Fixed-Point Designer™

Reference

MATLAB®

R2018a

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The MathWorks, Inc.
3 Apple Hill Drive
Natick, MA 01760-2098

Fixed-Point Designer™ Reference

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Apps — Alphabetical List

Fixed-Point Converter

Convert MATLAB code to fixed point

Description

The Fixed-Point Converter app converts floating-point MATLAB® code to fixed-point MATLAB code.

Using the app, you can:

- Propose data types based on simulation range data, static range data, or both.
- Propose fraction lengths based on default word lengths or propose word lengths based on default fraction lengths.
- Optimize whole numbers.
- Specify safety margins for simulation min/max data.
- View a histogram of bits used by each variable.
- Specify replacement functions or generate approximate functions for functions in the original MATLAB algorithm that do not support fixed point.
- Test the numerical behavior of the fixed-point code. You can then compare its behavior against the floating-point version of your algorithm using either the Simulation Data Inspector or your own custom plotting functions.

If your end goal is to generate fixed-point C code, use the MATLAB Coder™ app instead. See “Convert MATLAB Code to Fixed-Point C Code” (MATLAB Coder).

If your end goal is to generate HDL code, use the HDL Coder™ workflow advisor instead. See “Floating-Point to Fixed-Point Conversion” (HDL Coder).

Open the Fixed-Point Converter App

- MATLAB Toolstrip: On the **Apps** tab, under **Code Generation**, click the app icon.
- MATLAB command prompt: Enter `fixedPointConverter`.
- To open an existing Fixed-Point Converter app project, either double-click the `.prj` file or open the app and browse to the project file.

Creating a project or opening an existing project causes any other Fixed-Point Converter or MATLAB Coder projects to close.

- A MATLAB Coder project opens in the MATLAB Coder app. To convert the project to a Fixed-Point Converter app project, in the MATLAB Coder app:

  1. Click  and select **Reopen project as**.
  2. Select `Fixed-Point Converter`.

Examples

- "Propose Data Types Based on Simulation Ranges"
- "Propose Data Types Based on Derived Ranges"

Programmatic Use

`fixedPointConverter` opens the Fixed-Point Converter app.

`fixedPointConverter -tocode projectname` converts the existing project named `projectname.prj` to the equivalent script of MATLAB commands. It writes the script to the Command Window.

`fixedPointConverter -tocode projectname -script scriptname` converts the existing project named `projectname.prj` to the equivalent script of MATLAB commands. The script is named `scriptname.m`.

- If `scriptname` already exists, `fixedPointConverter` overwrites it.
- The script contains the MATLAB commands to:
  - Create a floating-point to fixed-point conversion configuration object that has the same fixed-point conversion settings as the project.
  - Run the `fiaccel` command to convert the floating-point MATLAB function to a fixed-point MATLAB function.

Before converting the project to a script, you must complete the **Test** step of the fixed-point conversion process.

See Also

Functions
`fiaccel`

Topics

"Propose Data Types Based on Simulation Ranges"
"Propose Data Types Based on Derived Ranges"
"Fixed-Point Conversion Workflows"
"Automated Fixed-Point Conversion"
"Generated Fixed-Point Code"
"Automated Conversion"

Introduced in R2014b

Fixed-Point Tool

Convert floating-point model to fixed-point

Description

In conjunction with Fixed-Point Designer software, the Fixed-Point Tool provides convenient access to:

- An interactive automatic data typing feature that proposes fixed-point data types for appropriately configured objects in your model, and then allows you to selectively accept and apply the data type proposals
- Model and subsystem parameters that control the signal logging, fixed-point instrumentation mode, and data type override
- Plotting capabilities that enable you to plot data that resides in the MATLAB workspace

Most of the functionality in the Fixed-Point Tool is for use with the Fixed-Point Designer software. However, even if you do not have Fixed-Point Designer software, you can configure data type override settings to simulate a model that specifies fixed-point data types. In this mode, the Simulink® software temporarily overrides fixed-point data types with floating-point data types when simulating the model.

Open the Fixed-Point Tool

- From the Simulink **Analysis** menu, select **Data Type Design > Fixed-Point Tool**.
- From a subsystem context (right-click) menu, select **Fixed-Point Tool**.
- From the MATLAB command prompt, enter `fxptdlg(system_name)` where `system_name` is the name of the model or system you want to convert, specified as a string.

Examples

- “Convert Floating-Point Model to Fixed Point”

- “Convert a Model to Fixed Point Using the Command Line”

See Also

“Autoscaling Using the Fixed-Point Tool” | “The Command-Line Interface for the Fixed-Point Tool” | `fxptdlg`

Topics

“Convert Floating-Point Model to Fixed Point”
“Convert a Model to Fixed Point Using the Command Line”

Introduced before R2006a

Lookup Table Optimizer

Optimize an existing lookup table or approximate a function with a lookup table

Description

Use the Lookup Table Optimizer to obtain an optimized (memory-efficient) lookup table that approximates an existing lookup table or math function. The optimizer supports any combination of floating-point and fixed-point data types. The original input and output data types can be kept or changed as desired. To minimize memory used, the optimizer selects the data types of breakpoints and table data, as well as the number and spacing of breakpoints.

Open the Lookup Table Optimizer

- In a Simulink model, select **Analysis** > **Data Type Design** > **Lookup Table Optimizer**

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`approximate` | `compare` | `displayallsolutions` | `displayfeasiblesolutions` | `solutionfromID` | `solve` | `totalmemoryusage`

Topics

"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

Single Precision Converter

Convert double-precision system to single precision

Description

The Single Precision Converter automatically converts a double-precision system to single precision.

During the conversion process, the converter replaces all user-specified double-precision data types, as well as output data types that compile to double precision, with single-precision data types. The converter does not change built-in integer, Boolean, or fixed-point data types.

Open the Single Precision Converter App

- From the Simulink **Analysis** menu, select **Data Type Design** > **Single Precision Converter**.

Examples

- "Convert a System to Single Precision"

Programmatic Use

`report = DataTypeWorkflow.Single.convertToSingle(systemToConvert)` converts the system specified by `systemToConvert` to single-precision and returns a report. The `systemToConvert` must be open before you begin the conversion.

See Also

Functions
`DataTypeWorkflow.Single.convertToSingle`

Topics

"Convert a System to Single Precision"
"Getting Started with Single Precision Converter"

Introduced in R2016b

Property Reference

fi Object Properties

The properties associated with fi objects are described in the following sections in alphabetical order.

You can set these properties when you create a fi object. For example, to set the stored integer value of a fi object:

```
x = fi(0,true,16,15,'int',4);
```

Note The fimath properties and numerictype properties are also properties of the fi object. Refer to “fimath Object Properties” and “numerictype Object Properties” for more information.

bin

Stored integer value of a fi object in binary.

data

Numerical real-world value of a fi object.

dec

Stored integer value of a fi object in decimal.

double

Real-world value of a fi object stored as a MATLAB double.

fimath

fimath properties associated with a fi object. fimath properties determine the rules for performing fixed-point arithmetic operations on fi objects. fi objects get their fimath properties from a local fimath object or from default values. The factory-default fimath values have the following settings:

```
    RoundingMethod: Nearest
    OverflowAction: Saturate
       ProductMode: FullPrecision
           SumMode: FullPrecision
```

To learn more about `fimath` objects, refer to “fimath Object Construction”. For more information about each of the `fimath` object properties, refer to “fimath Object Properties”.

hex

Stored integer value of a `fi` object in hexadecimal.

int

Stored integer value of a `fi` object, stored in a built-in MATLAB integer data type.

NumericType

The `numerictype` object contains all the data type and scaling attributes of a fixed-point object. The `numerictype` object behaves like any MATLAB structure, except that it only lets you set valid values for defined fields. For a table of the possible settings of each field of the structure, see “Valid Values for numerictype Object Properties” in the Fixed-Point Designer User's Guide.

Note You cannot change the `numerictype` properties of a `fi` object after `fi` object creation.

---

oct

Stored integer value of a `fi` object in octal.

Value

Full-precision real world value of a `fi` object, stored as a character vector.

fipref Object Properties

The properties associated with `fipref` objects are described in the following sections in alphabetical order.

DataTypeOverride

Data type override options for `fi` objects

- `ForceOff` — No data type override
- `ScaledDoubles` — Override with scaled doubles
- `TrueDoubles` — Override with doubles
- `TrueSingles` — Override with singles

Data type override only occurs when the `fi` constructor function is called.

The default value of this property is `ForceOff`.

DataTypeOverrideAppliesTo

Data type override application to `fi` objects

- `AllNumericTypes` — Apply data type override to all `fi` data types. This setting does not override builtin integer types.
- `Fixed-Point` — Apply data type override only to fixed-point data types
- `Floating-Point` — Apply data type override only to floating-point `fi` data types

`DataTypeOverrideAppliesTo` displays only if `DataTypeOverride` is not set to `ForceOff`.

The default value of this property is `AllNumericTypes`.

FimathDisplay

Display options for the `fimath` attributes of a `fi` object

- `full` — Displays all of the `fimath` attributes of a fixed-point object

- `none` — None of the `fimath` attributes are displayed

The default value of this property is `full`.

LoggingMode

Logging options for operations performed on `fi` objects

- `off` — No logging
- `on` — Information is logged for future operations

Overflows and underflows for assignment, plus, minus, and multiplication operations are logged as warnings when `LoggingMode` is set to `on`.

When `LoggingMode` is `on`, you can also use the following functions to return logged information about assignment and creation operations to the MATLAB command line:

- `maxlog` — Returns the maximum real-world value
- `minlog` — Returns the minimum value
- `noverflows` — Returns the number of overflows
- `nunderflows` — Returns the number of underflows

`LoggingMode` must be set to `on` before you perform any operation in order to log information about it. To clear the log, use the function `resetlog`.

The default value of this property of `off`.

NumericTypeDisplay

Display options for the `numerictype` attributes of a `fi` object

- `full` — Displays all the `numerictype` attributes of a fixed-point object
- `none` — None of the `numerictype` attributes are displayed.
- `short` — Displays an abbreviated notation of the fixed-point data type and scaling of a fixed-point object in the format `xWL,FL` where
  - `x` is `s` for signed and `u` for unsigned.
  - `WL` is the word length.

- FL is the fraction length.

The default value of this property is full.

NumberDisplay

Display options for the value of a fi object

- bin — Displays the stored integer value in binary format
- dec — Displays the stored integer value in unsigned decimal format
- RealWorldValue — Displays the stored integer value in the format specified by the MATLAB format function
- hex — Displays the stored integer value in hexadecimal format
- int — Displays the stored integer value in signed decimal format
- none — No value is displayed.

The default value of this property is RealWorldValue. In this mode, the value of a fi object is displayed in the format specified by the MATLAB format function: +, bank, compact, hex, long, long e, long g, loose, rat, short, short e, or short g. fi objects in rat format are displayed according to

$$\frac{1}{\left(2^{\text{fixed-point exponent}}\right)} \times \text{stored integer}$$

quantizer Object Properties

The properties associated with `quantizer` objects are described in the following sections in alphabetical order.

DataMode

Type of arithmetic used in quantization. This property can have the following values:

- `fixed` — Signed fixed-point calculations
- `float` — User-specified floating-point calculations
- `double` — Double-precision floating-point calculations
- `single` — Single-precision floating-point calculations
- `ufixed` — Unsigned fixed-point calculations

The default value of this property is `fixed`.

When you set the `DataMode` property value to `double` or `single`, the `Format` property value becomes read only.

Format

Data format of a `quantizer` object. The interpretation of this property value depends on the value of the `DataMode` property.

For example, whether you specify the `DataMode` property with fixed- or floating-point arithmetic affects the interpretation of the data format property. For some `DataMode` property values, the data format property is read only.

The following table shows you how to interpret the values for the `Format` property value when you specify it, or how it is specified in read-only cases.

DataMode Property Value	Interpreting the Format Property Values
fixed or ufixed	You specify the Format property value as a vector. The number of bits for the quantizer object word length is the first entry of this vector, and the number of bits for the quantizer object fraction length is the second entry. The word length can range from 2 to the limits of memory on your PC. The fraction length can range from 0 to one less than the word length.
float	You specify the Format property value as a vector. The number of bits you want for the quantizer object word length is the first entry of this vector, and the number of bits you want for the quantizer object exponent length is the second entry. The word length can range from 2 to the limits of memory on your PC. The exponent length can range from 0 to 11.
double	The Format property value is specified automatically (is read only) when you set the DataMode property to double. The value is [64 11], specifying the word length and exponent length, respectively.
single	The Format property value is specified automatically (is read only) when you set the DataMode property to single. The value is [32 8], specifying the word length and exponent length, respectively.

OverflowMode

Overflow-handling mode. The value of the OverflowMode property can be one of the following:

- Saturate — Overflows saturate.

  When the values of data to be quantized lie outside the range of the largest and smallest representable numbers (as specified by the data format properties), these values are quantized to the value of either the largest or smallest representable value, depending on which is closest.
- Wrap — Overflows wrap to the range of representable values.

  When the values of data to be quantized lie outside the range of the largest and smallest representable numbers (as specified by the data format properties), these values are wrapped back into that range using modular arithmetic relative to the smallest representable number.

The default value of this property is `Saturate`. This property becomes a read-only property when you set the `DataMode` property to `float`, `double`, or `single`.

Note Floating-point numbers that extend beyond the dynamic range overflow to `±inf`.

RoundingMode

Rounding method. The value of the `RoundingMode` property can be one of the following:

- `Ceiling` — Round up to the next allowable quantized value.
- `Convergent` — Round to the nearest allowable quantized value. Numbers that are exactly halfway between the two nearest allowable quantized values are rounded up only if the least significant bit (after rounding) would be set to 0.
- `Zero` — Round negative numbers up and positive numbers down to the next allowable quantized value.
- `Floor` — Round down to the next allowable quantized value.
- `Nearest` — Round to the nearest allowable quantized value. Numbers that are halfway between the two nearest allowable quantized values are rounded up.

The default value of this property is `Floor`.

Fixed-Point Tool

Fixed-Point Tool Parameters and Dialog Box

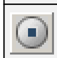
The Fixed-Point Tool includes the following components:

- **Main** toolbar
- **Model Hierarchy** pane
- **Contents** pane
- **Dialog** pane

Main Toolbar

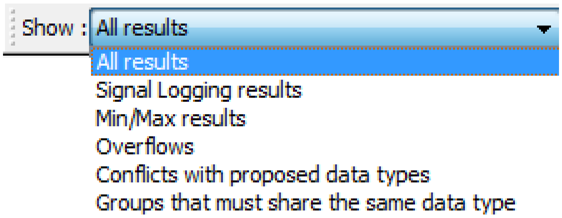
The Fixed-Point Tool's main toolbar appears near the top of the Fixed-Point Tool window under the Fixed-Point Tool's menu.

The toolbar contains the following buttons that execute commonly used Fixed-Point Tool commands:

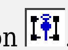
Button	Usage
	Open the Fixed-Point Advisor to prepare the model for conversion to fixed point.
	Simulate a model and store the run results.
	Pause a simulation.
	Stop a simulation.
	Analyze model and store derived minimum and maximum results.
	Propose data types. Propose fraction lengths for specified word lengths or propose word lengths for specified fraction lengths.
	Apply accepted data types.
	Compare selected runs.
	Create a difference plot for the selected signals.
	Plot the selected signal.

Button	Usage
	Create a histogram plot for the selected signal.

The toolbar also contains the **Show** option:



The **Show** option specifies the type of results to display in the **Contents** pane. The **Contents** pane displays information only after you simulate a system or propose fraction lengths. If there are no results that satisfy a particular filter option, the list will be blank.

Show Option	Result
All results	Displays all results for the selected tree node.
Signal Logging results	For the selected tree node, displays blocks whose output ports have logged signal data. The Fixed-Point tool marks these blocks with the logged signal icon . **Note** You can plot simulation results associated with logged signal data using the Simulation Data Inspector.
Min/Max results	For the selected tree node, displays blocks that record design Min/Max, simulation Min/Max, and overflow data. **Prerequisites**: **Fixed-point instrumentation mode** should not be set to `Force Off`.
Overflows	For the selected tree node, displays blocks that have non-zero overflows recorded. If a block has its **Saturate on integer overflow** option selected, overflow information appears in the **Saturations** column, otherwise it appears in the **OverflowWraps** column.

Show Option	Result
Conflicts with proposed data types	For the selected tree node, displays results that have potential data typing or scaling issues. **Prerequisites**: This information is available only after you propose data types. The Fixed-Point Tool marks these results with a yellow or red icon, as shown here:  The proposed data type poses potential issues for this object. Open the Result Details tab to review these issues.  The proposed data type will introduce errors if applied to this object. Open the Result Details tab for details about how to resolve these issues.
Groups that must share the same data type	For the selected tree node, displays blocks that must share the same data type because of data type propagation rules. **Prerequisites**: This information is available only after you propose fraction lengths. The Fixed-Point Tool allocates an identification tag to blocks that must share the same data type. This identification tag is displayed in the **DTGroup** column as follows: • If the selected tree node is the model root All results for the model are listed. The **DTGroup** column is sorted by default so that you can easily view all blocks in a group. • If the selected tree node is a subsystem The identification tags have a suffix that indicates the total number of results in each group. For example, `G2(2)` means group `G2` has 2 members. This information enables you to see how many members of a group belong to the selected subsystem and which groups share data types across subsystem boundaries.

Model Hierarchy Pane

The **Model Hierarchy** pane displays a tree-structured view of the Simulink model hierarchy. The first node in the pane represents a Simulink model. Expanding the root node displays subnodes that represent the model's subsystems, MATLAB Function blocks, Stateflow® charts, and referenced models.

The Fixed-Point Tool's **Contents** pane displays elements that comprise the object selected in the **Model Hierarchy** pane. The **Dialog** pane provides parameters for specifying the selected object's data type override and fixed-point instrumentation mode. You can also specify an object’s data type override and fixed-point instrumentation mode by right-clicking on the object. The **Model Hierarchy** pane indicates the value of these parameters by displaying the following abbreviations next to the object name:

Abbreviation	Parameter Value
Fixed-point instrumentation mode	
`mmo`	`Minimums, maximums and overflows`
`o`	`Overflows only`
`fo`	`Force off`
Data type override	
`scl`	`Scaled double`
`dbl`	`Double`
`sgl`	`Single`
`off`	`Off`

Contents Pane

The **Contents** pane displays a tabular view of objects that log fixed-point data in the system or subsystem selected in the **Model Hierarchy** pane. The table rows correspond to model objects, such as blocks, block parameters, and Stateflow data. The table columns correspond to attributes of those objects, such as the data type, design minimum and maximum values, and simulation minimum and maximum values.

The **Contents** pane displays information only after you simulate a system, analyze the model to derive minimum and maximum values, or propose fraction lengths.

You can control which of the following columns the Fixed-Point Tool displays in this pane. For more information, see “Customizing the Contents Pane View” on page 3-8.

Column Label	Description
Accept	Check box that enables you to selectively accept the Fixed-Point Tool's data type proposal.
CompiledDesignMax	Compile-time information for **DesignMax**.
CompiledDesignMin	Compile-time information for **DesignMin**.
CompiledDT	Compile-time data type. This data type appears on the signal line in `sfix` format. See “Fixed-Point Data Type and Scaling Notation”.
DerivedMax	Maximum value the Fixed-Point tool derives for this signal from design ranges specified for blocks.
DerivedMin	Minimum value the Fixed-Point tool derives for this signal from design ranges specified for blocks.
DesignMax	Maximum value the block specifies in its parameter dialog box, for example, the value of its **Output maximum** parameter.
DesignMin	Minimum value the block specifies in its parameter dialog box, for example, the value of its **Output minimum** parameter.
DivByZero	Number of divide-by-zero instances that occur during simulation.
DTGroup	Identification tag associated with objects that share data types.
InitValueMax	Maximum initial value for a signal or parameter. Some model objects provide parameters that allow you to specify the initial values of their signals. For example, the Constant block includes a **Constant value** that initializes the block output signal. **Note** The Fixed-Point Tool uses this parameter when it proposes data types.

Column Label	Description
InitValueMin	Minimum initial value for a signal or parameter. Some model objects provide parameters that allow you to specify the initial values of their signals. For example, the Constant block includes a **Constant value** that initializes the block output signal. **Note** The Fixed-Point Tool uses this parameter when it proposes data types.
LogSignal	Check box that allows you to enable or disable signal logging for an object.
ModelRequiredMin	Minimum value of a parameter used during simulation. For example, the n-D Lookup Table block uses the **Breakpoints** and **Table data** parameters to perform its lookup operation and generate output. In this example, the block uses more than one parameter so the Fixed-Point Tool sets **ModelRequiredMin** to the minimum of the minimum values of all these parameters. **Note** The Fixed-Point Tool uses this parameter when it proposes data types.
ModelRequiredMax	Maximum value of a parameter used during simulation. For example, the n-D Lookup Table block uses the **Breakpoints** and **Table data** parameters to perform its lookup operation and generate output. In this example, the block uses more than one parameter so the Fixed-Point Tool sets **ModelRequiredMax** to the maximum of the maximum values of all these parameters. **Note** The Fixed-Point Tool uses this parameter when it proposes data types.
Name	Identifies path and name of block.
OverflowWraps	Number of overflows that wrap during simulation.
ProposedDT	Data type that the Fixed-Point Tool proposes.

Column Label	Description
ProposedMax	Maximum value that results from the data type the Fixed-Point Tool proposes.
ProposedMin	Minimum value that results from the data type the Fixed-Point Tool proposes.
Run	Indicates the run name for these results.
Saturations	Number of overflows that saturate during simulation.
SimDT	Data type the block uses during simulation. This data type appears on the signal line in `sfix` format. See “Fixed-Point Data Type and Scaling Notation”.
SimMax	Maximum value that occurs during simulation.
SimMin	Minimum value that occurs during simulation.
SpecifiedDT	Data type the block specifies in its parameter dialog box, for example, the value of its **Output data type** parameter.

Customizing the Contents Pane View

You can customize the **Contents** pane in the following ways:

- “Using Column Views” on page 3-8
- “Changing Column Order and Width” on page 3-10
- “Sorting by Columns” on page 3-10

Using Column Views

The Fixed-Point Tool provides the following standard Column Views:

View Name	Columns Provided	When Does the Fixed-Point Tool Display this View?
`Simulation View` (default)	**Name**, **Run**, **CompiledDT**, **SpecifiedDT**, **SimMin**, **SimMax**, **DesignMin**, **DesignMax**, **OverflowWraps**, **Saturations**	After a simulating minimum and maximum values.

View Name	Columns Provided	When Does the Fixed-Point Tool Display this View?
`Automatic Data Typing View`	**Name**, **Run**, **CompiledDT**, **CompiledDesignMax**, **CompiledDesignMin**,**Accept**, **ProposedDT**, **SpecifiedDT**, **DesignMin**, **DesignMax**, **DerivedMin**, **DerivedMax**, **SimMin**, **SimMax**, **OverflowWraps**, **Saturations**, **ProposedMin**, **ProposedMax**	After proposing data types if proposal is based on simulation, derived, and design min/max.
`Automatic Data Typing With Simulation Min/Max View`	**Name**, **Run**, **CompiledDT**, **Accept**, **ProposedDT**, **SpecifiedDT**, **SimMin**, **SimMax**, **DesignMin**, **DesignMax**, **OverflowWraps**, **Saturations**, **ProposedMin**, **ProposedMax**	After proposing data types if the proposal is based on simulation and design min/max.
`Automatic Data Typing With Derived Min/Max View`	**Name**, **Run**, **CompiledDesignMax**, **CompiledDesignMin**,**Accept**, **ProposedDT**, **SpecifiedDT**, **DerivedMin**, **DerivedMax**, **ProposedMin**, **ProposedMax**	After proposing data types if the proposal is based on design min/max and/or derived min/max.
`Data Collection View`	**Name**, **Run**, **CompiledDT**, **SpecifiedDT**, **DerivedMin**, **DerivedMax**, **SimMin**, **SimMax**, **OverflowWraps**, **Saturations**	After simulating or deriving minimum and maximum values if the results have simulation min/max, derived min/max, and design min/max.
`Derived Min/Max View`	**Name**, **Run**, **CompiledDesignMax**, **CompiledDesignMin**, **DerivedMin**, **DerivedMax**	After deriving minimum and maximum values.

By selecting **Show Details**, you can:

- Customize the standard column views
- Create your own column views

- Export and import column views saved in MAT-files, which you can share with other users
- Reset views to factory settings

  If you upgrade to a new release of Simulink, and the column views available in the Fixed-Point Tool do not match the views described in the documentation, reset your views to factory settings. When you reset all views, the Model Explorer removes all the custom views you have created. Before you reset views to factory settings, export any views that you will want to use in the future.

You can prevent the Fixed-Point Tool from automatically changing the column view of the contents pane by selecting **View > Lock Column View** in the Fixed-Point Tool menu. For more information on controlling views, see “Customize Model Explorer Views” (Simulink).

Changing Column Order and Width

You can alter the order and width of columns that appear in the **Contents** pane as follows:

- To move a column, click and drag the head of a column to a new location among the column headers.
- To make a column wider or narrower, click and drag the right edge of a column header. If you double-click the right edge of a column header, the column width changes to fit its contents.

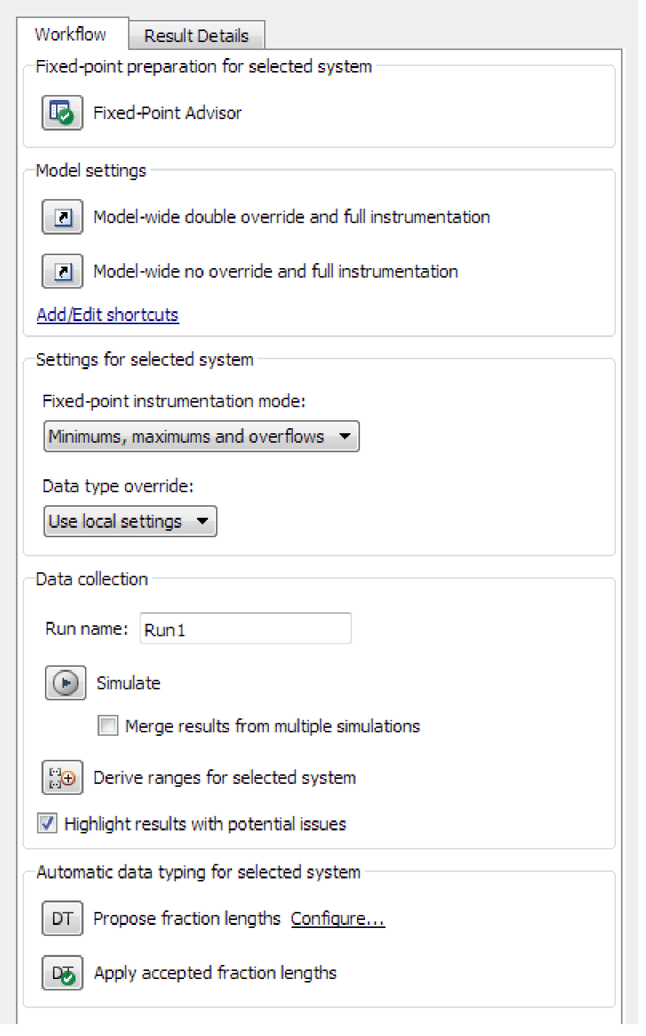
Sorting by Columns

By default, the **Contents** pane displays its contents in ascending order of the **Name** column. You can alter the order in which the **Contents** pane displays its rows as follows:

- To sort all the rows in ascending order of another column, click the head of that column.
- To change the order from ascending to descending, simply click again on the head of that column.

Dialog Pane

Use the Dialog pane to view and change properties associated with the system under design.



The Dialog pane includes the following components:

Component	Description
System under design	Displays the system under design for conversion. You can change the selected system by clicking **Change**.

Component	Description
Fixed-point preparation	Contains the **Fixed-Point Advisor** button. Use this button to open the Fixed-Point Advisor to guide you through the tasks to prepare your floating-point model for conversion to fixed point. For more information, see "Fixed-Point Advisor" on page 3-12.
Configure model settings	Contains default configurations that set up run parameters, such as the run name and data type override settings, by clicking a button. For more information, see "Configure model settings" on page 3-13.
Range collection	Contains controls to collect simulation or derived minimum and maximum data for your model.
Automatic data typing	Contains controls to propose and, optionally, accept data type proposals.
Result Details tab	Use this tab to view data type information about the object selected in the **Contents** pane.

Tips

From the Fixed-Point Tool **View** menu, you can customize the layout of the **Dialog** pane. Select:

- **Show Fixed-Point Preparation** to show/hide the **Fixed-Point Advisor** button. By default, the Fixed-Point Tool displays this button.
- **Show Dialog View** to show/hide the **Dialog** pane. By default, the Fixed-Point Tool displays this pane.
- **Settings for selected system** to show/hide the **Settings for selected system** pane. By default, the Fixed-Point Tool displays this pane.

Fixed-Point Advisor

Open the Fixed-Point Advisor to guide you through the tasks to prepare a floating-point model for conversion to fixed point. Use the Fixed-Point Advisor if your model contains blocks that do not support fixed-point data types.

Configure model settings

Use the configurations to set up model-wide data type override and instrumentation settings prior to simulation. The Fixed-Point Tool provides:

- Frequently-used factory default configurations
- The ability to add and edit custom configurations

Note The factory default configurations apply to the whole model. You cannot use these shortcuts to configure subsystems.

Factory Defaults

Factory Default Configuration	Description
Range collection using double override	Use this configuration to observe ideal numeric behavior of the model and collect ranges for data type proposals. This configuration sets: • **Run name** to `DoubleOverride` • **Fixed-point instrumentation mode** to `Minimums, maximums and overflows` • **Data type override** to `Double` • **Data type override applies to** to `All numeric types` By default, a button for this configuration appears in the **Configure model settings** pane.

Factory Default Configuration	Description
Range collection with specified data types	Use this configuration to collect ranges of actual model and to validate current behavior. This configuration sets: • **Run name** to `NoOverride` • **Fixed-point instrumentation mode** to `Minimums, maximums and overflows` • **Data type override** to `Use local settings` By default, a button for this shortcut appears in the **Configure model settings** pane.
Remove overrides and disable range collection	Use this configuration to cleanup settings after finishing fixed-point conversion and to restore maximum simulation speed. This configuration sets: • **Fixed-point instrumentation mode** to `Off` • **Data type override** to `Use local settings` By default, a button for this shortcut appears in the **Configure model settings** pane.

Advanced settings

Use **Advanced settings** to add new configurations or edit existing user-defined configurations.

Run name

Specifies the run name

If you use a default configuration to set up a run, the Fixed-Point Tool uses the run name associated with this configuration. You can override the run name by entering a new name in this field.

Tips

- To store data for multiple runs, provide a different run name for each run. Running two simulations with the same run name overwrites the original run unless you select **Merge results from multiple simulations**.
- You can edit the run name in the Contents pane **Run** column.

For more information, see “Run Management”.

Simulate

Simulates model and stores results.

Action

Simulates the model and stores the results with the run name specified in **Run name**. The Fixed-Point Tool displays the run name in the **Run** column of the **Contents** pane.

Merge instrumentation results from multiple simulations

Control how simulation results are stored

Settings

Default: Off

On

Merges new simulation minimum and maximum results with existing simulation results in the run specified by the run name parameter. Allows you to collect complete range information from multiple test benches. Does not merge signal logging results.

Off

Clears all existing simulation results from the run specified by the run name parameter before displaying new simulation results.

Command-Line Alternative

Parameter: `'MinMaxOverflowArchiveMode'`
Type: string
Value: `'Overwrite'` | `'Merge'`

Default: `'Overwrite'`

Tip

Select this parameter to log simulation minimum and maximum values captured over multiple simulations. For more information, see “Propose Data Types For Merged Simulation Ranges”.

Derive ranges for selected system

Derive minimum and maximum values for signals for the selected system.

The Fixed-Point Tool analyzes the selected system to compute derived minimum and maximum values based on design minimum and maximum values specified on blocks. For example, using the **Output minimum** and **Output maximum** for block outputs.

Action

Analyzes the selected system to compute derived minimum and maximum information based on the design minimum and maximum values specified on blocks.

By default, the Fixed-Point Tool displays the `Derived Min/Max View` with the following information in the **Contents** pane.

Command-Line Alternative

No command line alternative available.

Dependencies

Range analysis:

- Requires a Fixed-Point Designer license.

Propose

Signedness

Select whether you want The Fixed-Point Tool to propose signedness for results in your model. The Fixed-Point Tool proposes signedness based on collected range data and block constraints. By default, the **Signedness** check box is selected.

When the check box is selected, signals that are always strictly positive get an unsigned data type proposal. If you clear the check box, the Fixed-Point Tool proposes a signed data type for all results that currently specify a floating-point or an inherited output data type unless other constraints are present. If a result specifies a fixed-point output data type, the Fixed-Point Tool will propose a data type with the same signedness as the currently specified data type unless other constraints are present.

Word length or fraction length

Select whether you want the Fixed-Point Tool to propose word lengths or fraction lengths for the objects in your system.

- If you select **Word length**, the Fixed-Point Tool proposes a data type with the specified fraction length and the minimum word length to avoid overflows.
- If you select **Fraction length**, the Fixed-Point Tool proposes a data type with the specified word length and best-precision fraction length while avoiding overflows.

If a result currently specifies a fixed-point data type, that information will be used in the proposal. If a result specifies a floating-point or inherited output data type, and the **Inherited** and **Floating point** check boxes are selected, the Fixed-Point Tool uses the settings specified under **Automatic data typing** to make a data type proposal.

Propose for

Inherited

Propose data types for results that specify one of the inherited output data types.

Floating-point

Propose data types for results that specify floating-point output data types.

Default fraction length

Specify the default fraction length for objects in your model. The Fixed-Point Tool proposes a data type with the specified fraction length and the minimum word length that avoids overflows.

Command-Line Alternative

No command line alternative available.

Default word length

Specify the default word length for objects in your model. The Fixed-Point Tool will propose best-precision fraction lengths based on the specified default word length.

Command-Line Alternative

No command line alternative available.

When proposing types use

Specify the types of ranges to use for data type proposals.

Design and derived ranges

The Fixed-Point Tool uses the design ranges in conjunction with derived ranges to propose data types. Design ranges take precedence over derived ranges.

Design and simulation ranges

The Fixed-Point Tool uses the design ranges in conjunction with collected simulation ranges to propose data types. Design ranges take precedence over simulation ranges.

The **Safety margin for simulation min/max (%)** parameter specifies a range that differs from that defined by the simulation range. For more information, see “Safety margin for simulation min/max (%)” on page 3-18

All collected ranges

The Fixed-Point Tool uses design ranges in addition to derived and simulation ranges to propose data types.

Design minimum and maximum values take precedence over simulation and derived ranges.

Command-Line Alternative

No command line alternative available.

Safety margin for simulation min/max (%)

Specify safety factor for simulation minimum and maximum values.

Settings

Default: 0

The simulation minimum and maximum values are adjusted by the percentage designated by this parameter, allowing you to specify a range different from that obtained from the simulation run. The specified safety margin must be a real number greater than `-100`. For example, a value of 55 specifies that a range *at least* 55 percent larger is desired. A value of -15 specifies that a range *up to* 15 percent smaller is acceptable.

Dependencies

Before performing automatic data typing, you must specify design minimum and maximum values or run a simulation to collect simulation minimum and maximum data, or collect derived minimum and maximum values.

Command-Line Alternative

No command line alternative available.

Advanced Settings

In this section...

Advanced Settings Overview

Use the Advanced Settings dialog to control the fixed-point instrumentation mode, and data type override settings. You can also use the Advanced Settings dialog to add or edit user-defined configurations. You cannot modify the factory default configurations. If you add a new configuration and want it to appear as a button on the Fixed-Point Tool **Configure model settings** pane, use the controls in the **Shortcuts** tab.

Fixed-point instrumentation mode

Control which objects log minimum, maximum and overflow data during simulation.

Settings

Default: `Use local settings`

`Use local settings`

Logs data according to the value of this parameter set for each subsystem. Otherwise, settings for parent systems always override those of child systems.

`Minimums, maximums and overflows`

Logs minimum value, maximum value, and overflow data for all blocks in the current system or subsystem during simulation.

`Overflows only`

Logs only overflow data for all blocks in the current system or subsystem.

`Force off`

Does not log data for any block in the current system or subsystem. Use this selection to work with models containing fixed-point enabled blocks if you do not have a Fixed-Point Designer license.

Tips

- You cannot change the instrumentation mode for linked subsystems or referenced models.

Dependencies

The value of this parameter for parent systems controls min/max logging for all child subsystems, unless `Use local settings` is selected.

Command-Line Alternative

Parameter: `'MinMaxOverflowLogging'`
Type: string
Value: `'UseLocalSettings'` | `'MinMaxAndOverflow'` | `'OverflowOnly'` | `'ForceOff'`
Default: `'UseLocalSettings'`

Data type override

Control data type override of objects that allow you to specify data types in their dialog boxes.

Settings

Default: `Use local settings`

The value of this parameter for parent systems controls data type override for all child subsystems, unless `Use local settings` is selected.

`Use local settings`

Overrides data types according to the setting of this parameter for each subsystem.

`Scaled double`

Overrides the data type of all blocks in the current system and subsystem with doubles; however, the scaling and bias specified in the dialog box of each block is maintained.

`Double`

Overrides the output data type of all blocks in the current system or subsystem with doubles. The overridden values have no scaling or bias.

`Single`

Overrides the output data type of all blocks in the current system or subsystem with singles. The overridden values have no scaling or bias.

`Off`

No data type override is performed on any block in the current system or subsystem. The settings on the blocks are used.

Tips

- Set this parameter to `Double` or `Single` and the **Data type override applies to** parameter to `All numeric types` to work with models containing fixed-point enabled blocks if you do not have a Fixed-Point Designer license.
- You cannot change the **Data type override** setting on linked subsystems or referenced models.
- Data type override never applies to `boolean` data types.
- When you set the **Data type override** parameter of a parent system to `Double`, `Single`, `Scaled double` or `Off`, this setting also applies to all child subsystems and you cannot change the data type override setting for these child subsystems. When the **Data type override** parameter of a parent system is `Use local settings`, you can set the **Data type override** parameter for individual children.
- Use this parameter with the **Data type override applies to** parameter. The following table details how these two parameters affect the data types in your model.

Fixed-Point Tool Settings		Block Local Settings	
Data type override	**Data type override applies to**	**Floating-point types**	**Fixed-point types**
Use local settings/Off	N/A	Unchanged	Unchanged
Double	All numeric types	Double	Double
	Floating-point	Double	Unchanged
	Fixed-point	Unchanged	Double
Single	All numeric types	Single	Single
	Floating-point	Single	Unchanged
	Fixed-point	Unchanged	Single
Scaled double	All numeric types	Double	Scaled double equivalent of fixed-point type
	Floating-point	Double	Unchanged
	Fixed-point	Unchanged	Scaled double equivalent of fixed-point type

Dependencies

- The following Simulink blocks allow you to set data types in their block masks, but ignore the **Data type override** setting:
  - Probe
  - Trigger
  - Width

Command-Line Alternative

Parameter: `'DataTypeOverride'`
Type: string
Value: `'UseLocalSettings' | 'ScaledDouble' | 'Double' | 'Single' | 'Off'`
Default: `'UseLocalSettings'`

Data type override applies to

Specifies which data types the Fixed-Point Tool overrides

Settings

Default: `All numeric types`

`All numeric types`

Data type override applies to all numeric types, floating-point and fixed-point. It does not apply to `boolean` or enumerated data types.

`Floating-point`

Data type override applies only to floating-point data types, that is, `double` and `single`.

`Fixed-point`

Data type override applies only to fixed-point data types, for example, `uint8`, `fixdt`.

Tips

- Use this parameter with the **Data type override** parameter.
- Data type override never applies to `boolean` or enumerated data types or to buses.
- When you set the **Data type override** parameter of a parent system to `Double`, `Single`, `Scaled double` or `Off`, this setting also applies to all child subsystems and you cannot change the data type override setting for these child subsystems. When the **Data type override** parameter of a parent system is `Use local setting`, you can set the **Data type override** parameter for individual children.
- The following table details how these two parameters affect the data types in your model.

Fixed-Point Tool Settings		Block Local Settings	
Data type override	**Data type override applies to**	**Floating-point types**	**Fixed-point types**
Use local settings/Off	N/A	Unchanged	Unchanged
Double	All numeric types	Double	Double
	Floating-point	Double	Unchanged
	Fixed-point	Unchanged	Double
Single	All numeric types	Single	Single
	Floating-point	Single	Unchanged
	Fixed-point	Unchanged	Single

Fixed-Point Tool Settings		Block Local Settings	
Data type override	**Data type override applies to**	**Floating-point types**	**Fixed-point types**
Scaled double	All numeric types	Double	Scaled double equivalent of fixed-point type
	Floating-point	Double	Unchanged
	Fixed-point	Unchanged	Scaled double equivalent of fixed-point type

Dependencies

This parameter is enabled only when **Data type override** is set to `Scaled double`, `Double` or `Single`.

Command-Line Alternative

Parameter: `'DataTypeOverrideAppliesTo'`
Type: string
Value: `'AllNumericTypes'` | `'Floating-point'` | `'Fixed-point'`
Default: `'AllNumericTypes'`

Name of shortcut

Enter a unique name for your shortcut. By default, the Fixed-Point Tool uses this name as the **Run name** for this shortcut.

If the shortcut name already exists, the new settings overwrite the existing settings.

See Also

- “Run Management”

Allow modification of fixed-point instrumentation settings

Select whether to change the model fixed-point instrumentation settings when you apply this shortcut to the model.

Settings

Default: On

On

When you apply this shortcut to the model, changes the fixed-point instrumentation settings of the model and its subsystems to the setting defined in this shortcut.

Off

Does not change the fixed-point instrumentation settings when you apply this shortcut to the model.

Tip

If you want to control data type override settings without altering the fixed-point instrumentation settings on your model, clear this option.

See Also

- "Run Management"

Allow modification of data type override settings

Select whether to change the model data type override settings when you apply this shortcut to the model

Settings

Default: On

On

When you apply this shortcut to the model, changes the data type override settings of the model and its subsystems to the settings defined in this shortcut .

Off

Does not change the fixed-point instrumentation settings when you apply this shortcut to the model.

Allow modification of run name

Select whether to change the run name on the model when you apply this shortcut to the model

Settings

Default: On

 On

Changes the run name to the setting defined in this shortcut when you apply this shortcut to the model.

 Off

Does not change the run name when you apply this shortcut to the model.

Run name

Specify the run name to use when you apply this shortcut.

By default, the run name uses the name of the shortcut. Run names are case sensitive.

Dependency

Allow modification of run name enables this parameter.

Capture system settings

Copy the model and subsystem fixed-point instrumentation mode and data type override settings into the Shortcut editor.

Fixed-point instrumentation mode

Control which objects in the shortcut editor log minimum, maximum and overflow data during simulation.

This information is stored in the shortcut. To use the current model setting, click **Capture system settings**.

Settings

Default: Same as model setting

`Use local settings`

Logs data according to the value of this parameter set for each subsystem. Otherwise, settings for parent systems always override those of child systems.

`Minimums, maximums and overflows`

Logs minimum value, maximum value, and overflow data for all blocks in the current system or subsystem during simulation.

`Overflows only`

Logs only overflow data for all blocks in the current system or subsystem.

`Force off`

Does not log data for any block in the current system or subsystem. Use this selection to work with models containing fixed-point enabled blocks if you do not have a Fixed-Point Designer license.

Dependency

Allow modification of fixed-point instrumentation settings enables this parameter.

Data type override

Control data type override of objects that allow you to specify data types in their dialog boxes.

This information is stored in the shortcut. To use the current model settings, click **Capture system settings**.

Settings

Default: Same as model

The value of this parameter for parent systems controls data type override for all child subsystems, unless `Use local settings` is selected.

`Use local settings`

Overrides data types according to the setting of this parameter for each subsystem.

`Scaled double`

Overrides the data type of all blocks in the current system and subsystem with doubles; however, the scaling and bias specified in the dialog box of each block is maintained.

`Double`

Overrides the output data type of all blocks in the current system or subsystem with doubles. The overridden values have no scaling or bias.

`Single`

Overrides the output data type of all blocks in the current system or subsystem with singles. The overridden values have no scaling or bias.

`Off`

No data type override is performed on any block in the current system or subsystem. The settings on the blocks are used.

Dependency

Allow modification of data type override settings enables this parameter.

Data type override applies to

Specifies which data types to override when you apply this shortcut.

This information is stored in the shortcut. To use the current model setting, click **Capture system settings**.

Settings

Default: `All numeric types`

`All numeric types`

Data type override applies to all numeric types, floating-point and fixed-point. It does not apply to `boolean` or enumerated data types.

`Floating-point`

Data type override applies only to floating-point data types, that is, `double` and `single`.

`Fixed-point`

Data type override applies only to fixed-point data types, for example, `uint8`, `fixdt`.

Dependency

Allow modification of data type override settings enables this parameter.

Functions — Alphabetical List

abs

Absolute value of fi object

Syntax

```
c = abs(a)
c = abs(a,T)
c = abs(a,F)
c = abs(a,T,F)
```

Description

c = abs(a) returns the absolute value of fi object a with the same numerictype object as a. Intermediate quantities are calculated using the fimath associated with a. The output fi object c has the same local fimath as a.

c = abs(a,T) returns a fi object with a value equal to the absolute value of a and numerictype object T. Intermediate quantities are calculated using the fimath associated with a and the output fi object c has the same local fimath as a. See "Data Type Propagation Rules" on page 4-3.

c = abs(a,F) returns a fi object with a value equal to the absolute value of a and the same numerictype object as a. Intermediate quantities are calculated using the fimath object F. The output fi object c has no local fimath.

c = abs(a,T,F) returns a fi object with a value equal to the absolute value of a and the numerictype object T. Intermediate quantities are calculated using the fimath object F. The output fi object c has no local fimath. See "Data Type Propagation Rules" on page 4-3.

Note When the Signedness of the input numerictype object T is Auto, the abs function always returns an Unsigned fi object.

---

abs only supports fi objects with [Slope Bias] scaling when the bias is zero and the fractional slope is one. abs does not support complex fi objects of data type Boolean.

When the object a is real and has a signed data type, the absolute value of the most negative value is problematic since it is not representable. In this case, the absolute value saturates to the most positive value representable by the data type if the OverflowAction property is set to saturate. If OverflowAction is wrap, the absolute value of the most negative value has no effect.

Data Type Propagation Rules

For syntaxes for which you specify a numerictype object T, the abs function follows the data type propagation rules listed in the following table. In general, these rules can be summarized as “floating-point data types are propagated.” This allows you to write code that can be used with both fixed-point and floating-point inputs.

Data Type of Input fi Object a	Data Type of numerictype object T	Data Type of Output c
fi Fixed	fi Fixed	Data type of numerictype object T
fi ScaledDouble	fi Fixed	ScaledDouble with properties of numerictype object T
fi double	fi Fixed	fi double
fi single	fi Fixed	fi single
Any fi data type	fi double	fi double
Any fi data type	fi single	fi single

Examples

Example 1

The following example shows the difference between the absolute value results for the most negative value representable by a signed data type when OverflowAction is saturate or wrap.

```
P = fipref('NumericTypeDisplay','full',...
           'FimathDisplay','full');
```

```
a = fi(-128)

a =

  -128

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

abs(a)

ans =

  127.9961

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

a.OverflowAction = 'Wrap'

a =

  -128

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

  abs(a)

ans =

  -128
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Example 2

The following example shows the difference between the absolute value results for complex and real `fi` inputs that have the most negative value representable by a signed data type when `OverflowAction` is `wrap`.

```
re = fi(-1,1,16,15)

re =

    -1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15

im = fi(0,1,16,15)

im =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15

a = complex(re,im)

a =

    -1
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15

abs(a,re.numerictype,fimath('OverflowAction','Wrap'))

ans =

    1.0000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15

abs(re,re.numerictype,fimath('OverflowAction','Wrap'))

ans =

    -1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15
```

Example 3

The following example shows how to specify `numerictype` and `fimath` objects as optional arguments to control the result of the `abs` function for real inputs. When you specify a `fimath` object as an argument, that `fimath` object is used to compute intermediate quantities, and the resulting `fi` object has no local fimath.

```
a = fi(-1,1,6,5,'OverflowAction','Wrap')

a =

    -1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
```

```
        FractionLength: 5

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

abs(a)

ans =

    -1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 5

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

f = fimath('OverflowAction','Saturate')

f =

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

abs(a,f)

ans =

    0.9688

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 5

t = numerictype(a.numerictype, 'Signed', false)
```

```
t =


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 6
        FractionLength: 5

abs(a,t,f)

ans =

     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 6
        FractionLength: 5
```

Example 4

The following example shows how to specify `numerictype` and `fimath` objects as optional arguments to control the result of the `abs` function for complex inputs.

```
a = fi(-1-i,1,16,15,'OverflowAction','Wrap')

a =

  -1.0000 - 1.0000i

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

t = numerictype(a.numerictype,'Signed',false)
```

```
t =


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 15

abs(a,t)

ans =

    1.4142

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 15

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

f = fimath('OverflowAction','Saturate','SumMode',...
        'KeepLSB','SumWordLength',a.WordLength,...
        'ProductMode','specifyprecision',...
        'ProductWordLength',a.WordLength,...
        'ProductFractionLength',a.FractionLength)

f =


        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: SpecifyPrecision
     ProductWordLength: 16
 ProductFractionLength: 15
               SumMode: KeepLSB
         SumWordLength: 16
         CastBeforeSum: true

abs(a,t,f)
```

```
ans =

    1.4142

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 15
```

Algorithms

The absolute value y of a real input a is defined as follows:

y = a if a >= 0

y = -a if a < 0

The absolute value y of a complex input a is related to its real and imaginary parts as follows:

```
y = sqrt(real(a)*real(a) + imag(a)*imag(a))
```

The abs function computes the absolute value of complex inputs as follows:

1 Calculate the real and imaginary parts of a using the following equations:

   ```
   re = real(a)

   im = imag(a)
   ```
2 Compute the squares of re and im using one of the following objects:

   - The fimath object F if F is specified as an argument.
   - The fimath associated with a if F is not specified as an argument.
3 Cast the squares of re and im to unsigned types if the input is signed.
4 Add the squares of re and im using one of the following objects:

   - The fimath object F if F is specified as an argument.
   - The fimath object associated with a if F is not specified as an argument.

5 Compute the square root of the sum computed in step four using the `sqrt` function with the following additional arguments:

- The `numerictype` object `T` if `T` is specified, or the `numerictype` object of `a` otherwise.
- The `fimath` object `F` if `F` is specified, or the `fimath` object associated with `a` otherwise.

Note Step three prevents the sum of the squares of the real and imaginary components from being negative. This is important because if either `re` or `im` has the maximum negative value and the `OverflowAction` property is set to `wrap` then an error will occur when taking the square root in step five.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

accumneg

Subtract two `fi` objects or values

Syntax

```
c = accumneg(a,b)
c = accumneg(a,b,RoundingMethod)
c = accumneg(a,b,RoundingMethod,OverflowAction)
```

Description

`c = accumneg(a,b)` subtracts `b` from `a` using `a`'s data type. `b` is cast into `a`'s data type. If `a` is a fi object, the default `'Floor'` rounding method and default `'Wrap'` overflow action are used. The `fimath` properties of `a` and `b` are ignored.

`c = accumneg(a,b,RoundingMethod)` uses the rounding method specified in `RoundingMethod`.

`c = accumneg(a,b,RoundingMethod,OverflowAction)` uses the overflow action specified in `OverflowAction`.

Input Arguments

a

Number from which to subtract. `a` can be `fi` object or double, single, logical, or integer value. The data type of `a` is used to compute the output data type.

b

Number to subtract. `b` can be `fi` object or double, single, logical, or integer value. .

RoundingMethod

Rounding method to use if `a` is a `fi` object. Valid values are `'Ceiling'`, `'Convergent'`, `'Floor'`, `'Nearest'`, `'Round'` and `'Zero'`.

Default: `Floor`

OverflowAction

Overflow action to take if `a` is a `fi` object. Valid values are `'Saturate'` and `'Wrap'`,

Default: `Wrap`

Output Arguments

c

Result of subtracting input `b` from input `a`.

Examples

Subtract `fi` numbers using default `accumneg` settings and then, using non-default rounding method and overflow action.

```
a = fi(pi,1,16,13);
b = fi(1.5,1,16,14);
subtr_default  = accumneg(a,b);
subtr_custom = accumneg(a,b,'Nearest','Saturate');
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`accumneg`

Topics

"Avoid Multiword Operations in Generated Code"

Introduced in R2012a

accumpos

Add two fi objects or values

Syntax

```
c = accumpos(a,b)
c = accumpos(a,b,RoundingMethod)
c = accumpos(a,b,RoundingMethod,OverflowAction)
```

Description

c = accumpos(a,b) adds a and b using the a's data type. b is cast into a's data type. If a is a fi object, the default 'Floor' rounding method and default 'Wrap' overflow action are used. The fimath properties of a and b are ignored.

c = accumpos(a,b,RoundingMethod) uses the rounding method specified in RoundingMethod.

c = accumpos(a,b,RoundingMethod,OverflowAction) uses the overflow action specified in OverflowAction.

Input Arguments

a

Number to add. a can be fi object or double, single, logical, or integer value. The data type of a is used to compute the output data type.

b

Number to add. b can be fi object or double, single, logical, or integer value.

RoundingMethod

Rounding method to use if a is a fi object. Valid values are 'Ceiling', 'Convergent', 'Floor', 'Nearest', 'Round', and 'Zero'.

Default: Floor

OverflowAction

Overflow action to take if a is a fi object. Valid values are 'Saturate' and 'Wrap'.

Default: Wrap

Output Arguments

c

Result of adding the a and b inputs.

Examples

Add two fi numbers using default accumpos settings and then, using nondefault rounding method and overflow action.

```
a = fi(pi,1,16,13);
b = fi(1.5,1,16,14);
add_default  = accumpos(a,b);
add_custom = accumpos(a,b,'Nearest','Saturate');
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`accumneg`

Topics

"Avoid Multiword Operations in Generated Code"

Introduced in R2012a

add

Add two objects using `fimath` object

Syntax

`c = add(F,a,b)`

Description

`c = add(F,a,b)` adds objects `a` and `b` using `fimath` object `F`. This is helpful in cases when you want to override the `fimath` objects of `a` and `b`, or if the `fimath` properties associated with `a` and `b` are different. The output `fi` object `c` has no local fimath.

`a` and `b` must both be `fi` objects and must have the same dimensions unless one is a scalar. If either `a` or `b` is scalar, then `c` has the dimensions of the nonscalar object.

Examples

Add Two Fixed-Point Numbers

In this example, `c` is the 32-bit sum of `a` and `b` with fraction length 16.

```
a = fi(pi);
b = fi(exp(1));
F = fimath('SumMode','SpecifyPrecision',...
  'SumWordLength',32,'SumFractionLength',16);
c = add(F,a,b)
```

```
c = 
    5.8599

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 16
```

Algorithms

`c = add(F,a,b)` is similar to

```
a.fimath = F;
b.fimath = F;
c = a + b
c =

    5.8599

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 16

        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: SpecifyPrecision
         SumWordLength: 32
     SumFractionLength: 16
         CastBeforeSum: true
```

but not identical. When you use `add`, the `fimath` properties of `a` and `b` are not modified, and the output `fi` object `c` has no local fimath. When you use the syntax `c = a + b`, where `a` and `b` have their own `fimath` objects, the output `fi` object `c` gets assigned the same `fimath` object as inputs `a` and `b`. See “fimath Rules for Fixed-Point Arithmetic” in the Fixed-Point Designer User's Guide for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The syntax `F.add(a,b)` is not supported. You must use the syntax `add(F,a,b)`.

See Also

`divide` | `fi` | `fimath` | `mpy` | `mrdivide` | `numerictype` | `rdivide` | `sub` | `sum`

Introduced before R2006a

all

Determine whether all array elements are nonzero

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `all` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

and

Find logical AND of array or scalar inputs

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `and` reference page for more information.

Introduced before R2006a

any

Determine whether any array elements are nonzero

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `any` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

area

Create filled area 2-D plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `area` reference page for more information.

Introduced before R2006a

assignmentquantizer

Assignment `quantizer` object of `fi` object

Syntax

```
q = assignmentquantizer(a)
```

Description

`q = assignmentquantizer(a)` returns the `quantizer` object `q` that is used in assignment operations for the `fi` object `a`.

See Also

`quantize` | `quantizer`

Introduced in R2008a

atan2

Four-quadrant inverse tangent of fixed-point values

Syntax

```
z = atan2(y,x)
```

Description

`z = atan2(y,x)` returns the four-quadrant arctangent on page 4-28 of fi input `y/x` using a table-lookup algorithm.

Input Arguments

y,x

`y` and `x` can be real-valued, signed or unsigned scalars, vectors, matrices, or `N`-dimensional arrays containing fixed-point angle values in radians. The lengths of `y` and `x` must be the same. If they are not the same size, at least one input must be a scalar value. Valid data types of `y` and `x` are:

- fi single
- fi double
- fi fixed-point with binary point scaling
- fi scaled double with binary point scaling

Output Arguments

z

`z` is the four-quadrant arctangent of `y/x`. The numerictype of `z` depends on the signedness of `y` and `x`:

- If either y or x is signed, z is a signed, fixed-point number in the range [–pi,pi]. It has a 16-bit word length and 13-bit fraction length (`numerictype(1,16,13)`).
- If both y and x are unsigned, z is an unsigned, fixed-point number in the range [0,pi/2]. It has a 16-bit word length and 15-bit fraction length (`numerictype(0,16,15)`).

This arctangent calculation is accurate only to within the top 16 most-significant bits of the input.

Examples

Calculate the arctangent of unsigned and signed fixed-point input values. The first example uses unsigned, 16-bit word length values. The second example uses signed, 16-bit word length values.

```
y = fi(0.125,0,16);
x = fi(0.5,0,16);
z = atan2(y,x)

z =

    0.2450

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 15

y = fi(-0.1,1,16);
x = fi(-0.9,1,16);
z = atan2(y,x)

z =

   -3.0309

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Definitions

Four-Quadrant Arctangent

The four-quadrant arctangent is defined as follows, with respect to the atan function:

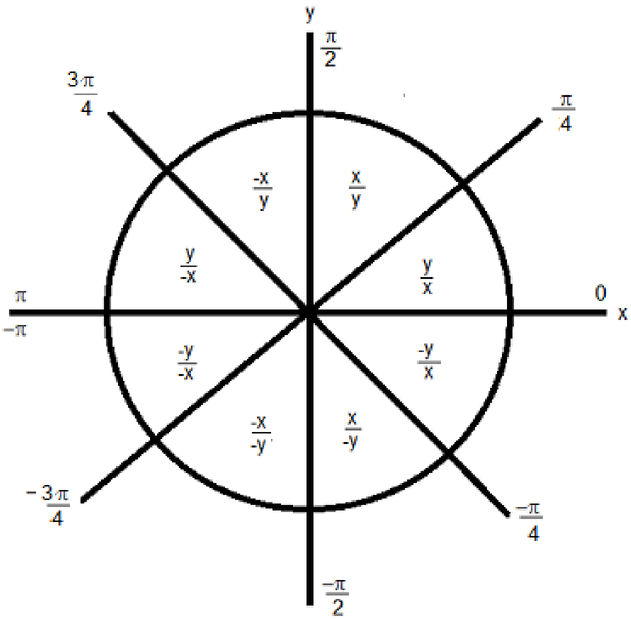
$$\operatorname{atan2}(y,x) = \begin{cases} \operatorname{atan}\left(\dfrac{y}{x}\right) & x > 0 \\ \pi + \operatorname{atan}\left(\dfrac{y}{x}\right) & y \ge 0, x < 0 \\ -\pi + \operatorname{atan}\left(\dfrac{y}{x}\right) & y < 0, x < 0 \\ \dfrac{\pi}{2} & y > 0, x = 0 \\ -\dfrac{\pi}{2} & y < 0, x = 0 \\ 0 & y = 0, x = 0 \end{cases}$$

Algorithms

The `atan2` function computes the four-quadrant arctangent of fixed-point inputs using an 8-bit lookup table as follows:

1. Divide the input absolute values to get an unsigned, fractional, fixed-point, 16-bit ratio between 0 and 1. The absolute values of y and x determine which value is the divisor.

   The signs of the `y` and `x` inputs determine in what quadrant their ratio lies. The input with the larger absolute value is used as the denominator, thus producing a value between 0 and 1.



2 Compute the table index, based on the 16-bit, unsigned, stored integer value:

   a Use the 8 most-significant bits to obtain the first value from the table.

   b Use the next-greater table value as the second value.

3 Use the 8 least-significant bits to interpolate between the first and second values using nearest neighbor linear interpolation. This interpolation produces a value in the range [0, pi/4).

4 Perform octant correction on the resulting angle, based on the values of the original `y` and `x` inputs.

fimath Propagation Rules

The `atan2` function ignores and discards any `fimath` attached to the inputs. The output, `z`, is always associated with the default `fimath`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`angle` | `atan2` | `cordicatan2` | `cos` | `sin`

Topics

Demo: Fixed-Point Arctangent Calculation

Introduced in R2012a

autofixexp

Automatically change scaling of fixed-point data types

Syntax

```
autofixexp
```

Description

The `autofixexp` script automatically changes the scaling for model objects that specify fixed-point data types. However, if an object's **Lock output data type setting against changes by the fixed-point tools** parameter is selected, the script refrains from scaling that object.

This script collects range data for model objects, either from design minimum and maximum values that objects specify explicitly, or from logged minimum and maximum values that occur during simulation. Based on these values, the tool changes the scaling of fixed-point data types in a model so as to maximize precision and cover the range.

You can specify design minimum and maximum values for model objects using parameters typically titled **Output minimum** and **Output maximum**. See “Blocks That Allow Signal Range Specification” (Simulink) for a list of Simulink blocks that permit you to specify these values. In the autoscaling procedure that the `autofixexp` script executes, design minimum and maximum values take precedence over the simulation range.

If you intend to scale fixed-point data types using simulation minimum and maximum values, the script yields meaningful results when exercising the full range of values over which your design is meant to run. Therefore, the simulation you run prior to using `autofixexp` must simulate your design over its full intended operating range. It is especially important that you use simulation inputs with appropriate speed and amplitude profiles for dynamic systems. The response of a linear dynamic system is frequency dependent. For example, a bandpass filter will show almost no response to very slow and very fast sinusoid inputs, whereas the signal of a sinusoid input with a frequency in the passband will be passed or even significantly amplified. The response of nonlinear dynamic systems can have complicated dependence on both the signal speed and amplitude.

Note If you already know the simulation range you need to cover, you can use an alternate autoscaling technique described in the `fixptbestprec` reference page.

To control the parameters associated with automatic scaling, such as safety margins, use the Fixed-Point Tool.

For more information, see “Fixed-Point Tool”.

To learn how to use the Fixed-Point Tool, refer to “Propose Fraction Lengths Using Simulation Range Data”.

See Also

`fxptdlg`

Introduced before R2006a

bar

Create vertical bar graph

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `bar` reference page for more information.

Introduced before R2006a

barh

Create horizontal bar graph

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `barh` reference page for more information.

Introduced before R2006a

bin

Binary representation of stored integer of `fi` object

Syntax

`bin(a)`

Description

`bin(a)` returns the stored integer of `fi` object `a` in unsigned binary format as a character vector. `bin(a)` is equivalent to `a.bin`.

Fixed-point numbers can be represented as

$$\textit{real-world value} = 2^{-\textit{fraction length}} \times \textit{stored integer}$$

or, equivalently as

$$\textit{real-world value} = (\textit{slope} \times \textit{stored integer}) + \textit{bias}$$

The stored integer is the raw binary number, in which the binary point is assumed to be at the far right of the word.

Examples

The following code

```
a = fi([-1 1],1,8,7);
y = bin(a)
z = a.bin
```

returns

```
y =
```

```
        10000000   01111111

z =

        10000000   01111111
```

See Also

`dec` | `hex` | `oct` | `storedInteger`

Introduced before R2006a

bin2num

Convert two's complement binary string to number using `quantizer` object

Syntax

`y = bin2num(q,b)`

Description

`y = bin2num(q,b)` uses the properties of `quantizer` object `q` to convert the binary character vector `b` to a numeric array `y`. When `b` is a cell array containing binary representations, `y` is a cell array of the same dimension containing numeric arrays. The fixed-point binary representation is two's complement. The floating-point binary representation is in IEEE® Standard 754 style.

`bin2num` and `num2bin` are inverses of one another. Note that `num2bin` always returns the binary representations in a column.

Examples

Create a `quantizer` object and an array of numeric character vectors. Convert the numeric character vectors to binary, then use `bin2num` to convert them back to numeric character vectors.

```
q=quantizer([4 3]);
[a,b]=range(q);
x=(b:-eps(q):a)';
b = num2bin(q,x)

b =

0111
0110
0101
0100
```

```
0011
0010
0001
0000
1111
1110
1101
1100
1011
1010
1001
1000
```

`bin2num` performs the inverse operation of `num2bin`.

```
y=bin2num(q,b)

y =

    0.8750
    0.7500
    0.6250
    0.5000
    0.3750
    0.2500
    0.1250
         0
   -0.1250
   -0.2500
   -0.3750
   -0.5000
   -0.6250
   -0.7500
   -0.8750
   -1.0000
```

See Also

`hex2num` | `num2bin` | `num2hex` | `num2int`

Introduced before R2006a

bitand

Bitwise AND of two fi objects

Syntax

```
c = bitand(a, b)
```

Description

`c = bitand(a, b)` returns the bitwise AND of fi objects a and b.

The numerictype properties associated with a and b must be identical. If both inputs have a local fimath object, the fimath objects must be identical. If the numerictype is signed, then the bit representation of the stored integer is in two's complement representation.

a and b must have the same dimensions unless one is a scalar.

bitand only supports fi objects with fixed-point data types.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Slope-bias scaled fi objects are not supported.

See Also

bitcmp | bitget | bitor | bitset | bitxor

Introduced before R2006a

bitandreduce

Reduce consecutive slice of bits to one bit by performing bitwise AND operation

Syntax

```
c = bitandreduce(a)
c = bitandreduce(a, lidx)
c = bitandreduce(a, lidx, ridx)
```

Description

`c = bitandreduce(a)` performs a bitwise AND operation on the entire set of bits in the fixed-point input, `a`, and returns the result as an unsigned integer of word length 1.

`c = bitandreduce(a, lidx)` performs a bitwise AND operation on a consecutive range of bits, starting at position `lidx` and ending at the LSB (the bit at position 1).

`c = bitandreduce(a, lidx, ridx)` performs a bitwise AND operation on a consecutive range of bits, starting at position `lidx` and ending at position `ridx`.

The `bitandreduce` arguments must satisfy the following condition:

```
a.WordLength >= lidx >= ridx >= 1
```

Examples

Perform Bitwise AND Operation on an Entire Set of Bits

Create a fixed-point number.

```
a = fi(73,0,8,0);
disp(bin(a))
```

```
01001001
```

Perform a bitwise AND operation on the entire set of bits in `a`.

```
c = bitandreduce(a)
```

```
c =
     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

Because the bits of `a` do not all have a value of 1, the output has a value of 0.

Perform Bitwise AND Operation on a Range of Bits in a Vector

Create a fixed-point vector.

```
a = fi([12, 4, 8, 15],0,8,0);
disp(bin(a))
```

```
00001100   00000100   00001000   00001111
```

Perform a bitwise AND operation on the bits of each element of `a`, starting at position `fi(4)`.

```
c = bitandreduce(a, fi(4))
```

```
c =
     0     0     0     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

The only element in output `c` with a value of 1 is the 4th element. This is because it is the only element of `a` that had only 1's between positions `fi(4)` and 1.

Perform Bitwise AND Operation on a Range of Bits in a Matrix

Create a fixed-point matrix.

```
a = fi([7, 8, 1; 5, 9, 5; 8, 37, 2], 0, 8, 0);
disp(bin(a))
```

```
00000111   00001000   00000001
00000101   00001001   00000101
00001000   00100101   00000010
```

Perform a bitwise AND operation on the bits of each element of matrix `a` beginning at position 3 and ending at position 1.

```
c = bitandreduce(a, 3, 1)
```

```
c =
     1     0     0
     0     0     0
     0     0     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

There is only one element in output `c` with a value of 1. This condition occurs because the corresponding element in `a` is the only element with only 1's between positions 3 and 1.

Input Arguments

a — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects.

`bitandreduce` supports both signed and unsigned inputs with arbitrary scaling. The sign and scaling properties do not affect the result type and value. `bitandreduce` performs the operation on a two's complement bit representation of the stored integer.

Data Types: fixed-point `fi`

`lidx` — Start position of range

scalar

Start position of range specified as a scalar of built-in type. `lidx` represents the position in the range closest to the MSB.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`ridx` — End position of range

scalar

End position of range specified as a scalar of built-in type. `ridx` represents the position in the range closest to the LSB (the bit at position 1).

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

`c` — Output array

scalar | vector | matrix | multidimensional array

Output array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects. `c` is unsigned with word length 1.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`bitconcat` | `bitorreduce` | `bitsliceget` | `bitxorreduce`

Introduced in R2007b

bitcmp

Bitwise complement of fi object

Syntax

```
c = bitcmp(a)
```

Description

`c = bitcmp(a)` returns the bitwise complement of `fi` object `a`. If `a` has a signed `numerictype`, the bit representation of the stored integer is in two's complement representation.

`bitcmp` only supports `fi` objects with fixed-point data types. `a` can be a scalar `fi` object or a vector `fi` object.

Examples

This example shows how to get the bitwise complement of a `fi` object. Consider the following unsigned fixed-point `fi` object with a value of 10, word length 4, and fraction length 0:

```
a = fi(10,0,4,0);
disp(bin(a))

1010
```

Complement the values of the bits in `a`:

```
c = bitcmp(a);
disp(bin(c))

0101
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`bitand` | `bitget` | `bitor` | `bitset` | `bitxor`

Introduced before R2006a

bitconcat

Concatenate bits of `fi` objects

Syntax

```
y = bitconcat(a)
y = bitconcat (a, b, ...)
```

Description

`y = bitconcat(a)` concatenates the bits of the elements of fixed-point `fi` input array, `a`.

`y = bitconcat (a, b, ...)` concatenates the bits of the fixed–point `fi` inputs.

Examples

Concatenate the Elements of a Vector

Create a fixed-point vector.

```
a = fi([1,2,5,7],0,4,0);
disp(bin(a))
```

```
0001   0010   0101   0111
```

Concatenate the bits of the elements of `a`.

```
y = bitconcat(a)
```

```
y =
        4695

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
```

```
          WordLength: 16
      FractionLength: 0
```

```
disp(bin(y))
```

```
0001001001010111
```

The word length of the output, y, equals the sum of the word lengths of each element of a.

Concatenate the Bits of Two fi Objects

Create two fixed-point numbers.

```
a = fi(5,0,4,0);
disp(bin(a))
```

```
0101
```

```
b = fi(10,0,4,0);
disp(bin(b))
```

```
1010
```

Concatenate the bits of the two inputs.

```
y = bitconcat(a,b)
```

```
y = 
    90

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 0
```

```
disp(bin(y))
```

```
01011010
```

The output, y, is unsigned with a word length equal to the sum of the word lengths of the two inputs, and a fraction length of 0.

Perform Element-by-Element Concatenation of Two Vectors

When a and b are both vectors of the same size, bitconcat performs element-wise concatenation of the two vectors and returns a vector.

Create two fixed-point vectors of the same size.

```
a = fi([1,2,5,7],0,4,0);
disp(bin(a))
```

```
0001   0010   0101   0111
```

```
b = fi([7,4,3,1],0,4,0);
disp(bin(b))
```

```
0111   0100   0011   0001
```

Concatenate the elements of a and b.

```
y = bitconcat(a,b)
```

```
y =
    23    36    83   113

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 0
```

```
disp(bin(y))
```

```
00010111   00100100   01010011   01110001
```

The output, y, is a vector of the same length as the input vectors, and with a word length equal to the sum of the word lengths of the two input vectors.

Perform Element-by-Element Concatenation of Two Matrices

When the inputs are both matrices of the same size, bitconcat performs element-wise concatenation of the two matrices and returns a matrix of the same size.

Create two fixed-point matrices.

```
a = fi([1,2,5;7,4,5;3,1,12],0,4,0);
disp(bin(a))
```

```
0001   0010   0101
0111   0100   0101
0011   0001   1100
```

```
b = fi([6,1,7;7,8,1;9,7,8],0,4,0);
disp(bin(b))
```

```
0110   0001   0111
0111   1000   0001
1001   0111   1000
```

Perform element-by-element concatenation of the bits of `a` and `b`.

```
y = bitconcat(a,b)
```

```
y =
    22    33    87
   119    72    81
    57    23   200

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 0
```

```
disp(bin(y))
```

```
00010110   00100001   01010111
01110111   01001000   01010001
00111001   00010111   11001000
```

The output, `y`, is a matrix with word length equal to the sum of the word lengths of `a` and `b`.

Input Arguments

a — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects. `bitconcat` accepts `varargin` number of inputs for concatenation.

Data Types: fixed-point `fi`

b — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects. If `b` is nonscalar, it must have the same dimension as the other inputs.

Data Types: fixed-point `fi`

Output Arguments

y — Output array
scalar | vector | matrix | multidimensional array

Output array, specified as a scalar, vector, matrix, or multidimensional array of unsigned fixed-point `fi` objects.

The output array has word length equal to the sum of the word lengths of the inputs and a fraction length of zero. The bit representation of the stored integer is in two's complement representation. Scaling does not affect the result type and value.

If the inputs are all scalar, then `bitconcat` concatenates the bits of the inputs and returns a scalar.

If the inputs are all arrays of the same size, then `bitconcat` performs element-wise concatenation of the bits and returns an array of the same size.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also

`bitand` | `bitcmp` | `bitget` | `bitor` | `bitreplicate` | `bitset` | `bitsliceget` | `bitxor`

Introduced in R2007b

bitget

Get bits at certain positions

Syntax

```
c = bitget(a, bit)
```

Description

`c = bitget(a, bit)` returns the values of the bits at the positions specified by `bit` in `a` as unsigned integers of word length 1.

Examples

Get Bit When Input and Index Are Both Scalar

Consider the following unsigned fixed-point `fi` number with a value of 85, word length 8, and fraction length 0:

```
a = fi(85,0,8,0);
disp(bin(a))
```

```
01010101
```

Get the binary representation of the bit at position 4:

```
c = bitget(a,4);
```

`bitget` returns the bit at position 4 in the binary representation of `a`.

Get Bit When Input Is a Matrix and the Index Is a fi

Begin with a signed fixed-point 3-by-3 matrix with word length 4 and fraction length 0.

```
a = fi([2 3 4;6 8 2;3 5 1],0,4,0);
disp(bin(a))
```

```
0010   0011   0100
0110   1000   0010
0011   0101   0001
```

Get the binary representation of the bits at a specified position.

```
c = bitget(a,fi(2))
```

```
c =
     1     1     0
     1     0     1
     1     0     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

MATLAB® returns a matrix of the bits in position `fi(2)` of `a`. The output matrix has the same dimensions as `a`, and a word length of 1.

Get Bit When Both Input and Index Are Vectors

Begin with a signed fixed-point vector with word length 16, fraction length 4.

```
a = fi([86 6 53 8 1],0,16,4);
disp(bin(a))
```

```
0000010101100000   0000000001100000   0000001101010000   0000000010000000   00000000000
```

Create a vector that specifies the positions of the bits to get.

```
bit = [1,2,5,7,4]
```

```
bit = 1×5

     1     2     5     7     4
```

Get the binary representation of the bits of `a` at the positions specified in `bit`.

```
c = bitget(a,bit)

c =
     0     0     1     0     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

`bitget` returns a vector of the bits of `a` at the positions specified in `bit`. The output vector has the same length as inputs, `a` and `bit`, and a word length of 1.

Get Bit When Input Is Scalar and Index Is a Vector

Create a default `fi` object with a value of `pi`.

```
a = fi(pi);
disp(bin(a))

0110010010001000
```

The default object is signed with a word length of 16.

Create a vector of the positions of the bits you want to get in `a`, and get the binary representation of those bits.

```
bit = fi([15,3,8,2]);
c = bitget(a,bit)

c =
     1     0     1     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

MATLAB® returns a vector of the bits in `a` at the positions specified by the index vector, `bit`.

Input Arguments

a — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects. If `a` and `bit` are both nonscalar, they must have the same dimension. If `a` has a signed `numerictype`, the bit representation of the stored integer is in two's complement representation.

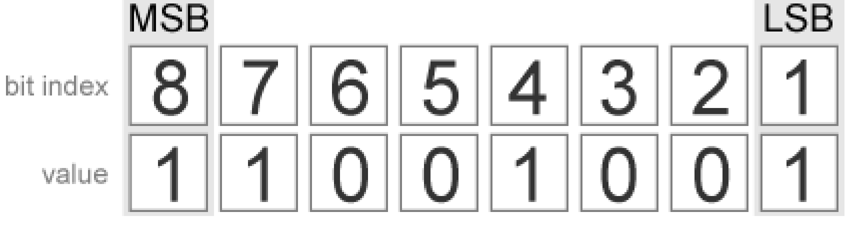
Data Types: fixed-point `fi`

bit — Bit index
scalar | vector | matrix | multidimensional array

Bit index, specified as a scalar, vector, matrix or multidimensional array of `fi` objects or built-in data types. If `a` and `bit` are both nonscalar, they must have the same dimension. `bit` must contain integer values between `1` and the word length of `a`, inclusive. The `LSB` (right-most bit) is specified by bit index `1` and the `MSB` (left-most bit) is specified by the word length of `a`. `bit` does not need to be a vector of sequential bit positions; it can also be a variable index value.

```
a = fi(pi,0,8);
a.bin
```

```
11001001
```



Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

c — Output array
scalar | vector | matrix | multidimensional array

Output array, specified as an unsigned scalar, vector, matrix, or multidimensional array with `WordLength` 1.

If `a` is an array and `bit` is a scalar, `c` is an unsigned array with word length 1. This unsigned array comprises the values of the bits at position `bit` in each fixed-point element in `a`.

If `a` is a scalar and `bit` is an array, `c` is an unsigned array with word length 1. This unsigned array comprises the values of the bits in `a` at the positions specified in `bit`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`bitand` | `bitcmp` | `bitor` | `bitset` | `bitxor`

Introduced before R2006a

bitor

Bitwise `OR` of two `fi` objects

Syntax

`c = bitor(a,b)`

Description

`c = bitor(a,b)` returns the bitwise `OR` of `fi` objects `a` and `b`. The output is determined as follows:

- Elements in the output array `c` are assigned a value of `1` when the corresponding bit in either input array has a value of `1`.
- Elements in the output array `c` are assigned a value of `0` when the corresponding bit in both input arrays has a value of `0`.

The `numerictype` properties associated with `a` and `b` must be identical. If both inputs have a local fimath, their local fimath properties must be identical. If the `numerictype` is signed, then the bit representation of the stored integer is in two's complement representation.

`a` and `b` must have the same dimensions unless one is a scalar.

`bitor` only supports `fi` objects with fixed-point data types.

Examples

The following example finds the bitwise `OR` of `fi` objects *a* and *b*.

```
a = fi(-30,1,6,0);
b = fi(12, 1, 6, 0);
c = bitor(a,b)

c =
```

```
   -18

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 0
```

You can verify the result by examining the binary representations of *a*, *b* and *c*.

```
binary_a = a.bin
binary_b = b.bin
binary_c = c.bin

binary_a =

100010

binary_b =

001100

binary_c =

101110
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Slope-bias scaled `fi` objects are not supported.

See Also

`bitand` | `bitcmp` | `bitget` | `bitset` | `bitxor`

Introduced before R2006a

bitorreduce

Reduce consecutive slice of bits to one bit by performing bitwise OR operation

Syntax

```
c = bitorreduce(a)
c = bitorreduce(a, lidx)
c = bitorreduce(a, lidx, ridx)
```

Description

`c = bitorreduce(a)` performs a bitwise OR operation on the entire set of bits in the fixed-point input, `a`, and returns the result as an unsigned integer of word length 1.

`c = bitorreduce(a, lidx)` performs a bitwise OR operation on a consecutive range of bits, starting at position `lidx` and ending at the LSB (the bit at position 1).

`c = bitorreduce(a, lidx, ridx)` performs a bitwise OR operation on a consecutive range of bits, starting at position `lidx` and ending at position `ridx`.

The `bitorreduce` arguments must satisfy the following condition:

```
a.WordLength >= lidx >= ridx >= 1
```

Examples

Perform Bitwise OR Operation on an Entire Set of Bits

Create a fixed-point number.

```
a = fi(73,0,8,0);
disp(bin(a))
```

```
01001001
```

Perform a bitwise OR operation on the entire set of bits in a.

```
c = bitorreduce(a)
```

```
c =
     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

Because there is at least one bit in a with a value of 1, the output has a value of 1.

Perform Bitwise OR Operation on a Range of Bits in a Vector

Create a fixed-point vector.

```
a=fi([12,4,8,15],0,8,0);
disp(bin(a))
```

```
00001100   00000100   00001000   00001111
```

Perform a bitwise OR operation on the bits of each element of a, starting at position fi(4).

```
c=bitorreduce(a,fi(4))
```

```
c =
     1     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

All of the entries of output c have a value of 1 because all of the entries of a have at least one bit with a value of 1 between the positions fi(4) and 1.

Perform Bitwise OR Operation on a Range of Bits in a Matrix

Create a fixed-point matrix.

```
a = fi([7,8,1;5,9,5;8,37,2],0,8,0);
disp(bin(a))
```

```
00000111   00001000   00000001
00000101   00001001   00000101
00001000   00100101   00000010
```

Perform a bitwise `OR` operation on the bits of each element of matrix `a` beginning at position 5, and ending at position 2.

```
c = bitorreduce(a,5,2)
```

```
c =
     1     1     0
     1     1     1
     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

There is only one element in output `c` that does not have a value of `1`. This condition occurs because the corresponding element in `a` is the only element of `a` that does not have any bits with a value of `1` between positions 5 and 2.

Input Arguments

a — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects.

`bitorreduce` supports both signed and unsigned inputs with arbitrary scaling. The sign and scaling properties do not affect the result type and value. `bitorreduce` performs the operation on a two's complement bit representation of the stored integer.

Data Types: fixed-point `fi`

`lidx` — Start position of range
scalar

Start position of range specified as a scalar of built-in type. `lidx` represents the position in the range closest to the MSB.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`ridx` — End position of range
scalar

End position of range specified as a scalar of built-in type. `ridx` represents the position in the range closest to the LSB (the bit at position 1).

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

`c` — Output array
scalar | vector | matrix | multidimensional array

Output array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects. `c` is unsigned with word length 1.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`bitandreduce` | `bitconcat` | `bitsliceget` | `bitxorreduce`

Introduced in R2007b

bitreplicate

Replicate and concatenate bits of `fi` object

Syntax

`c = bitreplicate(a,n)`

Description

`c = bitreplicate(a,n)` concatenates the bits in `fi` object *a* *n* times and returns an unsigned fixed-point value. The word length of the output `fi` object *c* is equal to *n* times the word length of *a* and the fraction length of *c* is zero. The bit representation of the stored integer is in two's complement representation.

The input `fi` object can be signed or unsigned. `bitreplicate` concatenates signed and unsigned bits the same way.

`bitreplicate` only supports `fi` objects with fixed-point data types.

`bitreplicate` does not support inputs with complex data types.

Sign and scaling of the input `fi` object does not affect the result type and value.

Examples

The following example uses `bitreplicate` to replicate and concatenate the bits of `fi` object `a`.

```
a = fi(14,0,6,0);
a_binary = a.bin
c = bitreplicate(a,2);
c_binary = c.bin
```

MATLAB returns the following:

```
a_binary =

001110


c_binary =

001110001110
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

bitand | bitconcat | bitget | bitor | bitset | bitsliceget | bitxor

Introduced in R2008a

bitrol

Bitwise rotate left

Syntax

```
c = bitrol(a, k)
```

Description

`c = bitrol(a, k)` returns the value of the fixed-point `fi` object, `a`, rotated left by `k` bits. `bitrol` rotates bits from the most significant bit (MSB) side into the least significant bit (LSB) side. It performs the rotate left operation on the stored integer bits of `a`.

`bitrol` does not check overflow or underflow. It ignores `fimath` properties such as `RoundingMode` and `OverflowAction`.

`a` and `c` have the same `fimath` and `numerictype` properties.

Examples

Rotate the Bits of a fi Object Left

Create an unsigned fixed-point `fi` object with a value of 10, word length 4, and fraction length 0.

```
a = fi(10,0,4,0);
disp(bin(a))
```

```
1010
```

Rotate `a` left 1 bit.

```
disp(bin(bitrol(a,1)))
```

```
0101
```

Rotate `a` left 2 bits.

```
disp(bin(bitrol(a,2)))
```

```
1010
```

Rotate Bits in a Vector Left

Create a vector of `fi` objects.

```
a = fi([1,2,5,7],0,4,0)
```

```
a = 
     1     2     5     7

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 4
        FractionLength: 0
```

```
disp(bin(a))
```

```
0001   0010   0101   0111
```

Rotate the bits in vector `a` left 1 bit.

```
disp(bin(bitrol(a,1)))
```

```
0010   0100   1010   1110
```

Rotate Bits Left Using fi to Specify Number of Bits to Rotate

Create an unsigned fixed-point `fi` object with a value 10, word length 4, and fraction length 0.

```
a = fi(10,0,4,0);
```

```
disp(bin(a))
```

```
1010
```

Rotate a left 1 bit where k is a fi object.

```
disp(bin(bitrol(a,fi(1))))
```

```
0101
```

Input Arguments

a — Data that you want to rotate
scalar | vector | matrix | multidimensional array

Data that you want to rotate, specified as a scalar, vector, matrix, or multidimensional array of fi objects. a can be signed or unsigned.

Data Types: fixed-point fi

Complex Number Support: Yes

k — Number of bits to rotate
non-negative, integer-valued scalar

Number of bits to rotate, specified as a non-negative integer-valued scalar fi object or built-in numeric type. k can be greater than the word length of a. This value is always normalized to mod(a.WordLength,k).

Data Types: fi |single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

bitconcat | bitror | bitshift | bitsliceget | bitsll | bitsra | bitsrl

Introduced in R2007b

bitror

Bitwise rotate right

Syntax

```
c = bitror(a, k)
```

Description

`c = bitror(a, k)` returns the value of the fixed-point `fi` object, `a`, rotated right by `k` bits. `bitror` rotates bits from the least significant bit (LSB) side into the most significant bit (MSB) side. It performs the rotate right operation on the stored integer bits of `a`.

`bitror` does not check overflow or underflow. It ignores `fimath` properties such as `RoundingMode` and `OverflowAction`.

`a` and `c` have the same `fimath` and `numerictype` properties.

Examples

Rotate Bits of a fi Object Right

Create an unsigned fixed-point `fi` object with a value 5, word length 4, and fraction length 0.

```
a = fi(5,0,4,0);
disp(bin(a))
```

```
0101
```

Rotate `a` right 1 bit.

```
disp(bin(bitror(a,1)))
```

```
1010
```

Rotate a right 2 bits.

```
disp(bin(bitror(a,2)))
```

```
0101
```

Rotate Bits in a Vector Right

Create a vector of fi objects.

```
a = fi([1,2,5,7],0,4,0);
disp(bin(a))
```

```
0001   0010   0101   0111
```

Rotate the bits in vector a right 1 bit.

```
disp(bin(bitror(a,fi(1))))
```

```
1000   0001   1010   1011
```

Rotate Bits Right Using fi to Specify Number of Bits to Rotate

Create an unsigned fixed-point fi object with a value 5, word length 4, and fraction length 0.

```
a = fi(5,0,4,0);
disp(bin(a))
```

```
0101
```

Rotate a right 1 bit where k is a fi object.

```
disp(bin(bitror(a,fi(1))))
```

```
1010
```

Input Arguments

a — Data that you want to rotate
scalar | vector | matrix | multidimensional array

Data that you want to rotate, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects. `a` can be signed or unsigned.

Data Types: fixed-point `fi`

Complex Number Support: Yes

k — Number of bits to rotate
non-negative, integer-valued scalar

Number of bits to rotate, specified as a non-negative integer-valued scalar `fi` object or built-in numeric type. `k` can be greater than the word length of `a`. This value is always normalized to `mod(a.WordLength,k)`.

Data Types: `fi` | `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`bitconcat` | `bitrol` | `bitshift` | `bitsliceget` | `bitsll` | `bitsra` | `bitsrl`

Introduced in R2007b

bitset

Set bits at certain positions

Syntax

```
c = bitset(a, bit)
c = bitset(a, bit, v)
```

Description

`c = bitset(a, bit)` returns the value of `a` with position `bit` set to `1` (on).

`c = bitset(a, bit, v)` returns the value of `a` with position `bit` set to `v`.

Examples

Set the Bit at a Certain Position

Begin with an unsigned fixed-point `fi` number with a value of 5, word length 4, and fraction length 0.

```
a = fi(5,0,4,0);
disp(bin(a))
```

```
0101
```

Set the bit at position 4 to `1` (on).

```
c = bitset(a,4);
disp(bin(c))
```

```
1101
```

Set the Bit at a Certain Position in a Vector

Consider the following fixed-point vector with word length 4 and fraction length 0.

```
a = fi([0 1 8 2 4],0,4,0);
disp(bin(a))
```

```
0000   0001   1000   0010   0100
```

In each element of vector `a`, set the bits at position 2 to `1`.

```
c = bitset(a,2,1);
disp(bin(c))
```

```
0010   0011   1010   0010   0110
```

Set the Bit at a Certain Position with Fixed Point Index

Consider the following fixed-point scalar with a value of 5.

```
a = fi(5,0,4,0);
disp(bin(a))
```

```
0101
```

Set the bit at position `fi(2)` to `1`.

```
c = bitset(a,fi(2),1);
disp(bin(c))
```

```
0111
```

Set the Bit When Index Is a Vector

Create a `fi` object with a value of `pi`.

```
a = fi(pi);
disp(bin(a))
```

```
0110010010001000
```

In this case, a is signed with a word length of 16.

Create a vector of the bit positions in a that you want to set to on. Then, get the binary representation of the resulting fi vector.

```
bit = fi([15,3,8,2]);
c = bitset(a,bit);
disp(bin(c))
```

```
0110010010001000   0110010010001100   0110010010001000   0110010010001010
```

Input Arguments

a — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point fi objects. If a has a signed numerictype, the bit representation of the stored integer is in two's complement representation.

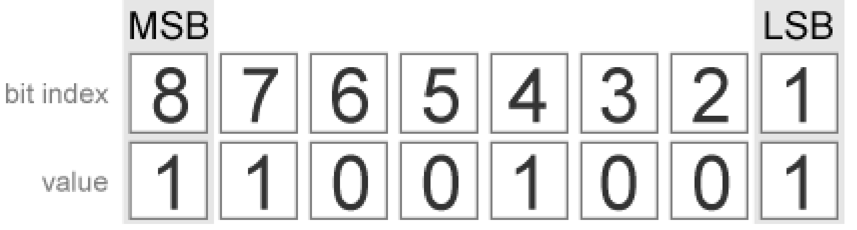
Data Types: fixed-point fi

bit — Bit index
scalar | vector | matrix | multidimensional array

Bit index, specified as a scalar, vector, matrix, or multidimensional array of fi objects or built-in data types. bit must be a number between 1 and the word length of a, inclusive. The LSB (right-most bit) is specified by bit index 1 and the MSB (left-most bit) is specified by the word length of a.

```
a = fi(pi,0,8);
a.bin
```

```
11001001
```



Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

v — Bit value
scalar | vector | matrix | multidimensional array

Bit value of `a` at index `bit`, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects or built-in data types. `v` can have values of `0`, or `1`. Any value other than `0` is automatically set to `1`. When `v` is nonscalar, it must have the same dimensions as one of the other inputs.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

c — Output array
scalar | vector | matrix | multidimensional array

Output array, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`bitand` | `bitcmp` | `bitget` | `bitor` | `bitxor`

Introduced before R2006a

bitshift

Shift bits specified number of places

Syntax

```
c = bitshift(a, k)
```

Description

`c = bitshift(a, k)` returns the value of `a` shifted by `k` bits. The input `fi` object `a` may be a scalar value or a vector and can be any fixed-point numeric type. The output `fi` object `c` has the same numeric type as `a`. `k` must be a scalar value and a MATLAB built-in numeric type.

The `OverflowAction` property of `a` is obeyed, but the `RoundingMethod` is always `Floor`. If obeying the `RoundingMethod` property of `a` is important, try using the `pow2` function.

When the overflow action is `Saturate` the sign bit is always preserved. The sign bit is also preserved when the overflow action is `Wrap`, and `k` is negative. When the overflow action is `Wrap` and `k` is positive, the sign bit is not preserved.

- When `k` is positive, 0-valued bits are shifted in on the right.
- When `k` is negative, and `a` is unsigned, or a signed and positive `fi` object, 0-valued bits are shifted in on the left.
- When `k` is negative and `a` is a signed and negative `fi` object, 1-valued bits are shifted in on the left.

Examples

This example highlights how changing the `OverflowAction` property of the `fimath` object can change the results returned by the `bitshift` function. Consider the following signed fixed-point `fi` object with a value of 3, word length 16, and fraction length 0:

```
a = fi(3,1,16,0);
```

By default, the `OverflowAction` `fimath` property is `Saturate`. When `a` is shifted such that it overflows, it is saturated to the maximum possible value:

```
for k=0:16,b=bitshift(a,k);...
disp([num2str(k,'%02d'),'. ',bin(b)]);end

00. 0000000000000011
01. 0000000000000110
02. 0000000000001100
03. 0000000000011000
04. 0000000000110000
05. 0000000001100000
06. 0000000011000000
07. 0000000110000000
08. 0000001100000000
09. 0000011000000000
10. 0000110000000000
11. 0001100000000000
12. 0011000000000000
13. 0110000000000000
14. 0111111111111111
15. 0111111111111111
16. 0111111111111111
```

Now change `OverflowAction` to `Wrap`. In this case, most significant bits shift off the “top” of `a` until the value is zero:

```
a = fi(3,1,16,0,'OverflowAction','Wrap');
for k=0:16,b=bitshift(a,k);...
disp([num2str(k,'%02d'),'. ',bin(b)]);end

00. 0000000000000011
01. 0000000000000110
02. 0000000000001100
03. 0000000000011000
04. 0000000000110000
05. 0000000001100000
06. 0000000011000000
07. 0000000110000000
08. 0000001100000000
09. 0000011000000000
10. 0000110000000000
11. 0001100000000000
```

```
12. 0011000000000000
13. 0110000000000000
14. 1100000000000000
15. 1000000000000000
16. 0000000000000000
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

bitand | bitcmp | bitget | bitor | bitset | bitsll | bitsra | bitsrl | bitxor | pow2

Introduced before R2006a

bitsliceget

Get consecutive slice of bits

Syntax

```
c = bitsliceget(a)
c = bitsliceget(a, lidx)
c = bitsliceget(a, lidx, ridx)
```

Description

`c = bitsliceget(a)` returns the entire set of bits in the fixed-point input `a`.

`c = bitsliceget(a, lidx)` returns a consecutive slice of bits from `a`, starting at position `lidx` and ending at the LSB (the bit at position 1).

`c = bitsliceget(a, lidx, ridx)` returns a consecutive slice of bits from `a`, starting at position `lidx` and ending at position `ridx`.

The `bitsliceget` arguments must satisfy the following condition:

```
a.WordLength >= lidx >= ridx >= 1
```

Examples

Get Entire Set of Bits

Begin with the following fixed-point number.

```
a = fi(85,0,8,0);
disp(bin(a))
```

```
01010101
```

Get the entire set of bits of `a`.

```
c = bitsliceget(a);
disp(bin(c))
```

```
01010101
```

Get a Slice of Consecutive Bits with Unspecified Endpoint

Begin with the following fixed-point number.

```
a = fi(85,0,8,0);
disp(bin(a))
```

```
01010101
```

Get the binary representation of the consecutive bits, starting at position 6.

```
c = bitsliceget(a,6);
disp(bin(c))
```

```
010101
```

Get a Slice of Consecutive Bits with Fixed-Point Indexes

Begin with the following fixed-point number.

```
a = fi(85,0,8,0);
disp(bin(a))
```

```
01010101
```

Get the binary representation of the consecutive bits from `fi(6)` to `fi(2)`.

```
c = bitsliceget(a,fi(6),fi(2));
disp(bin(c))
```

```
01010
```

Get a Specified Set of Consecutive Bits from Each Element of a Matrix

Begin with the following unsigned fixed-point 3-by-3 matrix.

