accel_bitmerge

Concatenates two components, MSB (most-significant bits) and LSB (lease-significant bits) into one output word.

Syntax

```
out = accel_bitmerge(msb, lsb, qmsb, qlsb, qout)
```

Description

This merge function concatenates two components, MSB (most-significant bits) and LSB (lease-significant bits) into one output word.

Example

```
qmsb  = quantizer('ufixed','floor','wrap',[2,0]);
qlsb  = quantizer('ufixed','floor','wrap',[2,0]);
qout  = quantizer('ufixed','floor','wrap',[4,0]);
out = accel_bitmerge(3,1,qmsb,qlsb,qout)
out =
    13
```

The quantizer qmsb defines the most significant bits as the upper two bits. The quantizer qlsb defines the least significant bits as the lower two bits. The MSB and LSB total must match the word width of the output quantizer qout (4 bits). In this case, the binary bits of the MSB (integer 3) concatenated to the binary bits of the LSB (integer 1) are 1101, which is equivalent to the integer 13.

2^3	2^2	2^1	2^0	
1	1	0	1	(13)
MSB		LSB		

Related Commands

accel_bitsplit

accel_bitnand

Returns the unsigned bit-wise NAND of two integers.

Syntax

```
out = accel_bitnand(a , b , qa, qb, qout )
out = accel_bitnand(a , b , q, qout ) where qa=qb=q
out = accel_bitnand(a , b , q ) where qa=qb=qout=q
```

Description

Returns the unsigned bit-wise NAND of two integers.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitnand(13,11,q)
y =
    6
```

The four-bit binary representations of the integers 13 and 11 are 1101 and 1011, respectively. Doing a bit-wise NAND on these two integers yields 0110, or 6.

	2^3	2^2	2^1	2^0	
	1	1	0	1	(13)
	1	0	1	1	(11)
NAND	↓	↓	↓	↓	
	0	1	1	0	(6)

Related Commands

accel_bitand
accel_bitcmp
accel_bitnor
accel_bitor
accel_bitxor

accel_bitnor

Returns the unsigned bit-wise NOR of two integers.

Syntax

```
out = accel_bitnor(a , b , qa, qb, qout )
out = accel_bitnor(a , b , q, qout ) where qa=qb=q
out = accel_bitnor(a , b , q ) where qa=qb=qout=q
```

Description

Returns the unsigned bit-wise NOR of two integers.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitnor(13,11,q)
y =
    0
```

The four-bit binary representations of the integers 13 and 11 are 1101 and 1011, respectively. Doing a bit-wise NOR on these two integers yields 0000, or 0.

	2^3	2^2	2^1	2^0	
	1	1	0	1	(13)
	1	0	1	1	(11)
NOR	↓	↓	↓	↓	
	0	0	0	0	(0)

Related Commands

accel_bitand
accel_bitcmp
accel_bitnand
accel_bitor
accel_bitxor

accel_bitor

Returns the unsigned bit-wise OR of two integers.

Syntax

```
out = accel_bitor(a , b , qa, qb, qout )
out = accel_bitor(a , b , q, qout ) where qa=qb=q
out = accel_bitor(a , b , q ) where qa=qb=qout=q
```

Related MATLAB Function

bitor

Description

Returns the unsigned bit-wise OR of two integers.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitor(13,11,q)
y =
    15
```

The four-bit binary representations of the integers 13 and 11 are 1101 and 1011, respectively. Doing a bit-wise OR on these two integers yields 1111, or 15.

	2^3	2^2	2^1	2^0	
	1	1	0	1	(13)
	1	0	1	1	(11)
OR	↓	↓	↓	↓	
	1	1	1	1	(15)

Related Commands

accel_bitand
accel_bitcmp
accel_bitnand
accel_bitnor
accel_bitxor

accel_bitpack

Returns a single value-representation of the bit-vector argument x quantized to quantizer q.

Syntax

```
out = accel_bitpack( x, q)
```

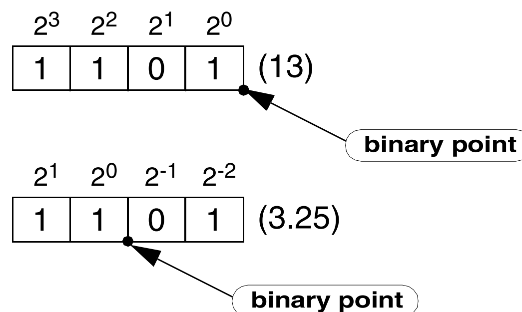
Description

Returns a single value-representation of the bit-vector argument x quantized to quantizer q.

Example

```
x   = [1 1 0 1];
qout   = quantizer('ufixed','floor','wrap',[4,0]);
out = accel_bitpack(x,qout)
out =
    13
qout   = quantizer('ufixed','floor','wrap',[4,2]);
out = accel_bitpack(x,qout)
out =
    3.25
```

The quantizer qout must specify a word width that matches the number of elements in the row vector. In the second example, the quantizer is changed so that the last 2 bits are defined as the fractional part. The equivalent integer is 3.25.



Related Commands

accel_bitunpack
accel_bitunpackselect

accel_bitrev2

Returns the unsigned digit reversal of the argument IN.

Syntax

```
out = accel_bitrev2( in, q)
```

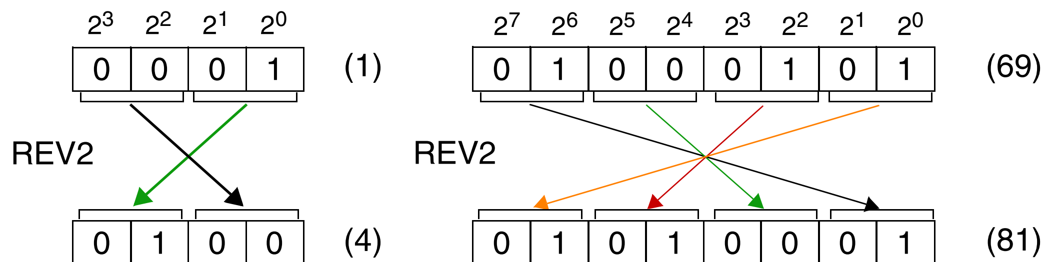
Description

Returns the unsigned digit reversal of the argument IN. Currently, the AccelDSP Synthesis Tool only supports 2-bit pairs.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
out = accel_bitrev2(1,q)
out =
    4
q  = quantizer('ufixed','floor','wrap',[8,0]);
out = accel_bitrev2(69,q)
out =
    81
```

In the examples below, the bit reversals are done in pairs of two.



Related Commands

accel_bitrev
accel_bitshl

accel_bitrev

Returns the unsigned bit-wise reversal of the argument IN.

Syntax

```
out = accel_bitrev( in, q)
```

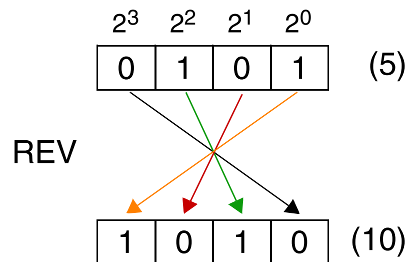
Description

Returns the unsigned bit-wise reversal of the argument IN.

Example

```
q   = quantizer('ufixed','floor','wrap',[4,0]);
out = accel_bitrev(5,q)
out =
    10
```

The illustration below shows how the bits are reversed by the rev function.



Related Commands

accel_bitrev2
accel_bitshl

accel_bitshl

Returns the unsigned bit-wise shift-left of the argument IN shifted left by N bits.

Syntax

```
C = accel_bitshl( in, n, qin, qout)
C = accel_bitshl( in, n, q ) where qin=qout=q
```

Related MATLAB Function

bitshift

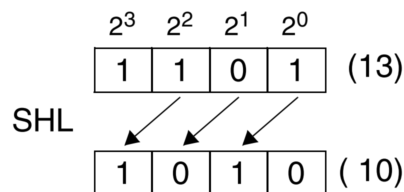
Description

Returns the unsigned bit shift left of the argument IN shifted left by N bits.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitshl(13,1,q)
y =
   10
```

The four-bit binary representation of the integer 13 is1101. Doing a 1- bit SHL on this integer yields 1010, or 10.



Related Commands

accel_bitshr

accel_bitshr

Returns the unsigned bit-wise shift-right of the argument IN shifted right by N bits.

Syntax

```
y = accel_bitshr( in, n, qin, qout)
y = accel_bitshr( in, n, q ) where qin=qout=q
```

Related MATLAB Function

bitshift

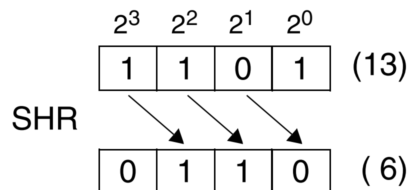
Description

Returns the unsigned bit shift right of the argument IN shifted left by N bits.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitshr(13,1,q)
y =
    6
```

The four-bit binary representation of the integer 13 is1101. Doing a 1- bit SHR on this integer yields 0110, or 6.



Related Commands

accel_bitshl

accel_bitsplit

Splits the input value into MSB (most-significant bits) and LSB (least-significant bits) components according to the bitwidths specified in the specified quantizers.

Syntax

```
[msb,lsb] = accel_bitsplit(in, qin, qmsb, qlsb)
```

Description

The function splits the input value into two components, MSB (most-significant bits) and LSB (least-significant bits) according to the bitwidths specified in the output quantizers. The word width of the MSB plus the word width of the LSB must match the word width of the unsigned input integer.