```
a = fi([2 3 4;6 8 2;3 5 1],0,4,0);
disp(bin(a))
```

```
0010   0011   0100
0110   1000   0010
0011   0101   0001
```

Get the binary representation of a consecutive set of bits of matrix `a`. For each element, start at position 4 and end at position 2.

```
c = bitsliceget(a,4,2);
disp(bin(c))
```

```
001   001   010
011   100   001
001   010   000
```

Input Arguments

a — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects. If `a` has a signed `numerictype`, the bit representation of the stored integer is in two's complement representation.

Data Types: fixed-point `fi`

`lidx` — Start position for slice
scalar

Start position of slice specified as a scalar of built-in type. `lidx` represents the position in the slice closest to the MSB.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

ridx — End position for slice
scalar

End position of slice specified as a scalar of built-in type. ridx represents the position in the slice closest to the LSB (the bit at position 1).

Data Types: fi|single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

Output Arguments

c — Output array
scalar | vector | matrix | multidimensional array

Fixed-point fi output, specified as a scalar, vector, matrix, or multidimensional array with no scaling. The word length is equal to slice length, lidx-ridx+1.

If lidx and ridx are equal, bitsliceget only slices one bit, and bitsliceget(a, lidx, ridx) is the same as bitget(a, lidx).

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
bitand | bitcmp | bitget | bitor | bitset | bitxor

Introduced in R2007b

bitsll

Bit shift left logical

Syntax

```
c = bitsll(a, k)
```

Description

`c = bitsll(a, k)` returns the result of a logical left shift by `k` bits on input `a` for fixed-point operations. `bitsll` shifts zeros into the positions of bits that it shifts left. The function does not check overflow or underflow. For floating-point operations, `bitsll` performs a multiply by 2^k.

`bitsll` ignores `fimath` properties such as `RoundingMode` and `OverflowAction`.

When `a` is a `fi` object, `a` and `c` have the same associated `fimath` and `numerictype` objects.

Examples

Shift Left a Signed fi Input

Shift a signed `fi` input left by 1 bit.

Create a `fi` object, and display its binary value.

```
a = fi(10,0,4,0);
disp(bin(a))
```

```
1010
```

Shift `a` left by 1 bit, and display its binary value.

```
disp(bin(bitsll(a,1)))
```

```
0100
```

Shift a left by 1 more bit.

```
disp(bin(bitsll(a,2)))
```

```
1000
```

Shift Left Using a fi Shift Value

Shift left a built-in `int8` input using a `fi` shift value.

```
k = fi(2);
a = int8(16);
bitsll(a,k)
```

```
ans = int8
    64
```

Shift Left a Built-in int8 Input

Use `bitsll` to shift an `int8` input left by 2 bits.

```
a = int8(4);
bitsll(a,2)
```

```
ans = int8
    16
```

Shift Left a Floating-Point Input

Scale a floating-point `double` input by 2^3.

```
a = double(16);
bitsll(a,3)
```

```
ans = 128
```

Input Arguments

a — Data that you want to shift
scalar | vector | matrix | multidimensional array

Data that you want to shift, specified as a scalar, vector, matrix, or multidimensional array of fi objects or built-in numeric types.

Data Types: `fi` | `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

k — Number of bits to shift
non-negative integer-valued scalar

Number of bits to shift, specified as a non-negative integer-valued scalar `fi` object or built-in numeric type.

Data Types: `fi` | `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Generated code might not handle out of range shifting.

See Also

`bitconcat` | `bitrol` | `bitror` | `bitshift` | `bitsra` | `bitsrl` | `pow2`

Introduced in R2007b

bitsra

Bit shift right arithmetic

Syntax

```
c=bitsra(a,k)
```

Description

`c=bitsra(a,k)` returns the result of an arithmetic right shift by `k` bits on input `a` for fixed-point operations. For floating-point operations, it performs a multiply by 2^{-k}.

If the input is unsigned, `bitsra` shifts zeros into the positions of bits that it shifts right. If the input is signed, `bitsra` shifts the most significant bit (MSB) into the positions of bits that it shifts right.

`bitsra` ignores `fimath` properties such as `RoundingMode` and `OverflowAction`.

When `a` is a `fi` object, `a` and `c` have the same associated `fimath` and `numerictype` objects.

Examples

Shift Right a Signed fi Input

Create a signed fixed-point `fi` object with a value of –8, word length 4, and fraction length 0. Then display the binary value of the object.

```
a = fi(-8,1,4,0);
disp(bin(a))
```

```
1000
```

Shift `a` right by 1 bit.

```
disp(bin(bitsra(a,1)))
```

```
1100
```

`bitsra` shifts the MSB into the position of the bit that it shifts right.

Shift Right a Built-in int8 Input

Use `bitsra` to shift an `int8` input right by 2 bits.

```
a = int8(64);
bitsra(a,2)
```

```
ans = int8
    16
```

Shift Right Using a fi Shift Value

Shift right a built-in `int8` input using a `fi` shift value.

```
k = fi(2);
a = int8(64);
bitsra(a,k)
```

```
ans = int8
    16
```

Shift Right a Floating-Point Input

Scale a floating-point `double` input by 2^{-3}.

```
a = double(128);
bitsra(a,3)
```

```
ans = 16
```

Input Arguments

a — Data that you want to shift
scalar | vector | matrix | multidimensional array

Data that you want to shift, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects or built-in numeric types.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

k — Number of bits to shift
non-negative integer-valued scalar

Number of bits to shift, specified as a non-negative integer-valued scalar `fi` object or built-in numeric type.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Generated code might not handle out of range shifting.

See Also

`bitshift` | `bitsll` | `bitsrl` | `pow2`

Introduced in R2007b

bitsrl

Bit shift right logical

Syntax

```
c = bitsrl(a, k)
```

Description

`c = bitsrl(a, k)` returns the result of a logical right shift by `k` bits on input `a` for fixed-point operations. `bitsrl` shifts zeros into the positions of bits that it shifts right. It does not check overflow or underflow.

`bitsrl` ignores `fimath` properties such as `RoundingMode` and `OverflowAction`.

When `a` is a `fi` object, `a` and `c` have the same associated `fimath` and `numerictype` objects.

Examples

Shift right a signed fi input

Shift a signed `fi` input right by 1 bit.

Create a signed fixed-point `fi` object with a value of -8, word length 4, and fraction length 0 and display its binary value.

```
a = fi(-8,1,4,0);
disp(bin(a))
```

```
1000
```

Shift `a` right by 1 bit, and display the binary value.

```
disp(bin(bitsrl(a,1)))
```

```
0100
```

`bitsrl` shifts a zero into the position of the bit that it shifts right.

Shift right using a fi shift value

Shift right a built-in `int8` input using a `fi` shift value.

```
k = fi(2);
a = int8(64);
bitsrl(a,k)

ans = int8
    16
```

Shift right a built-in uint8 input

Use `bitsrl` to shift a uint8 input right by 2 bits.

```
a = uint8(64);
bitsrl(a,2)

ans = uint8
    16
```

Input Arguments

a — Data that you want to shift
scalar | vector | matrix | multidimensional array

Data that you want to shift, specified as a scalar, vector, matrix, or multidimensional array.

Data Types: `fi` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

k — Number of bits to shift
non-negative integer-valued scalar

Number of bits to shift, specified as a non-negative integer-valued scalar.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Generated code might not handle out of range shifting.

See Also

`bitconcat` | `bitrol` | `bitror` | `bitshift` | `bitsliceget` | `bitsll` | `bitsra` | `pow2`

Introduced in R2007b

bitxor

Bitwise exclusive `OR` of two `fi` objects

Syntax

`c = bitxor(a,b)`

Description

`c = bitxor(a,b)` returns the bitwise exclusive `OR` of `fi` objects *a* and *b*. The output is determined as follows:

- Elements in the output array *c* are assigned a value of `1` when exactly one of the corresponding bits in the input arrays has a value of `1`.
- Elements in the output array *c* are assigned a value of `0` when the corresponding bits in the input arrays have the same value (e.g. both `1`'s or both `0`'s).

The `numerictype` properties associated with *a* and *b* must be identical. If both inputs have a local fimath, their local fimath properties must be identical. If the `numerictype` is signed, then the bit representation of the stored integer is in two's complement representation.

a and *b* must have the same dimensions unless one is a scalar.

`bitxor` only supports `fi` objects with fixed-point data types.

Examples

The following example finds the bitwise exclusive `OR` of `fi` objects *a* and *b*.

```
a = fi(-28,1,6,0);
b = fi(12, 1, 6, 0);
c = bitxor(a,b)

c =
```

```
   -24

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 0
```

You can verify the result by examining the binary representations of *a*, *b* and *c*.

```
binary_a = a.bin
binary_b = b.bin
binary_c = c.bin

binary_a =

100100

binary_b =

001100

binary_c =

101000
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Slope-bias scaled `fi` objects are not supported.

See Also

`bitand` | `bitcmp` | `bitget` | `bitor` | `bitset`

Introduced before R2006a

bitxorreduce

Reduce consecutive slice of bits to one bit by performing bitwise exclusive OR operation

Syntax

```
c = bitxorreduce(a)
c = bitxorreduce(a, lidx)
c = bitxorreduce(a, lidx, ridx)
```

Description

`c = bitxorreduce(a)` performs a bitwise exclusive OR operation on the entire set of bits in the fixed-point input, `a`. It returns the result as an unsigned integer of word length 1.

`c = bitxorreduce(a, lidx)` performs a bitwise exclusive OR operation on a consecutive range of bits. This operation starts at position `lidx` and ends at the LSB (the bit at position 1).

`c = bitxorreduce(a, lidx, ridx)` performs a bitwise exclusive OR operation on a consecutive range of bits, starting at position `lidx` and ending at position `ridx`.

The `bitxorreduce` arguments must satisfy the following condition:

```
a.WordLength >= lidx >= ridx >= 1
```

Examples

Perform Bitwise Exclusive OR Operation on an Entire Set of Bits

Create a fixed-point number.

```
a = fi(73,0,8,0);
disp(bin(a))
```

```
01001001
```

Perform a bitwise exclusive OR operation on the entire set of bits in a.

```
c = bitxorreduce(a)
```

```
c =
     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

Perform Bitwise Exclusive OR Operation on a Range of Bits in a Vector

Create a fixed-point vector.

```
a = fi([12,4,8,15],0,8,0);
disp(bin(a))
```

```
00001100   00000100   00001000   00001111
```

Perform a bitwise exclusive OR operation on the bits of each element of a, starting at position fi(4).

```
c = bitxorreduce(a,fi(4))
```

```
c =
     0     1     1     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

Perform a Bitwise Exclusive OR Operation on a Range of Bits in a Matrix

Create a fixed-point matrix.

```
a = fi([7,8,1;5,9,5;8,37,2],0,8,0);
disp(bin(a))
```

```
00000111   00001000   00000001
00000101   00001001   00000101
00001000   00100101   00000010
```

Perform a bitwise exclusive `OR` operation on the bits of each element of matrix `a` beginning at position 5 and ending at position 2.

```
c = bitxorreduce(a,5,2)
```

```
c =
     0     1     0
     1     1     1
     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

Input Arguments

a — Input array

scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point `fi` objects.

`bitxorreduce` supports both signed and unsigned inputs with arbitrary scaling. The sign and scaling properties do not affect the result type and value. `bitxorreduce` performs the operation on a two's complement bit representation of the stored integer.

Data Types: fixed-point `fi`

`lidx` — Start position of range

scalar

Start position of range specified as a scalar of built-in type. `lidx` represents the position in the range closest to the MSB.

Data Types: fi | single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

ridx — End position of range
scalar

End position of range specified as a scalar of built-in type. ridx represents the position in the range closest to the LSB (the bit at position 1).

Data Types: fi|single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

Output Arguments

c — Output array
scalar | vector | matrix | multidimensional array

Output array, specified as a scalar, vector, matrix, or multidimensional array of fixed-point fi objects. c is unsigned with word length 1.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

bitandreduce | bitconcat | bitorreduce | bitsliceget

Introduced in R2007b

buffer

Buffer signal vector into matrix of data frames

Description

This function accepts `fi` objects as inputs.

Refer to the `buffer` function reference page for more information.

Introduced before R2006a

buildInstrumentedMex

Generate compiled C code function including logging instrumentation

Syntax

```
buildInstrumentedMex fcn -options
buildInstrumentedMex fcn_1... fcn_n -options -coder
```

Description

`buildInstrumentedMex fcn -options` translates the MATLAB file *`fcn`*`.m` to a MEX function and enables instrumentation for logging minimum and maximum values of all named and intermediate variables. Optionally, you can enable instrumentation for log2 histograms of all named, intermediate and expression values. The general syntax and options of `buildInstrumentedMex` and `fiaccel` are the same, except `buildIntstrumentedMex` has no `fi` object restrictions and supports the `'-coder'` option.

`buildInstrumentedMex fcn_1... fcn_n -options -coder` translates the MATLAB functions *`fcn_1`* through *`fcn_n`* to a MEX function and enables instrumentation for logging minimum and maximum values of all named and intermediate variables. Generating a MEX function for multiple entry-point functions requires the `'-coder'` option.

Input Arguments

`fcn`, `fcn_1... fcn_n`

MATLAB entry-point functions to be instrumented. The entry-point functions must be suitable for code generation. For more information, see “Make the MATLAB Code Suitable for Code Generation” (MATLAB Coder).

options

Choice of compiler options. `buildInstrumentedMex` gives precedence to individual command-line options over options specified using a configuration object. If command-line options conflict, the rightmost option prevails.

`-args` *`example_inputs`*	Define the size, class, and complexity of all MATLAB function inputs. Use the values in *`example_inputs`* to define these properties. *`example_inputs`* must be a cell array that specifies the same number and order of inputs as the MATLAB function.
`-coder`	Use MATLAB Coder software to compile the MEX file, instead of the default Fixed-Point Designer `fiaccel` function. This option removes `fiaccel` restrictions and allows for full code generation support. You must have a MATLAB Coder license to use this option.
`-config` *`config_object`*	Specify MEX generation parameters, based on *`config_object`*, defined as a MATLAB variable using `coder.mexconfig`. For example: `cfg = coder.mexconfig;`

`-d` *`out_folder`*	Store generated files in the absolute or relative path specified by *`out_folder`*. If the folder specified by *`out_folder`* does not exist, `buildInstrumentedMex` creates it for you. If you do not specify the folder location, `buildInstrumentedMex` generates files in the default folder: *`fiaccel/mex/fcn`*. *`fcn`* is the name of the MATLAB function specified at the command line. The function does not support the following characters in folder names: asterisk (`*`), question-mark (`?`), dollar (`$`), and pound (`#`).
`-g`	Compiles the MEX function in debug mode, with optimization turned off. If not specified, `buildinstrumentedMex` generates the MEX function in optimized mode.

`-global` *`global_values`*	Specify initial values for global variables in MATLAB file. Use the values in cell array `global_values` to initialize global variables in the function you compile. The cell array should provide the name and initial value of each global variable. You must initialize global variables before compiling with `buildInstrumentedMex`. If you do not provide initial values for global variables using the `-global` option, `buildInstrumentedMex` checks for the variable in the MATLAB global workspace. If you do not supply an initial value, `buildInstrumentedMex` generates an error. The generated MEX code and MATLAB each have their own copies of global data. To ensure consistency, you must synchronize their global data whenever the two interact. If you do not synchronize the data, their global variables might differ.
`-histogram`	Compute the log2 histogram for all named, intermediate and expression values. A histogram column appears in the code generation report table.
`-I` *`include_path`*	Add *`include_path`* to the beginning of the code generation path. `buildInstrumentedMex` searches the code generation path *first* when converting MATLAB code to MEX code.
`-launchreport`	Generate and open a code generation report. If you do not specify this option, `buildInstrumentedMex` generates a report only if error or warning messages occur or you specify the `-report` option.

`-o` *`output_file_name`*	Generate the MEX function with the base name *`output_file_name`* plus a platform-specific extension. *`output_file_name`* can be a file name or include an existing path. If you do not specify an output file name, the base name is *`fcn_mex`*, which allows you to run the original MATLAB function and the MEX function and compare the results.
`-O` *`optimization_option`*	Optimize generated MEX code, based on the value of *`optimization_option`*: • `enable:inline` — Enable function inlining • `disable:inline` — Disable function inlining If not specified, `buildInstrumentedMex` uses inlining for optimization.
`-report`	Generate a code generation report. If you do not specify this option, `buildInstrumentedMex` generates a report only if error or warning messages occur or you specify the `-launchreport` option.

Examples

Create an Instrumented MEX Function

Create an instrumented MEX function. Run a test bench, then view logged results.

1. Create a temporary directory, then import an example function from Fixed-Point Designer.

```
tempdirObj=fidemo.fiTempdir('buildInstrumentedMex')
copyfile(fullfile(matlabroot,'toolbox','fixedpoint',...
   'fidemos','fi_m_radix2fft_withscaling.m'),...
   'testfft.m','f')
```

2 Define prototype input arguments.

```
n = 128;
x = complex(zeros(n,1));
W = coder.Constant(fidemo.fi_radix2twiddles(n));
```

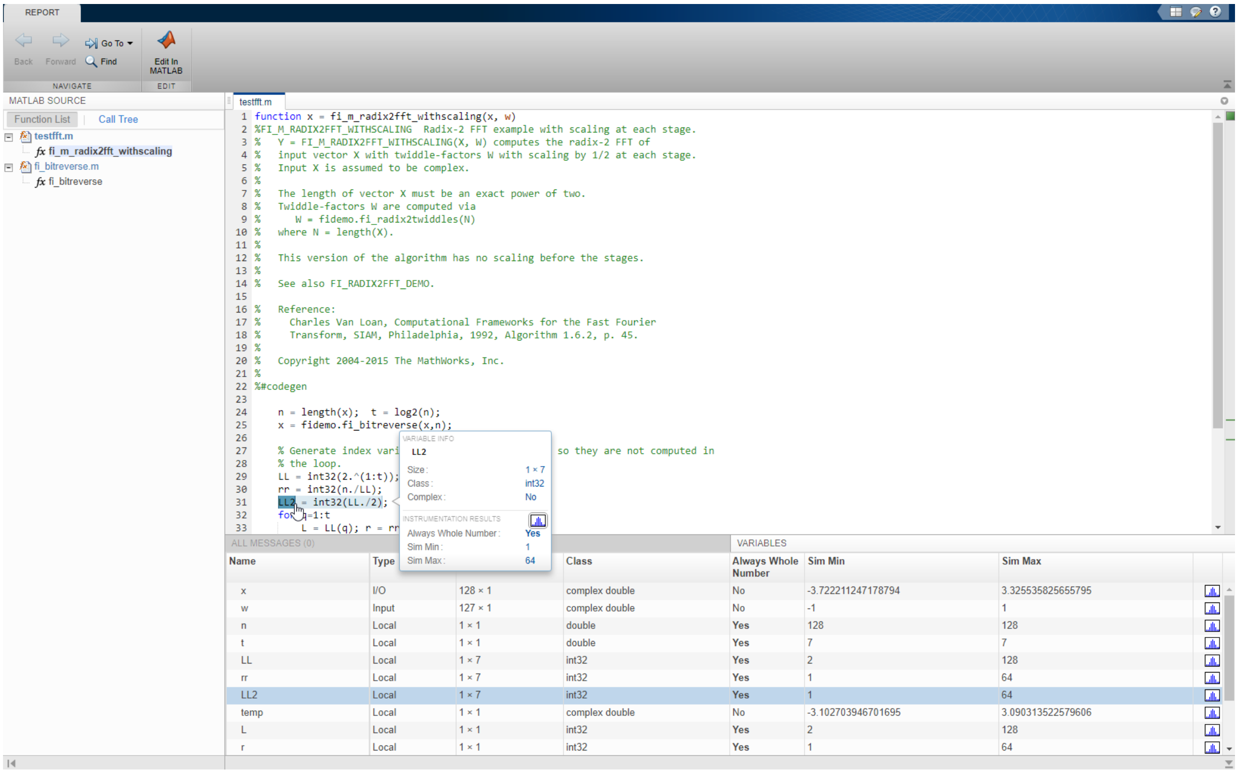
3 Generate an instrumented MEX function. Use the `-o` option to specify the MEX function name. Use the `-histogram` option to compute histograms. (If you have a MATLAB Coder license, you may want to also add the `-coder` option. In this case, use `buildInstrumentedMex testfft -coder -o testfft_instrumented -args {x,W}` instead of the following line of code.)

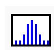
Note Like `fiaccel`, `buildInstrumentedMex` generates a MEX function. To generate C code, see the MATLAB Coder`codegen` function.

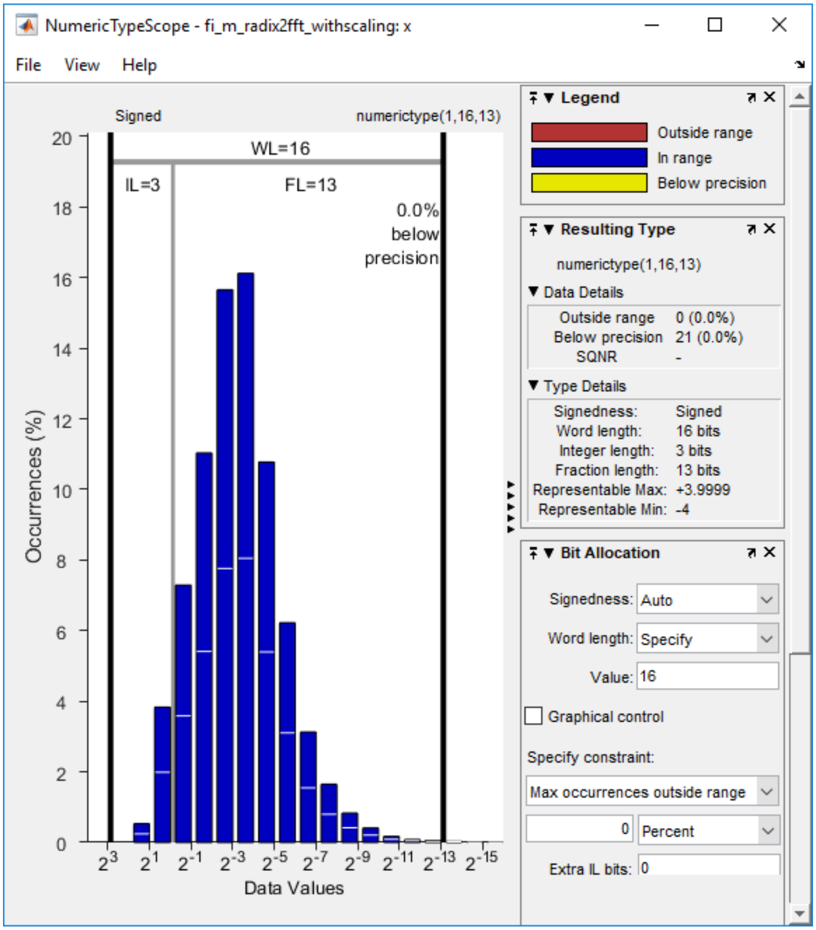
```
buildInstrumentedMex testfft -o testfft_instrumented...
-args {x,W} -histogram
```

4 Run a test file to record instrumentation results. Call `showInstrumentationResults` to open the report. View the simulation minimum and maximum values and whole number status by pausing over a variable in the report. You can also see proposed data types for double precision numbers in the table.

```
for i=1:20
   y = testfft_instrumented(randn(size(x)));
end

showInstrumentationResults testfft_instrumented
```



5 View the histogram for a variable by clicking  in the **Variables** tab.



For information on the figure, refer to the `NumericTypeScope` reference page.

6 Close the histogram display and then, clear the results log.

```
clearInstrumentationResults testfft_instrumented;
```

7 Clear the MEX function, then delete temporary files.

```
clear testfft_instrumented;
tempdirObj.cleanUp;
```

Build an Instrumented MEX Function for Multiple Entry Point Functions

In a local writable folder, create the functions `ep1.m` and `ep2.m`.

```
function y1 = ep1(u) %#codegen
y1 = u;
end
```

```
function y2 = ep2(u, v) %#codegen
y2 = u + v;
end
```

Generate an instrumented MEX function for the two entry-point functions. Use the `-o` option to specify the name of the MEX function. Use the `-histogram` option to compute histograms. Use the `-coder` option to enable generating multiple entry points with the `buildInstrumentedMex` function.

```
u = 1:100;
v = 5:104;
buildInstrumentedMex -o sharedmex ...
ep1 -args {u} ... % Entry point 1
ep2 -args {u, v} ... % Entry point 2
-histogram -coder
```

Call the first entry-point function using the generated MEX function.

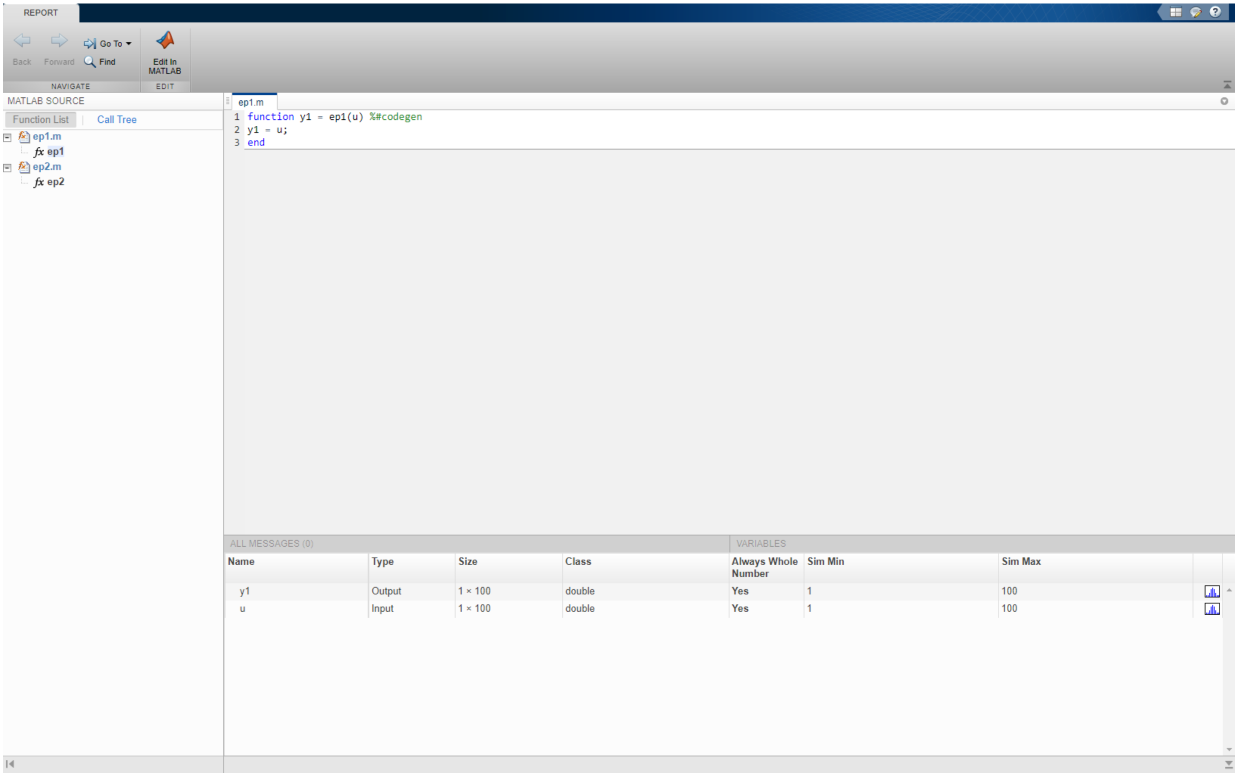
```
y1 = sharedmex('ep1', u);
```

Call the second entry-point function using the generated MEX function.

```
y2 = sharedmex('ep2', u, v);
```

Show the instrumentation results.

```
showInstrumentationResults sharedmex
```



Note Generating a MEX function for multiple entry-point functions using the `buildInstrumentedMex` function requires a MATLAB Coder license.

Tips

- You cannot instrument MATLAB functions provided with the software. If your top-level function is such a MATLAB function, nothing is logged. You also cannot instrument scripts.
- Instrumentation results are accumulated every time the instrumented MEX function is called. Use `clearInstrumentationResults` to clear previous results in the log.
- Some coding patterns pass a significant amount of data, but only use a small portion of that data. In such cases, you may see degraded performance when using

buildInstrumentedMex. In the following pattern, subfun only uses one element of input array, A. For normal execution, the amount of time to execute subfun once remains constant regardless of the size of A. The function topfun calls subfun N times, and thus the total time to execute topfun is proportional to N. When instrumented, however, the time to execute subfun once becomes proportional to N^2. This change occurs because the minimum and maximum data are calculated over the entire array. When A is large, the calculations can lead to significant performance degradation. Therefore, whenever possible, you should pass only the data that the function actually needs.

```
function A = topfun(A)
    N = numel(A);
    for i=1:N
        A(i) = subfun(A,i);
    end
end
function b = subfun(A,i)
    b = 0.5 * A(i);
end

function A = topfun(A)
    N = numel(A);
    for i=1:N
        A(i) = subfun(A(i));
    end
end
function b = subfun(a)
    b = 0.5 * a;
end
```

See Also

NumericTypeScope | clearInstrumentationResults | codegen | fiaccel | mex | showInstrumentationResults

Introduced in R2011b

cast

Cast variable to different data type

Syntax

```
b = cast(a,'like',p)
```

Description

`b = cast(a,'like',p)` converts `a` to the same `numerictype`, complexity (real or complex), and `fimath` as `p`. If `a` and `p` are both real, then `b` is also real. Otherwise, `b` is complex.

Examples

Convert an int8 Value to Fixed Point

Define a scalar 8–bit integer.

```
a = int8(5);
```

Create a signed `fi` object with word length of `24` and fraction length of `12`.

```
p = fi([],1,24,12);
```

Convert `a` to fixed point with `numerictype`, complexity (real or complex), and `fimath` of the specified `fi` object, `p`.

```
b = cast(a, 'like', p)
```

```
b =
     5

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
        WordLength: 24
    FractionLength: 12
```

???

Convert an Array to Fixed Point

Define a 2-by-3 matrix of ones.

```
A = ones(2,3);
```

Create a signed `fi` object with word length of `16` and fraction length of `8`.

```
p = fi([],1,16,8);
```

Convert `A` to the same data type and complexity (real or complex) as `p`.

```
B = cast(A,'like',p)
```

```
B =
     1     1     1
     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8
```

Write MATLAB Code That Is Independent of Data Types

Write a MATLAB algorithm that you can run with different data types without changing the algorithm itself. To reuse the algorithm, define the data types separately from the algorithm.

This approach allows you to define a baseline by running the algorithm with floating-point data types. You can then test the algorithm with different fixed-point data types and compare the fixed-point behavior to the baseline without making any modifications to the original MATLAB code.

Write a MATLAB function, `my_filter`, that takes an input parameter, `T`, which is a structure that defines the data types of the coefficients and the input and output data.

```
function [y,z] = my_filter(b,a,x,z,T)
    % Cast the coefficients to the coefficient type
    b = cast(b,'like',T.coeffs);
    a = cast(a,'like',T.coeffs);
    % Create the output using zeros with the data type
    y = zeros(size(x),'like',T.data);
    for i = 1:length(x)
        y(i) = b(1)*x(i) + z(1);
        z(1) = b(2)*x(i) + z(2) - a(2) * y(i);
        z(2) = b(3)*x(i)        - a(3) * y(i);
    end
end
```

Write a MATLAB function, `zeros_ones_cast_example`, that calls `my_filter` with a floating-point step input and a fixed-point step input, and then compares the results.

```
function zeros_ones_cast_example

    % Define coefficients for a filter with specification
    % [b,a] = butter(2,0.25)
    b = [0.097631072937818   0.195262145875635   0.097631072937818];
    a = [1.000000000000000  -0.942809041582063   0.333333333333333];

    % Define floating-point types
    T_float.coeffs = double([]);
    T_float.data   = double([]);

    % Create a step input using ones with the
    % floating-point data type
    t = 0:20;
    x_float = ones(size(t),'like',T_float.data);

    % Initialize the states using zeros with the
    % floating-point data type
    z_float = zeros(1,2,'like',T_float.data);

    % Run the floating-point algorithm
    y_float = my_filter(b,a,x_float,z_float,T_float);

    % Define fixed-point types
    T_fixed.coeffs = fi([],true,8,6);
    T_fixed.data   = fi([],true,8,6);

    % Create a step input using ones with the
    % fixed-point data type
```

```
    x_fixed = ones(size(t),'like',T_fixed.data);

    % Initialize the states using zeros with the
    % fixed-point data type
    z_fixed = zeros(1,2,'like',T_fixed.data);

    % Run the fixed-point algorithm
    y_fixed = my_filter(b,a,x_fixed,z_fixed,T_fixed);

    % Compare the results
    coder.extrinsic('clf','subplot','plot','legend')
    clf
    subplot(211)
    plot(t,y_float,'co-',t,y_fixed,'kx-')
    legend('Floating-point output','Fixed-point output')
    title('Step response')
    subplot(212)
    plot(t,y_float - double(y_fixed),'rs-')
    legend('Error')
    figure(gcf)
end
```

Input Arguments

a — Variable that you want to cast to a different data type
`fi` object | numeric variable

Variable, specified as a `fi` object or numeric variable.

Complex Number Support: Yes

p — Prototype
`fi` object | numeric variable

Prototype, specified as a `fi` object or numeric variable. To use the prototype to specify a complex object, you must specify a value for the prototype. Otherwise, you do not need to specify a value.

Complex Number Support: Yes

Tips

Using the `b = cast(a,'like',p)` syntax to specify data types separately from algorithm code allows you to:

- Reuse your algorithm code with different data types.
- Keep your algorithm uncluttered with data type specifications and switch statements for different data types.
- Improve readability of your algorithm code.
- Switch between fixed-point and floating-point data types to compare baselines.
- Switch between variations of fixed-point settings without changing the algorithm code.

See Also

`cast` | `ones` | `zeros`

Topics

“Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros”
“Manual Fixed-Point Conversion Workflow”
“Manual Fixed-Point Conversion Best Practices”

Introduced in R2013a

ceil

Round toward positive infinity

Syntax

```
y = ceil(a)
```

Description

`y = ceil(a)` rounds `fi` object `a` to the nearest integer in the direction of positive infinity and returns the result in `fi` object `y`.

`y` and `a` have the same `fimath` object and `DataType` property.

When the `DataType` property of `a` is `single`, `double`, or `boolean`, the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is zero or negative, `a` is already an integer, and the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is positive, the fraction length of `y` is `0`, its sign is the same as that of `a`, and its word length is the difference between the word length and the fraction length of `a` plus one bit. If `a` is signed, then the minimum word length of `y` is `2`. If `a` is unsigned, then the minimum word length of `y` is `1`.

For complex `fi` objects, the imaginary and real parts are rounded independently.

`ceil` does not support `fi` objects with nontrivial slope and bias scaling. Slope and bias scaling is trivial when the slope is an integer power of 2 and the bias is 0.

Examples

Example 1

The following example demonstrates how the `ceil` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 3.

```
a = fi(pi, 1, 8, 3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3

y = ceil(a)

y =

     4

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 0
```

Example 2

The following example demonstrates how the `ceil` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 12.

```
a = fi(0.025,1,8,12)

a =

    0.0249

          DataTypeMode: Fixed-point: binary point scaling
```

```
            Signedness: Signed
            WordLength: 8
        FractionLength: 12

y = ceil(a)

y =

     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 2
        FractionLength: 0
```

Example 3

The functions `ceil`, `fix`, and `floor` differ in the way they round `fi` objects:

- The `ceil` function rounds values to the nearest integer toward positive infinity
- The `fix` function rounds values toward zero
- The `floor` function rounds values to the nearest integer toward negative infinity

The following table illustrates these differences for a given `fi` object `a`.

a	ceil(a)	fix(a)	floor(a)
– 2.5	–2	–2	–3
–1.75	–1	–1	–2
–1.25	–1	–1	–2
–0.5	0	0	–1
0.5	1	0	0
1.25	2	1	1
1.75	2	1	1
2.5	3	2	2

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`convergent` | `fix` | `floor` | `nearest` | `round`

Introduced in R2008a

clabel

Create contour plot elevation labels

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `clabel` reference page for more information.

Introduced before R2006a

clearInstrumentationResults

Clear results logged by instrumented, compiled C code function

Syntax

```
clearInstrumentationResults('mex_fcn')
clearInstrumentationResults mex_fcn
clearInstrumentationResults all
```

Description

`clearInstrumentationResults('mex_fcn')` clears the results logged from calling the instrumented MEX function *`mex_fcn`*.

`clearInstrumentationResults` *`mex_fcn`* is alternative syntax for clearing the log.

`clearInstrumentationResults all` clears the results from all instrumented MEX functions.

Input Arguments

`mex_fcn`

Instrumented MEX function created using `buildInstrumentedMex`.

Examples

Run a test bench to log instrumentation, then use `clearInstrumentationResults` to clear the log.

1 Create a temporary directory, then import an example function from Fixed-Point Designer.

```
tempdirObj=fidemo.fiTempdir('showInstrumentationResults')
copyfile(fullfile(matlabroot,'toolbox','fixedpoint',...
   'fidemos','fi_m_radix2fft_withscaling.m'),...
   'testfft.m','f')
```

2 Define prototype input arguments.

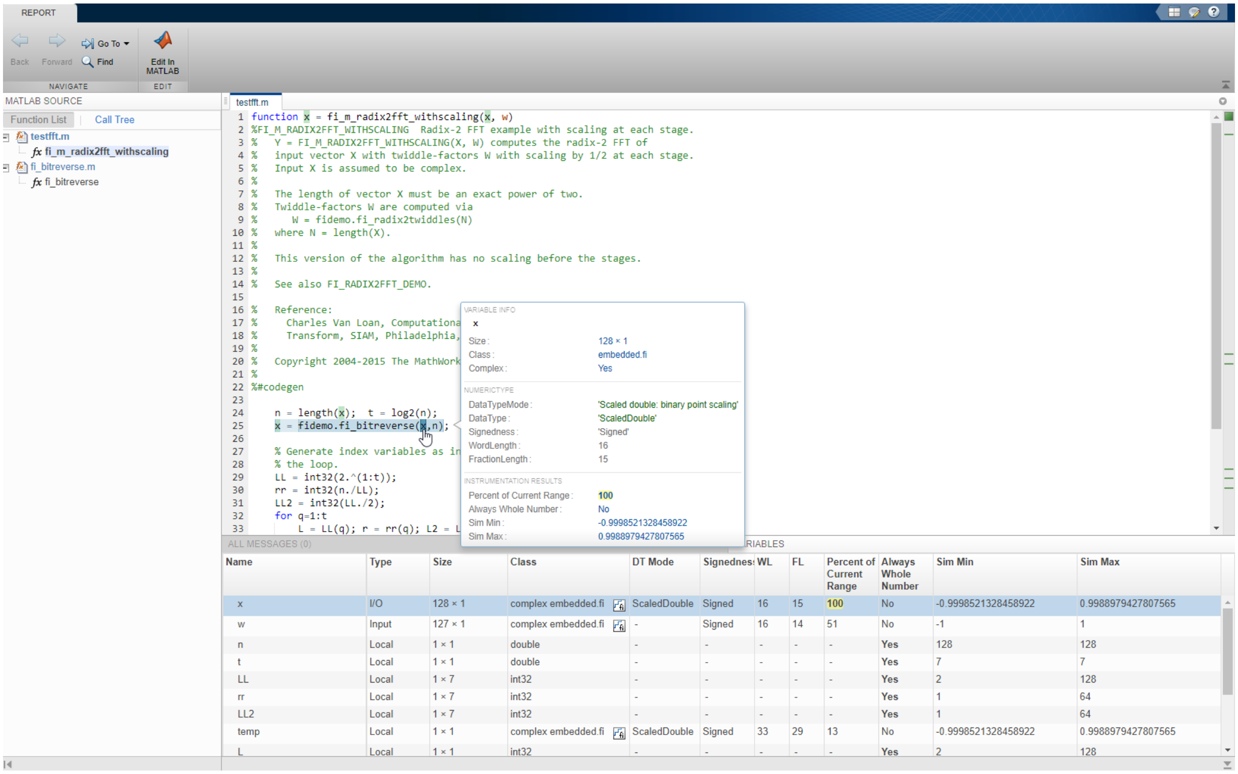
```
n = 128;
x = complex(fi(zeros(n,1),'DataType','ScaledDouble'));
W = coder.Constant(fi(fidemo.fi_radix2twiddles(n)));
```

3 Generate an instrumented MEX function. Use the `-o` option to specify the MEX function name.

```
buildInstrumentedMex testfft -o testfft_instrumented -args {x,W}
```

4 Run a test bench to record instrumentation results. Call `showInstrumentationResults` to open a report. View the simulation minimum and maximum values and whole number status by pausing over a variable in the report.

```
for i=1:20
    y = testfft_instrumented(cast(2*rand(size(x))-1,'like',x));
end

showInstrumentationResults testfft_instrumented
```

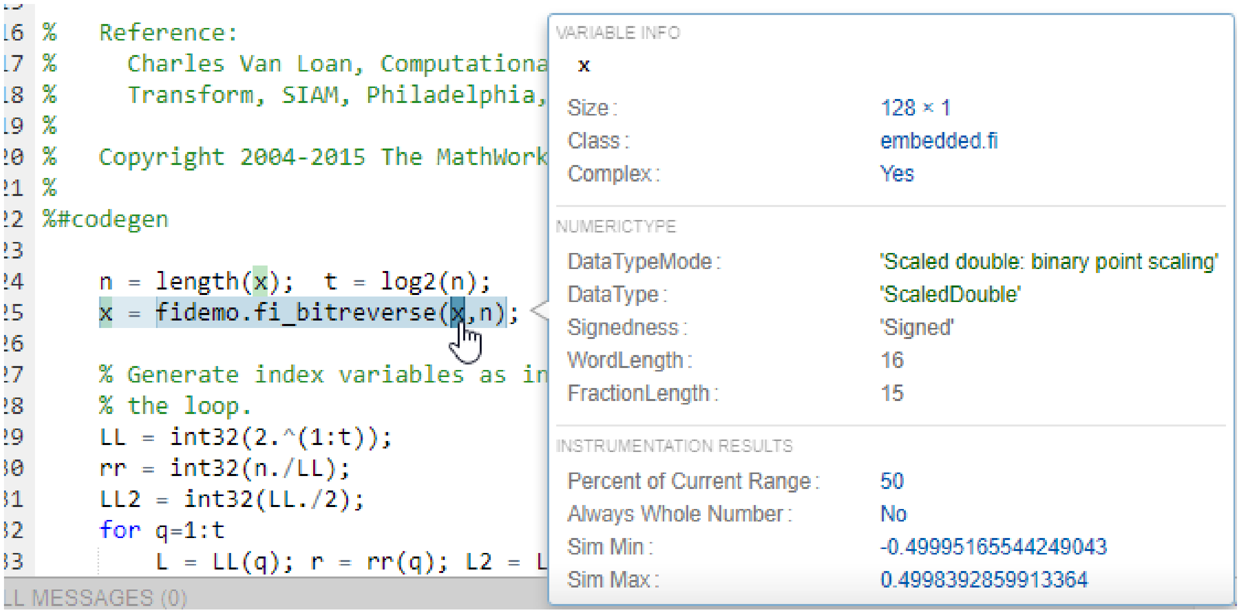


1 Clear the results log.

```
clearInstrumentationResults testfft_instrumented
```

2 Run a different test bench, then view the new instrumentation results.

```
for i=1:20
   y = testfft_instrumented(cast(rand(size(x))-0.5,'like',x));
end

showInstrumentationResults testfft_instrumented
```



3 Clear the MEX function and delete temporary files.

```
clear testfft_instrumented;
tempdirObj.cleanUp;
```

See Also

buildInstrumentedMex | codegen | fiaccel | mex | showInstrumentationResults

Introduced in R2011b

coder.approximation

Create function replacement configuration object

Syntax

```
q = coder.approximation(function_name)
q = coder.approximation('Function',function_name,Name,Value)
```

Description

`q = coder.approximation(function_name)` creates a function replacement configuration object for use during code generation or fixed-point conversion. The configuration object specifies how to create a lookup table approximation for the MATLAB function specified by `function_name`. To associate this approximation with a `coder.FixptConfig` object for use with the`fiaccel` function, use the `coder.FixptConfig` configuration object `addApproximation` method.

Use this syntax only for the functions that `coder.approximation` can replace automatically. These functions are listed in the `function_name` argument description.

`q = coder.approximation('Function',function_name,Name,Value)` creates a function replacement configuration object using additional options specified by one or more name-value pair arguments.

Examples

Replace log Function with Default Lookup Table

Create a function replacement configuration object using the default settings. The resulting lookup table in the generated code uses 1000 points.

```
logAppx = coder.approximation('log');
```

Replace log Function with Uniform Lookup Table

Create a function replacement configuration object. Specify the input range and prefix to add to the replacement function name. The resulting lookup table in the generated code uses 1000 points.

```
logAppx = coder.approximation('Function','log','InputRange',[0.1,1000],...
'FunctionNamePrefix','log_replace_');
```

Replace log Function with Optimized Lookup Table

Create a function replacement configuration object using the 'OptimizeLUTSize' option to specify to replace the log function with an optimized lookup table. The resulting lookup table in the generated code uses less than the default number of points.

```
    logAppx = coder.approximation('Function','log','OptimizeLUTSize', true,...
'InputRange',[0.1,1000],'InterpolationDegree',1,'ErrorThreshold',1e-3,...
'FunctionNamePrefix','log_optim_','OptimizeIterations',25);
```

Replace Custom Function with Optimized Lookup Table

Create a function replacement configuration object that specifies to replace the custom function, saturateExp, with an optimized lookup table.

Create a custom function, saturateExp.

```
saturateExp = @(x) 1/(1+exp(-x));
```

Create a function replacement configuration object that specifies to replace the saturateExp function with an optimized lookup table. Because the saturateExp function is not listed as a function for which coder.approximation can generate an approximation automatically, you must specify the CandidateFunction property.

```
saturateExp = @(x) 1/(1+exp(-x));
custAppx = coder.approximation('Function','saturateExp',...
'CandidateFunction', saturateExp,...
'NumberOfPoints',50,'InputRange',[0,10]);
```

- “Replace the exp Function with a Lookup Table”

- “Replace a Custom Function with a Lookup Table”

Input Arguments

`function_name` — Name of the function to replace
'acos' | 'acosd' | 'acosh' | 'acoth' | 'asin' | 'asind' | 'asinh' | 'atan' | 'atand' | 'atanh' | 'cos' | 'cosd' | 'cosh' | 'erf ' | 'erfc' | 'exp' | 'log' | 'normcdf' | 'reallog' | 'realsqrt' | 'reciprocal' | 'rsqrt' | 'sin' | 'sinc' | 'sind' | 'sinh' | 'sqrt' | 'tan' | 'tand'

Name of function to replace, specified as a string. The function must be one of the listed functions.

Example: `'sqrt'`

Data Types: `char`

Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `'Function', 'log'`

`Architecture` — Architecture of lookup table approximation
`'LookupTable'` (default) | `'Flat'`

Architecture of the lookup table approximation, specified as the comma-separated pair consisting of `'Architecture'` and a string. Use this argument when you want to specify the architecture for the lookup table. The `Flat` architecture does not use interpolation.

Data Types: `char`

`CandidateFunction` — Function handle of the replacement function
function handle | string

Function handle of the replacement function, specified as the comma-separated pair consisting of `'CandidateFunction'` and a function handle or string referring to a function handle. Use this argument when the function that you want to replace is not listed under `function_name`. Specify the function handle or string referring to a function handle of the function that you want to replace. You can define the function in a file or as an anonymous function.

If you do not specify a candidate function, then the function you chose to replace using the `Function` property is set as the `CandidateFunction`.

Example: `'CandidateFunction', @(x) (1./(1+x))`

Data Types: `function_handle` | `char`

`ErrorThreshold` — Error threshold value used to calculate optimal lookup table size

0.001 (default) | nonnegative scalar

Error threshold value used to calculate optimal lookup table size, specified as the comma-separated pair consisting of `'ErrorThreshold'` and a nonnegative scalar. If `'OptimizeLUTSize'` is `true`, this argument is required.

`Function` — Name of function to replace with a lookup table approximation

`function_name`

Name of function to replace with a lookup table approximation, specified as the comma-separated pair consisting of `'Function'` and a string. The function must be continuous and stateless. If you specify one of the functions that is listed under `function_name`, the conversion process automatically provides a replacement function. Otherwise, you must also specify the `'CandidateFunction'` argument for the function that you want to replace.

Example: `'Function'`,`'log'`

Example: `'Function'`, `'my_log'`,`'CandidateFunction'`,`@my_log`

Data Types: `char`

`FunctionNamePrefix` — Prefix for generated fixed-point function names

'replacement_' (default) | string

Prefix for generated fixed-point function names, specified as the comma-separated pair consisting of `'FunctionNamePrefix'` and a string. The name of a generated function consists of this prefix, followed by the original MATLAB function name.

Example: ‘log_replace_’

InputRange — Range over which to replace the function
[ ] (default) | 2x1 row vector | 2xN matrix

Range over which to replace the function, specified as the comma-separated pair consisting of 'InputRange' and a 2-by-1 row vector or a 2-by-*N* matrix.

Example: [-1 1]

InterpolationDegree — Interpolation degree
1 (default) | 0 | 2 | 3

Interpolation degree, specified as the comma-separated pair consisting of 'InterpolationDegree' and1 (linear), 0 (none), 2 (quadratic), or 3 (cubic).

NumberOfPoints — Number of points in lookup table
1000 (default) | positive integer

Number of points in lookup table, specified as the comma-separated pair consisting of 'NumberOfPoints' and a positive integer.

OptimizeIterations — Number of iterations
25 (default) | positive integer

Number of iterations to run when optimizing the size of the lookup table, specified as the comma-separated pair consisting of 'OptimizeIterations' and a positive integer.

OptimizeLUTSize — Optimize lookup table size
false (default) | true

Optimize lookup table size, specified as the comma-separated pair consisting of 'OptimizeLUTSize' and a logical value. Setting this property to true generates an area-optimal lookup table, that is, the lookup table with the minimum possible number of points. This lookup table is optimized for size, but might not be speed efficient.

PipelinedArchitecture — Option to enable pipelining
false (default) | true

Option to enable pipelining, specified as the comma-separated pair consisting of 'PipelinedArchitecture' and a logical value.

Output Arguments

q — Function replacement configuration object, returned as a `coder.mathfcngenerator.LookupTable` or a `coder.mathfcngenerator.Flat` configuration object

`coder.mathfcngenerator.LookupTable` configuration object | `coder.mathfcngenerator.Flat` configuration object

Function replacement configuration object that specifies how to create an approximation for a MATLAB function. Use the `coder.FixptConfig` configuration object `addApproximation` method to associate this configuration object with a `coder.FixptConfig` object. Then use the `fiaccel` function `-float2fixed` option with `coder.FixptConfig` to convert floating-point MATLAB code to fixed-point MATLAB code.

Property	Default Value
`Auto-replace function`	`''`
`InputRange`	`[]`
`FunctionNamePrefix`	`'replacement_'`
`Architecture`	`LookupTable` (read only)
`NumberOfPoints`	`1000`
`InterpolationDegree`	`1`
`ErrorThreshold`	`0.001`
`OptimizeLUTSize`	`false`
`OptimizeIterations`	`25`

See Also

Classes
`coder.FixptConfig`

Functions
`fiaccel`

Topics

“Replace the exp Function with a Lookup Table”
“Replace a Custom Function with a Lookup Table”
“Replacing Functions Using Lookup Table Approximations”

Introduced in R2014b

coder.allowpcode

Package: coder

Control code generation from protected MATLAB files

Syntax

`coder.allowpcode('plain')`

Description

`coder.allowpcode('plain')` allows you to generate protected MATLAB code (P-code) that you can then compile into optimized MEX functions or embeddable C/C++ code. This function does not obfuscate the generated MEX functions or embeddable C/C++ code.

With this capability, you can distribute algorithms as protected P-files that provide code generation optimizations, providing intellectual property protection for your source MATLAB code.

Call this function in the top-level function before control-flow statements, such as `if`, `while`, `switch`, and function calls.

MATLAB functions can call P-code. When the `.m` and `.p` versions of a file exist in the same folder, the P-file takes precedence.

`coder.allowpcode` is ignored outside of code generation.

Examples

Generate optimized embeddable code from protected MATLAB code:

1 Write an function `p_abs` that returns the absolute value of its input:

```
function out = p_abs(in)   %#codegen
% The directive %#codegen indicates that the function
```

```
% is intended for code generation
coder.allowpcode('plain');
out = abs(in);
```

2 Generate protected P-code. At the MATLAB prompt, enter:

```
pcode p_abs
```

The P-file, `p_abs.p`, appears in the current folder.

3 Generate a MEX function for `p_abs.p`, using the `-args` option to specify the size, class, and complexity of the input parameter (requires a MATLAB Coder license). At the MATLAB prompt, enter:

```
codegen p_abs -args { int32(0) }
```

`codegen` generates a MEX function in the current folder.

4 Generate embeddable C code for `p_abs.p` (requires a MATLAB Coder license). At the MATLAB prompt, enter:

```
codegen p_abs -config:lib -args { int32(0) };
```

`codegen` generates C library code in the `codegen\lib\p_abs` folder.

See Also

codegen | pcode

Introduced in R2011a

coder.ArrayType class

Package: coder
Superclasses:

Represent set of MATLAB arrays

Description

Specifies the set of arrays that the generated code accepts. Use only with the `fiaccel -args` option. Do not pass as an input to a generated MEX function.

Construction

`coder.ArrayType` is an abstract class. You cannot create instances of it directly. You can create `coder.EnumType`, `coder.FiType`, `coder.PrimitiveType`, and `coder.StructType` objects that derive from this class.

Properties

`ClassName`

Class of values in this set

`SizeVector`

The upper-bound size of arrays in this set.

`VariableDims`

A vector specifying whether each dimension of the array is fixed or variable size. If a vector element is `true`, the corresponding dimension is variable size.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

See Also

`coder.CellType` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.StructType` | `coder.Type` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Introduced in R2011a

coder.config

Create configuration object for fixed-point or single-precision conversion

Syntax

```
config_obj = coder.config('fixpt')
config_obj = coder.config('single')
```

Description

`config_obj = coder.config('fixpt')` creates a `coder.FixptConfig` configuration object. Use this object with the `fiaccel` function when converting floating-point MATLAB code to fixed-point MATLAB code.

`config_obj = coder.config('single')` creates a `coder.SingleConfig` configuration object for use with the `convertToSingle` function when generating single-precision MATLAB code from double-precision MATLAB code.

Examples

Convert Floating-Point MATLAB Code to Fixed-Point MATLAB Code

Create a `coder.FixptConfig` object, `fixptcfg`, with default settings.

```
fixptcfg = coder.config('fixpt');
```

Set the test bench name. In this example, the test bench function name is `dti_test`.

```
fixptcfg.TestBenchName = 'dti_test';
```

Convert your floating-point MATLAB design to fixed point. In this example, the MATLAB function name is `dti`.

```
fiaccel -float2fixed fixptcfg dti
```

Convert Double-Precision MATLAB Code to Single-Precision MATLAB Code

Create a `coder.SingleConfig` object, `scfg`.

```
scfg = coder.config('single');
```

Set the test bench name. In this example, the test bench function name is `myfun_test`. Enable numerics testing and data logging for comparison plotting of input and output variables.

```
scfg.TestBenchName = 'myfun_test';
scfg.TestNumerics = true;
scfg.LogIOForComparisonPlotting = true;
```

Convert the double-precision MATLAB code to single-precision MATLAB code. In this example, the MATLAB function name is `myfun`.

```
convertToSingle -config scfg myfun
```

See Also

`coder.FixptConfig` | `coder.SingleConfig` | `convertToSingle` | `fiaccel`

Introduced in R2014b

coder.const

Fold expressions into constants in generated code

Syntax

```
out = coder.const(expression)
[out1,...,outN] = coder.const(handle,arg1,...,argN)
```

Description

`out = coder.const(expression)` evaluates `expression` and replaces `out` with the result of the evaluation in generated code.

`[out1,...,outN] = coder.const(handle,arg1,...,argN)` evaluates the multi-output function having handle `handle`. It then replaces `out1,...,outN` with the results of the evaluation in the generated code.

Examples

Specify Constants in Generated Code

This example shows how to specify constants in generated code using `coder.const`.

Write a function `AddShift` that takes an input `Shift` and adds it to the elements of a vector. The vector consists of the square of the first 10 natural numbers. `AddShift` generates this vector.

```
function y = AddShift(Shift) %#codegen
y = (1:10).^2+Shift;
```

Generate code for `AddShift` using the `codegen` command. Open the Code Generation Report.

```
codegen -config:lib -launchreport AddShift -args 0
```

The code generator produces code for creating the vector. It adds `Shift` to each element of the vector during vector creation. The definition of `AddShift` in generated code looks as follows:

```
void AddShift(double Shift, double y[10])
{
  int k;
  for (k = 0; k < 10; k++) {
    y[k] = (double)((1 + k) * (1 + k)) + Shift;
  }
}
```

Replace the statement

```
y = (1:10).^2+Shift;
```

with

```
y = coder.const((1:10).^2)+Shift;
```

Generate code for `AddShift` using the `codegen` command. Open the Code Generation Report.

```
codegen -config:lib -launchreport AddShift -args 0
```

The code generator creates the vector containing the squares of the first 10 natural numbers. In the generated code, it adds `Shift` to each element of this vector. The definition of `AddShift` in generated code looks as follows:

```
void AddShift(double Shift, double y[10])
{
  int i0;
  static const signed char iv0[10] = { 1, 4, 9, 16, 25, 36,
                                49, 64, 81, 100 };

  for (i0 = 0; i0 < 10; i0++) {
    y[i0] = (double)iv0[i0] + Shift;
  }
}
```

Create Lookup Table in Generated Code

This example shows how to fold a user-written function into a constant in generated code.

Write a function `getsine` that takes an input `index` and returns the element referred to by `index` from a lookup table of sines. The function `getsine` creates the lookup table using another function `gettable`.

```
function y = getsine(index) %#codegen
  assert(isa(index, 'int32'));
  persistent tbl;
  if isempty(tbl)
           tbl = gettable(1024);
  end
  y = tbl(index);

function y = gettable(n)
      y = zeros(1,n);
      for i = 1:n
         y(i) = sin((i-1)/(2*pi*n));
      end
```

Generate code for `getsine` using an argument of type `int32`. Open the Code Generation Report.

```
codegen -config:lib -launchreport getsine -args int32(0)
```

The generated code contains instructions for creating the lookup table.

Replace the statement:

```
tbl = gettable(1024);
```

with:

```
tbl = coder.const(gettable(1024));
```

Generate code for `getsine` using an argument of type `int32`. Open the Code Generation Report.

The generated code contains the lookup table itself. `coder.const` forces the expression `gettable(1024)` to be evaluated during code generation. The generated code does not contain instructions for the evaluation. The generated code contains the result of the evaluation itself.

Specify Constants in Generated Code Using Multi-Output Function

This example shows how to specify constants in generated code using a multi-output function in a `coder.const` statement.

Write a function `MultiplyConst` that takes an input `factor` and multiplies every element of two vectors `vec1` and `vec2` with `factor`. The function generates `vec1` and `vec2` using another function `EvalConsts`.

```
function [y1,y2] = MultiplyConst(factor) %#codegen
  [vec1,vec2]=EvalConsts(pi.*(1./2.^(1:10)),2);
  y1=vec1.*factor;
  y2=vec2.*factor;

function [f1,f2]=EvalConsts(z,n)
  f1=z.^(2*n)/factorial(2*n);
  f2=z.^(2*n+1)/factorial(2*n+1);
```

Generate code for `MultiplyConst` using the `codegen` command. Open the Code Generation Report.

```
codegen -config:lib -launchreport MultiplyConst -args 0
```

The code generator produces code for creating the vectors.

Replace the statement

```
[vec1,vec2]=EvalConsts(pi.*(1./2.^(1:10)),2);
```

with

```
[vec1,vec2]=coder.const(@EvalConsts,pi.*(1./2.^(1:10)),2);
```

Generate code for `MultiplyConst` using the `codegen` command. Open the Code Generation Report.

```
codegen -config:lib -launchreport MultiplyConst -args 0
```

The code generator does not generate code for creating the vectors. Instead, it calculates the vectors and specifies the calculated vectors in generated code.

Read Constants by Processing XML File

This example shows how to call an extrinsic function using `coder.const`.

Write an XML file `MyParams.xml` containing the following statements:

```
<params>
    <param name="hello" value="17"/>
    <param name="world" value="42"/>
</params>
```

Save `MyParams.xml` in the current folder.

Write a MATLAB function `xml2struct` that reads an XML file. The function identifies the XML tag `param` inside another tag `params`.

After identifying `param`, the function assigns the value of its attribute `name` to the field name of a structure `s`. The function also assigns the value of attribute `value` to the value of the field.

```
function s = xml2struct(file)

s = struct();
doc = xmlread(file);
els = doc.getElementsByTagName('params');
for i = 0:els.getLength-1
    it = els.item(i);
    ps = it.getElementsByTagName('param');
    for j = 0:ps.getLength-1
        param = ps.item(j);
        paramName = char(param.getAttribute('name'));
        paramValue = char(param.getAttribute('value'));
        paramValue = evalin('base', paramValue);
        s.(paramName) = paramValue;
    end
end
```

Save `xml2struct` in the current folder.

Write a MATLAB function `MyFunc` that reads the XML file `MyParams.xml` into a structure `s` using the function `xml2struct`. Declare `xml2struct` as extrinsic using `coder.extrinsic` and call it in a `coder.const` statement.

```
function y = MyFunc(u) %#codegen
  assert(isa(u, 'double'));
```

```
  coder.extrinsic('xml2struct');
  s = coder.const(xml2struct('MyParams.xml'));
  y = s.hello + s.world + u;
```

Generate code for `MyFunc` using the `codegen` command. Open the Code Generation Report.

```
codegen -config:dll -launchreport MyFunc -args 0
```

The code generator executes the call to `xml2struct` during code generation. It replaces the structure fields `s.hello` and `s.world` with the values 17 and 42 in generated code.

Input Arguments

`expression` — MATLAB expression or user-written function
expression with constants | single-output function with constant arguments

MATLAB expression or user-defined single-output function.

The expression must have compile-time constants only. The function must take constant arguments only. For instance, the following code leads to a code generation error, because `x` is not a compile-time constant.

```
function y=func(x)
   y=coder.const(log10(x));
```

To fix the error, assign `x` to a constant in the MATLAB code. Alternatively, during code generation, you can use `coder.Constant` to define input type as follows:

```
codegen -config:lib func -args coder.Constant(10)
```

Example: 2*`pi`, `factorial(10)`

`handle` — Function handle
function handle

Handle to built-in or user-written function.

Example: `@log`, `@sin`

Data Types: `function_handle`

arg1,...,argN — Arguments to the function with handle handle

function arguments that are constants

Arguments to the function with handle `handle`.

The arguments must be compile-time constants. For instance, the following code leads to a code generation error, because `x` and `y` are not compile-time constants.

```
function y=func(x,y)
   y=coder.const(@nchoosek,x,y);
```

To fix the error, assign `x` and `y` to constants in the MATLAB code. Alternatively, during code generation, you can use `coder.Constant` to define input type as follows:

```
codegen -config:lib func -args {coder.Constant(10),coder.Constant(2)}
```

Output Arguments

out — Value of expression

value of the evaluated expression

Value of `expression`. In the generated code, MATLAB Coder replaces occurrences of `out` with the value of `expression`.

out1,...,outN — Outputs of the function with handle handle

values of the outputs of the function with handle `handle`

Outputs of the function with handle `handle`.MATLAB Coder evaluates the function and replaces occurrences of `out1,...,outN` with constants in the generated code.

Tips

- When possible, the code generator constant-folds expressions automatically. Typically, automatic constant-folding occurs for expressions with scalars only. Use `coder.const` when the code generator does not constant-fold expressions on its own.
- When constant-folding computationally intensive function calls, to reduce code generation time, make the function call extrinsic. The extrinsic function call causes evaluation of the function call by MATLAB instead of by the code generator. For example:

```
function j = fcn(z)
zTable = coder.const(0:0.01:100);
jTable = coder.const(feval('besselj',3,zTable));
j = interp1(zTable,jTable,z);
end
```

See “Use coder.const with Extrinsic Function Calls” (MATLAB Coder).

- If `coder.const` is unable to constant-fold a function call, try to force constant-folding by making the function call extrinsic. The extrinsic function call causes evaluation of the function call by MATLAB instead of by the code generator. For example:

```
function yi = fcn(xi)
y = coder.const(feval('rand',1,100));
yi = interp1(y,xi);
end
```

See “Use coder.const with Extrinsic Function Calls” (MATLAB Coder).

See Also

Topics

“Fold Function Calls into Constants” (MATLAB Coder)
“Use coder.const with Extrinsic Function Calls” (MATLAB Coder)

Introduced in R2013b

coder.Constant class

Package: coder
Superclasses:

Represent set containing one MATLAB value

Description

Use a `coder.Constant` object to define values that are constant during code generation. Use only with the `fiaccel -args` options. Do not pass as an input to a generated MEX function.

Construction

`const_type=coder.Constant(v)` creates a `coder.Constant` type from the value `v`.

`const_type=coder.newtype('constant', v)` creates a `coder.Constant` type from the value `v`.

Input Arguments

v

Constant value used to construct the type.

Properties

`Value`

The actual value of the constant.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create a constant with value 42.

```
k = coder.Constant(42);
```

Create a new constant type for use in code generation.

```
k = coder.newtype('constant', 42);
```

Limitations

- You cannot use `coder.Constant` on sparse matrices, or on structures, cell arrays, or classes that contain sparse matrices.

See Also

`coder.Type` | `coder.newtype` | `fiaccel`

Introduced in R2011a

coder.EnumType class

Package: coder
Superclasses:

Represent set of MATLAB enumerations

Description

Specifies the set of MATLAB enumerations that the generated code should accept. Use only with the `fiaccel -args` options. Do not pass as an input to a generated MEX function.

Construction

`enum_type = coder.typeof(enum_value)` creates a `coder.EnumType` object representing a set of enumeration values of class (`enum_value`).

`enum_type = coder.typeof(enum_value, sz, variable_dims)` returns a modified copy of `coder.typeof(enum_value)` with (upper bound) size specified by `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. When `sz` is [], the (upper bound) sizes of `v` do not change. If you do not specify `variable_dims`, the bounded dimensions of the type are fixed; the unbounded dimensions are variable size. When `variable_dims` is a scalar, it applies to bounded dimensions that are not `1` or `0` (which are fixed).

`enum_type = coder.newtype(enum_name,sz,variable_dims)` creates a `coder.EnumType` object that has variable size with (upper bound) sizes `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. If you do not specify `variable_dims`, the bounded dimensions of the type are fixed. When `variable_dims` is a scalar, it applies to bounded dimensions that are not `1` or `0` (which are fixed).

Input Arguments

enum_value

Enumeration value defined in a file on the MATLAB path.

sz

Size vector specifying each dimension of type object.

Default: [1 1] for `coder.newtype`

variable_dims

Logical vector that specifies whether each dimension is variable size (true) or fixed size (false).

Default: false(size(sz)) | sz==Inf for `coder.newtype`

enum_name

Name of enumeration defined in a file on the MATLAB path.

Properties

ClassName

Class of values in the set.

SizeVector

The upper-bound size of arrays in the set.

VariableDims

A vector specifying whether each dimension of the array is fixed or variable size. If a vector element is `true`, the corresponding dimension is variable size.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create a `coder.EnumType` object using a value from an existing MATLAB enumeration.

1. Define an enumeration `MyColors`. On the MATLAB path, create a file named 'MyColors' containing:

```
classdef MyColors < int32
    enumeration
        green(1),
        red(2),
    end
end
```

2. Create a `coder.EnumType` object from this enumeration.

```
t = coder.typeof(MyColors.red);
```

Create a `coder.EnumType` object using the name of an existing MATLAB enumeration.

1. Define an enumeration `MyColors`. On the MATLAB path, create a file named 'MyColors' containing:

```
classdef MyColors < int32
    enumeration
        green(1),
        red(2),
    end
end
```

2. Create a `coder.EnumType` object from this enumeration.

```
t = coder.newtype('MyColors');
```

See Also

`coder.ArrayType` | `coder.Type` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Topics

"Enumerations"

Introduced in R2011a

coder.extrinsic

Package: coder

Declare extrinsic function or functions

Syntax

`coder.extrinsic('`*`function_name`*`');`

`coder.extrinsic('`*`function_name_1`*`', ... , '`*`function_name_n`*`');`

`coder.extrinsic('`*`-sync:on`*`', '`*`function_name`*`');`

`coder.extrinsic('`*`-sync:on`*`', '`*`function_name_1`*`', ... , '`*`function_name_n`*`');`

`coder.extrinsic('`*`-sync:off`*`','`*`function_name`*`');`

`coder.extrinsic('`*`-sync:off`*`', '`*`function_name_1`*`', ... , '`*`function_name_n`*`');`

Arguments

`function_name`
`function_name_1``, ... ,` *`function_name_n`*

Declares *`function_name`* or *`function_name_1`* through *`function_name_n`* as extrinsic functions.

`–sync:on`

`function_name` or *`function_name_1`* through *`function_name_n`*.

Enables synchronization of global data between MATLAB and MEX functions before and after calls to the extrinsic functions, *`function_name`* or *`function_name_1`* through *`function_name_n`*. If only a few extrinsic calls modify global data, turn off synchronization before and after all extrinsic function calls by setting the global synchronization mode to `At MEX-function entry and exit`. Use the *–sync:on* option to turn on synchronization for only the extrinsic calls that *do* modify global data.

–sync:off

Disables synchronization of global data between MATLAB and MEX functions before and after calls to the extrinsic functions, `function_name` or `function_name_1` through `function_name_n`. If most extrinsic calls modify global data, but a few do not, you can use the *–sync:off* option to turn off synchronization for the extrinsic calls that *do not* modify global data.

Description

`coder.extrinsic` declares extrinsic functions. During simulation, the code generator produces code for the call to an extrinsic function, but does not produce the function's internal code. Therefore, simulation can run only on platforms where MATLAB software is installed. During standalone code generation, MATLAB attempts to determine whether the extrinsic function affects the output of the function in which it is called — for example by returning `mxArrays` to an output variable. Provided that there is no change to the output, MATLAB proceeds with code generation, but excludes the extrinsic function from the generated code. Otherwise, compilation errors occur.

You cannot use `coder.ceval` on functions that you declare extrinsic by using `coder.extrinsic`.

`coder.extrinsic` is ignored outside of code generation.

Limitations

- Extrinsic function calls have some overhead that can affect performance. Input data that is passed in an extrinsic function call must be provided to MATLAB, which requires making a copy of the data. If the function has any output data, this data must be transferred back into the MEX function environment, which also requires a copy.

Tips

- The code generator detects calls to many common visualization functions, such as `plot`, `disp`, and `figure`. The software treats these functions like extrinsic functions, but you do not have to declare them extrinsic using the `coder.extrinsic` function.

- Use the coder.screener function to detect which functions you must declare extrinsic. This function opens the code generations readiness tool that detects code generation issues in your MATLAB code.

Examples

The following code declares the MATLAB function patch as extrinsic in the MATLAB local function create_plot.

```
function c = pythagoras(a,b,color) %#codegen
% Calculates the hypotenuse of a right triangle
%  and displays the triangle as a patch object.

c = sqrt(a^2 + b^2);

create_plot(a, b, color);

function create_plot(a, b, color)

%Declare patch as extrinsic
coder.extrinsic('patch');

x = [0;a;a];
y = [0;0;b];
patch(x, y, color);
axis('equal');
```

By declaring patch as extrinsic, you instruct the code generator not to compile or produce code for patch. Instead, the code generator dispatches patch to MATLAB for execution.

See Also

coder.screener

Topics

"Extrinsic Functions"
"Controlling Synchronization for Extrinsic Function Calls" (MATLAB Coder)
"Resolution of Function Calls for Code Generation"

“Restrictions on Extrinsic Functions for Code Generation”

Introduced in R2011a

coder.FiType class

Package: coder
Superclasses:

Represent set of MATLAB fixed-point arrays

Description

Specifies the set of fixed-point array values that the generated code should accept. Use only with the `fiaccel -args` options. Do not pass as an input to the generated MEX function.

Construction

`t=coder.typeof(v)` creates a `coder.FiType` object representing a set of fixed-point values whose properties are based on the fixed-point input `v`.

`t=coder.typeof(v, sz, variable_dims)` returns a modified copy of `coder.typeof(v)` with (upper bound) size specified by `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. When `sz` is [], the (upper bound) sizes of `v` do not change. If you do not specify the `variable_dims` input parameter, the bounded dimensions of the type are fixed. When `variable_dims` is a scalar, it applies to the bounded dimensions that are not `1` or `0` (which are fixed).

`t=coder.newtype('embedded.fi', numerictype, sz, variable_dims)` creates a `coder.Type` object representing a set of fixed-point values with `numerictype` and (upper bound) sizes `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. When you do not specify `variable_dims`, the bounded dimensions of the type are fixed. When `variable_dims` is a scalar, it applies to the bounded dimensions that are not `1` or `0` (which are fixed).

`t=coder.newtype('embedded.fi', numerictype, sz, variable_dims, Name, Value)` creates a `coder.Type` object representing a set of fixed-point values with `numerictype` and additional options specified by one or more Name, Value pair arguments. `Name` can also be a property name and `Value` is the corresponding value. Specify `Name` as a character vector or string scalar. You can specify several name-value pair arguments in any order as `Name1,Value1,…,NameN,ValueN`.

Input Arguments

`v`

Fixed-point value used to create new `coder.FiType` object.

`sz`

Size vector specifying each dimension of type object.

Default: [1 1] for `coder.newtype`

`variable_dims`

Logical vector that specifies whether each dimension is variable size (true) or fixed size (false).

Default: false(size(sz)) | sz ==Inf for `coder.newtype`

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

`complex`

Set `complex` to `true` to create a `coder.Type` object that can represent complex values. The type must support complex data.

Default: false

`fimath`

Specify local `fimath`. If not, uses default `fimath`.

Properties

`ClassName`

Class of values in the set.

`Complex`

Indicates whether fixed-point arrays in the set are real (`false`) or complex (`true`).

`Fimath`

Local `fimath` that the fixed-point arrays in the set use.

`NumericType`

numerictype that the fixed-point arrays in the set use.

`SizeVector`

The upper-bound size of arrays in the set.

`VariableDims`

A vector specifying whether each dimension of the array is fixed or variable size. If a vector element is `true`, the corresponding dimension is variable size.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create a new fixed-point type `t`.

```
t = coder.typeof(fi(1));
% Returns
% coder.FiType
%   1x1 embedded.fi
%       DataTypeMode:Fixed-point: binary point scaling
```

```
%          Signedness:Signed
%          WordLength:16
%      FractionLength:14
```

Create a new fixed-point type for use in code generation. The fixed-point type uses the default `fimath`.

```
t = coder.newtype('embedded.fi',numerictype(1, 16, 15), [1 2])

t =
% Returns
% coder.FiType
%   1x2 embedded.fi
%           DataTypeMode: Fixed-point: binary point scaling
%           Signedness: Signed
%           WordLength: 16
%           FractionLength: 15
```

This new type uses the default `fimath`.

See Also

`coder.ArrayType` | `coder.Type` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Introduced in R2011a

coder.FixptConfig class

Package: coder

Floating-point to fixed-point conversion configuration object

Description

A `coder.FixptConfig` object contains the configuration parameters that the `fiaccel` function requires to convert floating-point MATLAB code to fixed-point MATLAB code. Use the `-float2fixed` option to pass this object to the `fiaccel` function.

Construction

`fixptcfg` `= coder.config('fixpt')` creates a `coder.FixptConfig` object for floating-point to fixed-point conversion.

Properties

`ComputeDerivedRanges`

Enable derived range analysis.

Values: `true`|`false` (default)

`ComputeSimulationRanges`

Enable collection and reporting of simulation range data. If you need to run a long simulation to cover the complete dynamic range of your design, consider disabling simulation range collection and running derived range analysis instead.

Values: `true` (default)|`false`

`DefaultFractionLength`

Default fixed-point fraction length.

Values: 4 (default) | positive integer

DefaultSignedness

Default signedness of variables in the generated code.

Values: `'Automatic'` (default) | `'Signed'` | `'Unsigned'`

DefaultWordLength

Default fixed-point word length.

Values: 14 (default) | positive integer

DetectFixptOverflows

Enable detection of overflows using scaled doubles.

Values: `true`| `false` (default)

fimath

`fimath` properties to use for conversion.

Values: `fimath('RoundingMethod', 'Floor', 'OverflowAction', 'Wrap', 'ProductMode', 'FullPrecision', 'SumMode', 'FullPrecision')` (default) | string

FixPtFileNameSuffix

Suffix for fixed-point file names.

Values: `'_fixpt'` | string

LaunchNumericTypesReport

View the numeric types report after the software has proposed fixed-point types.

Values: `true` (default) | `false`

LogIOForComparisonPlotting

Enable simulation data logging to plot the data differences introduced by fixed-point conversion.

Values: `true` (default) | `false`

OptimizeWholeNumber

Optimize the word lengths of variables whose simulation min/max logs indicate that they are always whole numbers.

Values: `true` (default) | `false`

PlotFunction

Name of function to use for comparison plots.

`LogIOForComparisonPlotting` must be set to true to enable comparison plotting. This option takes precedence over `PlotWithSimulationDataInspector`.

The plot function should accept three inputs:

- A structure that holds the name of the variable and the function that uses it.
- A cell array to hold the logged floating-point values for the variable.
- A cell array to hold the logged values for the variable after fixed-point conversion.

Values: `''` (default) | string

PlotWithSimulationDataInspector

Use Simulation Data Inspector for comparison plots.

`LogIOForComparisonPlotting` must be set to true to enable comparison plotting. The `PlotFunction` option takes precedence over `PlotWithSimulationDataInspector`.

Values: `true`| `false` (default)

ProposeFractionLengthsForDefaultWordLength

Propose fixed-point types based on `DefaultWordLength`.

Values: `true` (default) | `false`

ProposeTargetContainerTypes

By default (false), propose data types with the minimum word length needed to represent the value. When set to true, propose data type with the smallest word length that can represent the range and is suitable for C code generation (8,16,32, 64 …). For example, for a variable with range [0..7], propose a word length of 8 rather than 3.

Values: `true`| `false` (default)

ProposeWordLengthsForDefaultFractionLength

Propose fixed-point types based on `DefaultFractionLength`.

Values: `false` (default) | `true`

ProposeTypesUsing

Propose data types based on simulation range data, derived ranges, or both.

Values: `'BothSimulationAndDerivedRanges'` (default) |
`'SimulationRanges'`|`'DerivedRanges'`

SafetyMargin

Safety margin percentage by which to increase the simulation range when proposing fixed-point types. The specified safety margin must be a real number greater than `-100`.

Values: 0 (default) | double

StaticAnalysisQuickMode

Perform faster static analysis.

Values: `true` | `false` (default)

StaticAnalysisTimeoutMinutes

Abort analysis if timeout is reached.

Values: `''` (default) | positive integer

TestBenchName

Test bench function name or names, specified as a string or cell array of strings. You must specify at least one test bench.

If you do not explicitly specify input parameter data types, the conversion uses the first test bench function to infer these data types.

Values: `''` (default) | string | cell array of strings

TestNumerics

Enable numerics testing.

Values: `true`| `false` (default)

Methods

addApproximation	Replace floating-point function with lookup table during fixed-point conversion
addDesignRangeSpecification	Add design range specification to parameter
addFunctionReplacement	Replace floating-point function with fixed-point function during fixed-point conversion
clearDesignRangeSpecifications	Clear all design range specifications
getDesignRangeSpecification	Get design range specifications for parameter
hasDesignRangeSpecification	Determine whether parameter has design range
removeDesignRangeSpecification	Remove design range specification from parameter

Examples

Convert Floating-Point MATLAB Code to Fixed Point Based On Simulation Ranges

Create a `coder.FixptConfig` object, `fixptcfg`, with default settings.

```
fixptcfg = coder.config('fixpt');
```

Set the test bench name. In this example, the test bench function name is `dti_test`. The conversion process uses the test bench to infer input data types and collect simulation range data.

```
fixptcfg.TestBenchName = 'dti_test';
```

Select to propose data types based on simulation ranges only. By default, proposed types are based on both simulation and derived ranges.

```
fixptcfg.ProposeTypesUsing = 'SimulationRanges';
```

Convert a floating-point MATLAB function to fixed-point MATLAB code. In this example, the MATLAB function name is `dti`.

```
fiaccel -float2fixed fixptcfg dti
```

Convert Floating-Point MATLAB Code to Fixed Point Based On Simulation and Derived Ranges

Create a `coder.FixptConfig` object, `fixptcfg`, with default settings.

```
fixptcfg = coder.config('fixpt');
```

Set the name of the test bench to use to infer input data types. In this example, the test bench function name is `dti_test`. The conversion process uses the test bench to infer input data types.

```
fixptcfg.TestBenchName = 'dti_test';
```

Select to propose data types based on derived ranges.

```
fixptcfg.ProposeTypesUsing = 'DerivedRanges';
fixptcfg.ComputeDerivedRanges = true;
```

Add design ranges. In this example, the `dti` function has one scalar double input, `u_in`. Set the design minimum value for `u_in` to `-1` and the design maximum to `1`.

```
fixptcfg.addDesignRangeSpecification('dti', 'u_in', -1.0, 1.0);
```

Convert the floating-point MATLAB function, `dti`, to fixed-point MATLAB code.

```
fiaccel -float2fixed fixptcfg  dti
```

Enable Overflow Detection

When you select to detect potential overflows, `fiaccel` generates a scaled double version of the generated fixed-point MEX function. Scaled doubles store their data in double-precision floating-point, so they carry out arithmetic in full range. They also retain their fixed-point settings, so they are able to report when a computation goes out of the range of the fixed-point type.

Create a `coder.FixptConfig` object, `fixptcfg`, with default settings.

```
fixptcfg = coder.config('fixpt');
```

Set the test bench name. In this example, the test bench function name is `dti_test`.

```
fixptcfg.TestBenchName = 'dti_test';
```

Enable numerics testing with overflow detection.

```
fixptcfg.TestNumerics = true;
fixptcfg.DetectFixptOverflows = true;
```

Convert a floating-point MATLAB function to fixed-point MATLAB code. In this example, the MATLAB function name is `dti`.

```
fiaccel -float2fixed fixptcfg dti
```

- “Propose Data Types Based on Simulation Ranges”
- “Propose Data Types Based on Derived Ranges”
- “Detect Overflows”

Alternatives

You can convert floating-point MATLAB code to fixed-point code using the Fixed-Point Converter app. Open the app using one of these methods:

- On the **Apps** tab, in the **Code Generation** section, click **Fixed-Point Converter**.
- Use the `fixedPointConverter` command.

See Also

`coder.mexConfig` | `coder.mexconfig` | `fiaccel`

Topics

“Propose Data Types Based on Simulation Ranges”
“Propose Data Types Based on Derived Ranges”
“Detect Overflows”

coder.ignoreConst

Prevent use of constant value of expression for function specializations

Syntax

`coder.ignoreConst(expression)`

Description

`coder.ignoreConst(expression)` prevents the code generator from using the constant value of `expression` to create function specializations on page 4-175. `coder.ignoreConst(expression)` returns the value of `expression`.

Examples

Prevent Function Specializations Based on Constant Input Values

Use `coder.ignoreConst` to prevent function specializations for a function that is called with constant values.

Write the function `call_myfn`, which calls `myfcn`.

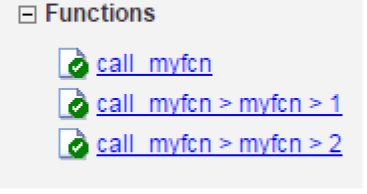
```
function [x, y] = call_myfcn(n)
%#codegen
x = myfcn(n, 'mode1');
y = myfcn(n, 'mode2');
end

function y = myfcn(n,mode)
coder.inline('never');
if strcmp(mode,'mode1')
    y = n;
else
    y = -n;
```

```
end
end
```

Generate standalone C code. For example, generate a static library. Enable the code generation report.

```
codegen -config:lib call_myfcn -args {1} -report
```

In the code generation report, you see two function specializations for `call_myfcn`.



The code generator creates `call_myfcn>myfcn>1` for `mode` with a value of `'mode1'`. It creates `call_myfcn>myfcn>2` for `mode` with a value of `'mode2'`.

In the generated C code, you see the specializations `my_fcn` and `b_my_fcn`.

```
static double b_myfcn(double n)
{
  return -n;
}

static double myfcn(double n)
{
  return n;
}
```

To prevent the function specializations, instruct the code generator to ignore that values of the `mode` argument are constant.

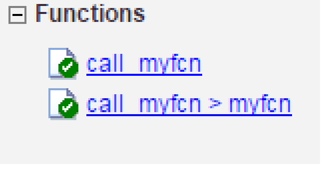
```
function [x, y] = call_myfcn(n)
%#codegen
x = myfcn(n, coder.ignoreConst('mode1'));
y = myfcn(n, coder.ignoreConst('mode2'));
end

function y = myfcn(n,mode)
coder.inline('never');
if strcmp(mode,'mode1')
```

```
    y = n;
else
    y = -n;
end
end
```

Generate the C code.

```
codegen -config:lib call_myfcn -args {1} -report
```

In the code generation report, you do not see multiple function specializations.



In the generated C code, you see one function for `my_fcn`.

Input Arguments

`expression` — Expression whose value is to be treated as a nonconstant
MATLAB expression

Definitions

Function Specialization

Version of a function in which an input type, size, complexity, or value is customized for a particular invocation of the function.

Function specialization produces efficient C code at the expense of code duplication. The code generation report shows all MATLAB function specializations that the code generator creates. However, the specializations might not appear in the generated C/C++ code due to later transformations or optimizations.

Tips

- For some recursive function calls, you can use `coder.ignoreConst` to force run-time recursion. See “Force Code Generator to Use Run-Time Recursion”.
- `coder.ignoreConst(expression)` prevents the code generator from using the constant value of `expression` to create function specializations. It does not prevent other uses of the constant value during code generation.

See Also

`coder.inline`

Topics

“Force Code Generator to Use Run-Time Recursion”
“Compile-Time Recursion Limit Reached”

Introduced in R2017a

coder.inline

Package: coder

Control inlining in generated code

Syntax

```
coder.inline('always')
coder.inline('never')
coder.inline('default')
```

Description

`coder.inline('always')` forces inlining on page 4-179 of the current function in the generated code. Place the `coder.inline` directive inside the function to which it applies. The code generator does not inline entry-point functions, inline functions into `parfor` loops, or inline functions called from `parfor` loops.

`coder.inline('never')` prevents inlining of the current function in the generated code. Prevent inlining when you want to simplify the mapping between the MATLAB source code and the generated code. You can disable inlining for all functions at the command line by using the `-O disable:inline` option of the `fiaccel` command.

`coder.inline('default')` uses internal heuristics to determine whether to inline the current function. Usually, the heuristics produce highly optimized code. Use `coder.inline` only when you need to fine-tune these optimizations.

Examples

- "Prevent Function Inlining" on page 4-178
- "Use coder.inline in Control Flow Statements" on page 4-178

Prevent Function Inlining

In this example, function foo is not inlined in the generated code:

```
function y = foo(x)
  coder.inline('never');
  y = x;
end
```

Use coder.inline in Control Flow Statements

You can use coder.inline in control flow code. If the software detects contradictory coder.inline directives, the generated code uses the default inlining heuristic and issues a warning.

Suppose that you want to generate code for a division function used by a system with limited memory. To optimize memory use in the generated code, the inline_division function manually controls inlining based on whether it performs scalar division or vector division:

```
function y = inline_division(dividend, divisor)

% For scalar division, inlining produces smaller code
% than the function call itself.
if isscalar(dividend) && isscalar(divisor)
   coder.inline('always');
else
% Vector division produces a for-loop.
% Prohibit inlining to reduce code size.
   coder.inline('never');
end

if any(divisor == 0)
   error('Cannot divide by 0');
end

y = dividend / divisor;
```

Definitions

Inlining

Technique that replaces a function call with the contents (body) of that function. Inlining eliminates the overhead of a function call, but can produce larger C/C++ code. Inlining can create opportunities for further optimization of the generated C/C++ code.

See Also

`fiaccel`

Introduced in R2011a

coder.load

Load compile-time constants from MAT-file or ASCII file into caller workspace

Syntax

```
S = coder.load(filename)
S = coder.load(filename,var1,...,varN)
S = coder.load(filename,'-regexp',expr1,...,exprN)
S = coder.load(filename,'-ascii')
S = coder.load(filename,'-mat')
S = coder.load(filename,'-mat',var1,...,varN)
S = coder.load(filename,'-mat','-regexp', expr1,...,exprN)
```

Description

`S = coder.load(filename)` loads compile-time constants from `filename`.

- If `filename` is a MAT-file, then `coder.load` loads variables from the MAT-file into a structure array.
- If `filename` is an ASCII file, then `coder.load` loads data into a double-precision array.

`S = coder.load(filename,var1,...,varN)` loads only the specified variables from the MAT-file `filename`.

`S = coder.load(filename,'-regexp',expr1,...,exprN)` loads only the variables that match the specified regular expressions.

`S = coder.load(filename,'-ascii')` treats `filename` as an ASCII file, regardless of the file extension.

`S = coder.load(filename,'-mat')` treats `filename` as a MAT-file, regardless of the file extension.

`S = coder.load(filename,'-mat',var1,...,varN)` treats `filename` as a MAT-file and loads only the specified variables from the file.

`S = coder.load(filename,'-mat','-regexp', expr1,...,exprN)` treats `filename` as a MAT-file and loads only the variables that match the specified regular expressions.

Examples

Load compile-time constants from MAT-file

Generate code for a function `edgeDetect1` which given a normalized image, returns an image where the edges are detected with respect to the threshold value. `edgeDetect1` uses `coder.load` to load the edge detection kernel from a MAT-file at compile time.

Save the Sobel edge-detection kernel in a MAT-file.

```
k = [1 2 1; 0 0 0; -1 -2 -1];
```

```
save sobel.mat k
```

Write the function `edgeDetect1`.

```
function edgeImage = edgeDetect1(originalImage, threshold) %#codegen
assert(all(size(originalImage) <= [1024 1024]));
assert(isa(originalImage, 'double'));
assert(isa(threshold, 'double'));

S = coder.load('sobel.mat','k');
H = conv2(double(originalImage),S.k, 'same');
V = conv2(double(originalImage),S.k','same');
E = sqrt(H.*H + V.*V);
edgeImage = uint8((E > threshold) * 255);
```

Create a code generation configuration object for a static library.

```
cfg = coder.config('lib');
```

Generate a static library for `edgeDetect1`.

```
codegen -report -config cfg edgeDetect1
```

`codegen` generates C code in the `codegen\lib\edgeDetect1` folder.

Load compile-time constants from ASCII file

Generate code for a function `edgeDetect2` which given a normalized image, returns an image where the edges are detected with respect to the threshold value. `edgeDetect2` uses `coder.load` to load the edge detection kernel from an ASCII file at compile time.

Save the Sobel edge-detection kernel in an ASCII file.

```
k = [1 2 1; 0 0 0; -1 -2 -1];
save sobel.dat k -ascii
```

Write the function `edgeDetect2`.

```
function edgeImage = edgeDetect2(originalImage, threshold) %#codegen
assert(all(size(originalImage) <= [1024 1024]));
assert(isa(originalImage, 'double'));
assert(isa(threshold, 'double'));

k = coder.load('sobel.dat');
H = conv2(double(originalImage),k, 'same');
V = conv2(double(originalImage),k','same');
E = sqrt(H.*H + V.*V);
edgeImage = uint8((E > threshold) * 255);
```

Create a code generation configuration object for a static library.

```
cfg = coder.config('lib');
```

Generate a static library for `edgeDetect2`.

```
codegen -report -config cfg edgeDetect2
```

`codegen` generates C code in the `codegen\lib\edgeDetect2` folder.

Input Arguments

`filename` — Name of file

character vector | string scalar

Name of file. `filename` must be a compile-time constant.

`filename` can include a file extension and a full or partial path. If `filename` has no extension, `load` looks for a file named `filename.mat`. If `filename` has an extension other than `.mat`, `load` treats the file as ASCII data.

ASCII files must contain a rectangular table of numbers, with an equal number of elements in each row. The file delimiter (the character between elements in each row) can be a blank, comma, semicolon, or tab character. The file can contain MATLAB comments (lines that begin with a percent sign, `%`).

Example: `'myFile.mat'`

`var1,...,varN` — Names of variables to load
character vector | string scalar

Names of variables, specified as one or more character vectors or string scalars. Each variable name must be a compile-time constant. Use the `*` wildcard to match patterns.

Example: `coder.load('myFile.mat','A*')` loads all variables in the file whose names start with `A`.

`expr1,...,exprN` — Regular expressions indicating which variables to load
character vector | string scalar

Regular expressions indicating which variables to load specified as one or more character vectors or string scalars. Each regular expression must be a compile-time constant.

Example: `coder.load('myFile.mat', '-regexp', '^A')` loads only variables whose names begin with `A`.

Output Arguments

`S` — Loaded variables or data
structure array | m-by-n array

If `filename` is a MAT-file, `S` is a structure array.

If `filename` is an ASCII file, `S` is an m-by-n array of type `double`. m is the number of lines in the file and n is the number of values on a line.

Limitations

- `coder.load` does not support loading objects.
- Arguments to `coder.load` must be compile-time constants.
- The output `S` must be the name of a structure or array without any subscripting. For example, `S(i) = coder.load('myFile.mat')` is not allowed.
- You cannot use `save` to save workspace data to a file inside a function intended for code generation. The code generator does not support the `save` function. Furthermore, you cannot use `coder.extrinsic` with `save`. Prior to generating code, you can use `save` to save workspace data to a file.

Tips

- `coder.load` loads data at compile time, not at run time. If you are generating MEX code or code for Simulink simulation, you can use the MATLAB function `load` to load run-time values.
- If the MAT-file contains unsupported constructs, use `coder.load(filename,var1,...,varN)` to load only the supported constructs.
- If you generate code in a MATLAB Coder project, the code generator practices incremental code generation for the `coder.load` function. When the MAT-file or ASCII file used by `coder.load` changes, the software rebuilds the code.

See Also

`matfile` | `regexp` | `save`

Topics

"Regular Expressions" (MATLAB)

Introduced in R2013a

coder.mexconfig

Package: coder

Code acceleration configuration object

Syntax

`config_obj = coder.mexconfig`

Description

`config_obj = coder.mexconfig` creates a `coder.MexConfig` code generation configuration object for use with `fiaccel`, which generates a MEX function.

Output Arguments

`config_obj`

Code generation configuration object for use when generating MEX functions using `fiaccel`.

Examples

Create a configuration object to disable run-time checks

```
cfg = coder.mexconfig
% Turn off Integrity Checks, Extrinsic Calls,
% and Responsiveness Checks
cfg.IntegrityChecks = false;
cfg.ExtrinsicCalls = false;
cfg.ResponsivenessChecks = false;
% Use fiaccel to generate a MEX function for file foo.m
fiaccel -config cfg foo
```

See Also

coder.ArrayType | coder.Constant | coder.EnumType | coder.FiType | coder.MexConfig | coder.PrimitiveType | coder.StructType | coder.Type | coder.newtype | coder.resize | coder.typeof | fiaccel

Introduced in R2011a

coder.newtype

Package: coder

Create a `coder.Type` object

Syntax

```
t = coder.newtype(numeric_class, sz, variable_dims)
t = coder.newtype(numeric_class, sz, variable_dims, Name, Value)
t = coder.newtype('constant', value)
t = coder.newtype('struct', struct_fields, sz, variable_dims)
t = coder.newtype('cell', cells, sz, variable_dims)
t = coder.newtype('embedded.fi', numerictype, sz, variable_dims,
Name, Value)
t = coder.newtype(enum_value, sz, variable_dims)
t = coder.newtype(class_name)
t = coder.newtype('string')
```

Description

Note `coder.newtype` is an advanced function that you can use to control the `coder.Type` object. Consider using `coder.typeof` instead. `coder.typeof` creates a type from a MATLAB example.

`t = coder.newtype(numeric_class, sz, variable_dims)` creates a `coder.Type` object representing values of class `numeric_class` with (upper bound) sizes `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. When `variable_dims` is not specified, the dimensions of the type are fixed except for those that are unbounded. When `variable_dims` is a scalar, it is applied to dimensions of the type that are not `1` or `0`, which are fixed.

`t = coder.newtype(numeric_class, sz, variable_dims, Name, Value)` creates a `coder.Type` object with additional options specified by one or more Name, Value pair arguments.

`t = coder.newtype('constant', value)` creates a `coder.Constant` object representing a single value. Use this type to specify a value that must be treated as a constant in the generated code.

`t = coder.newtype('struct', struct_fields, sz, variable_dims)` creates a `coder.StructType` object for an array of structures that has the same fields as the scalar structure `struct_fields`. The structure array type has the size specified by `sz` and variable-size dimensions specified by `variable_dims`.

`t = coder.newtype('cell', cells, sz, variable_dims)` creates a `coder.CellType` object for a cell array that has the cells and cell types specified by `cells`. The cell array type has the size specified by `sz` and variable-size dimensions specified by `variable_dims`. You cannot change the number of cells or specify variable-size dimensions for a heterogeneous cell array.

`t = coder.newtype('embedded.fi', numerictype, sz, variable_dims, Name, Value)` creates a `coder.FiType` object representing a set of fixed-point values with `numerictype` and additional options specified by one or more Name, Value pair arguments.

`t = coder.newtype(enum_value, sz, variable_dims)` creates a `coder.Type` object representing a set of enumeration values of class `enum_value`.

`t = coder.newtype(class_name)` creates a `coder.ClassType` object for an object of the class `class_name`.

`t = coder.newtype('string')` creates a type for a string scalar. A string scalar contains one piece of text represented as a character vector. To specify the size of the character vector and whether the second dimension is variable-size, create a type for the character vector and assign it to the `Value` property of the string scalar type. For example, `t.Properties.Value = coder.newtype('char',[1 10], [0 1])` specifies that the character vector inside the string scalar is variable-size with an upper bound of 10.

Input Arguments

numeric_class

Class of the set of values represented by the type object.

struct_fields

Scalar structure used to specify the fields in a new structure type.

cells

Cell array of coder.Type objects that specify the types of the cells in a new cell array type.

sz

Size vector specifying each dimension of type object. sz cannot change the number of cells for a heterogeneous cell array.

Default: [1 1]

class_name

Name of class from which to create the coder.ClassType, specified as a character vector or string scalar. class_name must be the name of a value class.

variable_dims

Logical vector that specifies whether each dimension is variable size (true) or fixed size (false). You cannot specify variable-size dimensions for a heterogeneous cell array.

Default: true for dimensions for which sz specifies an upper bound of inf; false for all other dimensions.

Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

complex

Set `complex` to `true` to create a `coder.Type` object that can represent complex values. The type must support complex data.

Default: false

fimath

Specify local `fimath`. If `fimath` is not specified, uses default fimath values.

Use only with `t=`coder.newtype('embedded.fi', numerictype,`sz`, `variable_dims`, Name, Value).

sparse

Set `sparse` to `true` to create a `coder.Type` object representing sparse data. The type must support sparse data.

Not for use with `t=`coder.newtype('embedded.fi', numerictype,`sz`, `variable_dims`, Name, Value)

Default: false

Output Arguments

t

New `coder.Type` object.

Examples

Create a type for use in code generation.

```
t=coder.newtype('double',[2 3 4],[1 1 0])
% Returns double :2x:3x4
% ':' indicates variable-size dimensions
```

Create a type for a matrix of doubles, first dimension unbounded, second dimension with fixed size

```
coder.newtype('double',[inf,3])
%   returns double:inf x 3

coder.newtype('double', [inf, 3], [1 0])
%   also returns double :inf x3
%   ':' indicates variable-size dimensions
```

Create a type for a matrix of doubles, first dimension unbounded, second dimension with variable size with an upper bound of `3`

```
coder.newtype('double', [inf,3],[0 1])
%  returns double :inf x :3
%  ':' indicates variable-size dimensions
```

Create a structure type to use in code generation.

```
ta = coder.newtype('int8',[1 1]);
tb = coder.newtype('double',[1 2],[1 1]);
coder.newtype('struct',struct('a',ta,'b',tb))
% returns struct 1x1
%            a: int8 1x1
%            b: double :1x:2
% ':' indicates variable-size dimensions
```

Create a cell array to use in code generation.

```
ta = coder.newtype('int8',[1 1]);
tb = coder.newtype('double',[1 2],[1 1]);
coder.newtype('cell',{ta, tb})
% returns 1x2 heterogeneous cell
%            f0: 1x1 int8
%            f1: :1x:2 double
% ':' indicates variable-size dimensions
```

Create a new constant type to use in code generation.

```
k = coder.newtype('constant', 42);
% Returns
% k =
%
% coder.Constant
%       42
```

Create a `coder.EnumType` object using the name of an existing MATLAB enumeration.

1 Define an enumeration `MyColors`. On the MATLAB path, create a file named 'MyColors' containing:

```
classdef MyColors < int32
    enumeration
        green(1),
        red(2),
    end
end
```

2 Create a `coder.EnumType` object from this enumeration.

```
t = coder.newtype('MyColors');
```

Create a fixed-point type for use in code generation. The fixed-point type uses default fimath values.

```
t = coder.newtype('embedded.fi',...
   numerictype(1, 16, 15), [1 2])

t =
% Returns
% coder.FiType
%   1x2 embedded.fi
%     DataTypeMode: Fixed-point: binary point scaling
%     Signedness: Signed
%     WordLength: 16
%     FractionLength: 15
```

Create a type for an object to use in code generation.

1 Create this value class:

```
classdef mySquare
    properties
        side;
    end
    methods
        function obj = mySquare(val)
        end
    end
    if nargin > 0
        obj.side = val;
    end
    function a = calcarea(obj)
    a = obj.side * obj.side;
```

```
        end
    end
end
```

2 Create a type for an object that has the same properties as `mySquare`.

```
t = coder.newtype('mySquare')
```

3 Change the type of the property `side`.

```
t.Properties.side = coder.typeof(int8(3))

t = 

coder.ClassType
   1×1 mySquare
      side: 1×1 int8
```

Create a type for a string scalar for use in code generation.

1 Create the string scalar type.

```
t = coder.newtype('string');
```

2 Specify the size.

```
t.Properties.Value = coder.newtype('char',[1, 10])

t = 

coder.ClassType
   1×1 string -> redirected to -> coder.internal.string
      Value: 1×10 char
```

3 Make the string variable-size with an upper bound of 10.

```
t.Properties.Value = coder.newtype('char',[1, 10], [0, 1])
```

4 Make the string variable-size with no upper bound.

```
t.Properties.Value = coder.newtype('char',[1, inf])
```

Tips

- `coder.newtype` fixes the size of a singleton dimension unless the `variable_dims` argument explicitly specifies that the singleton dimension has a variable size.

For example, the following code specifies a 1-by-:10 double. The first dimension (the singleton dimension) has a fixed size. The second dimension has a variable size.

```
t = coder.newtype('double',[1 10],1)
```

By contrast, the following code specifies a :1-by-:10 double. Both dimensions have a variable size.

```
t = coder.newtype('double',[1 10],[1 1])
```

Note For a MATLAB Function block, singleton dimensions of input or output signals cannot have a variable size.

Alternatives

`coder.typeof`

See Also

`coder.ArrayType` | `coder.CellType` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.StructType` | `coder.Type` | `coder.resize` | `fiaccel`

Introduced in R2011a

coder.nullcopy

Package: coder

Declare uninitialized variables

Syntax

`X = coder.nullcopy(A)`

Description

`X = coder.nullcopy(A)` copies type, size, and complexity of *A* to *X*, but does not copy element values. Preallocates memory for *X* without incurring the overhead of initializing memory.

Use With Caution

Use this function with caution. See “How to Eliminate Redundant Copies by Defining Uninitialized Variables”.

Examples

The following example shows how to declare variable *X* as a 1-by-5 vector of real doubles without performing an unnecessary initialization:

```
function X = foo

N = 5;
X = coder.nullcopy(zeros(1,N));
for i = 1:N
   if mod(i,2) == 0
      X(i) = i;
   else
      X(i) = 0;
```

```
    end
end
```

Using `coder.nullcopy` with `zeros` lets you specify the size of vector *X* without initializing each element to zero.

Limitations

- `coder.nullcopy` does not support MATLAB classes as inputs.
- You cannot use `coder.nullcopy` on sparse matrices, or on structures, cell arrays, or classes that contain sparse matrices.

See Also

Topics

"Eliminate Redundant Copies of Variables in Generated Code"

Introduced in R2011a

coder.PrimitiveType class

Package: coder
Superclasses:

Represent set of logical, numeric, or char arrays

Description

Specifies the set of logical, numeric, or char values that the generated code should accept. Supported classes are `double`,`single`,`int8`,`uint8`,`int16`,`uint16`,`int32`,`uint32`,`int64`,`uint64`, `char`, and `logical`. Use only with the `fiaccel -args` option. Do not pass as an input to a generated MEX function.

Construction

`t=coder.typeof(v)` creates a `coder.PrimitiveType` object denoting the smallest non-constant type that contains `v`. `v` must be a MATLAB numeric, logical or char.

`t=coder.typeof(v, sz, variable_dims)` returns a modified copy of `coder.typeof(v)` with (upper bound) size specified by `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is assumed to be unbounded and the dimension is assumed to be variable sized. When `sz` is [], the (upper bound) sizes of `v` remain unchanged. When `variable_dims` is not specified, the dimensions of the type are assumed to be fixed except for those that are unbounded. When `variable_dims` is a scalar, it is applied to bounded dimensions that are not `1` or `0` (which are assumed to be fixed).

`t=coder.newtype(numeric_class, sz, variable_dims)` creates a `coder.PrimitiveType` object representing values of class `numeric_class` with (upper bound) sizes `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is assumed to be unbounded and the dimension is assumed to be variable sized. When `variable_dims` is not specified, the dimensions of the type are assumed to be fixed except for those that are unbounded. When `variable_dims` is a scalar, it is applied to the dimensions of the type that are not `1` or `0` (which are assumed to be fixed).

t=coder.newtype(numeric_class, sz, variable_dims, Name, Value) creates a coder.PrimitiveType object with additional options specified by one or more Name, Value pair arguments. Name can also be a property name and Value is the corresponding value. Specify Name as character vector or string scalar. You can specify several name-value pair arguments in any order as Name1,Value1,…,NameN,ValueN.

Input Arguments

v

Input that is not a coder.Type object

sz

Size for corresponding dimension of type object. Size must be a valid size vector.

Default: [1 1] for coder.newtype

variable_dims

Logical vector that specifies whether each dimension is variable size (true) or fixed size (false).

Default: false(size(sz)) | sz==Inf for coder.newtype

numeric_class

Class of type object.

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

complex

Set complex to true to create a coder.PrimitiveType object that can represent complex values. The type must support complex data.

Default: false

sparse

Set `sparse` to `true` to create a `coder.PrimitiveType` object representing sparse data. The type must support sparse data.

Default: false

Properties

ClassName

Class of values in this set

Complex

Indicates whether the values in this set are real (`false`) or complex (`true`)

SizeVector

The upper-bound size of arrays in this set.

Sparse

Indicates whether the values in this set are sparse arrays (`true`)

VariableDims

A vector used to specify whether each dimension of the array is fixed or variable size. If a vector element is `true`, the corresponding dimension is variable size.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create a `coder.PrimitiveType` object.

```
z = coder.typeof(0,[2 3 4],[1 1 0]) % returns double :2x:3x4
% ':' indicates variable-size dimensions
```

See Also

`coder.ArrayType` | `coder.Type` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Introduced in R2011a

coder.resize

Package: coder

Resize a `coder.Type` object

Syntax

```
t_out = coder.resize(t, sz, variable_dims)
t_out = coder.resize(t, sz)
t_out = coder.resize(t,[],variable_dims)
t_out = coder.resize(t, sz, variable_dims, Name, Value)
t_out = coder.resize(t, 'sizelimits', limits)
```

Description

`t_out = coder.resize(t, sz, variable_dims)` returns a modified copy of `coder.Type` `t` with upper-bound size `sz`, and variable dimensions `variable_dims`. If `variable_dims` or `sz` are scalars, the function applies them to all dimensions of `t`. By default, `variable_dims` does not apply to dimensions where `sz` is `0` or `1`, which are fixed. Use the 'uniform' option to override this special case. `coder.resize` ignores `variable_dims` for dimensions with size `inf`. These dimensions are always variable size. `t` can be a cell array of types, in which case, `coder.resize` resizes all elements of the cell array.

`t_out = coder.resize(t, sz)` resizes `t` to have size `sz`.

`t_out = coder.resize(t,[],variable_dims)` changes `t` to have variable dimensions `variable_dims` while leaving the size unchanged.

`t_out = coder.resize(t, sz, variable_dims, Name, Value)` resizes `t` using additional options specified by one or more Name, Value pair arguments.

`t_out = coder.resize(t, 'sizelimits', limits)` resizes `t` with dimensions becoming variable based on the `limits` vector. When the size `S` of a dimension is greater than or equal to the first threshold defined in `limits`, the dimension becomes variable size with upper bound S. When the size S of a dimension is greater than or equal to the second threshold defined in limits, the dimension becomes unbounded variable size.

Input Arguments

limits

Two-element vector (or a scalar-expanded, one-element vector) of variable-sizing thresholds. If the size sz of a dimension of t is greater than or equal to the first threshold, the dimension becomes variable size with upper bound sz. If the size sz of a dimension of t is greater than or equal to the second threshold, the dimension becomes unbounded variable size.

sz

New size for coder.Type object, t_out

t

coder.Type object that you want to resize. If t is a coder.CellType object, the coder.CellType object must be homogeneous.

variable_dims

Specify whether each dimension of *t_out* is fixed or variable size.

Name-Value Pair Arguments

Specify optional comma-separated pairs of Name,Value arguments. Name is the argument name and Value is the corresponding value. Name must appear inside single quotes (' '). You can specify several name and value pair arguments in any order as Name1,Value1,...,NameN,ValueN.

recursive

Setting recursive to true resizes *t* and all types contained within it.

Default: false

uniform

Setting `uniform` to `true` resizes *t* but does not apply the heuristic for dimensions of size one.

Default: false

Output Arguments

t_out

Resized `coder.Type` object

Examples

Change a fixed-size array to a bounded, variable-size array.

```
t = coder.typeof(ones(3,3))
% t is     3x3
coder.resize(t, [4 5], 1)
% returns :4 x :5
% ':' indicates variable-size dimensions
```

Change a fixed-size array to an unbounded, variable-size array.

```
t = coder.typeof(ones(3,3))
% t is 3x3
coder.resize(t, inf)
% returns :inf x :inf
% ':' indicates variable-size dimensions
% 'inf' indicates unbounded dimensions
```

Resize a structure field.

```
ts = coder.typeof(struct('a', ones(3, 3)))
% returns field a as 3x3
coder.resize(ts, [5, 5], 'recursive', 1)
% returns field as 5x5
```

Resize a cell array.

```
tc = coder.typeof({1 2 3})
% returns 1x3 cell array
coder.resize(tc, [5, 5], 'recursive', 1)
% returns cell array as 5x5
```

Make a fixed-sized array variable size based on bounded and unbounded thresholds.

```
t = coder.typeof(ones(100,200))
% t is 100x200
coder.resize(t,'sizelimits', [99 199])
% returns :100x:inf
% ':' indicates variable-size dimensions
% :inf is unbounded variable size
```

See Also

`coder.newtype` | `coder.typeof` | `fiaccel`

Introduced in R2011a

coder.screener

Determine if function is suitable for code generation

Syntax

```
coder.screener(fcn)
coder.screener(fcn_1,...,fcn_n )
```

Description

`coder.screener(fcn)` analyzes the entry-point MATLAB function, `fcn`. It identifies unsupported functions and language features as code generation compliance issues. It displays the code generation compliance issues in a report. If `fcn` calls other functions directly or indirectly that are not MathWorks® functions, `coder.screener` analyzes these functions. It does not analyze MathWorks functions. It is possible that `coder.screener` does not detect all code generation issues. Under certain circumstances, it is possible that `coder.screener` reports false errors.

`coder.screener(fcn_1,...,fcn_n )` analyzes entry-point functions (`fcn_1,...,fcn_n`).

Input Arguments

`fcn`

Name of entry-point MATLAB function that you want to analyze. Specify as a character vector or a string scalar.

`fcn_1,...,fcn_n`

Comma-separated list of names of entry-point MATLAB functions that you want to analyze. Specify as character vectors or string scalars.

Examples

Identify Unsupported Functions

The `coder.screener` function identifies calls to functions that are not supported for code generation. It checks both the entry-point function, `foo1`, and the function `foo2` that `foo1` calls.

Write the function `foo2` and save it in the file `foo2.m`.

```
function out = foo2(in)
  out = eval(in);
end
```

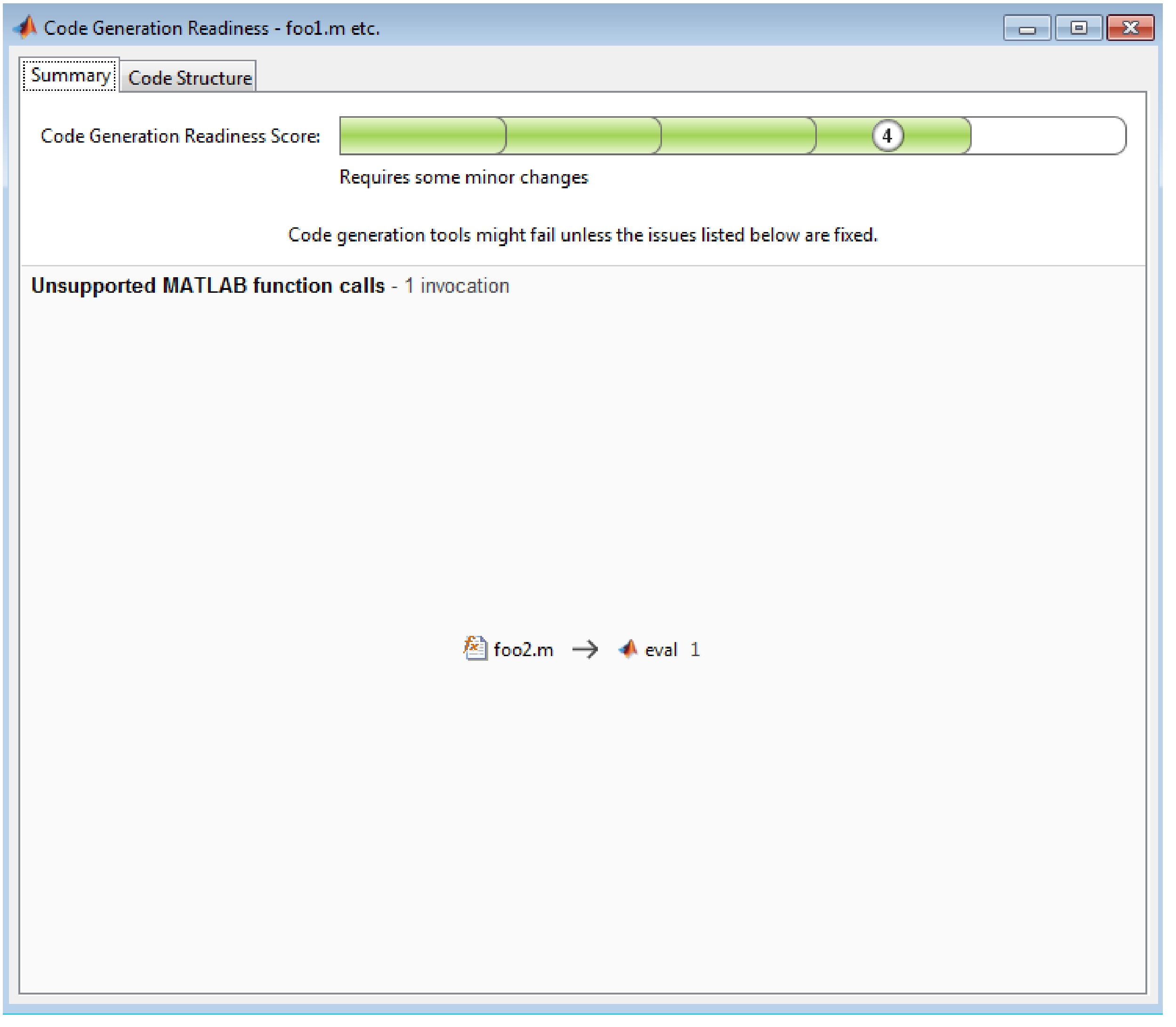
Write the function `foo1` that calls `foo2`. Save `foo1` in the file `foo1.m`.

```
function out = foo1(in)
  out = foo2(in);
  disp(out);
end
```

Analyze `foo1`.

```
coder.screener('foo1')
```

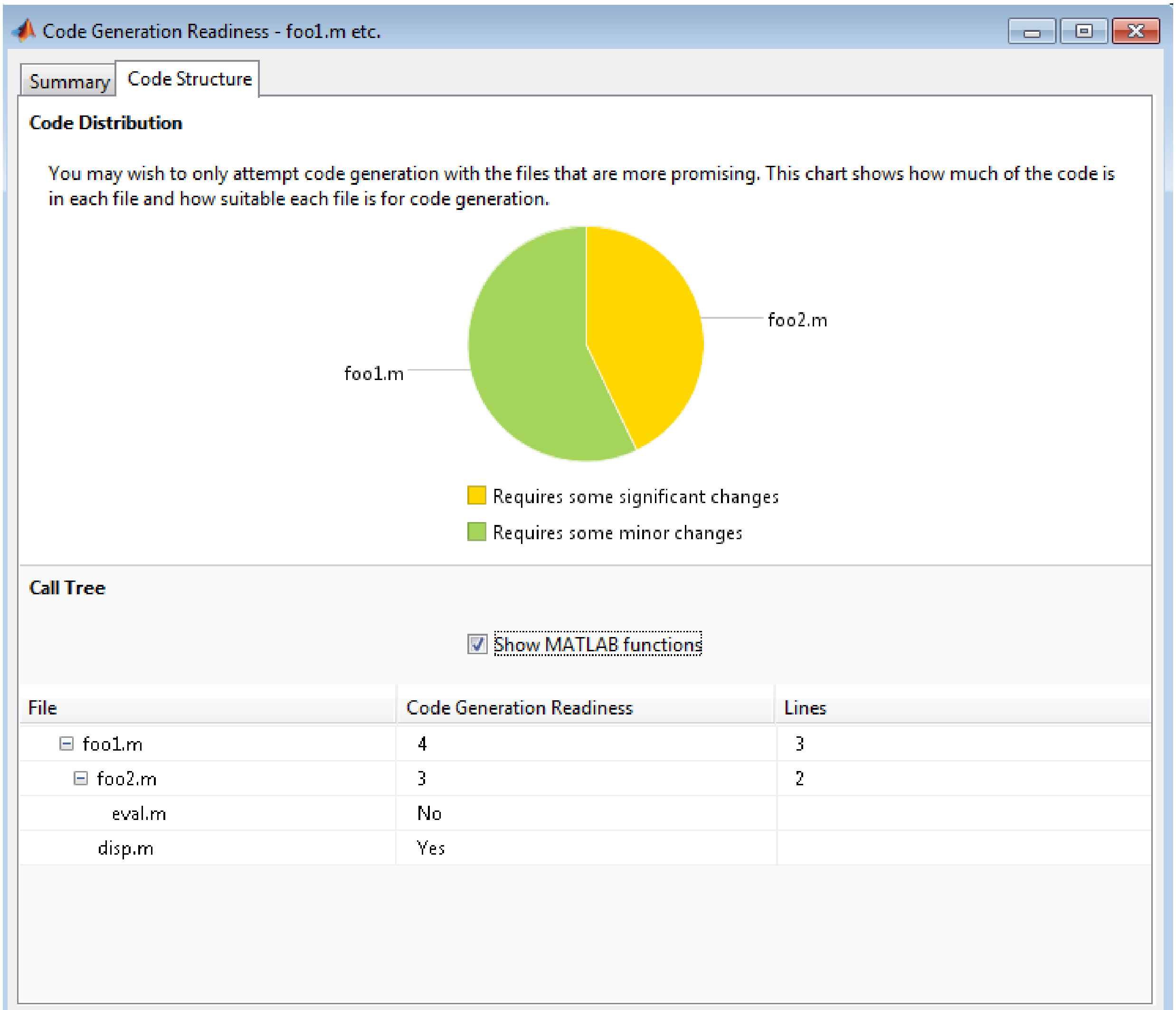
The code generation readiness report displays a summary of the unsupported MATLAB function calls. The function `foo2` calls one unsupported MATLAB function.



In the report, click the **Code Structure** tab and select the **Show MATLAB functions** check box.

This tab displays a pie chart showing the relative size of each file and how suitable each file is for code generation. In this case, the report:

- Colors `foo1.m` green to indicate that it is suitable for code generation.
- Colors `foo2.m` yellow to indicate that it requires significant changes.
- Assigns `foo1.m` a code generation readiness score of 4 and `foo2.m` a score of 3. The score is based on a scale of 1–5. 1 indicates that significant changes are required; 5 indicates that the code generation readiness tool does not detect issues.
- Displays a call tree.



The report **Summary** tab indicates that `foo2.m` contains one call to the `eval` function, which code generation does not support. To generate a MEX function for `foo2.m`, modify the code to make the call to `eval` extrinsic.

```
function out = foo2(in)
  coder.extrinsic('eval');
```

```
  out = eval(in);
end
```

Rerun the code generation readiness tool.

```
coder.screener('foo1')
```

The report no longer flags that code generation does not support the `eval` function. When you generate a MEX function for `foo1`, the code generator dispatches `eval` to MATLAB for execution. For standalone code generation, the code generator does not generate code for `eval`.

Identify Unsupported Data Types

The `coder.screener` function identifies MATLAB data types that code generation does not support.

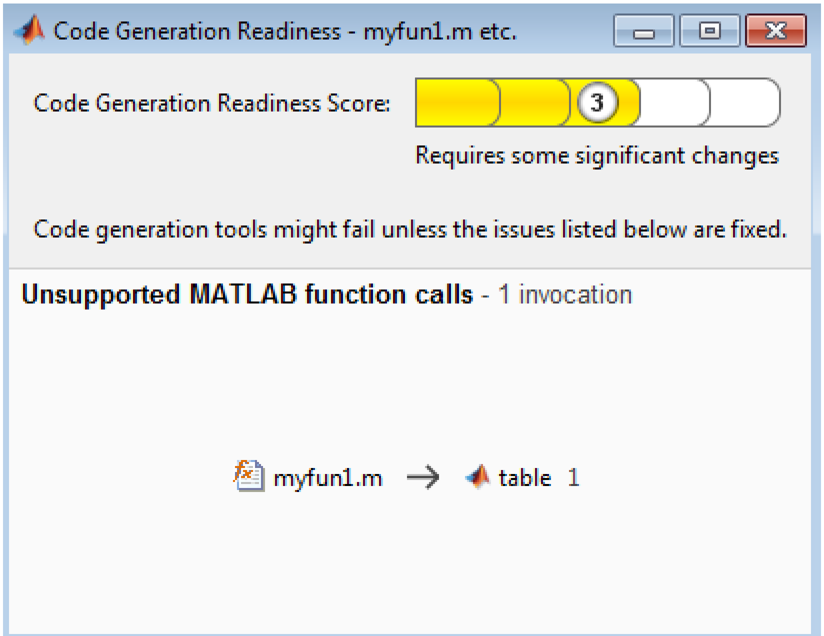
Write the function `myfun` that contains a MATLAB table.

```
function outTable = myfun1(A)
outTable = table(A);
end
```

Analyze `myfun`.

```
coder.screener('myfun1');
```

The code generation readiness report indicates that table data types are not supported for code generation.



The report assigns `myfun1` a code readiness score of `3`. Before generating code, you must fix the reported issues.

Tips

- Before using `coder.screener`, fix issues that the Code Analyzer identifies.
- Before generating code, use `coder.screener` to check that a function is suitable for code generation. Fix all the issues that it detects.

Alternatives

- "Run the Code Generation Readiness Tool From the Current Folder Browser"

See Also

`fiaccel`

Topics

“Functions Supported for Code Acceleration or C Code Generation”
“Code Generation Readiness Tool”

Introduced in R2012b

coder.StructType class

Package: coder
Superclasses:

Represent set of MATLAB structure arrays

Description

Specifies the set of structure arrays that the generated code should accept. Use only with the `fiaccel -args` option. Do not pass as an input to a generated MEX function.

Construction

`t=coder.typeof(struct_v)` creates a `coder.StructType` object for a structure with the same fields as the scalar structure `struct_v`.

`t=coder.typeof(struct_v, sz, variable_dims)` returns a modified copy of `coder.typeof(struct_v)` with (upper bound) size specified by `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is assumed to be unbounded and the dimension is assumed to be variable sized. When `sz` is [], the (upper bound) sizes of `struct_v` remain unchanged. If the `variable_dims` input parameter is not specified, the dimensions of the type are assumed to be fixed except for those that are unbounded. When `variable_dims` is a scalar, it is applied to the bounded dimensions that are not `1` or `0` (which are assumed to be fixed).

`t=coder.newtype('struct', struct_v, sz, variable_dims)` creates a `coder.StructType` object for an array of structures with the same fields as the scalar structure `struct_v` and (upper bound) size `sz` and variable dimensions `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is assumed to be unbounded and the dimension is assumed to be variable sized. When `variable_dims` is not specified, the dimensions of the type are assumed to be fixed except for those that are unbounded. When `variable_dims` is a scalar, it is applied to the dimensions of the type, except if the dimension is `1` or `0`, which is assumed to be fixed.

Input Arguments

struct_v

Scalar structure used to specify the fields in a new structure type.

sz

Size vector specifying each dimension of type object.

Default: [1 1] for `coder.newtype`

variable_dims

Logical vector that specifies whether each dimension is variable size (true) or fixed size (false).

Default: false(size(sz)) | sz==Inf for `coder.newtype`

Properties

Alignment

The run-time memory alignment of structures of this type in bytes. If you have an Embedded Coder® license and use Code Replacement Libraries (CRLs), the CRLs provide the ability to align data objects passed into a replacement function to a specified boundary. This capability allows you to take advantage of target-specific function implementations that require data to be aligned. By default, the structure is not aligned on a specific boundary so it will not be matched by CRL functions that require alignment.

`Alignment` must be either `-1` or a power of `2` that is no more than `128`.

ClassName

Class of values in this set.

Extern

Whether the structure type is externally defined.

Fields

A structure giving the `coder.Type` of each field in the structure.

HeaderFile

If the structure type is externally defined, name of the header file that contains the external definition of the structure, for example, `"mystruct.h"`.

By default, the generated code contains `#include` statements for custom header files after the standard header files. If a standard header file refers to the custom structure type, then the compilation fails. By specifying the `HeaderFile` option, MATLAB Coder includes that header file exactly at the point where it is required.

Must be a non-empty character vector or string scalar.

SizeVector

The upper-bound size of arrays in this set.

VariableDims

A vector used to specify whether each dimension of the array is fixed or variable size. If a vector element is `true`, the corresponding dimension is variable size.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create a type for a structure with a variable-size field.

```
x.a = coder.typeof(0,[3 5],1);
x.b = magic(3);
coder.typeof(x)
% Returns
% coder.StructType
%    1x1 struct
%      a:  :3x:5 double
```

```
%      b:  3x3  double
% ':' indicates variable-size dimensions
```

See Also

coder.ArrayType | coder.Constant | coder.EnumType | coder.FiType | coder.PrimitiveType | coder.Type | coder.newtype | coder.resize | coder.typeof | fiaccel

Introduced in R2011a

coder.target

Determine if code generation target is specified target

Syntax

```
tf = coder.target(target)
```

Description

`tf = coder.target(target)` returns true (1) if the code generation target is `target`. Otherwise, it returns false (0).

If you generate code for MATLAB classes, MATLAB computes class initial values at class loading time before code generation. If you use `coder.target` in MATLAB class property initialization, `coder.target('MATLAB')` returns true.

Examples

Use `coder.target` to Parametrize a MATLAB Function

Parametrize a MATLAB function so that it works in MATLAB or in generated code. When the function runs in MATLAB, it calls the MATLAB function `myabsval`. The generated code, however, calls a C library function `myabsval`.

Write a MATLAB function `myabsval`.

```
function y = myabsval(u)
%#codegen
y = abs(u);
```

Generate a C static library for `myabsval`, using the `-args` option to specify the size, type, and complexity of the input parameter.

```
codegen -config:lib myabsval -args {0.0}
```

The `codegen` function creates the library file `myabsval.lib` and header file `myabsval.h` in the folder `\codegen\lib\myabsval`. (The library file extension can change depending on your platform.) It generates the functions `myabsval_initialize` and `myabsval_terminate` in the same folder.

Write a MATLAB function to call the generated C library function using `coder.ceval`.

```
function y = callmyabsval(y)
%#codegen
% Check the target. Do not use coder.ceval if callmyabsval is
% executing in MATLAB
if coder.target('MATLAB')
  % Executing in MATLAB, call function myabsval
  y = myabsval(y);
else
  % add the required include statements to generated function code
  coder.updateBuildInfo('addIncludePaths','$(START_DIR)/codegen/lib/myabsval');
  coder.cinclude('myabsval_initialize.h');
  coder.cinclude('myabsval.h');
  coder.cinclude('myabsval_terminate.h');

  % Executing in the generated code.
  % Call the initialize function before calling the
  % C function for the first time
  coder.ceval('myabsval_initialize');

  % Call the generated C library function myabsval
  y = coder.ceval('myabsval',y);

  % Call the terminate function after
  % calling the C function for the last time
  coder.ceval('myabsval_terminate');
end
```

Generate the MEX function `callmyabsval_mex`. Provide the generated library file at the command line.

```
codegen -config:mex callmyabsval codegen\lib\myabsval\myabsval.lib -args {-2.75}
```

Rather than providing the library at the command line, you can use to specify the library within the function. Use this option to preconfigure the build. Add this line to the `else` block:

```
coder.updateBuildInfo('addLinkObjects','myabsval.lib','$(START_DIR)\codegen\lib\myabsva
```

Run the MEX function `callmyabsval_mex` which calls the library function `myabsval`.

```
callmyabsval_mex(-2.75)
```

```
ans =

    2.7500
```

Call the MATLAB function `callmyabsval`.

```
callmyabsval(-2.75)
```

```
ans =

    2.7500
```

The `callmyabsval` function exhibits the desired behavior for execution in MATLAB and in code generation.

Input Arguments

target — code generation target
'MATLAB' | 'MEX' | 'Sfun' | 'Rtw' | 'HDL ' | 'Custom'

Code generation target, specified as a character vector or a string scalar. Specify one of these targets.

'MATLAB'	Running in MATLAB (not generating code)
'MEX'	Generating a MEX function
'Sfun'	Simulating a Simulink model
'Rtw'	Generating a LIB, DLL, or EXE target
'HDL'	Generating an HDL target
'Custom'	Generating a custom target

Example: `tf = coder.target('MATLAB')`

Example: `tf = coder.target("MATLAB")`

See Also

Introduced in R2011a

coder.Type class

Package: coder

Represent set of MATLAB values

Description

Specifies the set of values that the generated code should accept. Use only with the `fiaccel -args` option. Do not pass as an input to a generated MEX function.

Construction

`coder.Type` is an abstract class, and you cannot create instances of it directly. You can create `coder.Constant`, `coder.EnumType`, `coder.FiType`, `coder.PrimitiveType`, `coder.StructType`, and `coder.CellType` objects that are derived from this class.

Properties

`ClassName`

Class of values in this set

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

See Also

`coder.ArrayType` | `coder.CellType` | `coder.Constant` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.StructType` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Introduced in R2011a

coder.typeof

Package: coder

Create `coder.Type` object to represent the type of an entry-point function input

Syntax

```
t = coder.typeof(v)
t = coder.typeof(v, sz, variable_dims)
t = coder.typeof(t)
```

Description

`t = coder.typeof(v)` creates an object that derives from `coder.Type` to represent the type of `v` for code generation. Use `coder.typeof` to specify only input parameter types. For example, use it with the `fiaccel` function `-args` option. Do not use it in MATLAB code from which you intend to generate a MEX function.

`t = coder.typeof(v, sz, variable_dims)` returns a modified copy of `t` = coder.typeof(`v`) with (upper bound) size specified by `sz` and variable dimensions specified by `variable_dims`.

- If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size.
- When `sz` is `[]`, the upper bounds of `v` do not change.
- If you do not specify the `variable_dims` input parameter, the bounded dimensions of the type are fixed.
- A scalar `variable_dims` applies to all dimensions. However, if `variable_dims` is `1`, the size of a singleton dimension remains fixed.
- When `v` is a cell array whose elements have the same classes, but different sizes, if you specify variable-size dimensions, `coder.typeof` creates a homogeneous cell array type. If the elements have different classes, `coder.typeof` reports an error.

`t = coder.typeof(t)`, where `t` is a `coder.Type` object, returns `t` itself.

Input Arguments

sz

Size vector specifying each dimension of type object.

t

`coder.Type` object

v

MATLAB expression that describes the set of values represented by this type.

`v` can be a MATLAB numeric, logical, char, enumeration, or fixed-point array. `v` can also be a cell array, structure, or value class that contains the previous types.

variable_dims

Logical vector that specifies whether each dimension is variable size (true) or fixed size (false).

For a cell array, if the elements have different classes, you cannot specify variable-size dimensions.

Output Arguments

t

`coder.Type` object

Examples

Create a type for a simple fixed-size `5x6` matrix of doubles.

```
coder.typeof(ones(5, 6))
 % returns 5x6 double
coder.typeof(0, [5 6])
 % also returns 5x6 double
```

Create a type for a variable-size matrix of doubles.

```
coder.typeof(ones(3,3), [], 1)
% returns :3 x :3 double
% ':' indicates variable-size dimensions
```

Create a type for a structure with a variable-size field.

```
x.a = coder.typeof(0,[3 5],1);
x.b = magic(3);
coder.typeof(x)
% Returns
% coder.StructType
%    1x1 struct
%      a:  :3x:5 double
%      b:  3x3  double
% ':' indicates variable-size dimensions
```

Create a type for a homogeneous cell array with a variable-size field.

```
a = coder.typeof(0,[3 5],1);
b = magic(3);
coder.typeof({a b})
% Returns
% coder.CellType
%   1x2 homogeneous cell
%      base: :3x:5 double
% ':' indicates variable-size dimensions
```

Create a type for a heterogeneous cell array.

```
a = coder.typeof('a');
b = coder.typeof(1);
coder.typeof({a b})
% Returns
% coder.CellType
%   1x2 heterogeneous cell
%      f0: 1x1 char
%      f1: 1x1 double
```

Create a variable-size homogeneous cell array type from a cell array that has the same class but different sizes.

1. Create a type for a cell array that contains two character vectors with different sizes. The cell array type is heterogeneous.

```
coder.typeof({'aa', 'bbb'})
% Returns
% coder.CellType
%   1x2 heterogeneous cell
%      f0: 1x2 char
%      f1: 1x3 char
```

2 Create a type using the same cell array input. This time, specify that the cell array type has variable-size dimensions. The cell array type is homogeneous.

```
coder.typeof({'aa','bbb'},[1,10],[0,1])
% Returns
% coder.CellType
%   1x:10 homogeneous cell
%      base: 1x:3 char
```

Create a type for a matrix with fixed-size and variable-size dimensions.

```
coder.typeof(0, [2,3,4], [1 0 1]);
% Returns :2x3x:4 double
% ':' indicates variable-size dimensions
```

```
coder.typeof(10, [1 5], 1)
% returns double 1 x  :5
% ':' indicates variable-size dimensions
```

Create a type for a matrix of doubles, first dimension unbounded, second dimension with fixed size.

```
coder.typeof(10,[inf,3])
% returns double:inf x 3
% ':' indicates variable-size dimensions
```

Create a type for a matrix of doubles, first dimension unbounded, second dimension with variable size with an upper bound of 3.

```
coder.typeof(10, [inf,3],[0 1])
% returns double :inf x :3
% ':' indicates variable-size dimensions
```

Convert a fixed-size matrix to a variable-size matrix.

```
 coder.typeof(ones(5,5), [], 1)
% returns double :5x:5
% ':' indicates variable-size dimensions
```

Create a nested structure (a structure as a field of another structure).

```
S = struct('a',double(0),'b',single(0))
SuperS.x = coder.typeof(S)
SuperS.y = single(0)
coder.typeof(SuperS)
% Returns
% coder.StructType
% SuperS:  1x1 struct
%   with fields
%      x:  1x1 struct
%         with fields
%             a: 1x1 double
%             b: 1x1 single
%      y:  1x1  single
```

Create a structure containing a variable-size array of structures as a field.

```
S = struct('a',double(0),'b',single(0))
SuperS.x = coder.typeof(S,[1 inf],[0 1])
SuperS.y = single(0)
coder.typeof(SuperS)
% Returns
% coder.StructType
% SuperS:  1x1 struct
%   with fields
%      x:  1x:inf struct
%         with fields
%             a: 1x1 double
%             b: 1x1 single
%      y:  1x1  single
% ':' indicates variable-size dimensions
```

Create a type for a value class object

1. Create this value class:

```
classdef mySquare
    properties
        side;
    end
    methods
        function obj = mySquare(val)
            if nargin > 0
                obj.side = val;
```

```
                end
            end
            function a = calcarea(obj)
                a = obj.side * obj.side;
            end
        end
    end
```

2 Create an object of `mySquare`.

```
sq_obj = coder.typeof(mySquare(4))

sq_obj =

coder.ClassType
   1×1 mySquare
      side: 1×1 double
```

3 Create a type for an object that has the same properties as `sq_obj`.

```
t = coder.typeof(sq_obj)

t =

coder.ClassType
   1×1 mySquare
      side: 1×1 double
```

Alternatively, you can create the type from the class definition:

```
t = coder.typeof(mySquare(4))

t =

coder.ClassType
   1×1 mySquare
      side: 1×1 double
```

Create a type for a string scalar

1 Define a string scalar. For example:

```
s = "mystring";
```

2 Create a type from `s`.

```
t = coder.typeof(s);
```

3 To make `t` variable-size, assign the `Value` property of `t` to a type for a variable-size character vector that has the upper bound that you want. For example, specify that type `t` is variable-size with an upper bound of 10.

```
t.Properties.Value = coder.typeof('a',[1 10], [0 1]);
```

To specify that `t` is variable-size with no upper bound:

```
t.Properties.Value = coder.typeof('a',[1 inf]);
```

4 Pass the type to `codegen` by using the `-args` option.

```
codegen myFunction -args {t}
```

Tips

- `coder.typeof` fixes the size of a singleton dimension unless the `variable_dims` argument explicitly specifies that the singleton dimension has a variable size.

  For example, the following code specifies a 1-by-:10 double. The first dimension (the singleton dimension) has a fixed size. The second dimension has a variable size.

  ```
  t = coder.typeof(5,[1 10],1)
  ```

  By contrast, the following code specifies a :1-by-:10 double. Both dimensions have a variable size.

  ```
  t = coder.typeof(5,[1 10],[1 1])
  ```

  Note For a MATLAB Function block, singleton dimensions of input or output signals cannot have a variable size.

- If you are already specifying the type of an input variable using a type function, do not use `coder.typeof` unless you also want to specify the size. For instance, instead of `coder.typeof(single(0))`, use the syntax `single(0)`.
- For cell array types, `coder.typeof` determines whether the cell array type is homogeneous or heterogeneous. If the cell array elements have the same class and size, `coder.typeof` returns a homogeneous cell array type. If the elements have different classes, `coder.typeof` returns a heterogeneous cell array type. For some cell arrays, the classification as homogeneous or heterogeneous is ambiguous. For example, the type for {1 [2 3]} can be a 1x2 heterogeneous type where the first element is double and the second element is 1x2 double. The type can also be a 1x3

homogeneous type in which the elements have class double and size 1x:2. For these ambiguous cases, `coder.typeof` uses heuristics to classify the type as homogeneous or heterogeneous. If you want a different classification, use the coder.CellType `makeHomogeneous` or `makeHeterogeneous` methods to make a type with the classification that you want. The `makeHomogeneous` method makes a homogeneous copy of a type. The `makeHeterogeneous` method makes a heterogeneous copy of a type.

The `makeHomogeneous` and `makeHeterogeneous` methods permanently assign the classification as heterogeneous and homogeneous, respectively. You cannot later use one of these methods to create a copy that has a different classification.

See Also

`coder.ArrayType` | `coder.CellType` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.StructType` | `coder.Type` | `coder.newtype` | `coder.resize` | `fiaccel`

Topics

"Define Input Properties by Example at the Command Line"
"Specify Cell Array Inputs at the Command Line"
"Specify Objects as Inputs"
"Define String Scalar Inputs"

Introduced in R2011a

coder.unroll

Unroll `for`-loop by making a copy of the loop body for each loop iteration

Syntax

```
coder.unroll()
coder.unroll(flag)
for i = coder.unroll(range)
for i = coder.unroll(range, flag)
```

Description

`coder.unroll()` unrolls a `for`-loop. The `coder.unroll` call must be on a line by itself immediately preceding the `for`-loop that it unrolls.

Instead of producing a `for`-loop in the generated code, loop unrolling produces a copy of the `for`-loop body for each loop iteration. In each iteration, the loop index becomes constant. To unroll a loop, the code generator must be able to determine the bounds of the `for-`loop.

For small, tight loops, unrolling can improve performance. However, for large loops, unrolling can increase code generation time significantly and generate inefficient code.

`coder.unroll` is ignored outside of code generation.

`coder.unroll(flag)` unrolls a `for`-loop if `flag` is `true`. `flag` is evaluated at code generation time. The `coder.unroll` call must be on a line by itself immediately preceding the `for`-loop that it unrolls.

`for i = coder.unroll(range)` is a legacy syntax that generates the same code as `coder.unroll()`.

`for i = coder.unroll(range, flag)` is a legacy syntax that generates the same code as `coder.unroll(flag)`.

Examples

Unroll a for-loop

To produce copies of a `for`-loop body in the generated code, use `coder.unroll`.

In one file, write the entry-point function `call_getrand` and a local function `getrand`. `getrand` unrolls a `for`-loop that assigns random numbers to an n-by-1 array. `call_getrand` calls `getrand` with the value 3.

```
function z = call_getrand
%#codegen
z = getrand(3);
end

function y = getrand(n)
coder.inline('never');
y = zeros(n, 1);
coder.unroll();
for i = 1:n
    y(i) = rand();
end
end
```

Generate a static library.

```
codegen -config:lib call_getrand -report
```

In the generated code, the code generator produces a copy of the `for`-loop body for each of the three loop iterations.

```
static void getrand(double y[3])
{
  y[0] = b_rand();
  y[1] = b_rand();
  y[2] = b_rand();
}
```

Control for-loop Unrolling with Flag

Control loop unrolling by using `coder.unroll` with the `flag` argument.

In one file, write the entry-point function `call_getrand_unrollflag` and a local function `getrand_unrollflag`. When the number of loop iterations is less than 10, `getrand_unrollflag` unrolls the `for`-loop. `call_getrand` calls `getrand` with the value 50.

```
function z = call_getrand_unrollflag
%#codegen
z = getrand_unrollflag(50);
end

function y = getrand_unrollflag(n)
coder.inline('never');
unrollflag = n < 10;
y = zeros(n, 1);
coder.unroll(unrollflag)
for i = 1:n
    y(i) = rand();
end
end
```

Generate a static library.

```
codegen -config:lib call_getrand_unrollflag -report
```

The number of iterations is not less than 10. Therefore, the code generator does not unroll the `for`-loop. It produces a `for`-loop in the generated code.

```
static void getrand_unrollflag(double y[50])
{
  int i;
  for (i = 0; i < 50; i++) {
    y[i] = b_rand();
  }
}
```

Use Legacy Syntax to Unroll for-Loop

```
function z = call_getrand
%#codegen
z = getrand(3);
end

function y = getrand(n)
coder.inline('never');
```

```
y = zeros(n, 1);
for i = coder.unroll(1:n)
    y(i) = rand();
end
end
```

Use Legacy Syntax to Control `for`-Loop Unrolling

```
function z = call_getrand_unrollflag
%#codegen
z = getrand_unrollflag(50);
end

function y = getrand_unrollflag(n)
coder.inline('never');
unrollflag = n < 10;
y = zeros(n, 1);
for i = coder.unroll(1:n, unrollflag)
    y(i) = rand();
end
end
```

Input Arguments

`flag` — Indicates whether to unroll the `for`-loop
true (default) | false

When `flag` is `true`, the code generator unrolls the `for`-loop. When `flag` is `false`, the code generator produces a `for`-loop in the generated code. `flag` is evaluated at code generation time.

Tips

Sometimes, the code generator unrolls a `for`-loop even though you do not use `coder.unroll`. For example, if a `for`-loop indexes into a heterogeneous cell array or into `varargin` or `varargout`, the code generator unrolls the loop. By unrolling the loop, the code generator can determine the value of the index for each loop iteration. The code generator uses heuristics to determine when to unroll a `for`-loop. If the heuristics fail to identify that unrolling is warranted, or if the number of loop iterations exceeds a limit, code generation fails. In these cases, you can force loop unrolling by using `coder.unroll`. See “Nonconstant Index into varargin or varargout in a for-Loop”.

See Also

`coder.inline`

Topics

“Nonconstant Index into varargin or varargout in a for-Loop”

Introduced in R2011a

coder.varsize

Package: coder

Declare variable-size array

Syntax

```
coder.varsize('var1', 'var2', ...)
coder.varsize('var1', 'var2', ..., ubound)
coder.varsize('var1', 'var2', ..., ubound, dims)
coder.varsize('var1', 'var2', ..., [], dims)
```

Description

`coder.varsize('var1', 'var2', ...)` declares one or more variables as variable-size data, allowing subsequent assignments to extend their size. Each `'varn'` is the name of a variable or structure field enclosed in quotes. If the structure field belongs to an array of structures, use colon (`:`) as the index expression to make the field variable-size for all elements of the array. For example, the expression `coder.varsize('data(:).A')` declares that the field `A` inside each element of `data` is variable sized.

`coder.varsize('var1', 'var2', ..., ubound)` declares one or more variables as variable-size data with an explicit upper bound specified in *`ubound`*. The argument *`ubound`* must be a constant, integer-valued vector of upper bound sizes for every dimension of each `'varn'`. If you specify more than one `'varn'`, each variable must have the same number of dimensions.

`coder.varsize('var1', 'var2', ..., ubound, dims)` declares one or more variables as variable size with an explicit upper bound and a mix of fixed and varying dimensions specified in *`dims`*. The argument *`dims`* is a logical vector, or double vector containing only zeros and ones. Dimensions that correspond to zeros or `false` in *`dims`* have fixed size; dimensions that correspond to ones or `true` vary in size. If you specify more than one variable, each fixed dimension must have the same value across all `'varn'`.

`coder.varsize('var1', 'var2', ..., [], dims)` declares one or more variables as variable size with a mix of fixed and varying dimensions. The empty vector `[]` means that you do not specify an explicit upper bound.

When you do *not* specify *ubound*, the upper bound is computed for each `'varn'` in generated code.

When you do *not* specify *dims*, dimensions are assumed to be variable except the singleton ones. A singleton dimension is a dimension for which `size(A,dim)` = 1.

You must add the `coder.varsize` declaration before each `'varn'` is used (read). You can add the declaration before the first assignment to each `'varn'`. However, for a cell array element, the `coder.varsize` declaration must follow the first assignment to the element. For example:

```
...
x = cell(3, 3);
x{1} = [1 2];
coder.varsize('x{1}');
...
```

You cannot use `coder.varsize` outside the MATLAB code intended for code generation. For example, the following code does not declare the variable, `var`, as variable-size data:

```
coder.varsize('var',10);
codegen -config:lib MyFile -args var
```

Instead, include the `coder.varsize` statement inside `MyFile` to declare `var` as variable-size data. Alternatively, you can use `coder.typeof` to declare `var` as variable-size outside `MyFile`. It can then be passed to `MyFile` during code generation using the `-args` option. For more information, see `coder.typeof`.

Examples

Develop a Simple Stack That Varies in Size up to 32 Elements as You Push and Pop Data at Run Time.

Write primary function `test_stack` to issue commands for pushing data on and popping data from a stack.

```
function test_stack %#codegen
    % The directive %#codegen indicates that the function
    % is intended for code generation
    stack('init', 32);
    for i = 1 : 20
        stack('push', i);
    end
    for i = 1 : 10
        value = stack('pop');
        % Display popped value
        value
    end
end
```

Write local function `stack` to execute the push and pop commands.

```
function y = stack(command, varargin)
    persistent data;
    if isempty(data)
        data = ones(1,0);
    end
    y = 0;
    switch (command)
    case {'init'}
        coder.varsize('data', [1, varargin{1}], [0 1]);
        data = ones(1,0);
    case {'pop'}
        y = data(1);
        data = data(2:size(data, 2));
    case {'push'}
        data = [varargin{1}, data];
    otherwise
        assert(false, ['Wrong command: ', command]);
    end
end
```

The variable `data` is the stack. The statement `coder.varsize('data', [1, varargin{1}], [0 1])` declares that:

- `data` is a row vector
- Its first dimension has a fixed size
- Its second dimension can grow to an upper bound of 32

Generate a MEX function for `test_stack`:

```
codegen -config:mex test_stack
```

`codegen` generates a MEX function in the current folder.

Run `test_stack_mex` to get these results:

```
value =
    20

value =
    19

value =
    18

value =
    17

value =
    16

value =
    15

value =
    14

value =
    13

value =
    12

value =
    11
```

At run time, the number of items in the stack grows from zero to 20, and then shrinks to 10.

Declare a Variable-Size Structure Field.

Write a function `struct_example` that declares an array `data`, where each element is a structure that contains a variable-size field:

```
function y=struct_example() %#codegen

  d = struct('values', zeros(1,0), 'color', 0);
  data = repmat(d, [3 3]);
  coder.varsize('data(:).values');

  for i = 1:numel(data)
      data(i).color = rand-0.5;
      data(i).values = 1:i;
  end

  y = 0;
  for i = 1:numel(data)
      if data(i).color > 0
          y = y + sum(data(i).values);
      end;
  end
```

The statement `coder.varsize('data(:).values')` marks as variable-size the field `values` inside each element of the matrix `data`.

Generate a MEX function for `struct_example`:

```
codegen -config:mex struct_example
```

Run `struct_example`.

Each time you run `struct_example` you get a different answer because the function loads the array with random numbers.

Make a Cell Array Variable-Size

Write the function `make_varsz_cell` that defines a local cell array variable `c` whose elements have the same class, but different sizes. Use `coder.varsize` to indicate that `c` has variable-size.

```
function y =  make_varsz_cell()
c = {1 [2 3]};
coder.varsize('c', [1 3], [0 1]);
y = c;
end
```

Generate a C static library.

```
codegen -config:lib make_varsz_cell -report
```

In the report, view the MATLAB variables.

`c` is a 1x:3 homogeneous cell array whose elements are 1x:2 double.

Make the Elements of a Cell Array Variable-Size

Write the function `mycell` that defines a local cell array variable `c`. Use `coder.varsize` to make the elements of `c` variable-size.

```
function y =  mycell()
c = {1 2 3};
coder.varsize('c{:}', [1 5], [0 1]);
y = c;
end
```

Generate a C static library.

```
codegen -config:lib mycell -report
```

In the report, view the MATLAB variables.

The elements of `c` are 1-by-:5 arrays of doubles.

Limitations

- If you use the cell function to create a `cell` array, you cannot use `coder.varsize` with that cell array.
- If you use `coder.varsize` with a cell array element, the `coder.varsize` declaration must follow the first assignment to the element. For example:

  ```
  ...
  x = cell(3, 3);
  x{1} = [1 2];
  coder.varsize('x{1}');
  ...
  ```
- You cannot use `coder.varsize` with a cell array input that is heterogeneous.
- You cannot use `coder.varsize` with global variables.

- You cannot use `coder.varsize` with MATLAB class properties.
- You cannot use `coder.varsize` with string scalars.

Tips

- `coder.varsize` fixes the size of a singleton dimension unless the `dims` argument explicitly specifies that the singleton dimension has a variable size.

  For example, the following code specifies that `v` has size 1-by-:10. The first dimension (the singleton dimension) has a fixed size. The second dimension has a variable size.

  ```
  coder.varsize('v', [1 10])
  ```

  By contrast, the following code specifies that `v` has size :1-by-:10. Both dimensions have a variable size.

  ```
  coder.varsize('v',[1,10],[1,1])
  ```

  Note For a MATLAB Function block, singleton dimensions of input or output signals cannot have a variable size.

- If you use input variables (or result of a computation using input variables) to specify the size of an array, it is declared as variable-size in the generated code. Do not use `coder.varsize` on the array again, unless you also want to specify an upper bound for its size.
- Using `coder.varsize` on an array without explicit upper bounds causes dynamic memory allocation of the array. This dynamic memory allocation can reduce the speed of generated code. To avoid dynamic memory allocation, use the syntax `coder.varsize('`var_1`', '`var_2`', ..., `*ubound*`)` to specify an upper bound for the array size (if you know it in advance).
- A cell array can be variable size only if it is homogeneous. When you use `coder.varsize` with a cell array, the code generator tries to make the cell array homogeneous. It tries to find a class and size that apply to all elements of the cell array. For example, if the first element is double and the second element is 1x2 double, all elements can be represented as 1x:2 double. If the code generator cannot find a common class and size, code generation fails. For example, suppose that the first element of a cell array is char and the second element is double. The code generator cannot find a class that can represent both elements.

See Also

`fiaccel` | `size`

Topics

"Code Generation for Variable-Size Arrays"
"Define Variable-Size Structure Fields"
"Incompatibilities with MATLAB in Variable-Size Support for Code Generation"
"Code Generation for Cell Arrays"

Introduced in R2011a

colon

Create vectors, array subscripting

Syntax

```
y = j:k
y = j:i:k
```

Description

`y = j:k` returns a regularly-spaced vector, [j, j+1 ,..., k]. `j:k` is empty when `j > k`.

At least one of the colon operands must be a `fi` object. All colon operands must have integer values. All the fixed-point operands must be binary-point scaled. Slope-bias scaling is not supported. If any of the operands is complex, the `colon` function generates a warning and uses only the real part of the operands.

`y = colon(j,k)` is the same as `y = j:k`.

`y = j:i:k` returns a regularly-spaced vector, `[j,j+i,j+2i, ...,j+m*i]`, where `m = fix((k-j)/i)`. `y = j:i:k` returns an empty matrix when`i == 0`, `i > 0` and `j > k`, or `i < 0` and `j < k`.

Examples

Use fi as a Colon Operator

When you use `fi` as a colon operator, all colon operands must have integer values.

```
a = fi(1,0,3,0);
b = fi(2,0,8,0);
c = fi(12,0,8,0);
x = a:b:c
```

```
x =
     1     3     5     7     9    11

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 0
```

Because all the input operands are unsigned, `x` is unsigned and the word length is 8. The fraction length of the resulting vector is always 0.

Use the colon Operator With Signed and Unsigned Operands

```
a= fi(int8(-1));
b = uint8(255);
c = a:b;
len = c.WordLength
```

```
len = 9
```

```
signedness = c.Signedness
```

```
signedness =
'Signed'
```

The word length of `c` requires an additional bit to handle the intersection of the ranges of `int8` and `uint8`. The data type of `c` is signed because the operand `a` is signed.

Create a Vector of Decreasing Values

If the beginning and ending operands are unsigned, the increment operand can be negative.

```
x = fi(4,false):-1:1
```

```
x =
     4     3     2     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
```

```
          WordLength: 16
      FractionLength: 0
```

Use the colon Operator With Floating-Point and fi Operands

If any of the operands is floating-point, the output has the same word length and signedness as the `fi` operand

```
x = fi(1):10
```

```
x =
     1     2     3     4     5     6     7     8     9    10

        DataTypeMode: Fixed-point: binary point scaling
          Signedness: Signed
          WordLength: 16
      FractionLength: 0
```

`x = fi(1):10` is equivalent to `fi(1:10, true, 16, 0)` so `x` is signed and its word length is 16 bits.

Rewrite Code That Uses Non-Integer Operands

If your code uses non-integer operands, rewrite the colon expression so that the operands are integers.

The following code does not work because the colon operands are not integer values.

```
Fs = fi(100);
n = 1000;
t  = (0:1/Fs:(n/Fs - 1/Fs));
```

Rewrite the colon expression to use integer operands.

```
Fs = fi(100);
n = 1000;
t  = (0:(n-1))/Fs;
```

All Colon Operands Must Be in the Range of the Data Type

If the value of any of the colon operands is outside the range of the data type used in the colon expression, MATLAB generates an error.

```
y = fi(1,true,8,0):256
```

MATLAB generates an error because 256 is outside the range of `fi(1,true, 8,0)`. This behavior matches the behavior for built-in integers. For example, `y = int8(1):256` generates the same error.

Input Arguments

j — Beginning operand
real scalar

Beginning operand, specified as a real scalar integer-valued `fi` object or built-in numeric type.

If you specify non-scalar arrays, MATLAB interprets `j:i:k` as `j(1):i(1):k(1)`.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

i — Increment
1 (default) | real scalar

Increment, specified as a real scalar integer-valued `fi` object or built-in numeric type. Even if the beginning and end operands, `j` and `k`, are both unsigned, the increment operand `i` can be negative.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

k — Ending operand
real scalar

Ending operand, specified as a real scalar integer-valued `fi` object or built-in numeric type.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

y — Regularly-spaced vector
real vector

Fixed-Point Designer determines the data type of the y using the following rules:

- The data type covers the union of the ranges of the fixed-point types of the input operands.
- If either the beginning or ending operand is signed, the resulting data type is signed. Otherwise, the resulting data type is unsigned.
- The word length of y is the smallest value such that the fraction length is 0 and the real-world value of the least-significant bit is 1.
- If any of the operands is floating-point, the word length and signedness of y is derived from the fi operand.
- If any of the operands is a scaled double, y is a scaled double.
- The fimath of y is the same as the fimath of the input operands.
- If all the fi objects are of data type double, the data type of y is double. If all the fi objects are of data type single, the data type of y is single. If there are both double and single inputs, and no fixed-point inputs, the output data type is single.

See Also

colon | fi

Introduced in R2013b

comet

Create 2-D comet plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `comet` reference page for more information.

Introduced before R2006a

comet3

Create 3-D comet plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `comet3` reference page for more information.

Introduced before R2006a

compass

Plot arrows emanating from origin

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `compass` reference page for more information.

Introduced before R2006a

complex

Construct complex `fi` object from real and imaginary parts

Syntax

```
c = complex(a,b)
c = complex(a)
c = complex(a)
```

Description

The `complex` function constructs a complex `fi` object from real and imaginary parts.

`c = complex(a,b)` returns the complex result `a + bi`, where `a` and `b` are identically sized real N-D arrays, matrices, or scalars of the same data type. When `b` is all zero, `c` is complex with an all-zero imaginary part. This is in contrast to the addition of `a` + 0i, which returns a strictly real result.

`c = complex(a)` for a real `fi` object `a` returns the complex result `a + bi` with real part `a` and an all-zero imaginary part. Even though its imaginary part is all zero, `c` is complex.

`c = complex(a)` returns the complex equivalent of `a`, such that `isreal(c)` returns logical 0 (false). If `a` is real, then `c` is `a + 0i`. If `a` is complex, then `c` is identical to `a`.

The output `fi` object `c` has the same `numerictype` and `fimath` properties as the input `fi` object `a`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

imag | real

Introduced before R2006a

coneplot

Plot velocity vectors as cones in 3-D vector field

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `coneplot` reference page for more information.

Introduced before R2006a

conj

Complex conjugate of `fi` object

Syntax

`conj(a)`

Description

`conj(a)` is the complex conjugate of `fi` object `a`.

When `a` is complex,

$$\text{conj}(a) = \text{real}(a) - i \times \text{imag}(a)$$

The `numerictype` and `fimath` properties associated with the input `a` are applied to the output.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`complex` | `imag` | `real`

Introduced before R2006a

contour

Create contour graph of matrix

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `contour` reference page for more information.

Introduced before R2006a

contour3

Create 3-D contour plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `contour3` reference page for more information.

Introduced before R2006a

contourc

Create two-level contour plot computation

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `contourc` reference page for more information.

Introduced before R2006a

contourf

Create filled 2-D contour plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `contourf` reference page for more information.

Introduced before R2006a

conv

Convolution and polynomial multiplication of `fi` objects

Syntax

```
c = conv(a,b)
c = conv(a,b,'shape')
```

Description

`c = conv(a,b)` outputs the convolution of input vectors `a` and `b`, at least one of which must be a `fi` object.

`c = conv(a,b,'shape')` returns a subsection of the convolution, as specified by the `shape` parameter:

- `full` — Returns the full convolution. This option is the default shape.
- `same` — Returns the central part of the convolution that is the same size as input vector `a`.
- `valid` — Returns only those parts of the convolution that the function computes without zero-padded edges. In this case, the length of output vector `c` is `max(length(a)-max(0,length(b)-1), 0)`.

The `fimath` properties associated with the inputs determine the `numerictype` properties of output `fi` object `c`:

- If either `a` or `b` has a local `fimath` object, `conv` uses that `fimath` object to compute intermediate quantities and determine the `numerictype` properties of `c`.
- If neither `a` nor `b` have an attached fimath, `conv` uses the default fimath to compute intermediate quantities and determine the `numerictype` properties of `c`.

If either input is a built-in data type, `conv` casts it into a `fi` object using best-precision rules before the performing the convolution operation.

The output `fi` object `c` always uses the default fimath.

Refer to the MATLAB conv reference page for more information on the convolution algorithm.

Examples

The following example illustrates the convolution of a 22-sample sequence with a 16-tap FIR filter.

- x is a 22-sample sequence of signed values with a word length of 16 bits and a fraction length of 15 bits.
- h is the 16 tap FIR filter.

```
u = (pi/4)*[1 1 1 -1 -1 -1 1 -1 -1 1 -1];
x = fi(kron(u,[1 1]));
h = firls(15, [0 .1 .2 .5]*2, [1 1 0 0]);
```

Because x is a fi object, you do not need to cast h into a fi object before performing the convolution operation. The conv function does so using best-precision scaling.

Finally, use the conv function to convolve the two vectors:

```
y = conv(x,h);
```

The operation results in a signed fi object y with a word length of 36 bits and a fraction length of 31 bits. The default fimath properties associated with the inputs determine the numerictype of the output. The output does not have a local fimath.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-sized inputs are only supported when the SumMode property of the governing fimath is set to Specify precision or Keep LSB.

- For variable-sized signals, you might see different results between generated code and MATLAB.
  - In the generated code, the output for variable-sized signals is computed using the `SumMode` property of the governing `fimath`.
  - In MATLAB, the output for variable-sized signals is computed using the `SumMode` property of the governing `fimath` when both inputs are nonscalar. However, if either input is a scalar, MATLAB computes the output using the `ProductMode` of the governing `fimath`.

See Also

`conv`

Introduced in R2009b

convergent

Round toward nearest integer with ties rounding to nearest even integer

Syntax

```
y = convergent(a)
y = convergent(x)
```

Description

`y = convergent(a)` rounds `fi` object `a` to the nearest integer. In the case of a tie, `convergent(a)` rounds to the nearest even integer.

`y` and `a` have the same `fimath` object and `DataType` property.

When the `DataType` property of `a` is `single`, `double`, or `boolean`, the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is zero or negative, `a` is already an integer, and the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is positive, the fraction length of `y` is `0`, its sign is the same as that of `a`, and its word length is the difference between the word length and the fraction length of `a`, plus one bit. If `a` is signed, then the minimum word length of `y` is `2`. If `a` is unsigned, then the minimum word length of `y` is `1`.

For complex `fi` objects, the imaginary and real parts are rounded independently.

`convergent` does not support `fi` objects with nontrivial slope and bias scaling. Slope and bias scaling is trivial when the slope is an integer power of 2 and the bias is 0.

`y = convergent(x)` rounds the elements of `x` to the nearest integer. In the case of a tie, `convergent(x)` rounds to the nearest even integer.

Examples

Example 1

The following example demonstrates how the `convergent` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 3.

```
a = fi(pi, 1, 8, 3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3

y = convergent(a)

y =

     3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 0
```

Example 2

The following example demonstrates how the `convergent` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 12.

```
a = fi(0.025,1,8,12)

a =

    0.0249
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 12

y = convergent(a)

y =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 2
        FractionLength: 0
```

Example 3

The functions `convergent`, `nearest` and `round` differ in the way they treat values whose least significant digit is 5:

- The `convergent` function rounds ties to the nearest even integer
- The `nearest` function rounds ties to the nearest integer toward positive infinity
- The `round` function rounds ties to the nearest integer with greater absolute value

The following table illustrates these differences for a given `fi` object `a`.

a	convergent(a)	nearest(a)	round(a)
–3.5	–4	–3	–4
–2.5	–2	–2	–3
–1.5	–2	–1	–2
–0.5	0	0	–1
0.5	0	1	1
1.5	2	2	2
2.5	2	3	3
3.5	4	4	4

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`ceil` | `fix` | `floor` | `nearest` | `round`

Introduced before R2006a

convertToSingle

Convert double-precision MATLAB code to single-precision MATLAB code

Syntax

```
convertTosingle options fcn_1, ..., fcn_n
convertTosingle options fcn_1, -args args_1 ,..., fcn_n -args args_n
```

Description

`convertTosingle options fcn_1, ..., fcn_n` generates single-precision MATLAB code from the specified function or functions. When you use this syntax, you must provide a test file that `convertToSingle` can use to determine the properties of the input parameters. To specify the test file, use `coder.config('single')` to create a `coder.SingleConfig` object. Specify the `TestBenchName` property.

`convertTosingle options fcn_1, -args args_1 ,..., fcn_n -args args_n` specifies the properties of the input arguments.

Examples

Convert to Single Precision and Validate Using a Test File

Generate single-precision code from a double-precision function `myfun.m`. Specify a test file for determining the argument properties and for verification of the converted types. Plot the error between the double-precision and single-precision values.

```
scfg = coder.config('single');
scfg.TestBenchName = 'myfun_test';
scfg.TestNumerics = true;
scfg.LogIOForComparisonPlotting = true;
convertToSingle -config scfg myfun
```

Convert Multiple Functions to Single Precision with the Default Configuration

Convert `myfun1.m` and `myfun2.m` to single precision. Specify that `myfun1` has a double scalar argument and `myfun2` has a 2x3 double argument.

```
convertToSingle -config cfg myfun1 -args {0} myfun2 -args {zeros(2, 3)}
```

Specify Input Argument Properties

Generate single-precision code from a double-precision function, `myfun.m`, whose first argument is double scalar and whose second argument is 2x3 double.

```
 convertToSingle  myfun -args {0, zeros(2, 3)}
```

- “Generate Single-Precision MATLAB Code”

Input Arguments

`fcn_n` — Function name
character vector

MATLAB function from which to generate single-precision code.

`args_n` — Argument properties
cell array of types or example values.

Definition of the size, class, and complexity of the input arguments specified as a cell array of types or example values. To create a type, use `coder.typeof`.

`options` — options for single-precision conversion
`-config` | `-globals`

Specify one of the following single-conversion options.

`-config` *`config_object`*	Specify the configuration object to use for conversion of double-precision MATLAB code to single-precision MATLAB code. To create the configuration object, use `coder.config('single');` If you do not use this option, the conversion uses a default configuration. When you omit `-config`, to specify the properties of the input arguments, use `-args`.

`-globals` *`global_values`*	Specify names and initial values for global variables in MATLAB files.
	`global_values` is a cell array of global variable names and initial values. The format of `global_values` is:
	`{g1, init1, g2, init2, ..., gn, initn}`
	`gn` is the name of a global variable. `initn` is the initial value. For example:
	`-globals {'g', 5}`
	Alternatively, use this format:
	`-globals {global_var, {type, initial_value}}`
	`type` is a type object. To create the type object, use `coder.typeof`.
	If you do not provide initial values for global variables using the `-globals` option, `convertToSingle` checks for the variable in the MATLAB global workspace. If you do not supply an initial value, `convertToSingle` generates an error.

See Also

`coder.SingleConfig` | `coder.config`

Topics

"Generate Single-Precision MATLAB Code"

Introduced in R2015b

copyobj

Make independent copy of `quantizer` object

Syntax

```
q1 = copyobj(q)
[q1,q2,...] = copyobj(obja,objb,...)
```

Description

`q1 = copyobj(q)` makes a copy of `quantizer` object `q` and returns it in `q1`.

`[q1,q2,...] = copyobj(obja,objb,...)`copies `obja` into `q1`, `objb` into `q2`, and so on.

Using `copyobj` to copy a `quantizer` object is not the same as using the command syntax `q1 = q` to copy a `quantizer` object. `quantizer` objects have memory (their read-only properties). When you use `copyobj`, the resulting copy is independent of the original item; it does not share the original object's memory, such as the values of the properties `min`, `max`, `noverflows`, or `noperations`. Using `q1 = q` creates a new object that is an alias for the original and shares the original object's memory, and thus its property values.

Examples

```
q = quantizer([8 7]);
q1 = copyobj(q)
```

See Also

`get` | `quantizer` | `set`

Introduced before R2006a

cordicabs

CORDIC-based absolute value

Syntax

```
r = cordicabs(c)
r = cordicabs(c,niters)
r = cordicabs(c,niters,'ScaleOutput',b)
r = cordicabs(c,'ScaleOutput',b)
```

Description

`r = cordicabs(c)` returns the magnitude of the complex elements of C.

`r = cordicabs(c,niters)` performs `niters` iterations of the algorithm.

`r = cordicabs(c,niters,'ScaleOutput',b)` specifies both the number of iterations and, depending on the Boolean value of `b`, whether to scale the output by the inverse CORDIC gain value.

`r = cordicabs(c,'ScaleOutput',b)` scales the output depending on the Boolean value of `b`.

Input Arguments

`c`

`c` is a vector of complex values.

`niters`

`niters` is the number of iterations the CORDIC algorithm performs. This argument is optional. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters`, or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is the word length of r or one less than the word length of theta, whichever is smaller. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results but also increases the expense of the computation and adds latency.

Name-Value Pair Arguments

Optional comma-separated pairs of Name,Value arguments, where Name is the argument name and Value is the corresponding value. Name must appear inside single quotes ('').

ScaleOutput

ScaleOutput is a Boolean value that specifies whether to scale the output by the inverse CORDIC gain factor. This argument is optional. If you set ScaleOutput to true or 1, the output values are multiplied by a constant, which incurs extra computations. If you set ScaleOutput to false or 0, the output is not scaled.

Default: true

Output Arguments

r

r contains the magnitude values of the complex input values. If the inputs are fixed-point values, r is also fixed point (and is always signed, with binary point scaling). All input values must have the same data type. If the inputs are signed, then the word length of r is the input word length + 2. If the inputs are unsigned, then the word length of r is the input word length + 3. The fraction length of r is always the same as the fraction length of the inputs.

Examples

Compare cordicabs and abs of double values.

```
dblValues = complex(rand(5,4),rand(5,4));
r_dbl_ref = abs(dblValues)
r_dbl_cdc = cordicabs(dblValues)
```

Compute absolute values of fixed-point inputs.

```
fxpValues = fi(dblValues);
r_fxp_cdc = cordicabs(fxpValues)
```

Definitions

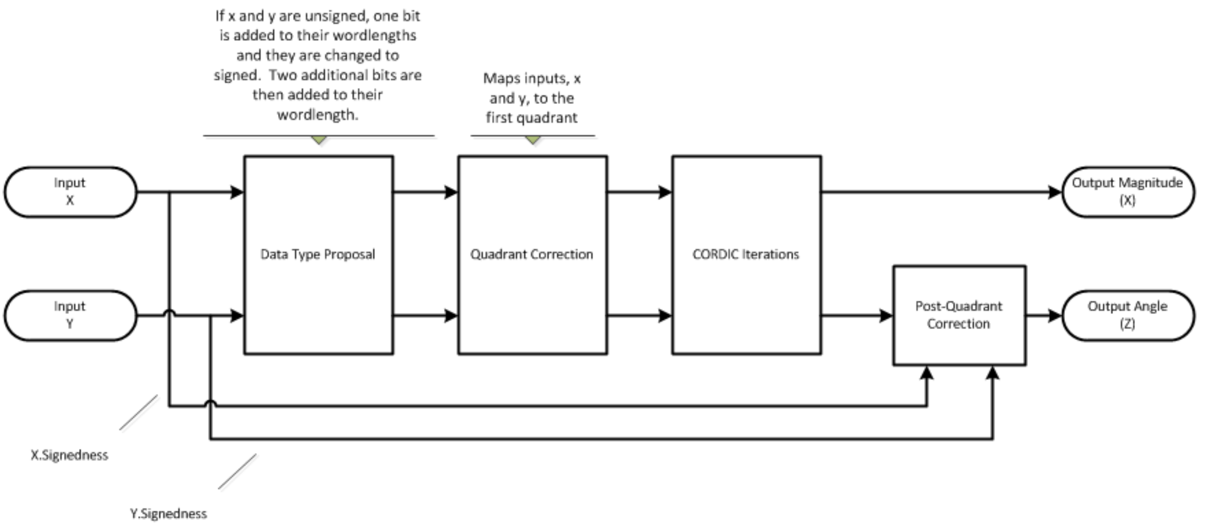
CORDIC

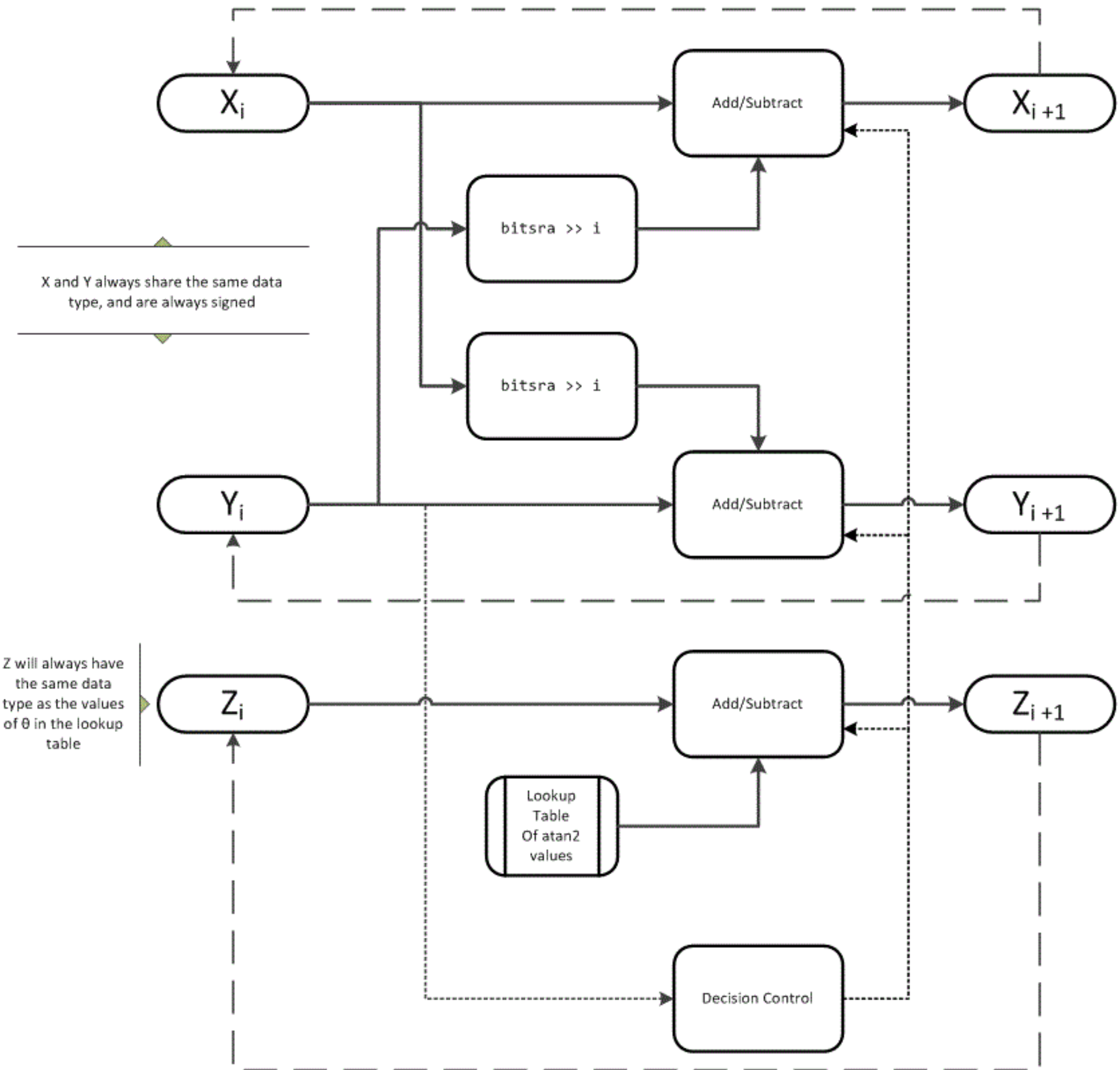
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams





X and Y always share the same data type, and are always signed
Z will always have the same data type as the values of θ in the lookup table
Add/Subtract
bitsra >> i
bitsra >> i
Add/Subtract
Add/Subtract
Lookup Table Of atan2 values
Decision Control

The accuracy of the CORDIC kernel depends on the choice of initial values for *X*, *Y*, and *Z*. This algorithm uses the following initial values:

x_0 is initialized to the x input value
y_0 is initialized to the y input value
z_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`abs` | `cordicangle` | `cordiccart2pol`

Introduced in R2011b

cordicangle

CORDIC-based phase angle

Syntax

```
theta = cordicangle(c)
theta = cordicangle(c,niters)
```

Description

`theta = cordicangle(c)` returns the phase angles, in radians, of matrix `c`, which contains complex elements.

`theta = cordicangle(c,niters)` performs `niters` iterations of the algorithm.

Input Arguments

`c`

Matrix of complex numbers

`niters`

`niters` is the number of iterations the CORDIC algorithm performs. This argument is optional. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters`, or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is the word length of `r` or one less than the word length of `theta`, whichever is smaller. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results but also increases the expense of the computation and adds latency.

Output Arguments

theta

theta contains the polar coordinates angle values, which are in the range [–pi, pi] radians. If x and y are floating-point, then theta has the same data type as x and y. Otherwise, theta is a fixed-point data type with the same word length as x and y and with a best-precision fraction length for the [-pi, pi] range.

Examples

Phase angle for double-valued input and for fixed-point-valued input.

```
dblRandomVals = complex(rand(5,4), rand(5,4));
theta_dbl_ref = angle(dblRandomVals);
theta_dbl_cdc = cordicangle(dblRandomVals)
fxpRandomVals = fi(dblRandomVals);
theta_fxp_cdc = cordicangle(fxpRandomVals)

theta_dbl_cdc =

    1.0422    1.0987    1.2536    0.6122
    0.5893    0.8874    0.3580    0.2020
    0.5840    0.2113    0.8933    0.6355
    0.7212    0.2074    0.9820    0.8110
    1.3640    0.3288    1.4434    1.1291

theta_fxp_cdc =

    1.0422    1.0989    1.2534    0.6123
    0.5894    0.8872    0.3579    0.2019
    0.5840    0.2112    0.8931    0.6357
    0.7212    0.2075    0.9819    0.8110
    1.3640    0.3289    1.4434    1.1289

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Definitions

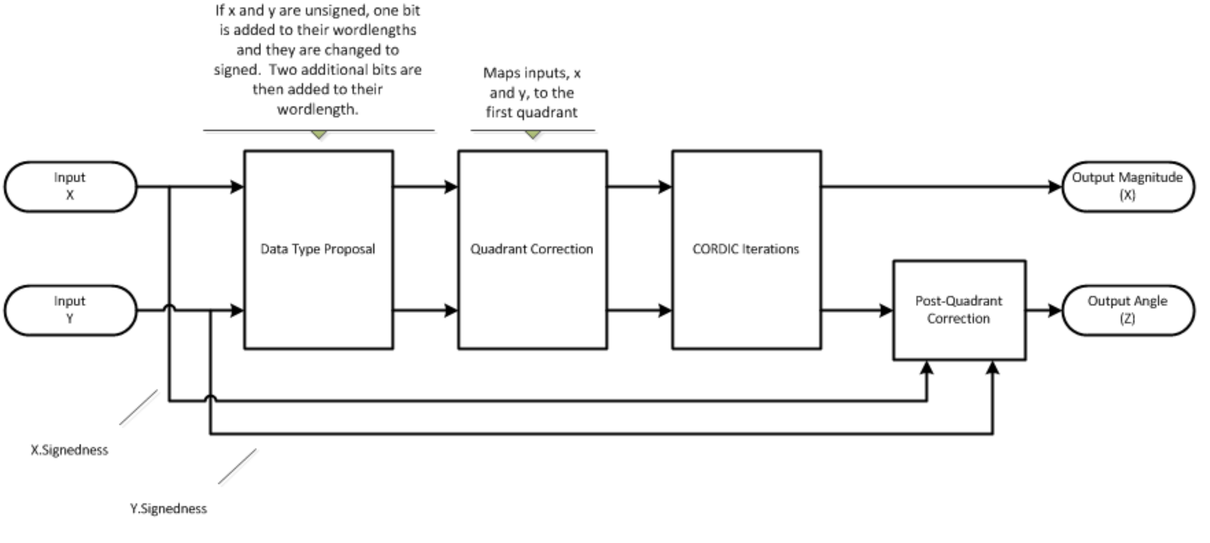
CORDIC

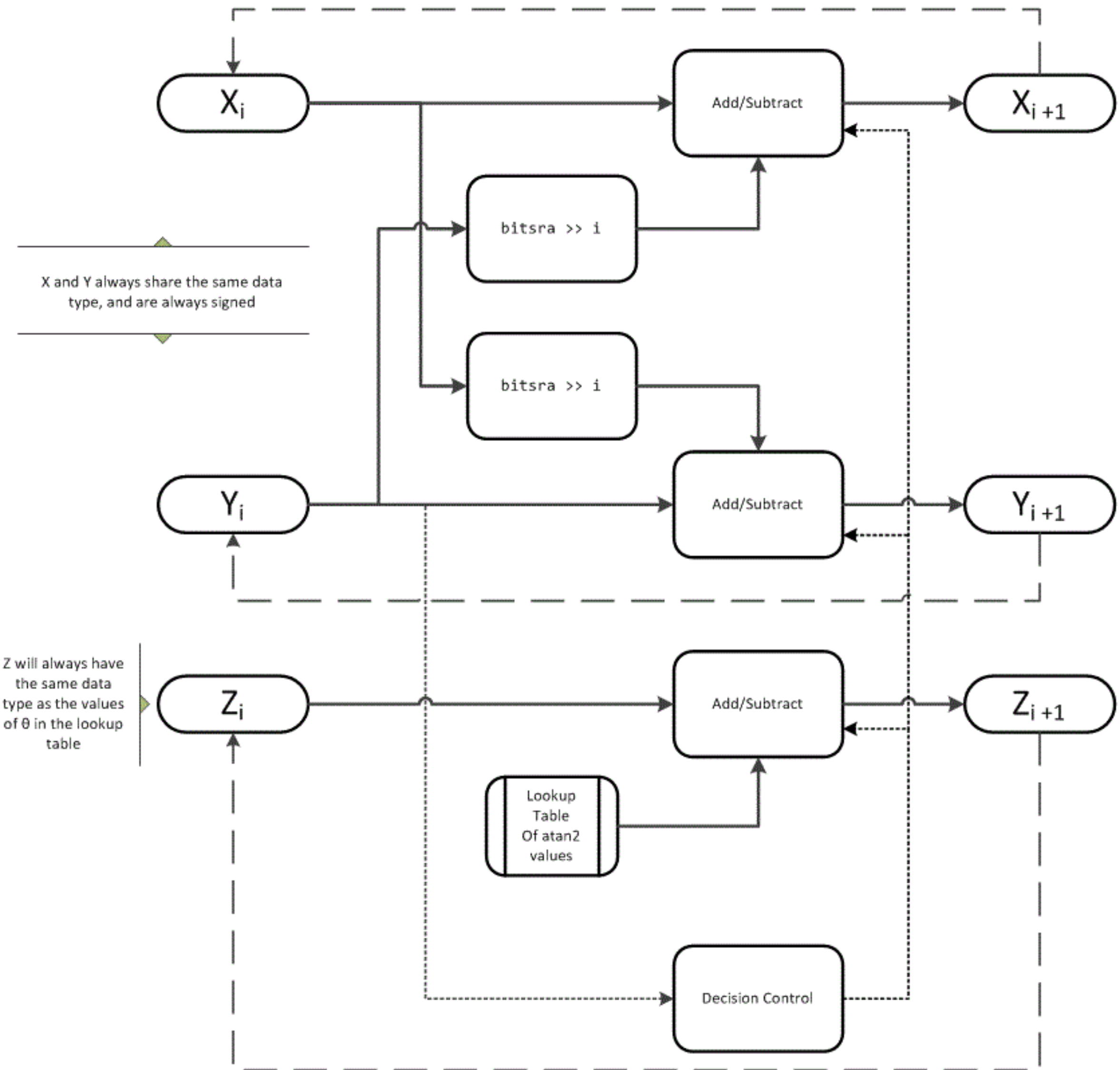
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




X_i
Add/Subtract
X_i +1
bitsra >> i
X and Y always share the same data type, and are always signed
bitsra >> i
Y_i
Add/Subtract
Y_i +1
Z will always have the same data type as the values of θ in the lookup table
Z_i
Add/Subtract
Z_i +1
Lookup Table Of atan2 values
Decision Control

The accuracy of the CORDIC kernel depends on the choice of initial values for *X*, *Y*, and *Z*. This algorithm uses the following initial values:

x_0 is initialized to the x input value
y_0 is initialized to the y input value
z_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`angle` | `cordicabs` | `cordicatan2` | `cordiccart2pol`

Introduced in R2011b

cordicatan2

CORDIC-based four quadrant inverse tangent

Syntax

```
theta = cordicatan2(y,x)
theta = cordicatan2(y,x,niters)
```

Description

`theta = cordicatan2(y,x)` computes the four quadrant arctangent of `y` and `x` using a "CORDIC" on page 4-286 algorithm approximation.

`theta = cordicatan2(y,x,niters)` performs `niters` iterations of the algorithm.

Input Arguments

`y,x`

`y,x` are Cartesian coordinates. `y` and `x` must be the same size. If they are not the same size, at least one value must be a scalar value. Both `y` and `x` must have the same data type.

`niters`

`niters` is the number of iterations the CORDIC algorithm performs. This is an optional argument. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters` or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is one less than the word length of `y` or `x`. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results but also increases the expense of the computation and adds latency.

Output Arguments

theta

theta is the arctangent value, which is in the range [-pi, pi] radians. If y and x are floating-point numbers, then theta has the same data type as y and x. Otherwise, theta is a fixed-point data type with the same word length as y and x and with a best-precision fraction length for the [-pi, pi] range.

Examples

Floating-point CORDIC arctangent calculation.

```
theta_cdat2_float = cordicatan2(0.5,-0.5)

theta_cdat2_float =
    2.3562
```

Fixed- point CORDIC arctangent calculation.

```
theta_cdat2_fixpt = cordicatan2(fi(0.5,1,16,15),fi(-0.5,1,16,15));

theta_cdat2_fixpt =
    2.3562

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Definitions

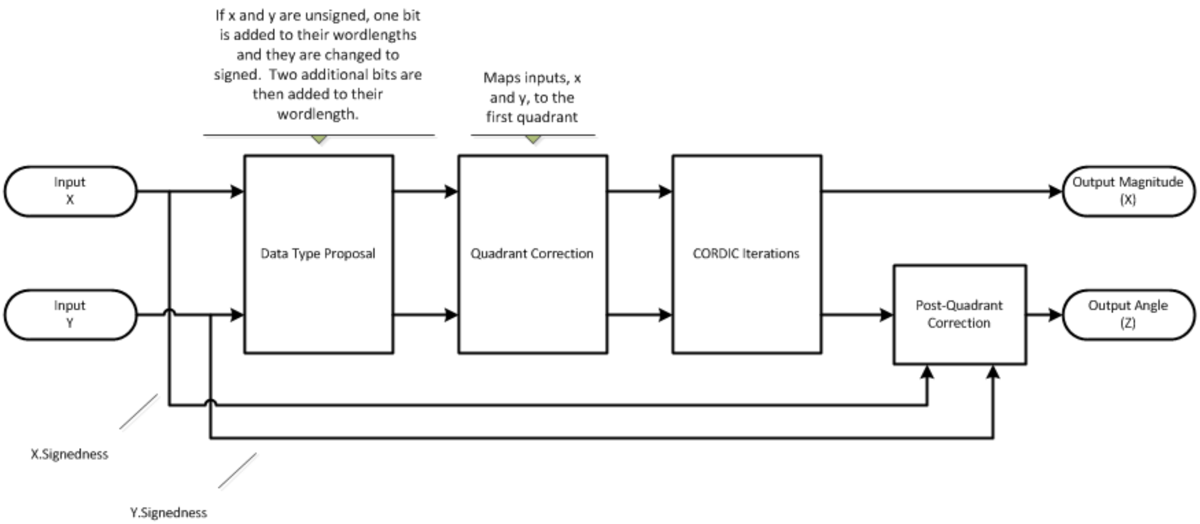
CORDIC

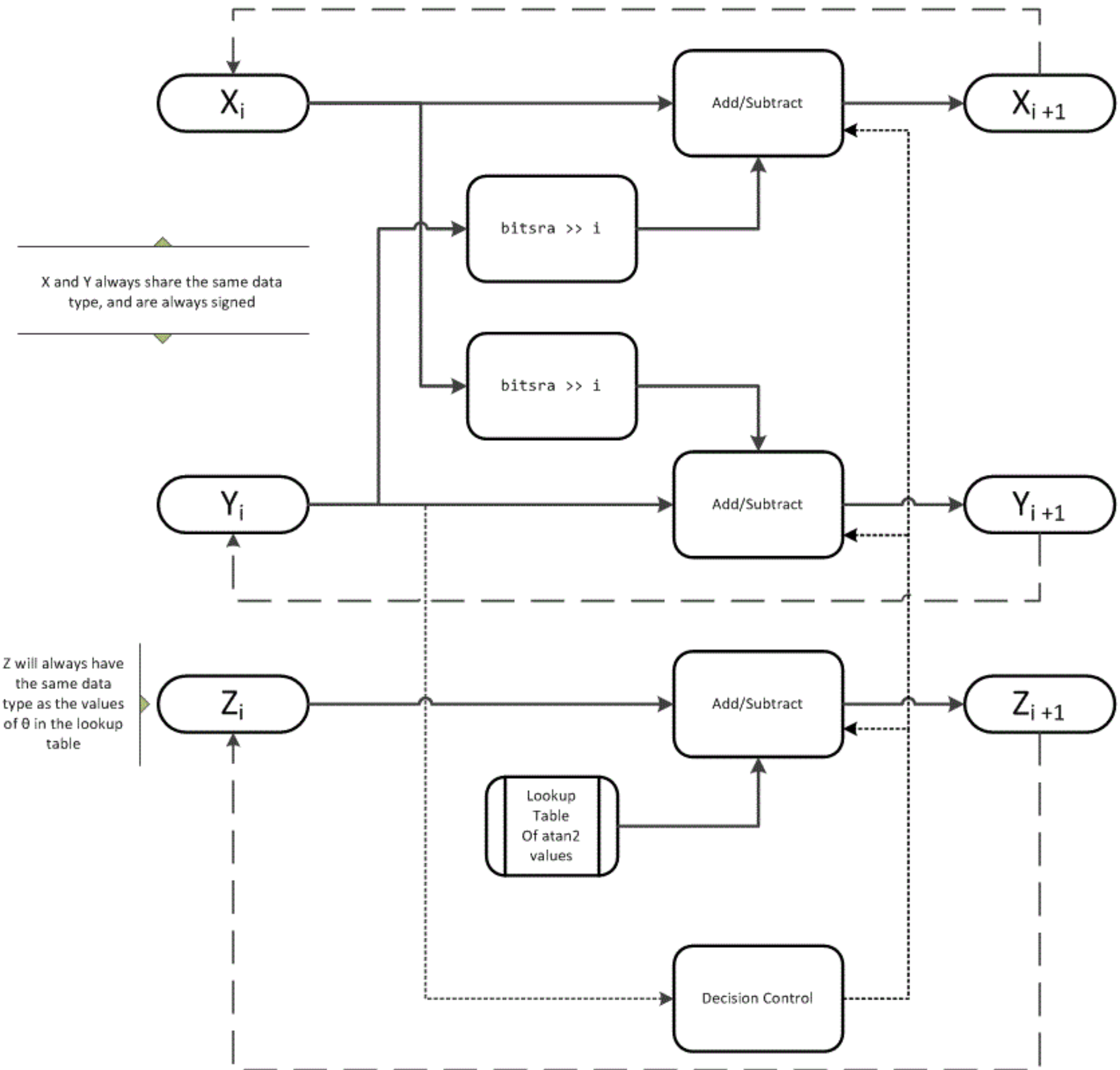
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




X and Y always share the same data type, and are always signed
Z will always have the same data type as the values of θ in the lookup table
Xi
Yi
Zi
Xi +1
Yi +1
Zi +1
Add/Subtract
Add/Subtract
Add/Subtract
bitsra >> i
bitsra >> i
Lookup Table Of atan2 values
Decision Control

The accuracy of the CORDIC kernel depends on the choice of initial values for *X*, *Y*, and *Z*. This algorithm uses the following initial values:

x_0 is initialized to the x input value

y_0 is initialized to the y input value

z_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also
`atan2` | `atan2` | `cordiccos` | `cordicsin`

Topics
Demo: Fixed-Point Arctangent Calculation

Introduced in R2011b

cordiccart2pol

CORDIC-based approximation of Cartesian-to-polar conversion

Syntax

```
[theta,r] = cordiccart2pol(x,y)
[theta,r] = cordiccart2pol(x,y, niters)
[theta,r] = cordiccart2pol(x,y, niters,'ScaleOutput',b)
[theta,r] = cordiccart2pol(x,y, 'ScaleOutput',b)
```

Description

`[theta,r] = cordiccart2pol(x,y)` using a CORDIC algorithm approximation, returns the polar coordinates, angle `theta` and radius `r`, of the Cartesian coordinates, `x` and `y`.

`[theta,r] = cordiccart2pol(x,y, niters)` performs `niters` iterations of the algorithm.

`[theta,r] = cordiccart2pol(x,y, niters,'ScaleOutput',b)` specifies both the number of iterations and, depending on the Boolean value of `b`, whether to scale the `r` output by the inverse CORDIC gain value.

`[theta,r] = cordiccart2pol(x,y, 'ScaleOutput',b)` scales the `r` output by the inverse CORDIC gain value, depending on the Boolean value of `b`.

Input Arguments

`x,y`

`x,y` are Cartesian coordinates. `x` and `y` must be the same size. If they are not the same size, at least one value must be a scalar value. Both `x` and `y` must have the same data type.

niters

niters is the number of iterations the CORDIC algorithm performs. This argument is optional. When specified, niters must be a positive, integer-valued scalar. If you do not specify niters, or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is the word length of r or one less than the word length of theta, whichever is smaller. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results but also increases the expense of the computation and adds latency.

Name-Value Pair Arguments

Optional comma-separated pairs of Name,Value arguments, where Name is the argument name and Value is the corresponding value. Name must appear inside single quotes ('').

ScaleOutput

ScaleOutput is a Boolean value that specifies whether to scale the output by the inverse CORDIC gain factor. This argument is optional. If you set ScaleOutput to true or 1, the output values are multiplied by a constant, which incurs extra computations. If you set ScaleOutput to false or 0, the output is not scaled.

Default: true

Output Arguments

theta

theta contains the polar coordinates angle values, which are in the range [–pi, pi] radians. If x and y are floating-point, then theta has the same data type as x and y. Otherwise, theta is a fixed-point data type with the same word length as x and y and with a best-precision fraction length for the [-pi, pi] range.

r

r contains the polar coordinates radius magnitude values. r is real-valued and can be a scalar value or have the same dimensions as theta If the inputs x,y are fixed-point values, r is also fixed point (and is always signed, with binary point scaling). Both x,y input values must have the same data type. If the inputs are signed, then the word length of `r` is the input word length + 2. If the inputs are unsigned, then the word length of `r` is the input word length + 3. The fraction length of `r` is always the same as the fraction length of the `x,y` inputs.

Examples

Convert fixed-point Cartesian coordinates to polar coordinates.