Example

```
qin    = quantizer('ufixed','floor','wrap',[4,0]);
qmsb  = quantizer('ufixed','floor','wrap',[2,0]);
qlsb  = quantizer('ufixed','floor','wrap',[2,0]);
[msb,lsb] = accel_bitsplit(13,qin,qmsb,qlsb)
msb =
    3
lsb =
    1
```

The four-bit binary representation of unsigned integer 13 is 1101. The quantizer qmsb defines the most significant bits as the upper two bits. The quantizer qlsb defines the least significant bits as the lower two bits. The MSB and LSB total must match the word width of the integer (4 bits). In this case, the most significant bits are equivalent to the integer 3 and the least significant bits are equivalent to the integer 1.

2^3	2^2	2^1	2^0	
1	1	0	1	(13)
MSB		LSB		

Related Commands

accel_bitmerge

accel_bitunpack

Returns a row-vector bit-representation of the scalar argument x quantized to quantizer qout.

Syntax

```
out = accel_bitunpack( x, qout )
```

Description

Returns a row-vector bit-representation of the scalar argument x quantized to quantizer qout.

Example

```
qout  = quantizer('ufixed','floor','wrap',[4,0]);
out = accel_bitunpack(13,qout)
out =
    1 1 0 1
qout  = quantizer('ufixed','floor','wrap',[8,0]);
out = accel_bitunpack(13,qout)
out =
    0 0 0 0 1 1 0 1
```

The quantizer qout specifies the word width of the row-vector. Notice that in each case, the binary representation is the equivalent to the integer 13, regardless of the word width.

2^3	2^2	2^1	2^0	
1	1	0	1	(13 quantized as a 4-bit binary word)

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	
0	0	0	0	1	1	0	1	(13 quantized as an 8-bit binary word)

Related Commands

accel_bitpack
accel_bitunpackselect

accel_bitunpackselect

Returns the i'th element from the output of accel_bitunpack(x, q).

Syntax

```
out = accel_bitunpackselect( i, x, qout )
```

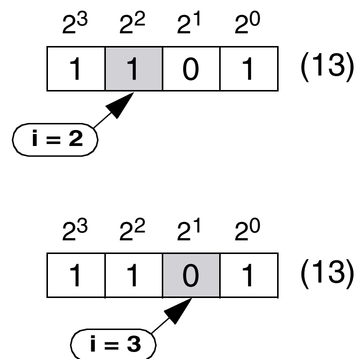
Description

Returns the i'th element (from the MSB) from the output of accel_bitunpack(x, qout).

Example

```
i = 2;
qout  = quantizer('ufixed','floor','wrap',[4,0]);
out = accel_bitunpackselect(i, 13,qout)
out =
    1
i = 3;
out = accel_bitunpackselect(i, 13,qout)
out =
    0
```

After the bit unpacking, the value returned is the bit position that is specified by the input.



Related Commands

accel_bitpack
accel_bitunpack

accel_bitxor

Returns the unsigned bit-wise XOR of two integers.

Syntax

```
out = accel_bitxor(a , b , qa, qb, qout )
out = accel_bitxor(a , b , q, qout ) where qa=qb=q
out = accel_bitxor(a , b , q ) where qa=qb=qout=q
```

Related MATLAB Function

bitxor

Description

Returns the unsigned bit-wise XOR of two integers.

Example

```
q  = quantizer('ufixed','floor','wrap',[4,0]);
y = accel_bitxor(13,11,q)
y =
   6
```

The for-bit binary representations of the integers 13 and 11 are 1101 and 1011, respectively. Doing a bit-wise XOR on these two integers yields 0110, or 6.

	2^3	2^2	2^1	2^0	
	1	1	0	1	(13)
	1	0	1	1	(11)
XOR	↓	↓	↓	↓	
	0	1	1	0	(6)

Related Commands

accel_bitand
accel_bitcmp
accel_bitnand
accel_bitnor
accel_bitor

accel_cmplxrot

Used to transform polar or cylindrical coordinates to Cartesian coordinates.

Syntax

```
[X,Y] = accel_cmplxrot(A,B,TH)
[X,Y] = accel_cmplxrot(A,B,TH,N)
```

Related MATLAB Function

There is no equivalent MATLAB function.

Description

Form 1: [X,Y] = accel_cmplxrot(A,B,TH)

Equivalent to Z = C.*exp(j.*TH) where Z = (X+j*Y), C = (A+j*B) and TH is a real value. A,B and TH can be scalar, vector, or two-dimensional matrix, BUT all must be the same shape.

Form 2: [X,Y] = accel_cmplxrot(A,B,TH,N)

Same as Form 1, but the angle is specified as a scaled value $-2^{(N-1)}$ <= TH <= $2^{(N-1)}-1$ or 0 <= TH <= $2^{(N)}-1$. Z = C.*exp(j.*TH*pi/$2^{(N-1)}$) . A,B and TH can be scalar, vector, or two-dimensional matrix, BUT all must be the same shape.

acos/accel_cos

Description

Returns the Inverse Cosine for each element of the input.

Related MATLAB Functions

acos

Differences with the MATLAB Function

The shape of the input is limited to a scalar, vector or 2-D matrix.

Extended Features of accel_acos()

The accel_acos() function provides the same functionality as the cos() function with the following extended features:

1. The accel_acos() function can create an optional asin() output with little additional hardware.
2. The accel_acos() function can specify input units of measure (InputType) in the following formats:
   - native form
   - scaled form

Syntax

AccelDSP acos() Function Call	Supported MATLAB Syntax
y = acos(x);	y = acos(x);
AccelDSP accel_acos() Function Call(s)	**Supported MATLAB Syntax**
y = accel_acos(x); [y,z] = accel_acos(x);	y = acos(x); z = asin(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 7

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
InputType	Specify the representation of the input word.	String	{native form | scaled form} Default = native form
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 100] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 1 to 14 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 1 to 16 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 32 Default = auto
Include asin()	A asin() output can be created with little additional hardware.	String	{yes | no} Default = {no}

Inputs / Outputs

acos() Input(s)			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix.	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

accel_acos() Input(s)			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix. (For InputType = native form).	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.
	May be a scalar, vector or 2-D matrix. (For InputType = scaled form).	Positive Integer	Range = [0 to 2^{IBITS}-1] or [-2^{IBITS}-1...$2^{IBITS-1}$-1] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

acos() Output(s)			
Name	**Description**	**Type**	**Range**
y	May be a scalar, vector, or 2-D matrix representing the acos of the corresponding input element. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

Additional accel_acos() Output			
Name	**Description**	**Type**	**Range**
z	An optional output scalar, vector, or 2-D matrix representing the asin of the corresponding input. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

all

Supported for scalars, vectors or two-dimensional matrices .

angle/accel_angle

Description

Computes the phase angle for a complex number.

Related MATLAB Functions

angle

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors and 2-D matrices.

Features of the accel_angle() Function

1. The accel_angle() function provides an angle() function with a complex input:
2. Accepts two values instead of a single complex value (x=a+jb).
3. Offers an optional abs() output with little additional hardware.
4. Offers a normalized output with range {-1 to 1} instead of {-π to π]}.

Syntax

AccelDSP angle() Function Call	Supported MATLAB Syntax
y = angle(x);	y = angle(x);
AccelDSP accel_angle() Function Calls	**Supported MATLAB Syntax**
y = accel_angle(a,b); [y,z] = accel_angle(a,b);	y = angle(x); z = abs(x);

Parameters

Input quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	{CORDIC}
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the larger of Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB.	Integer	[4 to 32] Default = [auto]
angle_output	The output can be returned in radians [-π to π] or normalized to [-1 to 1].	String	{Radians | Normalized} Default = {Radians}
Output bitwidth	Number of bits used to represent the angle() output y.	Positive Integer	Range = [4 to 32] Default = auto
Include abs() output	An abs() output can be created with little additional hardware.	String	{no | yes} Default = {no}

Inputs / Outputs

angle() Input(s)			
Name	**Description**	**Type**	**Range**
x	An input matrix representing real(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion.	Real	Range = $[-2^{IBITS-1}$ to $2^{IBITS-1}-1]/2^{IFBITS}$

accel_angle() Input(s)			
Name	**Description**	**Type**	**Range**
a	An input matrix representing real(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion.	Real	Range = $[-2^{IBITS-1}$ to $2^{IBITS-1}-1]/2^{IFBITS}$
b	An input matrix representing imag(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion.	Real	Range = $[-2^{IBITS-1}$ to $2^{IBITS-1}-1]/2^{IFBITS}$

angle() Output(s)			
Name	**Description**	**Type**	**Range**
y	An output matrix with each element OBITS-bits wide.	Real	Function of the Input Quantizer parameters.

Additional accel_angle() Output			
Name	**Description**	**Type**	**Range**
z	An optional Abs() output	Real	Function of the Input Quantizer parameters.

any

Supported for scalars, vectors or two-dimensional matrices .

asin/accel_asin

Description

Returns the inverse sine of the input matrix.

Related MATLAB Functions

asin

Differences with the MATLAB Function

1. The inputs must be pre-quantized to the accuracy specified by the input quantizer.
2. The shape of the input is limited to a scalar, vector or 2-D matrix.

Extended Features of accel_asin()

The accel_asin() function provides the same functionality as the asin() function plus the following extended features:

1. The accel_asin() function can create an optional acos() output with little additional hardware.
2. The accel_asin() function can specify input units of measure (InputType) in the following formats:
   - native form
   - scaled form

Syntax

AccelDSP asin() Function Call	Supported MATLAB Syntax
y = asin(x);	y = asin(x);
AccelDSP accel_asin() Function Call	**Supported MATLAB Syntax**
y = accel_asin(x); [y,z] = accel_asin(x);	y = sin(x) z = cos(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point model. Infers that the input range is -PI to PI. **ufixed**: unsigned fixed-point mode. Infers that the input range is 0 to 2*PI.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word.	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 7

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
InputType	Specify the representation of the input word.	String	{native form | scaled form} Default = native form
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 100] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 1 to 14 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 1 to 16 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 32 Default = auto
Include acos()	A acos() output can be created with little additional hardware.	String	{yes | no} Default = {no}

Inputs / Outputs

asin() Input(s)			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix.	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

accel_asin() Input(s)			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix. (For InputType = native form).	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.
	May be a scalar, vector or 2-D matrix. (For InputType = scaled form).	Positive Integer	Range = [0 to 2^{IBITS}-1] or [-2^{IBITS}-1...$2^{IBITS-1}$-1] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

asin() Output(s)			
Name	Description	Type	Range
y	May be a scalar, vector, or 2-D matrix representing the asin of the corresponding input element. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

Additional accel_asin() Output			
Name	Description	Type	Range
z	An optional output scalar, vector, or 2-D matrix representing the acos of the corresponding input. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

atan/accel_atan

Description

Returns the inverse tangent of the input matrix.