```
[thPos,r]=cordiccart2pol(sfi([0.75:-0.25:-1.0],16,15),sfi(0.5,16,15))

thPos =

    0.5881  0.7854  1.1072  1.5708  2.0344  2.3562  2.5535  2.6780

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

r =

    0.9014  0.7071  0.5591  0.5000  0.5591  0.7071  0.9014  1.1180

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 18
        FractionLength: 15

[thNeg,r]=...
  cordiccart2pol(sfi([0.75:-0.25:-1.0],16,15),sfi(-0.5,16,15))

thNeg =

 -0.5881 -0.7854 -1.1072 -1.5708 -2.0344 -2.3562 -2.5535 -2.6780

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

r =

 0.9014  0.7071  0.5591  0.5000  0.5591  0.7071  0.9014  1.1180
```

```
      DataTypeMode: Fixed-point: binary point scaling
        Signedness: Signed
        WordLength: 18
    FractionLength: 15
```

Definitions

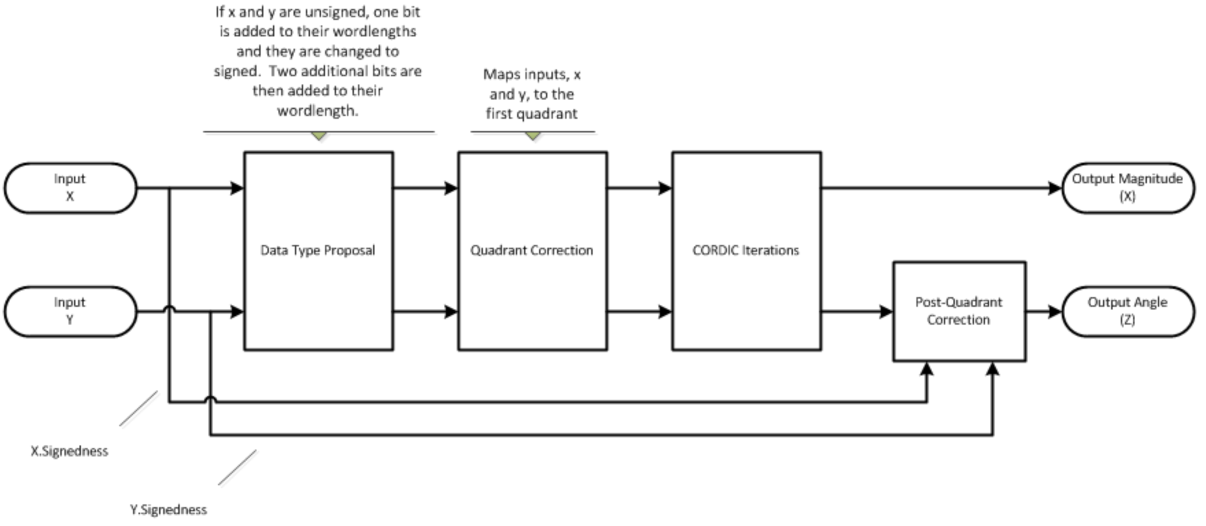
CORDIC

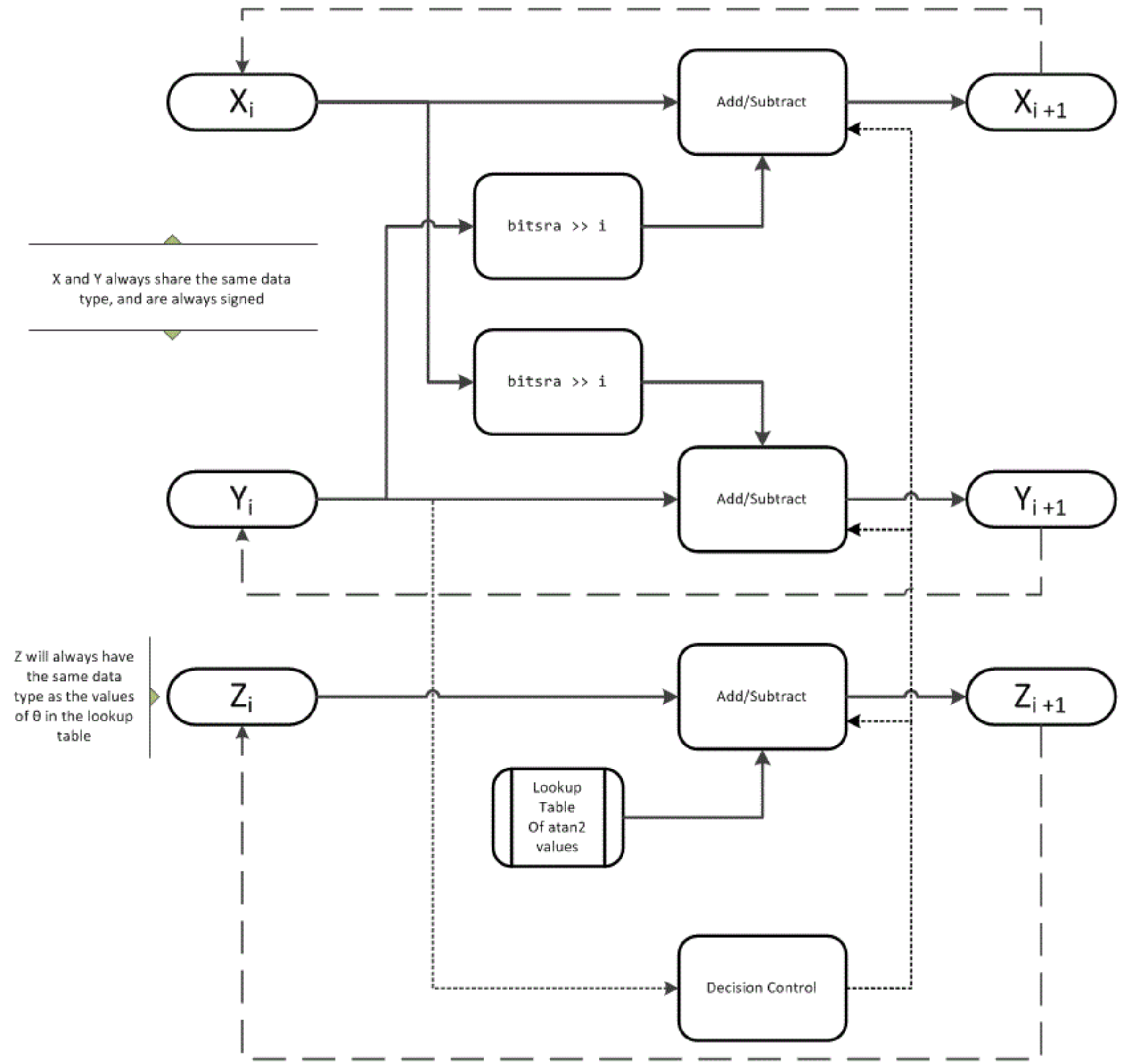
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




Xi
Add/Subtract
Xi +1
bitsra >> i
X and Y always share the same data type, and are always signed
bitsra >> i
Yi
Add/Subtract
Yi +1
Z will always have the same data type as the values of θ in the lookup table
Zi
Add/Subtract
Zi +1
Lookup Table Of atan2 values
Decision Control

The accuracy of the CORDIC kernel depends on the choice of initial values for X, Y, and Z. This algorithm uses the following initial values:

x_0 is initialized to the x input value

y_0 is initialized to the y input value

z_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. “The CORDIC Trigonometric Computing Technique.” *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. “A survey of CORDIC algorithm for FPGA based computers.” *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. “A Unified Algorithm for Elementary Functions.” Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. “Calculator Function Approximation.” *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`cart2pol` | `cordicatan2` | `cordicpol2cart`

Introduced in R2011b

cordiccexp

CORDIC-based approximation of complex exponential

Syntax

```
y = cordiccexp(theta,niters)
```

Description

`y = cordiccexp(theta,niters)` computes `cos(theta)` + *j**`sin(theta)` using a "CORDIC" on page 4-301 algorithm approximation. *y* contains the approximated complex result.

Input Arguments

theta

`theta` can be a signed or unsigned scalar, vector, matrix, or `N`-dimensional array containing the angle values in radians. All values of `theta` must be real and in the range [–2π 2π).

niters

`niters` is the number of iterations the CORDIC algorithm performs. This is an optional argument. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters` or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is one less than the word length of `theta`. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results, but it also increases the expense of the computation and adds latency.

Output Arguments

y

`y` is the approximated complex result of the `cordiccexp` function. When the input to the function is floating point, the output data type is the same as the input data type. When the input is fixed point, the output has the same word length as the input, and a fraction length equal to the `WordLength` – `2`.

Examples

The following example illustrates the effect of the number of iterations on the result of the `cordiccexp` approximation.

```
wrdLn = 8;
theta = fi(pi/2, 1, wrdLn);
fprintf('\n\nNITERS\t\tY (SIN)\t ERROR\t LSBs\t\tX (COS)\t ERROR\t LSBs\n');
fprintf('------\t\t-------\t ------\t ----\t\t-------\t ------\t ----\n');
for niters = 1:(wrdLn - 1)
 cis    = cordiccexp(theta, niters);
 fl     = cis.FractionLength;
 x      = real(cis);
 y      = imag(cis);
 x_dbl  = double(x);
 x_err  = abs(x_dbl - cos(double(theta)));
 y_dbl  = double(y);
 y_err  = abs(y_dbl - sin(double(theta)));
 fprintf('%d\t\t%1.4f\t%1.4f\t%1.1f\t\t%1.4f\t%1.4f\t%1.1f\n',...
   niters,y_dbl,y_err,(y_err*pow2(fl)),x_dbl,x_err,(x_err*pow2(fl)));
end
fprintf('\n');
```

The output table appears as follows:

```
NITERS   Y (SIN)  ERROR   LSBs    X (COS)  ERROR   LSBs
------    -------  ------  ----    -------  ------  ----
1         0.7031   0.2968  19.0    0.7031   0.7105  45.5
2         0.9375   0.0625  4.0     0.3125   0.3198  20.5
3         0.9844   0.0156  1.0     0.0938   0.1011  6.5
4         0.9844   0.0156  1.0     -0.0156  0.0083  0.5
5         1.0000   0.0000  0.0     0.0312   0.0386  2.5
6         1.0000   0.0000  0.0     0.0000   0.0073  0.5
7         1.0000   0.0000  0.0     0.0156   0.0230  1.5
```

Definitions

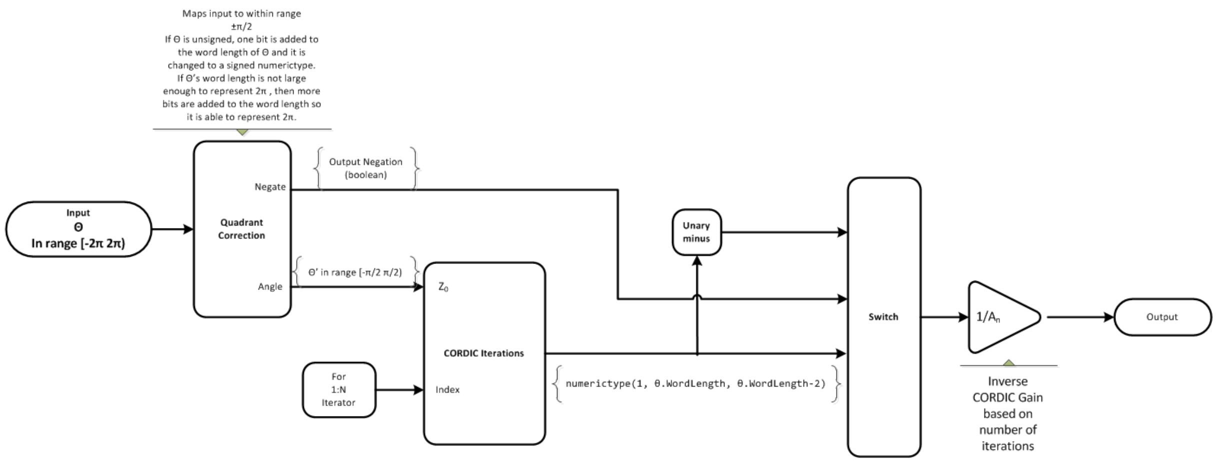
CORDIC

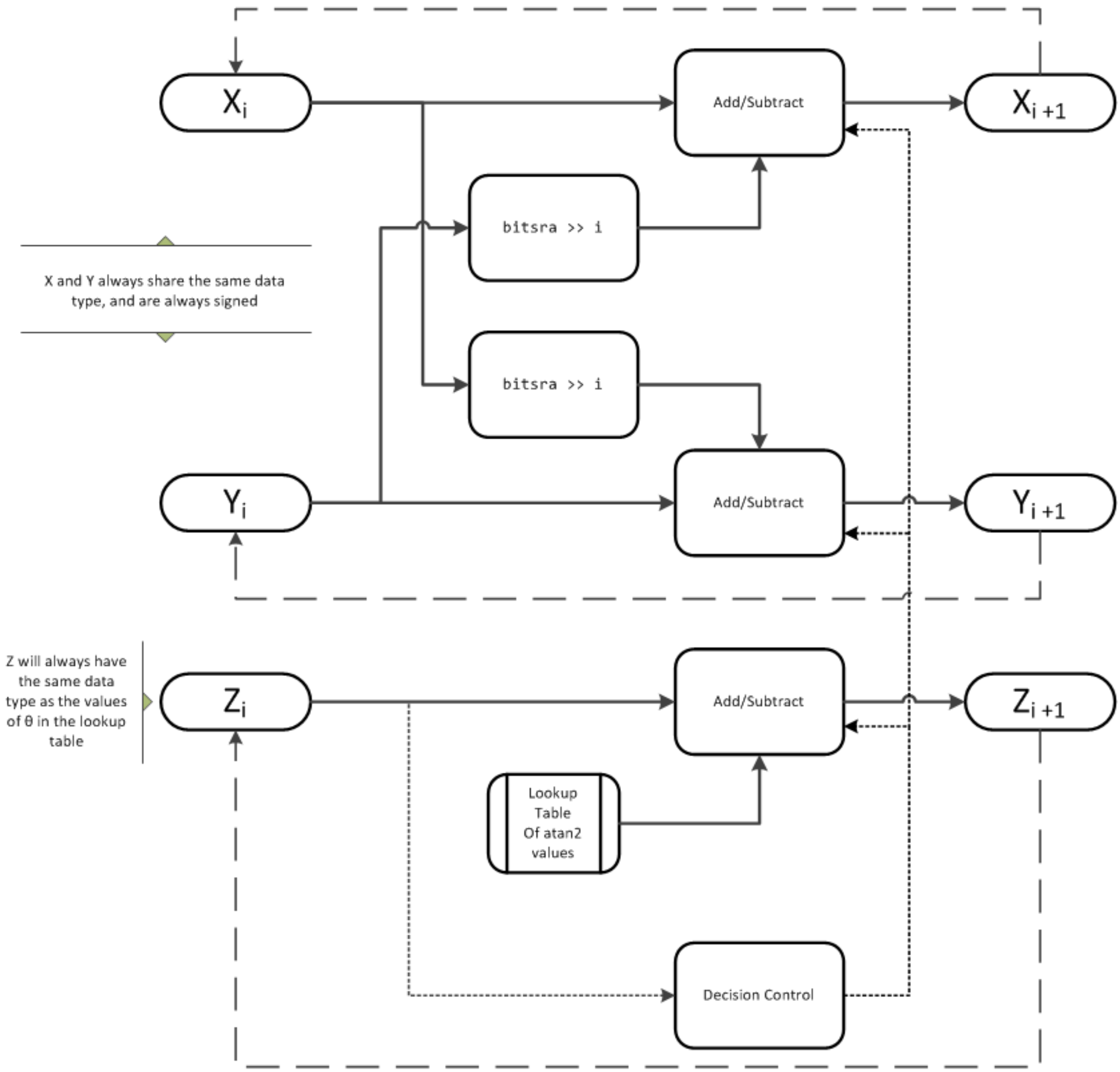
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




X_i
Add/Subtract
X_{i+1}
bitsra >> i
X and Y always share the same data type, and are always signed
bitsra >> i
Y_i
Add/Subtract
Y_{i+1}
Z will always have the same data type as the values of θ in the lookup table
Z_i
Add/Subtract
Z_{i+1}
Lookup Table Of atan2 values
Decision Control

X represents the real part, Y represents the imaginary part, and Z represents theta. The accuracy of the CORDIC rotation kernel depends on the choice of initial values for X, Y, and Z. This algorithm uses the following initial values:

z_0 is initialized to the θ input argument value

x_0 is initialized to $\frac{1}{A_N}$

y_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. “The CORDIC Trigonometric Computing Technique.” *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. “A survey of CORDIC algorithm for FPGA based computers.” *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. “A Unified Algorithm for Elementary Functions.” Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. “Calculator Function Approximation.” *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also
`cordiccos` | `cordicsin` | `cordicsincos`

Topics
Demo: Fixed-Point Sine and Cosine Calculation
Demo: Fixed-Point Arctangent Calculation

Introduced in R2010a

cordiccos

CORDIC-based approximation of cosine

Syntax

`y = cordiccos(theta, niters)`

Description

`y = cordiccos(theta, niters)` computes the cosine of `theta` using a "CORDIC" on page 4-308 algorithm approximation.

Input Arguments

`theta`

`theta` can be a signed or unsigned scalar, vector, matrix, or `N`-dimensional array containing the angle values in radians. All values of `theta` must be real and in the range [–2π 2π).

`niters`

`niters` is the number of iterations the CORDIC algorithm performs. This is an optional argument. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters` or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is one less than the word length of `theta`. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results, but it also increases the expense of the computation and adds latency.

Output Arguments

y

y is the CORDIC-based approximation of the cosine of `theta`. When the input to the function is floating point, the output data type is the same as the input data type. When the input is fixed point, the output has the same word length as the input, and a fraction length equal to the `WordLength` – 2.

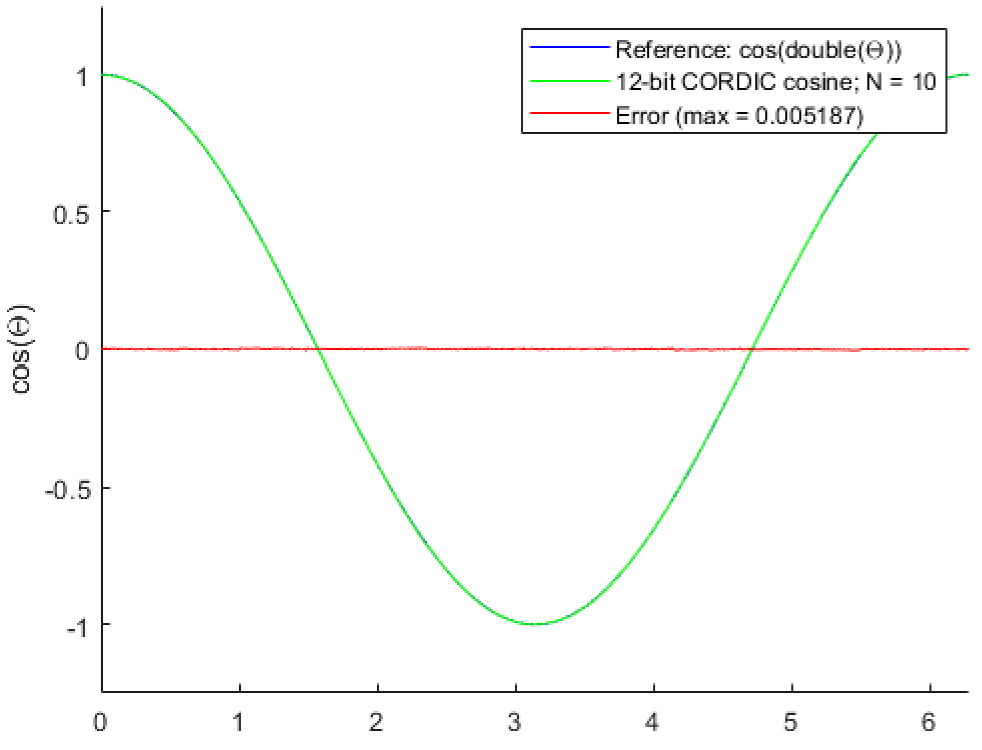
Examples

Compare Results of cordiccos and cos Functions

Compare the results produced by various iterations of the `cordiccos` algorithm to the results of the double-precision `cos` function.

```
% Create 1024 points between [0, 2*pi)
stepSize = pi/512;
thRadDbl = 0:stepSize:(2*pi - stepSize);
thRadFxp = sfi(thRadDbl, 12);    % signed, 12-bit fixed-point
cosThRef = cos(double(thRadFxp));   % reference results

% Use 12-bit quantized inputs and vary the number
% of iterations from 2 to 10.
% Compare the  fixed-point CORDIC results to the
% double-precision trig function results.
for niters = 2:2:10
    cdcCosTh  = cordiccos(thRadFxp,  niters);
    errCdcRef = cosThRef - double(cdcCosTh);
end

figure
hold on
axis([0 2*pi -1.25 1.25]);
    plot(thRadFxp, cosThRef,  'b');
    plot(thRadFxp, cdcCosTh,  'g');
    plot(thRadFxp, errCdcRef, 'r');
    ylabel('cos(\Theta)');
    gca.XTick = 0:pi/2:2*pi;
    gca.XTickLabel = {'0','pi/2','pi','3*pi/2','2*pi'};
    gca.YTick = -1:0.5:1;
```

```
gca.YTickLabel = {'-1.0','-0.5','0','0.5','1.0'};
ref_str = 'Reference: cos(double(\Theta))';
cdc_str = sprintf('12-bit CORDIC cosine; N = %d', niters);
err_str = sprintf('Error (max = %f)', max(abs(errCdcRef)));
legend(ref_str, cdc_str, err_str);
```



After 10 iterations, the CORDIC algorithm has approximated the cosine of `theta` to within 0.005187 of the double-precision cosine result.

- Demo: Fixed-Point Sine and Cosine Calculation
- Demo: Fixed-Point Arctangent Calculation

Definitions

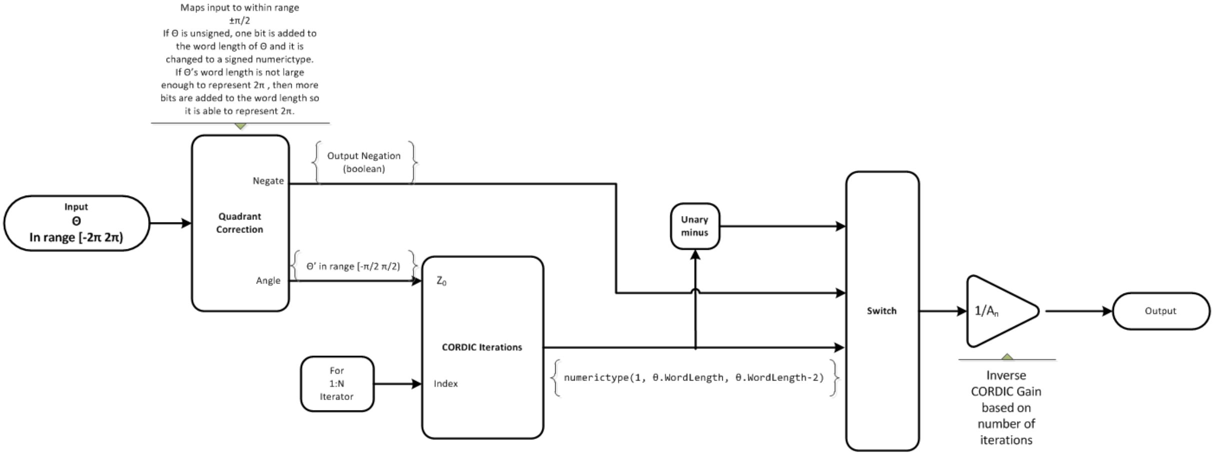
CORDIC

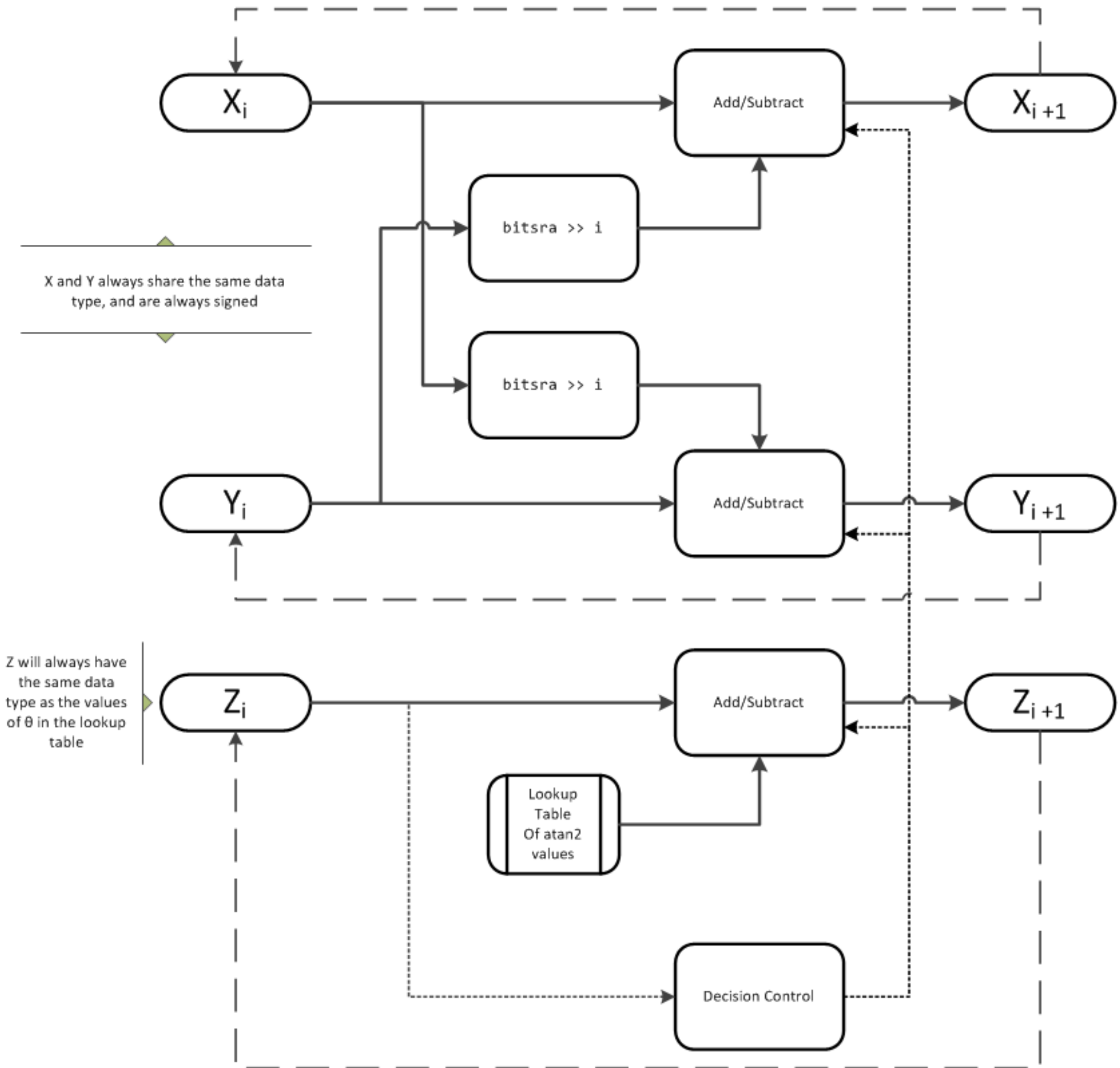
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams





X_i
Add/Subtract
X_{i+1}
bitsra >> i
X and Y always share the same data type, and are always signed
bitsra >> i
Y_i
Add/Subtract
Y_{i+1}
Z will always have the same data type as the values of θ in the lookup table
Z_i
Add/Subtract
Z_{i+1}
Lookup Table Of atan2 values
Decision Control

X represents the sine, Y represents the cosine, and Z represents theta. The accuracy of the CORDIC rotation kernel depends on the choice of initial values for X, Y, and Z. This algorithm uses the following initial values:

z_0 is initialized to the θ input argument value

x_0 is initialized to $\frac{1}{A_N}$

y_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction—Wrap`
- `RoundingMethod—Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`cordiccexp` | `cordicsin` | `cordicsincos` | `cos` | `sin`

Topics

Demo: Fixed-Point Sine and Cosine Calculation
Demo: Fixed-Point Arctangent Calculation

Introduced in R2010a

cordicpol2cart

CORDIC-based approximation of polar-to-Cartesian conversion

Syntax

```
[x,y] = cordicpol2cart(theta,r)
[x,y] = cordicpol2cart(theta,r,niters)
[x,y] = cordicpol2cart(theta,r,Name,Value)
[x,y] = cordicpol2cart(theta,r,niters,Name,Value)
```

Description

`[x,y] = cordicpol2cart(theta,r)` returns the Cartesian xy coordinates of `r*` e^(j*`theta`) using a CORDIC algorithm approximation.

`[x,y] = cordicpol2cart(theta,r,niters)` performs `niters` iterations of the algorithm.

`[x,y] = cordicpol2cart(theta,r,Name,Value)` scales the output depending on the Boolean value of `b`.

`[x,y] = cordicpol2cart(theta,r,niters,Name,Value)` specifies both the number of iterations and `Name,Value` pair for whether to scale the output.

Input Arguments

`theta`

`theta` can be a signed or unsigned scalar, vector, matrix, or *N*-dimensional array containing the angle values in radians. All values of `theta` must be in the range [–2π 2π).

`r`

`r` contains the input magnitude values and can be a scalar or have the same dimensions as `theta`. `r` must be real valued.

niters

niters is the number of iterations the CORDIC algorithm performs. This argument is optional. When specified, niters must be a positive, integer-valued scalar. If you do not specify niters, or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is the word length of r or one less than the word length of theta, whichever is smaller. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results but also increases the expense of the computation and adds latency.

Name-Value Pair Arguments

Optional comma-separated pairs of Name,Value arguments, where Name is the argument name and Value is the corresponding value. Name must appear inside single quotes ('').

ScaleOutput

ScaleOutput is a Boolean value that specifies whether to scale the output by the inverse CORDIC gain factor. This argument is optional. If you set ScaleOutput to true or 1, the output values are multiplied by a constant, which incurs extra computations. If you set ScaleOutput to false or 0, the output is not scaled.

Default: true

Output Arguments

[x,y]

[x,y] contains the approximated Cartesian coordinates. When the input r is floating point, the output [x,y] has the same data type as the input.

When the input r is a *signed* integer or fixed point data type, the outputs [x,y] are signed fi objects. These fi objects have word lengths that are two bits larger than that of r. Their fraction lengths are the same as the fraction length of r.

When the input r is an *unsigned* integer or fixed point, the outputs [x,y] are signed fi objects. These fi objects have word lengths are three bits larger than that of r. Their fraction lengths are the same as the fraction length of r.

Examples

Run the following code, and evaluate the accuracy of the CORDIC-based Polar-to-Cartesian conversion.

```
wrdLn = 16;
theta = fi(pi/3, 1, wrdLn);
u     = fi( 2.0, 1, wrdLn);

fprintf('\n\nNITERS\tX\t\t ERROR\t LSBs\t\tY\t\t ERROR\t LSBs\n');
fprintf('------\t-------\t ------\t ----\t\t-------\t ------\t ----\n');
for niters = 1:(wrdLn - 1)
 [x_ref, y_ref] = pol2cart(double(theta),double(u));
 [x_fi,  y_fi] = cordicpol2cart(theta, u, niters);
 x_dbl  = double(x_fi);
 y_dbl  = double(y_fi);
 x_err  = abs(x_dbl - x_ref);
 y_err  = abs(y_dbl - y_ref);
 fprintf('%d\t%1.4f\t %1.4f\t %1.1f\t\t%1.4f\t %1.4f\t %1.1f\n',...
   niters,x_dbl,x_err,(x_err * pow2(x_fi.FractionLength)),...
   y_dbl,y_err,(y_err * pow2(y_fi.FractionLength)));
end
fprintf('\n');
```

```
NITERS  X        ERROR    LSBs      Y      ERROR   LSBs
------    -------     ------     ----         -------     ------     ----
   1       1.4142   0.4142   3392.8  1.4142   0.3178   2603.8
   2       0.6324   0.3676   3011.2  1.8973   0.1653   1354.2
   3       1.0737   0.0737   603.8   1.6873   0.0448   366.8
   4       0.8561   0.1440   1179.2  1.8074   0.0753   617.2
   5       0.9672   0.0329   269.2   1.7505   0.0185   151.2
   6       1.0214   0.0213   174.8   1.7195   0.0126   102.8
   7       0.9944   0.0056   46.2    1.7351   0.0031   25.2
   8       1.0079   0.0079   64.8    1.7274   0.0046   37.8
   9       1.0011   0.0011   8.8     1.7313   0.0007   5.8
   10   0.9978   0.0022   18.2    1.7333   0.0012   10.2
   11   0.9994   0.0006   5.2     1.7323   0.0003   2.2
   12   1.0002   0.0002   1.8     1.7318   0.0002   1.8
   13   0.9999   0.0002   1.2     1.7321   0.0000   0.2
   14   0.9996   0.0004   3.2     1.7321   0.0000   0.2
   15   0.9998   0.0003   2.2     1.7321   0.0000   0.2
```

Definitions

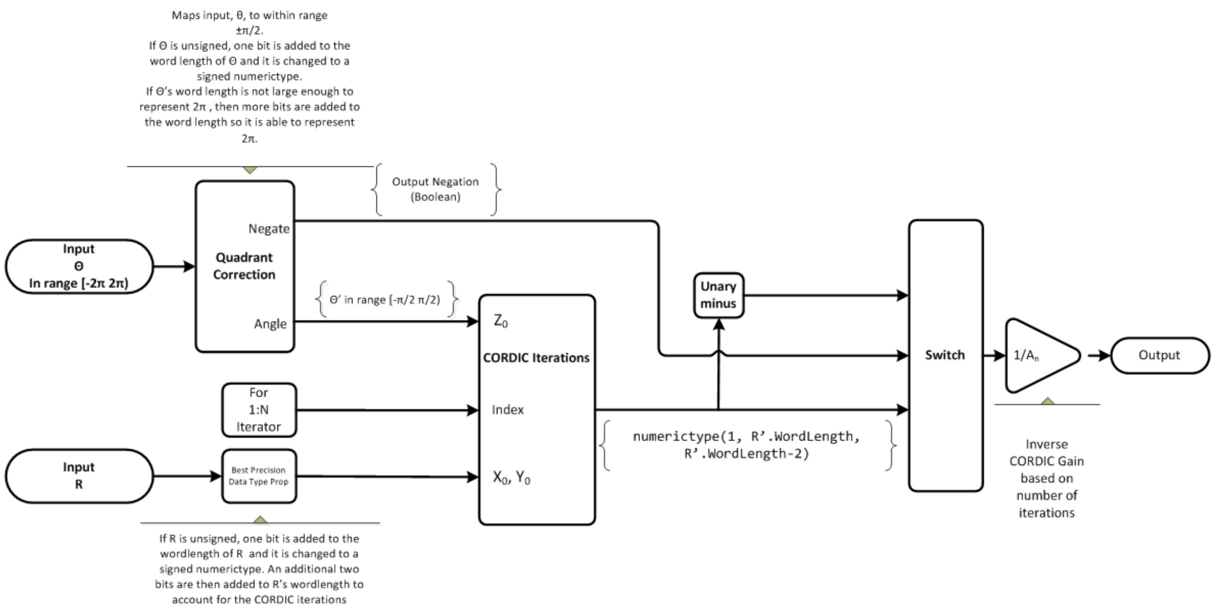
CORDIC

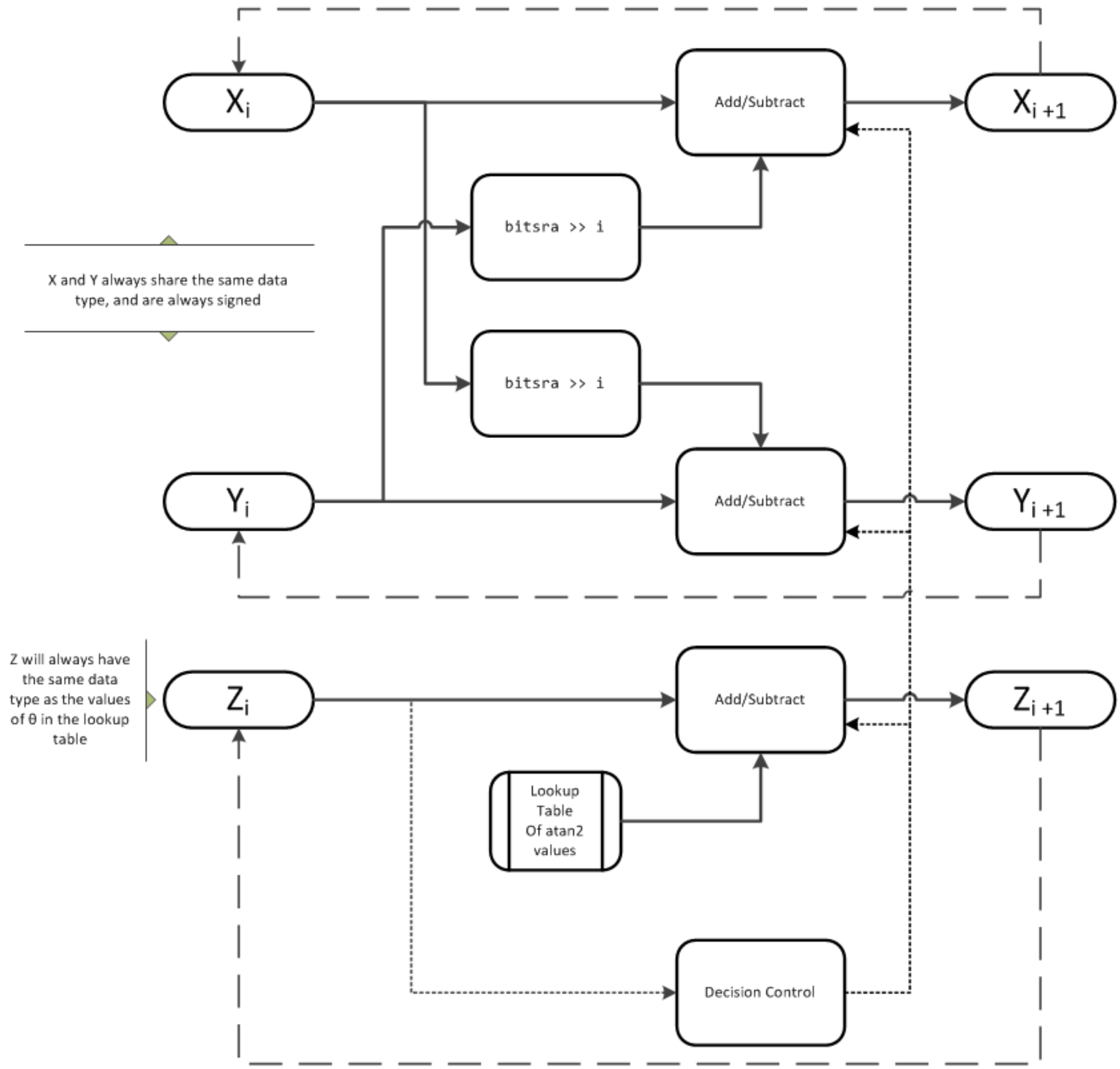
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




X and Y always share the same data type, and are always signed
Z will always have the same data type as the values of θ in the lookup table
X_i
Add/Subtract
X_{i+1}
bitsra >> i
bitsra >> i
Y_i
Add/Subtract
Y_{i+1}
Z_i
Add/Subtract
Z_{i+1}
Lookup Table Of atan2 values
Decision Control

X represents the real part, *Y* represents the imaginary part, and *Z* represents theta. This algorithm takes its initial values for *X*, *Y*, and *Z* from the inputs, `r` and `theta`.

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`cordicrotate` | `cordicsincos` | `pol2cart`

Introduced in R2011a

cordicrotate

Rotate input using CORDIC-based approximation

Syntax

```
v = cordicrotate(theta,u)
v = cordicrotate(theta,u,niters)
v = cordicrotate(theta,u,Name,Value)
v = cordicrotate(theta,u,niters,Name,Value)
```

Description

`v = cordicrotate(theta,u)` rotates the input `u` by `theta` using a CORDIC algorithm approximation. The function returns the result of `u` .* **e**^(**j***theta).

`v = cordicrotate(theta,u,niters)` performs `niters` iterations of the algorithm.

`v = cordicrotate(theta,u,Name,Value)` scales the output depending on the Boolean value, `b`.

`v = cordicrotate(theta,u,niters,Name,Value)` specifies both the number of iterations and the `Name,Value` pair for whether to scale the output.

Input Arguments

theta

`theta` can be a signed or unsigned scalar, vector, matrix, or *N*-dimensional array containing the angle values in radians. All values of `theta` must be in the range [–2π 2π).

u

`u` can be a signed or unsigned scalar value or have the same dimensions as `theta`. `u` can be real or complex valued.

niters

niters is the number of iterations the CORDIC algorithm performs. This argument is optional. When specified, niters must be a positive, integer-valued scalar. If you do not specify niters, or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is the word length of u or one less than the word length of theta, whichever is smaller. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results, but it also increases the expense of the computation and adds latency.

Name-Value Pair Arguments

Optional comma-separated pairs of Name,Value arguments, where Name is the argument name and Value is the corresponding value. Name must appear inside single quotes ('').

ScaleOutput

ScaleOutput is a Boolean value that specifies whether to scale the output by the inverse CORDIC gain factor. This argument is optional. If you set ScaleOutput to true or 1, the output values are multiplied by a constant, which incurs extra computations. If you set ScaleOutput to false or 0, the output is not scaled.

Default: true

Output Arguments

v

v contains the approximated result of the CORDIC rotation algorithm. When the input u is floating point, the output v has the same data type as the input.

When the input u is a *signed* integer or fixed point data type, the output v is a signed fi object. This fi object has a word length that is two bits larger than that of u. Its fraction length is the same as the fraction length of u.

When the input u is an *unsigned* integer or fixed point, the output v is a signed fi object. This fi object has a word length that is three bits larger than that of u. Its fraction length is the same as the fraction length of u.

Examples

Run the following code, and evaluate the accuracy of the CORDIC-based complex rotation.

```
wrdLn = 16;
theta = fi(-pi/3, 1, wrdLn);
u     = fi(0.25 - 7.1i, 1, wrdLn);
uTeTh = double(u) .* exp(1i * double(theta));

fprintf('\n\nNITERS\tReal\t ERROR\t LSBs\t\tImag\tERROR\tLSBs\n');
fprintf('------\t-------\t ------\t ----\t\t-------\t------\t----\n');
for niters = 1:(wrdLn - 1)
 v_fi   = cordicrotate(theta, u, niters);
 v_dbl  = double(v_fi);
 x_err  = abs(real(v_dbl) - real(uTeTh));
  y_err  = abs(imag(v_dbl) - imag(uTeTh));
 fprintf('%d\t%1.4f\t %1.4f\t %1.1f\t\t%1.4f\t %1.4f\t %1.1f\n',...
   niters, real(v_dbl),x_err,(x_err * pow2(v_fi.FractionLength)), ...
   imag(v_dbl),y_err, (y_err * pow2(v_fi.FractionLength)));
end
fprintf('\n');
```

The output table appears as follows:

```
NITERS  Real     ERROR    LSBs    Imag     ERROR    LSBs
------    -------     ------     ----       -------     ------     ------
1      -4.8438   1.1800   4833.5  -5.1973  1.4306  5859.8
2      -6.6567   0.6329   2592.5  -2.4824  1.2842  5260.2
3      -5.8560   0.1678   687.5   -4.0227  0.2560  1048.8
4      -6.3098   0.2860   1171.5  -3.2649  0.5018  2055.2
5      -6.0935   0.0697   285.5   -3.6528  0.1138  466.2
6      -5.9766   0.0472   193.5   -3.8413  0.0746  305.8
7      -6.0359   0.0121   49.5    -3.7476  0.0191  78.2
8      -6.0061   0.0177   72.5    -3.7947  0.0280  114.8
9      -6.0210   0.0028   11.5    -3.7710  0.0043  17.8
10     -6.0286   0.0048   19.5    -3.7590  0.0076  31.2
11     -6.0247   0.0009   3.5        -3.7651  0.0015  6.2
12     -6.0227   0.0011   4.5        -3.7683  0.0017  6.8
13     -6.0237   0.0001   0.5        -3.7666  0.0001  0.2
14     -6.0242   0.0004   1.5        -3.7656  0.0010  4.2
15     -6.0239   0.0001   0.5        -3.7661  0.0005  2.2
```

Definitions

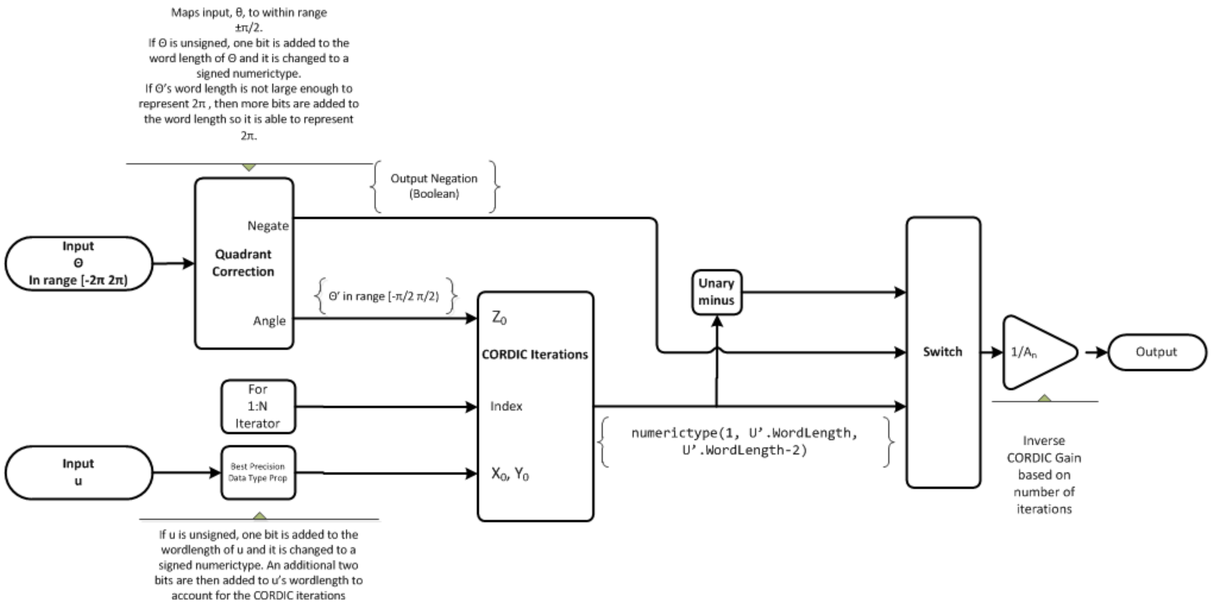
CORDIC

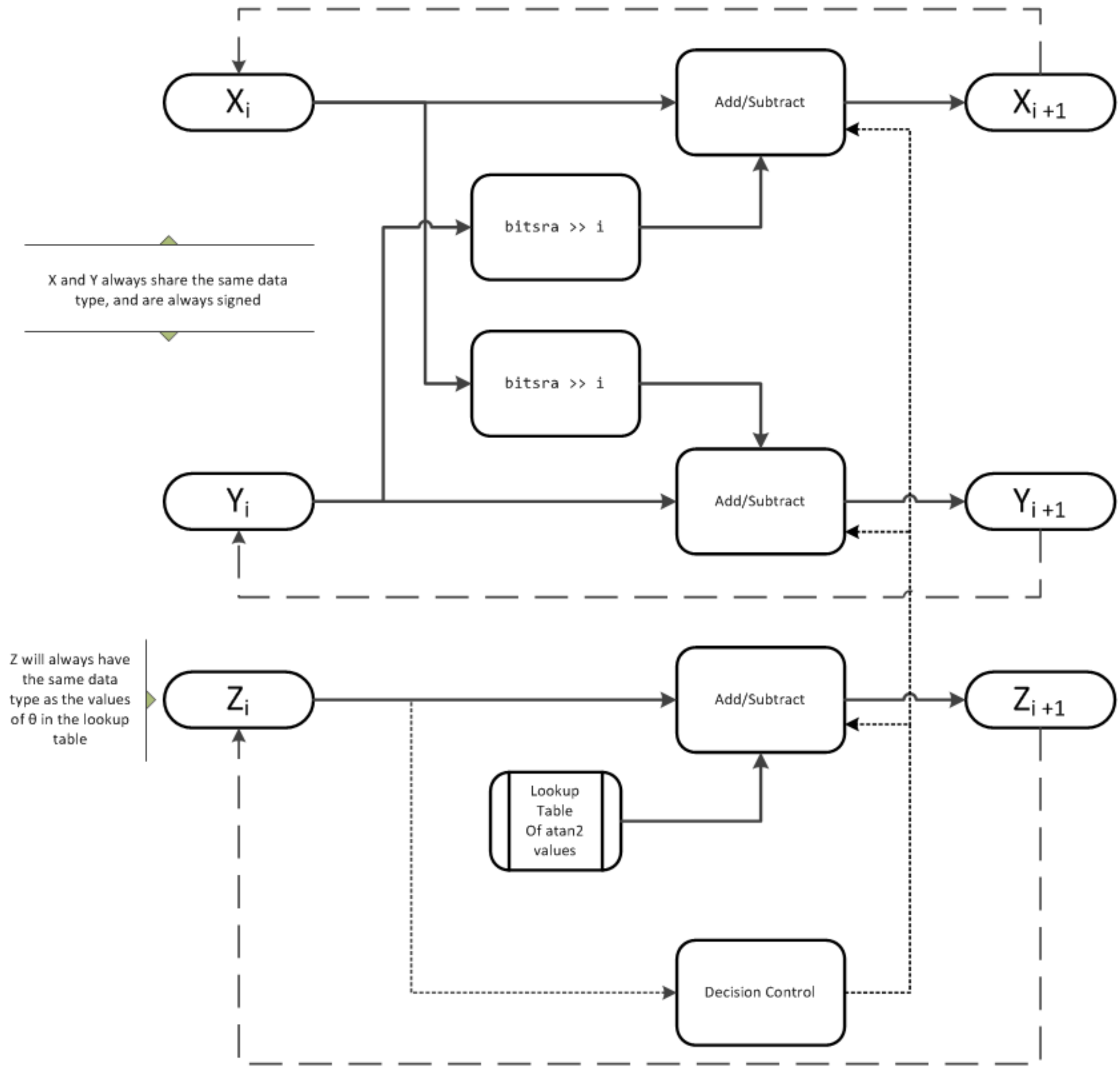
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams





X and Y always share the same data type, and are always signed
Z will always have the same data type as the values of θ in the lookup table
Xi
Yi
Zi
Add/Subtract
Add/Subtract
Add/Subtract
bitsra >> i
bitsra >> i
Lookup Table Of atan2 values
Decision Control
Xi +1
Yi +1
Zi +1

X represents the real part, *Y* represents the imaginary part, and *Z* represents theta. This algorithm takes its initial values for *X*, *Y*, and *Z* from the inputs, `u` and `theta`.

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`cordiccexp` | `cordicpol2cart`

Introduced in R2011a

cordicsin

CORDIC-based approximation of sine

Syntax

```
y = cordicsin(theta,niters)
```

Description

`y = cordicsin(theta,niters)` computes the sine of `theta` using a “CORDIC” on page 4-331 algorithm approximation.

Input Arguments

`theta`

`theta` can be a signed or unsigned scalar, vector, matrix, or `N`-dimensional array containing the angle values in radians. All values of `theta` must be real and in the range [–2π 2π).

`niters`

`niters` is the number of iterations the CORDIC algorithm performs. This is an optional argument. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters` or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is one less than the word length of `theta`. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results, but it also increases the expense of the computation and adds latency.

Output Arguments

y

y is the CORDIC-based approximation of the sine of `theta`. When the input to the function is floating point, the output data type is the same as the input data type. When the input is fixed point, the output has the same word length as the input, and a fraction length equal to the `WordLength` – 2.

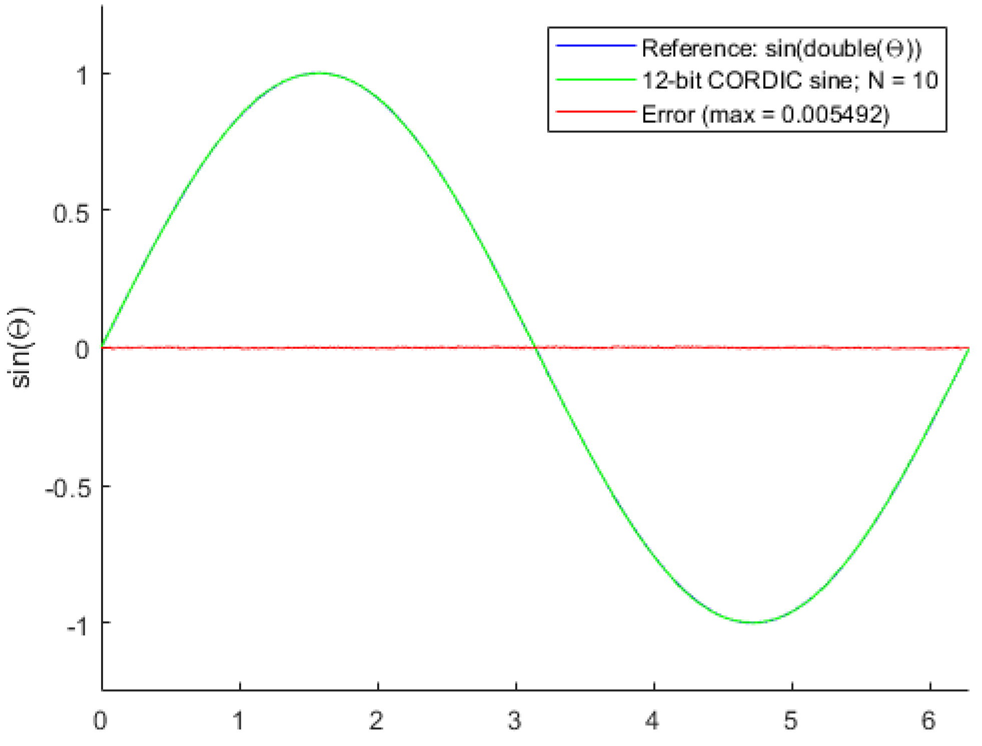
Examples

Compare Results of cordicsin and sin Functions

Compare the results produced by various iterations of the `cordicsin` algorithm to the results of the double-precision `sin` function.

```
% Create 1024 points between [0, 2*pi)
stepSize = pi/512;
thRadDbl = 0:stepSize:(2*pi - stepSize);
thRadFxp = sfi(thRadDbl, 12);       % signed, 12-bit fixed point
sinThRef = sin(double(thRadFxp));    % reference results

% Use 12-bit quantized inputs and vary the number of iterations
% from 2 to 10.
% Compare the fixed-point cordicsin function results to the
% results of the double-precision sin function.

for niters = 2:2:10
    cdcSinTh  = cordicsin(thRadFxp,  niters);
    errCdcRef = sinThRef - double(cdcSinTh);
end

figure
hold on
axis([0 2*pi -1.25 1.25])
plot(thRadFxp, sinThRef,  'b');
plot(thRadFxp, cdcSinTh,  'g');
plot(thRadFxp, errCdcRef, 'r');
ylabel('sin(\Theta)');
gca.XTick = 0:pi/2:2*pi;
gca.XTickLabel = {'0','pi/2','pi','3*pi/2','2*pi'};
```

```
gca.YTick = -1:0.5:1;
gca.YTickLabel = {'-1.0','-0.5','0','0.5','1.0'};
ref_str = 'Reference: sin(double(\Theta))';
cdc_str = sprintf('12-bit CORDIC sine; N = %d', niters);
err_str = sprintf('Error (max = %f)', max(abs(errCdcRef)));
legend(ref_str, cdc_str, err_str);
```



After 10 iterations, the CORDIC algorithm has approximated the sine of `theta` to within 0.005492 of the double-precision sine result.

- Demo: Fixed-Point Sine and Cosine Calculation
- Demo: Fixed-Point Arctangent Calculation

Definitions

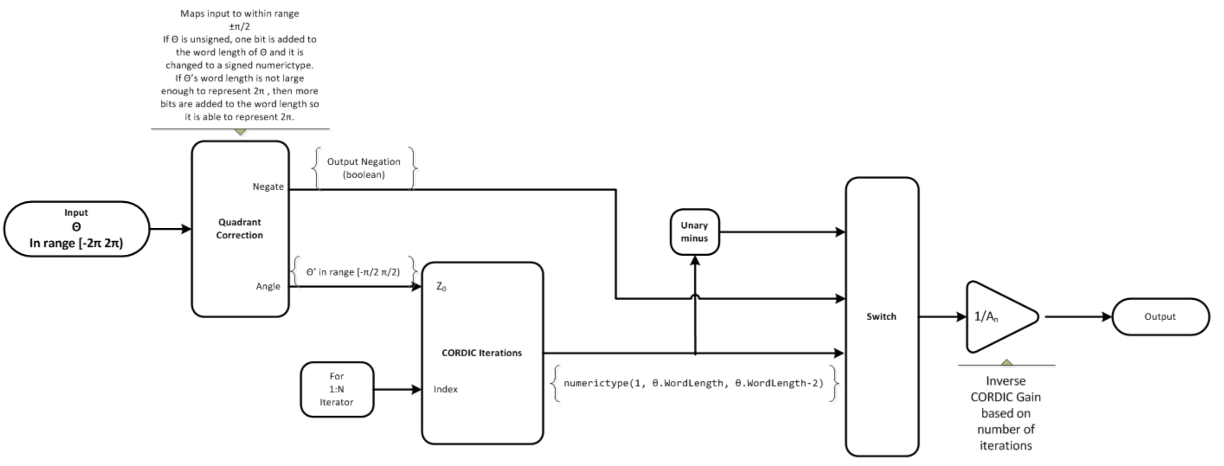
CORDIC

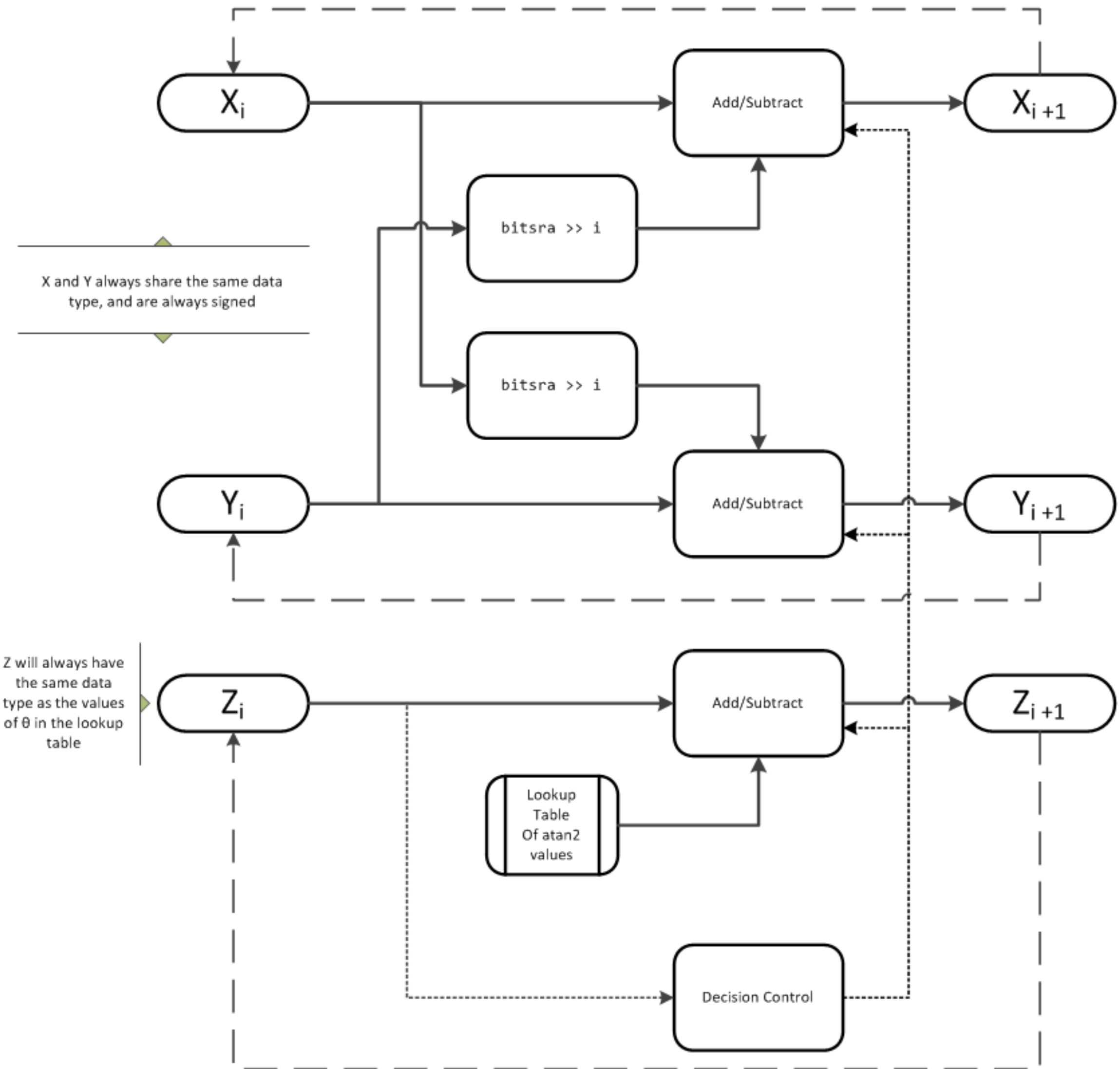
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




X_i
Add/Subtract
X_{i+1}
bitsra >> i
X and Y always share the same data type, and are always signed
bitsra >> i
Y_i
Add/Subtract
Y_{i+1}
Z will always have the same data type as the values of θ in the lookup table
Z_i
Add/Subtract
Z_{i+1}
Lookup Table Of atan2 values
Decision Control

X represents the sine, *Y* represents the cosine, and *Z* represents theta. The accuracy of the CORDIC rotation kernel depends on the choice of initial values for *X*, *Y*, and *Z*. This algorithm uses the following initial values:

z_0 is initialized to the θ input argument value

x_0 is initialized to $\frac{1}{A_N}$

y_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction`—`Wrap`
- `RoundingMethod`—`Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. "The CORDIC Trigonometric Computing Technique." *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. "A survey of CORDIC algorithm for FPGA based computers." *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. "A Unified Algorithm for Elementary Functions." Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. "Calculator Function Approximation." *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`cordiccexp` | `cordiccos` | `cordicsincos` | `cos` | `sin`

Topics

Demo: Fixed-Point Sine and Cosine Calculation
Demo: Fixed-Point Arctangent Calculation

Introduced in R2010a

cordicsincos

CORDIC-based approximation of sine and cosine

Syntax

```
[y, x] = cordicsincos(theta,niters)
```

Description

`[y, x] = cordicsincos(theta,niters)` computes the sine and cosine of `theta` using a “CORDIC” on page 4-337 algorithm approximation. *y* contains the approximated sine result, and *x* contains the approximated cosine result.

Input Arguments

`theta`

`theta` can be a signed or unsigned scalar, vector, matrix, or `N`-dimensional array containing the angle values in radians. All values of `theta` must be real and in the range [–2π 2π). When `theta` has a fixed-point data type, it must be signed.

`niters`

`niters` is the number of iterations the CORDIC algorithm performs. This is an optional argument. When specified, `niters` must be a positive, integer-valued scalar. If you do not specify `niters` or if you specify a value that is too large, the algorithm uses a maximum value. For fixed-point operation, the maximum number of iterations is one less than the word length of `theta`. For floating-point operation, the maximum value is 52 for double or 23 for single. Increasing the number of iterations can produce more accurate results, but it also increases the expense of the computation and adds latency.

Output Arguments

y

CORDIC-based approximated sine of `theta`. When the input to the function is floating point, the output data type is the same as the input data type. When the input is fixed point, the output has the same word length as the input, and a fraction length equal to the `WordLength` – 2.

x

CORDIC-based approximated cosine of `theta`. When the input to the function is floating point, the output data type is the same as the input data type. When the input is fixed point, the output has the same word length as the input, and a fraction length equal to the `WordLength` – 2.

Examples

The following example illustrates the effect of the number of iterations on the result of the `cordicsincos` approximation.

```
wrdLn = 8;
theta = fi(pi/2, 1, wrdLn);
fprintf('\n\nNITERS\t\tY (SIN)\t ERROR\t LSBs\t\tX (COS)\t ERROR\t LSBs\n');
fprintf('------\t\t-------\t ------\t ----\t\t-------\t ------\t ----\n');
for niters = 1:(wrdLn - 1)
  [y, x] = cordicsincos(theta, niters);
  y_FL   = y.FractionLength;
  y_dbl  = double(y);
  x_dbl  = double(x);
  y_err  = abs(y_dbl - sin(double(theta)));
  x_err  = abs(x_dbl - cos(double(theta)));
  fprintf(' %d\t\t%1.4f\t %1.4f\t %1.1f\t\t%1.4f\t %1.4f\t %1.1f\n', ...
   niters, y_dbl,y_err, (y_err * pow2(y_FL)), x_dbl,x_err, ...
   (x_err * pow2(y_FL)));
end
fprintf('\n');
```

The output table appears as follows:

```
NITERS    Y (SIN)  ERROR   LSBs   X (COS)  ERROR   LSBs
------    -------  ------  ----   -------  ------  ----
```

1	0.7031	0.2968	19.0	0.7031	0.7105	45.5
2	0.9375	0.0625	4.0	0.3125	0.3198	20.5
3	0.9844	0.0156	1.0	0.0938	0.1011	6.5
4	0.9844	0.0156	1.0	-0.0156	0.0083	0.5
5	1.0000	0.0000	0.0	0.0312	0.0386	2.5
6	1.0000	0.0000	0.0	0.0000	0.0073	0.5
7	1.0000	0.0000	0.0	0.0156	0.0230	1.5

Definitions

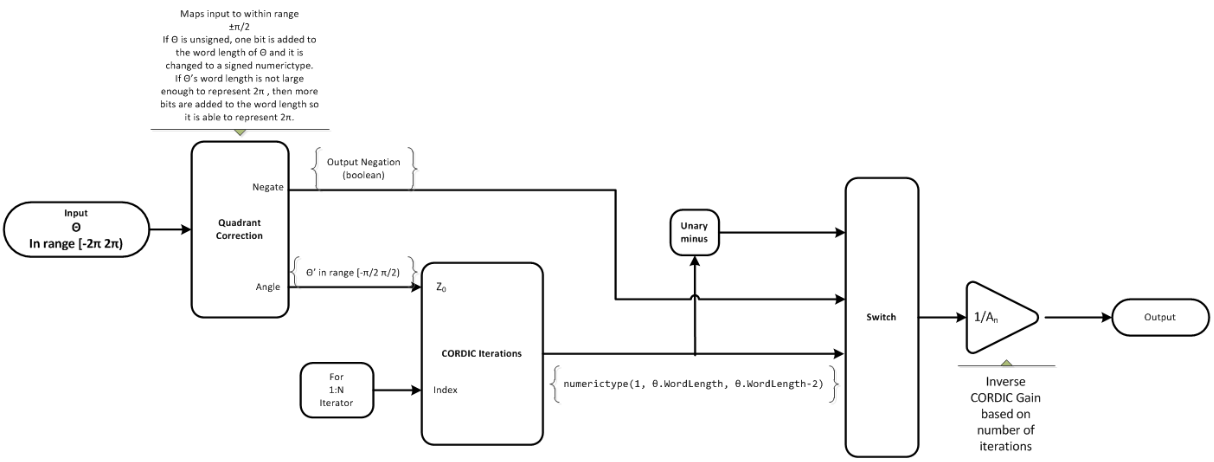
CORDIC

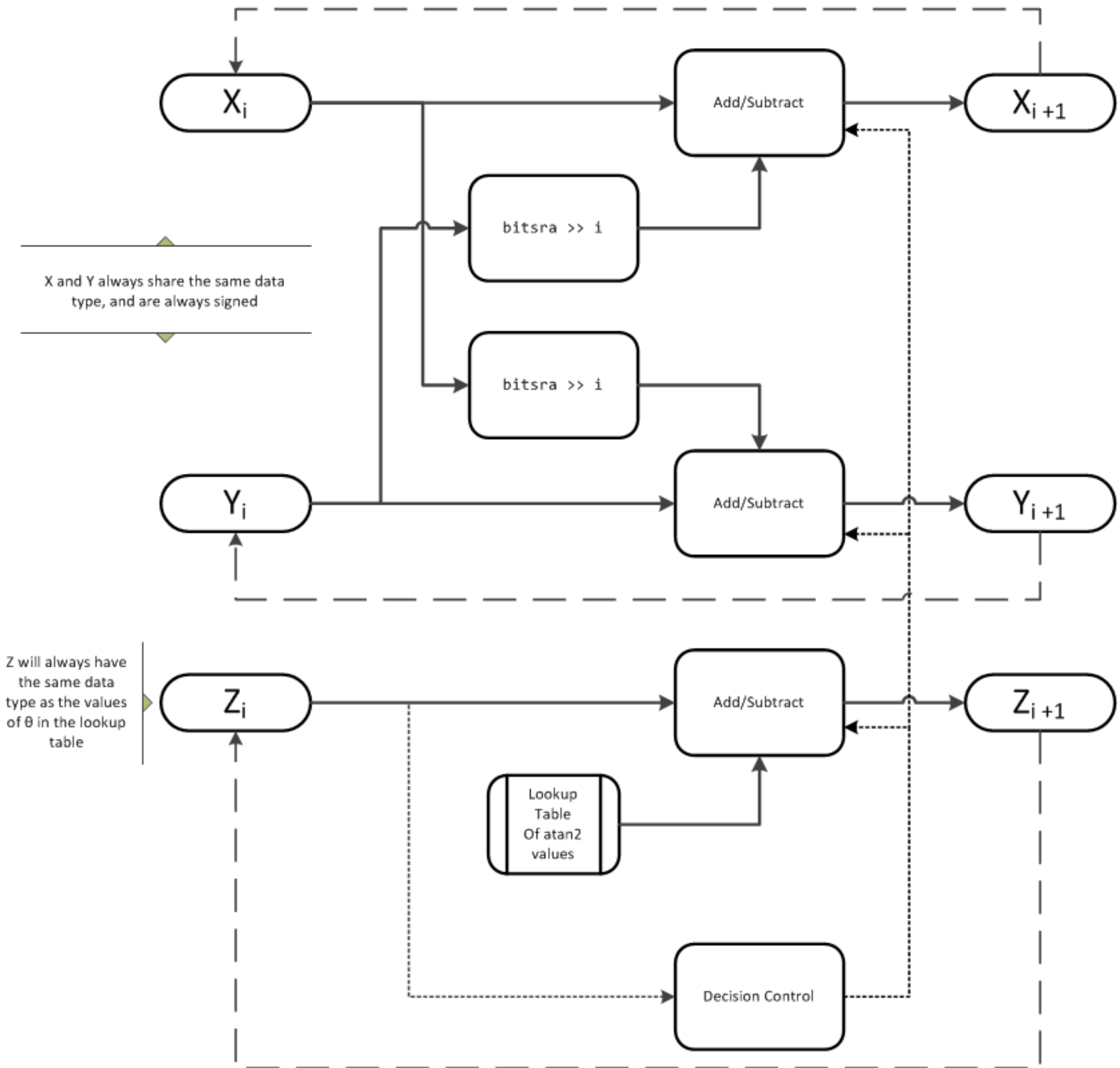
CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams




X_i
Add/Subtract
X_i +1
bitsra >> i
X and Y always share the same data type, and are always signed
bitsra >> i
Y_i
Add/Subtract
Y_i +1
Z will always have the same data type as the values of θ in the lookup table
Z_i
Add/Subtract
Z_i +1
Lookup Table Of atan2 values
Decision Control

X represents the sine, Y represents the cosine, and Z represents theta. The accuracy of the CORDIC rotation kernel depends on the choice of initial values for X, Y, and Z. This algorithm uses the following initial values:

z_0 is initialized to the θ input argument value

x_0 is initialized to $\frac{1}{A_N}$

y_0 is initialized to 0

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction—Wrap`
- `RoundingMethod—Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. “The CORDIC Trigonometric Computing Technique.” *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. “A survey of CORDIC algorithm for FPGA based computers.” *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. “A Unified Algorithm for Elementary Functions.” Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. “Calculator Function Approximation.” *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`cordiccexp` | `cordiccos` | `cordicsin`

Topics

Demo: Fixed-Point Sine and Cosine Calculation
Demo: Fixed-Point Arctangent Calculation

Introduced in R2010a

cordicsqrt

CORDIC-based approximation of square root

Syntax

```
y=cordicsqrt(u)
y=cordicsqrt(u, niters)
y=cordicsqrt( ___ , 'ScaleOutput', B)
```

Description

`y=cordicsqrt(u)` computes the square root of `u` using a CORDIC algorithm implementation.

`y=cordicsqrt(u, niters)` computes the square root of `u` by performing `niters` iterations of the CORDIC algorithm.

`y=cordicsqrt( ___ , 'ScaleOutput', B)` scales the output depending on the Boolean value of `B`.

Examples

Calculate the CORDIC Square Root

Find the square root of `fi` object `x` using a CORDIC implementation.

```
x = fi(1.6,1,12);
y = cordicsqrt(x)
```

```
y =
    1.2646

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
         WordLength: 12
     FractionLength: 10
```

Because you did not specify `niters`, the function performs the maximum number of iterations, `x.WordLength - 1`.

Compute the difference between the results of the `cordicsqrt` function and the double-precision `sqrt` function.

```
err = abs(sqrt(double(x))-double(y))
```

```
err = 1.0821e-04
```

Calculate the CORDIC Square Root With a Specified Number of Iterations

Compute the square root of x with three iterations of the CORDIC kernel.

```
x = fi(1.6,1,12);
y = cordicsqrt(x,3)
```

```
y = 
    1.2646

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 12
        FractionLength: 10
```

Compute the difference between the results of the `cordicsqrt` function and the double-precision `sqrt` function.

```
err = abs(sqrt(double(x))-double(y))
```

```
err = 1.0821e-04
```

Calculate the CORDIC Square Root Without Scaling the Output

```
x = fi(1.6,1,12);
y = cordicsqrt(x, 'ScaleOutput', 0)
```

```
y = 
    1.0479

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 12
        FractionLength: 10
```

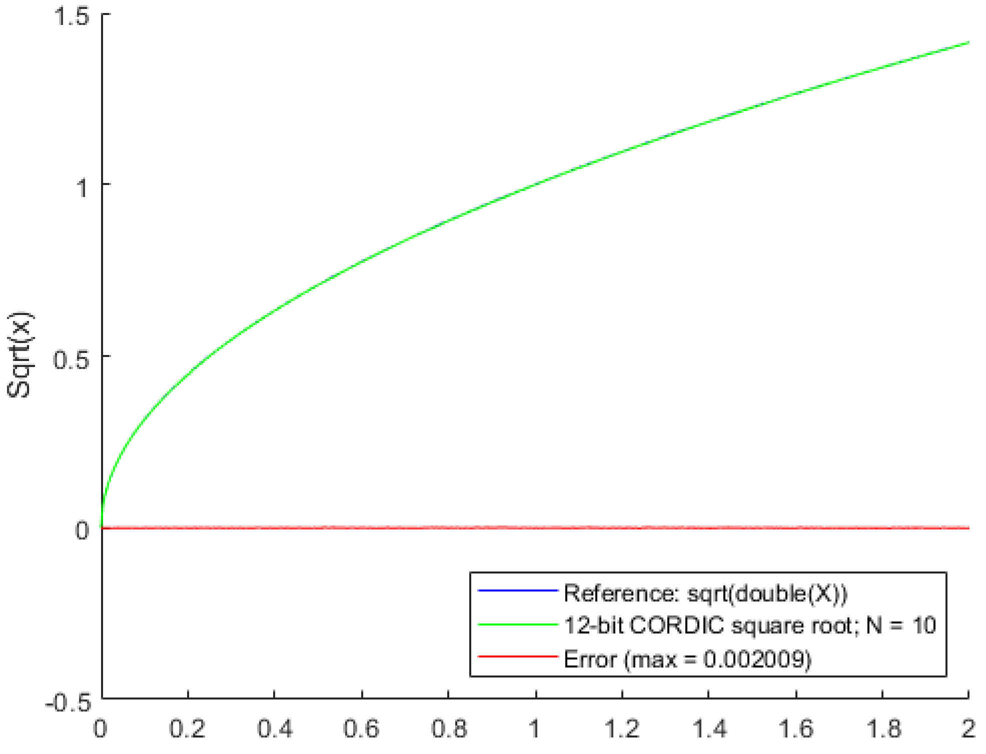
The output, `y`, was not scaled by the inverse CORDIC gain factor.

Compare Results of cordicsqrt and sqrt Functions

Compare the results produced by 10 iterations of the `cordicsqrt` algorithm to the results of the double-precision `sqrt` function.

```
% Create 500 points between [0, 2)
stepSize = 2/500;
XDbl = 0:stepSize:2;
XFxp = fi(XDbl, 1, 12);    % signed, 12-bit fixed-point
sqrtXRef = sqrt(double(XFxp));   % reference results

% Use 12-bit quantized inputs and set the number
% of iterations to 10.
% Compare the  fixed-point CORDIC results to the
% double-precision sqrt function results.

niters = 10;
cdcSqrtX  = cordicsqrt(XFxp,  niters);
errCdcRef = sqrtXRef - double(cdcSqrtX);
figure
hold on
axis([0 2 -.5 1.5])
plot(XFxp, sqrtXRef,  'b')
plot(XFxp, cdcSqrtX,  'g')
plot(XFxp, errCdcRef, 'r')
ylabel('Sqrt(x)')
gca.XTick = 0:0.25:2;
gca.XTickLabel = {'0','0.25','0.5','0.75','1','1.25','1.5','1.75','2'};
gca.YTick = -.5:.25:1.5;
gca.YTickLabel = {'-0.5','-0.25','0','0.25','0.5','0.75','1','1.25','1.5'};
ref_str = 'Reference: sqrt(double(X))';
cdc_str = sprintf('12-bit CORDIC square root; N = %d', niters);
```

```
err_str = sprintf('Error (max = %f)', max(abs(errCdcRef)));
legend(ref_str, cdc_str, err_str, 'Location', 'southeast')
```



- “Compute Square Root Using CORDIC”

Input Arguments

u — Data input array

scalar | vector | matrix | multidimensional array

Data input array, specified as a positive scalar, vector, matrix, or multidimensional array of fixed-point or built-in data types. When the input array contains values between 0.5 and

2, the algorithm is most accurate. A pre- and post-normalization process is performed on input values outside of this range. For more information on this process, see “Pre- and Post-Normalization” on page 4-350.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`niters` — Number of iterations

scalar

The number of iterations that the CORDIC algorithm performs, specified as a positive, integer-valued scalar. If you do not specify `niters`, the algorithm uses a default value. For fixed-point inputs, the default value of `niters` is `u.WordLength - 1`. For floating-point inputs, the default value of `niters` is 52 for double precision; 23 for single precision.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: `y= cordicsqrt(x,'ScaleOutput', 0)`

`ScaleOutput` — Whether to scale the output

true (default) | false

Boolean value that specifies whether to scale the output by the inverse CORDIC gain factor. If you set `ScaleOutput` to `true` or `1`, the output values are multiplied by a constant, which incurs extra computations. If you set `ScaleOutput` to `false` or `0`, the output is not scaled.

Data Types: `logical`

Output Arguments

y — Output array
scalar | vector | matrix | multidimensional array

Output array, returned as a scalar, vector, matrix, or multidimensional array.

Definitions

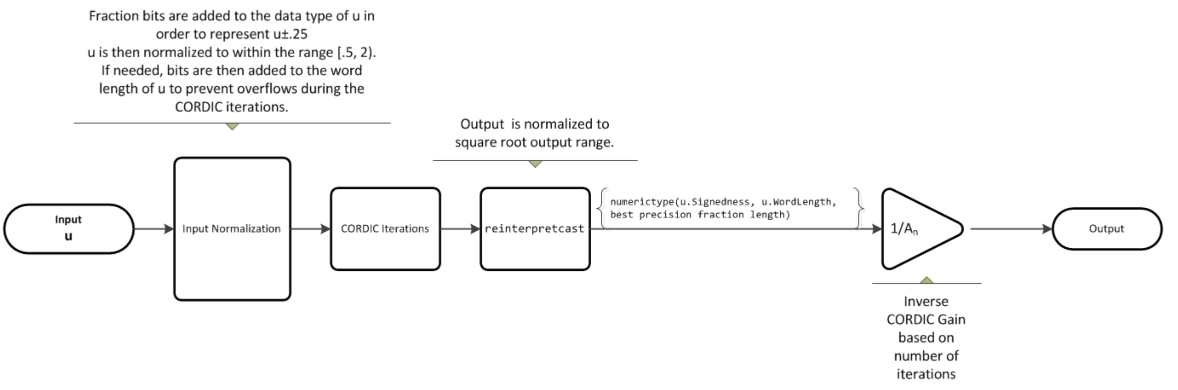
CORDIC

CORDIC is an acronym for COordinate Rotation DIgital Computer. The Givens rotation-based CORDIC algorithm is one of the most hardware-efficient algorithms available because it requires only iterative shift-add operations (see References). The CORDIC algorithm eliminates the need for explicit multipliers. Using CORDIC, you can calculate various functions, such as sine, cosine, arc sine, arc cosine, arc tangent, and vector magnitude. You can also use this algorithm for divide, square root, hyperbolic, and logarithmic functions.

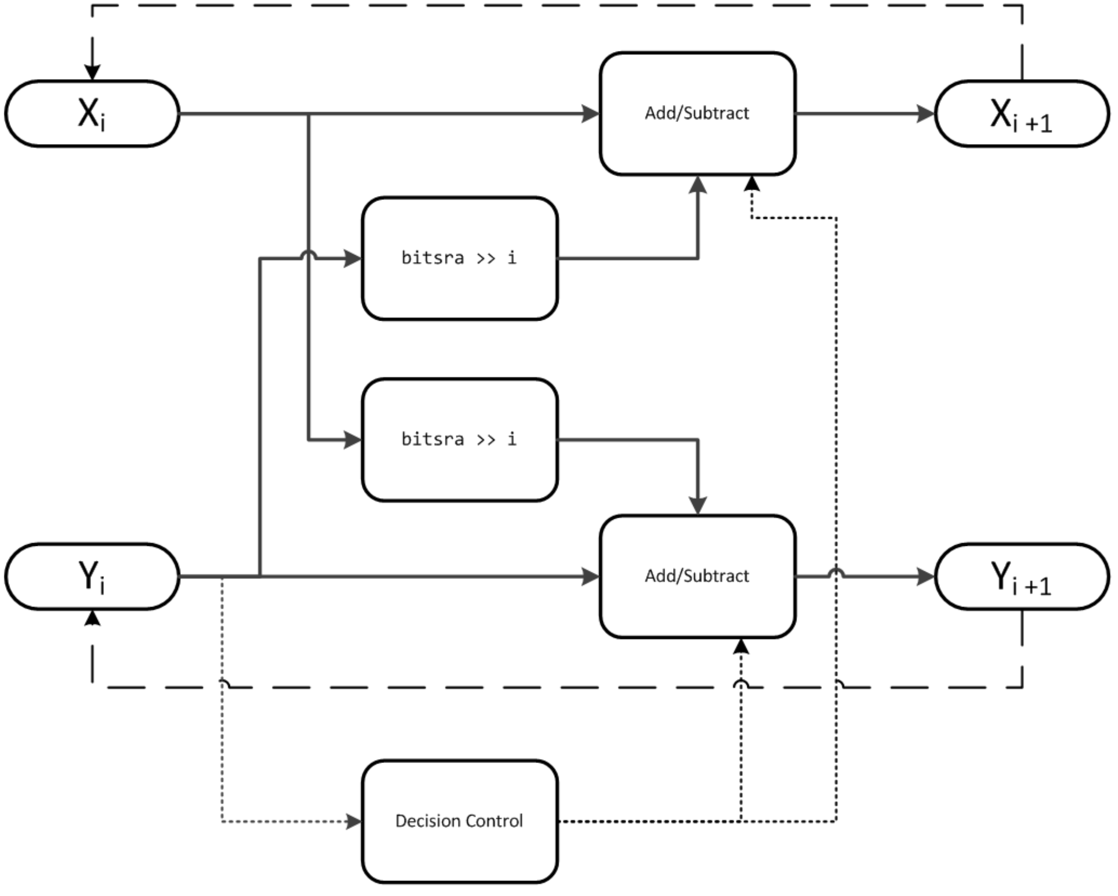
Increasing the number of CORDIC iterations can produce more accurate results, but doing so also increases the expense of the computation and adds latency.

Algorithms

Signal Flow Diagrams



For further details on the pre- and post-normalization process, see “Pre- and Post-Normalization” on page 4-350.



X is initialized to `u'+.25`, and *Y* is initialized to `u'-.25`, where `u'` is the normalized function input.

With repeated iterations of the CORDIC hyperbolic kernel, *X* approaches $A_N \sqrt{u'}$, where A_N represents the CORDIC gain. *Y* approaches `0`.

Pre- and Post-Normalization

For input values outside of the range of [0.5, 2) a pre- and post-normalization process occurs. This process performs bitshifts on the input array before passing it to the CORDIC kernel. The result is then shifted back into the correct output range during the post-normalization stage. For more details on this process see “Overcoming Algorithm Input Range Limitations” in “Compute Square Root Using CORDIC”.

fimath Propagation Rules

CORDIC functions discard any local `fimath` attached to the input.

The CORDIC functions use their own internal `fimath` when performing calculations:

- `OverflowAction—Wrap`
- `RoundingMethod—Floor`

The output has no attached `fimath`.

References

[1] Volder, JE. “The CORDIC Trigonometric Computing Technique.” *IRE Transactions on Electronic Computers*. Vol. EC-8, September 1959, pp. 330–334.

[2] Andraka, R. “A survey of CORDIC algorithm for FPGA based computers.” *Proceedings of the 1998 ACM/SIGDA sixth international symposium on Field programmable gate arrays*. Feb. 22–24, 1998, pp. 191–200.

[3] Walther, J.S. “A Unified Algorithm for Elementary Functions.” Hewlett-Packard Company, Palo Alto. Spring Joint Computer Conference, 1971, pp. 379–386. (from the collection of the Computer History Museum). www.computer.org/csdl/proceedings/afips/1971/5077/00/50770379.pdf

[4] Schelin, Charles W. “Calculator Function Approximation.” *The American Mathematical Monthly*. Vol. 90, No. 5, May 1983, pp. 317–325.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-size signals are not supported.
- The number of iterations the CORDIC algorithm performs, `niters`, must be a constant.

See Also

`sqrt`

Topics

"Compute Square Root Using CORDIC"

Introduced in R2014a

cordictanh

CORDIC-based hyperbolic tangent

Syntax

```
T = cordictanh(theta)
T = cordictanh(theta, niters)
```

Description

`T = cordictanh(theta)` returns the hyperbolic tangent of `theta`.

`T = cordictanh(theta, niters)` returns the hyperbolic tangent of theta by performing `niters` iterations of the CORDIC algorithm.

Examples

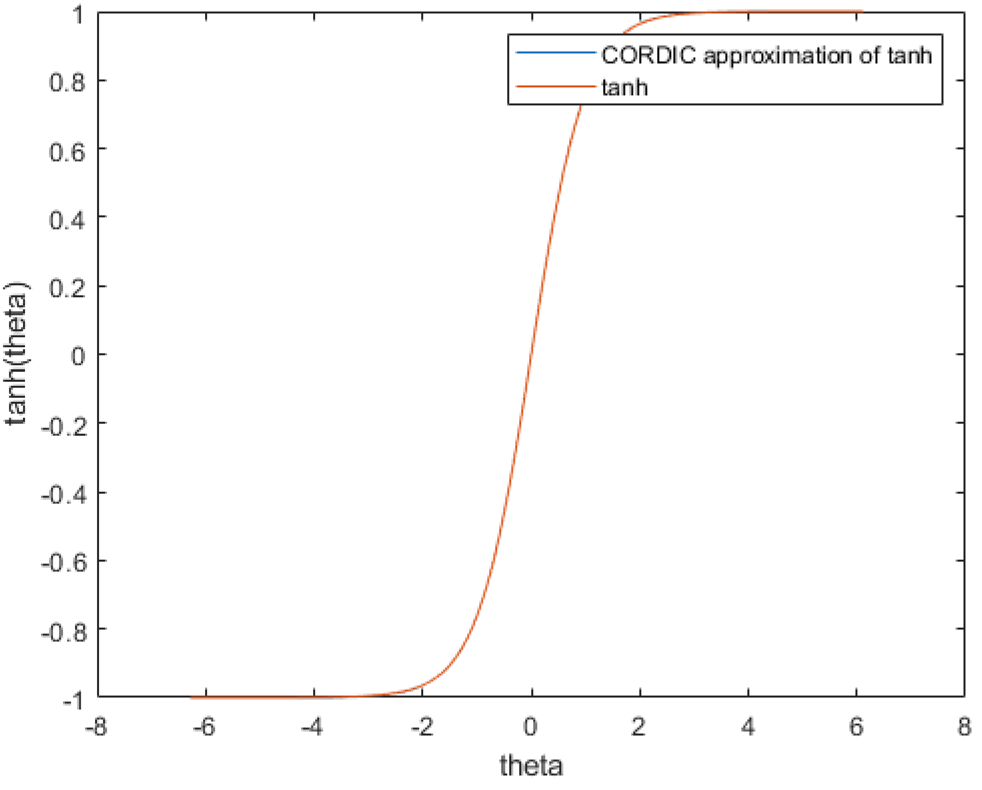
Compute CORDIC Hyperbolic Tangent

Find the hyperbolic tangent of `fi` object `theta` using a CORDIC implementation with the default number of iterations.

```
theta = fi(-2*pi:.1:2*pi-.1);
T_cordic = cordictanh(theta);
```

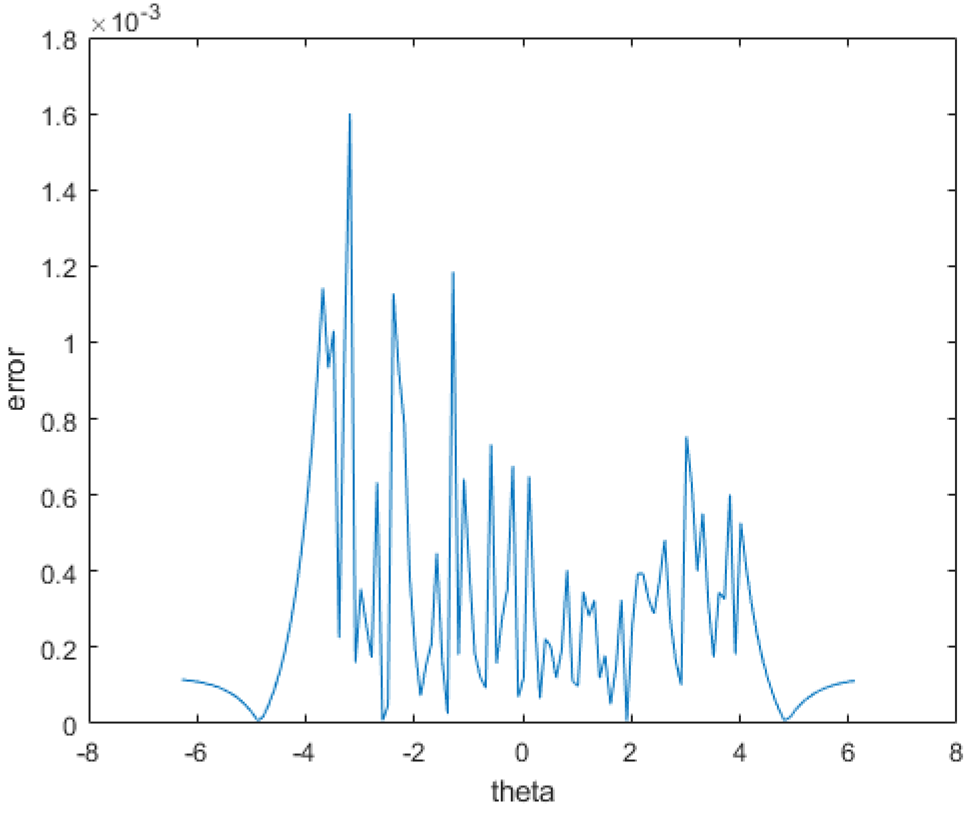
Plot the hyperbolic tangent of `theta` using the `tanh` function and its CORDIC approximation.

```
T = tanh(double(theta));
plot(theta, T_cordic);
hold on;
plot(theta, T);
legend('CORDIC approximation of tanh', 'tanh');
xlabel('theta');
ylabel('tanh(theta)');
```



Compute the difference between the results of the `cordictanh` function and the `tanh` function.

```
figure;
err = abs(T - double(T_cordic));
plot(theta, err);
xlabel('theta');
ylabel('error');
```

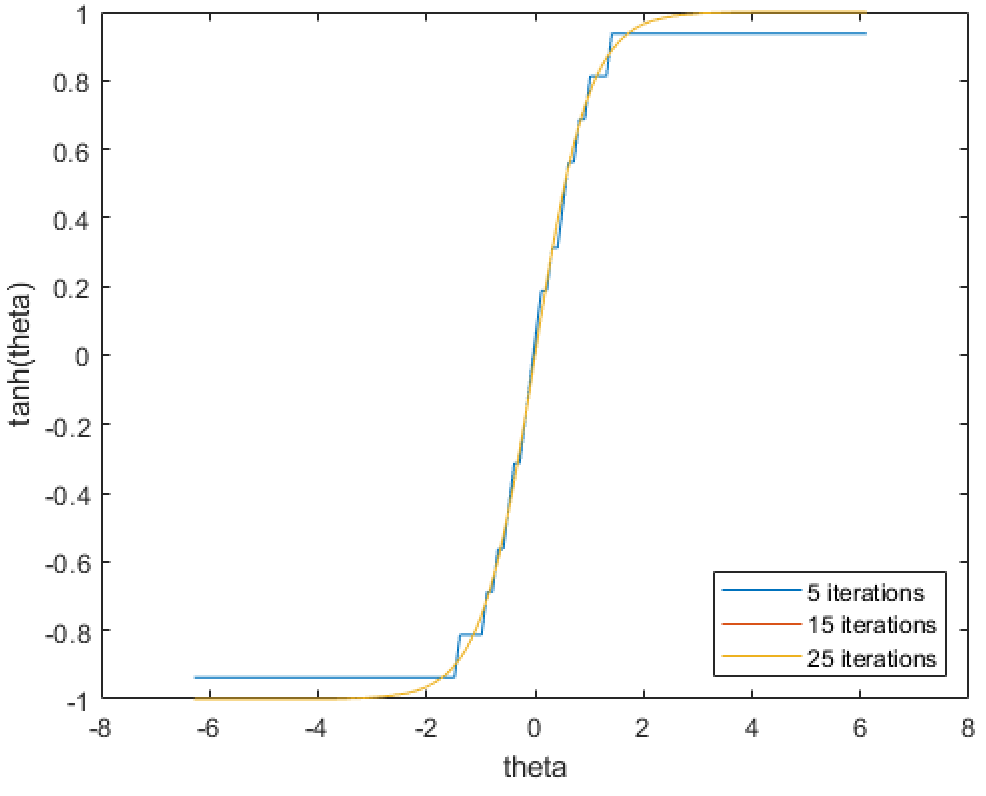


Compute CORDIC Hyperbolic Tangent with Specified Number of Iterations

Find the hyperbolic tangent of `fi` object `theta` using a CORDIC implementation and specify the number of iterations the CORDIC kernel should perform. Plot the CORDIC approximation of the hyperbolic tangent of theta with varying numbers of iterations.

```
theta = fi(-2*pi:.1:2*pi-.1);
for niters = 5:10:25
T_cordic = cordictanh(theta, niters);
plot(theta, T_cordic);
hold on;
```

```
end
xlabel('theta');
ylabel('tanh(theta)');
legend('5 iterations', '15 iterations', '25 iterations','Location','southeast');
```



Input Arguments

theta — angle values

scalar | vector | matrix | n-dimensional array

Angle values in radians specified as a scalar, vector, matrix, or N-dimensional array.

Data Types: single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64 | fi

niters — Number of iterations
scalar

The number of iterations that the CORDIC algorithm performs, specified as a positive, integer-valued scalar. If you do not specify niters, the algorithm uses a default value. For fixed-point inputs, the default value of niters is one less than the word length of the input array, theta. For double-precision inputs, the default value of niters is 52. For single-precision inputs, the default value is 23.

Data Types: single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64 | fi

Output Arguments

T — Output array
scalar | vector | matrix | n-dimensional array

T is the CORDIC-based approximation of the hyperbolic tangent of theta. When the input to the function is floating point, the output data type is the same as the input data type. When the input is fixed point, the output has the same word length as the input, and a fraction length equal to the WordLength – 2.

See Also

cordicatan2 | cordiccos | cordicsin | tanh

Introduced in R2017b

cos

Cosine of `fi` object

Syntax

`y = cos(theta)`

Description

`y = cos(theta)` returns the cosine on page 4-358 of `fi` input `theta` using a table-lookup algorithm.

Input Arguments

`theta`

`theta` can be a real-valued, signed or unsigned scalar, vector, matrix, or `N`-dimensional array containing the fixed-point angle values in radians. Valid data types of `theta` are:

- `fi` single
- `fi` double
- `fi` fixed-point with binary point scaling
- `fi` scaled double with binary point scaling

Output Arguments

`y`

`y` is the cosine of `theta`. `y` is a signed, fixed-point number in the range [-1,1]. It has a 16-bit word length and 15-bit fraction length (`numerictype(1,16,15)`).

Examples

Calculate the cosine of fixed-point input values.

```
theta = fi([0,pi/4,pi/3,pi/2,(2*pi)/3,(3*pi)/4,pi])

theta =

        0  0.7854  1.0472  1.5708  2.0944  2.3562  3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

y = cos(theta)

y =

    1.0000  0.7072  0.4999  0.0001 -0.4999  -0.7070  -1.0000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15
```

Definitions

Cosine

The cosine of angle Θ is defined as

$$\cos(\theta) = \frac{e^{i\theta} + e^{-i\theta}}{2}$$

Algorithms

The `cos` function computes the cosine of fixed-point input using an 8-bit lookup table as follows:

1. Perform a modulo 2π, so the input is in the range [0,2π) radians.
2. Cast the input to a 16-bit stored integer value, using the 16 most-significant bits.
3. Compute the table index, based on the 16-bit stored integer value, normalized to the full `uint16` range.
4. Use the 8 most-significant bits to obtain the first value from the table.
5. Use the next-greater table value as the second value.
6. Use the 8 least-significant bits to interpolate between the first and second values, using nearest-neighbor linear interpolation.

fimath Propagation Rules

The `cos` function ignores and discards any `fimath` attached to the input, `theta`. The output, `y`, is always associated with the default `fimath`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`angle` | `atan2` | `cordiccos` | `cordicsin` | `cos` | `sin`

Topics

Demo: Fixed-Point Sine and Cosine Calculation

Introduced in R2012a

ctranspose

Complex conjugate transpose of fi object

Syntax

```
ctranspose(a)
```

Description

This function accepts fi objects as inputs.

ctranspose(a) returns the complex conjugate transpose of fi object a. It is also called for the syntax a'.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

transpose

Introduced before R2006a

dec

Unsigned decimal representation of stored integer of `fi` object

Syntax

`dec(a)`

Description

`dec(a)` returns the stored integer of `fi` object `a` in unsigned decimal format as a character vector. `dec(a)` is equivalent to `a.dec`.

Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or, equivalently as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

The stored integer is the raw binary number, in which the binary point is assumed to be at the far right of the word.

Examples

The code

```
a = fi([-1 1],1,8,7);
y = dec(a)
z = a.dec
```

returns

```
y =
```

```
        128   127

z =

        128   127
```

See Also

`bin` | `hex` | `oct` | `sdec` | `storedInteger`

Introduced before R2006a

denormalmax

Largest denormalized quantized number for `quantizer` object

Syntax

```
x = denormalmax(q)
```

Description

`x = denormalmax(q)` is the largest positive denormalized quantized number where `q` is a `quantizer` object. Anything larger than `x` is a normalized number. Denormalized numbers apply only to floating-point format. When `q` represents fixed-point numbers, this function returns `eps(q)`.

Examples

```
q = quantizer('float',[6 3]);
x = denormalmax(q)

x =

    0.1875
```

Algorithms

When `q` is a floating-point `quantizer` object,

```
denormalmax(q) = realmin(q) - denormalmin(q)
```

When `q` is a fixed-point `quantizer` object,

```
denormalmax(q) = eps(q)
```

See Also

`denormalmin` | `eps` | `quantizer`

Introduced before R2006a

denormalmin

Smallest denormalized quantized number for `quantizer` object

Syntax

```
x = denormalmin(q)
```

Description

`x = denormalmin(q)` is the smallest positive denormalized quantized number where `q` is a `quantizer` object. Anything smaller than `x` underflows to zero with respect to the `quantizer` object `q`. Denormalized numbers apply only to floating-point format. When `q` represents a fixed-point number, `denormalmin` returns `eps(q)`.

Examples

```
q = quantizer('float',[6 3]);
x = denormalmin(q)

x =

    0.0625
```

Algorithms

When `q` is a floating-point `quantizer` object,

$$x = 2^{E_{min} - f}$$

where E_{min} is equal to `exponentmin(q)`.

When `q` is a fixed-point `quantizer` object,

$$x = \text{eps}(q) = 2^{-f}$$

where f is equal to `fractionlength(q)`.

See Also

`denormalmax` | `eps` | `quantizer`

Introduced before R2006a

diag

Diagonal matrices or diagonals of matrix

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `diag` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

If supplied, the index, `k`, must be a real and scalar integer value that is not a `fi` object.

Introduced before R2006a

disp

Display object

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `disp` reference page for more information.

Introduced before R2006a

divide

Divide two objects

Syntax

```
c = divide(T,a,b)
```

Description

c = divide(T,a,b) performs division on the elements of a by the elements of b. The result c has the numerictype object T.

If a and b are both fi objects, c has the same fimath object as a. If c has a fi Fixed data type, and any one of the inputs have fi floating point data types, then the fi floating point is converted into a fixed-point value. Intermediate quantities are calculated using the fimath object of a. See “Data Type Propagation Rules” on page 4-369.

a and b must have the same dimensions unless one is a scalar. If either a or b is scalar, then c has the dimensions of the nonscalar object.

If either a or b is a fi object, and the other is a MATLAB built-in numeric type, then the built-in object is cast to the word length of the fi object, preserving best-precision fraction length. Intermediate quantities are calculated using the fimath object of the input fi object. See “Data Type Propagation Rules” on page 4-369.

If a and b are both MATLAB built-in doubles, then c is the floating-point quotient a./b, and numerictype T is ignored.

Note The divide function is not currently supported for [Slope Bias] signals.

Data Type Propagation Rules

For syntaxes for which Fixed-Point Designer software uses the numerictype object T, the divide function follows the data type propagation rules listed in the following table.

In general, these rules can be summarized as "floating-point data types are propagated." This allows you to write code that can be used with both fixed-point and floating-point inputs.

Data Type of Input fi Objects a and b		**Data Type of numerictype object T**	**Data Type of Output c**
Built-in `double`	Built-in `double`	Any	Built-in `double`
`fi Fixed`	`fi Fixed`	`fi Fixed`	Data type of `numerictype` object `T`
`fi Fixed`	`fi Fixed`	`fi double`	`fi double`
`fi Fixed`	`fi Fixed`	`fi single`	`fi single`
`fi Fixed`	`fi Fixed`	`fi ScaledDouble`	`fi ScaledDouble` with properties of `numerictype` object `T`
`fi double`	`fi double`	`fi Fixed`	`fi double`
`fi double`	`fi double`	`fi double`	`fi double`
`fi double`	`fi double`	`fi single`	`fi single`
`fi double`	`fi double`	`fi ScaledDouble`	`fi double`
`fi single`	`fi single`	`fi Fixed`	`fi single`
`fi single`	`fi single`	`fi double`	`fi double`
`fi single`	`fi single`	`fi single`	`fi single`
`fi single`	`fi single`	`fi ScaledDouble`	`fi single`
`fi ScaledDouble`	`fi ScaledDouble`	`fi Fixed`	If either input `a` or `b` is of type `fi ScaledDouble`, then output `c` will be of type `fi ScaledDouble` with properties of `numerictype` object `T`

Data Type of Input fi Objects a and b		Data Type of numerictype object T	Data Type of Output c
fi ScaledDouble	fi ScaledDouble	fi double	fi double
fi ScaledDouble	fi ScaledDouble	fi single	fi single
fi ScaledDouble	fi ScaledDouble	fi ScaledDouble	If either input a or b is of type fi ScaledDouble, then output c will be of type fi ScaledDouble with properties of numerictype object T

Examples

This example highlights the precision of the `fi divide` function.

First, create an unsigned `fi` object with an 80-bit word length and 2^-83 scaling, which puts the leading 1 of the representation into the most significant bit. Initialize the object with double-precision floating-point value 0.1, and examine the binary representation:

```
P = ...
fipref('NumberDisplay','bin',...
       'NumericTypeDisplay','short',...
       'FimathDisplay','none');
a = fi(0.1, false, 80, 83)

a =

11001100110011001100110011001100110011001100110011010000
000000000000000000000000
      u80,83
```

Notice that the infinite repeating representation is truncated after 52 bits, because the mantissa of an IEEE standard double-precision floating-point number has 52 bits.

Contrast the above to calculating 1/10 in fixed-point arithmetic with the quotient set to the same numeric type as before:

```
T = numerictype('Signed',false,'WordLength',80,...
                          'FractionLength',83);
a = fi(1);
b = fi(10);
c = divide(T,a,b);
c.bin

ans =

11001100110011001100110011001100110011001100110011001100
110011001100110011001100
```

Notice that when you use the `divide` function, the quotient is calculated to the full 80 bits, regardless of the precision of `a` and `b`. Thus, the `fi` object `c` represents 1/10 more precisely than IEEE standard double-precision floating-point number can.

With 1000 bits of precision,

```
T = numerictype('Signed',false,'WordLength',1000,...
                          'FractionLength',1003);
a = fi(1);
b = fi(10);
c = divide(T,a,b);c.bin

ans =

11001100110011001100110011001100110011001100110011001100
11001100110011001100110011001100110011001100110011001100
11001100110011001100110011001100110011001100110011001100
11001100110011001100110011001100110011001100110011001100
11001100110011001100110011001100110011001100110011001100
11001100110011001100110011001100110011001100110011001100
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11001100110011001100110011001100110011001100110011001100
11001100110011001100110011001100110011001100110011001100
110011001100110011001100110011001100110011001100
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Any non-`fi` input must be constant; that is, its value must be known at compile time so that it can be cast to a `fi` object.
- Complex and imaginary divisors are not supported.
- Code generation does not support the syntax `T.divide(a,b)`.

See Also

`add` | `fi` | `fimath` | `mpy` | `mrdivide` | `numerictype` | `rdivide` | `sub` | `sum`

Introduced before R2006a

double

Double-precision floating-point real-world value of `fi` object

Syntax

`double(a)`

Description

`double(a)` returns the real-world value of a `fi` object in double-precision floating point. `double(a)` is equivalent to `a.double`.

Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or, equivalently as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

Examples

The code

```
a = fi([-1 1],1,8,7);
y = double(a)
z = a.double
```

returns

```
y =

           -1      0.9922
z =
```

```
         -1       0.9922
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- For the automated workflow, do not use explicit double or single casts in your MATLAB algorithm to insulate functions that do not support fixed-point data types. The automated conversion tool does not support these casts. Instead of using casts, supply a replacement function. For more information, see “Function Replacements”.

See Also

`single`

Introduced before R2006a

embedded.fi class

Fixed-point numeric object

Description

Use the `fi` function to create an `embedded.fi` object.

See Also

`embedded.fimath` | `embedded.numerictype` | `fi`

Topics

Class Attributes (MATLAB)
Property Attributes (MATLAB)

embedded.fimath class

fimath object

Description

Use the `fimath` function to create an `embedded.fimath` object.

See Also

`embedded.fi` | `embedded.numerictype` | `fimath`

Topics

Class Attributes (MATLAB)
Property Attributes (MATLAB)

embedded.numerictype class

numerictype object

Description

Use the `numerictype` function to create an `embedded.numerictype` object.

See Also

`embedded.fi` | `embedded.fimath` | `numerictype`

Topics

Class Attributes (MATLAB)
Property Attributes (MATLAB)

end

Last index of array

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `end` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

eps

Quantized relative accuracy for `fi` or `quantizer` objects

Syntax

`eps(obj)`

Description

`eps(obj)` returns the value of the least significant bit of the value of the `fi` object or `quantizer` object `obj`. The result of this function is equivalent to that given by the Fixed-Point Designer function `lsb`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Code generation supports scalar fixed-point signals only.
- Code generation supports scalar, vector, and matrix, `fi` single and `fi` double signals.

See Also

`intmax` | `intmin` | `lowerbound` | `lsb` | `range` | `realmax` | `realmin` | `upperbound`

Introduced before R2006a

eq

Determine whether real-world values of two `fi` objects are equal

Syntax

```
c = eq(a,b)
a == b
```

Description

`c = eq(a,b)` is called for the syntax `a == b` when `a` or `b` is a `fi` object. `a` and `b` must have the same dimensions unless one is a scalar. A scalar can be compared with another object of any size.

`a == b` does an element-by-element comparison between `a` and `b` and returns a matrix of the same size with elements set to `1` where the relation is true, and `0` where the relation is false.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the `fi` object, with best-precision scaling.

Examples

Compare Two fi Objects

Use the `isequal` function to determine if two `fi` objects have the same real-world value.

```
a = fi(pi);
b = fi(pi, 1, 32);
a == b
```

```
ans = logical
   0
```

Input `a` has a 16-bit word length, while input `b` has a 32-bit word length. The `eq` function returns `0` because the two `fi` objects do not have the same real-world value.

Compare a Double to a fi Object

When comparing a double to a `fi` object, the double is cast to the same word length and signedness of the `fi` object.

```
a = fi(pi);
b = pi;
a == b
```

```
ans = logical
   1
```

The `eq` function casts `b` to the same word length as `a`, and returns `1`. This behavior allows relational operations to work between `fi` objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals with different biases are not supported.

See Also

`ge` | `gt` | `isequal` | `le` | `lt` | `ne`

Introduced before R2006a

errmean

Mean of quantization error

Syntax

```
m = errmean(q)
```

Description

`m = errmean(q)` returns the mean of a uniformly distributed random quantization error that arises from quantizing a signal by `quantizer` object `q`.

Note The results are not exact when the signal precision is close to the precision of the `quantizer`.

Examples

Find `m`, the mean of the quantization error for `quantizer` `q`:

```
q = quantizer;
m = errmean(q)

m =

   -1.525878906250000e-005
```

Now compare `m` to `m_est`, the sample mean from a Monte Carlo experiment:

```
r = realmax(q);
u = 2*r*rand(1000,1)-r;  % Original signal
y = quantize(q,u);       % Quantized signal
e = y - u;               % Error
m_est = mean(e)          % Estimate of the error mean
```

```
m_est =

   -1.519507450175317e-005
```

See Also

errpdf | errvar | quantize

Introduced in R2008a

errorbar

Plot error bars along curve

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `errorbar` reference page for more information.

Introduced before R2006a

errpdf

Probability density function of quantization error

Syntax

```
[f,x] = errpdf(q)
f = errpdf(q,x)
```

Description

`[f,x] = errpdf(q)` returns the probability density function `f` evaluated at the values in `x`. The vector `x` contains the uniformly distributed random quantization errors that arise from quantizing a signal by `quantizer` object `q`.

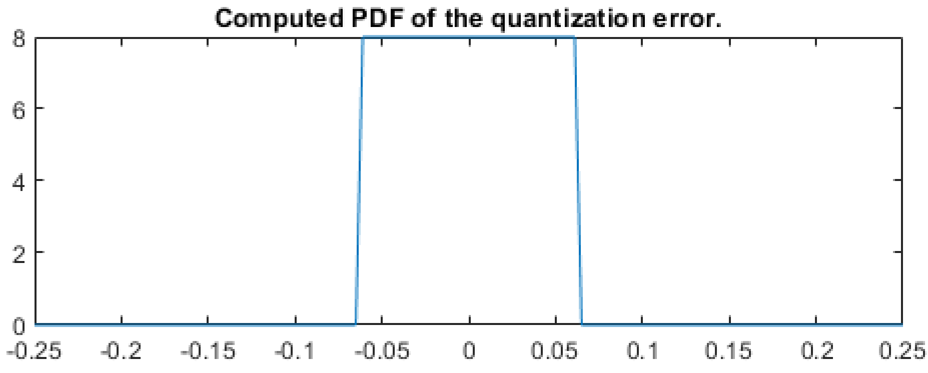
`f = errpdf(q,x)` returns the probability density function `f` evaluated at the values in vector `x`.

Note The results are not exact when the signal precision is close to the precision of the `quantizer`.

Examples

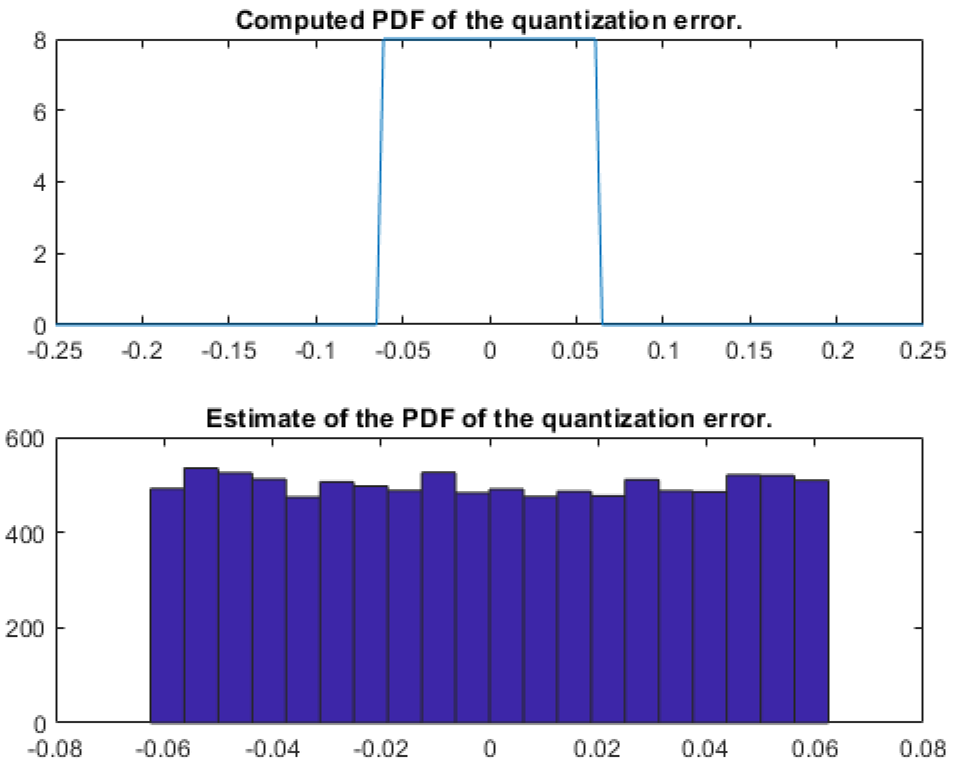
Compute the PDF of the quantization error

```
q = quantizer('nearest',[4 3]);
[f,x] = errpdf(q);
subplot(211)
plot(x,f)
title('Computed PDF of the quantization error.')
```



The output plot shows the probability density function of the quantization error. Compare this result to a plot of the sample probability density function from a Monte Carlo experiment:

```
r = realmax(q);
     u = 2*r*rand(10000,1)-r;  % Original signal
     y = quantize(q,u);        % Quantized signal
     e = y - u;                % Error
     subplot(212)
     hist(e,20)
     gca.xlim = [min(x) max(x)];
     title('Estimate of the PDF of the quantization error.')
```



See Also

`errmean` | `errvar` | `quantize`

Introduced in R2008a

errvar

Variance of quantization error

Syntax

```
v = errvar(q)
```

Description

`v = errvar(q)` returns the variance of a uniformly distributed random quantization error that arises from quantizing a signal by `quantizer` object `q`.

Note The results are not exact when the signal precision is close to the precision of the `quantizer`.

Examples

Find `v`, the variance of the quantization error for `quantizer` object `q`:

```
q = quantizer;
v = errvar(q)

v =

    7.761021455128987e-011
```

Now compare `v` to `v_est`, the sample variance from a Monte Carlo experiment:

```
r = realmax(q);
      u = 2*r*rand(1000,1)-r;  % Original signal
      y = quantize(q,u);     % Quantized signal
      e = y - u;           % Error
      v_est = var(e)     % Estimate of the error variance

v_est =
```

```
    7.520208858166330e-011
```

See Also

`errmean` | `errpdf` | `quantize`

Introduced in R2008a

etreeplot

Plot elimination tree

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `etreeplot` reference page for more information.

Introduced before R2006a

exponentbias

Exponent bias for `quantizer` object

Syntax

`b = exponentbias(q)`

Description

`b = exponentbias(q)` returns the exponent bias of the `quantizer` object `q`. For fixed-point `quantizer` objects, `exponentbias(q)` returns 0.

Examples

```
q = quantizer('double');
b = exponentbias(q)

b =

        1023
```

Algorithms

For floating-point `quantizer` objects,

$$b = 2^{e-1} - 1$$

where `e = eps(q)`, and `exponentbias` is the same as the exponent maximum.

For fixed-point `quantizer` objects, `b = 0` by definition.

See Also

`eps` | `exponentlength` | `exponentmax` | `exponentmin`

Introduced before R2006a

exponentlength

Exponent length of `quantizer` object

Syntax

```
e = exponentlength(q)
```

Description

`e = exponentlength(q)` returns the exponent length of `quantizer` object `q`. When `q` is a fixed-point `quantizer` object, `exponentlength(q)` returns `0`. This is useful because exponent length is valid whether the `quantizer` object mode is floating point or fixed point.

Examples

```
q = quantizer('double');
e = exponentlength(q)

e =

    11
```

Algorithms

The exponent length is part of the format of a floating-point `quantizer` object `[w e]`. For fixed-point `quantizer` objects, $e = 0$ by definition.

See Also

`eps` | `exponentbias` | `exponentmax` | `exponentmin`

Introduced before R2006a

exponentmax

Maximum exponent for `quantizer` object

Syntax

```
exponentmax(q)
```

Description

`exponentmax(q)` returns the maximum exponent for `quantizer` object `q`. When `q` is a fixed-point `quantizer` object, it returns `0`.

Examples

```
q = quantizer('double');
emax = exponentmax(q)

emax =

        1023
```

Algorithms

For floating-point `quantizer` objects,

$$E_{max} = 2^{e-1} - 1$$

For fixed-point `quantizer` objects, $E_{max} = 0$ by definition.

See Also

`eps` | `exponentbias` | `exponentlength` | `exponentmin`

Introduced before R2006a

exponentmin

Minimum exponent for `quantizer` object

Syntax

```
emin = exponentmin(q)
```

Description

`emin = exponentmin(q)` returns the minimum exponent for `quantizer` object `q`. If `q` is a fixed-point `quantizer` object, `exponentmin` returns 0.

Examples

```
q = quantizer('double');
emin = exponentmin(q)

emin =

      -1022
```

Algorithms

For floating-point `quantizer` objects,

$$E_{min} = -2^{e-1} + 2$$

For fixed-point `quantizer` objects, $E_{min} = 0$.

See Also

`eps` | `exponentbias` | `exponentlength` | `exponentmax`

Introduced before R2006a

eye

Create identity matrix with fixed-point properties

Syntax

```
I = eye('like',p)
I = eye(n,'like',p)
I = eye(n,m,'like',p)
I = eye(sz,'like',p)
```

Description

`I = eye('like',p)` returns the scalar 1 with the same fixed-point properties and complexity (real or complex) as the prototype argument, `p`. The output, `I`, contains the same `numerictype` and `fimath` properties as `p`.

`I = eye(n,'like',p)` returns an `n`-by-`n` identity matrix like `p`, with ones on the main diagonal and zeros elsewhere.

`I = eye(n,m,'like',p)` returns an `n`-by-`m` identity matrix like `p`.

`I = eye(sz,'like',p)` returns an array like `p`, where the size vector, `sz`, defines `size(I)`.

Examples

Create Identity Matrix with Fixed-Point Properties

Create a prototype `fi` object, `p`.

```
p = fi([],1,16,14);
```

Create a 3-by-4 identity matrix with the same fixed-point properties as `p`.

```
I = eye(3,4,'like',p)
```

```
I =
     1     0     0     0
     0     1     0     0
     0     0     1     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 14
```

Create Identity Matrix with Attached fimath

Create a signed `fi` object with word length of 16, fraction length of 15 and `OverflowAction` set to `Wrap`.

```
format long
p = fi([],1,16,15,'OverflowAction','Wrap');
```

Create a 2-by-2 identity matrix with the same `numerictype` properties as `p`.

```
X = eye(2,'like',p)
```

```
X =
   0.999969482421875                   0
                   0   0.999969482421875

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

1 cannot be represented by the data type of `p`, so the value saturates. The output `fi` object `X` has the same `numerictype` and `fimath` properties as `p`.

- “Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros”

Input Arguments

n — Size of first dimension of I
integer value

Size of first dimension of I, specified as an integer value.

- If n is the only integer input argument, then I is a square n-by-n identity matrix.
- If n is 0, then I is an empty matrix.
- If n is negative, then it is treated as 0.

Data Types: single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

m — Size of second dimension of I
integer value

Size of second dimension of I, specified as an integer value.

- If m is 0, then I is an empty matrix.
- If m is negative, then it is treated as 0.

Data Types: single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

sz — Size of I
row vector of no more than two integer values

Size of I, specified as a row vector of no more than two integer values.

- If an element of sz is 0, then I is an empty matrix.
- If an element of sz is negative, then the element is treated as 0.

Data Types: single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

p — Prototype
fi object | numeric variable

Prototype, specified as a fi object or numeric variable.

If the value 1 overflows the numeric type of `p`, the output saturates regardless of the specified `OverflowAction` property of the attached `fimath`. All subsequent operations performed on the output obey the rules of the attached `fimath`.

Data Types: `fi` | `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Tips

Using the `b = cast(a,'like',p)` syntax to specify data types separately from algorithm code allows you to:

- Reuse your algorithm code with different data types.
- Keep your algorithm uncluttered with data type specifications and switch statements for different data types.
- Improve readability of your algorithm code.
- Switch between fixed-point and floating-point data types to compare baselines.
- Switch between variations of fixed-point settings without changing the algorithm code.

See Also

`ones` | `zeros`

Topics

"Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros"
"Manual Fixed-Point Conversion Best Practices"

Introduced in R2015a

ezcontour

Easy-to-use contour plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezcontour` reference page for more information.

Introduced before R2006a

ezcontourf

Easy-to-use filled contour plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezcontourf` reference page for more information.

Introduced before R2006a

ezmesh

Easy-to-use 3-D mesh plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezmesh` reference page for more information.

Introduced before R2006a

ezplot

Easy-to-use function plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezplot` reference page for more information.

Introduced before R2006a

ezplot3

Easy-to-use 3-D parametric curve plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezplot3` reference page for more information.

Introduced before R2006a

ezpolar

Easy-to-use polar coordinate plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezpolar` reference page for more information.

Introduced before R2006a

ezsurf

Easy-to-use 3-D colored surface plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezsurf` reference page for more information.

Introduced before R2006a

ezsurfc

Easy-to-use combination surface/contour plotter

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ezsurfc` reference page for more information.

Introduced before R2006a

feather

Plot velocity vectors

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `feather` reference page for more information.

Introduced before R2006a

fi

Construct fixed-point numeric object

Syntax

```
a = fi
a = fi(v)
a = fi(v,s)
a = fi(v,s,w)
a = fi(v,s,w,f)
a = fi(v,s,w,slope,bias)
a = fi(v,s,w,slopeadjustmentfactor,fixedexponent,bias)
a = fi(v,T)
a = fi(v,F)
b = fi(a,F)
a = fi(v,T,F)
a = fi(v,s,F)
a = fi(v,s,w,F)
a = fi(v,s,w,f,F)
a = fi(v,s,w,slope,bias,F)
a = fi(v,s,w,slopeadjustmentfactor,fixedexponent,bias,F)
a = fi(...'PropertyName',PropertyValue...)
a = fi('PropertyName',PropertyValue...)
```

Description

You can use the `fi` constructor function in the following ways:

- `a = fi` is the default constructor and returns a `fi` object with no value, 16-bit word length, and 15-bit fraction length.
- `a = fi(v)` returns a signed fixed-point object with value `v`, 16-bit word length, and best-precision fraction length when `v` is a double. When `v` is not a double, the `fi` constructor preserves the `numerictype` of `v`, see “Create a fi Object From a Non-Double Value” on page 4-419.

- `a = fi(v,s)` returns a fixed-point object with value `v`, `Signed` property value `s`, 16-bit word length, and best-precision fraction length. `s` can be `0` (false) for unsigned or `1` (true) for signed.
- `a = fi(v,s,w)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, and best-precision fraction length.
- `a = fi(v,s,w,f)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, and fraction length `f`. Fraction length can be greater than word length or negative, see "Create a fi Object With Fraction Length Greater Than Word Length" on page 4-421 and "Create a fi Object With Negative Fraction Length" on page 4-422.
- `a = fi(v,s,w,slope,bias)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, `slope`, and `bias`.
- `a = fi(v,s,w,slopeadjustmentfactor,fixedexponent,bias)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, `slopeadjustmentfactor`, `fixedexponent`, and `bias`.
- `a = fi(v,T)` returns a fixed-point object with value `v` and `embedded.numerictype` `T`. Refer to "numerictype Object Construction" for more information on `numerictype` objects.
- `a = fi(v,F)` returns a fixed-point object with value `v`, `embedded.fimath` `F`, 16-bit word length, and best-precision fraction length. Refer to "fimath Object Construction" for more information on `fimath` objects.
- `b = fi(a,F)` allows you to maintain the value and `numerictype` object of `fi` object `a`, while changing its `fimath` object to `F`.
- `a = fi(v,T,F)` returns a fixed-point object with value `v`, `embedded.numerictype` `T`, and `embedded.fimath` `F`. The syntax `a = fi(v,T,F)` is equivalent to `a = fi(v,F,T)`.
- `a = fi(v,s,F)` returns a fixed-point object with value `v`, `Signed` property value `s`, 16-bit word length, best-precision fraction length, and `embedded.fimath` `F`.
- `a = fi(v,s,w,F)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, best-precision fraction length, and `embedded.fimath` `F`.
- `a = fi(v,s,w,f,F)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, fraction length `f`, and `embedded.fimath` `F`.
- `a = fi(v,s,w,slope,bias,F)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, `slope`, `bias`, and `embedded.fimath` `F`.

- `a = fi(v,s,w,slopeadjustmentfactor,fixedexponent,bias,F)` returns a fixed-point object with value `v`, `Signed` property value `s`, word length `w`, `slopeadjustmentfactor`, `fixedexponent`, `bias`, and `embedded.fimath` `F`.
- `a = fi(...'PropertyName',PropertyValue...)` and `a = fi('PropertyName',PropertyValue...)` allow you to set fixed-point objects for a `fi` object by property name/property value pairs.

The `fi` object has the following three general types of properties:

- "Data Properties" on page 4-415
- "fimath Properties" on page 4-416
- "numerictype Properties" on page 4-417

Note These properties are described in detail in "fi Object Properties" on page 2-2 in the Properties Reference.

Data Properties

The data properties of a `fi` object are always writable.

- `bin` — Stored integer value of a `fi` object in binary
- `data` — Numerical real-world value of a `fi` object
- `dec` — Stored integer value of a `fi` object in decimal
- `double` — Real-world value of a `fi` object, stored as a MATLAB `double`
- `hex` — Stored integer value of a `fi` object in hexadecimal
- `int` — Stored integer value of a `fi` object, stored in a built-in MATLAB integer data type
- `oct` — Stored integer value of a `fi` object in octal
- `Value` — Full-precision real-world value of a `fi` object, stored as a character vector

These properties are described in detail in "fi Object Properties" on page 2-2.

fimath Properties

When you create a `fi` object and specify `fimath` object properties in the `fi` constructor, a `fimath` object is created as a property of the `fi` object. If you do not specify any `fimath` properties in the `fi` constructor, the resulting `fi` has no attached `fimath` object.

- `fimath` — `fimath` properties associated with a `fi` object

The following `fimath` properties are, by transitivity, also properties of a `fi` object. The properties of the `fimath` object listed below are always writable.

- `CastBeforeSum` — Whether both operands are cast to the sum data type before addition

  Note This property is hidden when the `SumMode` is set to `FullPrecision`.

- `MaxProductWordLength` — Maximum allowable word length for the product data type
- `MaxSumWordLength` — Maximum allowable word length for the sum data type
- `OverflowAction` — Overflow mode
- `ProductBias` — Bias of the product data type
- `ProductFixedExponent` — Fixed exponent of the product data type
- `ProductFractionLength` — Fraction length, in bits, of the product data type
- `ProductMode` — Defines how the product data type is determined
- `ProductSlope` — Slope of the product data type
- `ProductSlopeAdjustmentFactor` — Slope adjustment factor of the product data type
- `ProductWordLength` — Word length, in bits, of the product data type
- `RoundingMethod` — Rounding mode
- `SumBias` — Bias of the sum data type
- `SumFixedExponent` — Fixed exponent of the sum data type
- `SumFractionLength` — Fraction length, in bits, of the sum data type
- `SumMode` — Defines how the sum data type is determined
- `SumSlope` — Slope of the sum data type
- `SumSlopeAdjustmentFactor` — Slope adjustment factor of the sum data type

- SumWordLength — The word length, in bits, of the sum data type

These properties are described in detail in “fimath Object Properties”.

numerictype Properties

When you create a fi object, a numerictype object is also automatically created as a property of the fi object.

numerictype — Object containing all the data type information of a fi object, Simulink signal or model parameter

The following numerictype properties are, by transitivity, also properties of a fi object. The properties of the numerictype object become read only after you create the fi object. However, you can create a copy of a fi object with new values specified for the numerictype properties.

- Bias — Bias of a fi object
- DataType — Data type category associated with a fi object
- DataTypeMode — Data type and scaling mode of a fi object
- DataTypeOverride — Data type override for applying fipref data type override settings to fi objects. This property provides a convenient way to ignore a global fipref data type override setting. Note that this property is not visible when its value is the default, Inherit. When this property is set to Off, the fi object uses the numerictype data type settings and ignores fipref settings.
- FixedExponent — Fixed-point exponent associated with a fi object
- SlopeAdjustmentFactor — Slope adjustment associated with a fi object
- FractionLength — Fraction length of the stored integer value of a fi object in bits
- Scaling — Fixed-point scaling mode of a fi object
- Signed — Whether a fi object is signed or unsigned
- Signedness — Whether a fi object is signed or unsigned

Note numerictype objects can have a Signedness of Auto, but all fi objects must be Signed or Unsigned. If a numerictype object with Auto Signedness is used to create a fi object, the Signedness property of the fi object automatically defaults to Signed.

- `Slope` — Slope associated with a `fi` object
- `WordLength` — Word length of the stored integer value of a `fi` object in bits

For further details on these properties, see “numerictype Object Properties”.

Examples

Note For information about the display format of `fi` objects, refer to “View Fixed-Point Data”.

For examples of casting, see “Cast fi Objects”.

Create a `fi` Object

Create a signed `fi` object with a value of `pi`, a word length of 8 bits, and a fraction length of 3 bits.

```
a = fi(pi, 1, 8, 3)
```

```
a = 

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3
```

Create an Array of `fi` Objects

```
a = fi((magic(3)/10), 1, 16, 12)
```

```
a = 

    0.8000    0.1001    0.6001
    0.3000    0.5000    0.7000
    0.3999    0.8999    0.2000

          DataTypeMode: Fixed-point: binary point scaling
```

```
         Signedness: Signed
         WordLength: 16
     FractionLength: 12
```

Create a `fi` Object With Default Precision

If you omit the argument `f`, the fraction length is set automatically to achieve the best precision possible.

```
 a = fi(pi, 1, 8)

a =

    3.1563

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 5
```

Create a `fi` Object With Default Word Length and Precision

If you omit `w` and `f`, the word length is set automatically to 16 bits and the fraction length is set to achieve the best precision possible.

```
a = fi(pi, 1)

a =

    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Create a fi Object From a Non-Double Value

When you create a `fi` object using the default constructor and a non-double input value, `v`, the constructor retains the `numerictype` of `v`.

When the input is a built-in integer, the fixed-point attributes match the attributes of the integer type.

```
v = uint32(5);
a = fi(v)

a =
     5

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 32
        FractionLength: 0
```

The output `a` is a `fi` object that uses the word length, fraction length, and signedness of the input `v`.

When the input is a `fi` object, the output uses the same word length, fraction length, and signedness of the input `fi` object.

```
v = fi(pi, 1, 24, 12);
a = fi(v)

a =
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

When the input `v` is logical, then the output `a` has `DataTypeMode: Boolean`.

```
v = true;
a =  fi(v)

a =
   1

          DataTypeMode: Boolean
```

When the input is single, the output `a` has `DataTypeMode: Single`.

```
v = single(pi);
a =  fi(v)

a =
    3.1416
```

```
        DataTypeMode: Single
```

Create a fi Object With Fraction Length Greater Than Word Length

When you use binary-point representation for a fixed-point number, the fraction length can be greater than the word length. In this case, there are implicit leading zeros (for positive numbers) or ones (for negative numbers) between the binary point and the first significant binary digit.

Consider a signed value with a word length of 8, fraction length of 10 and a stored integer value of 5. We can calculate the real-world value.

```
RealWorldValue = StoredInteger * 2 ^ -FractionLength
RealWorldValue = 5 * 2 ^ -10 = 0.0049
```

Create a signed `fi` object with a value of `0.0048828125`, a word length of 8 bits, and a fraction length of 10 bits.

```
a = fi(0.0048828125, true, 8, 10)
```

```
a = 

    0.0049

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 10
```

Get the stored integer value of `a`.

```
a.int
```

```
ans = 

  int8

   5
```

Get the binary value of the stored integer.

```
a.bin
```

```
ans =

    '00000101'
```

Because the fraction length is 2 bits longer than the word length, the binary value of the stored integer is `x.xx00000101` , where `x` is a placeholder for implicit zeros. `0.0000000101` (binary) is equivalent to `0.0049` (decimal).

Create a fi Object With Negative Fraction Length

When you use binary-point representation for a fixed-point number, the fraction length can be negative. In this case, there are implicit trailing zeros (for positive numbers) or ones (for negative numbers) between the binary point and the first significant binary digit.

Consider a signed value with a word length of 8, fraction length of –2 and a stored integer value of 5. We can calculate the real-world value.

```
RealWorldValue = StoredInteger * 2 ^ -FractionLength
RealWorldValue = 5 * 2 ^ 2 = 20
```

Create a signed `fi` object with a value of `20`, a word length of 8 bits, and a fraction length of –2 bits.

```
a = fi(20, true, 8, -2)
```

```
a =

    20

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: -2
```

Get the stored integer value of `a`.

```
a.int
```

```
ans =

  int8

   5
```

Get the binary value of the stored integer.

```
a.bin
```

```
ans =

    '00000101'
```

Because the fraction length is negative, the binary value of the stored integer is `00000101xx` , where `x` is a placeholder for implicit zeros. `000000010100` (binary) is equivalent to `20` (decimal).

Create a `fi` Object Specifying Rounding and Overflow

You can use property name/property value pairs to set `fi` properties, such as rounding method and overflow action, when you create the object.

```
a = fi(pi, 'RoundingMethod', 'Floor', 'OverflowAction', 'Wrap')
```

```
a = 
    3.1415

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Remove Local `fimath`

You can remove a local `fimath` object from a `fi` object at any time using the `removefimath` function.

```
a = fi(pi, 'RoundingMethod', 'Floor', 'OverflowAction', 'Wrap')
a = removefimath(a)
```

```
a =
    3.1415

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision

a =
    3.1415

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

`fi` object `a` now has no local `fimath`. To reassign it a local `fimath` object, use the `setfimath` function.

```
a = setfimath(a, fimath('ProductMode', 'KeepLSB'))
```

```
a =
    3.1415

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: KeepLSB
```

```
     ProductWordLength: 32
               SumMode: FullPrecision
```

fi object a now has a local fimath object with a ProductMode of KeepLSB. The values of the remaining fimath object properties are default fimath values.

Use fi as an Indexing Argument

Set up an array to be indexed.

```
x = 10:-1:1
```

```
x = 1×10

    10     9     8     7     6     5     4     3     2     1
```

Create a fi object and use it to index into x.

```
k = fi(3);
y = x(k)
```

```
y = 8
```

Use fi in a Switch Statement

You can use a fi object as the switch condition and as one or more of the cases in the switch expression.

```
function y = test_switch(u, v)
   cExpr = fi(u + v, 0, 2, 0);
   t = 1;

   switch cExpr  % condition expression type: ufix2
      case 0
         y = t * 2;
      case fi(1,0,2,0)
         y = t * 3;
      case 2
         y = t * 4;
      case 3
         y = t * 3;
      otherwise
```

```
        y = 0;
   end
end

y = test_switch(1,2.0)

y =
     3
```

Use fi as a Colon Operator

Use a `fi` object as a colon operator.

When you use `fi` as a colon operator, all colon operands must have integer values.

```
a=fi(1,0,3,0);
b=fi(2,0,8,0);
c=fi(12,0,8,0);
x=a:b:c

x =
     1     3     5     7     9    11

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 0
```

Create Fixed-point Vector With Non-integer Spacing

To create a fixed-point vector with non-integer spacing, first create the vector, then cast the vector to fixed-point.

```
x = fi(0:0.1:10);
```

Alternatively, use the `linspace` function.

```
x = fi(linspace(0,10, 101));
```

The following code, where one of the colon operands is not an integer, generates an error.

```
a = fi(0);
b = fi(0.1);
```

```
c = fi(10);
z = a:b:c
```

Use fi in a For Loop

Use a `fi` object as the index of a for-loop.

```
a = fi(1,0,8,0);
b = fi(2,0,8,0);
c = fi(10,0,8,0);

for x = a:b:c
 x
end
```

Set Data Type Override on a fi Object

Set the `DataTypeOverride` property of a `fi` object so that the `fi` object does not use the data type override settings of the `fipref` object.

Save the current `fipref` settings to restore later.

```
fp = fipref;
initialDTOSetting = fp.DataTypeOverride;
```

Set up `fipref` with data type override set to `'TrueDoubles'` for all numeric types.

```
fipref('DataTypeOverride', 'TrueDoubles')
```

```
ans =
                NumberDisplay: 'RealWorldValue'
           NumericTypeDisplay: 'full'
                FimathDisplay: 'full'
                  LoggingMode: 'Off'
             DataTypeOverride: 'TrueDoubles'
    DataTypeOverrideAppliesTo: 'AllNumericTypes'
```

Create a new `fi` object without specifying its `DataTypeOverride` property so that it uses the data type override settings specified using `fipref`.

```
x = fi(pi, 1, 16, 13)
```

```
x = 
    3.1416

          DataTypeMode: Double
```

Now create a `fi` object and set its `DataTypeOverride` property to `'Off'` so that it ignores the data type override settings specified using `fipref`.

```
y = fi(pi, 1, 16, 13, 'DataTypeOverride','Off')
```

```
y = 
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Restore the `fipref` settings saved at the start of the example.

```
fp.DataTypeOverride = initialDTOSetting;
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The default constructor syntax without any input arguments is not supported.
- If the `numerictype` is not fully specified, the input to `fi` must be a constant, a `fi`, a single, or a built-in integer value. If the input is a built-in double value, it must be a constant. This limitation allows `fi` to autoscale its fraction length based on the known data type of the input.
- All properties related to data type must be constant for code generation.
- `numerictype` object information must be available for nonfixed-point Simulink inputs.

See Also
fimath | fipref | isfimathlocal | numerictype | quantizer | sfi | ufi

Topics
"fi Object Functions"
"Binary Point Interpretation"

Introduced before R2006a

fiaccel

Accelerate fixed-point code and convert floating-point MATLAB code to fixed-point MATLAB code

Syntax

```
fiaccel -options fcn
fiaccel -float2fixed fcn
```

Description

`fiaccel -options fcn` translates the MATLAB file `fcn.m` to a MEX function, which accelerates fixed-point code. To use `fiaccel`, your code must meet one of these requirements:

- The top-level function has no inputs or outputs, and the code uses `fi`
- The top-level function has an output or a non-constant input, and at least one output or input is a `fi`.
- The top-level function has at least one input or output containing a built-in integer class (`int8`, `uint8`, `int16`, `uint16`, `int32`, `uint32`, `int64`, or `uint64`), and the code uses `fi`.

Note If your top-level file is on a path that contains Unicode characters, code generation might not be able to find the file.

`fiaccel -float2fixed fcn` converts the floating-point MATLAB function, `fcn` to fixed-point MATLAB code.

Input Arguments

`fcn`

MATLAB function from which to generate a MEX function. *`fcn`* must be suitable for code generation. For information on code generation, see “Code Acceleration and Code Generation from MATLAB”

`options`

Choice of compiler options. `fiaccel` gives precedence to individual command-line options over options specified using a configuration object. If command-line options conflict, the rightmost option prevails.

`-args` *`example_inputs`*	Define the size, class, and complexity of MATLAB function inputs by providing a cell array of example input values. The position of the example input in the cell array must correspond to the position of the input argument in the MATLAB function definition. To generate a function that has fewer input arguments than the function definition has, omit the example values for the arguments that you do not want. Specify the example inputs immediately after the function to which they apply. Instead of an example value, you can provide a `coder.Type` object. To create a `coder.Type` object, use `coder.typeof`.
`-config` *`config_object`*	Specify MEX generation parameters, based on *`config_object`*, defined as a MATLAB variable using `coder.mexconfig`. For example: `cfg = coder.mexconfig;`

`-d` *`out_folder`*	Store generated files in the absolute or relative path specified by *`out_folder`*. If the folder specified by *`out_folder`* does not exist, `fiaccel` creates it for you. If you do not specify the folder location, `fiaccel` generates files in the default folder: `fiaccel/`*`mex/fcn`*`.` *`fcn`* is the name of the MATLAB function specified at the command line. The function does not support the following characters in folder names: asterisk (*), question-mark (?), dollar ($), and pound (#).
`-float2fixed` *`float2fixed_cfg_name`*	Generates fixed-point MATLAB code using the settings specified by the floating-point to fixed-point conversion configuration object named *`float2fixed_cfg_name`*. For this option, `fiaccel` generates files in the folder `codegen/fcn_name/fixpt`. You must set the `TestBenchName` property of *`float2fixed_cfg_name`*. For example: `fixptcfg.TestBenchName = 'myadd_test';` specifies that `myadd_test` is the test file for the floating-point to fixed-point configuration object `fixptcfg`. You cannot use this option with the `-global` option.
`-g`	Compiles the MEX function in debug mode, with optimization turned off. If not specified, `fiaccel` generates the MEX function in optimized mode.

`-global` *`global_values`*	Specify initial values for global variables in MATLAB file. Use the values in cell array `global_values` to initialize global variables in the function you compile. The cell array should provide the name and initial value of each global variable. You must initialize global variables before compiling with `fiaccel`. If you do not provide initial values for global variables using the `-global` option, `fiaccel` checks for the variable in the MATLAB global workspace. If you do not supply an initial value, `fiaccel` generates an error. The generated MEX code and MATLAB each have their own copies of global data. To ensure consistency, you must synchronize their global data whenever the two interact. If you do not synchronize the data, their global variables might differ. You cannot use this option with the `-float2fixed` option.
`-I` *`include_path`*	Add *`include_path`* to the beginning of the code generation path. `fiaccel` searches the code generation path *first* when converting MATLAB code to MEX code.
`-launchreport`	Generate and open a code generation report. If you do not specify this option, `fiaccel` generates a report only if error or warning messages occur or you specify the `-report` option.

`-nargout`	Specify the number of output arguments in the generated entry-point function. The code generator produces the specified number of output arguments in the order in which they occur in the MATLAB function definition.
`-o` *`output_file_name`*	Generate the MEX function with the base name *`output_file_name`* plus a platform-specific extension. *`output_file_name`* can be a file name or include an existing path. If you do not specify an output file name, the base name is *`fcn_mex`*, which allows you to run the original MATLAB function and the MEX function and compare the results.
`-O` *`optimization_option`*	Optimize generated MEX code, based on the value of *`optimization_option`*: • `enable:inline` — Enable function inlining • `disable:inline` — Disable function inlining If not specified, `fiaccel` uses inlining for optimization.
`-report`	Generate a code generation report. If you do not specify this option, `fiaccel` generates a report only if error or warning messages occur or you specify the `-launchreport` option.
`-?`	Display help for `fiaccel` command.

Examples

Create a test file and compute the moving average. Then, use `fiaccel` to accelerate the code and compare.

```
function avg = test_moving_average(x)
%#codegen
if nargin < 1,
    x = fi(rand(100,1),1,16,15);
end
z = fi(zeros(10,1),1,16,15);
avg = x;
for k = 1:length(x)
    [avg(k),z] = moving_average(x(k),z);
end

function [avg,z] = moving_average(x,z)
%#codegen
if nargin < 2,
    z = fi(zeros(10,1),1,16,15);
end
z(2:end) = z(1:end-1);      % Update buffer
z(1) = x;                      % Add new value
avg = mean(z);          % Compute moving average

% Use fiaccel to create a MEX function and
% accelerate the code
x = fi(rand(100,1),1,16,15);
fiaccel test_moving_average -args {x} -report

% Compare the non-accelerated and accelerated code.
x = fi(rand(100,1),1,16,15);

% Non-compiled version
tic,avg = test_moving_average(x);toc
% Compiled version
tic,avg = test_moving_average_mex(x);toc
```

Convert Floating-Point MATLAB Code to Fixed Point

Create a `coder.FixptConfig` object, `fixptcfg`, with default settings.

```
fixptcfg = coder.config('fixpt');
```

Set the test bench name. In this example, the test bench function name is `dti_test`.

```
fixptcfg.TestBenchName = 'dti_test';
```

Convert a floating-point MATLAB function to fixed-point MATLAB code. In this example, the MATLAB function name is `dti`.

```
fiaccel -float2fixed fixptcfg dti
```

See Also

`coder.ArrayType` | `coder.Constant` | `coder.EnumType` | `coder.FiType` | `coder.FixptConfig` | `coder.MexConfig` | `coder.PrimitiveType` | `coder.StructType` | `coder.Type` | `coder.config` | `coder.mexconfig` | `coder.newtype` | `coder.resize` | `coder.typeof`

Introduced in R2011a

filter

One-dimensional digital filter of `fi` objects

Syntax

```
y = filter(b,1,x)
[y,zf] = filter(b,1,x,zi)
y = filter(b,1,x,zi,dim)
```

Description

`y = filter(b,1,x)` filters the data in the fixed-point vector *x* using the filter described by the fixed-point vector *b*. The function returns the filtered data in the output `fi` object *y*. Inputs *b* and *x* must be `fi` objects. `filter` always operates along the first non-singleton dimension. Thus, the filter operates along the first dimension for column vectors and nontrivial matrices, and along the second dimension for row vectors.

`[y,zf] = filter(b,1,x,zi)` gives access to initial and final conditions of the delays, *zi*, and *zf*. *zi* is a vector of length `length(b)-1`, or an array with the leading dimension of size `length(b)-1` and with remaining dimensions matching those of *x*. *zi* must be a `fi` object with the same data type as *y* and *zf*. If you do not specify a value for *zi*, it defaults to a fixed-point array with a value of `0` and the appropriate `numerictype` and size.

`y = filter(b,1,x,zi,dim)` performs the filtering operation along the specified dimension. If you do not want to specify the vector of initial conditions, use `[]` for the input argument *zi*.

Input Arguments

b

Fixed-point vector of the filter coefficients.

x

Fixed-point vector containing the data for the function to filter.

zi

Fixed-point vector containing the initial conditions of the delays. If the initial conditions of the delays are zero, you can specify zero, or, if you do not know the appropriate size and `numerictype` for *`zi`*, use `[]`.

If you do not specify a value for *`zi`*, the parameter defaults to a fixed-point vector with a value of zero and the same `numerictype` and size as the output *`zf`* (default).

dim

Dimension along which to perform the filtering operation.

Output Arguments

y

Output vector containing the filtered fixed-point data.

zf

Fixed-point output vector containing the final conditions of the delays.

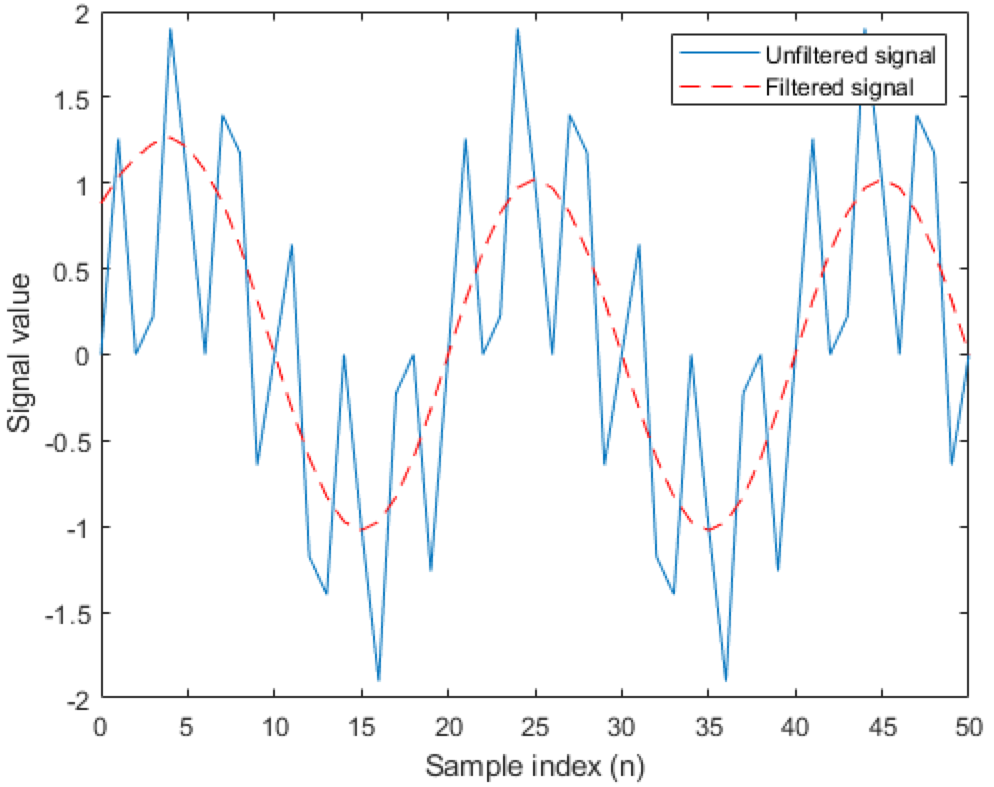
Examples

Filter a high-frequency fixed-point sinusoid from a signal

The following example filters a high-frequency fixed-point sinusoid from a signal that contains both a low- and high-frequency fixed-point sinusoid.

```
w1 = .1*pi;
w2 = .6*pi;
n  = 0:999;
xd = sin(w1*n) + sin(w2*n);
x  = sfi(xd,12);
```

```
b  = ufi([.1:.1:1,1-.1:-.1:.1]/4,10);
gd = (length(b)-1)/2;
y  = filter(b,1,x);

% Plot results, accommodate for group-delay of filter
plot(n(1:end-gd),x(1:end-gd))
hold on
plot(n(1:end-gd),y(gd+1:end),'r--')
axis([0 50 -2 2])
legend('Unfiltered signal','Filtered signal')
xlabel('Sample index (n)')
ylabel('Signal value')
```



The resulting plot shows both the unfiltered and filtered signals.

Definitions

Filter length (L)

The filter length is `length(b)`, or the number of filter coefficients specified in the fixed-point vector *b*.

Filter order (N)

The filter order is the number of states (delays) of the filter, and is equal to ***L*-1**.

Tips

- The `filter` function only supports FIR filters. In the general filter representation, *b/a*, the denominator, *a*, of an FIR filter is the scalar 1, which is the second input of this function.
- The `numerictype` of *b* can be different than the `numerictype` of *x*.
- If you want to specify initial conditions, but do not know what `numerictype` to use, first try filtering your data without initial conditions. You can do so by specifying `[]` for the input *zi*. After performing the filtering operation, you have the `numerictype` of *y* and *zf* (if requested). Because the `numerictype` of *zi* must match that of *y* and *zf*, you now know the `numerictype` to use for the initial conditions.

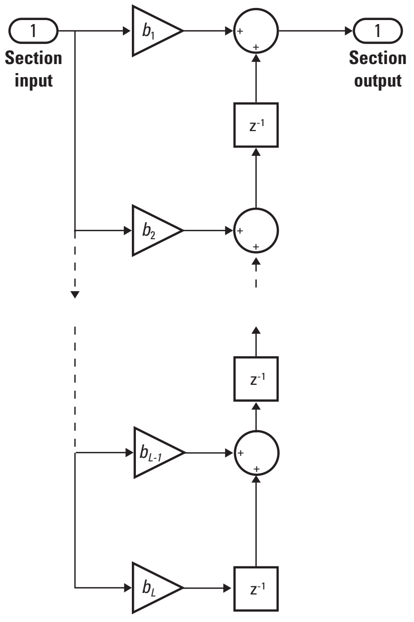
Algorithms

The `filter` function uses a Direct-Form Transposed FIR implementation of the following difference equation:

$$y(n) = b_1 * x_n + b_2 * x_{n-1} + ... + b_L * x_{n-N}$$

where *L* is the filter length on page 4-440 and *N* is the filter order on page 4-440.

The following diagram shows the direct-form transposed FIR filter structure used by the `filter` function:



fimath Propagation Rules

The `filter` function uses the following rules regarding `fimath` behavior:

- `globalfimath` is obeyed.
- If any of the inputs has an attached `fimath`, then it is used for intermediate calculations.
- If more than one input has an attached `fimath`, then the `fimaths` must be equal.
- The output, `y`, is always associated with the default `fimath`.
- If the input vector, `zi`, has an attached `fimath`, then the output vector, `zf`, retains this `fimath`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-sized inputs are only supported when the `SumMode` property of the governing `fimath` is set to `Specify precision` or `Keep LSB`.

See Also

`conv` | `filter`

Introduced in R2010a

fimath

Set fixed-point math settings

Syntax

```
F = fimath
F = fimath(...'PropertyName',PropertyValue...)
```

Description

You can use the `fimath` constructor function in the following ways:

- `F = fimath` creates a `fimath` object with default fimath property settings:

```
        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

- `F = fimath(...'PropertyName',PropertyValue...)` allows you to set the attributes of a `fimath` object using property name/property value pairs. All property names that you do not specify in the constructor use default values.

The properties of the `fimath` object are listed below. These properties are described in detail in “fimath Object Properties” in the Properties Reference.

- `CastBeforeSum` — Whether both operands are cast to the sum data type before addition

  Note This property is hidden when the `SumMode` is set to `FullPrecision`.

- `OverflowAction` — Action to take on overflow
- `ProductBias` — Bias of the product data type
- `ProductFixedExponent` — Fixed exponent of the product data type
- `ProductFractionLength` — Fraction length, in bits, of the product data type

- `ProductMode` — Defines how the product data type is determined
- `ProductSlope` — Slope of the product data type
- `ProductSlopeAdjustmentFactor` — Slope adjustment factor of the product data type
- `ProductWordLength` — Word length, in bits, of the product data type
- `RoundingMethod` — Rounding method
- `SumBias` — Bias of the sum data type
- `SumFixedExponent` — Fixed exponent of the sum data type
- `SumFractionLength` — Fraction length, in bits, of the sum data type
- `SumMode` — Defines how the sum data type is determined
- `SumSlope` — Slope of the sum data type
- `SumSlopeAdjustmentFactor` — Slope adjustment factor of the sum data type
- `SumWordLength` — Word length, in bits, of the sum data type

Examples

Create a Default fimath Object

```
F = fimath
```

```
F =
        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Set Properties of a fimath Object

Set properties of a fimath object at the time of object creation by including properties after the arguments of the fimath constructor function. For example, set the overflow action to Saturate and the rounding method to Convergent.

```
F = fimath('OverflowAction','Saturate','RoundingMethod','Convergent')
```

```
F =
        RoundingMethod: Convergent
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

- “fimath Object Construction”

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals coming in to a MATLAB Function block from Simulink are assigned a `fimath` object. You define this object in the MATLAB Function block dialog in the Model Explorer.
- Use to create `fimath` objects in the generated code.
- If the `ProductMode` property of the `fimath` object is set to anything other than `FullPrecision`, the `ProductWordLength` and `ProductFractionLength` properties must be constant.
- If the `SumMode` property of the `fimath` object is set to anything other than `FullPrecision`, the `SumWordLength` and `SumFractionLength` properties must be constant.

See Also

`fi` | `fipref` | `globalfimath` | `numerictype` | `quantizer` | `removefimath` | `setfimath`

Topics

“fimath Object Construction”
“fimath Object Properties”
How Functions Use fimath

"fimath Properties Usage for Fixed-Point Arithmetic"

Introduced before R2006a

fipref

Set fixed-point preferences

Syntax

```
P = fipref
P = fipref(...'PropertyName',PropertyValue...)
```

Description

You can use the `fipref` constructor function in the following ways:

- `P = fipref` creates a default `fipref` object.
- `P = fipref(...'PropertyName',PropertyValue...)` allows you to set the attributes of a object using property name/property value pairs.

The properties of the `fipref` object are listed below. These properties are described in detail in "fipref Object Properties" on page 2-4.

- `FimathDisplay` — Display options for the local `fimath` attributes of `fi` objects. When `fi` objects to not have a local fimath, their `fimath` attributes are never displayed.
- `DataTypeOverride` — Data type override options.
- `DataTypeOverrideAppliesTo`— Data type override setting applicability.
- `LoggingMode` — Logging options for operations performed on `fi` objects.
- `NumericTypeDisplay` — Display options for the numeric type attributes of a `fi` object.
- `NumberDisplay` — Display options for the value of a `fi` object.

Your `fipref` settings persist throughout your MATLAB session. Use `reset(fipref)` to return to the default settings during your session. Use `savefipref` to save your display preferences for subsequent MATLAB sessions.

See “View Fixed-Point Data” for more information on the display preferences used for most code examples in the documentation.

Examples

Example 1

Type

```
P = fipref
```

to create a default `fipref` object.

```
P =

         NumberDisplay: 'RealWorldValue'
    NumericTypeDisplay: 'full'
         FimathDisplay: 'full'
           LoggingMode: 'Off'
      DataTypeOverride: 'ForceOff'
```

Example 2

You can set properties of `fipref` objects at the time of object creation by including properties after the arguments of the `fipref` constructor function. For example, to set `NumberDisplay` to `bin` and `NumericTypeDisplay` to `short`,

```
P = fipref('NumberDisplay','bin',...
   'NumericTypeDisplay', 'short')

P =

         NumberDisplay: 'bin'
    NumericTypeDisplay: 'short'
         FimathDisplay: 'full'
           LoggingMode: 'Off'
      DataTypeOverride: 'ForceOff'
```

See Also

`fi` | `fimath` | `numerictype` | `quantizer` | `savefipref`

Topics

“fipref Object Construction”
“fipref Object Properties”

Introduced before R2006a

fix

Round toward zero

Syntax

```
y = fix(a)
```

Description

y = fix(a) rounds fi object a to the nearest integer in the direction of zero and returns the result in fi object y.

y and a have the same fimath object and DataType property.

When the DataType property of a is single, double, or boolean, the numerictype of y is the same as that of a.

When the fraction length of a is zero or negative, a is already an integer, and the numerictype of y is the same as that of a.

When the fraction length of a is positive, the fraction length of y is 0, its sign is the same as that of a, and its word length is the difference between the word length and the fraction length of a. If a is signed, then the minimum word length of y is 2. If a is unsigned, then the minimum word length of y is 1.

For complex fi objects, the imaginary and real parts are rounded independently.

fix does not support fi objects with nontrivial slope and bias scaling. Slope and bias scaling is trivial when the slope is an integer power of 2 and the bias is 0.

Examples

Example 1

The following example demonstrates how the `fix` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 3.

```
a = fi(pi, 1, 8, 3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3

y = fix(a)

y =

     3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 5
        FractionLength: 0
```

Example 2

The following example demonstrates how the `fix` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 12.

```
a = fi(0.025,1,8,12)

a =

    0.0249

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
            WordLength: 8
        FractionLength: 12

y = fix(a)

y =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 2
        FractionLength: 0
```

Example 3

The functions `ceil`, `fix`, and `floor` differ in the way they round `fi` objects:

- The `ceil` function rounds values to the nearest integer toward positive infinity
- The `fix` function rounds values toward zero
- The `floor` function rounds values to the nearest integer toward negative infinity

The following table illustrates these differences for a given `fi` object `a`.

a	ceil(a)	fix(a)	floor(a)
– 2.5	–2	–2	–3
–1.75	–1	–1	–2
–1.25	–1	–1	–2
–0.5	0	0	–1
0.5	1	0	0
1.25	2	1	1
1.75	2	1	1
2.5	3	2	2

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`ceil` | `convergent` | `floor` | `nearest` | `round`

Introduced in R2008a

fixed.aggregateType

Compute aggregate numerictype

Syntax

```
aggNT = fixed.aggregateType(A,B)
```

Description

`aggNT = fixed.aggregateType(A,B)` computes the smallest binary point scaled numerictype that is able to represent both the full range and precision of inputs `A` and `B`.

Input Arguments

A

An integer, binary point scaled fixed-point `fi` object, or numerictype object.

B

An integer, binary point scaled fixed-point `fi` object, or numerictype object.

Output Arguments

aggNT

A numerictype object.

Examples

Compute the aggregate numerictype of two numerictype objects.

```
% can represent range [-4,4) and precision 2^-13
a_nt = numerictype(1,16,13);
% can represent range [-2,2) and precision 2^-16
b_nt = numerictype(1,18,16);

% can represent range [-4,4) and precision 2^-16
aggNT = fixed.aggregateType(a_nt,b_nt)
aggNT =


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 19
        FractionLength: 16
```

Compute the aggregate numerictype of two `fi` objects.

```
% Unsigned, WordLength: 16, FractionLength: 14
a_fi = ufi(pi,16);
% Signed, WordLength: 24, FractionLength: 21
b_fi = sfi(-pi,24);

% Signed, WordLength: 24, FractionLength: 21
aggNT = fixed.aggregateType(a_fi,b_fi)
aggNT =


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 21
```

Compute the aggregate numerictype of a `fi` object and an integer.

```
% Unsigned, WordLength: 16, FractionLength: 14
% can represent range [0,3] and precision 2^-14
a_fi = ufi(pi,16);
% Unsigned, WordLength: 8, FractionLength: 0
% can represent range [0,255] and precision 2^0
cInt = uint8(0);

% Unsigned with WordLength: 14+8, FractionLength: 14
% can represent range [0,255] and precision 2^-14
aggNT = fixed.aggregateType(a_fi,cInt)
aggNT =
```

```
      DataTypeMode: Fixed-point: binary point scaling
        Signedness: Unsigned
        WordLength: 22
    FractionLength: 14
```

See Also

fi | numerictype

Introduced in R2011b

fixed.Quantizer

Quantize fixed-point numbers

Syntax

```
q = fixed.Quantizer
q = fixed.Quantizer(nt,rm,oa)
q = fixed.Quantizer(s,wl,fl,rm,oa)
q = fixed.Quantizer(Name,Value)
```

Description

`q = fixed.Quantizer` creates a quantizer `q` that quantizes fixed-point (`fi`) numbers using default fixed-point settings.

`q = fixed.Quantizer(nt,rm,oa)` uses the `numerictype` (`nt`) object information and the `RoundingMethod` (`rm`) and `OverflowAction` (`oa`) properties.

The `numerictype`, rounding method, and overflow action apply only during the quantization. The resulting, quantized `q` does not have any fimath attached to it.

`q = fixed.Quantizer(s,wl,fl,rm,oa)` uses the `Signed` (`s`), `WordLength` (`wl`), `FractionLength` (`fl`), `RoundingMethod` (`rm`), and `OverflowAction` (`oa`) properties.

`q = fixed.Quantizer(Name,Value)` creates a quantizer with the property options specified by one or more `Name,Value` pair arguments. You separate pairs of `Name,Value` arguments with commas. `Name` is the argument name, and `Value` is the corresponding value. `Name` must appear inside single quotes (`''`). You can specify several name-value pair arguments in any order as `Name1,Value1,…,NameN,ValueN`.

Input Arguments

nt

Binary-point, scaled numerictype object or slope-bias scaled, fixed-point numerictype object. If your `fixed.Quantizer` uses a numerictype object that has either a `Signedness` of `Auto` or unspecified `Scaling`, an error occurs.

rm

Rounding method to apply to the output data. Valid rounding methods are: `Ceiling`, `Convergent`, `Floor`, `Nearest`, `Round`, and `Zero`. The associated property name is `RoundingMethod`.

Default: `Floor`

oa

Overflow action to take in case of data overflow. Valid overflow actions are `Saturate` and `Wrap`. The associated property name is `OverflowAction`.

Default: `Wrap`

s

Logical value, `true` or `false`, indicating whether the output is signed or unsigned, respectively. The associated property name is `Signed`.

Default: `true`

wl

Word length (number of bits) of the output data. The associated property name is `WordLength`.

Default: 16

fl

Fraction length of the output data. The associated property name is `FractionLength`.

Default: 15

Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

`Bias`

The bias is part of the numerical representation used to interpret a fixed-point number on page 4-462. Along with the slope, the bias forms the scaling of the number.

Default: 0

`FixedExponent`

Fixed-point exponent associated with the object. The exponent is part of the numerical representation used to express a fixed-point number on page 4-462.

The exponent of a fixed-point number is equal to the negative of the fraction length. `FixedExponent` must be an integer.

Default: -15

`FractionLength`

Fraction length of the stored integer value of the object, in bits. The fraction length can be any integer value.

This property automatically defaults to the best precision possible based on the value of the word length and the real-world value of the `fi` object.

Default: 15

`OverflowAction`

Action to take in case of data overflow. Valid overflow actions are `Saturate` and `Wrap`. .

Default: `Wrap`

RoundingMethod

Rounding method to apply to the output data. Valid rounding methods are: `Ceiling`, `Convergent`, `Floor`, `Nearest`, `Round`, and `Zero`.

Default: `Floor`

Signed

Whether the object is signed. The possible values of this property are:

- `1` — signed
- `0` — unsigned
- `true` — signed
- `false` — unsigned

Note Although the `Signed` property is still supported, the `Signedness` property always appears in the `numerictype` object display. If you choose to change or set the signedness of your `numerictype` object using the `Signed` property, MATLAB updates the corresponding value of the `Signedness` property.

Default: `true`

Signedness

Whether the object is signed, unsigned, or has an unspecified sign. The possible values of this property are:

- `Signed` — signed
- `Unsigned` — unsigned

Default: `Signed`

Slope

Slope associated with the object. The slope is part of the numerical representation used to express a fixed-point number on page 4-462. Along with the bias, the slope forms the scaling of a fixed-point number.

Default: 2^-15

`SlopeAdjustmentFactor`

Slope adjustment associated with the object. The slope adjustment is equivalent to the fractional slope of a fixed-point number. The fractional slope is part of the numerical representation used to express a fixed-point number.

`SlopeAdjustmentFactor` must be greater than or equal to 1 and less than 2.

Default: 1

`WordLength`

Word length of the stored integer value of the object, in bits. The word length can be any positive integer value.

Default: 16

Output Arguments

`q`

Quantizer that quantizes fi input numbers

Examples

Use `fixed.Quantizer` to reduce the word length that results from adding two fixed-point numbers.

```
q = fixed.Quantizer;
x1 = fi(0.1,1,16,15);
x2 = fi(0.8,1,16,15);
y  = quantize(q,x1+x2);
```

Use `fixed.Quantizer` object to change a binary point scaled fixed-point fi to a slope-bias scaled fixed-point fi

```
qsb = fixed.Quantizer(numerictype(1,7,1.6,0.2),...
  'Round','Saturate');
ysb = quantize(qsb,fi(pi,1,16,13));
```

Definitions

Fixed-point numbers

Fixed-point numbers can be represented as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{fixed\ exponent}$$

Tips

- Use `y = quantize(q,x)` to quantize input array `x` using the fixed-point settings of quantizer `q`. `x` can be any fixed-point number fi, except a Boolean value. If `x` is a scaled double, the `x` and `y` data will be the same, but `y` will have fixed-point settings. If `x` is a double or single then `y` = `x`. This functionality lets you share the same code for both floating-point data types and fi objects when quantizers are present.
- Use `n = numerictype(q)` to get a numerictype for the current settings of quantizer `q`.
- Use `clone(q)` to create a quantizer object with the same property values as `q`.
- If you use a `fixed.quantizer` in code generation, note that it is a handle object and must be declared as persistent.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`fi` | `numerictype` | `quantizer`

Topics

"Set numerictype Object Properties"

Introduced in R2011b

fixpt_instrument_purge

Remove corrupt fixed-point instrumentation from model

Note `fixpt_instrument_purge` will be removed in a future release.

Syntax

```
fixpt_instrument_purge
fixpt_instrument_purge(modelName, interactive)
```

Description

The `fixpt_instrument_purge` script finds and removes fixed-point instrumentation from a model left by the Fixed-Point Tool and the fixed-point autoscaling script. The Fixed-Point Tool and the fixed-point autoscaling script each add callbacks to a model. For example, the Fixed-Point Tool appends commands to model-level callbacks. These callbacks make the Fixed-Point Tool respond to simulation events. Similarly, the autoscaling script adds instrumentation to some parameter values that gathers information required by the script.

Normally, these types of instrumentation are automatically removed from a model. The Fixed-Point Tool removes its instrumentation when the model is closed. The autoscaling script removes its instrumentation shortly after it is added. However, there are cases where abnormal termination of a model leaves fixed-point instrumentation behind. The purpose of `fixpt_instrument_purge` is to find and remove fixed-point instrumentation left over from abnormal termination.

`fixpt_instrument_purge(modelName, interactive)` removes instrumentation from model `modelName`. `interactive` is `true` by default, which prompts you to make each change. When `interactive` is set to `false`, all found instrumentation is automatically removed from the model.

See Also

`autofixexp` | `fxptdlg`

Introduced before R2006a

flip

Flip order of elements

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `flip` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The dimensions argument must be a built-in type; it cannot be a `fi` object.

Introduced in R2014a

fliplr

Flip matrix left to right

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `fliplr` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced in R2007a

flipud

Flip matrix up to down

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `flipud` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced in R2007a

floor

Round toward negative infinity

Syntax

```
y = floor(a)
```

Description

`y = floor(a)` rounds `fi` object `a` to the nearest integer in the direction of negative infinity and returns the result in `fi` object `y`.

`y` and `a` have the same `fimath` object and `DataType` property.

When the `DataType` property of `a` is `single`, `double`, or `boolean`, the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is zero or negative, `a` is already an integer, and the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is positive, the fraction length of `y` is `0`, its sign is the same as that of `a`, and its word length is the difference between the word length and the fraction length of `a`. If `a` is signed, then the minimum word length of `y` is `2`. If `a` is unsigned, then the minimum word length of `y` is `1`.

For complex `fi` objects, the imaginary and real parts are rounded independently.

`floor` does not support `fi` objects with nontrivial slope and bias scaling. Slope and bias scaling is trivial when the slope is an integer power of 2 and the bias is 0.

Examples

Example 1

The following example demonstrates how the `floor` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 3.

```
a = fi(pi, 1, 8, 3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3

y = floor(a)

y =

     3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 5
        FractionLength: 0
```

Example 2

The following example demonstrates how the `floor` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 12.

```
a = fi(0.025,1,8,12)

a =

    0.0249

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
            WordLength: 8
        FractionLength: 12

y = floor(a)

y =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 2
        FractionLength: 0
```

Example 3

The functions `ceil`, `fix`, and `floor` differ in the way they round `fi` objects:

- The `ceil` function rounds values to the nearest integer toward positive infinity
- The `fix` function rounds values toward zero
- The `floor` function rounds values to the nearest integer toward negative infinity

The following table illustrates these differences for a given `fi` object `a`.

a	ceil(a)	fix(a)	floor(a)
– 2.5	-2	-2	-3
-1.75	-1	-1	-2
-1.25	-1	-1	-2
-0.5	0	0	-1
0.5	1	0	0
1.25	2	1	1
1.75	2	1	1
2.5	3	2	2

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

ceil | convergent | fix | nearest | round

Introduced in R2008a

for

Execute statements specified number of times

Syntax

```
for index = values
   statements
end
```

Description

`for index = valuesstatements, end` executes a group of statements in a loop for a specified number of times.

If a `colon` operation with `fi` objects is used as the index, then the `fi` objects must be whole numbers.

Refer to the MATLAB `for` reference page for more information.

Example

Use `fi` in a For Loop

Use a `fi` object as the index of a for-loop.

```
a = fi(1,0,8,0);
b = fi(2,0,8,0);
c = fi(10,0,8,0);

for x = a:b:c
```

```
  x
end
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced in R2014b

fplot

Plot function between specified limits

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `fplot` reference page for more information.

Introduced before R2006a

fractionlength

Fraction length of `quantizer` object

Syntax

```
fractionlength(q)
```

Description

`fractionlength(q)` returns the fraction length of `quantizer` object `q`.

Algorithms

For floating-point `quantizer` objects, $f = w - e - 1$, where w is the word length and e is the exponent length.

For fixed-point `quantizer` objects, f is part of the format $[w\ f]$.

See Also

`fi` | `numerictype` | `quantizer` | `wordlength`

Introduced before R2006a

fxpopt

Optimize data types of a system

Syntax

```
result = fxpopt(model, sud, options)
```

Description

`result = fxpopt(model, sud, options)` optimizes the data types in the model or subsystem specified by `sud` in the model, `model`, with additional options specified in the `fxpOptimizationOptions` object, `options`.

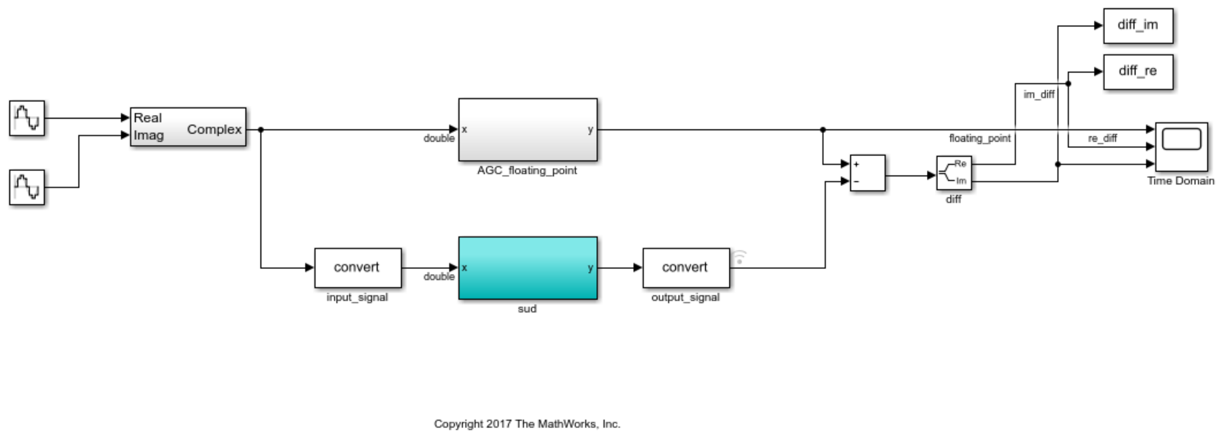
Examples

Optimize Fixed-Point Data Types

This example shows how to optimize the data types used by a system based on specified tolerances.

To begin, open the system for which you want to optimize the data types.

```
model = 'ex_auto_gain_controller';
sud = 'ex_auto_gain_controller/sud';
open_system(model)
```



Create an `fxpOptimizationOptions` object to define constraints and tolerances to meet your design goals.

```
opt = fxpOptimizationOptions()


opt = 

  fxpOptimizationOptions with properties:

           MaxIterations: 50
                 MaxTime: 600
                Patience: 10
               Verbosity: High
    AllowableWordLengths: [1x128 double]

   Advanced Options
         AdvancedOptions: [1x1 struct]
```

Use the `addTolerance` method to define tolerances for the differences between the original behavior of the system, and the behavior using the optimized fixed-point data types. You can also specify word lengths to allow in your design.

```
tol = 10e-2;
addTolerance(opt, [model '/output_signal'], 1, 'AbsTol', tol);
opt.AllowableWordLengths = 10:24;
```

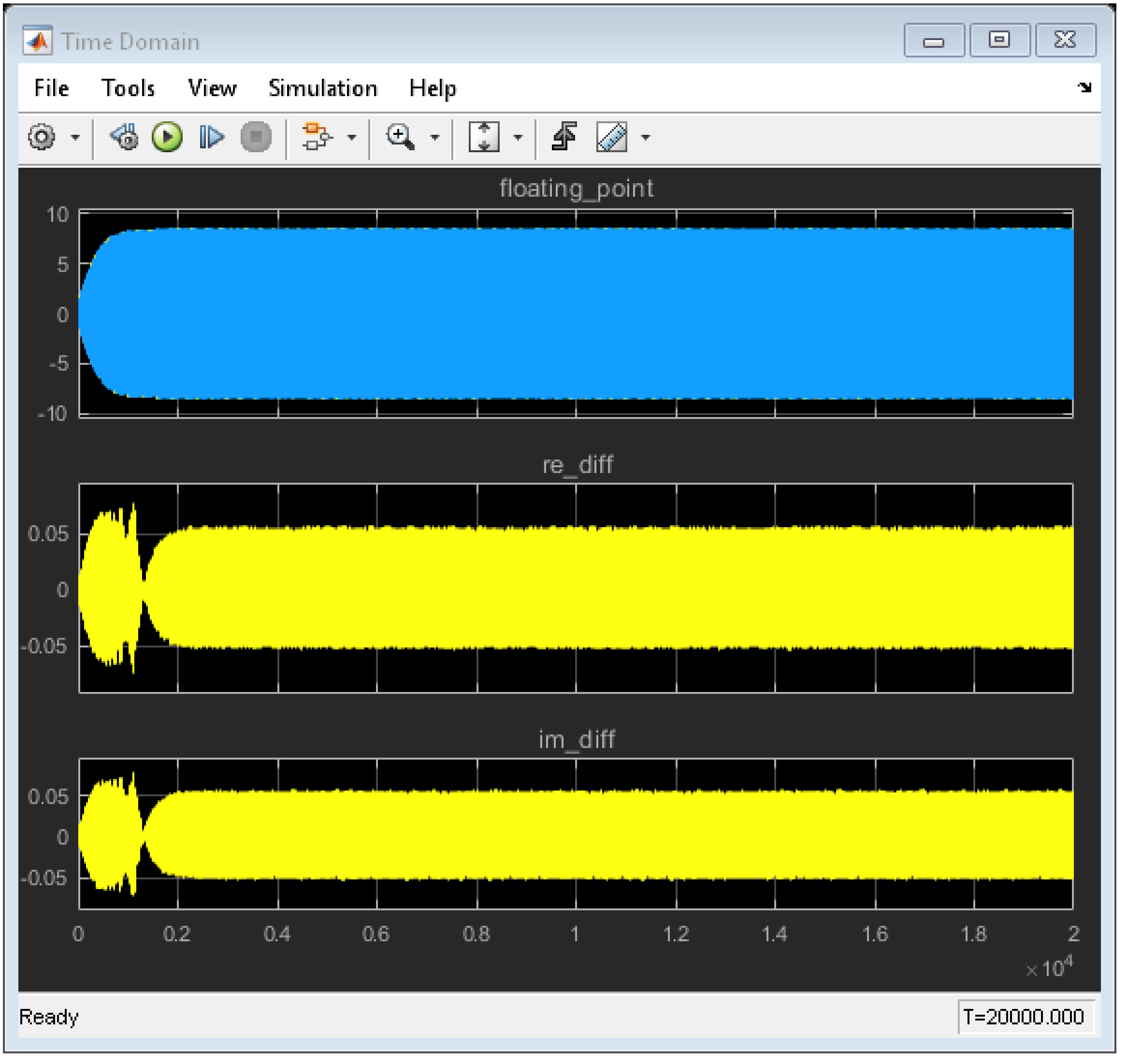
Use the `fxpopt` function to run the optimization. The software analyzes ranges of objects in your system under design and the constraints specified in the `fxpOptimizationOptions` object to apply heterogeneous data types to your system while minimizing total bit width.

```
result = fxpopt(model, sud, opt);
```

```
    + Preprocessing
    + Modeling the optimization problem
        - Constructing decision variables
        - Binding constraints
    + Running the optimization solver
        - Evaluating new solution: cost 180, does not meet the tolerances.
        - Evaluating new solution: cost 198, does not meet the tolerances.
        - Evaluating new solution: cost 216, does not meet the tolerances.
        - Evaluating new solution: cost 234, does not meet the tolerances.
        - Evaluating new solution: cost 252, does not meet the tolerances.
        - Evaluating new solution: cost 270, does not meet the tolerances.
        - Evaluating new solution: cost 288, does not meet the tolerances.
        - Evaluating new solution: cost 306, meets the tolerances.
        - Updated best found solution, cost: 306
        - Evaluating new solution: cost 304, meets the tolerances.
        - Updated best found solution, cost: 304
        - Evaluating new solution: cost 300, meets the tolerances.
        - Updated best found solution, cost: 300
        - Evaluating new solution: cost 299, meets the tolerances.
        - Updated best found solution, cost: 299
        - Evaluating new solution: cost 298, meets the tolerances.
        - Updated best found solution, cost: 298
        - Evaluating new solution: cost 297, meets the tolerances.
        - Updated best found solution, cost: 297
        - Evaluating new solution: cost 296, meets the tolerances.
        - Updated best found solution, cost: 296
        - Evaluating new solution: cost 295, meets the tolerances.
        - Updated best found solution, cost: 295
        - Evaluating new solution: cost 294, does not meet the tolerances.
        - Evaluating new solution: cost 293, meets the tolerances.
        - Updated best found solution, cost: 293
        - Evaluating new solution: cost 292, meets the tolerances.
        - Updated best found solution, cost: 292
        - Evaluating new solution: cost 291, meets the tolerances.
        - Updated best found solution, cost: 291
        - Evaluating new solution: cost 290, meets the tolerances.
        - Updated best found solution, cost: 290
```

```
- Evaluating new solution: cost 289, meets the tolerances.
- Updated best found solution, cost: 289
- Evaluating new solution: cost 287, meets the tolerances.
- Updated best found solution, cost: 287
- Evaluating new solution: cost 283, meets the tolerances.
- Updated best found solution, cost: 283
- Evaluating new solution: cost 282, meets the tolerances.
- Updated best found solution, cost: 282
- Evaluating new solution: cost 281, meets the tolerances.
- Updated best found solution, cost: 281
- Evaluating new solution: cost 280, meets the tolerances.
- Updated best found solution, cost: 280
- Evaluating new solution: cost 279, meets the tolerances.
- Updated best found solution, cost: 279
- Evaluating new solution: cost 278, meets the tolerances.
- Updated best found solution, cost: 278
- Evaluating new solution: cost 277, does not meet the tolerances.
- Evaluating new solution: cost 276, meets the tolerances.
- Updated best found solution, cost: 276
- Evaluating new solution: cost 275, meets the tolerances.
- Updated best found solution, cost: 275
- Evaluating new solution: cost 274, meets the tolerances.
- Updated best found solution, cost: 274
- Evaluating new solution: cost 273, meets the tolerances.
- Updated best found solution, cost: 273
- Evaluating new solution: cost 272, meets the tolerances.
- Updated best found solution, cost: 272
- Evaluating new solution: cost 270, meets the tolerances.
- Updated best found solution, cost: 270
- Evaluating new solution: cost 266, meets the tolerances.
- Updated best found solution, cost: 266
- Evaluating new solution: cost 265, meets the tolerances.
- Updated best found solution, cost: 265
- Evaluating new solution: cost 264, meets the tolerances.
- Updated best found solution, cost: 264
- Evaluating new solution: cost 263, meets the tolerances.
- Updated best found solution, cost: 263
- Evaluating new solution: cost 262, meets the tolerances.
- Updated best found solution, cost: 262
- Evaluating new solution: cost 261, meets the tolerances.
- Updated best found solution, cost: 261
- Evaluating new solution: cost 260, does not meet the tolerances.
- Evaluating new solution: cost 259, does not meet the tolerances.
- Evaluating new solution: cost 260, meets the tolerances.
```

```
    - Updated best found solution, cost: 260
    - Evaluating new solution: cost 259, meets the tolerances.
    - Updated best found solution, cost: 259
    - Evaluating new solution: cost 258, meets the tolerances.
    - Updated best found solution, cost: 258
    - Evaluating new solution: cost 257, meets the tolerances.
    - Updated best found solution, cost: 257
    - Evaluating new solution: cost 255, meets the tolerances.
    - Updated best found solution, cost: 255
    - Evaluating new solution: cost 251, meets the tolerances.
    - Updated best found solution, cost: 251
    - Evaluating new solution: cost 250, meets the tolerances.
    - Updated best found solution, cost: 250
    - Evaluating new solution: cost 249, meets the tolerances.
    - Updated best found solution, cost: 249
    - Evaluating new solution: cost 248, meets the tolerances.
    - Updated best found solution, cost: 248
    - Evaluating new solution: cost 247, meets the tolerances.
    - Updated best found solution, cost: 247
    - Evaluating new solution: cost 246, meets the tolerances.
    - Updated best found solution, cost: 246
    - Evaluating new solution: cost 245, does not meet the tolerances.
    - Evaluating new solution: cost 244, does not meet the tolerances.
    - Evaluating new solution: cost 245, meets the tolerances.
    - Updated best found solution, cost: 245
    - Evaluating new solution: cost 244, meets the tolerances.
    - Updated best found solution, cost: 244
+ Optimization has finished.
    - Neighborhood search complete.
+ Fixed-point implementation that met the tolerances found.
    - Total cost: 244
    - Maximum absolute difference: 0.077478
    - Use the explore method of the result to explore the implementation.
```



Use the explore method of the `OptimizationResult` object, `result`, to launch Simulation Data Inspector and explore the design containing the smallest total number of bits while maintaining the numeric tolerances specified in the `opt` object.

```
explore(result);
```

Input Arguments

`model` — Model containing system under design, `sud`
character vector

Name of the model containing the system that you want to optimize.

Data Types: `char`

`sud` — Model or subsystem whose data types you want to optimize
character vector

Model or subsystem whose data types you want to optimize, specified as a character vector containing the path to the system.

Data Types: `char`

`options` — Additional optimization options
`fxpOptimizationOptions` object

`fxpOptimizationOptions` object specifying additional options to use during the data type optimization process.

Output Arguments

`result` — Object containing the optimized design
`OptimizationResult` object

Result of the optimization, returned as an `OptimizationResult` object. Use the `explore` method of the object to open the Simulation Data Inspector and view the behavior of the optimized system. You can also explore other solutions found during the optimization that may or may not meet the constraints specified in the `fxpOptimizationOptions` object, `options`.

See Also

Classes
`OptimizationResult` | `OptimizationSolution` | `fxpOptimizationOptions`

Functions
`addTolerance` | `explore` | `showTolerances`

Topics
"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

ge

Determine whether real-world value of one fi object is greater than or equal to another

Syntax

```
c = ge(a,b)
a >= b
```

Description

c = ge(a,b) is called for the syntax a >= b when a or b is a fi object. a and b must have the same dimensions unless one is a scalar. A scalar can be compared with another object of any size.

a >= b does an element-by-element comparison between a and b and returns a matrix of the same size with elements set to 1 where the relation is true, and 0 where the relation is false.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the fi object, with best-precision scaling.

Examples

Compare Two fi Objects

Use the ge function to determine whether the real-world value of one fi object is greater than or equal to another.

```
a = fi(pi);
b = fi(pi, 1, 32);
b >= a
```

```
ans = logical
   0
```

Input a has a 16-bit word length, while input b has a 32-bit word length. The ge function returns 0 because after quantization, the value of a is slightly greater than that of b.

Compare a Double to a fi Object

When comparing a double to a fi object, the double is cast to the same word length and signedness of the fi object.

```
a = fi(pi);
b = pi;
a >= b
```

```
ans = logical
   1
```

The ge function casts b to the same word length as a, and returns 1 because the two inputs have the same real-world value. This behavior allows relational operations to work between fi objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals with different biases are not supported.

See Also

eq | gt | le | lt | ne

Introduced before R2006a

get

Property values of object

Syntax

```
value = get(o,'propertyname')
structure = get(o)
```

Description

`value = get(o,'propertyname')` returns the property value of the property `'propertyname'` for the object `o`. If you replace `'propertyname'` by a cell array of a vector of strings containing property names, `get` returns a cell array of a vector of corresponding values.

`structure = get(o)` returns a structure containing the properties and states of object `o`.

`o` can be a `fi`, `fimath`, `fipref`, `numerictype`, or `quantizer` object.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The syntax `structure = get(o)` is not supported.

See Also

`set`

Introduced before R2006a

getlsb

Least significant bit

Syntax

`c = getlsb(a)`

Description

`c = getlsb(a)` returns the value of the least significant bit in `a` as a `u1,0`.

`a` can be a scalar `fi` object or a vector `fi` object.

`getlsb` only supports `fi` objects with fixed-point data types.