Related MATLAB Functions

atan

Differences with the MATLAB Function

1. The inputs must be pre-quantized to the accuracy specified by the input quantizer.
2. The shape of the input is limited to a scalar, vector or 2-D matrix.

Extended Features of accel_atan()

The accel_atan() function provides the same functionality as the atan() function plus the following extended features:

1. The accel_atan() function can specify input units of measure (InputType) in the following formats:
   - native form
   - scaled form

Syntax

AccelDSP atan() Function Call	Supported MATLAB Syntax
y = atan(x);	y = atan(x);
AccelDSP accel_atan() Function Call	**Supported MATLAB Syntax**
y = accel_atan(x);	y = atan(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point model. Infers that the input range is -PI to PI. **ufixed**: unsigned fixed-point mode. Infers that the input range is 0 to 2*PI.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word.	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 9

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
InputType	Specify the representation of the input word.	String	{native form | scaled form} Default = native form
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 100] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 1 to 14 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 1 to 16 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 32 Default = auto

Inputs / Outputs

atan() Input			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix.	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

accel_atan() Input			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix. (For InputType = native form).	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.
	May be a scalar, vector or 2-D matrix. (For InputType = scaled form).	Positive Integer	Range = [0 to 2^{IBITS}-1] or [-2^{IBITS}-1...$2^{IBITS-1}$-1] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

atan() Output			
Name	**Description**	**Type**	**Range**
y	May be a scalar, vector, or 2-D matrix representing the sine of the corresponding input element. OBITS = Output bitwidth.	Real	Range = [-$2^{OBITS-1}$ to $2^{OBITS-1}$ -1]/2^{OFBITS}

atan2/accel_atan2

Description

Four-quadrant inverse tangent

Related MATLAB Functions

atan2

Differences with the MATLAB Function

1. The inputs must be pre-quantized to the accuracy specified by the Input Quantizer parameters.
2. The shape of the input is limited to scalars, vectors and 2-D matrices.

Extended Features of accel_atan2()

The accel_atan2() function provides the same functionality as the atan2() function plus the following extended features:

1. Offers a normalized output with range {-1 to 1} instead of {-π to π]}.
2. Offers an optional abs() output with little additional hardware.

Syntax

AccelDSP atan2() Function Call	Supported MATLAB Syntax
p = atan2(y,x);	p = atan2(y,x);

AccelDSP accel_atan2() Function Call(s)	Supported MATLAB Syntax
p = accel_atan2(y,x); [p,z] = accel_atan2(y,x);	p = atan2(y,x); z = abs(x+jy);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	{CORDIC}
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Implementation Parameters			
Name	**Description**	**Type**	**Range**
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth and Angle OBITS to compute the number of iterations required to ensure the maximum error is ~1 LSB.	Integer	[4 to 32] Default = [auto]
angle_output	The output can be returned in radians [-π to π] or normalized to [-1 to 1].	String	{Radians | Normalized} Default = {Radians}
Output bitwidth	Number of bits used to represent the output.	Positive Integer	Range = [4 to 32] Default = auto
Include abs() output	A abs() output can be created with little additional hardware.	String	{no | yes} Default = {no}

Inputs / Outputs

atan2() Input(s)			
Name	**Description**	**Type**	**Range**
y	An input matrix representing real(y) each IBITS-bits wide with IFBITS-bits representing the fractional portion. IBITS = Input Word Length and IFBITS = Input Fractional Length.	Real	Specified by the Input Quantizer.
x	An input matrix representing real(x) each IBITS-bits wide with IFBITS-bits representing the fractional portion. IBITS = Input Word Length and IFBITS = Input Fractional Length.	Real	Specified by the Input Quantizer.

atan2() Output			
Name	**Description**	**Type**	**Range**
p	An output matrix with each element OBITS-bits wide.	Real	Function of the SigInQ parameters

Additional atan2() Output			
Name	**Description**	**Type**	**Range**
z	An optional abs() output.	Real	Function of the SigInQ parameters

bchdec

Communications Toolbox function supported through AccelWare.

bchenc

Communications Toolbox function supported through AccelWare.

bi2de

Supported for synthesis. First argument can be a variable representing a scalar, vector or two-dimensional matrix. The second argument specifies the numeric base of the first argument and must be an unsigned constant integer. The second argument is currently restricted to 2. The third parameter <flg> is supported where <flg> can be a string equal to 'right-msb' or 'left-msb'. The value 'right-msb' produces the default behavior.

bitand

Supported for scalars, vectors and two-dimensional matrices.

Extended capability is provided by calling the function accel_bitand.

bitcmp

Overloaded with accel_bitcmp.

Extended capability is provided by calling the function accel_bitcmp.

bitget

Supported for scalars, vectors and two-dimensional matrices.

bitor

Supported for scalars, vectors and two-dimensional matrices.

Extended capability is provided by calling the function accel_bitor.

bitset

Supported for scalars, vectors and two-dimensional matrices.

bitshift

Overloaded with accel_bitshl and accel_bitshr.

bitxor

Supported for scalars, vectors and two-dimensional matrices.

Extended capability is provided by calling the function accel_bitxor.

cart2pol

Supported for scalars, vectors and two-dimensional matrices containing both positive and negative numbers.

case

Supported as part of the switch statement.

Example

```
switch (x)
 case (0)
  y = y + 1;
 case (1)
  y = y + 2;
end
```

cat

Supported for synthesis.

ceil

Supported for synthesis.

Example 2

```
y = ceil(x);
```

char

Create a string constant inside the design function. Refer to “'char' Data Type,” for details.

chol

Supported through AccelWare.

cicdecim

Filter Design Toolbox function supported through AccelWare.

cicinter

Filter Design Toolbox function supported through AccelWare.

complex

Construct complex data from real and imaginary components. The complex function is fully supported for synthesis.

Complex Normalization

Description

Normalizes the magnitude of the complex number represented by the pair of inputs containing the real and imaginary values. Mathematically, the input/output relationship is as follows:

function

```
[u,v] = accel_cmplxnorm(x,y)
```

Where

```
abs(u + i*v) = 1.0;
angle(u + i*v) = angle(x + i*y);
```

abs() and angle() are the corresponding MATLAB functions that generate the complex modulus and angle() of the complex input pair.

Related MATLAB Functions

atan2

sin

Differences in Operation to MATLAB Functions

The cmplxnorm() function does not have a single equivalent function in MATLAB. The functionality of cmplxnorm(), however, is equivalent to the combination of the MATLAB atan2() and sin() as follows.

```
phi = atan2(x,y)
[u,v] = [sin(phi), cos(phi)]
```

Syntax

AccelDSP cmplxnorm() Function Call	Supported MATLAB Syntax
[u,v] = accel_cmplxnorm(x,y)	phi - atan2(x,y) [u,v] = [sin(phi) cos(phi)]

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	{CORDIC}
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Implementation Parameters			
Name	**Description**	**Type**	**Range**
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB.	Integer	[4 to 32] Default = [auto]
Output bitwidth	Number of bits used to represent the output.	Positive Integer	Range = [4 to 32] Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
x	Input representing the real(x) part of the input complex number to normalize.	Real	Function of the Input Quantizer parameters
y	Input representing the imag(x) part of the input complex number to normalize.	Real	Function of the Input Quantizer parameters

Output(s)			
Name	**Description**	**Type**	**Range**
u	Output representing the real(x) part of the normalized complex number.	Real	Function of the Output bitwidth parameter.
v	Output representing the imag(x) part of the normalized complex number.	Real	Function of the Output bitwidth parameter.

conj

Complex conjugate function is fully supported for synthesis.

convenc

Communications Toolbox function supported through AccelWare.

convergent

Convergent is supported for synthesis.

convdenintlv

Convolutional Deinterleaver. Supported through AccelWare.

convinctlv

Convolutional Interleaver. Supported through AccelWare.

colon

Supported for synthesis except in control constructs.

cos/accel_cos

Description

Returns the cosine of the input matrix.

Related MATLAB Functions

cos

Differences with the MATLAB Function

1. The inputs must be pre-quantized to the accuracy specified by the input quantizer.
2. The shape of the input is limited to a scalar, vector or 2-D matrix.

Extended Features of accel_cos()

The accel_cos() function provides the same functionality as the cos() function plus the following extended features:

1. The accel_cos() function can create an optional sin() output with little additional hardware.
2. The accel_cos() function can specify input units of measure (InputType) in the following formats:
   - native form
   - scaled form

Syntax

AccelDSP cos() Function Call	Supported MATLAB Syntax
y = cos(x);	y = cos(x);
AccelDSP accel_cos() Function Call(s)	**Supported MATLAB Syntax**
y = accel_cos(x); [y,z] = accel_cos(x);	y = cos(x); z = sin(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 7

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
InputType	Specify the representation of the input word.	String	{native form | scaled form} Default = native form
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 100] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 1 to 6 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 1 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 32 Default = auto
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC

Inputs / Outputs

cos() Input			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix.	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

accel_cos() Input			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix. (For InputType = native form).	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.
	May be a scalar, vector or 2-D matrix. (For InputType = scaled form).	Positive Integer	Range = [0 to 2^{IBITS}-1] or [-2^{IBITS}-1...$2^{IBITS-1}$-1] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

cos() Output			
Name	**Description**	**Type**	**Range**
y	May be a scalar, vector, or 2-D matrix representing the cosine of the corresponding input element. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1}-1]/2^{OFBITS}$

Additional accel_cos() Output			
Name	**Description**	**Type**	**Range**
z	An optional output scalar, vector, or 2-D matrix representing the sine of the corresponding input. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1}-1]/2^{OFBITS}$

cumprod

Cumprod is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

cumsum

Cumsum is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

de2bi

The syntax b = de2bi(d, n) is supported for synthesis, where d can be a variable representing a scalar, vector or two-dimensional matrix. n must be a positive integer (constant) which specifies the ouput word width. The syntax b = de2bi(d) is not supported.

dfilt

Filter Design Toolbox function supported through AccelWare.

diff

Supported for synthesis.

dot

else

Else is supported as part of an IF structure.