Examples

The following example uses `getlsb` to find the least significant bit in the `fi` object *a*.

```
a = fi(-26, 1, 6, 0);
c = getlsb(a)

c =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
```

You can verify that the least significant bit in the `fi` object *a* is `0` by looking at the binary representation of *a*.

```
disp(bin(a))

100110
```

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`bitand` | `bitandreduce` | `bitconcat` | `bitget` | `bitor` | `bitorreduce` | `bitset` | `bitxor` | `bitxorreduce` | `getmsb`

Introduced in R2007b

getmsb

Most significant bit

Syntax

```
c = getmsb(a)
```

Description

`c = getmsb(a)` returns the value of the most significant bit in `a` as a `u1,0`.

`a` can be a scalar `fi` object or a vector `fi` object.

`getmsb` only supports `fi` objects with fixed-point data types.

Examples

The following example uses `getmsb` to find the most significant bit in the `fi` object *a*.

```
a = fi(-26, 1, 6, 0);
c = getmsb(a)

c =

     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 1
        FractionLength: 0
>>
```

You can verify that the most significant bit in the `fi` object *a* is `1` by looking at the binary representation of *a*.

```
disp(bin(a))

100110
```

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`bitand` | `bitandreduce` | `bitconcat` | `bitget` | `bitor` | `bitorreduce` | `bitset` | `bitxor` | `bitxorreduce` | `getlsb`

Introduced in R2007b

globalfimath

Configure global fimath and return handle object

Syntax

```
G = globalfimath
G = globalfimath('PropertyName1',PropertyValue1,...)
G = globalfimath(f)
```

Description

`G = globalfimath` returns a handle object to the global fimath. The global fimath has identical properties to a `fimath` object but applies globally.

`G = globalfimath('PropertyName1',PropertyValue1,...)` sets the global fimath using the named properties and their corresponding values. Properties that you do not specify in this syntax are automatically set to that of the current global fimath.

`G = globalfimath(f)` sets the properties of the global fimath to match those of the input `fimath` object *f*, and returns a handle object to it.

Unless, in a previous release, you used the `saveglobalfimathpref` function to save global fimath settings to your MATLAB preferences, the global fimath properties you set with the `globalfimath` function apply only to your current MATLAB session. It is best practice to remove global fimath from the MATLAB preferences so that you start each MATLAB session using the default `fimath` settings. To remove the global fimath, use the `removeglobalfimathpref` function.

Examples

Modifying globalfimath

Use the globalfimath function to set, change, and reset the global fimath.

Create a fimath object and use it as the global fimath.

```
G = globalfimath('RoundMode','Floor','OverflowMode','Wrap')
```

```
G = 
        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Create another fimath object using the new default.

```
F1 = fimath
```

```
F1 = 
        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Create a fi object, A, associated with the global fimath.

```
A = fi(pi)
```

```
A = 
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Now set the "SumMode" property of the global fimath to "KeepMSB" and retain all the other property values of the current global fimath.

```
G = globalfimath('SumMode','KeepMSB')
```

```
G = 
        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: KeepMSB
         SumWordLength: 32
         CastBeforeSum: true
```

Change the global fimath by directly interacting with the handle object G.

```
G.ProductMode = 'SpecifyPrecision'

G =
        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: SpecifyPrecision
     ProductWordLength: 32
 ProductFractionLength: 30
               SumMode: KeepMSB
         SumWordLength: 32
         CastBeforeSum: true
```

Reset the global fimath to the factory default by calling the reset method on G. This is equivalent to using the resetglobalfimath function.

```
reset(G);
G

G =
        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Tips

If you always use the same `fimath` settings and you are not sharing code with other people, using the `globalfimath` function is a quick, convenient method to configure these settings. However, if you share the code with other people or if you use the `fiaccel` function to accelerate the algorithm or you generate C code for your algorithm, consider the following alternatives.

Goal	Issue Using globalfimath	Solution
Share code	If you share code with someone who is using different global `fimath` settings, they might see different results.	Separate the `fimath` properties from your algorithm by using types tables. For more information, see “Separate Data Type Definitions from Algorithm”.

Goal	Issue Using globalfimath	Solution
Accelerate your algorithm using `fiaccel` or generate C code from your MATLAB algorithm using `codegen`	You cannot use `globalfimath` within that algorithm. If you generate code with one `globalfimath` setting and run it with a different `globalfimath` setting, results might vary. For more information, see Specifying Default fimath Values for MEX Functions.	Use types tables in the algorithm from which you want to generate code. This insulates you from the global settings and makes the code portable. For more information, see “Separate Data Type Definitions from Algorithm”.

See Also

`codegen` | `fiaccel` | `fimath` | `removeglobalfimathpref` | `resetglobalfimath`

Introduced in R2010a

gplot

Plot set of nodes using adjacency matrix

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `gplot` reference page for more information.

Introduced before R2006a

gt

Determine whether real-world value of one `fi` object is greater than another

Syntax

```
c = gt(a,b)
a > b
```

Description

`c = gt(a,b)` is called for the syntax `a > b` when `a` or `b` is a `fi` object. `a` and `b` must have the same dimensions unless one is a scalar. A scalar can be compared with another object of any size.

`a > b` does an element-by-element comparison between `a` and `b` and returns a matrix of the same size with elements set to `1` where the relation is true, and `0` where the relation is false.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the `fi` object, with best-precision scaling.

Examples

Compare Two fi Objects

Use the `gt` function to determine whether the real-world value of one `fi` object is greater than another.

```
a = fi(pi);
b = fi(pi, 1, 32);
a > b
```

```
ans = logical
   1
```

Input a has a 16-bit word length, while input b has a 32-bit word length. The gt function returns 1 because after quantization, the value of a is greater than that of b.

Compare a Double to a fi Object

When comparing a double to a fi object, the double is cast to the same word length and signedness of the fi object.

```
a = fi(pi);
b = pi;
a > b
```

```
ans = logical
   0
```

The gt function casts b to the same word length as a, and returns 0 because the two inputs have the same real-world value. This behavior allows relational operations to work between fi objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals with different biases are not supported.

See Also

`eq` | `ge` | `le` | `lt` | `ne`

Introduced before R2006a

hankel

Hankel matrix

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `hankel` reference page for more information.

Introduced before R2006a

hex

Hexadecimal representation of stored integer of `fi` object

Syntax

`hex(a)`

Description

`hex(a)` returns the stored integer of `fi` object `a` in hexadecimal format as a character vector. `hex(a)` is equivalent to `a.hex`.

Fixed-point numbers can be represented as

$$\textit{real-world value} = 2^{-\textit{fraction length}} \times \textit{stored integer}$$

or, equivalently as

$$\textit{real-world value} = (\textit{slope} \times \textit{stored integer}) + \textit{bias}$$

The stored integer is the raw binary number, in which the binary point is assumed to be at the far right of the word.

Examples

Example 4.1. Viewing fi Objects in Hexadecimal Format

The following code

```
a = fi([-1 1],1,8,7);
y = hex(a)
z = a.hex
```

returns

```
y =

        80   7f

z =

        80   7f
```

Example 4.2. Writing Hex Data to a File

The following example shows how to write hex data from the MATLAB workspace into a text file.

First, define your data and create a writable text file called `hexdata.txt`:

```
x = (0:15)'/16;
a = fi(x,0,16,16);

h = fopen('hexdata.txt','w');
```

Use the `fprintf` function to write your data to the `hexdata.txt` file:

```
for k=1:length(a)
    fprintf(h,'%s\n',hex(a(k)));
end
fclose(h);
```

To see the contents of the file you created, use the `type` function:

```
type hexdata.txt
```

MATLAB returns:

```
0000
1000
2000
3000
4000
5000
6000
7000
8000
9000
a000
b000
```

```
c000
d000
e000
f000
```

Example 4.3. Reading Hex Data from a File

The following example shows how to read hex data from a text file back into the MATLAB workspace.

Open `hexdata.txt` for reading and read its contents into a workspace variable:

```
h = fopen('hexdata.txt','r');

nextline = '';
str='';
while ischar(nextline)
    nextline = fgetl(h);
    if ischar(nextline)
        str = [str;nextline];
    end
end
```

Create a `fi` object with the correct scaling and assign it the hex values stored in the `str` variable:

```
b = fi([],0,16,16);
b.hex = str

b =
         0
    0.0625
    0.1250
    0.1875
    0.2500
    0.3125
    0.3750
    0.4375
    0.5000
    0.5625
    0.6250
    0.6875
    0.7500
    0.8125
    0.8750
```

```
    0.9375

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 16
```

See Also

bin | dec | oct | storedInteger

Introduced before R2006a

hex2num

Convert hexadecimal string to number using `quantizer` object

Syntax

```
x = hex2num(q,h)
[x1,x2,...] = hex2num(q,h1,h2,...)
```

Description

`x = hex2num(q,h)` converts hexadecimal character vector `h` to numeric matrix `x`. The attributes of the numbers in `x` are specified by `quantizer` object `q`. When `h` is a cell array, `hex2num` returns `x` as a cell array of the same dimension containing numbers. For fixed-point hexadecimal representations, `hex2num` uses two's complement representation. For floating-point, the representation is IEEE Standard 754 style.

When there are fewer hexadecimal digits than needed to represent the number, the fixed-point conversion zero-fills on the left. Floating-point conversion zero-fills on the right.

`[x1,x2,...] = hex2num(q,h1,h2,...)` converts hexadecimal representations `h1`, `h2`,... to numeric matrices `x1`, `x2`,....

`hex2num` and `num2hex` are inverses of one another, with the distinction that `num2hex` returns the hexadecimal representations in a column.

Examples

To create all the 4-bit fixed-point two's complement numbers in fractional form, use the following code.

```
q = quantizer([4 3]);
h = ['7 3 F B';'6 2 E A';'5 1 D 9';'4 0 C 8'];
x = hex2num(q,h)

x =
```

```
    0.8750    0.3750   -0.1250   -0.6250
    0.7500    0.2500   -0.2500   -0.7500
    0.6250    0.1250   -0.3750   -0.8750
    0.5000         0   -0.5000   -1.0000
```

See Also

bin2num | num2bin | num2hex | num2int

Introduced before R2006a

hist

Create histogram plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `hist` reference page for more information.

Introduced before R2006a

histc

Histogram count

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `histc` reference page for more information.

Introduced before R2006a

horzcat

Horizontally concatenate multiple `fi` objects

Syntax

```
c = horzcat(a,b,...)
[a, b, ...]
```

Description

`c = horzcat(a,b,...)` is called for the syntax `[a, b, ...]` when any of `a`, `b`, ... , is a `fi` object.

`[a b, ...]` or `[a,b, ...]` is the horizontal concatenation of matrices `a` and `b`. `a` and `b` must have the same number of rows. Any number of matrices can be concatenated within one pair of brackets. N-D arrays are horizontally concatenated along the second dimension. The first and remaining dimensions must match.

Horizontal and vertical concatenation can be combined together as in `[1 2;3 4]`.

`[a b; c]` is allowed if the number of rows of `a` equals the number of rows of `b`, and if the number of columns of `a` plus the number of columns of `b` equals the number of columns of `c`.

The matrices in a concatenation expression can themselves be formed via a concatenation as in `[a b;[c d]]`.

Note The `fimath` and `numerictype` properties of a concatenated matrix of `fi` objects `c` are taken from the leftmost `fi` object in the list `(a,b,...)`.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`vertcat`

Introduced before R2006a

imag

Imaginary part of complex number

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `imag` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

innerprodintbits

Number of integer bits needed for fixed-point inner product

Syntax

innerprodintbits(a,b)

Description

innerprodintbits(a,b) computes the minimum number of integer bits necessary in the inner product of a'*b to guarantee that no overflows occur and to preserve best precision.

- a and b are fi vectors.
- The values of a are known.
- Only the numeric type of b is relevant. The values of b are ignored.

Examples

The primary use of this function is to determine the number of integer bits necessary in the output Y of an FIR filter that computes the inner product between constant coefficient row vector B and state column vector Z. For example,

```
for k=1:length(X);
  Z = [X(k);Z(1:end-1)];
  Y(k) = B * Z;
end
```

Algorithms

In general, an inner product grows log2(n) bits for vectors of length n. However, in the case of this function the vector a is known and its values do not change. This knowledge is used to compute the smallest number of integer bits that are necessary in the output to guarantee that no overflow will occur.

The largest gain occurs when the vector `b` has the same sign as the constant vector `a`. Therefore, the largest gain due to the vector `a` is `a*sign(a')`, which is equal to `sum(abs(a))`.

The overall number of integer bits necessary to guarantee that no overflow occurs in the inner product is computed by:

```
n = ceil(log2(sum(abs(a)))) + number of integer bits in b + 1 sign bit
```

The extra sign bit is only added if both `a` and `b` are signed and `b` attains its minimum. This prevents overflow in the event of (-1)*(-1).

Introduced before R2006a

int8

Convert fi object to signed 8-bit integer

Syntax

c = int8(a)

Description

c = int8(a) returns the built-in int8 value of fi object a, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an int8.

Examples

This example shows the int8 values of a fi object.

```
a = fi([-pi 0.1 pi],1,8);
c = int8(a)

c =

   -3    0    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

int16 | int32 | int64 | storedInteger | uint16 | uint32 | uint64 | uint8

Introduced before R2006a

int16

Convert `fi` object to signed 16-bit integer

Syntax

`c = int16(a)`

Description

`c = int16(a)` returns the built-in `int16` value of `fi` object `a`, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an `int16`.

Examples

This example shows the `int16` values of a fi object.

```
a = fi([-pi 0.1 pi],1,16);
c = int16(a)

c =

   -3    0    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`int32` | `int64` | `int8` | `storedInteger` | `uint16` | `uint32` | `uint64` | `uint8`

Introduced before R2006a

int32

Convert `fi` object to signed 32-bit integer

Syntax

`c = int32(a)`

Description

`c = int32(a)` returns the built-in `int32` value of `fi` object `a`, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an `int32`.

Examples

This example shows the `int32` values of a fi object.

```
a = fi([-pi 0.1 pi],1,32);
c = int32(a)

c =

   -3    0    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`int16` | `int64` | `int8` | `storedInteger` | `uint16` | `uint32` | `uint64` | `uint8`

Introduced before R2006a

int64

Convert `fi` object to signed 64-bit integer

Syntax

`c = int64(a)`

Description

`c = int64(a)` returns the built-in `int64` value of `fi` object `a`, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an `int64`.

Examples

This example shows the `int64` values of a fi object.

```
a = fi([-pi 0.1 pi],1,64);
c = int64(a)

c =

   -3    0    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`int16` | `int32` | `int8` | `storedInteger` | `uint16` | `uint32` | `uint64` | `uint8`

Introduced in R2008b

intmax

Largest positive stored integer value representable by `numerictype` of `fi` object

Syntax

```
x = intmax(a)
```

Description

`x = intmax(a)` returns the largest positive stored integer value representable by the `numerictype` of `a`.

Examples

```
a = fi(pi, true, 16, 12);
x = intmax(a)

x =

       32767

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 0
```

See Also

`eps` | `intmin` | `lowerbound` | `lsb` | `range` | `realmax` | `realmin` | `stripscaling` | `upperbound`

Introduced before R2006a

intmin

Smallest stored integer value representable by `numerictype` of `fi` object

Syntax

`x = intmin(a)`

Description

`x = intmin(a)` returns the smallest stored integer value representable by the `numerictype` of `a`.

Examples

```
a = fi(pi, true, 16, 12);
x = intmin(a)
```

```
x = 

      -32768

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 0
```

See Also

`eps` | `intmax` | `lowerbound` | `lsb` | `range` | `realmax` | `realmin` | `stripscaling` | `upperbound`

Introduced before R2006a

ipermute

Inverse permute dimensions of multidimensional array

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ipermute` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isboolean

Determine whether input is Boolean

Syntax

```
y = isboolean(a)
y = isboolean(T)
```

Description

`y = isboolean(a)` returns `1` when the `DataType` property of `fi` object `a` is `boolean`, and `0` otherwise.

`y = isboolean(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `boolean`, and `0` otherwise.

See Also

`isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified` | `issingle`

Introduced in R2008a

iscolumn

Determine whether `fi` object is column vector

Syntax

`y = iscolumn(a)`

Description

`y = iscolumn(a)` returns `1` if the `fi` object `a` is a column vector, and `0` otherwise.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`isrow`

Introduced before R2006a

isdouble

Determine whether input is double-precision data type

Syntax

```
y = isdouble(a)
y = isdouble(T)
```

Description

`y = isdouble(a)` returns `1` when the `DataType` property of `fi` object `a` is `double`, and `0` otherwise.

`y = isdouble(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `double`, and `0` otherwise.

See Also

`isboolean` | `isfixed` | `isfloat` | `isscaleddouble` | `isscaledtype` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified` | `issingle`

Introduced in R2008a

isempty

Determine whether array is empty

Description

Refer to the MATLAB `isempty` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isequal

Determine whether real-world values of two fi objects are equal, or determine whether properties of two fimath, numerictype, or quantizer objects are equal

Syntax

```
y = isequal(a,b,...)
y = isequal(F,G,...)
y = isequal(T,U,...)
y = isequal(q,r,...)
```

Description

y = isequal(a,b,...) returns 1 if all the fi object inputs have the same real-world value. Otherwise, the function returns 0.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the fi object, with best-precision scaling.

y = isequal(F,G,...) returns 1 if all the fimath object inputs have the same properties. Otherwise, the function returns 0.

y = isequal(T,U,...) returns 1 if all the numerictype object inputs have the same properties. Otherwise, the function returns 0.

y = isequal(q,r,...) returns 1 if all the quantizer object inputs have the same properties. Otherwise, the function returns 0.

Examples

Compare Two fi Objects

Use the isequal function to determine if two fi objects have the same real-world value.

```
a = fi(pi);
b = fi(pi, 1, 32);
y = isequal(a, b)
```

```
y = logical
   0
```

Input `a` has a 16-bit word length, while input `b` has a 32-bit word length. The `isequal` function returns `0` because the two `fi` objects do not have the same real-world value.

Compare a Double to a fi Object

When comparing a double to a `fi` object, the double is cast to the same word length and signedness of the `fi` object.

```
a = fi(pi);
b = pi;
y = isequal(a, b)
```

```
y = logical
   1
```

The `isequal` function casts `b` to the same word length as `a`, and returns `1`. This behavior allows relational operations to work between `fi` objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`eq` | `fi` | `fimath` | `ispropequal` | `numerictype` | `quantizer`

Introduced before R2006a

isequivalent

Determine if two numerictype objects have equivalent properties

Syntax

```
y = isequivalent (T1, T2)
```

Description

y = isequivalent (T1, T2) determines whether the numerictype object inputs have equivalent properties and returns a logical 1 (true) or 0 (false). Two numerictype objects are equivalent if they describe the same data type.

Examples

Compare two numerictype objects

Use isequivalent to determine if two numerictype objects have the same data type.

```
T1 = numerictype(1, 16, 2^-12, 0)
```

```
T1 =


          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
            WordLength: 16
                 Slope: 2^-12
                  Bias: 0
```

```
T2 = numerictype(1, 16, 12)
```

```
T2 =
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 12
```

```
isequivalent(T1,T2)
```

```
ans = logical
   1
```

Although the Data Type Mode is different for `T1` and `T2`, the function returns `1` (`true`) because the two objects have the same data type.

Input Arguments

T1, T2 — Inputs to be compared
`numerictype` objects

Inputs to be compared, specified as `numerictype` objects.

See Also

`eq` | `isequal` | `ispropequal`

Introduced in R2014a

isfi

Determine whether variable is `fi` object

Syntax

```
y = isfi(a)
```

Description

`y = isfi(a)` returns `1` if `a` is a `fi` object, and `0` otherwise.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Avoid using the `isfi` function in code that you intend to convert using the automated workflow. The value returned by `isfi` in the fixed-point code might differ from the value returned in the original MATLAB algorithm. The behavior of the fixed-point code might differ from the behavior of the original algorithm.

See Also

`fi` | `isfimath` | `isfipref` | `isnumerictype` | `isquantizer`

Introduced before R2006a

isfimath

Determine whether variable is `fimath` object

Syntax

```
y = isfimath(F)
```

Description

`y = isfimath(F)` returns `1` if `F` is a `fimath` object, and `0` otherwise.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`fimath` | `isfi` | `isfipref` | `isnumerictype` | `isquantizer`

Introduced before R2006a

isfimathlocal

Determine whether fi object has local fimath

Syntax

```
y = isfimathlocal(a)
```

Description

`y = isfimathlocal(a)` returns `1` if the `fi` object `a` has a local `fimath` object, and 0 if `a` does not have a local fimath.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`fimath` | `isfi` | `isfimathlocal` | `isfipref` | `isnumerictype` | `isquantizer` | `removefimath` | `sfi` | `ufi`

Introduced in R2009b

isfinite

Determine whether array elements are finite

Description

Refer to the MATLAB `isfinite` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isfipref

Determine whether input is `fipref` object

Syntax

```
y = isfipref(P)
```

Description

`y = isfipref(P)` returns `1` if `P` is a `fipref` object, and `0` otherwise.

See Also

`fipref` | `isfi` | `isfimath` | `isnumerictype` | `isquantizer`

Introduced in R2008a

isfixed

Determine whether input is fixed-point data type

Syntax

```
y = isfixed(a)
y = isfixed(T)
y = isfixed(q)
```

Description

`y = isfixed(a)` returns `1` when the `DataType` property of `fi` object `a` is `Fixed`, and `0` otherwise.

`y = isfixed(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `Fixed`, and `0` otherwise.

`y = isfixed(q)` returns `1` when `q` is a fixed-point `quantizer`, and `0` otherwise.

See Also

`isboolean` | `isdouble` | `isfloat` | `isscaleddouble` | `isscaledtype` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified` | `issingle`

Introduced in R2008a

isfloat

Determine whether input is floating-point data type

Syntax

```
y = isfloat(a)
y = isfloat(T)
y = isfloat(q)
```

Description

`y = isfloat(a)` returns `1` when the `DataType` property of `fi` object `a` is `single` or `double`, and `0` otherwise.

`y = isfloat(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `single` or `double`, and `0` otherwise.

`y = isfloat(q)` returns `1` when `q` is a floating-point `quantizer`, and `0` otherwise.

See Also

`isboolean` | `isdouble` | `isfixed` | `isscaleddouble` | `isscaledtype` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified` | `issingle`

Introduced in R2008a

isinf

Determine whether array elements are infinite

Description

Refer to the MATLAB `isinf` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isnan

Determine whether array elements are NaN

Description

Refer to the MATLAB `isnan` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isnumeric

Determine whether input is numeric array

Description

Refer to the MATLAB `isnumeric` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isnumerictype

Determine whether input is `numerictype` object

Syntax

```
y = isnumerictype(T)
```

Description

`y = isnumerictype(T)` returns `1` if `T` is a `numerictype` object, and `0` otherwise.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`isfi` | `isfimath` | `isfipref` | `isquantizer` | `numerictype`

Introduced before R2006a

isobject

Determine whether input is MATLAB object

Description

Refer to the MATLAB `isobject` reference page for more information.

Introduced before R2006a

ispropequal

Determine whether properties of two `fi` objects are equal

Syntax

```
y = ispropequal(a,b,...)
```

Description

`y = ispropequal(a,b,...)` returns `1` if all the inputs are `fi` objects and all the inputs have the same properties. Otherwise, the function returns `0`.

To compare the real-world values of two `fi` objects `a` and `b`, use `a == b` or `isequal(a,b)`.

See Also

`fi` | `isequal`

Introduced before R2006a

isquantizer

Determine whether input is `quantizer` object

Syntax

```
y = isquantizer(q)
```

Description

`y = isquantizer(q)` returns `1` when `q` is a `quantizer` object, and `0` otherwise.

See Also

`isfi` | `isfimath` | `isfipref` | `isnumerictype` | `quantizer`

Introduced in R2008a

isreal

Determine whether array elements are real

Description

Refer to the MATLAB `isreal` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isrow

Determine whether `fi` object is row vector

Syntax

```
y = isrow(a)
```

Description

`y = isrow(a)` returns `1` if the `fi` object `a` is a row vector, and `0` otherwise.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`iscolumn`

Introduced before R2006a

isscalar

Determine whether input is scalar

Description

Refer to the MATLAB `isscalar` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

isscaleddouble

Determine whether input is scaled double data type

Syntax

```
y = isscaleddouble(a)
y = isscaleddouble(T)
```

Description

`y = isscaleddouble(a)` returns `1` when the `DataType` property of `fi` object `a` is `ScaledDouble`, and `0` otherwise.

`y = isscaleddouble(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `ScaledDouble`, and `0` otherwise.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaledtype` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified` | `issingle`

Introduced in R2008a

isscaledtype

Determine whether input is fixed-point or scaled double data type

Syntax

```
y = isscaledtype(a)
y = isscaledtype(T)
```

Description

`y = isscaledtype(a)` returns `1` when the `DataType` property of `fi` object `a` is `Fixed` or `ScaledDouble`, and `0` otherwise.

`y = isscaledtype(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `Fixed` or `ScaledDouble`, and `0` otherwise.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified` | `issingle` | `numerictype`

Introduced in R2008a

isscalingbinarypoint

Determine whether input has binary point scaling

Syntax

```
y = isscalingbinarypoint(a)
y = isscalingbinarypoint(T)
```

Description

`y = isscalingbinarypoint(a)` returns `1` when the `fi` object `a` has binary point scaling or trivial slope and bias scaling. Otherwise, the function returns `0`. Slope and bias scaling is trivial when the slope is an integer power of two and the bias is zero.

`y = isscalingbinarypoint(T)` returns `1` when the `numerictype` object `T` has binary point scaling or trivial slope and bias scaling. Otherwise, the function returns `0`. Slope and bias scaling is trivial when the slope is an integer power of two and the bias is zero.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscaledtype` | `isscalingslopebias` | `isscalingunspecified` | `issingle`

Introduced in R2010b

isscalingslopebias

Determine whether input has nontrivial slope and bias scaling

Syntax

```
y = isscalingslopebias(a)
y = isscalingslopebias(T)
```

Description

`y = isscalingslopebias(a)` returns `1` when the `fi` object `a` has nontrivial slope and bias scaling, and `0` otherwise. Slope and bias scaling is trivial when the slope is an integer power of two and the bias is zero.

`y = isscalingslopebias(T)` returns `1` when the `numerictype` object `T` has nontrivial slope and bias scaling, and `0` otherwise. Slope and bias scaling is trivial when the slope is an integer power of two and the bias is zero.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscaledtype` | `isscalingbinarypoint` | `isscalingunspecified` | `issingle`

Introduced in R2010b

isscalingunspecified

Determine whether input has unspecified scaling

Syntax

```
y = isscalingunspecified(a)
y = isscalingunspecified(T)
```

Description

`y = isscalingunspecified(a)` returns `1` if `fi` object `a` has a fixed-point or scaled double data type and its scaling has not been specified.

`y = isscalingunspecified(T)` returns `1` if `numerictype` object `T` has a fixed-point or scaled double data type and its scaling has not been specified.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscaledtype` | `isscalingbinarypoint` | `isscalingslopebias` | `issingle`

Introduced in R2010b

issigned

Determine whether `fi` object is signed

Syntax

```
y = issigned(a)
```

Description

`y = issigned(a)` returns `1` if the `fi` object `a` is signed, and `0` if it is unsigned.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

issingle

Determine whether input is single-precision data type

Syntax

```
y = issingle(a)
y = issingle(T)
```

Description

`y = issingle(a)` returns `1` when the `DataType` property of `fi` object `a` is `single`, and `0` otherwise.

`y = issingle(T)` returns `1` when the `DataType` property of `numerictype` object `T` is `single`, and `0` otherwise.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscaledtype` | `isscalingbinarypoint` | `isscalingslopebias` | `isscalingunspecified`

Introduced in R2008a

isslopebiasscaled

Determine whether `numerictype` object has nontrivial slope and bias

Syntax

```
y = isslopebiasscaled(T)
```

Description

`y = isslopebiasscaled(T)` returns `1` when `numerictype` object `T` has nontrivial slope and bias scaling, and `0` otherwise. Slope and bias scaling is trivial when the slope is an integer power of 2, and the bias is `0`.

See Also

`isboolean` | `isdouble` | `isfixed` | `isfloat` | `isscaleddouble` | `isscaledtype` | `issingle` | `numerictype`

Introduced in R2008a

isvector

Determine whether input is vector

Description

Refer to the MATLAB `isvector` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

le

Determine whether real-world value of `fi` object is less than or equal to another

Syntax

```
c = le(a,b)
a <= b
```

Description

`c = le(a,b)` is called for the syntax `a <= b` when `a` or `b` is a `fi` object. `a` and `b` must have the same dimensions unless one is a scalar. A scalar can be compared with another object of any size.

`a <= b` does an element-by-element comparison between `a` and `b` and returns a matrix of the same size with elements set to `1` where the relation is true, and `0` where the relation is false.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the `fi` object, with best-precision scaling.

Examples

Compare Two fi Objects

Use the `le` function to determine whether the real-world value of one `fi` object is less than or equal to another.

```
a = fi(pi);
b = fi(pi, 1, 32);
a <= b
```

```
ans = logical
   0
```

Input `a` has a 16-bit word length, while input `b` has a 32-bit word length. The `le` function returns `0` because after quantization, the value of `a` is greater than that of `b`.

Compare a Double to a fi Object

When comparing a double to a `fi` object, the double is cast to the same word length and signedness of the `fi` object.

```
a = fi(pi);
b = pi;
a <= b
```

```
ans = logical
   1
```

The `le` function casts `b` to the same word length as `a`, and returns `1` because the two inputs have the same real-world value. This behavior allows relational operations to work between `fi` objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals with different biases are not supported.

See Also

eq | ge | gt | lt | ne

Introduced before R2006a

length

Vector length

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `length` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

line

Create line object

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `line` reference page for more information.

Introduced before R2006a

logical

Convert numeric values to logical

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `logical` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

loglog

Create log-log scale plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `loglog` reference page for more information.

Introduced before R2006a

logreport

Quantization report

Syntax

```
logreport(a)
logreport(a, b, ...)
```

Description

`logreport(a)` displays the `minlog`, `maxlog`, `lowerbound`, `upperbound`, `noverflows`, and `nunderflows` for the `fi` object `a`.

`logreport(a, b, ...)` displays the report for each `fi` object `a, b, ...`.

Examples

The following example produces a `logreport` for `fi` objects `a` and `b`:

```
fipref('LoggingMode','On');
a = fi(pi);
b = fi(randn(10),1,8,7);

Warning: 27 overflows occurred in the fi assignment operation.
Warning: 1 underflow occurred in the fi assignment operation.

logreport(a,b)
         minlog      maxlog  lowerbound    upperbound   noverflows   nunderflows
 a    3.141602    3.141602          -4      3.999878            0             0
 b          -1   0.9921875          -1     0.9921875           27             1
```

See Also

`fipref` | `quantize` | `quantizer`

Introduced in R2008a

lowerbound

Lower bound of range of `fi` object

Syntax

```
lowerbound(a)
```

Description

`lowerbound(a)` returns the lower bound of the range of `fi` object `a`. If `L=lowerbound(a)` and `U=upperbound(a)`, then `[L,U]=range(a)`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`eps` | `intmax` | `intmin` | `lsb` | `range` | `realmax` | `realmin` | `upperbound`

Introduced before R2006a

lsb

Scaling of least significant bit of `fi` object, or value of least significant bit of `quantizer` object

Syntax

```
b = lsb(a)
p = lsb(q)
```

Description

`b = lsb(a)` returns the scaling of the least significant bit of `fi` object `a`. The result is equivalent to the result given by the `eps` function.

`p = lsb(q)` returns the quantization level of `quantizer` object `q`, or the distance from `1.0` to the next largest floating-point number if `q` is a floating-point `quantizer` object.

Examples

This example uses the `lsb` function to find the value of the least significant bit of the `quantizer` object `q`.

```
q = quantizer('fixed',[8 7]);
p = lsb(q)
```

```
p =

    0.0078
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Code generation supports scalar fixed-point signals only.
- Code generation supports scalar, vector, and matrix, `fi` single and double signals.

See Also

`eps` | `intmax` | `intmin` | `lowerbound` | `quantize` | `range` | `realmax` | `realmin` | `upperbound`

Introduced before R2006a

lt

Determine whether real-world value of one `fi` object is less than another

Syntax

```
c = lt(a,b)
a < b
```

Description

`c = lt(a,b)` is called for the syntax `a < b` when `a` or `b` is a `fi` object. `a` and `b` must have the same dimensions unless one is a scalar. A scalar can be compared with another object of any size.

`a < b` does an element-by-element comparison between `a` and `b` and returns a matrix of the same size with elements set to `1` where the relation is true, and `0` where the relation is false.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the `fi` object, with best-precision scaling.

Examples

Compare Two fi Objects

Use the `lt` function to determine whether the real-world value of one `fi` object is less than another.

```
a = fi(pi);
b = fi(pi, 1, 32);
a < b
```

```
ans = logical
   0
```

Input `a` has a 16-bit word length, while input `b` has a 32-bit word length. The `lt` function returns `0` because after quantization, the value of `a` is greater than that of `b`.

Compare a Double to a fi Object

When comparing a double to a `fi` object, the double is cast to the same word length and signedness of the `fi` object.

```
a = fi(pi);
b = pi;
a < b
```

```
ans = logical
   0
```

The `lt` function casts `b` to the same word length as `a`, and returns `0` because the two inputs have the same real-world value. This behavior allows relational operations to work between `fi` objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals with different biases are not supported.

See Also

eq | ge | gt | le | ne

Introduced before R2006a

mat2str

Convert matrix to string

Syntax

```
str = mat2str(A)
str = mat2str(A, n)
str = mat2str(A, 'class')
str = mat2str(A, n, 'class')
```

Description

`str = mat2str(A)` converts `fi` object `A` to a string representation. The output is suitable for input to the `eval` function such that `eval(str)` produces the original `fi` object exactly.

`str = mat2str(A, n)` converts `fi` object `A` to a string representation using `n` bits of precision.

`str = mat2str(A, 'class')` creates a string representation with the name of the class of `A` included. This option ensures that the result of evaluating `str` will also contain the class information.

`str = mat2str(A, n, 'class')` uses `n` bits of precision and includes the class of `A`.

Examples

Convert fi Object to a String

Convert the `fi` object `a` to a string.

```
a = fi(pi);
str = mat2str(a)
```

```
str =
'3.1416015625'
```

Convert fi Object to a String with Specified Precision

Convert the `fi` object `a` to a string using eight bits of precision.

```
a = fi(pi);
str = mat2str(a, 8)
```

```
str =
'3.1416016'
```

Input Arguments

`A` — Input array
scalar | vector | matrix

Input array, specified as a scalar, vector, or matrix. `A` cannot be a multidimensional array.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

n — Number of bits of precision
positive integer

Number of bits of precision in the output, specified as a positive integer.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

`str` — String representation of input array
character array

String representation of input array, returned as a character array.

See Also

`mat2str` | `tostring`

Introduced in R2015b

max

Largest element in array of `fi` objects

Syntax

```
x = max(a)
x= max(a,[],dim)
[x,y] = max( ___ )

m = max(a,b)
```

Description

`x = max(a)` returns the largest elements along different dimensions of `fi` array `a`.

If `a` is a vector, `max(a)` returns the largest element in `a`.

If `a` is a matrix, `max(a)` treats the columns of `a` as vectors, returning a row vector containing the maximum element from each column.

If `a` is a multidimensional array, `max` operates along the first nonsingleton dimension and returns an array of maximum values.

`x= max(a,[],dim)` returns the largest elements along dimension `dim`.

`[x,y] = max( ___ )` finds the indices of the maximum values and returns them in array `y`, using any of the input arguments in the previous syntaxes. If the largest value occurs multiple times, the index of the first occurrence is returned.

`m = max(a,b)` returns an array the same size as `a` and `b` with the largest elements taken from `a` or `b`.

Examples

Largest Element in a Vector

Create a fixed-point vector, and return the maximum value from the vector.

```
a = fi([1,5,4,9,2],1,16);
x = max(a)
```

```
x = 
     9

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

Largest Element of Each Matrix Row

Create a fixed-point matrix.

```
a = fi(magic(4),1,16)
```

```
a = 
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

Find the largest element of each row by finding the maximum values along the second dimension.

```
x = max(a,[],2)
```

```
x = 
    16
    11
    12
    15
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

The output vector, `x`, is a column vector that contains the largest element of each row.

Largest Element of Each Matrix Column

Create a fixed-point matrix.

```
a = fi(magic(4),1,16)
```

```
a =
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

Find the largest element of each column.

```
x = max(a)
```

```
x =
    16    14    15    13

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

The output, `x`, is a row vector that contains the largest elements from each column of `a`.

Find the index of each of the maximum elements.

```
[x,y] = max(a)
```

```
x =
    16    14    15    13
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10

y = 1×4

     1     4     4     1
```

Vector y contains the indices to the minimum elements in x.

Maximum Elements from Two Arrays

Create two fixed-point arrays of the same size.

```
a = fi([2.3,4.7,6;0,7,9.23],1,16);
b = fi([9.8,3.21,1.6;pi,2.3,1],1,16);
```

Find the largest elements from a or b.

```
m = max(a,b)
```

```
m =
    9.7998    4.7002    6.0000
    3.1416    7.0000    9.2300

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

m contains the largest elements from each pair of corresponding elements in a and b.

Largest Element of a Complex Vector

Create a complex fixed-point vector, a.

```
a = fi([1+2i,3+6i,6+3i,2-4i],1,16)
```

```
a =
   1.0000 + 2.0000i   3.0000 + 6.0000i   6.0000 + 3.0000i   2.0000 - 4.0000i

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 12
```

The function finds the largest element of a complex vector by taking the element with the largest magnitude.

```
abs(a)
```

```
ans =
    2.2361    6.7083    6.7083    4.4722

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 12
```

In vector `a`, the largest elements, at position `2` and `3`, have a magnitude of `6.7083`. The `max` function returns the largest element in output `x` and the index of that element in output `y`.

```
[x,y] = max(a)
```

```
x =
   3.0000 + 6.0000i

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 12

y = 2
```

Although the elements at index 2 and 3 have the same magnitude, the index of the first occurrence of that value is always returned.

Input Arguments

a — Input `fi` array

`fi` object | numeric variable

`fi` input array, specified as a scalar, vector, matrix, or multidimensional array. The dimensions of `a` and `b` must match unless one is a scalar.

The `max` function ignores `NaNs`.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

b — Second input `fi` array

`fi` object | numeric variable

Second `fi` input array, specified as a scalar, vector, matrix, or multidimensional array. The dimensions of `a` and `b` must match unless one is a scalar.

The `max` function ignores `NaNs`.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

`dim` — dimension to operate along

positive integer scalar

Dimension to operate along, specified as a positive integer scalar. `dim` can also be a `fi` object. If you do not specify a value, the default value is the first array dimension whose size does not equal 1.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Output Arguments

x — Maximum values
scalar | vector | matrix | multidimensional array

Maximum values, returned as a scalar, vector, matrix, or multidimensional array. `x` always has the same data type as the input.

y — Index of maximum values
scalar | vector | matrix | multidimensional array

Indices of the maximum values in array `x`, returned as a scalar, vector, matrix, or multidimensional array. If the largest value occurs more than once, then `y` contains the index to the first occurrence of the value. `y` is always of data type `double`.

m — Array of maximum values
scalar | vector | matrix | multidimensional array

Array of maximum values of `a` and `b`, returned as a scalar, vector, matrix, or multidimensional array.

Algorithms

When `a` or `b` is complex, the `max` function returns the elements with the largest magnitude. If two magnitudes are equal, then `max` returns the first value. This behavior differs from how the builtin `max` function resolves ties between complex numbers.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`mean` | `median` | `min` | `sort`

Introduced before R2006a

maxlog

Log maximums

Syntax

```
y = maxlog(a)
y = maxlog(q)
```

Description

`y = maxlog(a)` returns the largest real-world value of `fi` object `a` since logging was turned on or since the last time the log was reset for the object.

Turn on logging by setting the `fipref` object `LoggingMode` property to `on`. Reset logging for a `fi` object using the `resetlog` function.

`y = maxlog(q)` is the maximum value after quantization during a call to `quantize(q,...)` for `quantizer` object `q`. This value is the maximum value encountered over successive calls to `quantize` since logging was turned on, and is reset with `resetlog(q)`. `maxlog(q)` is equivalent to `get(q,'maxlog')` and `q.maxlog`.

Examples

Example 1: Using maxlog with fi objects

```
P = fipref('LoggingMode','on');
format long g
a = fi([-1.5 eps 0.5], true, 16, 15);
a(1) = 3.0;
maxlog(a)

Warning: 1 overflow occurred in the fi
assignment operation.
> In embedded.fi.fi at 510
```

```
  In fi at 220

Warning: 1 underflow occurred in the fi
 assignment operation.
> In embedded.fi.fi at 510
  In fi at 220

Warning: 1 overflow occurred in the fi
assignment operation.

ans =

         0.999969482421875
```

The largest value `maxlog` can return is the maximum representable value of its input. In this example, `a` is a signed `fi` object with word length `16`, fraction length `15` and range:

$$-1 \leq x \leq 1 - 2^{-15}$$

You can obtain the numerical range of any `fi` object `a` using the `range` function:

```
format long g
r = range(a)

r =

                        -1         0.999969482421875
```

Example 2: Using maxlog with quantizer objects

```
q = quantizer;
warning on
format long g
x = [-20:10];
y = quantize(q,x);
maxlog(q)

Warning: 29 overflows.
> In embedded.quantizer.quantize at 74

ans =

        .999969482421875
```

The largest value `maxlog` can return is the maximum representable value of its input. You can obtain the range of `x` after quantization using the `range` function:

```
format long g
r = range(q)

r =

                        -1         0.999969482421875
```

See Also

`fipref` | `minlog` | `noverflows` | `nunderflows` | `reset` | `resetlog`

Introduced before R2006a

mean

Average or mean value of fixed-point array

Syntax

```
c = mean(a)
c = mean(a,dim)
```

Description

`c = mean(a)` computes the mean value of the fixed-point array *a* along its first nonsingleton dimension.

`c = mean(a,dim)` computes the mean value of the fixed-point array *a* along dimension *dim*. *dim* must be a positive, real-valued integer with a power-of-two slope and a bias of 0.

The input to the `mean` function must be a real-valued fixed-point array.

The fixed-point output array *c* has the same `numerictype` properties as the fixed-point input array *a*. If the input, *a*, has a local `fimath`, then it is used for intermediate calculations. The output, *c*, is always associated with the default `fimath`.

When *a* is an empty fixed-point array (value = `[]`), the value of the output array is zero.

Examples

Compute the mean value along the first dimension (rows) of a fixed-point array.

```
x = fi([0 1 2; 3 4 5], 1, 32);
% x is a signed FI object with a 32-bit word length
% and a best-precision fraction length of 28-bits
mx1 = mean(x,1)
```

Compute the mean value along the second dimension (columns) of a fixed-point array.

```
x = fi([0 1 2; 3 4 5], 1, 32);
% x is a signed FI object with a 32-bit word length
% and a best-precision fraction length of 28 bits
mx2 = mean(x,2)
```

Algorithms

The general equation for computing the `mean` of an array *a*, across dimension *dim* is:

```
sum(a,dim)/size(a,dim)
```

Because `size(a,dim)` is always a positive integer, the algorithm casts `size(a,dim)` to an unsigned 32-bit `fi` object with a fraction length of zero (`SizeA`). The algorithm then computes the mean of *a* according to the following equation, where `Tx` represents the `numerictype` properties of the fixed-point input array *a*:

```
c = Tx.divide(sum(a,dim), SizeA)
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`max` | `median` | `min`

Introduced in R2010a

median

Median value of fixed-point array

Syntax

```
c = median(a)
c = median(a,dim)
```

Description

`c = median(a)` computes the median value of the fixed-point array *a* along its first nonsingleton dimension.

`c = median(a,dim)` computes the median value of the fixed-point array *a* along dimension *dim*. *dim* must be a positive, real-valued integer with a power-of-two slope and a bias of 0.

The input to the `median` function must be a real-valued fixed-point array.

The fixed-point output array *c* has the same `numerictype` properties as the fixed-point input array *a*. If the input, *a*, has a local `fimath`, then it is used for intermediate calculations. The output, *c*, is always associated with the default `fimath`.

When *a* is an empty fixed-point array (value = `[]`), the value of the output array is zero.

Examples

Compute the median value along the first dimension of a fixed-point array.

```
x = fi([0 1 2; 3 4 5; 7 2 2; 6 4 9], 1, 32)
% x is a signed FI object with a 32-bit word length
% and a best-precision fraction length of 27 bits
mx1 = median(x,1)
```

Compute the median value along the second dimension (columns) of a fixed-point array.

```
x = fi([0 1 2; 3 4 5; 7 2 2; 6 4 9], 1, 32)
% x is a signed FI object with a 32-bit word length
% and a best-precision fraction length of 27 bits
mx2 = median(x, 2)
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

max | mean | min

Introduced in R2010a

mesh

Create mesh plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `mesh` reference page for more information.

Introduced before R2006a

meshc

Create mesh plot with contour plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `meshc` reference page for more information.

Introduced before R2006a

meshz

Create mesh plot with curtain plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `meshz` reference page for more information.

Introduced before R2006a

min

Smallest element in array of `fi` objects

Syntax

```
x = min(a)
x= min(a,[],dim)
[x,y] = min( ___ )

m = min(a,b)
```

Description

`x = min(a)` returns the smallest elements along different dimensions of `fi` array `a`.

If `a` is a vector, `min(a)` returns the smallest element in `a`.

If `a` is a matrix, `min(a)` treats the columns of `a` as vectors, returning a row vector containing the minimum element from each column.

If `a` is a multidimensional array, `min` operates along the first nonsingleton dimension and returns an array of minimum values.

`x= min(a,[],dim)` returns the smallest elements along dimension `dim`.

`[x,y] = min( ___ )` finds the indices of the minimum values and returns them in array `y`, using any of the input arguments in the previous syntaxes. If the smallest value occurs multiple times, the index of the first occurrence is returned.

`m = min(a,b)` returns an array the same size as `a` and `b` with the smallest elements taken from `a` or `b`.

Examples

Smallest Element in a Vector

Create a fixed-point vector, and return the minimum value from the vector.

```
a = fi([1,5,4,9,2],1,16);
x = min(a)
```

```
x = 
     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

Minimum Element of Each Matrix Row

Create a matrix of fixed-point values.

```
a = fi(magic(4),1,16)
```

```
a = 
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

Find the smallest element of each row by finding the minimum values along the second dimension.

```
x = min(a,[],2)
```

```
x = 
     2
     5
     6
     1
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

The output, x, is a column vector that contains the smallest element of each row of a.

Minimum Element of Each Matrix Column

Create a fixed-point matrix.

```
a = fi(magic(4),1,16)
```

```
a = 
    16     2     3    13
     5    11    10     8
     9     7     6    12
     4    14    15     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

Find the smallest element of each column.

```
x = min(a)
```

```
x = 
     4     2     3     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

The output, x, is a row vector that contains the smallest element of each column of a.

Find the index of each of the minimum elements.

```
[x,y] = min(a)
```

```
x = 
     4     2     3     1
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 10
```

```
y = 1×4

     4     1     1     4
```

Minimum Elements from Two Arrays

Create two fixed-point arrays of the same size.

```
a = fi([2.3,4.7,6;0,7,9.23],1,16);
b = fi([9.8,3.21,1.6;pi,2.3,1],1,16);
```

Find the minimum elements from `a` or `b`.

```
m = min(a,b)
```

```
m = 
    2.2998    3.2100    1.6001
         0    2.2998    1.0000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

`m` contains the smallest elements from each pair of corresponding elements in `a` and `b`.

Minimum Element of a Complex Vector

Create a complex fixed-point vector, `a`.

```
a = fi([1+2i,2+i,3+8i,9+i],1,8)
```

```
a = 
   1.0000 + 2.0000i   2.0000 + 1.0000i   3.0000 + 8.0000i   9.0000 + 1.0000i
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3
```

The function finds the smallest element of a complex vector by taking the element with the smallest magnitude.

```
abs(a)
```

```
ans =
    2.2500    2.2500    8.5000    9.0000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3
```

In vector `a`, the smallest elements, at position `1` and `2`, have a magnitude of `2.25`. The `min` function returns the smallest element in output `x`, and the index of that element in output, `y`.

```
[x,y] = min(a)
```

```
x =
   1.0000 + 2.0000i

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3

y = 1
```

Although the elements at index 1 and 2 have the same magnitude, the index of the first occurrence of that value is always returned.

Input Arguments

a — Input `fi` array

`fi` object | numeric variable

fi input array, specified as a scalar, vector, matrix, or multidimensional array. The dimensions of a and b must match unless one is a scalar.

The min function ignores NaNs.

Data Types: fi|single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

Complex Number Support: Yes

b — Second input fi array

fi object | numeric variable

Second fi input array, specified as a scalar, vector, matrix, or multidimensional array. The dimensions of a and b must match unless one is a scalar.

The min function ignores NaNs.

Data Types: fi|single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

Complex Number Support: Yes

dim — dimension to operate along

positive integer scalar

Dimension to operate along, specified as a positive integer scalar. dim can also be a fi object. If you do not specify a value, the default value is the first array dimension whose size does not equal 1.

Data Types: fi|single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

Output Arguments

x — Minimum values

scalar | vector | matrix | multidimensional array

Minimum values, returned as a scalar, vector, matrix, or multidimensional array. x always has the same data type as the input.

y — Index of minimum values
scalar | vector | matrix | multidimensional array

Indices of the minimum values in array x, returned as a scalar, vector, matrix, or multidimensional array. If the smallest value occurs more than once, then y contains the index to the first occurrence of the value. y is always of data type double.

m — Array of minimum values
scalar | vector | matrix | multidimensional array

Array of minimum values of a and b, returned as a scalar, vector, matrix, or multidimensional array.

Algorithms

When a or b is complex, the min function returns the element with the smallest magnitude. If two magnitudes are equal, then min returns the first value. This behavior differs from how the builtin min function resolves ties between complex numbers.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

max | mean | median | sort

Introduced before R2006a

minlog

Log minimums

Syntax

```
y = minlog(a)
y = minlog(q)
```

Description

`y = minlog(a)` returns the smallest real-world value of `fi` object `a` since logging was turned on or since the last time the log was reset for the object.

Turn on logging by setting the `fipref` object `LoggingMode` property to `on`. Reset logging for a `fi` object using the `resetlog` function.

`y = minlog(q)` is the minimum value after quantization during a call to `quantize(q,...)` for `quantizer` object `q`. This value is the minimum value encountered over successive calls to `quantize` since logging was turned on, and is reset with `resetlog(q)`. `minlog(q)` is equivalent to `get(q,'minlog')` and `q.minlog`.

Examples

Example 1: Using minlog with fi objects

```
P = fipref('LoggingMode','on');
a = fi([-1.5 eps 0.5], true, 16, 15);
a(1) = 3.0;
minlog(a)

ans =

     -1
```

The smallest value `minlog` can return is the minimum representable value of its input. In this example, `a` is a signed `fi` object with word length `16`, fraction length `15` and range:

$-1 \leq x \leq 1 - 2^{-15}$

You can obtain the numerical range of any `fi` object `a` using the `range` function:

```
format long g
r = range(a)

r =

                        -1         0.999969482421875
```

Example 2: Using minlog with quantizer objects

```
q = quantizer;
warning on
x = [-20:10];
y = quantize(q,x);
minlog(q)

Warning: 29 overflows.
> In embedded.quantizer.quantize at 74

ans =

    -1
```

The smallest value `minlog` can return is the minimum representable value of its input. You can obtain the range of `x` after quantization using the `range` function:

```
format long g
r = range(q)

r =

                        -1         0.999969482421875
```

See Also

`fipref` | `maxlog` | `noverflows` | `nunderflows` | `reset` | `resetlog`

Introduced before R2006a

minus

Matrix difference between `fi` objects

Syntax

`minus(a,b)`

Description

`minus(a,b)` is called for the syntax `a - b` when `a` or `b` is an object.

`a - b` subtracts matrix `b` from matrix `a`. `a` and `b` must have the same dimensions unless one is a scalar value (a 1-by-1 matrix). A scalar value can be subtracted from any other value.

`minus` does not support `fi` objects of data type `Boolean`.

Note For information about the `fimath` properties involved in Fixed-Point Designer calculations, see "fimath Properties Usage for Fixed-Point Arithmetic" and "fimath ProductMode and SumMode" in the Fixed-Point Designer User's Guide.

For information about calculations using Fixed-Point Designer software, see the Fixed-Point Designer documentation.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Any non-`fi` input must be constant; that is, its value must be known at compile time so that it can be cast to a `fi` object.

See Also

`mtimes` | `plus` | `times` | `uminus`

Introduced before R2006a

mod

Modulus after division for `fi` objects

Syntax

```
M = mod(X,Y)
```

Description

`M = mod(X,Y)` if `Y ~= 0`, returns `X-n.*Y`, where `n = floor(X./Y)`. The inputs `X` and `Y` must be real arrays of the same size, or either can be a real scalar. For fixed-point or integer input arguments, the output data type is the aggregate type of both input signedness, word lengths, and fraction lengths. For floating-point input arguments, the output data type is the same as the inputs.

The `mod` function ignores and discards any `fimath` attached to the inputs. The output is always associated with the default `fimath`.

Note The combination of fixed-point and floating-point inputs is not currently supported.

Input Arguments

X

Integer, fixed-point, or floating-point array, or real scalar.

Y

Array of the same size as `X`, or real scalar.

Output Arguments

M

Result of modulus operation. If both inputs X and Y are floating-point, then the data type of M is the same as the inputs. If either input X or Y is fixed-point, then the data type of M is the aggregate numerictype. This value equals that of `fixed.aggregateType(X,Y)`.

Examples

Calculate the `mod` of two `fi` objects.

```
% 7-bit signed fixed-point object
x = fi(-3,1,7,0);
% 15-bit signed fixed-point object
y = fi(2,1,15,0);
M1 = mod(x,y)
M1 =

     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 15
        FractionLength: 0
M2 = mod(y,x)
M2 =

    -1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 15
        FractionLength: 0
```

Convert the `fi` inputs in the previous example to double type, and calculate the `mod`.

```
Mf1 = mod(double(x),double(y))
Mf1 =

     1
Mf2 = mod(double(y),double(x))
```

```
Mf2 =

    -1
```

See Also

fixed.aggregateType | mod

Introduced in R2011b

mpower

Fixed-point matrix power (^)

Syntax

```
c = mpower(a,k)
c = a^k
```

Description

`c = mpower(a,k)` and `c = a^k` compute matrix power. The exponent *k* requires a positive, real-valued integer value.

The fixed-point output array *c* has the same local fimath as the input *a*. If *a* has no local fimath, the output *c* also has no local fimath. The matrix power operation is performed using default fimath settings.

Examples

Compute the power of a 2-dimensional square matrix for exponent values 0, 1, 2, and 3.

```
x = fi([0 1; 2 4], 1, 32);

px0 = x^0
px1 = x^1
px2 = x^2
px3 = x^3
```

Tips

For more information about the `mpower` function, see the MATLAB `mpower` reference page.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- When the exponent `k` is a variable and the input is a scalar, the `ProductMode` property of the governing `fimath` must be `SpecifyPrecision`.
- When the exponent `k` is a variable and the input is not scalar, the `SumMode` property of the governing `fimath` must be `SpecifyPrecision`.
- Variable-sized inputs are only supported when the `SumMode` property of the governing `fimath` is set to `SpecifyPrecision` or `Keep LSB`.
- For variable-sized signals, you may see different results between the generated code and MATLAB.
  - In the generated code, the output for variable-sized signals is computed using the `SumMode` property of the governing `fimath`.
  - In MATLAB, the output for variable-sized signals is computed using the `SumMode` property of the governing `fimath` when the first input, *a*, is nonscalar. However, when *a* is a scalar, MATLAB computes the output using the `ProductMode` of the governing `fimath`.

See Also

`mpower` | `power`

Introduced in R2010a

mpy

Multiply two objects using `fimath` object

Syntax

```
c = mpy(F,a,b)
```

Description

`c = mpy(F,a,b)` performs elementwise multiplication on `a` and `b` using `fimath` object `F`. This is helpful in cases when you want to override the `fimath` objects of `a` and `b`, or if the `fimath` properties associated with `a` and `b` are different. The output `fi` object `c` has no local fimath.

`a` and `b` can both be `fi` objects with the same dimensions unless one is a scalar. If either `a` or `b` is scalar, then `c` has the dimensions of the nonscalar object. `a` and `b` can also be doubles, singles, or integers.

Examples

In this example, `c` is the 40-bit product of `a` and `b` with fraction length 30.

```
a = fi(pi);
b = fi(exp(1));
F = fimath('ProductMode','SpecifyPrecision',...
        'ProductWordLength',40,'ProductFractionLength',30);
c = mpy(F, a, b)

c =

    8.5397


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
           WordLength: 40
       FractionLength: 30
```

Algorithms

`c = mpy(F,a,b)` is similar to

```
a.fimath = F;
b.fimath = F;
c = a .* b

c =
    8.5397

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 40
        FractionLength: 30

        RoundingMethod: nearest
        OverflowAction: saturate
           ProductMode: SpecifyPrecision
     ProductWordLength: 40
 ProductFractionLength: 30
               SumMode: FullPrecision
```

but not identical. When you use `mpy`, the `fimath` properties of `a` and `b` are not modified, and the output `fi` object `c` has no local fimath. When you use the syntax `c = a .* b`, where `a` and `b` have their own `fimath` objects, the output `fi` object `c` gets assigned the same `fimath` object as inputs `a` and `b`. See “fimath Rules for Fixed-Point Arithmetic” in the Fixed-Point Designer User's Guide for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Code generation does not support the syntax `F.mpy(a,b)`. You must use the syntax `mpy(F,a,b)`.
- When you provide complex inputs to the `mpy` function inside of a MATLAB Function block, you must declare the input as complex before running the simulation. To do so, go to the **Ports and data manager** and set the **Complexity** parameter for all known complex inputs to `On`.

See Also

`add` | `divide` | `fi` | `fimath` | `mrdivide` | `numerictype` | `rdivide` | `sub` | `sum`

Introduced before R2006a

mrdivide

Forward slash (/) or right-matrix division

Syntax

```
c = mrdivide(a,b)
c = a/b
```

Description

`c = mrdivide(a,b)` and `c = a/b` perform right-matrix division.

When one or both of the inputs is a `fi` object, the denominator input, `b`, must be a scalar and the output `fi` object `c` is equivalent to `c = rdivide(a,b)` or `c = a./b` (right-array division).

The numerator input `a` can be complex, but the denominator input `b` must always be real-valued. When the numerator input `a` is complex, the real and imaginary parts of `a` are independently divided by `b`.

For information on the data type rules used by the `mrdivide` function, see the `rdivide` reference page.

Examples

In this example, you use the forward slash (/) to perform right matrix division on a 3-by-3 magic square of `fi` objects. Because the numerator input is a `fi` object, the denominator input `b` must be a scalar:

```
a = fi(magic(3))
b = fi(3, 1, 12, 8)
c = a/b
```

The `mrdivide` function outputs a signed 3-by-3 array of `fi` objects, each of which has a word length of 16 bits and a fraction length of 3 bits.

```
a =

     8     1     6
     3     5     7
     4     9     2

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
b =

     3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 12
        FractionLength: 8

c =

    2.6250    0.3750    2.0000
    1.0000    1.6250    2.3750
    1.3750    3.0000    0.6250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

add | divide | fi | fimath | numerictype | rdivide | sub | sum

Introduced in R2009a

mtimes

Matrix product of fi objects

Syntax

```
mtimes(a,b)
```

Description

mtimes(a,b) is called for the syntax a * b when a or b is an object.

a * b is the matrix product of a and b. A scalar value (a 1-by-1 matrix) can multiply any other value. Otherwise, the number of columns of a must equal the number of rows of b.

mtimes does not support fi objects of data type Boolean.

Note For information about the fimath properties involved in Fixed-Point Designer calculations, see “fimath Properties Usage for Fixed-Point Arithmetic” and “fimath ProductMode and SumMode” in the Fixed-Point Designer documentation.

For information about calculations using Fixed-Point Designer software, see the Fixed-Point Designer documentation.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Any non-fi input must be constant; that is, its value must be known at compile time so that it can be cast to a fi object.

- Variable-sized inputs are only supported when the `SumMode` property of the governing `fimath` is set to `SpecifyPrecision` or `KeepLSB`.
- For variable-sized signals, you may see different results between the generated code and MATLAB.

  - In the generated code, the output for variable-sized signals is computed using the `SumMode` property of the governing `fimath`.
  - In MATLAB, the output for variable-sized signals is computed using the `SumMode` property of the governing `fimath` when both inputs are nonscalar. However, if either input is a scalar, MATLAB computes the output using the `ProductMode` of the governing `fimath`.

See Also

`minus` | `plus` | `times` | `uminus`

Introduced before R2006a

ndgrid

Generate arrays for N-D functions and interpolation

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ndgrid` reference page for more information.

Introduced in R2008a

ndims

Number of array dimensions

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ndims` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

ne

Determine whether real-world values of two `fi` objects are not equal

Syntax

```
c = ne(a,b)
a ~= b
```

Description

`c = ne(a,b)` is called for the syntax `a ~= b` when `a` or `b` is a `fi` object. `a` and `b` must have the same dimensions unless one is a scalar. A scalar can be compared with another object of any size.

`a ~= b` does an element-by-element comparison between `a` and `b` and returns a matrix of the same size with elements set to `1` where the relation is true, and `0` where the relation is false.

In relational operations comparing a floating-point value to a fixed-point value, the floating-point value is cast to the same word length and signedness as the `fi` object, with best-precision scaling.

Examples

Compare Two fi Objects

Use the `ne` function to determine whether the real-world values of two `fi` objects are not equal.

```
a = fi(pi);
b = fi(pi, 1, 32);
a ~= b
```

```
ans = logical
   1
```

Input a has a 16-bit word length, while input b has a 32-bit word length. The ne function returns 1 because after quantization, the value of a is greater than that of b.

Compare a Double to a fi Object

When comparing a double to a fi object, the double is cast to the same word length and signedness of the fi object.

```
a = fi(pi);
b = pi;
a ~= b
```

```
ans = logical
   0
```

The ne function casts b to the same word length as a, and returns 0 because the two inputs have the same real-world value. This behavior allows relational operations to work between fi objects and floating-point constants without introducing floating-point values in generated code.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals with different biases are not supported.

See Also

eq | ge | gt | le | lt

Introduced before R2006a

nearest

Round toward nearest integer with ties rounding toward positive infinity

Syntax

```
y = nearest(a)
```

Description

`y = nearest(a)` rounds `fi` object `a` to the nearest integer or, in case of a tie, to the nearest integer in the direction of positive infinity, and returns the result in `fi` object `y`.

`y` and `a` have the same `fimath` object and `DataType` property.

When the `DataType` property of `a` is `Single`, `Double`, or `Boolean`, the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is zero or negative, `a` is already an integer, and the `numerictype` of `y` is the same as that of `a`.

When the fraction length of `a` is positive, the fraction length of `y` is `0`, its sign is the same as that of `a`, and its word length is the difference between the word length and the fraction length of `a`, plus one bit. If `a` is signed, then the minimum word length of `y` is `2`. If `a` is unsigned, then the minimum word length of `y` is `1`.

For complex `fi` objects, the imaginary and real parts are rounded independently.

`nearest` does not support `fi` objects with nontrivial slope and bias scaling. Slope and bias scaling is trivial when the slope is an integer power of 2 and the bias is 0.

Examples

Example 1

The following example demonstrates how the `nearest` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 3.

```
a = fi(pi, 1, 8, 3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3
y = nearest(a)

y =

     3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 0
```

Example 2

The following example demonstrates how the `nearest` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 12.

```
a = fi(0.025,1,8,12)

a =

    0.0249

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
```

```
        FractionLength: 12

y = nearest(a)

y =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 2
        FractionLength: 0
```

Example 3

The functions `convergent`, `nearest` and `round` differ in the way they treat values whose least significant digit is 5:

- The `convergent` function rounds ties to the nearest even integer
- The `nearest` function rounds ties to the nearest integer toward positive infinity
- The `round` function rounds ties to the nearest integer with greater absolute value

The following table illustrates these differences for a given `fi` object `a`.

a	convergent(a)	nearest(a)	round(a)
–3.5	–4	–3	–4
–2.5	–2	–2	–3
–1.5	–2	–1	–2
–0.5	0	0	–1
0.5	0	1	1
1.5	2	2	2
2.5	2	3	3
3.5	4	4	4

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`ceil` | `convergent` | `fix` | `floor` | `round`

Introduced in R2008a

noperations

Number of operations

Syntax

```
noperations(q)
```

Description

`noperations(q)` is the number of quantization operations during a call to `quantize(q,...)` for `quantizer` object `q`. This value accumulates over successive calls to `quantize`. You reset the value of `noperations` to zero by issuing the command `resetlog(q)`.

Each time any data element is quantized, `noperations` is incremented by one. The real and complex parts are counted separately. For example, `(complex * complex)` counts four quantization operations for products and two for sum, because`(a+bi)*(c+di) = (a*c - b*d) + (a*d + b*c)`. In contrast, `(real*real)` counts one quantization operation.

In addition, the real and complex parts of the inputs are quantized individually. As a result, for a complex input of length 204 elements, `noperations` counts 408 quantizations: 204 for the real part of the input and 204 for the complex part.

If any inputs, states, or coefficients are complex-valued, they are all expanded from real values to complex values, with a corresponding increase in the number of quantization operations recorded by `noperations`. In concrete terms, `(real*real)` requires fewer quantizations than `(real*complex)` and `(complex*complex)`. Changing all the values to complex because one is complex, such as the coefficient, makes the `(real*real)` into `(real*complex)`, raising `noperations` count.

See Also

`maxlog` | `minlog`

Introduced before R2006a

not

Find logical NOT of array or scalar input

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `not` reference page for more information.

Introduced before R2006a

noverflows

Number of overflows

Syntax

```
y = noverflows(a)
y = noverflows(q)
```

Description

`y = noverflows(a)` returns the number of overflows of `fi` object `a` since logging was turned on or since the last time the log was reset for the object.

Turn on logging by setting the `fipref` property `LoggingMode` to `on`. Reset logging for a `fi` object using the `resetlog` function.

`y = noverflows(q)` returns the accumulated number of overflows resulting from quantization operations performed by a `quantizer` object `q`.

See Also

`maxlog` | `minlog` | `nunderflows` | `resetlog`

Introduced before R2006a

nts

Determine fixed-point data type

Syntax

```
nts
nts({'block',PORT})
nts({line-handle})
nts({gsl})
```

Description

`nts` opens the `NumericTypeScope` window. To connect to a signal in a Simulink model, select the signal and then, in the `NumericTypeScope` window, select **File > Connect to Simulink Signal**.

The `NumericTypeScope` suggests a fixed-point data type in the form of a `numerictype` object based on the dynamic range of the input data and the criteria that you specify in the "Bit Allocation Panel" on page 4-642. The scope allows you to visualize the dynamic range of data in the form of a `log2` histogram. It displays the data values on the X-axis and the number or percentage of occurrences on the Y-axis. Each bin in the histogram corresponds to a bit in a word. For example, 2^0 corresponds to the first integer bit in the binary word, 2^{-1} corresponds to the first fractional bit in the binary word.

`nts({'block',PORT})` opens the `NumericTypeScope` window and connects the scope to the signal output from `block` on output port with index `PORT`. If the block has more than one output port, you must specify the port index. The scope cannot connect to more than one output port.

`nts({line-handle})` opens the `NumericTypeScope` window and connects the scope to the Simulink signal which has the line handle specified in `line-handle`.

`nts({gsl})` opens the `NumericTypeScope` window and connects the scope to the currently selected Simulink signal. You must select a signal in a Simulink model first, otherwise the scope opens with no signal selected.

Input Arguments

block

Full path to the specified block.

line-handle

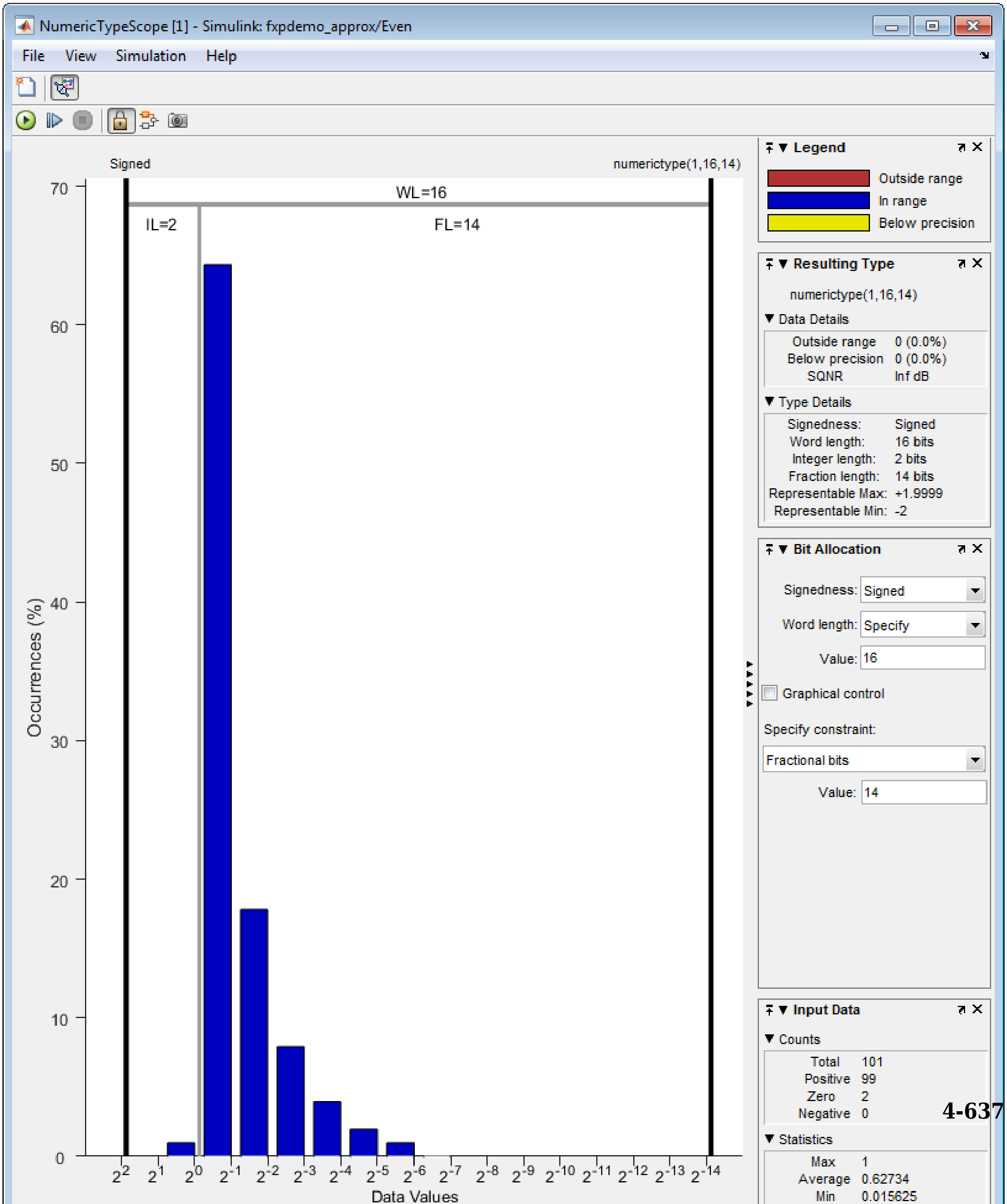
Handle of the Simulink signal that you want to view with the scope. To get the handle of the currently selected signal, at the MATLAB command line, enter `gsl`.

PORT

Index of the output port that you want to view with the scope. If the block has more than one output port, you must specify the index. The scope cannot connect to more than one output port.

The NumericTypeScope Window

The `NumericTypeScope` opens with the default toolbars on page 4-638 displayed at the top of the window and the dialog panels on page 4-642 to the right.


NumericTypeScope [1] - Simulink: fxpdemo_approx/Even
File
View
Simulation
Help
Legend
Outside range
In range
Below precision
Resulting Type
numerictype(1,16,14)
Data Details
Outside range 0 (0.0%)
Below precision 0 (0.0%)
SQNR Inf dB
Type Details
Signedness: Signed
Word length: 16 bits
Integer length: 2 bits
Fraction length: 14 bits
Representable Max: +1.9999
Representable Min: -2
Bit Allocation
Signedness: Signed
Word length: Specify
Value: 16
Graphical control
Specify constraint:
Fractional bits
Value: 14
Input Data
Counts
Total 101
Positive 99
Zero 2
Negative 0
Statistics
Max 1
Average 0.62734
Min 0.015625
Signed
numerictype(1,16,14)
WL=16
IL=2
FL=14
Occurrences (%)
Data Values
70
60
50
40
30
20
10
0
2^2 2^1 2^0 2^-1 2^-2 2^-3 2^-4 2^-5 2^-6 2^-7 2^-8 2^-9 2^-10 2^-11 2^-12 2^-13 2^-14

Toolbars

By default the scope displays a toolbar that provides these options:

Button	Action
	New NumericTypeScope.
	Connect to Simulink signal. The scope connects to the currently selected signal. If a block with only one output port is selected and the **Connect scope on selection of** is set to `Signal lines or blocks`, connects to the output port of the selected block. For more information, see "Sources Pane" on page 4-641.

After connecting the scope to a signal in a Simulink model, the scope displays an additional toolbar with the following options:

Button	Action
	Stop simulation
	Start simulation
	Simulate one step
	Snapshot. Freezes the display so that you can examine the results. To reenable display refreshing, click the button again.
	Highlight Simulink signal.
	Persistent. By default, the scope makes a persistent connection to the selected signal. If you want to view different signals during the simulation, click this button to make a floating connection. You can then select any signal in the model and the scope displays it.

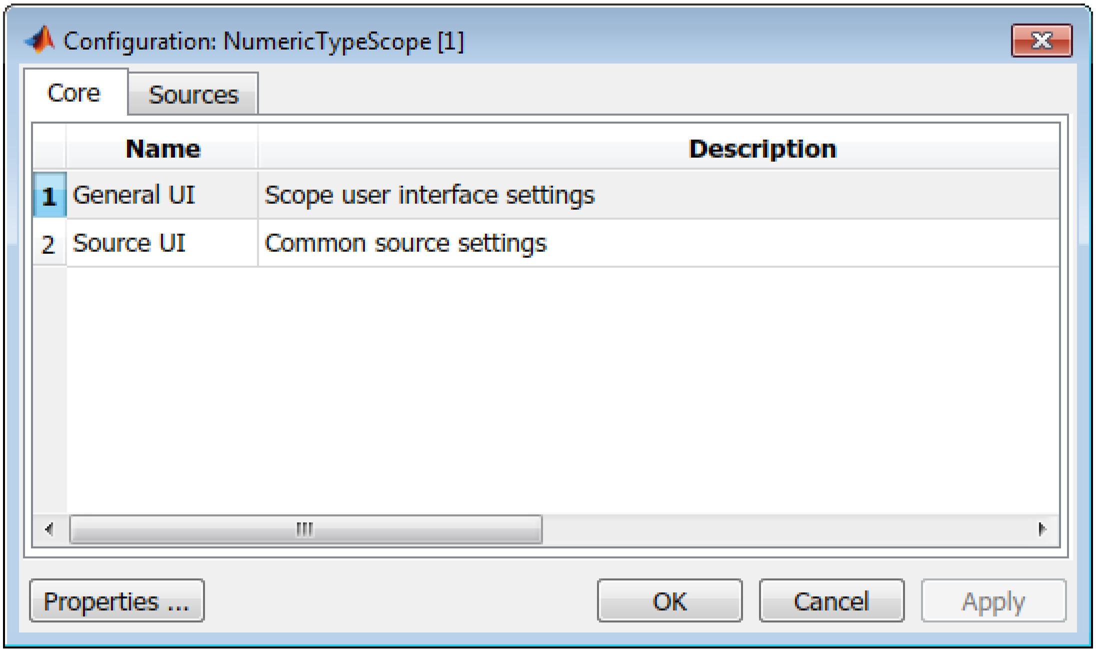
Dialog Boxes and Panels

- "Configuration Dialog Box" on page 4-639
- "Dialog Panels" on page 4-642

Configuration Dialog Box

Use the `NumericTypeScope` configuration dialog box to control the behavior and appearance of the scope window.

To open the **Configuration** dialog box, from the scope main menu, select **File > Configuration > Edit**, or, with the scope as your active window, press the **N** key.



For information about each pane, see "Core Pane" on page 4-640 and "Sources Pane" on page 4-641.

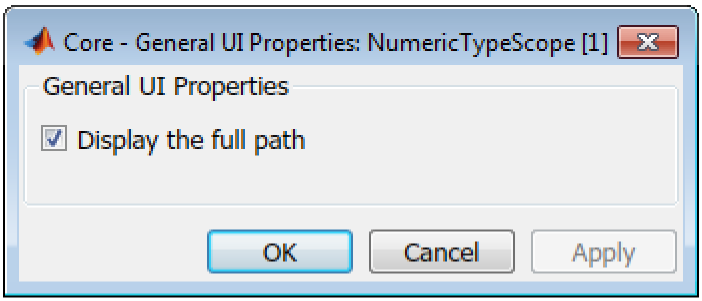
To save configuration settings for future use, select **File > Configuration > Save as**. The configuration settings you save become the default configuration settings for the `NumericTypeScope`.

Caution Before saving your own set of configuration settings in the `matlab/toolbox/fixpoint` folder, save a backup copy of the default configuration settings in another location. If you do not save a backup copy of the default configuration settings, you cannot restore these settings at a later time.

To save your configuration settings for future use, save them in the `matlab/toolbox/fixpoint` folder with the file name `NumericTypeScopeSL.cfg`. You can re-save your configuration settings at anytime, but you must save them in this folder with this filename.

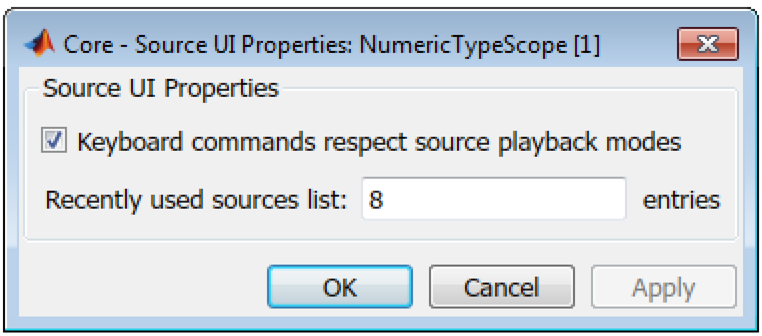
The **Core** pane controls the general settings of the scope.

To open the **Core - General UI Properties** dialog box, select **General UI** and then click **Properties**.



- **Display the full source path in the title bar**—Select this check box to display the full path to the selected block in the model. Otherwise, the scope displays only the block name.

To open the **Core - Source UI Properties** dialog box, select **Source UI** and then click **Properties**.



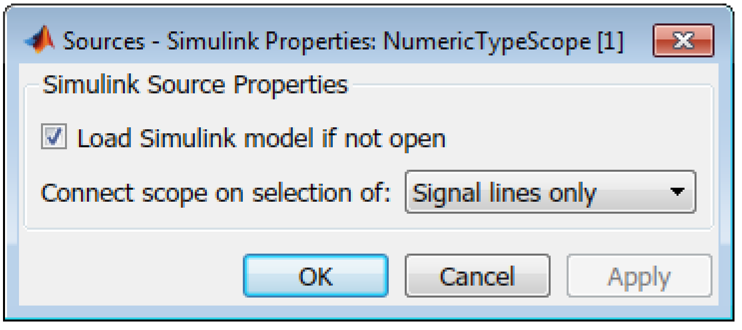
- **Keyboard commands respect source playback modes**—Has no effect. The following table shows the keyboard shortcut mapping. You cannot disable this mapping.

Action	Keyboard Shortcut
Open new NumericTypeScope	Insert
Change configuration	N
Display keyboard help	K
Play simulation	P
Pause simulation	Space
Stop simulation	S
Step forward	Right arrow, Page down

- **Recently used sources list**—Sets the maximum number of recently used sources displayed under the **Files** menu option.

The **Sources** pane controls how the scope connects to Simulink. You cannot disable the Simulink source.

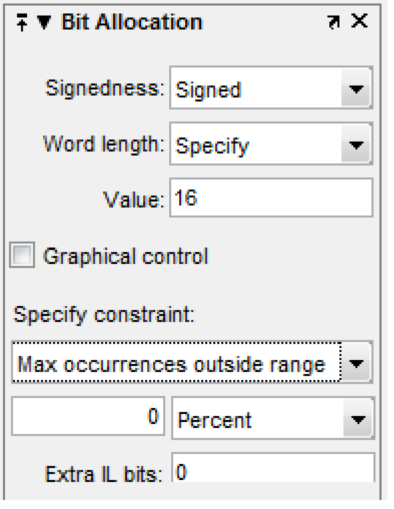
To open the **Sources - Simulink Properties** dialog box, select the **Sources** tab and then click **Properties**.



- **Load Simulink model if not open**—When selected, if you specify a signal in a Simulink model that is not currently open, the scope opens the model.
- **Connect scope on selection of**—Connects the scope only when you select signal lines or when you select signal lines or blocks. If you select `Signal lines or blocks`, the scope cannot connect to blocks that have more than one output port.

Dialog Panels

The scope **Bit Allocation** panel provides options for specifying data type criteria. Adjust these criteria to observe the effect on suggested numerictype. For streaming data, the suggested numerictype adjusts over time in order to continue to satisfy the specified criteria.

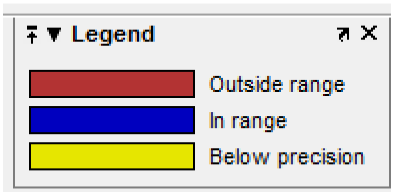


You can:

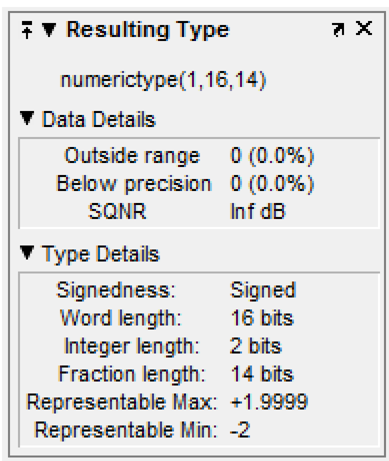
- Specify a known word length and signedness and, using **Specify constraint**, add additional constraints such as the maximum number of occurrences outside range or the smallest value that the suggested data type must represent.
- Specify **Integer length** and **Fraction length** constraints so that the scope suggests an appropriate word length.
- Set the **Signedness** and **Word length** to `Auto` so that the scope suggests values for these parameters.
- Enable **Graphical control** and use the cursors on either side of the binary point to adjust the fraction length and observe the effect on the suggested numerictype on the input data. For example, you can see the number of values that are outside range, below precision, or both. You can also view representable minimum and maximum values of the changed suggested data type.

- Specify extra bits for either the fraction length or the integer length. The extra bits act as a safety margin to minimize the risk of overflow and precision loss.

The scope **Legend** panel informs you which colors the scope uses to indicate values. These colors represent values that are outside range, in range, or below precision when displayed in the scope.



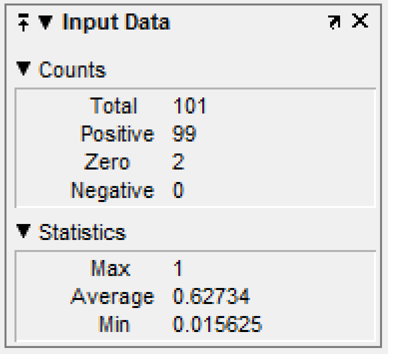
The **Resulting Type** panel describes the fixed-point data type as defined by scope settings. By manipulating the visual display (via the **Bit Allocation** panel or with the cursors), you can change the data type specification.



The **Data Details** section displays the percentage of values that fall outside range or below precision with the `numerictype` object located at the top of this panel. SQNR (Signal Quantization Noise Ratio) varies depending on the signal. If the parameter has no value, then there is not enough data to calculate the SQNR. When scope information or the `numerictype` changes, the SQNR resets.

The **Type Details** section provides details about the fixed-point data type. You can copy the numerictype specification by right-clicking the **Resulting Type** pane and then selecting `Copy numerictype`.

The **Input Data** panel provides statistical information about the values currently displayed in the `NumericScopeType`.



Examples

Connect a NumericTypeScope to a signal in a Simulink model

Open a `NumericTypeScope` window and connect to a signal.

Open the model.

```
fxpdemo_approx
```

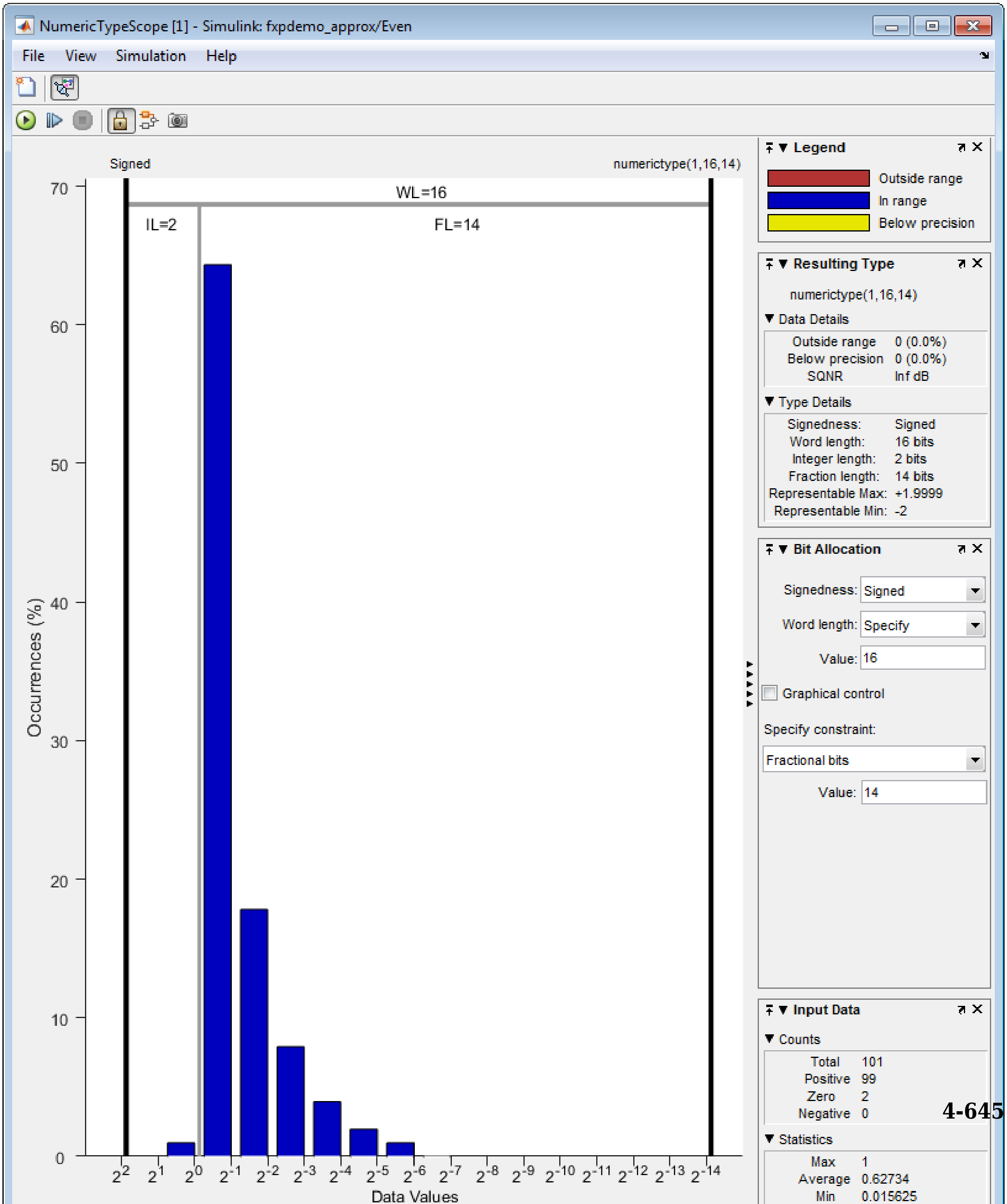
Open a NumericTypeScope.

```
nts
```

In the `fxpdemo_approx` model, select the `yEven` signal.

In the `NumericTypeScope` window, select **File > Connect to Simulink Signal**.

Run the simulation to view the dynamic range of the output. The `NumericTypeScope` suggests a data type for the output.


NumericTypeScope [1] - Simulink: fxpdemo_approx/Even
File View Simulation Help
Signed
numerictype(1,16,14)
WL=16
IL=2
FL=14
Occurrences (%)
Data Values
Legend
Outside range
In range
Below precision
Resulting Type
numerictype(1,16,14)
Data Details
Outside range 0 (0.0%)
Below precision 0 (0.0%)
SQNR Inf dB
Type Details
Signedness: Signed
Word length: 16 bits
Integer length: 2 bits
Fraction length: 14 bits
Representable Max: +1.9999
Representable Min: -2
Bit Allocation
Signedness: Signed
Word length: Specify
Value: 16
Graphical control
Specify constraint:
Fractional bits
Value: 14
Input Data
Counts
Total 101
Positive 99
Zero 2
Negative 0
Statistics
Max 1
Average 0.62734
Min 0.015625

Connect a NumericTypeScope to a block output port

Connect a NumericTypeScope to a block output port and view the dynamic range of block output.

Specify the block path and name and the output port number.

```
blk='fxpdemo_approx/Even';
nts({blk,1})
```

Run the simulation to view the dynamic range of the output. The `NumericTypeScope` suggests a data type for the output.

Specify a Simulink signal to display

Connect a NumericTypeScope to a signal selected in a model.

Open the model.

```
fxpdemo_approx
```

In the `fxpdemo_approx` model, select the `yEven` signal.

Open a `NumericTypeScope`, specifying the line handle of the selected signal.

```
nts({gsl})
```

Tips

- Use the `NumericTypeScope` to help you identify any values that are outside range or below precision based on the current data type.

  When the information is available, the scope indicates values that are outside range, below precision, and in range of the data type by color-coding the histogram bars as follows:

  - Blue — Histogram bin contains values that are in range of the current data type.
  - Red — Histogram bin contains values that are outside range in the current data type.

  - Yellow — Histogram bin contains values that are below precision in the current data type.
- Select **View** > **Vertical Units** to select whether to display values as a percentage or as an actual count.
- Use the **View** > **Bring All NumericTypeScope Windows Forward** menu option to manage your `NumericTypeScope` windows. Selecting this option or pressing **Ctrl+F** brings all `NumericTypeScope` windows into view.

See Also

`hist` | `log2` | `numerictypescope`

Introduced in R2012a

num2bin

Convert number to binary representation using `quantizer` object

Syntax

```
y = num2bin(q,x)
```

Description

`y = num2bin(q,x)` converts numeric array `x` into binary character vectors returned in `y`. When `x` is a cell array, each numeric element of `x` is converted to binary. If `x` is a structure, each numeric field of `x` is converted to binary.

`num2bin` and `bin2num` are inverses of one another, differing in that `num2bin` returns the binary representations in a column.

Examples

```
x = magic(3)/9;
q = quantizer([4,3]);
y = num2bin(q,x)

Warning: 1 overflow.

y =

0111
0010
0011
0000
0100
0111
0101
0110
0001
```

See Also

`bin2num` | `hex2num` | `num2hex` | `num2int`

Introduced before R2006a

num2hex

Convert number to hexadecimal equivalent using `quantizer` object

Syntax

```
y = num2hex(q,x)
```

Description

`y = num2hex(q,x)` converts numeric array `x` into hexadecimal returned in `y`. When `x` is a cell array, each numeric element of `x` is converted to hexadecimal. If `x` is a structure, each numeric field of `x` is converted to hexadecimal.

For fixed-point `quantizer` objects, the representation is two's complement. For floating-point `quantizer` objects, the representation is IEEE Standard 754 style.

For example, for `q = quantizer('double')`

```
num2hex(q,nan)

ans =

fff8000000000000
```

The leading fraction bit is 1, all other fraction bits are 0. Sign bit is 1, exponent bits are all 1.

```
num2hex(q,inf)

ans =

7ff0000000000000
```

Sign bit is 0, exponent bits are all 1, all fraction bits are 0.

```
num2hex(q,-inf)

ans =
```

```
fff0000000000000
```

Sign bit is 1, exponent bits are all 1, all fraction bits are 0.

`num2hex` and `hex2num` are inverses of each other, except that `num2hex` returns the hexadecimal values in a column.

Examples

This is a floating-point example using a `quantizer` object `q` that has 6-bit word length and 3-bit exponent length.

```
x = magic(3);
q = quantizer('float',[6 3]);
y = num2hex(q,x)

y =

18
12
14
0c
15
18
16
17
10
```

See Also

`bin2num` | `hex2num` | `num2bin` | `num2int`

Introduced before R2006a

num2int

Convert number to signed integer

Syntax

```
y = num2int(q,x)
[y1,y,...] = num2int(q,x1,x,...)
```

Description

`y = num2int(q,x)` uses `q.format` to convert numeric `x` to an integer.

`[y1,y,...] = num2int(q,x1,x,...)` uses `q.format` to convert numeric values `x1, x2,...` to integers `y1,y2,...`

Examples

All the two's complement 4-bit numbers in fractional form are given by

```
x = [0.875 0.375 -0.125 -0.625
     0.750 0.250 -0.250 -0.750
     0.625 0.125 -0.375 -0.875
     0.500 0.000 -0.500 -1.000];

q=quantizer([4 3]);

y = num2int(q,x)

y =

     7     3    -1    -5
     6     2    -2    -6
     5     1    -3    -7
     4     0    -4    -8
```

Algorithms

When q is a fixed-point quantizer object, f is equal to fractionlength(q), and x is numeric

$$y = x \times 2^f$$

When q is a floating-point quantizer object, $y = x$. num2int is meaningful only for fixed-point quantizer objects.

See Also

bin2num | hex2num | num2bin | num2hex

Introduced before R2006a

num2str

Convert numbers to character array

Syntax

```
s = num2str(A)
s = num2str(A,precision)
s = num2str(A,formatSpec)
```

Description

`s = num2str(A)` converts `fi` object `A` into a character array representation. The output is suitable for input to the `eval` function such that `eval(s)` produces the original `fi` object exactly.

`s = num2str(A,precision)` converts `fi` object `A` to a character array representation using the number of digits of precision specified by `precision`.

`s = num2str(A,formatSpec)` applies a format specified by `formatSpec` to all elements of `A`.

Examples

Convert a fi Object to a Character Vector

Create a `fi` object, `A`, and convert it to a character vector.

```
A = fi(pi)

A = 

    3.1416

          DataTypeMode: Fixed-point: binary point scaling
```

```
          Signedness: Signed
          WordLength: 16
      FractionLength: 13
```

```
S = num2str(A)
```

```
S =

    '3.1416'
```

Convert a fi Object to a Character with Specified Precision

Create a `fi` object and convert it to a character vector with 8 digits of precision.

```
A = fi(pi)
```

```
A =

    3.1416

        DataTypeMode: Fixed-point: binary point scaling
          Signedness: Signed
          WordLength: 16
      FractionLength: 13
```

```
S = num2str(A,8)
```

```
S =

    '3.1416016'
```

Input Arguments

A — Input array
numeric array

Input array, specified as a numeric array.

Data Types: `fi` | `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64` | `logical`
Complex Number Support: Yes

precision — Number of digits of precision
positive integer

Maximum number of significant digits in the output string, specified as a positive integer.

Data Types: single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

formatSpec — Format of output fields
formatting operators

Format of the output fields, specified using formatting operators. formatSpec also can include ordinary text and special characters.

For more information on formatting operators, see the num2str reference page in the MATLAB documentation.

Output Arguments

s — Text representation of input array
character array

Text representation of the input array, returned as a character array.

See Also

mat2str | num2str | tostring

Introduced in R2016a

numberofelements

Number of data elements in an array

Note `numberofelements` will be removed in a future release. Use `numel` instead.

Syntax

`numberofelements(a)`

Description

`numberofelements(a)` returns the number of data elements in an array. Using `numberofelements` in your MATLAB code returns the same result for built-in types and `fi` objects. Use `numberofelements` to write data-type independent MATLAB code for array handling.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- `numberofelements` will be removed in a future release. Use `numel` instead.

See Also

`nargin` | `nargout` | `numel` | `prod` | `size` | `subsasgn` | `subsref`

Introduced before R2006a

numel

Number of data elements in fi array

Syntax

```
n = numel(A)
```

Description

`n = numel(A)` returns the number of elements, `n`, in `fi` array `A`.

Using `numel` in your MATLAB code returns the same result for built-in types and `fi` objects. Use `numel` to write data-type independent MATLAB code for array handling.

Examples

Number of Elements in 2-D fi Array

Create a 2-by-3- array of `fi` objects.

```
X = fi(ones(2,3),1,24,12)
```

```
X =
     1     1     1
     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

`numel` counts 6 elements in the matrix.

```
n = numel(X)
```

```
n = 6
```

Number of Elements in Multidimensional fi Array

Create a 2-by-3-by-4 array of `fi` objects.

```
X = fi(ones(2,3,4),1,24,12)
```

```
X = 
(:,:,1) =
     1     1     1
     1     1     1
(:,:,2) =
     1     1     1
     1     1     1
(:,:,3) =
     1     1     1
     1     1     1
(:,:,4) =
     1     1     1
     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

`numel` counts 24 elements in the matrix.

```
n = numel(X)
```

```
n = 24
```

Input Arguments

A — Input array
scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects.

Complex Number Support: Yes

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`numel`

Introduced in R2013b

numerictype

Construct numerictype object

Syntax

```
T = numerictype
T = numerictype(s)
T = numerictype(s,w)
T = numerictype(s,w,f)
T = numerictype(s,w,slope,bias)
T = numerictype(s,w,slopeadjustmentfactor,fixedexponent,bias)
T = numerictype(property1,value1, ...)
T = numerictype(T1, property1, value1, ...)
T = numerictype('double')
T = numerictype('single')
T = numerictype('boolean')
```

Description

You can use the numerictype constructor function in the following ways:

- T = numerictype creates a default numerictype object.
- T = numerictype(s) creates a numerictype object with Fixed-point: unspecified scaling, Signed property value s, and 16-bit word length.
- T = numerictype(s,w) creates a numerictype object with Fixed-point: unspecified scaling, Signed property value s, and word length w.
- T = numerictype(s,w,f) creates a numerictype object with Fixed-point: binary point scaling, Signed property value s, word length w and fraction length f.
- T = numerictype(s,w,slope,bias) creates a numerictype object with Fixed-point: slope and bias scaling, Signed property value s, word length w, slope, and bias.
- T = numerictype(s,w,slopeadjustmentfactor,fixedexponent,bias) creates a numerictype object with Fixed-point: slope and bias scaling,

Signed property value s, word length w, slopeadjustmentfactor, fixedexponent, and bias.

- T = numerictype(property1,value1, ...) allows you to set properties for a numerictype object using property name/property value pairs. All properties for which you do not specify a value get assigned their default value.
- T = numerictype(T1, property1, value1, ...) allows you to make a copy of an existing numerictype object, while modifying any or all of the property values.
- T = numerictype('double') creates a double numerictype.
- T = numerictype('single') creates a single numerictype.
- T = numerictype('boolean') creates a Boolean numerictype.

The properties of the numerictype object are listed below. These properties are described in detail in "numerictype Object Properties".

- Bias — Bias
- DataType — Data type category
- DataTypeOverride — Data type override settings. Note that this property is not visible when its value is the default, Inherit.
- DataTypeMode — Data type and scaling mode
- FixedExponent — Fixed-point exponent
- SlopeAdjustmentFactor — Slope adjustment
- FractionLength — Fraction length of the stored integer value, in bits
- Scaling — Fixed-point scaling mode
- Signed — Signed or unsigned
- Signedness — Signed, unsigned, or auto
- Slope — Slope
- WordLength — Word length of the stored integer value, in bits

Examples

Create a default numerictype object

Type

```
T = numerictype
```

to create a default `numerictype` object.

```
T =

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15
```

Create a `numerictype` object with specified word and fraction lengths

The following code creates a signed `numerictype` object with a 32-bit word length and 30-bit fraction length.

```
T = numerictype(1, 32, 30)
```

```
 T =

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 30
```

Create a `numerictype` object with unspecified scaling

If you omit the argument `f`, the scaling is unspecified.

```
T = numerictype(1, 32)
```

```
T =

          DataTypeMode: Fixed-point: unspecified scaling
            Signedness: Signed
            WordLength: 32
```

Create a `numerictype` object with default word length and scaling

If you omit the arguments `w` and `f`, the word length is automatically set to 16 bits and the scaling is unspecified.

```
T = numerictype(1)
```

```
T =
 
          DataTypeMode: Fixed-point: unspecified scaling
            Signedness: Signed
            WordLength: 16
```

Create a `numerictype` object with specified property values

You can use property name/property value pairs to set `numerictype` properties when you create the object.

```
T = numerictype('Signed', true, 'DataTypeMode',...
 'Fixed-point: slope and bias scaling',...
 'WordLength', 32, 'Slope', 2^-2, 'Bias', 4)
```

```
T =
 
          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
            WordLength: 32
                 Slope: 0.25
                  Bias: 4
```

Note When you create a `numerictype` object using property name/property value pairs, Fixed-Point Designer software first creates a default `numerictype` object, and then, for each property name you specify in the constructor, assigns the corresponding value. This behavior differs from the behavior that occurs when you use a syntax such as `T = numerictype(s,w)`. See “Example: Construct a numerictype Object with Property Name and Property Value Pairs” in the Fixed-Point Designer User's Guide for more information.

Create a numerictype object with unspecified sign

You can create a numerictype object with an unspecified sign by using property name/property values pairs to set the Signedness property to Auto.

```
T = numerictype('Signedness', 'Auto')
```

```
T =


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Auto
            WordLength: 16
        FractionLength: 15
```

Note Although you can create numerictype objects with an unspecified sign (Signedness: Auto), all fi objects must have a Signedness of Signed or Unsigned. If you use a numerictype object with Signedness: Auto to construct a fi object, the Signedness property of the fi object automatically defaults to Signed.

Create a numerictype object with specified data type

You can create a numerictype object with a specific data type by including the property name/property value pair in the numerictype constructor.

```
T = numerictype(0, 24, 12, 'DataType', 'ScaledDouble')
```

```
 T =


          DataTypeMode: Scaled double: binary point scaling
            Signedness: Unsigned
            WordLength: 24
        FractionLength: 12
```

MATLAB returns an unsigned numerictype object, T, with the specified WordLength of 24, FractionLength of 12, and with DataType set to ScaledDouble.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Fixed-point signals coming in to a MATLAB Function block from Simulink are assigned a `numerictype` object that is populated with the signal's data type and scaling information.
- Returns the data type when the input is a nonfixed-point signal.
- Use to create `numerictype` objects in generated code.
- All `numerictype` object properties related to the data type must be constant.

See Also

`fi` | `fimath` | `fipref` | `quantizer`

Topics

"numerictype Objects Usage to Share Data Type and Scaling Settings of fi objects"
"numerictype Object Properties"

Introduced before R2006a

NumericTypeScope

Determine fixed-point data type

Syntax

```
H = NumericTypeScope
show(H)
step(H, data)
release(H)
reset(H)
```

Description

The `NumericTypeScope` is an object that provides information about the dynamic range of your data. The scope provides a visual representation of the dynamic range of your data in the form of a `log2` histogram. In this histogram, the bit weights appear along the X-axis, and the percentage of occurrences along the Y-axis. Each bin of the histogram corresponds to a bit in the binary word. For example, 2^0 corresponds to the first integer bit in the binary word, 2^{-1} corresponds to the first fractional bit in the binary word.

The scope suggests a data type in the form of a `numerictype` object that satisfies the specified criteria. See the section on Bit Allocation in “Dialog Panels” on page 4-674.

`H = NumericTypeScope` returns a `NumericTypeScope` object that you can use to view the dynamic range of data in MATLAB. To view the `NumericTypeScope` window after creating *H*, use the `show` method.

`show(H)` opens the `NumericTypeScope` object *H* and brings it into view. Closing the scope window does not delete the object from your workspace. If the scope object still exists in your workspace, you can open it and bring it back into view using the `show` method.

`step(H, data)` processes your data and allows you to visualize the dynamic range. The object *H* retains previously collected information about the variable between each call to `step`.

`release(H)` releases system resources (such as memory, file handles or hardware connections) and allows all properties and input characteristics to be changed.

`reset(H)` clears all stored information from the `NumericTypeScope` object *H*. Resetting the object clears the information displayed in the scope window.

Identifying Values Outside Range and Below Precision

The `NumericTypeScope` can also help you identify any values that are outside range or below precision based on the current data type. To prepare the `NumericTypeScope` to identify them, provide an input variable that is a `fi` object and verify that one of the following conditions is true:

- The `DataTypeMode` of the `fi` object is set to `Scaled doubles: binary point scaling`.
- The `DataTypeOverride on page 2-4` property of the Fixed-Point Designer `fipref` object is set to `ScaledDoubles`.

When the information is available, the scope indicates values that are outside range, below precision, and in range of the data type by color-coding the histogram bars as follows:

- Blue — Histogram bin contains values that are in range of the current data type.
- Red — Histogram bin contains values that are outside range in the current data type.
- Yellow — Histogram bin contains values that are below precision in the current data type.

For an example of the scope color coding, see the figures in "Vertical Units" on page 4-677.

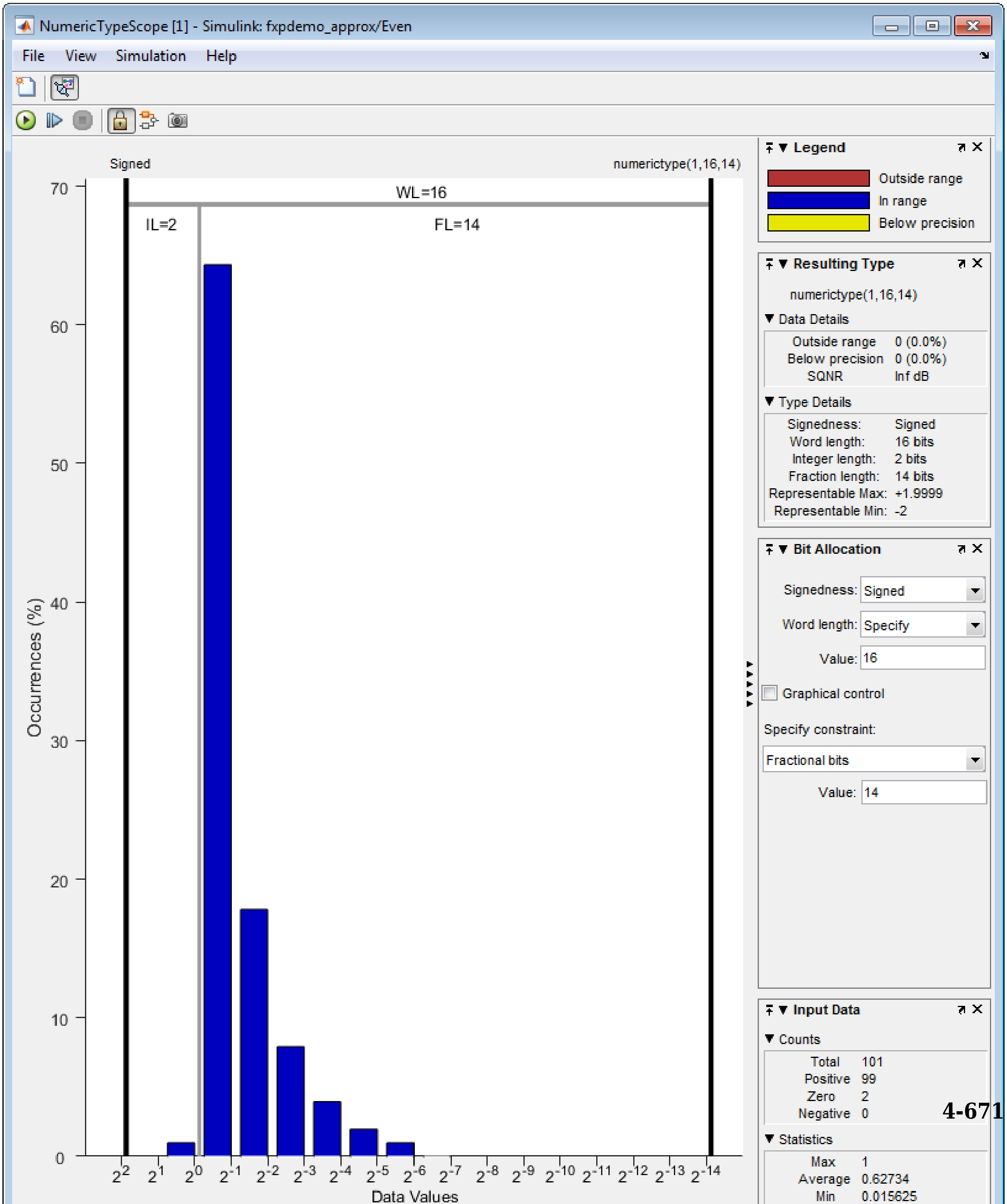
See also Legend in "Dialog Panels" on page 4-674.

See the "Examples" on page 4-0 section to learn more about using the `NumericTypeScope` to select data types.

Dialog Boxes and Toolbar

The NumericTypeScope Window

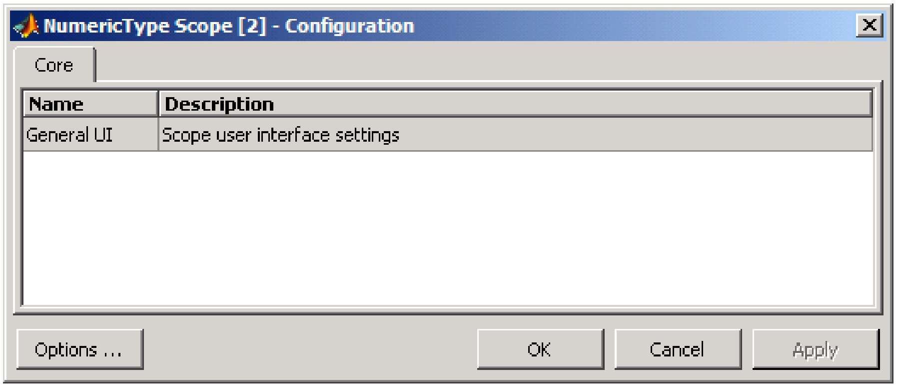
The `NumericTypeScope` opens with the default toolbars displayed at the top of the window and the dialog panels to the right.


NumericTypeScope [1] - Simulink: fxpdemo_approx/Even
File View Simulation Help
Signed
numerictype(1,16,14)
WL=16
IL=2
FL=14
Occurrences (%)
Data Values
Legend
Outside range
In range
Below precision
Resulting Type
numerictype(1,16,14)
Data Details
Outside range 0 (0.0%)
Below precision 0 (0.0%)
SQNR Inf dB
Type Details
Signedness: Signed
Word length: 16 bits
Integer length: 2 bits
Fraction length: 14 bits
Representable Max: +1.9999
Representable Min: -2
Bit Allocation
Signedness: Signed
Word length: Specify
Value: 16
Graphical control
Specify constraint:
Fractional bits
Value: 14
Input Data
Counts
Total 101
Positive 99
Zero 2
Negative 0
Statistics
Max 1
Average 0.62734
Min 0.015625

Configuration Dialog Box

The `NumericTypeScope` configuration allows you to control the behavior and appearance of the scope window.

To open the Configuration dialog box, select **File** > **Configuration** > **Edit**, or, with the scope as your active window, press the **N** key.



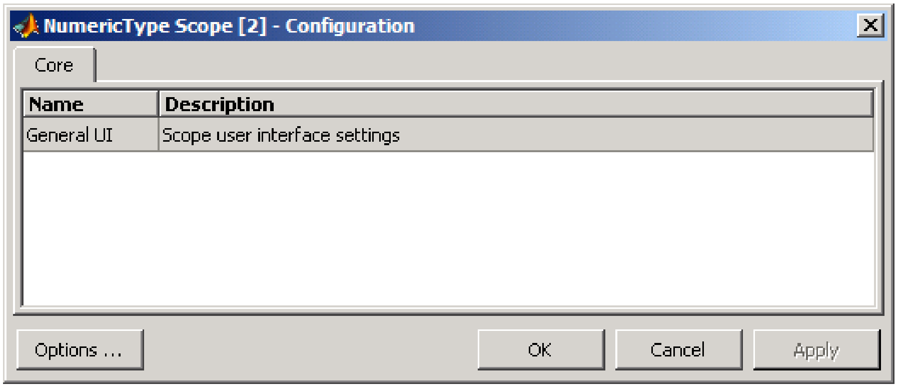
The Configuration Dialog box contains a series of panes each containing a table of configuration options. See the reference section for each pane for instructions on setting the options on each one. This dialog box has one pane, the Core pane, with only one option, for General UI settings for the scope user interface.

To save configuration settings for future use, select **File** > **Configuration** > **Save as**. The configuration settings you save become the default configuration settings for the `NumericTypeScope` object.

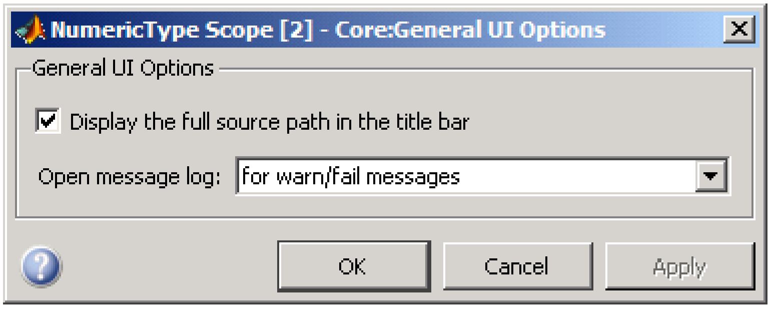
Caution Before saving your own set of configuration settings in the matlab/toolbox/fixedpoint/fixedpoint folder, save a backup copy of the default configuration settings in another location. If you do not save a backup copy of the default configuration settings, you cannot restore these settings at a later time.

To save your configuration settings for future use, save them in the matlab/toolbox/fixedpoint/fixedpoint folder with the file name `NumericTypeScopeComponent.cfg`. You can re-save your configuration settings at anytime, but remember to do so in the specified folder using the specified file name.

The Core pane in the Configuration dialog box controls the general settings of the scope.



Click General UI and then click **Options** to open the Core:General UI Options dialog box.



- **Display the full source path in the title bar**—Select this check box to display the file name and variable name in the scope title bar. If the scope is not from a file, or if you clear this check box, the scope displays only the variable name in the title bar.
- **Open message log**—Control when the Message Log window opens. The Message log window helps you debug issues with the scope. Choose to open the Message Log window for any of these conditions:
  - `for any new messages`
  - `for warn/fail messages`
  - `only for fail messages`
  - `manually`

The option defaults to `for warn/fail messages`.

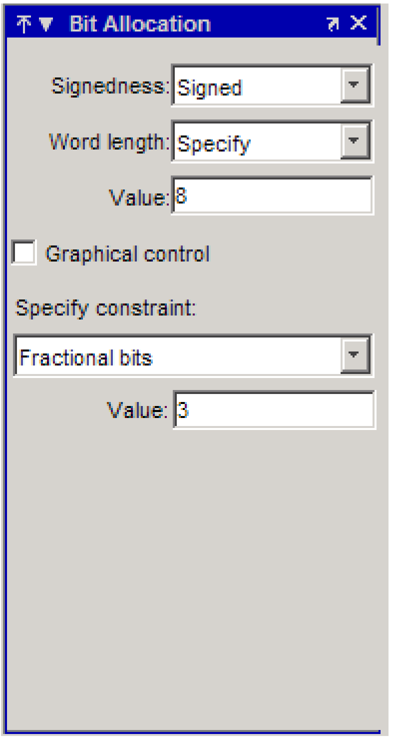
You can open the Message Log at any time by selecting **Help > Message Log** or by pressing **Ctrl+M**. The Message Log dialog box provides a system level record of loaded configuration settings and registered extensions. The Message Log displays summaries and details of each message, and you can filter the display of messages by Type and Category.

- **Type**—Select the type of messages to display in the Message Log. You can select `All`, `Info`, `Warn`, or `Fail`. Type defaults to `All`.
- **Category**—Select the category of messages to display in the Message Log. You can select `All`, `Configuration`, or `Extension`. The scope uses Configuration messages to indicate when new configuration files are loaded, and Extension messages to indicate when components are registered. Category defaults to `All`.

Dialog Panels

- "Bit Allocation" on page 4-674
- "Legend" on page 4-675
- "Resulting Type" on page 4-676
- "Input Data" on page 4-676

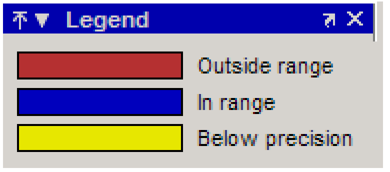
The scope Bit Allocation dialog panel, as shown in the following figure, offers you several options for specifying data type criteria.



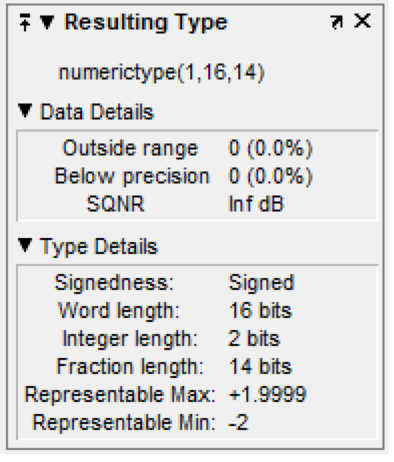
You can use this panel to specify a known word length and the desired maximum occurrences outside range. You can also use the panel to specify the desired number of occurrences outside range and the smallest value to be represented by the suggested data type. For streaming data, the suggested numerictype object adjusts over time in order to continue to satisfy the specified criteria.

The scope also allows you to interact with the histogram plot. When you select **Graphical control** on the Bit Allocation dialog panel, you enable cursors on either side of the binary point. You can interact with these cursors and observe the effect of the suggested numerictype on the input data. For example, you can see the number of values that are outside range, below precision, or both. You can also view representable minimum and maximum values of the data type.

The scope Legend panel informs you which colors the scope uses to indicate values. These colors represent values that are outside range, in range, or below precision when displayed in the scope.



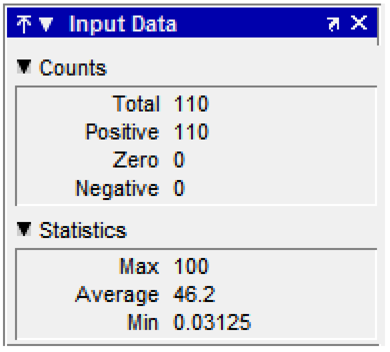
The Resulting Type panel describes the fixed-point data type as defined by scope settings. By manipulating the visual display (via the Bit Allocation panel or with the cursors) you can change the value of the data type.



The Data Details section displays the percentage of values that fall outside range or below precision with the `numerictype` object located at the top of this panel. SQNR (Signal Quantization Noise Ratio) varies depending on the signal. If the parameter has no value, then there is not enough data to calculate the SQNR. When scope information or the `numerictype` changes, the SQNR resets.

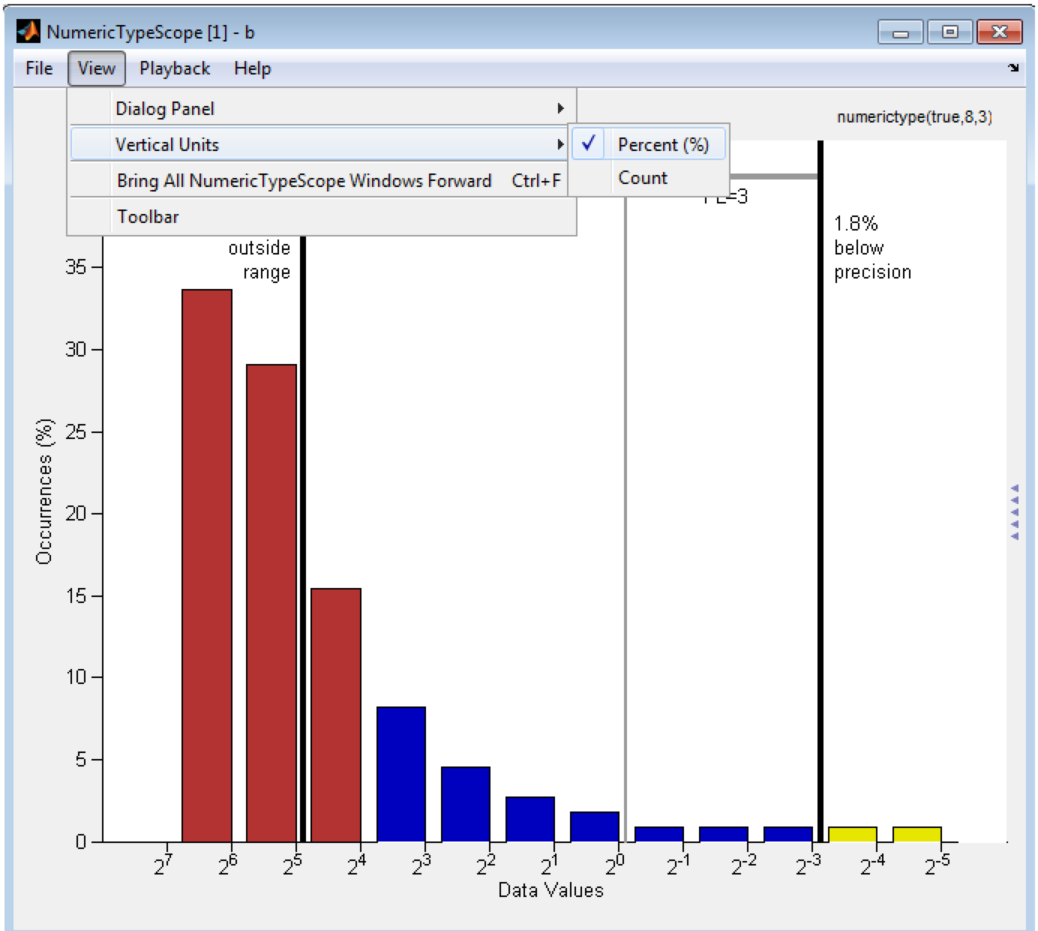
Type Details section provides details about the fixed-point data type.

The Input Data panel provides statistical information about the values currently displayed in the `NumericScopeType` object.

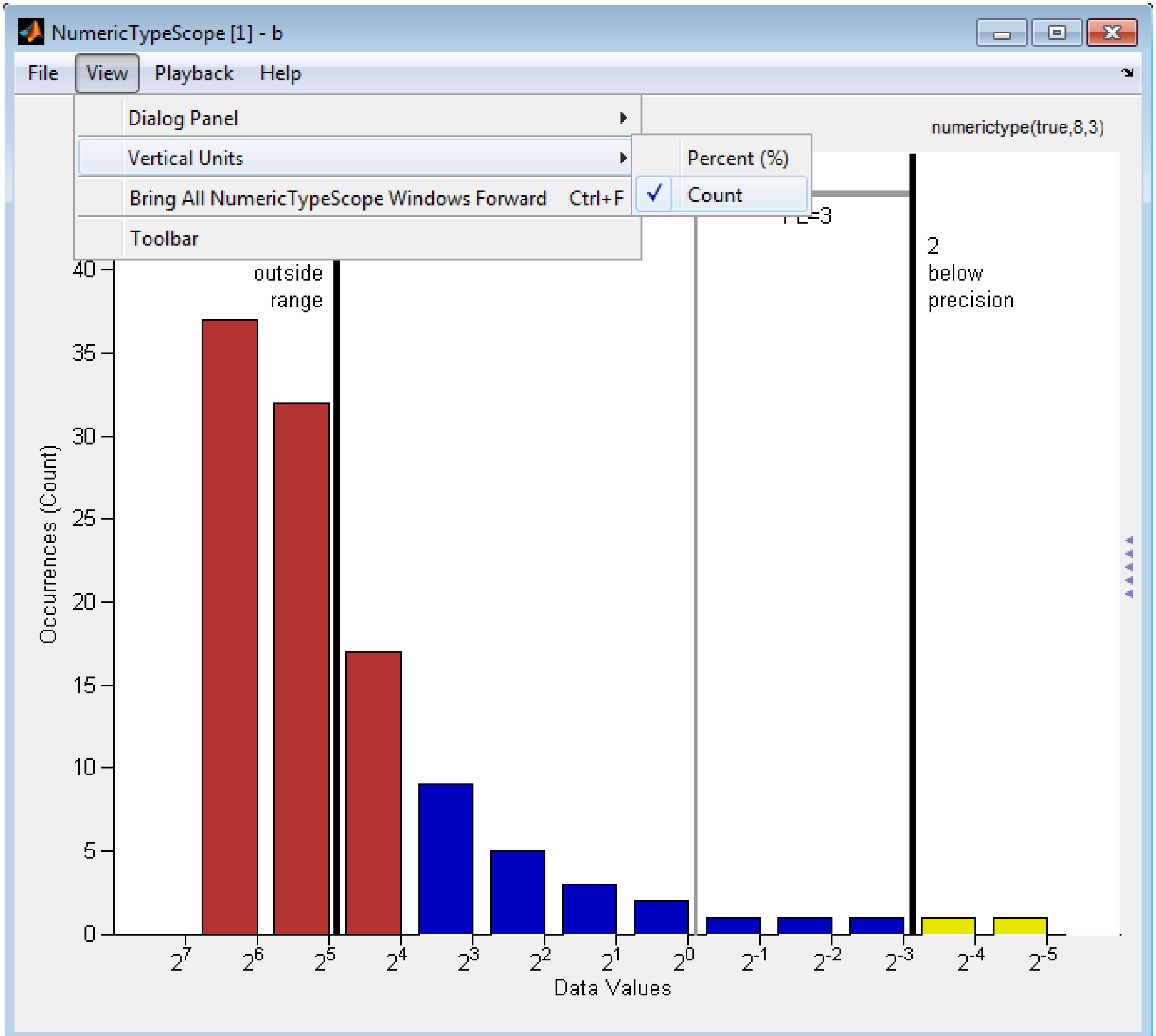


Vertical Units

Use the Vertical Units selection to display values that are outside range or below precision as a percentage or as an actual count. For example, the following image shows the values that are outside range or below precision as a percentage of the total values.

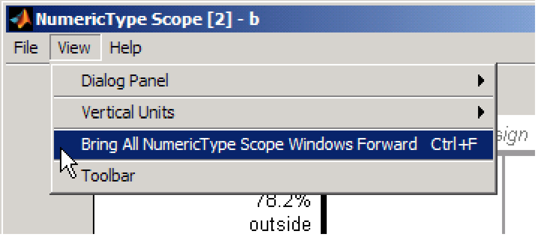


This next example shows the values that are outside range or below precision as an actual count.



Bring All NumericType Scope Windows Forward

The `NumericScopeType` GUI offers a **View > Bring All NumericType Scopes Forward** menu option to help you manage your `NumericTypeScope` windows. Selecting this option or pressing **Ctrl+F** brings all `NumericTypeScope` windows into view. If a `NumericTypeScope` window is not currently open, this menu option opens the window and brings it into view.



Toolbar (Mac Only)

Activate the Toolbar by selecting **View** > **Toolbar**. When this tool is active, you can dock or undock the scope from the GUI.

The toolbar feature is for the Mac only. Selecting **Toolbar** on Windows® and UNIX® versions displays only an empty toolbar. The docking icon always appears in the GUI in the upper-right corner for these versions.

Methods

release

Use this method to release system resources (such as memory, file handles or hardware connections) and allow all properties and input characteristics to be changed.

Example:

```
>>release(H)
```

reset

Use this method to clear the information stored in the object *H*. Doing so allows you to reuse *H* to process data from a different variable.

Example:

```
>>reset(H)
```

show

Use this method to open the scope window and bring it into view.

Example:

```
>>show(H)
```

step

Use this method to process your data and visualize the dynamic range in the scope window.

Example:

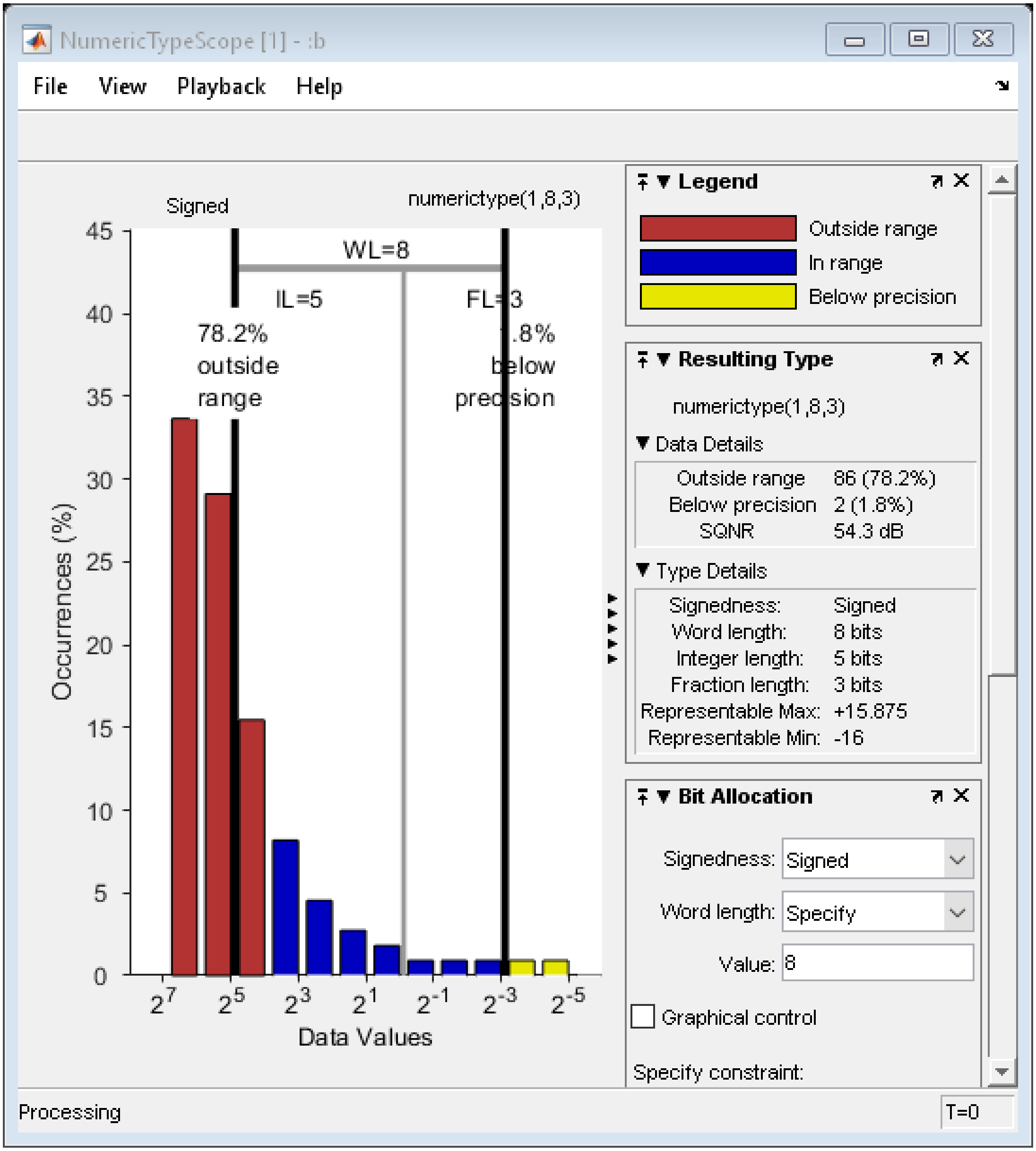
```
>>step(H, data)
```

Examples

View the Dynamic Range of a fi Object

Set the fi object DataTypeOverride to Scaled Doubles, and then view its dynamic range.

```
fp = fipref;
initialDTOSetting = fp.DataTypeOverride;
fp.DataTypeOverride = 'ScaledDoubles';
a = fi(magic(10),1,8,2);
b = fi([a; 2.^(-5:4)],1,8,3);
h = NumericTypeScope;
step(h,b);
```




```
fp.DataTypeOverride = initialDTOSetting;
```

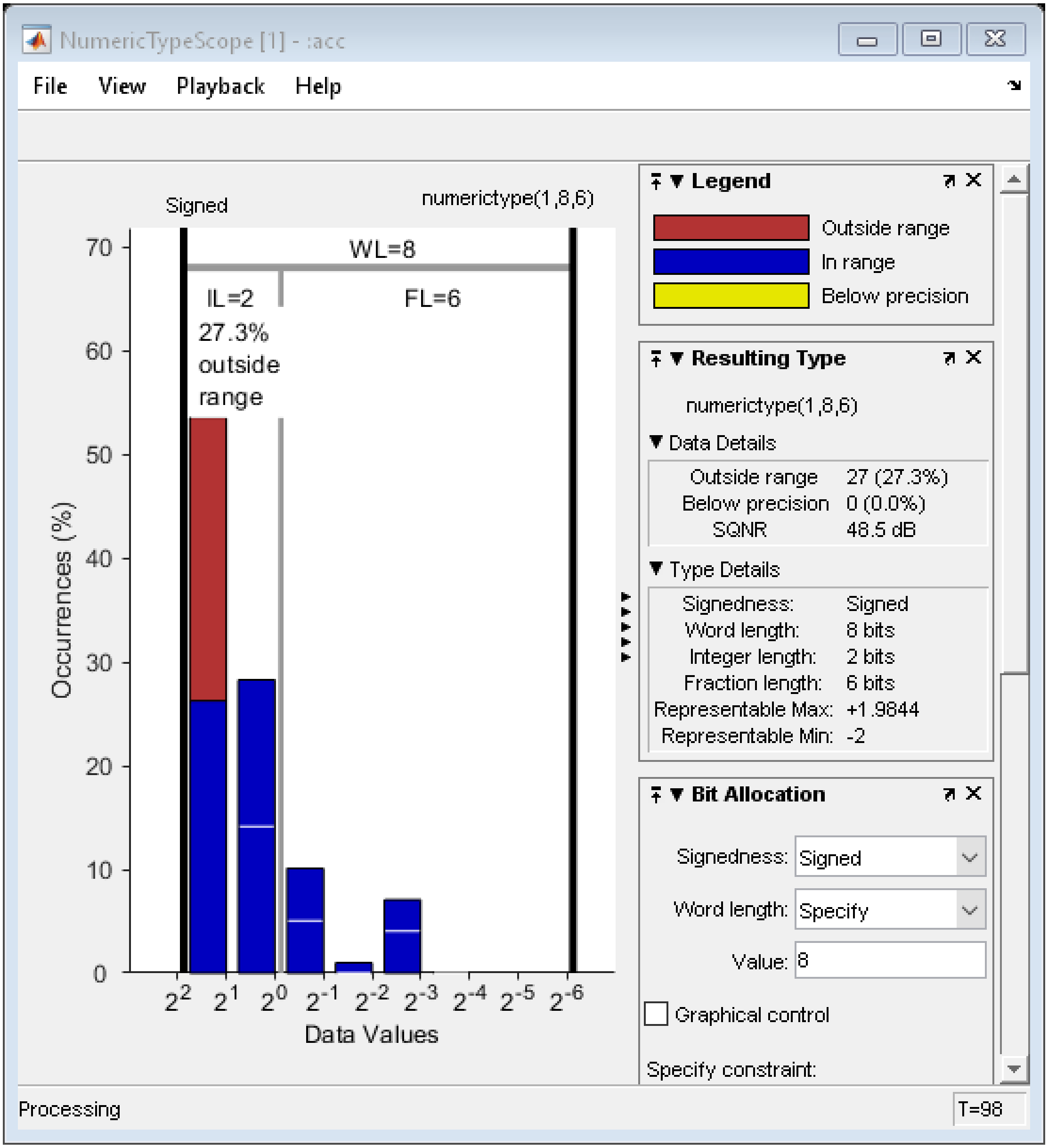
The log2 histogram display shows that the values appear both outside range and below precision in the variable. In this case, b has a data type of numerictype(1,8,3). The numerictype(1,8,3) data type provides 5 integer bits (including the signed bit), and 3 fractional bits. Thus, this data type can represent only values between -2^4 and 2^4-2^-3 (from -16 to 15.8750). Given the range and precision of this data type, values greater than 2^4 fall outside the range and values less than 2^-3 fall below the precision of the data type. When you examine the NumericTypeScope display, you can see that values requiring bits 5, 6, and 7 are outside range and values requiring fractional bits 4 and 5 are below precision. Given this information, you can prevent values that are outside range and below precision by changing the data type of the variable b to numerictype(0,13,5).

Determine Numeric Type For a fi Object

View the dynamic range, and determine an appropriate numeric type for a fi object with a DataTypeMode of Scaled double: binary point scaling.

Create a numerictype object with a DataTypeMode of Scaled double: binary point scaling. You can then use that numerictype object to construct your fi objects. Because you set the DataTypeMode to Scaled double: binary point scaling, the NumericTypeScope can now identify overflows in your data.

```
T = numerictype;
T.DataTypeMode = 'Scaled double: binary point scaling';
T.WordLength = 8;
T.FractionLength = 6;
a = fi(sin(0:100)*3.5, T);
b = fi(cos(0:100)*1.75,T);
acc = fi(0,T);
h = NumericTypeScope;
for i = 1:length(a)
    acc(:) = a(i)*0.7+b(i);
    step(h,acc)
end
```

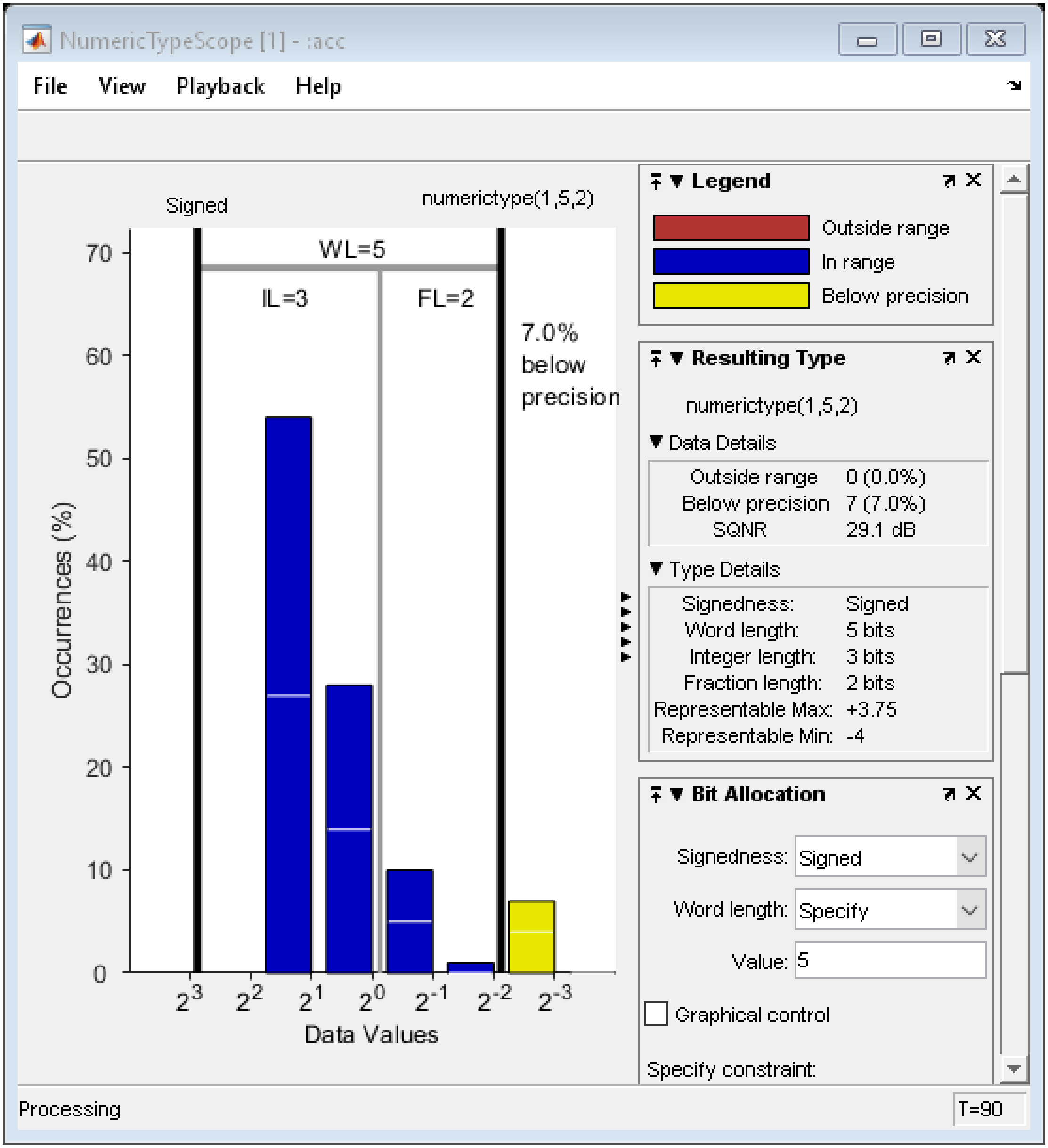


NumericTypeScope [1] - :acc
File View Playback Help
Signed
numerictype(1,8,6)
WL=8
IL=2
FL=6
27.3%
outside
range
Occurrences (%)
70
60
50
40
30
20
10
0
2^2 2^1 2^0 2^{-1} 2^{-2} 2^{-3} 2^{-4} 2^{-5} 2^{-6}
Data Values
Legend
Outside range
In range
Below precision
Resulting Type
numerictype(1,8,6)
Data Details
Outside range 27 (27.3%)
Below precision 0 (0.0%)
SQNR 48.5 dB
Type Details
Signedness: Signed
Word length: 8 bits
Integer length: 2 bits
Fraction length: 6 bits
Representable Max: +1.9844
Representable Min: -2
Bit Allocation
Signedness: Signed
Word length: Specify
Value: 8
Graphical control
Specify constraint:
Processing
T=98

This dynamic range analysis shows that you can represent the entire range of data in the accumulator with 5 bits; two to the left of the binary point (integer bits) and three to the right of it (fractional bits). You can verify that this data type is able to represent all the values by changing the WordLength and FractionLength properties of the numerictype object T. Then, use T to redefine the accumulator.

To view the dynamic range analysis based on this new data type, reset the NumericTypeScope object h, and rerun the loop.

```
T.WordLength = 5;
T.FractionLength = 2;
acc = fi(0,T);
release(h)
reset(h)
for i = 1:length(a)
    acc(:) = a(i)*0.7 + b(i);
    step(h,acc)
end
```


NumericTypeScope [1] - :acc
File View Playback Help
Signed
numerictype(1,5,2)
WL=5
IL=3
FL=2
7.0% below precision
Occurrences (%)
70
60
50
40
30
20
10
0
2^3 2^2 2^1 2^0 2^{-1} 2^{-2} 2^{-3}
Data Values
Legend
Outside range
In range
Below precision
Resulting Type
numerictype(1,5,2)
Data Details
Outside range 0 (0.0%)
Below precision 7 (7.0%)
SQNR 29.1 dB
Type Details
Signedness: Signed
Word length: 5 bits
Integer length: 3 bits
Fraction length: 2 bits
Representable Max: +3.75
Representable Min: -4
Bit Allocation
Signedness: Signed
Word length: Specify
Value: 5
Graphical control
Specify constraint:
Processing
T=90

See Also

`hist` | `log2`

Introduced in R2010a

nunderflows

Number of underflows

Syntax

```
y = nunderflows(a)
y = nunderflows(q)
```

Description

`y = nunderflows(a)` returns the number of underflows of `fi` object `a` since logging was turned on or since the last time the log was reset for the object.

Turn on logging by setting the `fipref` property `LoggingMode` to `on`. Reset logging for a `fi` object using the `resetlog` function.

`y = nunderflows(q)` returns the accumulated number of underflows resulting from quantization operations performed by a `quantizer` object `q`.

See Also

`maxlog` | `minlog` | `noverflows` | `resetlog`

Introduced before R2006a

oct

Octal representation of stored integer of `fi` object

Syntax

`oct(a)`

Description

`oct(a)` returns the stored integer of `fi` object `a` in octal format. `oct(a)` is equivalent to `a.oct`.

Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or, equivalently as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

The stored integer is the raw binary number, in which the binary point is assumed to be at the far right of the word.

Examples

The following code

```
a = fi([-1 1],1,8,7);
y = oct(a)
z = a.oct
```

returns

```
y =
```

```
        200   177

z =

        200   177
```

See Also

bin | dec | hex | storedInteger

Introduced before R2006a

ones

Create array of all ones with fixed-point properties

Syntax

```
X = ones('like',p)
X = ones(n,'like',p)
X = ones(sz1,...,szN,'like',p)
X = ones(sz,'like',p)
```

Description

`X = ones('like',p)` returns a scalar `1` with the same `numerictype`, complexity (real or complex), and `fimath` as `p`.

`X = ones(n,'like',p)` returns an `n`-by-`n` array of ones like `p`.

`X = ones(sz1,...,szN,'like',p)` returns an `sz1`-by-...-by-`szN` array of ones like `p`.

`X = ones(sz,'like',p)` returns an array of ones like `p`. The size vector, `sz`, defines `size(X)`.

Examples

2-D Array of Ones With Fixed-Point Attributes

Create a 2-by-3 array of ones with specified numerictype and `fimath` properties.

Create a signed `fi` object with word length of `24` and fraction length of `12`.

```
p = fi([],1,24,12);
```

Create a 2-by-3- array of ones that has the same numerictype properties as `p`.

```
X = ones(2,3,'like',p)
```

```
X = 
     1     1     1
     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Size Defined by Existing Array

Define a 3-by-2 array A.

```
A = [1 4 ; 2 5 ; 3 6];
```

```
sz = size(A)
```

```
sz = 1×2

     3     2
```

Create a signed fi object with word length of 24 and fraction length of 12.

```
p = fi([],1,24,12);
```

Create an array of ones that is the same size as A and has the same numerictype properties as p.

```
X = ones(sz,'like',p)
```

```
X = 
     1     1
     1     1
     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Square Array of Ones With Fixed-Point Attributes

Create a 4-by-4 array of ones with specified numerictype and `fimath` properties.

Create a signed `fi` object with word length of `24` and fraction length of `12`.

```
p = fi([],1,24,12);
```

Create a 4-by-4 array of ones that has the same numerictype properties as `p`.

```
X = ones(4, 'like', p)
```

```
X =
     1     1     1     1
     1     1     1     1
     1     1     1     1
     1     1     1     1

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Create Array of Ones with Attached fimath

Create a signed `fi` object with word length of 16, fraction length of 15 and `OverflowAction` set to `Wrap`.

```
format long
p = fi([],1,16,15,'OverflowAction','Wrap');
```

Create a 2-by-2 array of ones with the same `numerictype` properties as `p`.

```
X = ones(2,'like',p)
```

```
X =
   0.999969482421875   0.999969482421875
   0.999969482421875   0.999969482421875

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
```

```
        FractionLength: 15

        RoundingMethod: Nearest
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

1 cannot be represented by the data type of `p`, so the value saturates. The output `fi` object `X` has the same `numerictype` and `fimath` properties as `p`.

Complex Fixed-Point One

Create a scalar fixed-point `1` that is not real valued, but instead is complex like an existing array.

Define a complex `fi` object.

```
p = fi( [1+2i 3i],1,24,12);
```

Create a scalar `1` that is complex like `p`.

```
X = ones('like',p)
```

```
X = 
   1.0000 + 0.0000i

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Write MATLAB Code That Is Independent of Data Types

Write a MATLAB algorithm that you can run with different data types without changing the algorithm itself. To reuse the algorithm, define the data types separately from the algorithm.

This approach allows you to define a baseline by running the algorithm with floating-point data types. You can then test the algorithm with different fixed-point data types and compare the fixed-point behavior to the baseline without making any modifications to the original MATLAB code.

Write a MATLAB function, `my_filter`, that takes an input parameter, `T`, which is a structure that defines the data types of the coefficients and the input and output data.

```
function [y,z] = my_filter(b,a,x,z,T)
    % Cast the coefficients to the coefficient type
    b = cast(b,'like',T.coeffs);
    a = cast(a,'like',T.coeffs);
    % Create the output using zeros with the data type
    y = zeros(size(x),'like',T.data);
    for i = 1:length(x)
        y(i) = b(1)*x(i) + z(1);
        z(1) = b(2)*x(i) + z(2) - a(2) * y(i);
        z(2) = b(3)*x(i)        - a(3) * y(i);
    end
end
```

Write a MATLAB function, `zeros_ones_cast_example`, that calls `my_filter` with a floating-point step input and a fixed-point step input, and then compares the results.

```
function zeros_ones_cast_example

    % Define coefficients for a filter with specification
    % [b,a] = butter(2,0.25)
    b = [0.097631072937818   0.195262145875635   0.097631072937818];
    a = [1.000000000000000  -0.942809041582063   0.333333333333333];

    % Define floating-point types
    T_float.coeffs = double([]);
    T_float.data   = double([]);

    % Create a step input using ones with the
    % floating-point data type
    t = 0:20;
    x_float = ones(size(t),'like',T_float.data);

    % Initialize the states using zeros with the
    % floating-point data type
    z_float = zeros(1,2,'like',T_float.data);

    % Run the floating-point algorithm
    y_float = my_filter(b,a,x_float,z_float,T_float);
```

```
    % Define fixed-point types
    T_fixed.coeffs = fi([],true,8,6);
    T_fixed.data   = fi([],true,8,6);

    % Create a step input using ones with the
    % fixed-point data type
    x_fixed = ones(size(t),'like',T_fixed.data);

    % Initialize the states using zeros with the
    % fixed-point data type
    z_fixed = zeros(1,2,'like',T_fixed.data);

    % Run the fixed-point algorithm
    y_fixed = my_filter(b,a,x_fixed,z_fixed,T_fixed);

    % Compare the results
    coder.extrinsic('clf','subplot','plot','legend')
    clf
    subplot(211)
    plot(t,y_float,'co-',t,y_fixed,'kx-')
    legend('Floating-point output','Fixed-point output')
    title('Step response')
    subplot(212)
    plot(t,y_float - double(y_fixed),'rs-')
    legend('Error')
    figure(gcf)
end
```

- “Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros”

Input Arguments

n — Size of square matrix

integer value

Size of square matrix, specified as an integer value, defines the output as a square, n-by-n matrix of ones.

- If n is zero, X is an empty matrix.
- If n is negative, it is treated as zero.

Data Types: `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`sz1,...,szN` — Size of each dimension
two or more integer values

Size of each dimension, specified as two or more integer values, defines X as a sz1-by...-by-szN array.

- If the size of any dimension is zero, X is an empty array.
- If the size of any dimension is negative, it is treated as zero.
- If any trailing dimensions greater than two have a size of one, the output, X, does not include those dimensions.

Data Types: `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`sz` — Output size
row vector of integer values

Output size, specified as a row vector of integer values. Each element of this vector indicates the size of the corresponding dimension.

- If the size of any dimension is zero, X is an empty array.
- If the size of any dimension is negative, it is treated as zero.
- If any trailing dimensions greater than two have a size of one, the output, X, does not include those dimensions.

Example: `sz = [2,3,4]` defines X as a 2-by-3-by-4 array.

Data Types: `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`p` — Prototype
`fi` object | numeric variable

Prototype, specified as a `fi` object or numeric variable. To use the prototype to specify a complex object, you must specify a value for the prototype. Otherwise, you do not need to specify a value.

If the value 1 overflows the numeric type of `p`, the output saturates regardless of the specified `OverflowAction` property of the attached `fimath`. All subsequent operations performed on the output obey the rules of the attached `fimath`.

Complex Number Support: Yes

Tips

Using the `b = cast(a,'like',p)` syntax to specify data types separately from algorithm code allows you to:

- Reuse your algorithm code with different data types.
- Keep your algorithm uncluttered with data type specifications and switch statements for different data types.
- Improve readability of your algorithm code.
- Switch between fixed-point and floating-point data types to compare baselines.
- Switch between variations of fixed-point settings without changing the algorithm code.

See Also

`cast` | `ones` | `zeros`

Topics

“Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros”
“Manual Fixed-Point Conversion Workflow”
“Manual Fixed-Point Conversion Best Practices”

Introduced in R2013a

or

Find logical OR of array or scalar inputs

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `or` reference page for more information.

Introduced before R2006a

patch

Create patch graphics object

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `patch` reference page for more information.

Introduced before R2006a

pcolor

Create pseudocolor plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `pcolor` reference page for more information.

Introduced before R2006a

permute

Rearrange dimensions of multidimensional array

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `permute` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The dimensions argument must be a built-in type; it cannot be a `fi` object.

Introduced before R2006a

plot

Create linear 2-D plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `plot` reference page for more information.

Introduced before R2006a

plot3

Create 3-D line plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `plot3` reference page for more information.

Introduced before R2006a

plotmatrix

Draw scatter plots

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `plotmatrix` reference page for more information.

Introduced before R2006a

plotyy

Create graph with y-axes on right and left sides

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `plotyy` reference page for more information.

Introduced before R2006a

plus

Matrix sum of fi objects

Syntax

```
plus(a,b)
```

Description

plus(a,b) is called for the syntax a + b when a or b is an object.

a + b adds matrices a and b. a and b must have the same dimensions unless one is a scalar value (a 1-by-1 matrix). A scalar value can be added to any other value.

plus does not support fi objects of data type Boolean.

Note For information about the fimath properties involved in Fixed-Point Designer calculations, see “fimath Properties Usage for Fixed-Point Arithmetic” and “fimath ProductMode and SumMode” in the Fixed-Point Designer documentation.

For information about calculations using Fixed-Point Designer software, see the Fixed-Point Designer documentation.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Any non-fi inputs must be constant; that is, its value must be known at compile time so that it can be cast to a fi object.

See Also

minus | mtimes | times | uminus

Introduced before R2006a

polar

Plot polar coordinates

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `polar` reference page for more information.

Introduced before R2006a

pow2

Efficient fixed-point multiplication by 2^K

Syntax

```
b = pow2(a,K)
```

Description

`b = pow2(a,K)` returns the value of `a` shifted by `K` bits where `K` is an integer and `a` and `b` are `fi` objects. The output `b` always has the same word length and fraction length as the input `a`.

Note In fixed-point arithmetic, shifting by `K` bits is equivalent to, and more efficient than, computing $b = a*2^k$.

If `K` is a non-integer, the `pow2` function will round it to `floor` before performing the calculation.

The scaling of `a` must be equivalent to binary point-only scaling; in other words, it must have a power of 2 slope and a bias of 0.

`a` can be real or complex. If `a` is complex, `pow2` operates on both the real and complex portions of `a`.

The `pow2` function obeys the `OverflowAction` and `RoundingMethod` properties associated with `a`. If obeying the `RoundingMethod` property associated with `a` is not important, try using the `bitshift` function.

The `pow2` function does not support `fi` objects of data type `Boolean`.

The function also does not support the syntax `b = pow2(a)` when `a` is a `fi` object.

Examples

Example 4.4. Example 1

In the following example, a is a real-valued fi object, and K is a positive integer.

The pow2 function shifts the bits of a 3 places to the left, effectively multiplying a by 2^3.

```
a = fi(pi,1,16,8)
b = pow2(a,3)
binary_a = bin(a)
binary_b = bin(b)
```

MATLAB returns:

```
a =

    3.1406

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

b =

   25.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

binary_a =

0000001100100100


binary_b =

0001100100100000
```

Example 4.5. Example 2

In the following example, a is a real-valued fi object, and K is a negative integer.

The pow2 function shifts the bits of a 4 places to the right, effectively multiplying a by 2^{-4}.

```
a = fi(pi,1,16,8)
b = pow2(a,-4)
binary_a = bin(a)
binary_b = bin(b)
```

MATLAB returns:

```
a =

    3.1406

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

b =

    0.1953

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 8

binary_a =

0000001100100100


binary_b =

0000000000110010
```

Example 4.6. Example 3

The following example shows the use of pow2 with a complex fi object:

```
format long g
P = fipref('NumericTypeDisplay', 'short');
a = fi(57 - 2i, 1, 16, 8)

a =
```

```
                              57 -                        2i
      s16,8

pow2(a, 2)

ans =
               127.99609375 -                      8i
      s16,8
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

bitshift | bitsll | bitsra | bitsrl

Introduced before R2006a

power

Fixed-point array power (.^)

Syntax

```
c = power(a,k)
c = a.^k
```

Description

`c = power(a,k)` and `c = a.^k` compute element-by-element power. The exponent *k* requires a positive, real-valued integer value.

The fixed-point output array *c* has the same local fimath as the input *a*. If *a* has no local fimath, the output *c* also has no local fimath. The array power operation is performed using default fimath settings.

Examples

Compute the power of a 2-dimensional array for exponent values 0, 1, 2, and 3.

```
x = fi([0 1 2; 3 4 5], 1, 32);

px0 = x.^0
px1 = x.^1
px2 = x.^2
px3 = x.^3
```

Tips

For more information about the `power` function, see the MATLAB `power` reference page.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- When the exponent `k` is a variable, the `ProductMode` property of the governing `fimath` must be `SpecifyPrecision`.

See Also

`mpower` | `power`

Introduced in R2010a

qr

Orthogonal-triangular decomposition

Description

The Fixed-Point Designer `qr` function differs from the MATLAB `qr` function as follows:

- The input `A` in `qr(A)` must be a real, signed `fi` object.
- The `qr` function ignores and discards any `fimath` attached to the input. The output is always associated with the default `fimath`.
- Pivoting is not supported for fixed-point inputs. You cannot use the following syntaxes:
  - `[~,~,E] = qr(...)`
  - `qr(A,'vector')`
  - `qr(A,B,'vector')`
- Economy size decomposition is not supported for fixed-point inputs. You cannot use the following syntax: `[Q,R] = qr(A,0)`.
- The least-squares-solution form is not supported for fixed-point inputs. You cannot use the following syntax: `qr(A,B)`.

Refer to the MATLAB `qr` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced in R2014a

quantize

Quantize fixed-point numbers

Syntax

```
y = quantize(x)
y = quantize(x,nt)
y = quantize(x,nt,rm)
y = quantize(x,nt,rm,oa)

yBP = quantize(x,s)
yBP = quantize(x,s,wl)
yBP = quantize(x,s,wl,fl)
yBP = quantize(x,s,wl,fl,rm)
yBP = quantize(x,s,wl,fl,rm,oa)
```

Description

`y = quantize(x)` quantizes `x` using these default values:

- `numerictype (true,16,15)`
- `Floor` rounding method
- `Wrap` overflow action

The `numerictype`, rounding method, and overflow action apply only during the quantization. The resulting value, quantized `y`, does not have any fimath attached to it.

`y = quantize(x,nt)` quantizes `x` to the specified `numerictype` `nt`. The rounding method and overflow action use default values.

`y = quantize(x,nt,rm)` quantizes `x` to the specified `numerictype`, `nt` and rounding method, `rm`. The overflow action uses the default value.

`y = quantize(x,nt,rm,oa)` quantizes `x` to the specified `numerictype`, `nt`, rounding method, `rm`, and overflow action, `oa`.

yBP = quantize(x,s) quantizes x to a binary-point, scaled fixed-point number. The s input specifies the sign to be used in numerictype (s,16,15). Unspecified properties use these default values:

- WordLength 16
- FractionLength 15
- RoundingMethod Floor
- OverflowAction Wrap

yBP = quantize(x,s,wl) uses the specified word length, wl. The fraction length defaults to wl–1. Unspecified properties use default values.

yBP = quantize(x,s,wl,fl) uses the specified fraction length, fl. Unspecified properties use default values.

yBP = quantize(x,s,wl,fl,rm) uses the specified rounding method, rm. Unspecified properties use default values.

yBP = quantize(x,s,wl,fl,rm,oa) uses the specified overflow action, oa.

Examples

Quantize Binary-Point Scaled to Binary-Point Scaled Data

Create numerictype object, ntBP, which specifies a signed, 8-bit word length, 4-bit fraction length data type.

```
ntBP = numerictype(1,8,4);
```

Define the input.

```
x_BP = fi(pi)
```

```
x_BP =
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Use the defined numerictype, ntBP, to quantize the input, x_BP, to a binary-point scaled data type.

```
yBP1 = quantize(x_BP,ntBP)
```

```
yBP1 =
    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 4
```

Quantize Binary-Point Scaled to Slope-Bias Data

Create a numerictype object, ntSB, which specifies a slope-bias data type.

```
ntSB = numerictype('Scaling','SlopeBias', ...
      'SlopeAdjustmentFactor',1.8,'Bias',...
      1,'FixedExponent',-12);
```

Define the input.

```
x_BP = fi(pi)
```

```
x_BP =
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Use the defined numerictype, ntSB, to quantize the input, x_BP, to a slope-bias data type.

```
ySB1 = quantize(x_BP, ntSB)
```

```
ySB1 =
    3.1415

          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
```

```
            WordLength: 16
                 Slope: 0.000439453125
                  Bias: 1
```

Quantize Slope-Bias Scaled to Binary-Point Scaled Data

Create a `numerictype` object, `ntBP`, which specifies a signed, 8-bit word length, 4-bit fraction length data type.

```
ntBP = numerictype(1,8,4);
```

Define the input.

```
x_SB = fi(rand(5,3),numerictype('Scaling','SlopeBias','Bias',-0.125))
```

```
x_SB =
    0.8147    0.0975    0.1576
    0.8750    0.2785    0.8750
    0.1270    0.5469    0.8750
    0.8750    0.8750    0.4854
    0.6324    0.8750    0.8003

          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
            WordLength: 16
                 Slope: 3.0517578125e-5
                  Bias: -0.125
```

Use the defined `numerictype`, `ntBP`, to quantize the input, `x_SB`, to a binary point scaled data type.

```
yBP2 = quantize(x_SB,ntBP,'Nearest','Saturate')
```

```
yBP2 =
    0.8125    0.1250    0.1875
    0.8750    0.2500    0.8750
    0.1250    0.5625    0.8750
    0.8750    0.8750    0.5000
    0.6250    0.8750    0.8125

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
          WordLength: 8
      FractionLength: 4
```

Quantize Slope-Bias Scaled to Slope-Bias Scaled Data

Create a `numerictype` object, `ntSB`, which specifies a slope-bias data type.

```
ntSB = numerictype('Scaling','SlopeBias', ...
      'SlopeAdjustmentFactor',1.8,'Bias',...
      1,'FixedExponent',-12);
```

Define the input.

```
x_SB = fi(rand(5,3),numerictype('Scaling','SlopeBias','Bias',-0.125))
```

```
x_SB =
    0.8147    0.0975    0.1576
    0.8750    0.2785    0.8750
    0.1270    0.5469    0.8750
    0.8750    0.8750    0.4854
    0.6324    0.8750    0.8003

          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
            WordLength: 16
                 Slope: 3.0517578125e-5
                  Bias: -0.125
```

Use the defined `numerictype`, `ntSB`, to quantize the input, `x_SB`, to a slope-bias data type.

```
ySB2 = quantize(x_SB,ntSB,'Ceiling','Wrap')
```

```
ySB2 =
    0.8150    0.0978    0.1580
    0.8752    0.2789    0.8752
    0.1272    0.5469    0.8752
    0.8752    0.8752    0.4854
    0.6326    0.8752    0.8005

          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
```

```
           WordLength: 16
                Slope: 0.000439453125
                 Bias: 1
```

Quantize Built-in Integer to Binary-Point Scaled Data

Create a `numerictype` object, `ntBP`, which specifies a signed, 8-bit word length, 4-bit fraction length data type.

```
ntBP = numerictype(1,8,4);
```

Define the input.

```
xInt = int8(-16:4:16)
```

```
xInt = 1x9 int8 row vector

   -16   -12    -8    -4     0     4     8    12    16
```

Use the defined `numerictype`, `ntBP`, to quantize the input|xInt| to a binary point scaled data type.

```
yBP3 = quantize(xInt,ntBP,'Zero')
```

```
yBP3 = 
     0     4    -8    -4     0     4    -8    -4     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 4
```

Show the range of the quantized output.

```
range(yBP3)
```

```
ans = 
   -8.0000    7.9375

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
            WordLength: 8
        FractionLength: 4
```

The first two and last three values are wrapped because they are outside the representable range of the output type.

Quantize Built-in Integer to Slope-Bias Data

Create a `numerictype` object `ntSB`, which specifies a slope-bias data type.

```
ntSB = numerictype('Scaling','SlopeBias', ...
      'SlopeAdjustmentFactor',1.8,'Bias',...
      1,'FixedExponent',-12);
```

Define the input.

```
xInt = int8(-16:4:16)
```

```
xInt = 1x9 int8 row vector

   -16   -12    -8    -4     0     4     8    12    16
```

Use the defined `numerictype`, `ntSB`, to quantize the input, `xInt`, to a slope-bias data type.

```
ySB3 = quantize(xInt,ntSB,'Round','Saturate')
```

```
ySB3 =
  Columns 1 through 7
  -13.4000  -11.9814   -7.9877   -3.9939   -0.0002    3.9936    7.9873
  Columns 8 through 9
   11.9811   15.3996

          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
            WordLength: 16
                 Slope: 0.000439453125
                  Bias: 1
```

Show the range of the quantized output.

```
range(ySB3)
```

```
ans =
  -13.4000   15.3996

          DataTypeMode: Fixed-point: slope and bias scaling
            Signedness: Signed
            WordLength: 16
                 Slope: 0.000439453125
                  Bias: 1
```

The first and last values saturate because they are at the limits of he representable range of the output type.

- “Compute Quantization Error”

Input Arguments

x — Input data
fi objects or built-in integers

Input data to quantize. Valid inputs are:

- Built-in signed or unsigned integers (`int8`, `int16`, `int32`, `int64`, `uint8`, `uint16`, `uint32`, `uint64`)
- Binary point scaled fixed-point fi
- Slope-bias scaled fixed-point fi

Although fi doubles and fi singles are allowed as inputs, they pass through the `quantize` function without being quantized.

nt — Numerictype
`(true,16,15)` (default)

Numerictype object that defines the sign, word length, and fraction length of a fixed-point number.

rm — Rounding method
`Floor` (default) | `Ceiling` | `Convergent` | `Nearest` | `Round` | `Zero`

Rounding method to use

oa — Overflow action
`Wrap` (default) | `Saturate`

Action to take when a data overflow occurs

s — Signedness
`true` (default) | `false`

Whether the fixed-point number is signed (`true`) or unsigned (`false`)

wl — Word length
`16` (default)

Word length of the fixed-point number

fl — Fraction length
`15` (default)

Fraction length of the fixed-point number

Output Arguments

y — Quantized output
`fi` object

Quantized value of the input

yBP — Quantized output
`fi` object

Input quantized to binary-point scaled value

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

fi | fimath | fixed.Quantizer | numerictype

Topics

"Compute Quantization Error"

Introduced before R2006a

quantizenumeric

Quantize numeric data

Syntax

```
y = quantizenumeric(x, s, w, f, r, o)
y = quantizenumeric(x, s, w, f, r)
```

Description

`y = quantizenumeric(x, s, w, f, r, o)` quantizes the value specified in `x` based on the numeric type information specified in `s`, `w`, `f`, `r`, and `o`.

`y = quantizenumeric(x, s, w, f, r)` quantizes the value specified in `x` using the numeric type information specified in `s`, `w`, `f`, and `r`.

Examples

Quantize value of pi

Quantize the value of pi using specified numeric type properties.

```
x = pi;
y = quantizenumeric(x,1,16,13,'ceil')
```

```
y = 3.1416
```

Specify a different rounding method. Observe how it affects the quantized value.

```
x = pi;
y = quantizenumeric(x,1,16,13,'fix')
```

```
y = 3.1415
```

Input Arguments

`x` — Value to quantize

scalar | vector | array

The value to quantize, specified as a scalar, vector, matrix or multidimensional array.

Data Types: `double`

`s` — signedness

1 | 0

The signedness of the quantized value, specified as either `0` (unsigned) or `1` (signed).

Data Types: `double`

`w` — word length

scalar integer

The word length of the quantized value, specified as a scalar integer.

Data Types: `double`

`f` — fraction length

scalar integer

The fraction length of the quantized value, specified as a scalar integer.

Data Types: `double`

`r` — Rounding method

character vector

Rounding method to use for quantization, specified as one of the following:

- `ceil`— Round towards positive infinity (same as `'ceiling'`)
- `ceiling`— Round towards positive infinity (same as `'ceil'`)
- `convergent`— Convergent rounding
- `fix`— Round towards zero (same as `'zero'`)
- `floor`— Round towards negative infinity
- `nearest`— Round towards nearest with ties rounding towards positive infinity

- `round`— Round towards nearest with ties rounding up in absolute value
- `zero`— Round towards zero (same as `'fix'`)

Data Types: `char`

o — Overflow action
`saturate` | `wrap`

Overflow action to use for quantization, specified as either `'saturate'` or `'wrap'`. When no overflow action is specified, quantize numeric uses `saturate`.

Example:

Data Types: `char`

Output Arguments

y — quantized output value
scalar | vector | matrix | multidimensional array

The quantized output value. `y` always has the same dimensions as `x`, and is always a double.

See Also

`cast` | `fi` | `fimath` | `fixed.Quantizer` | `numerictype` | `quantize` | `quantizer`

Introduced in R2016a

quantize method

Apply `quantizer` object to data

Syntax

```
y = quantize(q, x)
[y1,y2,...] = quantize(q,x1,x2,...)
```

Description

`y = quantize(q, x)` uses the `quantizer` object `q` to quantize `x`. When `x` is a numeric array, each element of `x` is quantized. When `x` is a cell array, each numeric element of the cell array is quantized. When `x` is a structure, each numeric field of `x` is quantized. Quantize does not change nonnumeric elements or fields of `x`, nor does it issue warnings for nonnumeric values. The output `y` is a built-in double. When the input `x` is a structure or cell array, the fields of `y` are built-in doubles.

`[y1,y2,...] = quantize(q,x1,x2,...)` is equivalent to `y1 = quantize(q,x1), y2 = quantize(q,x2),...`

The `quantizer` object states

- `max` — Maximum value before quantizing
- `min` — Minimum value before quantizing
- `noverflows` — Number of overflows
- `nunderflows` — Number of underflows
- `noperations` — Number of quantization operations

are updated during the call to `quantize`, and running totals are kept until a call to `resetlog` is made.

Examples

Custom Precision Floating-Point

The following example demonstrates using `quantize` to quantize data.

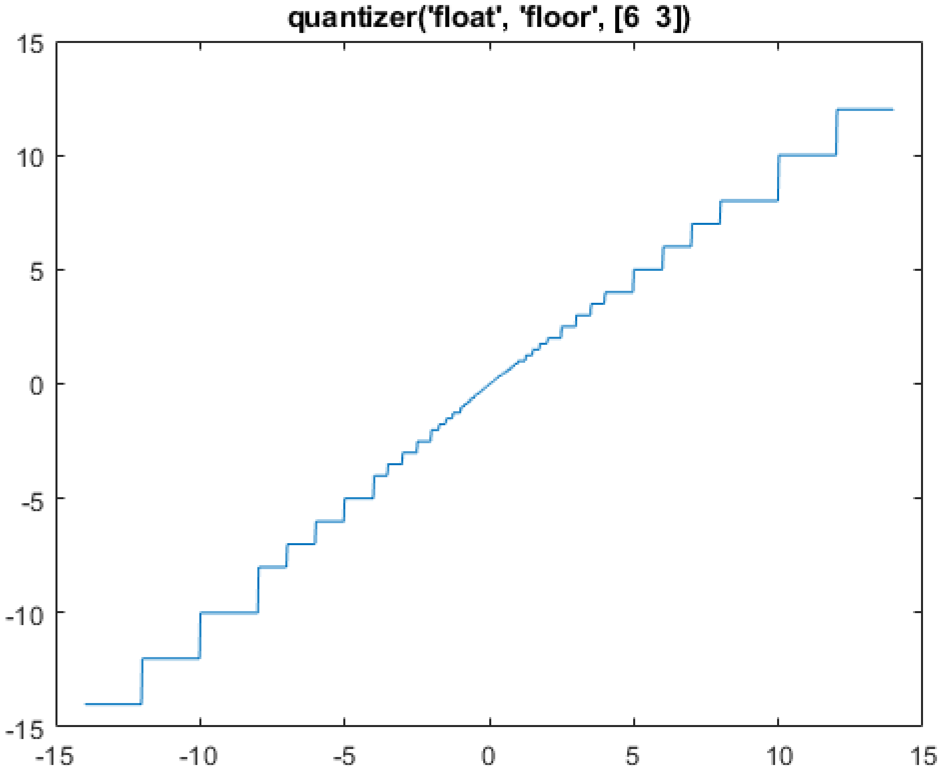
```
u=linspace(-15, 15, 1000);
q=quantizer([6 3], 'float');
range(q)
```

```
ans = 1×2

   -14    14
```

```
y=quantize(q, u);
```

```
Warning: 68 overflow(s) occurred in the fi quantize operation.
```

```
plot(u, y); title(tostring(q))
```



Fixed-Point

The following example demonstrates using `quantize` to quantize data.

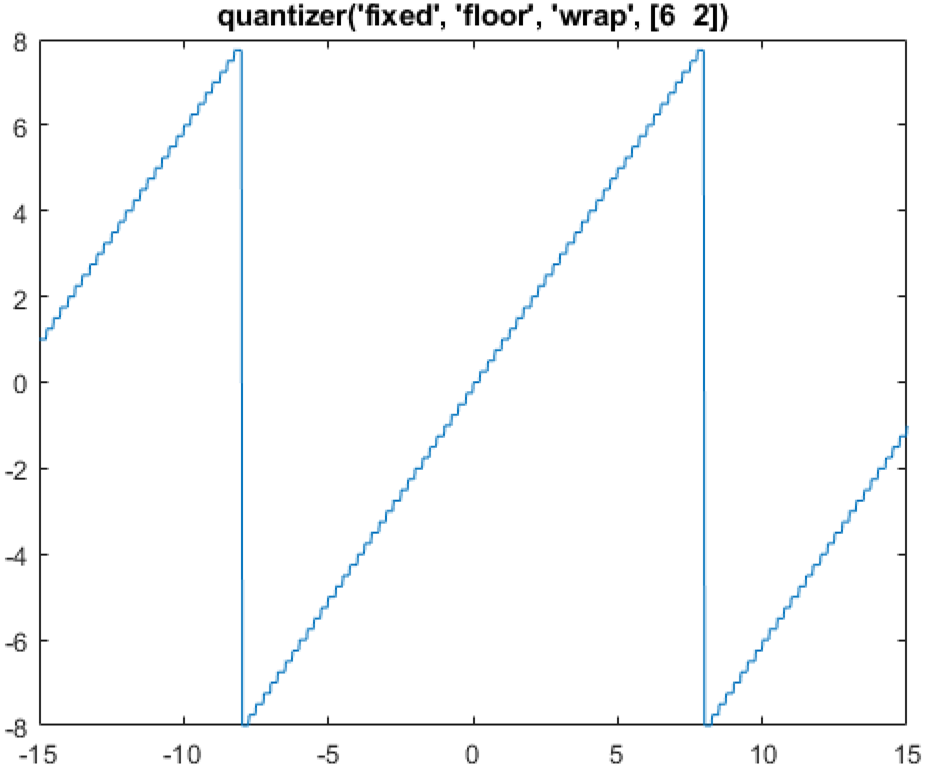
```
u=linspace(-15, 15, 1000);
q=quantizer([6 2], 'wrap');
range(q)
```

```
ans = 1×2

   -8.0000    7.7500
```

```
y=quantize(q, u);
```

```
Warning: 468 overflow(s) occurred in the fi quantize operation.
```

```
plot(u, y); title(tostring(q))
```



See Also

assignmentquantizer | quantizer | set | unitquantize | unitquantizer

Introduced in R2012b

quantizer

Construct `quantizer` object

Syntax

```
q = quantizer
q = quantizer('PropertyName1',PropertyValue1,...)
q = quantizer(PropertyValue1,PropertyValue2,...)
q = quantizer(struct)
q = quantizer(pn,pv)
```

Description

`q = quantizer` creates a `quantizer` object with properties set to their default values. To use this object to quantize values, use the quantize method.

`q = quantizer('PropertyName1',PropertyValue1,...)` uses property name/ property value pairs.

`q = quantizer(PropertyValue1,PropertyValue2,...)` creates a `quantizer` object with the listed property values. When two values conflict, `quantizer` sets the last property value in the list. Property values are unique; you can set the property names by specifying just the property values in the command.

`q = quantizer(struct)`, where `struct` is a structure whose field names are property names, sets the properties named in each field name with the values contained in the structure.

`q = quantizer(pn,pv)` sets the named properties specified in the cell array of character vectors `pn` to the corresponding values in the cell array `pv`.

The `quantizer` object property values are listed below. These properties are described in detail in "quantizer Object Properties" on page 2-7.

Property Name	Property Value	Description
mode	'double'	Double-precision mode. Override all other parameters.
	'float'	Custom-precision floating-point mode.
	'fixed'	Signed fixed-point mode.
	'single'	Single-precision mode. Override all other parameters.
	'ufixed'	Unsigned fixed-point mode.
roundmode	'ceil'	Round toward positive infinity.
	'convergent'	Round to nearest integer with ties rounding to nearest even integer.
	'fix'	Round toward zero.
	'floor'	Round toward negative infinity.
	'Nearest'	Round to nearest integer with ties rounding toward positive infinity.
	'Round'	Round to nearest integer with ties rounding to nearest integer with greater absolute value.
overflowmode (fixed-point only)	'saturate'	Saturate on overflow.
	'wrap'	Wrap on overflow.

Property Name	Property Value	Description
format	[wordlength fractionlength]	Format for fixed or ufixed mode.
	[wordlength exponentlength]	Format for float mode.

The default property values for a quantizer object are

```
        DataMode = fixed
       RoundMode = floor
    OverflowMode = saturate
          Format = [16  15]
```

Along with the preceding properties, quantizer objects have read-only states: max, min, noverflows, nunderflows, and noperations. They can be accessed through quantizer/get or q.maxlog, q.minlog, q.noverflows, q.nunderflows, and q.noperations, but they cannot be set. They are updated during the quantizer/quantize method, and are reset by the resetlog function.

The following table lists the read-only quantizer object states:

Property Name	Description
max	Maximum value before quantizing
min	Minimum value before quantizing
noverflows	Number of overflows
nunderflows	Number of underflows
noperations	Number of data points quantized

Examples

The following example operations are equivalent.

Setting quantizer object properties by listing property values only in the command,

```
q = quantizer('fixed', 'Ceiling', 'Saturate', [5 4])
```

Using a structure struct to set quantizer object properties,

```
struct.mode = 'fixed';
struct.roundmode = 'ceil';
struct.overflowmode = 'saturate';
struct.format = [5 4];
q = quantizer(struct);
```

Using property name and property value cell arrays `pn` and `pv` to set `quantizer` object properties,

```
pn = {'mode',  'roundmode', 'overflowmode', 'format'};
pv = {'fixed', 'ceil', 'saturate', [5 4]};
q = quantizer(pn, pv)
```

Using property name/property value pairs to configure a `quantizer` object,

```
q = quantizer( 'mode', 'fixed','roundmode','ceil',...
'overflowmode', 'saturate', 'format', [5 4]);
```

See Also

`assignmentquantizer` | `fi` | `fimath` | `fipref` | `numerictype` | `quantize` | `quantizenumeric` | `set` | `unitquantize` | `unitquantizer`

Introduced before R2006a

quiver

Create quiver or velocity plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `quiver` reference page for more information.

Introduced before R2006a

quiver3

Create 3-D quiver or velocity plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `quiver3` reference page for more information.

Introduced before R2006a

randquant

Generate uniformly distributed, quantized random number using `quantizer` object

Syntax

```
randquant(q,n)
randquant(q,m,n)
randquant(q,m,n,p,...)
randquant(q,[m,n])
randquant(q,[m,n,p,...])
```

Description

`randquant(q,n)` uses `quantizer` object `q` to generate an `n`-by-`n` matrix with random entries whose values cover the range of `q` when `q` is a fixed-point `quantizer` object. When `q` is a floating-point `quantizer` object, `randquant` populates the `n`-by-`n` array with values covering the range

```
-[square root of realmax(q)] to [square root of realmax(q)]
```

`randquant(q,m,n)` uses `quantizer` object `q` to generate an `m`-by-`n` matrix with random entries whose values cover the range of `q` when `q` is a fixed-point `quantizer` object. When `q` is a floating-point `quantizer` object, `randquant` populates the `m`-by-`n` array with values covering the range

```
-[square root of realmax(q)] to [square root of realmax(q)]
```

`randquant(q,m,n,p,...)` uses `quantizer` object q to generate an `m`-by-`n`-by-`p`-by ... matrix with random entries whose values cover the range of `q` when `q` is fixed-point `quantizer` object. When `q` is a floating-point `quantizer` object, `randquant` populates the matrix with values covering the range

```
-[square root of realmax(q)] to [square root of realmax(q)]
```

`randquant(q,[m,n])` uses `quantizer` object `q` to generate an `m`-by-`n` matrix with random entries whose values cover the range of `q` when `q` is a fixed-point `quantizer` object. When `q` is a floating-point `quantizer` object, `randquant` populates the `m`-by-`n` array with values covering the range

```
-[square root of realmax(q)] to [square root of realmax(q)]
```

`randquant(q,[m,n,p,...])` uses `quantizer` object `q` to generate `p` `m`-by-`n` matrices containing random entries whose values cover the range of `q` when `q` is a fixed-point `quantizer` object. When `q` is a floating-point `quantizer` object, `randquant` populates the `m`-by-`n` arrays with values covering the range

```
-[square root of realmax(q)] to [square root of realmax(q)]
```

`randquant` produces pseudorandom numbers. The number sequence `randquant` generates during each call is determined by the state of the generator. Because MATLAB resets the random number generator state at startup, the sequence of random numbers generated by the function remains the same unless you change the state.

`randquant` works like `rng` in most respects.

Examples

```
q=quantizer([4 3]);
rng('default')
randquant(q,3)

ans =

    0.5000    0.6250   -0.5000
    0.6250    0.1250         0
   -0.8750   -0.8750    0.7500
```

See Also

`quantizer` | `rand` | `range` | `realmax`

Introduced before R2006a

range

Numerical range of `fi` or `quantizer` object

Syntax

```
range(a)
[min_val, max_val]= range(a)
r = range(q)
[min_val, max_val] = range(q)
```

Description

`range(a)` returns a fi object with the minimum and maximum possible values of `fi` object `a`. All possible quantized real-world values of `a` are in the range returned. If `a` is a complex number, then all possible values of `real(a)` and `imag(a)` are in the range returned.

`[min_val, max_val]= range(a)` returns the minimum and maximum values of `fi` object `a` in separate output variables.

`r = range(q)` returns the two-element row vector $r = [a\ b]$ such that for all real x, `y = quantize(q,x)` returns y in the range $a \le y \le b$.

`[min_val, max_val] = range(q)` returns the minimum and maximum values of the range in separate output variables.

Examples

```
q = quantizer('float',[6 3]);
r = range(q)

r =

   -14    14
q = quantizer('fixed',[4 2],'floor');
```

```
[min_val,max_val] = range(q)

min_val =

    -2


max_val =

   1.7500
```

Algorithms

If `q` is a floating-point `quantizer` object, a = `-realmax`(q), b = `realmax`(q).

If `q` is a signed fixed-point `quantizer` object `(datamode = 'fixed')`,

$$a = -\text{realmax}(q) - \text{eps}(q) = \frac{-2^{w-1}}{2^f}$$

$$b = \text{realmax}(q) = \frac{2^{w-1} - 1}{2^f}$$

If `q` is an unsigned fixed-point `quantizer` object `(datamode = 'ufixed')`,

$$a = 0$$

$$b = \text{realmax}(q) = \frac{2^{w} - 1}{2^f}$$

See `realmax` for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`eps` | `exponentmax` | `exponentmin` | `fractionlength` | `intmax` | `intmin` | `lowerbound` | `lsb` | `max` | `min` | `realmax` | `realmin` | `upperbound`

Introduced before R2006a

rdivide

Right-array division (./)

Syntax

```
c = rdivide(a,b)
c = a./b
```

Description

`c = rdivide(a,b)` and `c = a./b` perform right-array division by dividing each element of `a` by the corresponding element of `b`. If inputs `a` and `b` are not the same size, one of them must be a scalar value.

The numerator input `a` can be complex, but the denominator `b` requires a real-valued input. If `a` is complex, the real and imaginary parts of `a` are independently divided by `b`.

The following table shows the rules used to assign property values to the output of the `rdivide` function.

Output Property	Rule
`Signedness`	If either input is `Signed`, the output is `Signed`. If both inputs are `Unsigned`, the output is `Unsigned`.
`WordLength`	The output word length equals the maximum of the input word lengths.
`FractionLength`	For `c = a./b`, the fraction length of output `c` equals the fraction length of `a` minus the fraction length of `b`.

The following table shows the rules the `rdivide` function uses to handle inputs with different data types.

Case	Rule
Interoperation of `fi` objects and built-in integers	Built-in integers are treated as fixed-point objects. For example, `B = int8(2)` is treated as an `s8,0` `fi` object.
Interoperation of `fi` objects and constants	MATLAB for code generation treats constant integers as fixed-point objects with the same word length as the `fi` object and a fraction length of `0`.
Interoperation of mixed data types	Similar to all other `fi` object functions, when inputs `a` and `b` have different data types, the data type with the higher precedence determines the output data type. The order of precedence is as follows: **1** `ScaledDouble` **2** `Fixed-point` **3** Built-in `double` **4** Built-in `single` When both inputs are `fi` objects, the only data types that are allowed to mix are `ScaledDouble` and `Fixed-point`.

Examples

In this example, you perform right-array division on a 3-by-3 magic square of `fi` objects. Each element of the 3-by-3 magic square is divided by the corresponding element in the 3-by-3 input array `b`.

```
a = fi(magic(3))
b = int8([3  3 4; 1 2 4 ; 3 1 2 ])
c = a./b
```

The `mrdivide` function outputs a 3-by-3 array of signed `fi` objects, each of which has a word length of 16 bits and fraction length of 11 bits.

```
a =

     8     1     6
```

```
    3     5     7
    4     9     2

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11

b =

     3     3     4
     1     2     4
     3     1     2


c =

    2.6665    0.3335    1.5000
    3.0000    2.5000    1.7500
    1.3335    9.0000    1.0000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

add | divide | fi | fimath | mrdivide | numerictype | sub | sum

Introduced in R2009a

real

Real part of complex number

Description

Refer to the MATLAB `real` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

realmax

Largest positive fixed-point value or quantized number

Syntax

```
realmax(a)
realmax(q)
```

Description

`realmax(a)` is the largest real-world value that can be represented in the data type of `fi` object `a`. Anything larger overflows.

`realmax(q)` is the largest quantized number that can be represented where `q` is a `quantizer` object. Anything larger overflows.

Examples

```
q = quantizer('float',[6 3]);
x = realmax(q)

x =

    14
```

Algorithms

If `q` is a floating-point `quantizer` object, the largest positive number, *x*, is

$$x = 2^{E_{max}} \cdot (2 - eps(q))$$

If `q` is a signed fixed-point `quantizer` object, the largest positive number, *x*, is

$$x = \frac{2^{w-1} - 1}{2^f}$$

If `q` is an unsigned fixed-point `quantizer` object `(datamode = 'ufixed')`, the largest positive number, *x*, is

$$x = \frac{2^w - 1}{2^f}$$

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`eps` | `exponentmax` | `exponentmin` | `fractionlength` | `intmax` | `intmin` | `lowerbound` | `lsb` | `quantizer` | `range` | `realmin` | `upperbound`

Introduced before R2006a

realmin

Smallest positive normalized fixed-point value or quantized number

Syntax

```
x=realmin(a)
x=realmin(q)
```

Description

`x=realmin(a)` is the smallest positive real-world value that can be represented in the data type of `fi` object `a`. Anything smaller than `x` underflows or is an IEEE “denormal” number.

`x=realmin(q)` is the smallest positive normal quantized number where `q` is a `quantizer` object. Anything smaller than `x` underflows or is an IEEE “denormal” number.

Examples

```
q = quantizer('float',[6 3]);
x = realmin(q)

x =

    0.2500
```

Algorithms

If `q` is a floating-point `quantizer` object, $x = 2^{E_{min}}$ where $E_{min} = \text{exponentmin}(q)$ is the minimum exponent.

If q is a signed or unsigned fixed-point quantizer object, $x = 2^{-f} = \varepsilon$ where f is the fraction length.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

eps | exponentmax | exponentmin | fractionlength | intmax | intmin | lowerbound | lsb | range | realmax | upperbound

Introduced before R2006a

reinterpretcast

Convert fixed-point data types without changing underlying data

Syntax

`c = reinterpretcast(a, T)`

Description

`c = reinterpretcast(a, T)` converts the input `a` to the data type specified by `numerictype` object `T` without changing the underlying data. The result is returned in `fi` object `c`.

The input `a` must be a built-in integer or a `fi` object with a fixed-point data type. `T` must be a `numerictype` object with a fully specified fixed-point data type. The word length of inputs `a` and `T` must be the same.

The `reinterpretcast` function differs from the MATLAB `typecast` and `cast` functions in that it only operates on `fi` objects and built-in integers, and it does not allow the word length of the input to change.

Examples

In the following example, `a` is a signed `fi` object with a word length of 8 bits and a fraction length of 7 bits. The `reinterpretcast` function converts `a` into an unsigned `fi` object `c` with a word length of 8 bits and a fraction length of 0 bits. The real-world values of `a` and `c` are different, but their binary representations are the same.

```
 a = fi([-1 pi/4], 1, 8, 7)
 T = numerictype(0, 8, 0);
 c = reinterpretcast(a, T)
a =

   -1.0000    0.7891
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 7

c =

   128   101

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 0
```

To verify that the underlying data has not changed, compare the binary representations of `a` and `c`:

```
binary_a = bin(a)
binary_c = bin(c)
binary_a =

10000000   01100101


binary_c =

10000000   01100101
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`cast` | `fi` | `numerictype` | `typecast`

Introduced in R2008b

removefimath

Remove fimath object from `fi` object

Syntax

```
y = removefimath(x)
```

Description

`y = removefimath(x)` returns a `fi` object `y` with `x`'s `numerictype` and value, and no fimath object attached. You can use this function as `y = removefimath(y)`, which gives you localized control over the fimath settings. This function also is useful for preventing errors about `embedded.fimath` of both operands needing to be equal.

Examples

Remove fimath Object from fi Object

This example shows how to define a `fi` object, define a fimath object, attach the `fimath` object to the `fi` object and then, remove the attached `fimath` object.

```
a = fi(pi)
```

```
a = 
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

```
f = fimath('RoundingMethod','Floor','OverflowAction','Wrap');
a = setfimath(a,f)
```

```
a = 
    3.1416
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

```
b = removefimath(a)
```

```
b = 
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Set and Remove fimath for Code Generation

Use the pattern `x = setfimath(x,f)` and `y = removefimath(y)` to insulate variables from `fimath` settings outside the function. This pattern does not create copies of the data in generated code.

```
function y = fixed_point_32bit_KeepLSB_plus_example(a,b)
   f = fimath('OverflowAction','Wrap',...
      'RoundingMethod','Floor',...
      'SumMode','KeepLSB',...
      'SumWordLength',32);
   a = setfimath(a,f);
   b = setfimath(b,f);
   y = a + b;
   y = removefimath(y);
end
```

If you have the MATLAB Coder product, you can generate C code. This example generates C code on a computer with 32-bit, native integer type.

```
a = fi(0,1,16,15);
b = fi(0,1,16,15);
```

```
codegen -config:lib  fixed_point_32bit_KeepLSB_plus_example...
       -args {a,b} -launchreport
```

```
int fixed_point_32bit_KeepLSB_plus_example(short a, short b)
{
  return a + b;
}
```

Input Arguments

x — Input data

fi object | built-in integer | double | single

Input data, specified as a `fi` object or built-in integer, from which to copy the data type and value to the output. `x` must be a `fi` object or an integer data type (`int8`, `int16`, `int32`, `int64`, `uint8`, `uint16`, `uint32`, or `uint64`). If `x` is not a fi object or integer data type, then `y = x`.

Output Arguments

y — Output fi object

fi object | built-in integer | double | single

Output fi object, returned as a `fi` object with no fimath object attached. The data type and value of the output match the input. If the input, `x`, is not a `fi` object `y = x`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`fi` | `fimath` | `setfimath`

Introduced in R2012b

repmat

Replicate and tile array

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `repmat` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The dimensions argument must be a built-in type; it cannot be a `fi` object.

Introduced before R2006a

rescale

Change scaling of fi object

Syntax

```
b = rescale(a, fractionlength)
```

```
b = rescale(a, slope, bias)
```

```
b = rescale(a, slopeadjustmentfactor, fixedexponent, bias)
```

```
b = rescale(a, ..., PropertyName, PropertyValue, ...)
```

Description

The rescale function acts similarly to the fi copy function with the following exceptions:

- The fi copy constructor preserves the real-world value, while rescale preserves the stored integer value.
- rescale does not allow the Signed and WordLength properties to be changed.

Examples

In the following example, fi object a is rescaled to create fi object b. The real-world values of a and b are different, while their stored integer values are the same:

```
p = fipref('FimathDisplay','none',...
        'NumericTypeDisplay','short');
a = fi(10,1,8,3)

a =

    10
      s8,3
```

```
b = rescale(a,1)

b =

    40
      s8,1

stored_integer_a = storedInteger(a);
stored_integer_b = storedInteger(b);
isequal(stored_integer_a, stored_integer_b)

ans =

1
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`fi`

Introduced before R2006a

reset

Reset objects to initial conditions

Syntax

```
reset(P)
reset(q)
```

Description

`reset(P)` resets the `fipref` object `P` to its initial conditions.