Example

```
if ( a > b)
  c = a;
else
  c = 0;
end
```

elseif

Elseif is supported as part of an IF structure.

Example

```
if ( a > b)
  c = a;
elseif (a == b)
  c = d;
else
  c = 0;
end
```

end

End is supported as part of IF, FOR, and WHILE statements.

eps

Supported for synthesis.

eq

Supported for synthesis.

A==B

tmp = eq(A,B)

exp/accel_exp

Description

Returns e (the base of natural logarithms) raised to a power. The exp function operates element-by-element on arrays. For example, Y = exp(X) returns the exponential for each element of X

Related MATLAB Functions

exp

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors, or 2-D matrices. The AccelWare exp() function does not support complex numbers.

Limitations

Fixed point severely limits the dynamic range. Answers in most cases will not match MATLAB. When large exponent values are detected, AccelDSP displays a WARNING message about the accuracy of the results.

To allow more accurate results, a floating point engine that returns a mantissa and an exponent instead of a single number is used for computing exp() under all conditions: [f,e]=accel_exp(X) where z=f*2^e. Even for type="fixed point" in the exp() model, the accel_exp() model is called and floating point math is used. The fixed point type maintains the MATLAB format of a single number output.

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
Y = exp(X);	Y = exp(X);

AccelDSP accel_exp() Function Call	Notes
[f,e] = accel_exp(X); Y = f*2^e	

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 9

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	CORDIC Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Implementation Parameters			
Name	**Description**	**Type**	**Range**
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 47] Default = [auto]
Type	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range [fixed point | floating point | auto] Default = floating point
Output bitwidth	The number of bits in the output word(s).		Range 4 to 31 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
X	May be a scalar, vector or 2-D matrix. Each element is IBITS-bits wide.	Positive Integer	Specified by the Input Quantizer parameters

exp Output(s)			
Name	**Description**	**Type**	**Range**
Y	A scalar, vector or 2-D matrix with each element representing the exp() of the corresponding element in the input. Each element is OBITS-bits wide.	Real	Range = [$-2^{OBITS-1}$ to $-2^{OBITS-1}-1$] $/2^{OFBITS}$. OFBITS is automatically computed as a function of the Input Quantizer.

accel_exp Output(s)			
Name	**Description**	**Type**	**Range**
f	Represents the mantissa of the floating-point output where Z = f*2^e	Real	
e	Represents the exponent of the floating-point output where Z = f*2^e	Real	

Example

Z = exp(X,Y);

Alternative Function accel_exp()

Fixed-point math severely limits the acceptable dynamic range of the exp() input. As an alternative function, you can use accel_exp() which computes the power using floating point math.

Example

[f,e] = accel_exp(X,Y);

Z = f*2^e

The results should be much closer to the MATLAB results.

eye

Eye is supported for generation of scalars, 1-D and 2-D matrices.

Example 1

A = eye;

Example 2

A = eye(1);

Example 3

A = eye(2);

Example 4

A = eye(2,3);

Limitations:

eye(0) is unsupported. Eye is not supported for 3-D and higher matrices.

factorial

Factorial of constants is supported when x in factorial(x) resolves to a positive constant integer. Factorial of non-constants is not supported for synthesis in this release as in factorial(x) where x is not a constant.

Example

A = factorial(3);

false

Supported for synthesis.

Example 1

A = false;

Example 2

A = false(1,5);

fft

Supported through AccelWare.

filter

Supported through AccelWare.

firhalfband

Filter Design Toolbox function supported through AccelWare.

fix

Supported for synthesis.

fliplr

Supported for synthesis.

fliprl

Supported for synthesis.

flipud

Supported for synthesis.

floor

Supported for synthesis as a function. Supported in the “Roundmode” when defining a quantizer type.

Example 1

```
q = quantizer(‘fixed’,’floor’,’wrap’, [24 8]):  % This usage of floor is supported
```

Example 2

```
y = floor(x);
```

for

Supported for synthesis when start:stride:end resolve to integers. Arbitrary nested for loops are also supported.

Example 1

```
for i = start:stride:end
 Statement 1;
 Statement 2;
 …
 Statement n;
end
```

Example 2

```
for i = start:end
 Statement 1;
 Statement 2;
 …
 Statement n;
end
```

Example 3

```
NUMTAPS = 16;
for i = 1:NUMTAPS
 Statement 1;
 Statement 2;
 …
 Statement n;
end
```

Example 4

```
for i = start:end
 for j = start:end
  Statement 1;
  Statement 2;
  …
  Statement n;
 end  % j
end  % i
```

function

Arbitrary levels of function hierarchy are supported. Subfunctions and private functions are also supported.

gf

Create a Galois field array. Supported for synthesis as a function.

Givens Array Rotation

Performs a givens rotation on a vector pair. Supported through AccelWare.

hypot

Supported for synthesis.

if

Supported as part of an if / end construct. Also supported with else and elseif constructs.

Example 1

```
if ( a > b)
 c = a;
else
 c = 0;
end
```

Example 2

```
if ( a > b)
 c = a;
elseif (a == b)
```

```
  c = d;
else
  c = 0;
end
```

ifft

Supported through AccelWare.

imag

Imaginary part of complex number. Fully supported for synthesis.

inv

Supported through AccelWare.

Inverse Square Root

Returns the inverse square root of the input matrix. Supported with AccelWare.

isempty

Supported for synthesis when used to set an initial value of a persistent variable.

Example

```
persistent z1; % declare persistent filter state
if isempty(z1)
  z1 = 0.5; % initialize filter state
end
```

ldivide

Supported for synthesis.

length

Supported for synthesis when the argument is statically determinant.

Example

```
A = [2 4 6 8 10];
B = length(A);
```

load

Only supported for .txt files, not .mat files. The supported usage is as follows:

```
X = load('my_file.txt');
```

log

Description

Natural logarithm

Related MATLAB Functions

log

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors, or 2-D matrices.

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
y = log(x);	y = log(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 32] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 2 to 32 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 2 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 31 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
SigIn	May be a scalar, vector or 2-D matrix. Each element is IBITS-bits wide.	Positive Integer	Specified by the SigIn quantizer parameters

Output(s)			
Name	**Description**	**Type**	**Range**
SigOut	A scalar, vector or 2-D matrix with each element representing the natural logarithm of the corresponding element in the input. Each element is OBITS-bits wide.	Real	Range = [$-2^{OBITS-1}$ to $-2^{OBITS-1}-1$] /2^{OFBITS}. OFBITS is automatically computed as a function of the input quantizer.

log10

Description

Base-10 logarithm

Related MATLAB Functions

log10

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors, or 2-D matrices.

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
SigOut = log10(SigIn);	y = log10(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 32] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 2 to 32 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 2 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 31 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
SigIn	May be a scalar, vector or 2-D matrix. Each element is IBITS-bits wide.	Positive Integer	Specified by the SigIn quantizer parameters

Output(s)			
Name	**Description**	**Type**	**Range**
SigOut	A scalar, vector or 2-D matrix with each element representing the log10() of the corresponding element in the input. Each element is OBITS-bits wide.	Real	Range = $[-2^{OBITS-1}$ to $-2^{OBITS-1}-1] / 2^{OFBITS.}$ OFBITS is automatically computed as a function of the input quantizer.

log2

Description

Base-2 logarithm

Related MATLAB Functions

log2

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors, or 2-D matrices.

Syntax

AccelDSP Function Call(s)	MATLAB Syntax	Notes
SigOut = log2(SigIn);	Y = log2(X);	
[F,E] = log2(SigIn);	[F,E] = log2(X);	Dissect the floating point number into F and E where F*2^E represents the floating point number. This is the auto-inferrable form.

Inferring the 'Dissect Floating Point Number' Form of the log2 Function

The code sample below shows how to infer the log2 function:

```
function [E,F] = log2_function(in1)

% infer the log2 function
[E,F] = log2(in1);
```

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = ufixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 32] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 2 to 32 Default = auto
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 2 to 32 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Function Type	Returns the Base-2 logarithm or F and E. In the latter, the floating point input X is dissected into the elements F and E where X = F*2^E.	String	{Base-2 logarithm | dissect floating pint number}
Output bitwidth	The number of bits in the output word(s).		Range 4 to 31 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
SigIn	May be a scalar, vector or 2-D matrix. Each element is IBITS-bits wide.	Positive Integer	Specified by the SigIn quantizer parameters

Output(s)			
Name	**Description**	**Type**	**Range**
SigOut	A scalar, vector or 2-D matrix with each element representing the log2() of the corresponding element in the input. Each element is OBITS-bits wide.	Real	Range = $[-2^{OBITS-1}$ to $-2^{OBITS-1}-1] / 2^{OFBITS}$. OFBITS is automatically computed as a function of the input quantizer.

max

Supported for synthesis. When the argument is a constant, the max function will resolve to a constant in hardware. If the argument is not a constant, hardware will be generated to calculate the maximum.

Example

```
a = [1 2 3 4 7 4];
if (b > max(a))
   c = b;
else
   c = b + 2;
end
```

mean

Supported through AccelWare.

mfilt.firdecim

Filter Design Toolbox function supported through AccelWare.

mfilt.firtdecim

Filter Design Toolbox function supported through AccelWare.

min

Supported for synthesis. When the argument is a constant, the min function will resolve to a constant in hardware. If the argument is not a constant, hardware will be generated to calculate the minimum.

Example

```
a = [1 2 3 4 7 4];
if (b > min(a))
  c = b;
else
  c = b + 2;
end
```

minus/accel_complex_minus

Description

Return the matrix difference.

Related MATLAB Functions

minus

Syntax

AccelDSP minus() Function	Supported MATLAB Syntax
C = minus(A,B);	C = minus(A,B);

AccelDSP accel_complex_minus() Function Call	Notes
[C_real,C_imag] = accel_complex_minus(A_real,A_imag,B_real,B_imag);	

Parameters

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the data type.	String	{double | galoisfield} Default = double
Rows in A input	Specify the number of rows in the A input.	String	Range = [3 to 1024] Default = 3
Columns in A input	Specify the number of Columns in the A input.	String	Range = [3 to 1024] Default = 3
Rows in B input	Specify the number of rows in the B input.	String	Range = [3 to 1024] Default = 3
Columns in B input	Specify the number of Columns in the B input.	String	Range = [3 to 1024] Default = 3
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Inputs / Outputs

minus() Inputs			
Name	**Description**	**Type**	**Range**
A	May be a scalar, vector or 2-D matrix.	Real	
B	May be a scalar, vector or 2-D matrix.	Real	

accel_complex_minus() Inputs			
Name	**Description**	**Type**	**Range**
A_real	May be a scalar, vector or 2-D matrix.	Real	
A_imag	May be a scalar, vector or 2-D matrix.	Real	
B_real	May be a scalar, vector or 2-D matrix.	Real	
B_imag	May be a scalar, vector or 2-D matrix.	Real	

minus() Output			
Name	**Description**	**Type**	**Range**
C	Result of matrix difference	Real	

accel_complex_minus() Outputs			
Name	**Description**	**Type**	**Range**
C_real	Result of matrix difference.	Real	
C_imag	Result of matrix difference.	Real	

mod

Description

Modulus after division

Related MATLAB Functions

mod

Differences with the MATLAB Function

None

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
SigOut = mod(SigIn_N,SigIn_D);	Z = mod(X,Y);

ParametersParameters

Denominator Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = ufixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 0

Numerator Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Newton-Raphson Goldschmidt Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Newton-Raphson | Goldschmidt | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Positive Integer	[4 to 32] Default = [auto]
Iterations	This parameter dictates the number of iterations to use in the Newton Raphson or Goldschmidt algorithm.	Positive Integer	Range = [1, 2 or 3] Default = [auto]
Init Lut Bits	Specifies the number of MSB bits to use for the initialization table when Newton Raphson or Goldschmidt implementations are specified.	Positive Integer	Range 2 to 32 Default = [default]

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.	Positive Integer	Range = 2 to 32 Default = auto
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.	Positive Integer	Range 2 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).	Positive Integer	Range 4 to 32 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
SigIn_N	An input stream of numbers that represent the numerator of the division operation.	Real	The range of the numbers is defined by the SigIn_N quantizer settings.
SigIn_D	An input stream of numbers that represent the denominator of the modulus operation.	Real	The range of the numbers is defined by the SigIn_D quantizer settings.

Output(s)			
Name	**Description**	**Type**	**Range**
SigOut	An output stream of numbers that represent the result of the modulus operation.	Real	If either the numerator or the denominator is type 'fixed', the range of the output will be equal to $[-2^{OBITS-1}, -2^{OBITS-1}-1]/2^{OFBITS}$ However, if both inputs are type 'ufixed', the range of the output will be equal to $[0, -2^{OBITS-1}-1]/2^{OFBITS}$ The number of fractional bits (OFBITS) is automatically selected to cover the maximum possible output value.

mpower

Matrix power. Support includes X to the power y when y is an integer and a scalar.

Example

```
X = [1 2; 3 4];
y= 3;
Z = mpower(X,y);
```

mtimes/accel_complex_mtimes

Description

Matrix multiplication

Related MATLAB Functions

mtimes

Syntax

AccelDSP mtimes() Function	Supported MATLAB Syntax
C = mtimes(A,B);	C = mtimes(A,B);

AccelDSP accel_complex_mtimes() Function Call	Notes
[C_real,C_imag] = accel_complex_mtimes(A_real,A_imag,B_real,B_imag);	

Parameters

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	{array-array | array-scalar | scalar-arrayT} Default = array-array
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Inputs / Outputs

mtimes() Inputs			
Name	**Description**	**Type**	**Range**
A	May be a scalar, vector or 2-D matrix. Matrix size is limited to 4096 rows by 4096 columns.	Real	Rows: [1-4096] Columns: [1-4096]
B	May be a scalar, vector or 2-D matrix.	Real	Rows: [1-4096] Columns: [1-4096]

accel_complex_mtimes() Inputs			
Name	**Description**	**Type**	**Range**
A_real	May be a scalar, vector or 2-D matrix.	Real	
A_imag	May be a scalar, vector or 2-D matrix.	Real	
B_real	May be a scalar, vector or 2-D matrix.	Real	
B_imag	May be a scalar, vector or 2-D matrix.	Real	

mtimes() Output			
Name	**Description**	**Type**	**Range**
C	Result of matrix multiplication.	Real	

accel_complex_mtimes() Outputs			
Name	**Description**	**Type**	**Range**
C_real	Result of matrix multiplication.	Real	
C_imag	Result of matrix multiplication.	Real	

ndims

Supported for synthesis.

ne

Supported for synthesis.

nexpow2

Supported for synthesis.

norm

Supported through AccelWare.

ones

Supported for synthesis in this release for up to two dimensions.

Example 1

```
a = ones;
```

Example 2

```
a = ones(1,5);
```

otherwise

Supported as part of the switch statement.

Example

```
switch (x)
  case (0)
    y = y + 1;
  otherwise (1)
    y = y + 2;
end
```

persistent

Supported for synthesis if the declared variable(s) are initialized by an isempty statement.

Example

```
persistent z1; % declare persistent filter state
if isempty(z1)
  z1 = 0.5; % initialize filter state
end
```

pi

Supported for synthesis.

plus/accel_complex_plus

Description

Return the matrix sum.

Related MATLAB Functions

plus

Syntax

AccelDSP plus() Function	Supported MATLAB Syntax
C = plus(A,B);	C = plus(A,B);

AccelDSP accel_complex_plus() Function Call	Notes
C_real,C_imag] = accel_complex_plus(A_real,A_imag,B_real,B_imag);	

Parameters

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the data type.	String	{double | galoisfield} Default = double
Rows in A input	Specify the number of rows in the A input.	String	Range = [3 to 1024] Default = 3
Columns in A input	Specify the number of Columns in the A input.	String	Range = [3 to 1024] Default = 3
Rows in B input	Specify the number of rows in the B input.	String	Range = [3 to 1024] Default = 3

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Columns in B input	Specify the number of Columns in the B input.	String	Range = [3 to 1024] Default = 3
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Inputs / Outputs

plus() Input(s)			
Name	**Description**	**Type**	**Range**
A	May be a scalar, vector or 2-D matrix.	Real	
B	May be a scalar, vector or 2-D matrix.	Real	

accel_plus_minus() Inputs			
Name	**Description**	**Type**	**Range**
A_real	May be a scalar, vector or 2-D matrix.	Real	
A_imag	May be a scalar, vector or 2-D matrix.	Real	
B_real	May be a scalar, vector or 2-D matrix.	Real	
B_imag	May be a scalar, vector or 2-D matrix.	Real	

plus() Output(s)			
Name	**Description**	**Type**	**Range**
C	Result of matrix difference	Real	

accel_complex_plus() Inputs			
Name	**Description**	**Type**	**Range**
C_real	Result of matrix difference.	Real	
C_imag	Result of matrix difference.	Real	

pol2cart

Supported for scalars, vectors and two-dimensional matrices containing both positive and negative numbers.

poly2trellis

Communications Toolbox function supported through AccelWare.

polyval

Supported through AccelWare.

pow2

Pow2 of constants is supported when x in pow2(x) resolves to a constant. Pow2 of non-constants is not supported for synthesis in this release as in pow2(x) where x is not a constant.

Example

```
A = pow2(4);
```

power/accel_power

Description

Return the result of the power.

Related MATLAB Functions

power

Differences with the MATLAB Function

The shape of the input is limited to scalars, vectors, or 2-D matrices. The AccelWare power() function does not support complex numbers.

Limitations

Fixed point severely limits the dynamic range. Answers in most cases will not match MATLAB. When large exponent values are detected, AccelDSP displays a WARNING message about the accuracy of the results.

To allow more accurate results, a floating point engine that returns a mantissa and an exponent instead of a single number is used for computing power() under all conditions: [f,e]=accel_power(X,Y) where z=f*2^e. Even for type="fixed point" in the power() model, the accel_exp() model is called and floating point math is used. The fixed point type maintains the MATLAB format of a single number output.

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
Z = power(X,Y);	Z = power(X,Y);

AccelDSP accel_power() Function Call	Notes
[f,e] = accel_power(X,Y); Z = f*2^e	

Parameters

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	Range = {default}
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
Type	See Limitations above		Range [fixed point | floating point | galiosfield] Default = floating point
Output bitwidth	The number of bits in the output word(s).		Range [4 to 31] Default = auto

Inputs / Outputs

power Input(s)			
Name	**Description**	**Type**	**Range**
X	May be a scalar, vector or 2-D matrix.	Positive Integer	
Y	May be a scalar, vector or 2-D matrix.	Positive Integer	

power Output(s)			
Name	Description	Type	Range
Z	A scalar, vector or 2-D matrix with each element representing the exp() of the corresponding element in the input. Each element is OBITS-bits wide.	Real	Range = $[-2^{OBITS-1}$ to $-2^{OBITS-1}-1] / 2^{OFBITS}$. OFBITS is automatically computed.

accel_powerOutput(s)			
Name	Description	Type	Range
f	Represents the mantissa of the floating-point output where Z = f*2^e	Real	
e	Represents the exponent of the floating-point output where Z = f*2^e	Real	

prod

Prod is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

qr

Supported through AccelWare.

qrdrls

QRD-RLS Spatial Filter. Supported through AccelWare.

quantize

Defines the fixed-point parameters of a variable.

quantizer

Applies the quantize object to a variable.

rcosflt

Communications Toolbox function supported through AccelWare.

rdivide

Description

Right array division.

Related MATLAB Functions

Array Right Division

rdivide

Differences with the MATLAB Function

None

Syntax

AccelDSP rdivide() Function	Supported MATLAB Syntax
Y = rdivide(N,D); [Y,dz] = rdivide(N,D);	Y = N./D; y = rdivide(N,D);

AccelDSP accel_rdivide() Function Call	Supported MATLAB Syntax
Y = accel_rdivide(N,D); [Y,dz] = accel_rdivide(N,D);	Y = N./D; y = rdivide(N,D);

Parameters

Denominator Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = ufixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor

Denominator Quantization			
Name	**Description**	**Type**	**Range**
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 0

Numerator Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = ufixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Type	Select the data type	String	double | galoisfield | complex: separate real and imag IO Default = double
Implementation	Select the hardware architecture to create. CORDIC Newton-Raphson Goldschmidt Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Newton-Raphson | Goldschmidt | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
Resource Sharing	**Newton Raphson**: This parameter determines the type of resource sharing to use in the Newton Raphson algorithm.	String	{single multiplier | single N-R iteration (2 mults}
additional mult. pipes(-5:5)	**Newton Raphson/Goldschmidt**: This parameter determines the number of additional pipe stages to insert in the multiplier chains of the Newton Raphson and Goldschmidt algorithm.	String	Range = [-5:5] Default = 0

Implementation Parameters			
Name	**Description**	**Type**	**Range**
additional adder pipes(-5:5)	**Newton Raphson/Goldschmidt**: This parameter determines the number of additional pipe stages to insert in the adder chains of the Newton Raphson algorithm.	String	Range = [-5:5] Default = 0
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Positive Integer	[4 to 32] Default = [auto]
Iterations	This parameter dictates the number of iterations to use in the Newton Raphson or Goldschmidt algorithm.	Positive Integer	Range = [1, 2 or 3] Default = [auto]
Init Lut Bits	Specifies the number of MSB bits to use for the initialization table when Newton Raphson or Goldschmidt implementations are specified.	Positive Integer	Range 2 to 32 Default = [default]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.	Positive Integer	Range = 2 to 5 Default = auto
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.	Positive Integer	Range 2 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).	Positive Integer	Range 4 to 32 Default = auto
Divide by Zero Flag	Include a divide-by-zero flag signal.	String	Range = [yes | no] Default = no

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
Sig_N	An input stream of numbers that represent the numerator of the division operation.		The range of the numbers is defined by the SigIn_N quantizer settings.
D	An input stream of numbers that represent the denominator of the division operation.		The range of the numbers is defined by the SigIn_D quantizer settings.

Output(s)			
Name	**Description**	**Type**	**Range**
Y	An output stream of numbers that represent the result of the division operation.		If either the numerator or the denominator is type 'fixed', the range of the output will be equal to $[-2^{OBITS-1}, -2^{OBITS-1}-1]/2^{OFBITS}$ However, if both inputs are type 'ufixed', the range of the output will be equal to $[0, -2^{OBITS-1}-1]/2^{OFBITS}$ The number of fractional bits (OFBITS) is automatically selected to cover the maximum possible output value.

Additional accel_rdivide() Output			
Name	**Description**	**Type**	**Range**
dz	Optional divide-by-zero flag.		A binary value that is set to '1' if the denominator is zero.

reallog

Supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

real

Real part of complex number. Fully supported for synthesis.

realpow

Supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

realsqrt

Supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

rem

Description

Remainder after division

Related MATLAB Functions

rem

Differences with the MATLAB Function

When Y = 0, MATLAB rem(X,Y) = NaN

When Y = 0, rem(X,Y) = 0 with "DivZero" output driven to 1

Syntax

AccelDSP rem() Function Call	Supported MATLAB Syntax
R = rem(X,Y);	R = rem(X,Y);

ParametersParameters

Denominator Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = ufixed
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = ufixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10

Numerator Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor

Numerator Quantization			
Name	**Description**	**Type**	**Range**
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Newton-Raphson Goldschmidt Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Newton-Raphson | Goldschmidt | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
CORDIC Iterations	Selects the number of CORDIC iterations to perform. ‘auto’ can be used to automatically select the number of iterations to perform. ‘auto’ uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Positive Integer	[4 to 32] Default = [auto]

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Iterations	This parameter dictates the number of iterations to use in the Newton Raphson or Goldschmidt algorithm.	Positive Integer	Range = [1, 2 or 3] Default = [auto]
Init Lut Bits	Specifies the number of MSB bits to use for the initialization table when Newton Raphson or Goldschmidt implementations are specified.	Positive Integer	Range 2 to 32 Default = [default]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.	Positive Integer	Range = 2 to 32 Default = auto
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.	Positive Integer	Range 2 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).	Positive Integer	Range 4 to 32 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
SigIn_N	The numerator of the division operation.	Real	The range of the numbers is defined by the SigIn_N quantizer settings.
SigIn_D	The denominator of the remainder operation.	Real	The range of the numbers is defined by the SigIn_D quantizer settings.

Output(s)			
Name	**Description**	**Type**	**Range**
SigOut	An output stream of numbers that represent the result of the remainder operation.	Real	If either the numerator or the denominator is type 'fixed', the range of the output will be equal to $[-2^{OBITS-1}, -2^{OBITS-1}-1]/2^{OFBITS}$ However, if both inputs are type 'ufixed', the range of the output will be equal to $[0, -2^{OBITS-1}-1]/2^{OFBITS}$ The number of fractional bits (OFBITS) is automatically selected to cover the maximum possible output value.
DivZero	An output stream of numbers that will always be 0 unless y is zero, in which case DivZero = 1.	Integer	Range = [0 to 1]

reshape

Supported for synthesis in this release for up to 2 dimensions.

rot90

Supported for synthesis.

round

Supported for synthesis.

rsdec

Communications Toolbox function supported through AccelWare.

rsenc

Communications Toolbox function supported through AccelWare.

sign

Sign is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

sin/accel_sin

Description

Sine Function

Related MATLAB Functions

sin

Differences with the MATLAB Function

1. The inputs must be pre-quantized to the accuracy specified by the input quantizer.
2. The shape of the input is limited to a scalar, vector or 2-D matrix.

Extended Features of accel_sin()

The accel_sin() function provides the same functionality as the sin() function plus the following extended features:

1. The accel_sin() function can create an optional cos() output with little additional hardware.
2. The accel_sin() function can specify input units of measure (InputType) in the following formats:
   - native form
   - scaled form

Syntax

AccelDSP sin() Function	Supported MATLAB Syntax
y = sin(x);	y = sin(x);

AccelDSP accel_sin() Function Call	Notes
y = accel_sin(x); [y,z] = accel_sin(x);	y = sin(x) z = cos(x);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Name	Description	Type	Range
Sign Mode	**fixed**: signed fixed-point model. Infers that the input range is -PI to PI. **ufixed**: unsigned fixed-point mode. Infers that the input range is 0 to 2*PI.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word.	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 7

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
InputType	Specify the representation of the input word.	String	{native form | scaled form} Default = native form
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses OBITS to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 100] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 1 to 6 Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 1 to 32 Default = auto
Output bitwidth	The number of bits in the output word(s).		Range 4 to 32 Default = auto
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT Default = CORDIC

Inputs / Outputs

sin() Input			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix.	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

accel_sin() Input			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix. (For InputType = native form).	Real	Range = [0 to 2π] or [-π to π] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.
	May be a scalar, vector or 2-D matrix. (For InputType = scaled form).	Positive Integer	Range = [0 to 2^{IBITS}-1] or [-2^{IBITS}-1...$2^{IBITS-1}$-1] depending on the Sign Mode of the Input Quantizer, 'ufixed' and 'fixed', respectively.

sin() Output			
Name	**Description**	**Type**	**Range**
y	May be a scalar, vector, or 2-D matrix representing the sine of the corresponding input element. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

Additional accel_sin() Output			
Name	**Description**	**Type**	**Range**
z	An optional output scalar, vector, or 2-D matrix representing the cosine of the corresponding input. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

size

Supported for synthesis in this release when the argument resolves to a constant.

Example 1

```
a = [4 9 7 ; -12 10 8];
b = size(a,1)
```

Example 2

```
a = [4 9 7 -12 10 8];
[b c] = size(a)
```

Example 3

```
a = [4 9 7 ; -12 10 8];
b = size(a)
```

sqrt

Description

Square Root

Related MATLAB Functions

sqrt

Differences with the MATLAB Function

In MATLAB, the input <x> is a vector of complex numbers passed to sqrt() in parallel with the output <y> occurring as a vector of complex numbers in parallel as well. Since this is not practical in hardware, in the sqrt() function, the input <x> occurs as a serial stream of IBITS-bit real un-signed numbers and the output <y> occurs as serial stream of OBITS-bit real un-signed numbers.

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
y = sqrt(x); [y inv_y] = sqrt(x);	y = sqrt(x);
	Unsupported MATLAB Syntax
	Complex and Negative inputs are not supported in this version due to the complex outputs generated by the sqrt function.

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point model. Infers that the input range is -PI to PI. **ufixed**: unsigned fixed-point mode. Infers that the input range is 0 to 2*PI.	String	Mode = fixed | ufixed Default = fixed
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed

Input Quantization			
Name	**Description**	**Type**	**Range**
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap
Word Length	The number of bits for the input word(s).	String	Default = 10

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. CORDIC Bipartite Tables (more) Linerly Interpolated Lookup Tables (more) Newton-Raphson Newton-Raphson with Inverse	String	CORDIC | Bipartite Tables | Linearly Interpolated LUT | Newton-Raphson | Newton-Raphson with Inverse Default = CORDIC
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Implementation Parameters			
Name	**Description**	**Type**	**Range**
CORDIC Iterations	Selects the number of CORDIC iterations to perform. 'auto' can be used to automatically select the number of iterations to perform. 'auto' uses the Output bitwidth to compute the number of iterations required to ensure the maximum error is ~1 LSB	Integer	[4 to 32] Default = [auto]
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.		Range = 2 to 5 Default = auto
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.		Range 2 to 32 Default = auto
Iterations	This parameter dictates the number of iterations to use in the Newton Raphson algorithm.	Positive Integer	Range = [1, 2 or 3] Default = [auto]
Output bitwidth	The number of bits in the output word(s).		Range 4 to 31 Default = auto

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix. Each element is IBITS-bits wide.	Positive Integer	Range = [0 to 2^{IBITS} -1] /2^{IFBITS}

Output(s)			
Name	**Description**	**Type**	**Range**
y	A scalar, vector or 2-D matrix with each element representing the sqrt(x) of the corresponding element in the input. Each element is OBITS-bits wide.	Real	Range = $[0 \text{ to } 2^{OBITS} -1] / 2^{OFBITS}$
inv_y	An optional output representing the 1/sqrt(x) of each element in the input. Each output element is OBITS-bits wide.	Real	Range = $[0 \text{ to } 2^{OBITS} -1] / 2^{OFBITS}$

std

Standard Deviation function supported through AccelWare.

structure

Create a structure inside the design function. Refer to "'structure' Data Type," for details.

sum

Sum is supported for scalars, vectors or two-dimensional matrices containing both positive and negative numbers.

svd

Singular Value Decomposition. Supported through AccelWare.

switch

Supported for synthesis.

Example

```
switch (x)
  case (0)
    y = y + 1;
  otherwise (1)
    y = y + 2;
end
```

tan

Description

Tangent Function

Related MATLAB Functions

tan

Differences with the MATLAB Function

1. The inputs must be pre-quantized to the accuracy specified by the Input Bit Width.
2. The shape of the input is limited to a scalar, vector or 2-D matrix.

Extended Features of accel_sin()

The accel_tan() function provides the same functionality as the tan() function plus the following extended features:

1. The accel_tan() function allows you to manually set the Input Bit Width.

Syntax

AccelDSP tan() Function Call	Supported MATLAB Syntax
y = tan(x);	y = tan(x);
AccelDSP accel_tan() Function Call	**Notes**
y = accel_tan(x);	y = tan(x)

Parameters

Functional Parameters			
Name	**Description**	**Type**	**Range**
Input Bit Width	The number of bits for the input word.	String	Range [4 to 24] Default = 10

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create. Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	{ Bipartite Tables | Linearly Interpolated LUT} Default = Bipartite Tables
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}
Bipartite Sections	**Bipartite Tables**: Specify the bit width parameters to use for the Bipartite Tables [A B C] or just [A]. When [A B C] is specified A+B+C must equal IBITS. If just [A] is specified B and C will be selected to minimized the table sizes.	String	Range = 1 to 5 Default = auto
Address bits	**Linearly Interpolated LUT**: max(16, N), where N is the value required to limit the number of address bits to 14.	String	Range 1 to 10 Default = auto
Output bitwidth	The number of bits in the output word(s).	String	Range 4 to 32 Default = auto
Implementation	Select the hardware architecture to create. Bipartite Tables (more) Linerly Interpolated Lookup Tables (more)	String	{ Bipartite Tables | Linearly Interpolated LUT} Default = Bipartite Tables

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
x	May be a scalar, vector or 2-D matrix.	Real	

Output(s)			
Name	**Description**	**Type**	**Range**
y	May be a scalar, vector, or 2-D matrix representing the sine of the corresponding input element. OBITS = Output bitwidth.	Real	Range = $[-2^{OBITS-1}$ to $2^{OBITS-1} -1]/2^{OFBITS}$

times/accel_complex_times

Description

Return the result of element-by-element multiplication.

Related MATLAB Functions

times

Syntax

AccelDSP mtimes() Function	Supported MATLAB Syntax
C = times(A,B);	C = times(A,B);

AccelDSP accel_complex_mtimes() Function Call	Notes
[C_real,C_imag] = accel_complex_times(A_real,A_imag,B_real,B_imag);	

Parameters

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Implementation	Select the hardware architecture to create.	String	{ vector-vector | vector-scalar | scalar-vectorT} Default = vector-vector
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined}

Inputs / Outputs

times() Inputs			
Name	**Description**	**Type**	**Range**
A	May be a scalar, vector or 2-D matrix.	Real	
B	May be a scalar, vector or 2-D matrix.	Real	

accel_complex_times() Inputs			
Name	**Description**	**Type**	**Range**
A_real	May be a scalar, vector or 2-D matrix.	Real	
A_imag	May be a scalar, vector or 2-D matrix.	Real	

accel_complex_times() Inputs			
Name	**Description**	**Type**	**Range**
B_real	May be a scalar, vector or 2-D matrix.	Real	
B_imag	May be a scalar, vector or 2-D matrix.	Real	

times() Output			
Name	**Description**	**Type**	**Range**
C	Result of matrix multiplication.	Real	

accel_complex_times() Outputs			
Name	**Description**	**Type**	**Range**
C_real	Result of matrix multiplication.	Real	
C_imag	Result of matrix multiplication.	Real	

true

Supported for synthesis.

Example 1

```
A = true;
```

Example 2

```
A = true(1,5);
```

var

Description

Variance

Related MATLAB Functions

var

Differences with the MATLAB Function

In MATLAB, the length of <x> may vary from call to call. This var() function requires the length of <x> to be constant from call to call. The function can be created with a known mean value on the input sequence, which significantly reduces the complexity of the hardware.

Syntax

AccelDSP Function Call	Supported MATLAB Syntax
y = var(x,flag); y = var(x,w,dim);	y = var(x); y = var(x,w,dim);

Parameters

Input Quantization			
Name	**Description**	**Type**	**Range**
Sign Mode	**fixed**: signed fixed-point mode **ufixed**: unsigned fixed-point mode.	String	Mode = fixed | ufixed Default = fixed
Round Mode	**floor**: round both positive and negative number toward positive infinity **round**: round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.	String	RoundMode = [floor | round] Default = floor
Overflow Mode	**wrap**: wrap on overflow. **saturate**: saturate a maximum value on overflow.	String	OverflowMode = [wrap | saturate] Default = wrap

Input Quantization			
Name	**Description**	**Type**	**Range**
Word Length	The number of bits for the input word(s).	String	Default = 10
Fractional Length	The number of fractional bits for the input word(s).	String	Default = 5

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Speed vs. Area	**Speed** fast = resource shared / non-pipelined faster = resource shared / pipelined fastest = non-resource shared / pipelined **Area** smallest = resource shared / non-pipelined smaller = resource shared / pipelined small = non-resource shared / pipelined	String	{resource shared / non-pipelined | resource shared / pipelined | non-resource shared / pipelined} Default = {resource shared / non-pipelined}
N (2:65000)	Length of the input vector.	Positive Integer	Range = [2 to 65000] Default = 16
Flag (0:1)	Sets the normalization factor to use. '0' causes the value to be normalized by N-1, while '1' causes the value to be normalized by N.	Binary	Range = 0 | 1 Default = 0
Output bitwidth	Number of bits used to represent the output y.	Positive Integer	Range = [4 to 32] Default = auto

Implementation Parameters			
Name	**Description**	**Type**	**Range**
Mean	If a number is supplied for the mean(x), no hardware will be implemented to compute the mean value. Instead, the value supplied will be directly substituted into the var equation. Hardware will be used to calculate the mean if this parameter is set to "Computed".	Real	Default = Computed
Data I/O Format	Scalar, one sample at a time; Array, N array of samples at a time. 'Array' is typically used when var is embedded in a design.	String	Range = Scalar | Array Default = Scalar

Inputs / Outputs

Input(s)			
Name	**Description**	**Type**	**Range**
x	An input stream of vectors to compute the variance. Each element in the vector is IBITS-bits wide with IFBITS-bits representing the fractional part.	Real	Range = [0 to 2^{IBITS} -1] /2^{IFBITS}

Output(s)			
Name	**Description**	**Type**	**Range**
y	An output stream of numbers each OBITS-bits wide with OFBITS-bits representing the fractional part. OFBITS is automatically selected.	Real	Range = [0 to 2^{OBITS} -1] /2^{OFBITS}
z	An optional output stream of numbers each OBITS-bits wide with OFBITS-bits representing the fractional part. OFBITS is automatically selected.	Real	Range = [0 to 2^{OBITS} -1] /2^{OFBITS}

while

Supported for synthesis.

Example

```
while (i < 5)
   a = a + 10;
   i = i + 1;
end
```

zeros

Supported for synthesis in this release for up to two dimensions.

Example 1

```
a = zeros;
```

Example 2

```
a = zeros(1,5);
```

XILINX®

Chapter 4

Table of Synthesizable MATLAB Constructs

Programming with MATLAB

Data Types and Quantize Functions

Name	Description
Scalar arrays	An array with dimensions 1 x 1
Vector arrays	An array with dimensions 1 x n
Matrix arrays	An array with dimensions m x n
structure	Create a structure inside the design function
char	Limited to String Constants
gf	Create a Galois field array
quantize	Defines the fixed-point parameters of a variable
quantizer	Applies the quantize object to a variable

Flow Control

Name	Description
if-elseif-else	Evaluates an expression and executes a set of commands
for / end	Repeats a set of commands a specified number of times
switch-case	Executes a set of commands based on an expression
while / end	Repeats a set of commands until a logical condition is false
end	Defines the end of an IF, FOR and WHILE statement
otherwise	Supported as part of the switch statement.

Scripts and Functions

Name	Description
function	Defines a function containing executable MATLAB
persistent	Define persistent variable
%	Comment

Basic Information

Name	Description
eps	Floating-point relative accuracy
isempty	True for an empty matrix. Supported for the initialization of persistent variables.
length	Length of a vector
ndims	Number of array dimensions
size	Size of a matrix

Array Operations and Manipulations

Name	Description
:	Index into array
dot	Scalar product of two vectors
end	Last index
max	Max elements of array
min	Min elements of array
reshape	Use to modify the shape of a matrix
inv	Matrix Inverse. Supported with AccelWare.
norm	Vector and matrix norm
mean	Return the mean of a matrix or array elements
all	Test to determine if all elements are non-zero
any	Test for non-zeros
sum	Sum of an array of elements
cumsum	Cumulative sum along different dims
prod	Product of the elements of an array
cumprod	Cumulative product of the elements of an array
fliplr	Flip matrices left-right
flipud	Flip matrices up-down
rot90	Rotate matrix 90 degrees
diff	Differences and approximate derivatives
cat	Concatenation. Limited to two variables

Elementary Matrices and Arrays

Name	Description
:	Regularly spaced vector
eye	Identity matrix
ones	Create array on all ones
zeros	Create array of all zeros
bi2de	Convert input matrices to decimal numbers. Input is restricted to base 2 numbers.
de2bi	Convert decimal numbers to binary vectors

Opening, Loading, Saving Files

Name	Description
load	load workspace from disk

Mathematics

Mathematical Operators

Name	Description
+, plus, accel_complex_plus	Addition
-, minus, accel_complex_minus	Subtraction
.*, times, accel_complex_times	Array multiplication
*, mtimes, accel_complex_mtimes	Matrix multiplication
.^, power	Array power
^, mpower	Matrix power where the exponent must be a scalar integer
pow2	Base 2 power and scale floating-point number
nextpow2	Next power of two
./	Right array divide
/, rdivide	Right matrix divide
.\	Left array divide
\, ldivide	Left matrix divide
'	Transpose
.'	Noconjugated transpose

Relational Operators

Name	Description
<	Less than
<=	Less than or equal
>	Greater than
>=	Greater than or equal

Name	Description
==, eq	Test for equality
~=, ne	Not equal

Logical Operators

Name	Description
&&	Logical AND
||	Logical OR
&	Logical AND for arrays
|	Logical OR for arrays
~	Logical NOT
false	False array
true	True array

MATLAB Bit-wise Operators

Name	Description
bitand	Bitwise and
bitcmp	Bitwise compare. Overloaded with accel_bitcmp
bitget	Bitwise get
bitor	Bitwise or
bitset	Bitwise set
bitshift	Bitwise shift. Overloaded with accel_bitshl and accel_bitshr.
bitxor	Bitwise xor

AccelDSP Bit-wise Operators

Base Function	Description
accel_bitand	Returns the unsigned bit-wise AND of two integers
accel_bitcmp	Returns the unsigned bit-wise complement of an integers
accel_bitmerge	Cincatenates two components, MSB (nost-significant bits) and LSB (least-significant bits) into one output word
accel_bitnand	Returns the unsigned bit-wise NAND of two integers
accel_bitnor	Returns the unsigned bit-wise NOR of two integers
accel_bitor	Returns the unsigned bit-wise OR of two integers
accel_bitpack	Returns a single value-representation of the bit-vector argument x quantized to quantizer q
accel_bitrev2	Return the unsigned digit reversal of the argument IN
accel_bitrev	Return the unsigned bit-wise reversal of the argument IN
accel_bitshl	Returns the unsigned bit-wise shift-left of the argument IN shifted left by N bits
accel_bitshr	Returns the unsigned bit-wise shift-right of the argument IN shifted right by N bits
accel_bitsplit	Splits the input value into MSB (most-significant bits) and LSB (least-significant bits) components according to the bitwidths specified in the specified quantizers
accel_bitunpack	Returns a row-vector bit-representation of the scalar argument x quantized to the quantizer qout
accel_bitunpackselect	Returns the i'th element fron the output of accel_bitunpack(x,q)
accel_bitxor	Returns the unsigned bit-wise XOR of two integers

Linear Algebra

Name	Description
chol	Matrix factorization using Cholesky method. Supported with AccelWare.
inv	Matrix Inverse (QR,Cholesky, Upper Triangular). Supported with AccelWare.
qr	Matrix factorization using QR Decomposition method. Supported with AccelWare.
qrdrls	QRD-RLS Spatial Filter. Supported with AccelWare.
svd	Singular value decomposition. Supported with AccelWare.
vector rotation	Preforms a givens rotation on a vector pair. Supported with AccelWare.
Triangular System of Equations Solver	Computes the solution to an upper or lower triangular system of equations using backward or forward substitution, respectively. Supported with AccelWare.

Statistics

Name	Description
mean	Mean value. Supported with AccelWare.
norm	norm. Supported with AccelWare.
std	Standard Deviation. Supported with AccelWare.
var	Variance. Supported with AccelWare.

Trigonometric Functions

Name	Description
sin, accel_sin	Sine
cos, accel_cos	Cosine
tan, accel_tan	Tangent
asin, accel_asin	Inverse sine
acos, accel_acos	Inverse cosine
atan, accel_atan	Inverse tangent
atan2, accel_atan2	Four-quandrant inverse tan

Polynomials

Name	Description
polyval	Returns the value of a polynomial. Supported with AccelWare.

Exponential Functions

Name	Description
exp	Exponential
log	Natural logarithm
log10	Base 2 logarithm
log2	Base 10 logarithm
pow2	Base 2 power
power	Array power. Same as X.^Y
mpower	Matrix power where the exponent must be a scalar integer. Same as X^Y where Y is a scalar integer.
reallog	Base e logarithm
sqrt	Square root
realsqrt	Square root for non-negative real arrays
Inverse Square Root	Returns 1/sqrt(x). Supported through AccelWare.
realpow	Array power for real output

Complex Numbers

Name	Description
abs, accel_abs	Absolute value
angle, accel_angle	Returns phase angle and magnitude
cart2pol	Cartesian corrdinates to polar or cylindrical
complex norm	Complex Normalization. Supported with AccelWare.
pol2cart	Polar or cylindrical corrdinates to Cartesian
conj	Complex conjugate of the elements of the array
complex	Construct complex data from real and imaginary components
imag	Imaginary part of a complex number
real	Real part of a complex number

Rounding and Remainder

Name	Description
ceil	Round towards positive infinity
convergent	Round to nearest integer
fix	Round towards zero
floor	Round towards negative infinity
mod	Modulus after division
rem	Remainder after division
nearest	Round towards integer
sign	Signum

Discrete Math

Name	Description
factorial	Is the product of all the integers from 1 to n

Math Constants

Name	Description
pi	Ratio of a circle's circumference / diameter

Signal Processing Library

Filters - FIR - General Purpose

Name	Description
dfilt	Discrete-Time Filters. Supported with AccelWare.
filter	Fixed coefficient FIR filter. Supported with AccelWare.
filter - loadcoef	Loadable coefficients FIR filter. Supported with AccelWare.
filter - multchan	Multi-channel FIR filter. Supported with AccelWare.

Filters - Multirate

Name	Description
cicdecim	Cascaded Integrator-Comb decimation filter. Supported with AccelWare.
cicinterp	Cascaded Integrator-Comb interpolation filter. Supported with AccelWare.
mfilt.firdecim	Construct direct-form FIR polyphase decimator filter. Supported with AccelWare.
mfilt.firtdecim	Construct direct-form transposed FIR filter. Supported with AccelWare.
firhalfband	Half-band FIR filter. Supported with AccelWare.

Filters - Other

Name	Description
a_dsinccompensation	A/D Sinc Compensation filter. Supported with AccelWare.
cicdecimate	Cascaded Integrator-Comb (CIC) decimation filter. Supported with AccelWare.
cicinterpolate	Cascaded Integrator-Comb (CIC) interpolation filter. Supported with AccelWare.
rcosfir	Root-Raised Cosine (RRC) filter. Supported with AccelWare.

Transformations

Name	Description
fft - radix 2	Fast-Fourier transform. Supported with AccelWare.
ifft - radix 2	Inverse Fast-Fourier transform. Supported with AccelWare.
fft - radix 4	Fast-Fourier transform. Supported with AccelWare.
ifft - radix 4	Inverse Fast-Fourier transform. Supported with AccelWare.

Communications Library

Direct Digital Synthesizers

Name	Description
dds	Direct Digital Synthesizer. Supported with AccelWare.

Encoders/Decoders

Name	Description
convenc	Convolutional encoder. Supported with AccelWare.
convintlv	Convolutional interleaver. Supported with AccelWare.
convdeintlv	Convolutional deinterleaver. Supported with AccelWare.
rsenc	Reed Solomon/BCH encoder. Supported with AccelWare.
rsdec	Reed Solomon/BCH decoder. Supported with AccelWare.
vitdec	Viterbi decoder. Supported with AccelWare.
bchenc	BCH encoder. Supported with AccelWare.
bchdec	BCH decoder. Supported with AccelWare.

Scramblers / Descramblers

Name	Description
scrambler	Custom 16-bit wide scrambler. Supported with AccelWare.
descrambler	Custom 16-bit wide scrambler. Supported with AccelWare.

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