`reset(q)` resets the following `quantizer` object properties to their initial conditions:

- `minlog`
- `maxlog`
- `noverflows`
- `nunderflows`
- `noperations`

See Also

`resetlog`

Introduced before R2006a

resetglobalfimath

Set global fimath to MATLAB factory default

Syntax

```
resetglobalfimath
```

Description

`resetglobalfimath` sets the global fimath to the MATLAB factory default in your current MATLAB session. The MATLAB factory default has the following properties:

```
      RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Examples

In this example, you create your own `fimath` object `F` and set it as the global fimath. Then, using the `resetglobalfimath` command, reset the global fimath to the MATLAB factory default setting.

```
F = fimath('RoundingMethod','Floor','OverflowAction','Wrap');
globalfimath(F);
F1 = fimath
a = fi(pi)

F1 =


        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

```
a = 

    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Now, set the global fimath back to the factory default setting using `resetglobalfimath`:

```
resetglobalfimath;
F2 = fimath
a = fi(pi)

F2 = 


      RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: FullPrecision
a = 

    3.1416

       DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

You've now set the global fimath in your current MATLAB session back to the factory default setting. To use the factory default setting of the global fimath in future MATLAB sessions, you must use the `removeglobalfimathpref` command.

Alternatives

`reset(G)` — If `G` is a handle to the global fimath, `reset(G)` is equivalent to using the `resetglobalfimath` command.

See Also

`fimath` | `globalfimath` | `removeglobalfimathpref`

Introduced in R2010a

removeglobalfimathpref

Remove global fimath preference

Syntax

```
removeglobalfimathpref
```

Description

`removeglobalfimathpref` removes your global fimath from the MATLAB preferences. Once you remove the global fimath from your preferences, you cannot save it to them again. It is best practice to remove global fimath from the MATLAB preferences so that you start each MATLAB session using the default `fimath` settings.

The `removeglobalfimathpref` function does not change the global fimath for your current MATLAB session. To revert back to the factory default setting of the global fimath in your current MATLAB session, use the `resetglobalfimath` command.

Examples

Example 4.7. Removing Your Global fimath from the MATLAB Preferences

Typing

```
removeglobalfimathpref;
```

at the MATLAB command line removes your global fimath from the MATLAB preferences. Using the `removeglobalfimathpref` function allows you to:

- Continue using your global fimath in the current MATLAB session
- Use the MATLAB factory default setting of the global fimath in all future MATLAB sessions

To revert back to the MATLAB factory default setting of the global fimath in both your current and future MATLAB sessions, use both the `resetglobalfimath` and the `removeglobalfimathpref` commands:

```
resetglobalfimath;
removeglobalfimath;
```

See Also

`fimath` | `globalfimath` | `resetglobalfimath`

Introduced in R2010a

resetlog

Clear log for `fi` or `quantizer` object

Syntax

```
resetlog(a)
resetlog(q)
```

Description

`resetlog(a)` clears the log for `fi` object a.

`resetlog(q)` clears the log for `quantizer` object q.

Turn logging on or off by setting the `fipref` property `LoggingMode`.

See Also

`fipref` | `maxlog` | `minlog` | `noperations` | `noverflows` | `nunderflows` | `reset`

Introduced before R2006a

reshape

Reshape array

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `reshape` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

rgbplot

Plot colormap

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `rgbplot` reference page for more information.

Introduced before R2006a

ribbon

Create ribbon plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ribbon` reference page for more information.

Introduced before R2006a

rose

Create angle histogram

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `rose` reference page for more information.

Introduced before R2006a

rot90

Rotate array 90 degrees

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `rot90` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- In the syntax `rot90(A,k)`, the argument `k` must be a built-in type; it cannot be a `fi` object.

Introduced in R2014b

round

Round fi object toward nearest integer or round input data using quantizer object

Syntax

```
y = round(a)
y = round(q,x)
```

Description

y = round(a) rounds fi object a to the nearest integer. In the case of a tie, round rounds values to the nearest integer with greater absolute value. The rounded value is returned in fi object y.

y and a have the same fimath object and DataType property.

When the DataType of a is single, double, or boolean, the numerictype of y is the same as that of a.

When the fraction length of a is zero or negative, a is already an integer, and the numerictype of y is the same as that of a.

When the fraction length of a is positive, the fraction length of y is 0, its sign is the same as that of a, and its word length is the difference between the word length and the fraction length of a, plus one bit. If a is signed, then the minimum word length of y is 2. If a is unsigned, then the minimum word length of y is 1.

For complex fi objects, the imaginary and real parts are rounded independently.

round does not support fi objects with nontrivial slope and bias scaling. Slope and bias scaling is trivial when the slope is an integer power of 2 and the bias is 0.

y = round(q,x) uses the RoundingMethod and FractionLength settings of q to round the numeric data x, but does not check for overflows during the operation. Input x must be a builtin numeric variable. Use the cast function to work with fi objects.

Examples

Example 1

The following example demonstrates how the `round` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 3.

```
a = fi(pi, 1, 8, 3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3

y = round(a)

y =

     3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 6
        FractionLength: 0
```

Example 2

The following example demonstrates how the `round` function affects the `numerictype` properties of a signed `fi` object with a word length of 8 and a fraction length of 12.

```
a = fi(0.025,1,8,12)

a =

    0.0249

          DataTypeMode: Fixed-point: binary point scaling
```

```
            Signedness: Signed
            WordLength: 8
        FractionLength: 12

y = round(a)

y =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 2
        FractionLength: 0
```

Example 3

The functions `convergent`, `nearest` and `round` differ in the way they treat values whose least significant digit is 5:

- The `convergent` function rounds ties to the nearest even integer
- The `nearest` function rounds ties to the nearest integer toward positive infinity
- The `round` function rounds ties to the nearest integer with greater absolute value

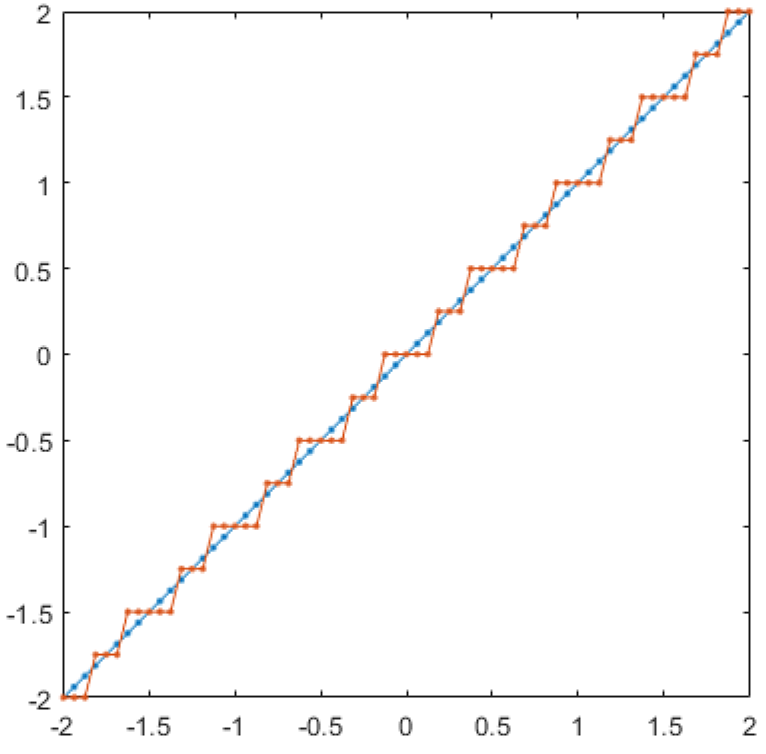
The following table illustrates these differences for a given `fi` object `a`.

a	convergent(a)	nearest(a)	round(a)
–3.5	–4	–3	–4
–2.5	–2	–2	–3
–1.5	–2	–1	–2
–0.5	0	0	–1
0.5	0	1	1
1.5	2	2	2
2.5	2	3	3
3.5	4	4	4

Quantize an input

Create a quantizer object, and use it to quantize input data. The quantizer object applies its properties to the input data to return quantized output.

```
q = quantizer('fixed', 'convergent', 'wrap', [3 2]);
x = (-2:eps(q)/4:2)';
y = round(q,x);
plot(x,[x,y],'.-');
axis square;
```



Applying quantizer object q to the data resulted in a staircase-shape output plot. Linear data input results in output where y shows distinct quantization levels.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`ceil` | `convergent` | `fix` | `floor` | `nearest` | `quantize` | `quantizer`

Introduced before R2006a

savefipref

Save `fi` preferences for next MATLAB session

Syntax

```
savefipref
```

Description

`savefipref` saves the settings of the current `fipref` object for the next MATLAB session.

See Also

`fipref`

Introduced before R2006a

scatter

Create scatter or bubble plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `scatter` reference page for more information.

Introduced before R2006a

scatter3

Create 3-D scatter or bubble plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `scatter3` reference page for more information.

Introduced before R2006a

sdec

Signed decimal representation of stored integer of `fi` object

Syntax

```
sdec(a)
```

Description

Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or, equivalently as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

The stored integer is the raw binary number, in which the binary point is assumed to be at the far right of the word.

`sdec(a)` returns the stored integer of `fi` object `a` in signed decimal format.

Examples

The code

```
a = fi([-1 1],1,8,7);
sdec(a)
```

returns

```
-128   127
```

See Also

`bin` | `dec` | `hex` | `oct` | `storedInteger`

Introduced before R2006a

semilogx

Create semilogarithmic plot with logarithmic x-axis

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `semilogx` reference page for more information.

Introduced before R2006a

semilogy

Create semilogarithmic plot with logarithmic y-axis

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `semilogy` reference page for more information.

Introduced before R2006a

set

Set or display property values for `quantizer` objects

Syntax

```
set(q, PropertyValue1, PropertyValue2,...)

set(q,s)

set(q,pn,pv)

set(q,'PropertyName1',PropertyValue1,'PropertyName2',
PropertyValue2,...)

q.PropertyName = Value

s = set(q)
```

Description

`set(q, PropertyValue1, PropertyValue2,...)` sets the properties of `quantizer` object `q`. If two property values conflict, the last value in the list is the one that is set.

`set(q,s)`, where `s` is a structure whose field names are object property names, sets the properties named in each field name with the values contained in the structure.

`set(q,pn,pv)` sets the named properties specified in the cell array of strings `pn` to the corresponding values in the cell array `pv`.

`set(q,'PropertyName1',PropertyValue1,'PropertyName2',
PropertyValue2,...)` sets multiple property values with a single statement.

Note You can use property name/property value string pairs, structures, and property name/property value cell array pairs in the same call to `set`.

`q.PropertyName = Value` uses dot notation to set property `PropertyName` to `Value`.

`set(q)` displays the possible values for all properties of `quantizer` object `q`.

`s = set(q)` returns a structure containing the possible values for the properties of `quantizer` object `q`.

Note The `set` function operates on `quantizer` objects. To learn about setting the properties of other objects, see properties of `fi`, `fimath`, `fipref`, and `numerictype` objects.

See Also

`get`

Introduced before R2006a

setfimath

Attach fimath object to fi object

Syntax

```
y = setfimath(x,f)
```

Description

y = setfimath(x,f) returns a fi object, y, with x's numerictype and value, and attached fimath object, f. This function and the related removefimath function are useful for preventing errors about embedded.fimath of both operands needing to be equal.

The y = setfimath(x,f) syntax does not modify the input, x. To modify x, use x = setfimath(x,f). If you use setfimath in an expression, such as, a*setfimath(b,f), the fimath object is used in the temporary variable, but b is not modified.

Examples

Add fimath object to fi Object

Define a fi object, define a fimath object, and use setfimath to attach the fimath object to the fi object.

Create a fi object without a fimath object.

```
a = fi(pi)
```

```
a =
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
          WordLength: 16
        FractionLength: 13
```

Create a `fimath` object and attach it to the `fi` object.

```
f = fimath('OverflowAction','Wrap','RoundingMethod','Floor');
b = setfimath(a,f)

b = 
    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13

        RoundingMethod: Floor
        OverflowAction: Wrap
           ProductMode: FullPrecision
               SumMode: FullPrecision
```

Set and Remove `fimath` for Code Generation

Use the pattern `x = setfimath(x,f)` and `y = removefimath(y)` to insulate variables from `fimath` settings outside the function. This pattern does not create copies of the data in generated code.

```
function y = fixed_point_32bit_KeepLSB_plus_example(a,b)
   f = fimath('OverflowAction','Wrap',...
      'RoundingMethod','Floor',...
      'SumMode','KeepLSB',...
      'SumWordLength',32);
   a = setfimath(a,f);
   b = setfimath(b,f);
   y = a + b;
   y = removefimath(y);
end
```

If you have the MATLAB Coder product, you can generate C code. This example generates C code on a computer with 32-bit, native integer type.

```
a = fi(0,1,16,15);
b = fi(0,1,16,15);
codegen -config:lib  fixed_point_32bit_KeepLSB_plus_example...
       -args {a,b} -launchreport
```

```
int fixed_point_32bit_KeepLSB_plus_example(short a, short b)
{
  return a + b;
}
```

Input Arguments

x — Input data

fi object | built-in integer | double | single

Input data, specified as a `fi` object or built-in integer value, from which to copy the data type and value to the output. `x` must be a `fi` object or an integer data type (`int8`, `int16`, `int32`, `int64`, `uint8`, `uint16`, `uint32`, or `uint64`). Otherwise, the fimath object is not applied. If `x` is not a `fi` object or integer data type, `y` = `x`.

f — Input `fimath` object

`fimath` object

Input `fimath` object, specified as an existing fimath object to attach to the output. An error occurs if `f` is not a `fimath` object.

Output Arguments

y — Output `fi` object

`fi` object

Output `fi` object, returned as a `fi` object with the same data type and value as the `x` input. `y` also has attached `fimath` object, `f`. If the input, `x`, is not a `fi` object or integer data type, then `y` = `x`.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`fi` | `fimath` | `removefimath`

Introduced in R2012b

sfi

Construct signed fixed-point numeric object

Syntax

```
a = sfi
a = sfi(v)
a = sfi(v,w)
a = sfi(v,w,f)
a = sfi(v,w,slope,bias)
a = sfi(v,w,slopeadjustmentfactor,fixedexponent,bias)
```

Description

You can use the `sfi` constructor function in the following ways:

- `a = sfi` is the default constructor and returns a signed `fi` object with no value, 16-bit word length, and 15-bit fraction length.
- `a = sfi(v)` returns a signed fixed-point object with value `v`, 16-bit word length, and best-precision fraction length.
- `a = sfi(v,w)` returns a signed fixed-point object with value `v`, word length `w`, and best-precision fraction length.
- `a = sfi(v,w,f)` returns a signed fixed-point object with value `v`, word length `w`, and fraction length `f`.
- `a = sfi(v,w,slope,bias)` returns a signed fixed-point object with value `v`, word length `w`, `slope`, and `bias`.
- `a = sfi(v,w,slopeadjustmentfactor,fixedexponent,bias)` returns a signed fixed-point object with value `v`, word length `w`, `slopeadjustmentfactor`, `fixedexponent`, and `bias`.

`fi` objects created by the `sfi` constructor function have the following general types of properties:

- “Data Properties” on page 4-415
- “fimath Properties” on page 4-793
- “numerictype Properties” on page 4-417

These properties are described in detail in “fi Object Properties” on page 2-2 in the Properties Reference.

Note `fi` objects created by the `sfi` constructor function have no local fimath.

Data Properties

The data properties of a `fi` object are always writable.

- `bin` — Stored integer value of a `fi` object in binary
- `data` — Numerical real-world value of a `fi` object
- `dec` — Stored integer value of a `fi` object in decimal
- `double` — Real-world value of a `fi` object, stored as a MATLAB `double`
- `hex` — Stored integer value of a `fi` object in hexadecimal
- `int` — Stored integer value of a `fi` object, stored in a built-in MATLAB integer data type. You can also use `int8`, `int16`, `int32`, `int64`, `uint8`, `uint16`, `uint32`, and `uint64` to get the stored integer value of a `fi` object in these formats
- `oct` — Stored integer value of a `fi` object in octal

These properties are described in detail in “fi Object Properties” on page 2-2.

fimath Properties

When you create a `fi` object with the `sfi` constructor function, that `fi` object does not have a local `fimath` object. You can attach a `fimath` object to that `fi` object if you do not want to use the default fimath settings. For more information, see “fimath Object Construction” in the Fixed-Point Designer documentation.

- `fimath` — fixed-point math object

The following `fimath` properties are always writable and, by transitivity, are also properties of a `fi` object.

- `CastBeforeSum` — Whether both operands are cast to the sum data type before addition

  Note This property is hidden when the `SumMode` is set to `FullPrecision`.

- `OverflowAction` — Action to take on overflow
- `ProductBias` — Bias of the product data type
- `ProductFixedExponent` — Fixed exponent of the product data type
- `ProductFractionLength` — Fraction length, in bits, of the product data type
- `ProductMode` — Defines how the product data type is determined
- `ProductSlope` — Slope of the product data type
- `ProductSlopeAdjustmentFactor` — Slope adjustment factor of the product data type
- `ProductWordLength` — Word length, in bits, of the product data type
- `RoundingMethod` — Rounding method
- `SumBias` — Bias of the sum data type
- `SumFixedExponent` — Fixed exponent of the sum data type
- `SumFractionLength` — Fraction length, in bits, of the sum data type
- `SumMode` — Defines how the sum data type is determined
- `SumSlope` — Slope of the sum data type
- `SumSlopeAdjustmentFactor` — Slope adjustment factor of the sum data type
- `SumWordLength` — The word length, in bits, of the sum data type

These properties are described in detail in “fimath Object Properties”.

numerictype Properties

When you create a `fi` object, a `numerictype` object is also automatically created as a property of the `fi` object.

`numerictype` — Object containing all the data type information of a `fi` object, Simulink signal or model parameter

The following `numerictype` properties are, by transitivity, also properties of a `fi` object. The properties of the `numerictype` object become read only after you create the `fi` object. However, you can create a copy of a `fi` object with new values specified for the `numerictype` properties.

- `Bias` — Bias of a `fi` object
- `DataType` — Data type category associated with a `fi` object
- `DataTypeMode` — Data type and scaling mode of a `fi` object
- `FixedExponent` — Fixed-point exponent associated with a `fi` object
- `SlopeAdjustmentFactor` — Slope adjustment associated with a `fi` object
- `FractionLength` — Fraction length of the stored integer value of a `fi` object in bits
- `Scaling` — Fixed-point scaling mode of a `fi` object
- `Signed` — Whether a `fi` object is signed or unsigned
- `Signedness` — Whether a `fi` object is signed or unsigned

Note `numerictype` objects can have a `Signedness` of `Auto`, but all `fi` objects must be `Signed` or `Unsigned`. If a `numerictype` object with `Auto` `Signedness` is used to create a `fi` object, the `Signedness` property of the `fi` object automatically defaults to `Signed`.

- `Slope` — Slope associated with a `fi` object
- `WordLength` — Word length of the stored integer value of a `fi` object in bits

For further details on these properties, see “numerictype Object Properties”.

Examples

Note For information about the display format of `fi` objects, refer to Display Settings.

For examples of casting, see “Cast fi Objects”.

Example 1

For example, the following creates a signed `fi` object with a value of `pi`, a word length of 8 bits, and a fraction length of 3 bits:

```
a = sfi(pi,8,3)
```

```
a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 3
```

Default `fimath` properties are associated with `a`. When a `fi` object does not have a local `fimath` object, no `fimath` object properties are displayed in its output. To determine whether a `fi` object has a local `fimath` object, use the `isfimathlocal` function.

```
isfimathlocal(a)

ans =
     0
```

A returned value of `0` means the `fi` object does not have a local `fimath` object. When the `isfimathlocal` function returns a `1`, the `fi` object has a local `fimath` object.

Example 2

The value `v` can also be an array:

```
a = sfi((magic(3)/10),16,12)

a =

    0.8000    0.1001    0.6001
    0.3000    0.5000    0.7000
    0.3999    0.8999    0.2000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 12
```

Example 3

If you omit the argument `f`, it is set automatically to the best precision possible:

```
a = sfi(pi,8)
```

```
a =

    3.1563

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 5
```

Example 4

If you omit `w` and `f`, they are set automatically to 16 bits and the best precision possible, respectively:

```
a = sfi(pi)

a =

    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 13
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- All properties related to data type must be constant for code generation.

See Also

`fi` | `fimath` | `fipref` | `isfimathlocal` | `numerictype` | `quantizer` | `ufi`

Introduced in R2009b

shiftdata

Shift data to operate on specified dimension

Syntax

```
[x,perm,nshifts] = shiftdata(x,dim)
```

Description

`[x,perm,nshifts] = shiftdata(x,dim)` shifts data `x` to permute dimension `dim` to the first column using the same permutation as the built-in `filter` function. The vector `perm` returns the permutation vector that is used.

If `dim` is missing or empty, then the first non-singleton dimension is shifted to the first column, and the number of shifts is returned in `nshifts`.

`shiftdata` is meant to be used in tandem with `unshiftdata`, which shifts the data back to its original shape. These functions are useful for creating functions that work along a certain dimension, like `filter`, `goertzel`, `sgolayfilt`, and `sosfilt`.

Examples

Example 1

This example shifts `x`, a 3-x-3 magic square, permuting dimension `2` to the first column. `unshiftdata` shifts `x` back to its original shape.

1. Create a 3-x-3 magic square:

```
x = fi(magic(3))

x =

     8     1     6
```

```
     3     5     7
     4     9     2
```

2. Shift the matrix x to work along the second dimension:

```
[x,perm,nshifts] = shiftdata(x,2)
```

The permutation vector, perm, and the number of shifts, nshifts, are returned along with the shifted matrix, x:

```
x =

     8     3     4
     1     5     9
     6     7     2


perm =

     2     1


nshifts =

     []
```

3. Shift the matrix back to its original shape:

```
y = unshiftdata(x,perm,nshifts)

y =

     8     1     6
     3     5     7
     4     9     2
```

Example 2

This example shows how shiftdata and unshiftdata work when you define dim as empty.

1. Define x as a row vector:

```
x = 1:5

x =

     1     2     3     4     5
```

2. Define dim as empty to shift the first non-singleton dimension of x to the first column:

```
[x,perm,nshifts] = shiftdata(x,[])
```

x is returned as a column vector, along with perm, the permutation vector, and nshifts, the number of shifts:

```
x =

     1
     2
     3
     4
     5


perm =

     []


nshifts =

     1
```

3. Using unshiftdata, restore x to its original shape:

```
y = unshiftdata(x,perm,nshifts)

y =

     1     2     3     4     5
```

See Also

`permute` | `shiftdim` | `unshiftdata`

Introduced in R2008a

shiftdim

Shift dimensions

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `shiftdim` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The dimensions argument must be a built-in type; it cannot be a `fi` object.

Introduced in R2007a

showfixptsimerrors

Show overflows from most recent fixed-point simulation

Note `showfixptsimerrors` will be removed in a future release. Use `fxptdlg` instead.

Syntax

`showfixptsimerrors`

Description

The `showfixptsimerrors` script displays any overflows from the most recent fixed-point simulation. This information is also visible in the Fixed-Point Tool.

See Also

`autofixexp` | `fxptdlg`

Introduced before R2006a

showfixptsimranges

Show logged maximum values, minimum values, and overflow data from fixed-point simulation

---

Note `showfixptsimranges` will be removed in a future release. Use `fxptdlg` instead.

Syntax

```
showfixptsimranges
showfixptsimranges(action)
```

Description

`showfixptsimranges` displays the logged maximum values, minimum values, and overflow data from the most recent fixed-point simulation in the MATLAB Command Window.

`showfixptsimranges(action)` stores the logged maximum values, minimum values, and overflow data from the most recent fixed-point simulation in the workspace variable `FixPtSimRanges`. If `action` is `'verbose'`, the logged data also appears in the MATLAB Command Window. If `action` is `'quiet'`, no data appears.

See Also

`autofixexp` | `fxptdlg`

Introduced before R2006a

showInstrumentationResults

Results logged by instrumented, compiled C code function

Syntax

```
showInstrumentationResults('mex_fcn')
showInstrumentationResults ('mex_fcn' '-options')
showInstrumentationResults mex_fcn
showInstrumentationResults mex_fcn -options
```

Description

`showInstrumentationResults('`*`mex_fcn`*`')` opens the Code Generation Report, showing results from calling the instrumented MEX function *`mex_fcn`*. Hovering over variables and expressions in the report displays the logged information. The logged information includes minimum and maximum values, proposed fraction or word lengths, percent of current range, and whether the value is always a whole number, depending on which options you specify. If you specify to include them in the `buildInstrumentedMex` function, histograms are also included. The same information is displayed in a summary table in the Variables tab.

`showInstrumentationResults ('`*`mex_fcn`*`' '`*`-options`*`')` specifies options for the instrumentation results section of the Code Generation Report.

`showInstrumentationResults` *`mex_fcn`* and `showInstrumentationResults` *`mex_fcn -options`* are alternative syntaxes for opening the Code Generation Report.

When you call `showInstrumentationResults`, a file named `instrumentation/`*`mex_fcn`*`/html/index.html` is created. *`mex_fcn`* is the name of the corresponding instrumented MEX function. Selecting this file opens a web-based version of the Code Generation Report. To open this file from within MATLAB, right-click on the file and select **Open Outside MATLAB**. `showInstrumentationResults` returns an error if the instrumented *`mex_fcn`* has not yet been called.

Input Arguments

mex_fcn

Instrumented MEX function created using `buildInstrumentedMex`.

options

Instrumentation results options.

`-defaultDT` *T*	Default data type to propose for double or single data type inputs, where *T* is either a numerictype object or one of the following: `'remainFloat'`, `'double'`, `'single'`, `'int8'`, `'int16'`, `'int32'`, `'int64'`, `'uint8'`, `'uint16'`, `'uint32'`, or `'uint64'`. If you specify an `int` or `uint`, the signedness and word length are that `int` or `uint` value and a fraction length is proposed. The default is `remainFloat`, which does not propose any data types.
`-nocode`	Do not display MATLAB code in the printable report. Display only the tables of logged variables. This option only has effect in combination with the `-printable` option.
`-optimizeWholeNumbers`	Optimize the word length of variables whose simulation min/max logs indicate that they are always whole numbers.
`-percentSafetyMargin` *N*	Safety margin for simulation min/max, where *N* is a percent value.
`-printable`	Create and open a printable HTML report. The report opens in the system browser.
`-proposeFL`	Propose fraction lengths for specified word lengths.
`-proposeWL`	Propose word lengths for specified fraction lengths.

Examples

Generate an instrumented MEX function, then run a test bench. Call `showInstrumentationResults` to open the Code Generation Report.

Note The logged results from `showInstrumentationResults` are an accumulation of all previous calls to the instrumented MEX function. To clear the log, see `clearInstrumentationResults`.

---

1 Create a temporary directory, then import an example function from Fixed-Point Designer.

```
tempdirObj=fidemo.fiTempdir('showInstrumentationResults')
copyfile(fullfile(matlabroot,'toolbox','fixedpoint',...
   'fidemos','fi_m_radix2fft_withscaling.m'),...
   'testfft.m','f')
```

2 Define prototype input arguments.

```
T = numerictype('DataType','ScaledDouble','Scaling',...
   'Unspecified');

n = 128;
x = complex(fi(zeros(n,1),T));
W = coder.Constant(fi(fidemo.fi_radix2twiddles(n),T));
```

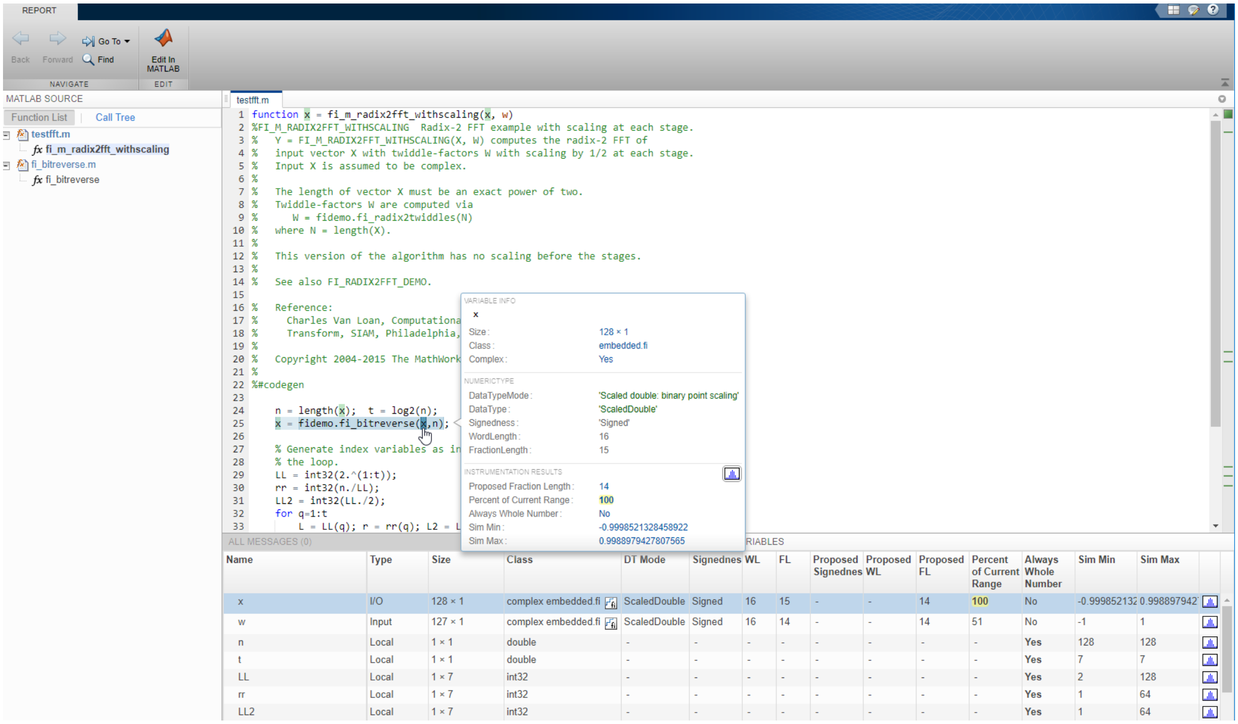
3 Generate an instrumented MEX function. Use the `-o` option to specify the MEX function name.

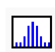
```
buildInstrumentedMex testfft -o testfft_instrumented...
   -args {x,W} -histogram
```

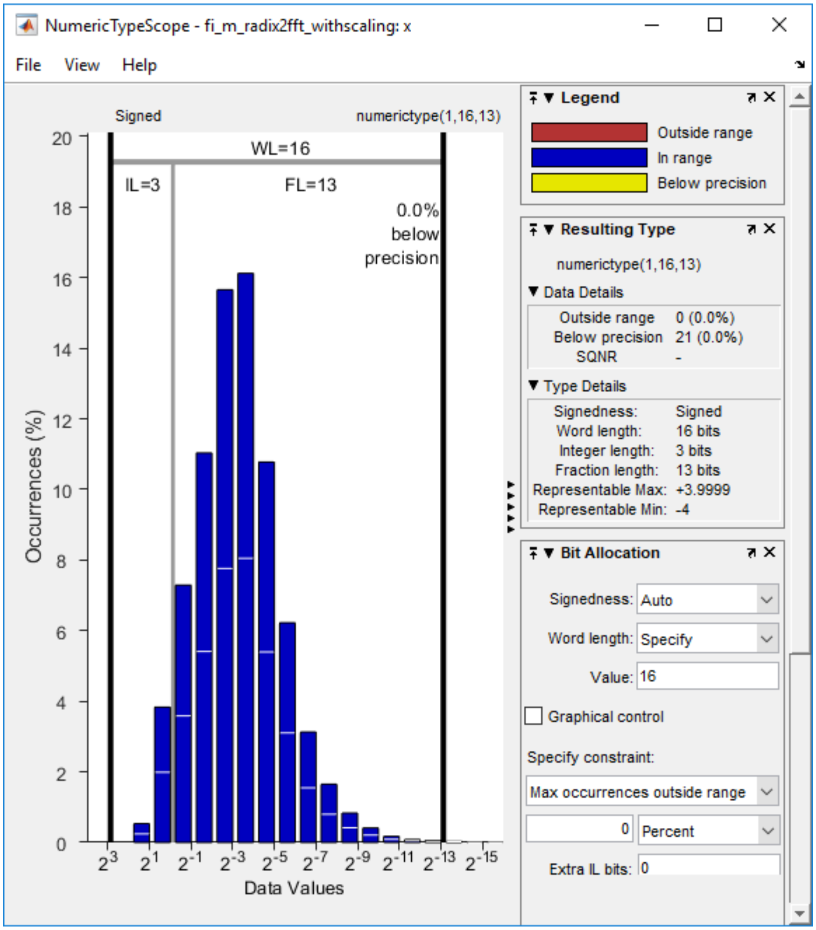
4 Run a test bench to record instrumentation results. Call `showInstrumentationResults` to open a report. View the simulation minimum and maximum values, proposed fraction length, percent of current range, and whole number status by pausing over a variable in the report.

```
for i=1:20
   x(:) = 2*rand(size(x))-1;
   y = testfft_instrumented(x);
end
```

```
showInstrumentationResults testfft_instrumented...
   -proposeFL -percentSafetyMargin 10
```



1 View the histogram for a variable by clicking  in the **Variables** tab.



For information on the figure, refer to the `NumericTypeScope` reference page.

2 Close the histogram display and then, clear the results log.

```
clearInstrumentationResults testfft_instrumented
```

3 Clear the MEX function, then delete temporary files.

```
clear testfft_instrumented;
tempdirObj.cleanUp;
```

See Also

`NumericTypeScope` | `buildInstrumentedMex` | `clearInstrumentationResults` | `codegen` | `fiaccel` | `mex`

Introduced in R2011b

sin

Sine of fixed-point values

Syntax

```
y = sin(theta)
```

Description

`y = sin(theta)` returns the sine on page 4-813 of fi input `theta` using a table-lookup algorithm.

Input Arguments

`theta`

`theta` can be a real-valued, signed or unsigned scalar, vector, matrix, or `N`-dimensional array containing the fixed-point angle values in radians. Valid data types of `theta` are:

- fi single
- fi double
- fi fixed-point with binary point scaling
- fi scaled double with binary point scaling

Output Arguments

`y`

`y` is the sine of `theta`. `y` is a signed, fixed-point number in the range [-1,1]. It has a 16-bit word length and 15-bit fraction length (`numerictype(1,16,15)`) .

Examples

Calculate the sine of fixed-point input values.

```
theta = fi([-pi/2,-pi/3,-pi/4 0, pi/4,pi/3,pi/2])

theta =

theta =

   -1.5708  -1.0472  -0.7854  0  0.7854  1.0472  1.5708

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 14

y = sin(theta)

y =

   -1.0000  -0.8661  -0.7072   0  0.7070  0.8659  0.9999

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15
```

Definitions

Sine

The sine of angle Θ is defined as

$$\sin(\theta) = \frac{e^{i\theta} - e^{-i\theta}}{2i}$$

Algorithms

The `sin` function computes the sine of fixed-point input using an 8-bit lookup table as follows:

1. Perform a modulo 2π, so the input is in the range [0,2π) radians.
2. Cast the input to a 16-bit stored integer value, using the 16 most-significant bits.
3. Compute the table index, based on the 16-bit stored integer value, normalized to the full `uint16` range.
4. Use the 8 most-significant bits to obtain the first value from the table.
5. Use the next-greater table value as the second value.
6. Use the 8 least-significant bits to interpolate between the first and second values, using nearest-neighbor linear interpolation.

fimath Propagation Rules

The `sin` function ignores and discards any `fimath` attached to the input, `theta`. The output, `y`, is always associated with the default `fimath`.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`angle` | `atan2` | `cordiccos` | `cordicsin` | `cos` | `sin`

Topics

Demo: Fixed-Point Sine and Cosine Calculation

Introduced in R2012a

sign

Perform signum function on array

Syntax

```
c = sign(a)
```

Description

`c = sign(a)` returns an array `c` the same size as `a`, where each element of `c` is

- `1` if the corresponding element of `a` is greater than zero
- `0` if the corresponding element of `a` is zero
- `-1` if the corresponding element of `a` is less than zero

The elements of `c` are of data type `int8`.

`sign` does not support complex `fi` inputs.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

single

Single-precision floating-point real-world value of `fi` object

Syntax

`single(a)`

Description

Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or, equivalently as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

`single(a)` returns the real-world value of a `fi` object in single-precision floating point.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- For the automated workflow, do not use explicit double or single casts in your MATLAB algorithm to insulate functions that do not support fixed-point data types. The automated conversion tool does not support these casts. Instead of using casts, supply a replacement function. For more information, see “Function Replacements”.

See Also

`double`

Introduced before R2006a

size

Array dimensions

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `size` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

slice

Create volumetric slice plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `slice` reference page for more information.

Introduced before R2006a

sort

Sort elements of real-valued `fi` object in ascending or descending order

Description

This function accepts `fi` objects as inputs.

`sort` does not support complex fixed-point inputs, or pairs of `Name, Value` arguments. Refer to the MATLAB `sort` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- The dimensions argument must be a built-in type; it cannot be a `fi` object.

Introduced in R2008b

spy

Visualize sparsity pattern

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `spy` reference page for more information.

Introduced before R2006a

sqrt

Square root of fi object

Syntax

```
c = sqrt(a)
c = sqrt(a,T)
c = sqrt(a,F)
c = sqrt(a,T,F)
```

Description

This function computes the square root of a fi object using a bisection algorithm.

c = sqrt(a) returns the square root of fi object a. Intermediate quantities are calculated using the fimath associated with a. The numerictype object of c is determined automatically for you using an internal rule on page 4-824.

c = sqrt(a,T) returns the square root of fi object a with numerictype object T. Intermediate quantities are calculated using the fimath associated with a. See “Data Type Propagation Rules” on page 4-824.

c = sqrt(a,F) returns the square root of fi object a. Intermediate quantities are calculated using the fimath object F. The numerictype object of c is determined automatically for you using an internal rule on page 4-824. When a is a built-in double or single data type, this syntax is equivalent to c = sqrt(a) and the fimath object F is ignored.

c = sqrt(a,T,F) returns the square root fi object a with numerictype object T. Intermediate quantities are also calculated using the fimath object F. See “Data Type Propagation Rules” on page 4-824.

sqrt does not support complex, negative-valued, or [Slope Bias] inputs.

Internal Rule

For syntaxes where the `numerictype` object of the output is not specified as an input to the `sqrt` function, it is automatically calculated according to the following internal rule:

$$sign_c = sign_a$$

$$WL_c = \text{ceil}(\frac{WL_a}{2})$$

$$FL_c = WL_c - \text{ceil}(\frac{WL_a - FL_a}{2})$$

Data Type Propagation Rules

For syntaxes for which you specify a `numerictype` object `T`, the `sqrt` function follows the data type propagation rules listed in the following table. In general, these rules can be summarized as "floating-point data types are propagated." This allows you to write code that can be used with both fixed-point and floating-point inputs.

Data Type of Input fi Object a	Data Type of numerictype object T	Data Type of Output c
Built-in `double`	Any	Built-in `double`
Built-in `single`	Any	Built-in `single`
`fi Fixed`	`fi Fixed`	Data type of `numerictype` object `T`
`fi ScaledDouble`	`fi Fixed`	`ScaledDouble` with properties of `numerictype` object `T`
`fi double`	`fi Fixed`	`fi double`
`fi single`	`fi Fixed`	`fi single`
Any `fi` data type	`fi double`	`fi double`
Any `fi` data type	`fi single`	`fi single`

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Complex and [Slope Bias] inputs error out.
- Negative inputs yield a 0 result.

Introduced in R2006b

squeeze

Remove singleton dimensions

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `squeeze` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

stairs

Create stairstep graph

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `stairs` reference page for more information.

Introduced before R2006a

stem

Plot discrete sequence data

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `stem` reference page for more information.

Introduced before R2006a

stem3

Plot 3-D discrete sequence data

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `stem3` reference page for more information.

Introduced before R2006a

storedInteger

Stored integer value of `fi` object

Syntax

`st_int = storedInteger(f)`

Description

`st_int = storedInteger(f)` returns the stored integer value of fi object `f`.

Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or, equivalently as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

The stored integer is the raw binary number, in which the binary point is assumed to be at the far right of the word.

Input Arguments

f — Fixed-point numeric object
`fi` object

Fixed-point numeric object from which you want to get the stored integer value.

Output Arguments

st_int — Stored integer value of fi object
integer

Data Types: int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64

The returned stored integer value is the smallest built-in integer data type in which the stored integer value f fits. Signed fi values return stored integers of type int8, int16, int32, or int64. Unsigned fi values return stored integers of type uint8, uint16, uint32, or uint64. The return type is determined based on the stored integer word length (WL):

- WL ≤ 8 bits, the return type is int8 or uint8.
- 8 bits < WL ≤ 16 bits, the return type is int16 or uint16.
- 16 bits < WL ≤ 32 bits, the return type is int32 or uint32.
- 32 bits < WL ≤ 64 bits, the return type is int64 or uint64.

Note When the word length is greater than 64 bits, the storedInteger function errors. For bit-true integer representation of very large word lengths, use bin, oct, dec, hex, or sdec.

Examples

Stored Integer Value of fi Objects

Find the stored integer values for two fi objects. Use the class function to display the stored integer data types.

```
x = fi([0.2 0.3 0.5 0.3 0.2]);
in_x = storedInteger(x);
c1 = class(in_x)

numtp = numerictype('WordLength',17);
x_n = fi([0.2 0.3 0.5 0.3 0.2],'numerictype',numtp);
in_xn = storedInteger(x_n);
c2 = class(in_xn)
```

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`int16` | `int32` | `int64` | `int8` | `storedIntegerToDouble` | `uint16` | `uint32` | `uint64` | `uint8`

Introduced in R2012a

storedIntegerToDouble

Convert stored integer value of `fi` object to built-in double value

Syntax

`d = storedIntegerToDouble(f)`

Description

`d = storedIntegerToDouble(f)` converts the stored integer value of `fi` object, `f`, to a double-precision floating-point value, `d`.

If the input word length is greater than 52 bits, a quantization error may occur. `INF` is returned if the stored integer value of the input `fi` object is outside the representable range of built-in double values.

Input Arguments

`f`

fi object

Examples

Convert Stored Integer Value of fi Object to Double-Precision Value

Convert the stored integer of a `fi` value to a double-precision value. Use the `class` function to verify that the stored integer is a double-precision value.

```
f = fi(pi,1,16,12);
d = storedIntegerToDouble(f);
dtype = class(d)
```

```
dtype =
'double'
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`class` | `fi` | `storedInteger`

Introduced in R2012a

streamribbon

Create 3-D stream ribbon plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `streamribbon` reference page for more information.

Introduced before R2006a

streamslice

Draw streamlines in slice planes

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `streamslice` reference page for more information.

Introduced before R2006a

streamtube

Create 3-D stream tube plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `streamtube` reference page for more information.

Introduced before R2006a

stripscaling

Stored integer of `fi` object

Syntax

```
I = stripscaling(a)
```

Description

`I = stripscaling(a)` returns the stored integer of `a` as a `fi` object with binary-point scaling, zero fraction length and the same word length and sign as `a`.

Examples

Stripscaling is useful for converting the value of a `fi` object to its stored integer value.

```
fipref('NumericTypeDisplay','short', ...
       'FimathDisplay','none');
format long g
a = fi(0.1,true,48,47)

a = 

         0.100000000000001
      s48,47
b = stripscaling(a)

b = 

            14073748835533
      s48,0
bin(a)

ans =

000011001100110011001100110011001100110011001101
```

```
bin(b)

ans =

0000110011001100110011001100110011001100110011001101
```

Notice that the stored integer values of `a` and `b` are identical, while their real-world values are different.

Introduced before R2006a

sub

Subtract two objects using `fimath` object

Syntax

```
c = sub(F,a,b)
```

Description

`c = sub(F,a,b)` subtracts objects `a` and `b` using `fimath` object `F`. This is helpful in cases when you want to override the `fimath` objects of `a` and `b`, or if the `fimath` properties associated with `a` and `b` are different. The output `fi` object `c` has no local fimath.

`a` and `b` must both be `fi` objects and must have the same dimensions unless one is a scalar. If either `a` or `b` is scalar, then `c` has the dimensions of the nonscalar object.

Examples

In this example, `c` is the 32-bit difference of `a` and `b` with fraction length 16.

```
a = fi(pi);
b = fi(exp(1));
F = fimath('SumMode','SpecifyPrecision',...
        'SumWordLength',32,'SumFractionLength',16);
c = sub(F, a, b)

c =

    0.4233


          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 16
```

Algorithms

`c = sub(F,a,b)` is similar to

```
a.fimath = F;
b.fimath = F;
c = a - b

c =
    0.4233

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 16

        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: SpecifyPrecision
         SumWordLength: 32
     SumFractionLength: 16
         CastBeforeSum: true
```

but not identical. When you use `sub`, the `fimath` properties of `a` and `b` are not modified, and the output `fi` object `c` has no local fimath. When you use the syntax `c = a - b`, where `a` and `b` have their own `fimath` objects, the output `fi` object `c` gets assigned the same `fimath` object as inputs `a` and `b`. See “fimath Rules for Fixed-Point Arithmetic” in the Fixed-Point Designer User's Guide for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Code generation does not support the syntax `F.sub(a,b)`. You must use the syntax `sub(F,a,b)`.

See Also

add | divide | fi | fimath | mpy | mrdivide | numerictype | rdivide

Introduced before R2006a

subsasgn

Subscripted assignment

Syntax

```
a(I) = b
a(I,J) = b
a(I,:) = b
a(:,I) = b
a(I,J,K,...) = b
a = subsasgn(a,S,b)
```

Description

`a(I) = b` assigns the values of `b` into the elements of `a` specified by the subscript vector `I`. `b` must have the same number of elements as `I` or be a scalar value.

`a(I,J) = b` assigns the values of `b` into the elements of the rectangular submatrix of `a` specified by the subscript vectors `I` and `J`. `b` must have `LENGTH(I)` rows and `LENGTH(J)` columns.

A colon used as a subscript, as in `a(I,:) = b` or `a(:,I) = b` indicates the entire column or row.

For multidimensional arrays, `a(I,J,K,...) = b` assigns `b` to the specified elements of `a`. `b` must be `length(I)`-by-`length(J)`-by-`length(K)`-... or be shiftable to that size by adding or removing singleton dimensions.

`a = subsasgn(a,S,b)` is called for the syntax `a(i)=b`, `a{i}=b`, or `a.i=b` when `a` is an object. `S` is a structure array with the following fields:

- type — One of the following: `'()'`, `'{}'`, or `'.'` specifying the subscript type
- subs — Cell array or character vector containing the actual subscripts

For instance, the syntax `a(1:2,:) = b` calls `a=subsasgn(a,S,b)` where `S` is a 1-by-1 structure with `S.type='()'` and `S.subs = {1:2,':'}`. A colon used as a subscript is passed as `':'`.

You can use fixed-point assignment, for example `a(:) = b`, to cast a value with one `numerictype` object into another `numerictype` object. This subscripted assignment statement assigns the value of `b` into `a` while keeping the `numerictype` object of `a`. Subscripted assignment works the same way for integer data types.

Examples

Cast a 16-bit Number into an 8-bit Number

For `fi` objects `a` and `b`, there is a difference between

```
a = b
```

and

```
a(:) = b
```

In the first case, `a = b` replaces `a` with `b` while `a` assumes the value, `numerictype` object and `fimath` object associated with `b`. In the second case, `a(:) = b` assigns the value of `b` into `a` while keeping the `numerictype` object of `a`. You can use this to cast a value with one `numerictype` object into another `numerictype` object.

For example, cast a 16-bit number into an 8-bit number.

```
a = fi(0, 1, 8, 7)
```

```
a =

     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 7
```

```
b = fi(pi/4, 1, 16, 15)
```

```
b =

    0.7854

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 15
```

```
a(:) = b
```

```
a =

    0.7891

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 8
        FractionLength: 7
```

Emulate a 40-bit Accumulator of a DSP

This example defines a variable `acc` to emulate a 40-bit accumulator of a DSP. The products and sums in this example are assigned into the accumulator using the syntax `acc(1)=...` Assigning values into the accumulator is like storing a value in a register. To begin, turn the logging mode on and define the variables. In this example, `n` is the number of points in the input data `x` and output data `y`, and `t` represents time. The remaining variables are all defined as `fi` objects. The input data `x` is a high-frequency sinusoid added to a low-frequency sinusoid.

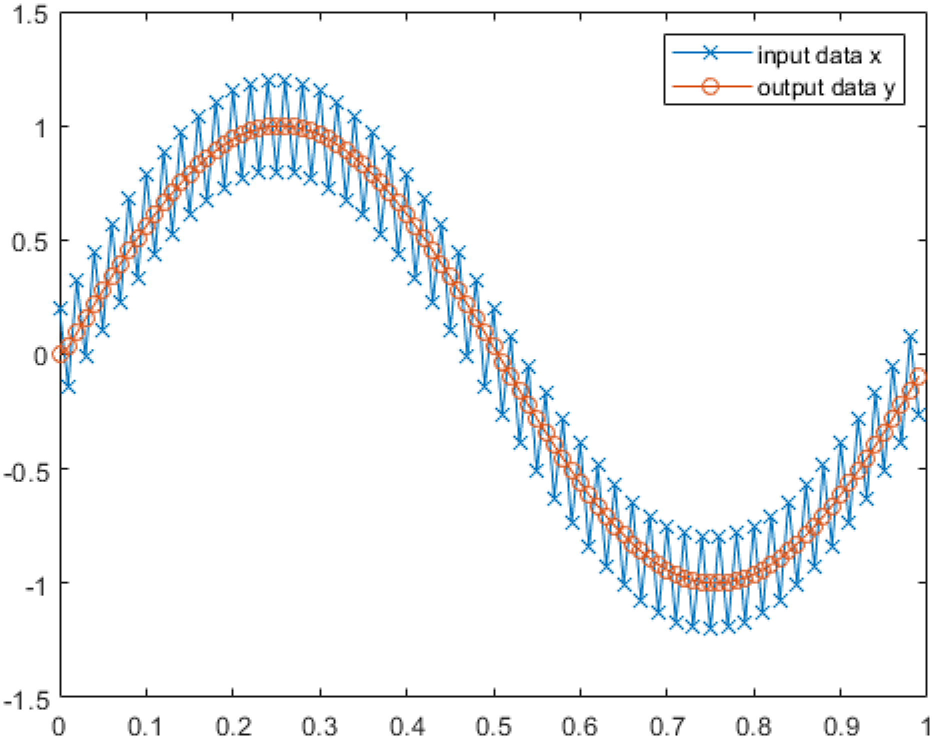
```
fipref('LoggingMode', 'on');
n = 100;
t = (0:n-1)/n;
x = fi(sin(2*pi*t) + 0.2*cos(2*pi*50*t));
b = fi([.5 .5]);
y = fi(zeros(size(x)), numerictype(x));
acc = fi(0.0, true, 40, 30);
```

The following loop takes a running average of the input `x` using the coefficients in `b` . Notice that `acc` is assigned into `acc(1)=...` versus using `acc=...`, which would overwrite and change the data type of `acc` .

```
for k = 2:n
    acc(1) = b(1)*x(k);
    acc(1) = acc + b(2)*x(k-1);
    y(k) = acc;
end
```

By averaging every other sample, the loop shown above passes the low-frequency sinusoid through and attenuates the high-frequency sinusoid.

```
plot(t,x,'x-',t,y,'o-')
legend('input data x','output data y')
```



The log report shows the minimum and maximum logged values and ranges of the variables used. Because `acc` is assigned into, rather than overwritten, these logs reflect the accumulated minimum and maximum values.

```
logreport(x, y, b, acc)
```

```
                 minlog         maxlog      lowerbound      upperbound      noverflows
         x      -1.200012       1.197998            -2        1.999939               0
         y     -0.9990234      0.9990234            -2        1.999939               0
         b            0.5            0.5            -1       0.9999695               0
       acc     -0.9990234      0.9989929          -512             512               0
```

Display `acc` to verify that its data type did not change.

```
acc
```

```
acc =
   -0.0941

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 40
        FractionLength: 30
```

Reset the fipref object to restore its default values.

```
reset(fipref)
```

- “Cast fi Objects”

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`subsref`

Topics

"Cast fi Objects"

Introduced before R2006a

subsref

Subscripted reference

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `subsref` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

sum

Sum of array elements

Syntax

```
S= sum (A)
S= sum ( A, dim)
S = sum (___ , type )
```

Description

`S= sum (A)` returns the sum along different dimensions of the `fi` array `A`.

If `A` is a vector, `sum(A)` returns the sum of the elements.

If `A` is a matrix, `sum(A)` treats the columns of `A` as vectors, returning a row vector of the sums of each column.

If `A` is a multidimensional array, `sum(A)` treats the values along the first non-singleton dimension as vectors, returning an array of row vectors.

`S= sum ( A, dim)` sums along the dimension `dim` of `A`.

`S = sum (___ , type )` returns an array in the class specified by `type`, using any of the input arguments in the previous syntaxes. `type` can be `'double'` or `'native'`.

- If `type` is `'double'`, then `sum` returns a double-precision array, regardless of the input data type.
- If `type` is `'native'`, then `sum` returns an array with the same class of input array `A`.

The `fimath` object is used in the calculation of the sum. If `SumMode` is `FullPrecision`, `KeepLSB`, or `KeepMSB`, then the number of integer bits of growth for `sum(A)` is `ceil(log2(size(A,dim)))`.

`sum` does not support `fi` objects of data type `Boolean`.

Examples

Sum of Vector Elements

Create a `fi` vector, and specify `fimath` properties in the constructor.

```
A=fi([1 2 5 8 5], 'SumMode', 'KeepLSB', 'SumWordLength', 32)
```

```
A = 
     1     2     5     8     5

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11

        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: KeepLSB
         SumWordLength: 32
         CastBeforeSum: true
```

Compute the sum of the elements of `A`.

```
S=sum(A)
```

```
S = 
    21

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 11

        RoundingMethod: Nearest
        OverflowAction: Saturate
           ProductMode: FullPrecision
               SumMode: KeepLSB
         SumWordLength: 32
         CastBeforeSum: true
```

The output `S` is a scalar with the specified `SumWordLength` of 32. The `FractionLength` of `S` is 11 because `SumMode` was set to `KeepLSB`.

Sum of Elements in Each Column

Create a `fi` array, and compute the sum of the elements in each column.

```
A=fi([1 2 8;3 7 0;1 2 2])
```

```
A =
     1     2     8
     3     7     0
     1     2     2

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

```
S=sum(A)
```

```
S =
     5    11    10

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 18
        FractionLength: 11
```

MATLAB® returns a row vector with the sums of each column of `A`. The `WordLength` of `S` has increased by two bits because `ceil(log2(size(A,1)))=2`. The `FractionLength` remains the same because the default setting of `SumMode` is `FullPrecision`.

Sum of Elements in Each Row

Compute the sum along the second dimension (`dim=2`) of 3-by-3 matrix `A`.

```
A=fi([1 2 8;3 7 0;1 2 2])
```

```
A =
     1     2     8
     3     7     0
     1     2     2
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

```
S=sum(A, 2)
```

```
S =
    11
    10
     5

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 18
        FractionLength: 11
```

MATLAB® returns a column vector of the sums of the elements in each row. The `WordLength` of `S` is 18 because `ceil(log2(size(A,2)))=2`.

Sum of Elements Preserving Data Type

Compute the sums of the columns of `A` so that the output array, `S`, has the same data type.

```
A=fi([1 2 8;3 7 0;1 2 2]), class(A)
```

```
A =
     1     2     8
     3     7     0
     1     2     2

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11

ans =
'embedded.fi'
```

```
S=sum(A, 'native'), class(S)
```

```
S =
     5    11    10
```

```
          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 18
        FractionLength: 11

ans =
'embedded.fi'
```

MATLAB® preserves the data type of `A` and returns a row vector `S` of type `embedded.fi`.

Input Arguments

`A` — Input `fi` array
`fi` object | numeric variable

`fi` input array, specified as a scalar, vector, matrix, or multidimensional array.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

`dim` — Dimension to operate along
positive integer scalar

Dimension to operate along, specified as a positive integer scalar. `dim` can also be a `fi` object. If no value is specified, the default is the first array dimension whose size does not equal 1.

Data Types: `fi`|`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`type` — Output class
`'double'` | `'native'`

Output class, specified as `'double'` or `'native'`, defines the data type that the operation is performed in and returned in.

Data Types: `char`

Output Arguments

S — Sum array
scalar | vector | matrix | multidimensional array

Sum array, returned as a scalar, vector, matrix, or multidimensional array.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Variable-sized inputs are only supported when the `SumMode` property of the governing `fimath` is set to `Specify precision` or `Keep LSB`.

See Also

`add` | `divide` | `fi` | `fimath` | `mpy` | `mrdivide` | `numerictype` | `rdivide` | `sub` | `sum`

Introduced before R2006a

surf

Create 3-D shaded surface plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `surf` reference page for more information.

Introduced before R2006a

surfc

Create 3-D shaded surface plot with contour plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `surfc` reference page for more information.

Introduced before R2006a

surfl

Create surface plot with colormap-based lighting

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `surfl` reference page for more information.

Introduced before R2006a

surfnorm

Compute and display 3-D surface normals

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `surfnorm` reference page for more information.

Introduced before R2006a

text

Create text object in current axes

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `text` reference page for more information.

Introduced before R2006a

times

Element-by-element multiplication of fi objects

Syntax

```
C =A.*B
C = times(A, B)
```

Description

C =A.*B performs element-by-element multiplication of A and B, and returns the result in C.

C = times(A, B) is an alternate way to execute A.*B.

Examples

Multiply a fi Object by a Scalar

Use the times function to perform element-by-element multiplication of a fi object and a scalar.

```
a=4;
b=fi([2 4 7; 9 0 2])
```

```
b =
     2     4     7
     9     0     2

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 11
```

a is a scalar double, and b is a matrix of fi objects. When doing arithmetic between a fi and a double, the double is cast to a fi with the same word length and signedness of the fi, and best-precision fraction length. The result of the operation is a fi.

```
c=a.*b
```

```
c =
     8    16    28
    36     0     8

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 32
        FractionLength: 23
```

During the operation, a was cast to a fi object with wordlength 16. The output, c, is a fi object with word length 32, the sum of the word lengths of the two multiplicands, a and b. This is because the default setting of ProductMode in fimath is FullPrecision.

Multiply Two fi Objects

Use the times function to perform element-by-element multiplication of two fi objects.

```
a=fi([5 9 9; 1 2 -3], 1, 16, 3)
```

```
a =
     5     9     9
     1     2    -3

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 16
        FractionLength: 3
```

```
b=fi([2 4 7; 9 0 2], 1, 16, 3)
```

```
b =
     2     4     7
     9     0     2

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
```

```
        WordLength: 16
    FractionLength: 3
```

```
c=a.*b
```

```
c =
    10    36    63
     9     0    -6

      DataTypeMode: Fixed-point: binary point scaling
        Signedness: Signed
        WordLength: 32
    FractionLength: 6
```

The word length and fraction length of `c` are equal to the sums of the word lengths and fraction lengths of `a` and `b`. This is because the default setting of `ProductMode` in `fimath` is `FullPrecision`.

Input Arguments

A — Input array

scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects or built-in types. `A` and `B` must have the same dimensions unless one is a scalar value.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

B — Input array

scalar | vector | matrix | multidimensional array

Input array, specified as a scalar, vector, matrix, or multidimensional array of `fi` objects or built-in types. `A` and `B` must have the same dimensions unless one is a scalar value.

Data Types: `fi` |`single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

Complex Number Support: Yes

Output Arguments

C — Output array
scalar | vector | matrix | multidimensional array

Output array, specified as a scalar, vector, matrix or multidimensional array.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- Any non-fi input must be constant; that is, its value must be known at compile time so that it can be cast to a fi object.
- When you provide complex inputs to the times function inside of a MATLAB Function block, you must declare the input as complex before running the simulation. To do so, go to the **Ports and data manager** and set the **Complexity** parameter for all known complex inputs to On.

See Also

minus | mtimes | plus | uminus

Introduced before R2006a

toeplitz

Create Toeplitz matrix

Syntax

```
t = toeplitz(a,b)
t = toeplitz(b)
```

Description

`t = toeplitz(a,b)` returns a nonsymmetric Toeplitz matrix having `a` as its first column and `b` as its first row. `b` is cast to the `numerictype` of `a`.

`t = toeplitz(b)` returns the symmetric or Hermitian Toeplitz matrix formed from vector `b`, where `b` is the first row of the matrix.

The output `fi` object `t` has the same `numerictype` properties as the leftmost `fi` object input. If the leftmost `fi` object input has a local fimath, the output `fi` object `t` is assigned the same local fimath. Otherwise, the output `fi` object `t` has no local fimath.

Examples

`toeplitz(a,b)` casts `b` into the data type of `a`. In this example, overflow occurs:

```
fipref('NumericTypeDisplay','short');
format short g
a = fi([1 2 3],true,8,5)

a =

     1     2     3
      s8,5
b = fi([1 4 8],true,16,10)

b =
```

```
     1     4     8
      s16,10
toeplitz(a,b)

ans =

            1       3.9688       3.9688
            2            1       3.9688
            3            2            1
      s8,5
```

`toeplitz(b,a)` casts `a` into the data type of `b`. In this example, overflow does not occur:

```
toeplitz(b,a)

ans =

     1     2     3
     4     1     2
     8     4     1
      s16,10
```

If one of the arguments of `toeplitz` is a built-in data type, it is cast to the data type of the `fi` object.

```
x = [1 exp(1) pi]

x =

            1       2.7183       3.1416

toeplitz(a,x)

ans =

            1       2.7188       3.1563
            2            1       2.7188
            3            2            1
      s8,5
toeplitz(x,a)

ans =

            1            2            3
```

```
    2.7188            1            2
    3.1563       2.7188            1
  s8,5
```

Introduced before R2006a

tostring

Convert `numerictype` or `quantizer` object to string

Syntax

```
s = tostring(f)
s = tostring(F)
s = tostring(T)
s = tostring(q)
```

Description

`s = tostring(f)` converts `fi` object `f` to a character vector `s` such that `eval(s)` would create a `fi` object with the same properties as `f`.

`s = tostring(F)` converts `fimath` object `F` to a character vector `s` such that `eval(s)` would create a `fimath` object with the same properties as `F`.

`s = tostring(T)` converts `numerictype` object `T` to a character vector `s` such that `eval(s)` would create a `numerictype` object with the same properties as `T`.

`s = tostring(q)` converts `quantizer` object `q` to a character vector `s`. After converting `q`, the function `eval(s)` can use `s` to create a `quantizer` object with the same properties as `q`.

Examples

Convert a `numerictype` Object to a String

This example uses the `tostring` function to convert a `numerictype` object `T` to a string `s`.

```
T = numerictype(1,16,15);
s = tostring(T);
```

```
T1 = eval(s);
isequal(T,T1)

ans =

     1
```

Convert a fi Object to a character vector

This example uses the `tostring` function to convert a `fi` object `f` to a character vector `s`.

```
f = fi(pi,1,16,10);
s = tostring(f);
f1 = eval(s);
isequal(f,f1)

ans =

     1
```

See Also

`eval` | `fi` | `fimath` | `numerictype` | `quantizer`

Introduced before R2006a

transpose

Transpose operation

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `transpose` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

treeplot

Plot picture of tree

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `treeplot` reference page for more information.

Introduced before R2006a

tril

Lower triangular part of matrix

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `tril` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- If supplied, the index, `k`, must be a real and scalar integer value that is not a `fi` object.

Introduced before R2006a

trimesh

Create triangular mesh plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `trimesh` reference page for more information.

Introduced before R2006a

triplot

Create 2-D triangular plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `triplot` reference page for more information.

Introduced before R2006a

trisurf

Create triangular surface plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `trisurf` reference page for more information.

Introduced before R2006a

triu

Upper triangular part of matrix

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `triu` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- If supplied, the index, `k`, must be a real and scalar integer value that is not a `fi` object.

Introduced before R2006a

ufi

Construct unsigned fixed-point numeric object

Syntax

```
a = ufi
a = ufi(v)
a = ufi(v,w)
a = ufi(v,w,f)
a = ufi(v,w,slope,bias)
a = ufi(v,w,slopeadjustmentfactor,fixedexponent,bias)
```

Description

You can use the `ufi` constructor function in the following ways:

- `a = ufi` is the default constructor and returns an unsigned `fi` object with no value, 16-bit word length, and 15-bit fraction length.
- `a = ufi(v)` returns an unsigned fixed-point object with value `v`, 16-bit word length, and best-precision fraction length.
- `a = ufi(v,w)` returns an unsigned fixed-point object with value `v`, word length `w`, and best-precision fraction length.
- `a = ufi(v,w,f)` returns an unsigned fixed-point object with value `v`, word length `w`, and fraction length `f`.
- `a = ufi(v,w,slope,bias)` returns an unsigned fixed-point object with value `v`, word length `w`, `slope`, and `bias`.
- `a = ufi(v,w,slopeadjustmentfactor,fixedexponent,bias)` returns an unsigned fixed-point object with value `v`, word length `w`, `slopeadjustmentfactor`, `fixedexponent`, and `bias`.

`fi` objects created by the `ufi` constructor function have the following general types of properties:

- “Data Properties” on page 4-415
- “fimath Properties” on page 4-878
- “numerictype Properties” on page 4-417

These properties are described in detail in “fi Object Properties” on page 2-2 in the Properties Reference.

Note `fi` objects created by the `ufi` constructor function have no local fimath.

Data Properties

The data properties of a `fi` object are always writable.

- `bin` — Stored integer value of a `fi` object in binary
- `data` — Numerical real-world value of a `fi` object
- `dec` — Stored integer value of a `fi` object in decimal
- `double` — Real-world value of a `fi` object, stored as a MATLAB `double`
- `hex` — Stored integer value of a `fi` object in hexadecimal
- `int` — Stored integer value of a `fi` object, stored in a built-in MATLAB integer data type. You can also use `int8`, `int16`, `int32`, `int64`, `uint8`, `uint16`, `uint32`, and `uint64` to get the stored integer value of a `fi` object in these formats
- `oct` — Stored integer value of a `fi` object in octal

These properties are described in detail in “fi Object Properties” on page 2-2.

fimath Properties

When you create a `fi` object with the `ufi` constructor function, that `fi` object does not have a local `fimath` object. You can attach a `fimath` object to that `fi` object if you do not want to use the default fimath settings. For more information, see “fimath Object Construction” in the Fixed-Point Designer documentation.

- `fimath` — fixed-point math object

The following `fimath` properties are always writable and, by transitivity, are also properties of a `fi` object.

- CastBeforeSum — Whether both operands are cast to the sum data type before addition

Note This property is hidden when the SumMode is set to FullPrecision.

- OverflowAction — Action to take on overflow
- ProductBias — Bias of the product data type
- ProductFixedExponent — Fixed exponent of the product data type
- ProductFractionLength — Fraction length, in bits, of the product data type
- ProductMode — Defines how the product data type is determined
- ProductSlope — Slope of the product data type
- ProductSlopeAdjustmentFactor — Slope adjustment factor of the product data type
- ProductWordLength — Word length, in bits, of the product data type
- RoundingMethod — Rounding method
- SumBias — Bias of the sum data type
- SumFixedExponent — Fixed exponent of the sum data type
- SumFractionLength — Fraction length, in bits, of the sum data type
- SumMode — Defines how the sum data type is determined
- SumSlope — Slope of the sum data type
- SumSlopeAdjustmentFactor — Slope adjustment factor of the sum data type
- SumWordLength — The word length, in bits, of the sum data type

These properties are described in detail in “fimath Object Properties”.

numerictype Properties

When you create a fi object, a numerictype object is also automatically created as a property of the fi object.

numerictype — Object containing all the data type information of a fi object, Simulink signal or model parameter

The following numerictype properties are, by transitivity, also properties of a fi object. The properties of the numerictype object become read only after you create the fi object. However, you can create a copy of a fi object with new values specified for the numerictype properties.

- Bias — Bias of a fi object
- DataType — Data type category associated with a fi object
- DataTypeMode — Data type and scaling mode of a fi object
- FixedExponent — Fixed-point exponent associated with a fi object
- SlopeAdjustmentFactor — Slope adjustment associated with a fi object
- FractionLength — Fraction length of the stored integer value of a fi object in bits
- Scaling — Fixed-point scaling mode of a fi object
- Signed — Whether a fi object is signed or unsigned
- Signedness — Whether a fi object is signed or unsigned

  Note numerictype objects can have a Signedness of Auto, but all fi objects must be Signed or Unsigned. If a numerictype object with Auto Signedness is used to create a fi object, the Signedness property of the fi object automatically defaults to Signed.

- Slope — Slope associated with a fi object
- WordLength — Word length of the stored integer value of a fi object in bits

For further details on these properties, see “numerictype Object Properties”.

Examples

Note For information about the display format of fi objects, refer to “View Fixed-Point Data”.

For examples of casting, see “Cast fi Objects”.

Example 1

For example, the following creates an unsigned fi object with a value of pi, a word length of 8 bits, and a fraction length of 3 bits:

```
a = ufi(pi,8,3)

a =

    3.1250

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 3
```

Default `fimath` properties are associated with `a`. When a `fi` object does not have a local `fimath` object, no `fimath` object properties are displayed in its output. To determine whether a `fi` object has a local `fimath` object, use the `isfimathlocal` function.

```
isfimathlocal(a)

ans =
     0
```

A returned value of `0` means the `fi` object does not have a local `fimath` object. When the `isfimathlocal` function returns a `1`, the `fi` object has a local `fimath` object.

Example 2

The value `v` can also be an array:

```
a = ufi((magic(3)/10),16,12)

a =

    0.8000    0.1001    0.6001
    0.3000    0.5000    0.7000
    0.3999    0.8999    0.2000

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 12
>>
```

Example 3

If you omit the argument `f`, it is set automatically to the best precision possible:

```
a = ufi(pi,8)

a =

    3.1406

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 8
        FractionLength: 6
```

Example 4

If you omit `w` and `f`, they are set automatically to 16 bits and the best precision possible, respectively:

```
a = ufi(pi)

a =

    3.1416

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Unsigned
            WordLength: 16
        FractionLength: 14
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Usage notes and limitations:

- All properties related to data type must be constant for code generation.

See Also

`fi` | `fimath` | `fipref` | `isfimathlocal` | `numerictype` | `quantizer` | `sfi`

Introduced in R2009b

uint8

Convert `fi` object to unsigned 8-bit integer

Syntax

`c = uint8(a)`

Description

`c = uint8(a)` returns the built-in `uint8` value of `fi` object `a`, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an `uint8`.

Examples

This example shows the `uint8` values of a fi object.

```
a = fi([-pi 0.5 pi],0,8);
c = uint8(a)

c =

   0    1    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`int16` | `int32` | `int64` | `int8` | `storedInteger` | `uint16` | `uint32` | `uint64`

Introduced before R2006a

uint16

Convert fi object to unsigned 16-bit integer

Syntax

```
c = uint16(a)
```

Description

c = uint16(a) returns the built-in uint16 value of fi object a, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an uint16.

Examples

This example shows the uint16 values of a fi object.

```
a = fi([-pi 0.5 pi],0,16);
c = uint16(a)

c =

   0    1    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

int16 | int32 | int64 | int8 | storedInteger | uint32 | uint64 | uint8

Introduced before R2006a

uint32

Stored integer value of `fi` object as built-in `uint32`

Syntax

`c = uint32(a)`

Description

`c = uint32(a)` returns the built-in `uint32` value of `fi` object `a`, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an `uint32`.

Examples

This example shows the `uint32` values of a fi object.

```
a = fi([-pi 0.5 pi],0,32);
c = uint32(a)

c =

   0    1    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`int16` | `int32` | `int64` | `int8` | `storedInteger` | `uint16` | `uint64` | `uint8`

Introduced before R2006a

uint64

Convert `fi` object to unsigned 64-bit integer

Syntax

`c = uint64(a)`

Description

`c = uint64(a)` returns the built-in `uint64` value of `fi` object `a`, based on its real world value. If necessary, the data is rounded-to-nearest and saturated to fit into an `uint64`.

Examples

This example shows the `uint64` values of a fi object.

```
a = fi([-pi 0.5 pi],0,64);
c = uint64(a)

c =

   0    1    3
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

`int16` | `int32` | `int64` | `int8` | `storedInteger` | `uint16` | `uint32` | `uint8`

Introduced in R2008b

uminus

Negate elements of fi object array

Syntax

uminus(a)

Description

uminus(a) is called for the syntax -a when a is an object. -a negates the elements of a.

uminus does not support fi objects of data type Boolean.

Examples

When wrap occurs, -(-1) = -1 :

```
fipref('NumericTypeDisplay','short', ...
       'fimathDisplay','none');
format short g
a = fi(-1,true,8,7,'OverflowAction','Wrap')

a = 

    -1
      s8,7
-a

ans = 

    -1
      s8,7
b = fi([-1-i -1-i],true,8,7,'OverflowAction','Wrap')

b = 
```

```
            -1 -          1i            -1 -          1i
      s8,7
-b

ans =

            -1 -          1i            -1 -          1i
      s8,7
b'

ans =

            -1 -          1i
            -1 -          1i
      s8,7
```

When saturation occurs, -(-1) = 0.99... :

```
c = fi(-1,true,8,7,'OverflowAction','Saturate')

c =

    -1
      s8,7
-c

ans =

      0.99219
      s8,7
d = fi([-1-i -1-i],true,8,7,'OverflowAction','Saturate')

d =

            -1 -          1i            -1 -          1i
      s8,7
-d

ans =

      0.99219 +    0.99219i      0.99219 +    0.99219i
      s8,7
d'

ans =
```

```
      -1 +    0.99219i
      -1 +    0.99219i
s8,7
```

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

minus | mtimes | plus | times

Introduced before R2006a

unitquantize

Quantize except numbers within `eps` of `+1`

Syntax

```
y = unitquantize(q, x)
[y1,y2,...] = unitquantize(q,x1,x2,...)
```

Description

`y = unitquantize(q, x)` works the same as `quantize` except that numbers within `eps(q)` of `+1` are made exactly equal to `+1` .

`[y1,y2,...] = unitquantize(q,x1,x2,...)` is equivalent to `y1 = unitquantize(q,x1), y2 = unitquantize(q,x2),...`

Examples

This example demonstrates the use of `unitquantize` with a `quantizer` object `q` and a vector `x`.

```
q = quantizer('fixed','floor','saturate',[4 3]);
x = (0.8:.1:1.2)';
y = unitquantize(q,x);
z = [x y]
e = eps(q)
```

This quantization outputs an array containing the original values of `x` and the quantized values of `x`, followed by the value of `eps(q)`:

```
z =

    0.8000    0.7500
    0.9000    1.0000
    1.0000    1.0000
    1.1000    1.0000
```

```
    1.2000    1.0000

e =

    0.1250
```

See Also

`eps` | `quantize` | `quantizer` | `unitquantizer`

Introduced in R2008a

unitquantizer

Constructor for `unitquantizer` object

Syntax

```
q = unitquantizer(...)
```

Description

`q = unitquantizer(...)` constructs a `unitquantizer` object, which is the same as a `quantizer` object in all respects except that its `quantize` method quantizes numbers within `eps(q)` of `+1` to exactly `+1`.

See `quantizer` for parameters.

Examples

In this example, a vector `x` is quantized by a `unitquantizer` object `u` .

```
u = unitquantizer([4 3]);
x = (0.8:.1:1.2)';
y = quantize(u,x);
z = [x y]
e = eps(u)
```

This quantization outputs an array containing the original values of `x` and the values of `x` that were quantized by the `unitquantizer` object `u`. The output also includes `e`, the value of `eps(u)`.

```
z =

    0.8000    0.7500
    0.9000    1.0000
    1.0000    1.0000
    1.1000    1.0000
    1.2000    1.0000
```

```
e =

    0.1250
```

See Also
quantize | quantizer | unitquantize

Introduced in R2008a

unshiftdata

Inverse of `shiftdata`

Syntax

`y = unshiftdata(x,perm,nshifts)`

Description

`y = unshiftdata(x,perm,nshifts)` restores the orientation of the data that was shifted with `shiftdata`. The permutation vector is given by `perm`, and `nshifts` is the number of shifts that was returned from `shiftdata`.

`unshiftdata` is meant to be used in tandem with `shiftdata`. These functions are useful for creating functions that work along a certain dimension, like `filter`, `goertzel`, `sgolayfilt`, and `sosfilt`.

Examples

Example 1

This example shifts `x`, a `3-by-3` magic square, permuting dimension `2` to the first column. `unshiftdata` shifts `x` back to its original shape.

1. Create a `3-by-3` magic square:

```
x = fi(magic(3))

x =

     8     1     6
     3     5     7
     4     9     2
```

2. Shift the matrix x to work along the second dimension:

```
[x,perm,nshifts] = shiftdata(x,2)
```

This command returns the permutation vector, perm, and the number of shifts, nshifts, are returned along with the shifted matrix, x:

```
x =

     8     3     4
     1     5     9
     6     7     2


perm =

     2     1


nshifts =

     []
```

3. Shift the matrix back to its original shape:

```
y = unshiftdata(x,perm,nshifts)

y =

     8     1     6
     3     5     7
     4     9     2
```

Example 2

This example shows how shiftdata and unshiftdata work when you define dim as empty.

1. Define x as a row vector:

```
x = 1:5
```

```
x =

     1     2     3     4     5
```

2. Define `dim` as empty to shift the first non-singleton dimension of `x` to the first column:

```
[x,perm,nshifts] = shiftdata(x,[])
```

This command returns `x` as a column vector, along with `perm`, the permutation vector, and `nshifts`, the number of shifts:

```
x =

     1
     2
     3
     4
     5


perm =

     []


nshifts =

     1
```

3. Using `unshiftdata`, restore `x` to its original shape:

```
y = unshiftdata(x,perm,nshifts)

y =

     1     2     3     4     5
```

See Also

`ipermute` | `shiftdata` | `shiftdim`

Introduced in R2008a

uplus

Unary plus

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `uplus` reference page for more information.

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

Introduced before R2006a

upperbound

Upper bound of range of fi object

Syntax

upperbound(a)

Description

upperbound(a) returns the upper bound of the range of fi object a. If L = lowerbound(a) and U = upperbound(a), then [L,U] = range(a).

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using MATLAB® Coder™.

See Also

eps | intmax | intmin | lowerbound | lsb | range | realmax | realmin

Introduced before R2006a

vertcat

Vertically concatenate multiple `fi` objects

Syntax

```
c = vertcat(a,b,...)
[a; b; ...]
[a;b]
```

Description

`c = vertcat(a,b,...)` is called for the syntax `[a; b; ...]` when any of `a`, `b`, `...` , is a `fi` object.

`[a;b]` is the vertical concatenation of matrices `a` and `b`. `a` and `b` must have the same number of columns. Any number of matrices can be concatenated within one pair of brackets. N-D arrays are vertically concatenated along the first dimension. The remaining dimensions must match.

Horizontal and vertical concatenation can be combined, as in `[1 2;3 4]`.

`[a b; c]` is allowed if the number of rows of `a` equals the number of rows of `b`, and if the number of columns of `a` plus the number of columns of `b` equals the number of columns of `c`.

The matrices in a concatenation expression can themselves be formed via a concatenation, as in `[a b;[c d]]`.

Note The `fimath` and `numerictype` objects of a concatenated matrix of `fi` objects `c` are taken from the leftmost `fi` object in the list `(a,b,...)`.

Extended Capabilities

C/C++ Code Generation
Generate C and C++ code using MATLAB® Coder™.

See Also
`horzcat`

Introduced before R2006a

voronoi

Create Voronoi diagram

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `voronoi` reference page for more information.

Introduced before R2006a

voronoin

Create n-D Voronoi diagram

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `voronoin` reference page for more information.

Introduced before R2006a

waterfall

Create waterfall plot

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `waterfall` reference page for more information.

Introduced before R2006a

wordlength

Word length of `quantizer` object

Syntax

```
wordlength(q)
```

Description

`wordlength(q)` returns the word length of the `quantizer` object `q`.

Examples

```
q = quantizer([16 15]);
wordlength(q)

ans =

    16
```

See Also

`exponentlength` | `fi` | `fractionlength` | `numerictype` | `quantizer`

Introduced before R2006a

xlim

Set or query x-axis limits

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `xlim` reference page for more information.

Introduced before R2006a

xor

Logical exclusive-OR

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `xor` reference page for more information.

Introduced in R2008a

ylim

Set or query y-axis limits

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `ylim` reference page for more information.

Introduced before R2006a

zeros

Create array of all zeros with fixed-point properties

Syntax

```
X = zeros('like',p)
X = zeros(n,'like',p)
X = zeros(sz1,...,szN,'like',p)
X = zeros(sz,'like',p)
```

Description

`X = zeros('like',p)` returns a scalar `0` with the same `numerictype`, complexity (real or complex), and `fimath` as `p`.

`X = zeros(n,'like',p)` returns an `n`-by-`n` array of zeros like `p`.

`X = zeros(sz1,...,szN,'like',p)` returns an `sz1`-by-...-by-`szN` array of zeros like `p`.

`X = zeros(sz,'like',p)` returns an array of zeros like `p`. The size vector, `sz`, defines `size(X)`.

Examples

2-D Array of Zeros With Fixed-Point Attributes

Create a 2-by-3 array of zeros with specified numerictype and `fimath` properties.

Create a signed `fi` object with word length of `24` and fraction length of `12`.

```
p = fi([],1,24,12);
```

Create a 2-by-3 array of zeros that has the same numerictype properties as `p`.

```
X = zeros(2,3,'like',p)
```

```
X = 
     0     0     0
     0     0     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Size Defined by Existing Array

Define a 3-by-2 array A.

```
A = [1 4 ; 2 5 ; 3 6];
```

```
sz = size(A)
```

```
sz = 1×2

     3     2
```

Create a signed fi object with word length of 24 and fraction length of 12.

```
p = fi([],1,24,12);
```

Create an array of zeros that is the same size as A and has the same numerictype properties as p.

```
X = zeros(sz,'like',p)
```

```
X = 
     0     0
     0     0
     0     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Square Array of Zeros With Fixed-Point Attributes

Create a 4-by-4 array of zeros with specified numerictype and `fimath` properties.

Create a signed `fi` object with word length of `24` and fraction length of `12`.

```
p = fi([],1,24,12);
```

Create a 4-by-4 array of zeros that has the same numerictype properties as `p`.

```
X = zeros(4, 'like', p)
```

```
X =
     0     0     0     0
     0     0     0     0
     0     0     0     0
     0     0     0     0

          DataTypeMode: Fixed-point: binary point scaling
            Signedness: Signed
            WordLength: 24
        FractionLength: 12
```

Complex Fixed-Point Zero

Create a scalar fixed-point `0` that is not real valued, but instead is complex like an existing array.

Define a complex `fi` object.

```
p = fi( [1+2i 3i],1,24,12);
```

Create a scalar `1` that is complex like `p`.

```
X = zeros('like',p)
```

```
X =
   0.0000 + 0.0000i

          DataTypeMode: Fixed-point: binary point scaling
```

```
          Signedness: Signed
          WordLength: 24
      FractionLength: 12
```

Write MATLAB Code That Is Independent of Data Types

Write a MATLAB algorithm that you can run with different data types without changing the algorithm itself. To reuse the algorithm, define the data types separately from the algorithm.

This approach allows you to define a baseline by running the algorithm with floating-point data types. You can then test the algorithm with different fixed-point data types and compare the fixed-point behavior to the baseline without making any modifications to the original MATLAB code.

Write a MATLAB function, `my_filter`, that takes an input parameter, `T`, which is a structure that defines the data types of the coefficients and the input and output data.

```
function [y,z] = my_filter(b,a,x,z,T)
    % Cast the coefficients to the coefficient type
    b = cast(b,'like',T.coeffs);
    a = cast(a,'like',T.coeffs);
    % Create the output using zeros with the data type
    y = zeros(size(x),'like',T.data);
    for i = 1:length(x)
        y(i) = b(1)*x(i) + z(1);
        z(1) = b(2)*x(i) + z(2) - a(2) * y(i);
        z(2) = b(3)*x(i)        - a(3) * y(i);
    end
end
```

Write a MATLAB function, `zeros_ones_cast_example`, that calls `my_filter` with a floating-point step input and a fixed-point step input, and then compares the results.

```
function zeros_ones_cast_example

    % Define coefficients for a filter with specification
    % [b,a] = butter(2,0.25)
    b = [0.097631072937818   0.195262145875635   0.097631072937818];
    a = [1.000000000000000  -0.942809041582063   0.333333333333333];
```

```
% Define floating-point types
T_float.coeffs = double([]);
T_float.data   = double([]);

% Create a step input using ones with the
% floating-point data type
t = 0:20;
x_float = ones(size(t),'like',T_float.data);

% Initialize the states using zeros with the
% floating-point data type
z_float = zeros(1,2,'like',T_float.data);

% Run the floating-point algorithm
y_float = my_filter(b,a,x_float,z_float,T_float);

% Define fixed-point types
T_fixed.coeffs = fi([],true,8,6);
T_fixed.data   = fi([],true,8,6);

% Create a step input using ones with the
% fixed-point data type
x_fixed = ones(size(t),'like',T_fixed.data);

% Initialize the states using zeros with the
% fixed-point data type
z_fixed = zeros(1,2,'like',T_fixed.data);

% Run the fixed-point algorithm
y_fixed = my_filter(b,a,x_fixed,z_fixed,T_fixed);

% Compare the results
coder.extrinsic('clf','subplot','plot','legend')
clf
subplot(211)
plot(t,y_float,'co-',t,y_fixed,'kx-')
legend('Floating-point output','Fixed-point output')
title('Step response')
subplot(212)
plot(t,y_float - double(y_fixed),'rs-')
legend('Error')
```

```
    figure(gcf)
end
```

- “Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros”

Input Arguments

n — Size of square matrix
integer value

Size of square matrix, specified as an integer value, defines the output as a square, n-by-n matrix of ones.

- If `n` is zero, `X` is an empty matrix.
- If `n` is negative, it is treated as zero.

Data Types: `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`sz1,...,szN` — Size of each dimension
two or more integer values

Size of each dimension, specified as two or more integer values, defines `X` as a sz1-by...-by-szN array.

- If the size of any dimension is zero, `X` is an empty array.
- If the size of any dimension is negative, it is treated as zero.
- If any trailing dimensions greater than two have a size of one, the output, `X`, does not include those dimensions.

Data Types: `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`sz` — Output size
row vector of integer values

Output size, specified as a row vector of integer values. Each element of this vector indicates the size of the corresponding dimension.

- If the size of any dimension is zero, X is an empty array.
- If the size of any dimension is negative, it is treated as zero.
- If any trailing dimensions greater than two have a size of one, the output, X, does not include those dimensions.

Example: `sz = [2,3,4]` defines X as a 2-by-3-by-4 array.

Data Types: `double` | `single` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

p — Prototype
`fi` object | numeric variable

Prototype, specified as a `fi` object or numeric variable. To use the prototype to specify a complex object, you must specify a value for the prototype. Otherwise, you do not need to specify a value.

Complex Number Support: Yes

Tips

Using the `b = cast(a,'like',p)` syntax to specify data types separately from algorithm code allows you to:

- Reuse your algorithm code with different data types.
- Keep your algorithm uncluttered with data type specifications and switch statements for different data types.
- Improve readability of your algorithm code.
- Switch between fixed-point and floating-point data types to compare baselines.
- Switch between variations of fixed-point settings without changing the algorithm code.

See Also

`cast` | `ones` | `zeros`

Topics

"Implement FIR Filter Algorithm for Floating-Point and Fixed-Point Types using cast and zeros"

"Manual Fixed-Point Conversion Workflow"
"Manual Fixed-Point Conversion Best Practices"

Introduced in R2013a

zlim

Set or query z-axis limits

Description

This function accepts `fi` objects as inputs.

Refer to the MATLAB `zlim` reference page for more information.

Introduced before R2006a

Classes — Alphabetical List

coder.CellType class

Package: coder
Superclasses:

Represent set of MATLAB cell arrays

Description

Specifies the set of cell arrays that the generated code accepts. Use only with the `fiaccel -args` option. Do not pass as an input to a generated MEX function.

Construction

`t = coder.typeof(cells)` creates a `coder.CellType` object for a cell array that has the same cells and cell types as `cells`. The cells in `cells` are type objects or example values.

`t = coder.typeof(cells, sz, variable_dims)` creates a `coder.CellType` object that has upper bounds specified by `sz` and variable dimensions specified by `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. When `sz` is `[]`, the upper bounds do not change. If you do not specify the `variable_dims` input parameter, except for the unbounded dimensions, the dimensions of the type are fixed. A scalar `variable_dims` applies to the bounded dimensions that are not `1` or `0`.

When `cells` specifies a cell array whose elements have different classes, you cannot use `coder.typeof` to create a `coder.CellType` object for a variable-size cell array.

`t = coder.newtype(cells)` creates a `coder.CellType` object for a cell array that has the cells and cell types specified by `cells`. The cells in `cells` must be type objects.

`t = coder.newtype(cell_array, sz, variable_dims)` creates a `coder.CellType` that has upper bounds specified by `sz` and variable dimensions specified by `variable_dims`. If `sz` specifies `inf` for a dimension, then the size of the dimension is unbounded and the dimension is variable size. When `sz` is `[]`, the upper bounds do not change. If you do not specify the `variable_dims` input parameter, except for the unbounded dimensions, the dimensions of the type are fixed. A scalar `variable_dims` applies to the bounded dimensions that are not `1` or `0`.

When `cells` specifies a cell array whose elements have different classes, you cannot use `coder.newtype` to create a `coder.CellType` object for a variable-size cell array.

Input Arguments

`cells` — Specification of cell types
cell array

Cell array that specifies the cells and cell types for the output `coder.CellType` object. For `coder.typeof`, `cells` can contain type objects or example values. For `coder.newtype`, `cells` must contain type objects.

`sz` — Size of cell array
row vector of integer values

Specifies the upper bound for each dimension of the cell array type object. For `coder.newtype`, `sz` cannot change the number of cells for a heterogeneous cell array.

For `coder.newtype`, the default is `[1 1]`.

`variable_dims` — Dimensions that are variable size
row vector of logical values

Specifies whether each dimension is variable size (true) or fixed size (false).

For `coder.newtype`, the default is `true` for dimensions for which `sz` specifies an upper bound of `inf` and `false` for all other dimensions.

When `cells` specifies a cell array whose elements have different classes, you cannot create a `coder.CellType` object for a variable-size cell array.

Properties

`Cells` — Types of cells
cell array

A cell array that specifies the `coder.Type` of each cell.

`ClassName` — Name of class
character vector or string scalar

Class of values in this set.

`SizeVector` — Size of cell array
row vector of integer values

The upper bounds of dimensions of the cell array.

`VariableDims` — Dimensions that are variable size
row vector of logical values

A vector that specifies whether each dimension of the array is fixed or variable size. If a vector element is `true`, the corresponding dimension is variable size.

Methods

isHeterogeneous	Determine whether cell array type represents a heterogeneous cell array
isHomogeneous	Determine whether cell array type represents a homogeneous cell array
makeHeterogeneous	Make a heterogeneous copy of a cell array type
makeHomogeneous	Create a homogeneous copy of a cell array type

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create a Type for a Cell Array Whose Elements Have the Same Class

Create a type for a cell array whose first element has class char and whose second element has class double.

```
t = coder.typeof({1 2 3})
```

```
t = 

coder.CellType
   1x3 homogeneous cell 
      base: 1x1 double
```

The type is homogeneous.

Create a Heterogeneous Type for a Cell Array Whose Elements Have the Same Class

To create a heterogeneous type when the elements of the example cell array type have the same class, use the `makeHeterogeneous` method.

```
t = makeHeterogeneous(coder.typeof({1 2 3}))
```

```
t = 

coder.CellType
   1×3 locked heterogeneous cell 
      f1: 1×1 double
      f2: 1×1 double
      f3: 1×1 double
```

The cell array type is heterogeneous. It is represented as a structure in the generated code.

Create a Cell Array Type for a Cell Array Whose Elements Have Different Classes

Define variables that are example cell values.

```
a = 'a';
b = 1;
```

Pass the example cell values to `coder.typeof`.

```
t = coder.typeof({a, b})
```

```
t = 
```

```
coder.CellType
   1x2 heterogeneous cell
      f0: 1x1 char
      f1: 1x1 double
```

Create a Type for a Variable-Size Homogeneous Cell Array from an Example Cell Array Whose Elements Have Different Classes

Create a type for a cell array that contains two character vectors that have different sizes.

```
t = coder.typeof({'aa', 'bbb'})
```

```
t =

coder.CellType
   1x2 heterogeneous cell
      f0: 1x2 char
      f1: 1x3 char
```

The cell array type is heterogeneous.

Create a type using the same cell array input. This time, specify that the cell array type has variable-size dimensions.

```
t = coder.typeof({'aa','bbb'},[1,10],[0,1])
```

```
t =

coder.CellType
   1×:10 locked homogeneous cell
      base: 1×:3 char
```

The cell array type is homogeneous. `coder.typeof` determined that the base type `1x:3 char` can represent `'aa'`, and `'bbb'`.

Create a New Cell Array Type from a Cell Array of Types

Create a type for a scalar `int8`.

```
ta = coder.newtype('int8',[1 1]);
```

Create a type for a :1x:2 double row vector.

```
tb = coder.newtype('double',[1 2],[1 1]);
```

Create a cell array type whose cells have the types specified by `ta` and `ta`.

```
t = coder.newtype('cell',{ta,tb})
```

```
t =

coder.CellType
   1x2 heterogeneous cell
      f0: 1x1 int8
      f1: :1x:2 double
```

Tips

- In the display of a `coder.CellType` object, the terms `locked heterogeneous` or `locked homogeneous` indicate that the classification as homogeneous or heterogeneous is permanent. You cannot later change the classification by using the `makeHomogeneous` or `makeHeterogeneous` methods.
- `coder.typeof` determines whether the cell array type is homogeneous or heterogeneous. If the cell array elements have the same class and size, `coder.typeof` returns a homogeneous cell array type. If the elements have different classes, `coder.typeof` returns a heterogeneous cell array type. For some cell arrays, the classification as homogeneous or heterogeneous is ambiguous. For example, the type for {1 [2 3]} can be a 1x2 heterogeneous type. The first element is double and the second element is 1x2 double. The type can also be a 1x3 homogeneous type in which the elements have class double and size 1x:2. For these ambiguous cases, `coder.typeof` uses heuristics to classify the type as homogeneous or heterogeneous. If you want a different classification, use the `makeHomogeneous` or `makeHeterogeneous` methods. The `makeHomogeneous` method makes a homogeneous copy of a type. The `makeHeterogeneous` method makes a heterogeneous copy of a type.

  The `makeHomogeneous` and `makeHeterogeneous` methods permanently assign the classification as homogeneous and heterogeneous, respectively. You cannot later use one of these methods to create a copy that has a different classification.

See Also

`coder.ArrayType` | `coder.Constant` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.StructType` | `coder.Type` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Topics

"Code Generation for Cell Arrays"

Introduced in R2015b

coder.ClassType class

Package: coder
Superclasses:

Represent set of MATLAB classes

Description

Specifies the set of value class objects that the generated code can accept. Use only with the `fiaccel -args` option. Do not pass as an input to a generated MEX function.

Construction

`t = coder.typeof(value_class_object)` creates a `coder.ClassType` object for the object `value_class_object`.

`t = coder.newtype(value_class_name)` creates a `coder.ClassType` object for an object of the class `value_class_name`.

Input Arguments

`value_class_object`

Value class object from which to create the `coder.ClassType` object. `value_class_object` is an expression that evaluates to an object of a value class. For example:

```
v = myValueClass;
t = coder.typeof(v);

t = coder.typeof(myValueClass(2,3));
```

`value_class_name`

Name of a value class definition file on the MATLAB path. Specify as a character vector or string scalar. For example:

```
t = coder.newtype('myValueClass');
```

Properties

When you create a `coder.ClassType` object by using `coder.typeof`, the `coder.ClassType` object has the same properties as the object from which it is constructed.

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create Type Based on Example Object

Create a type based on an example object in the workspace.

Create a value class `myRectangle`.

```
classdef myRectangle
    properties
        length;
        width;
    end
    methods
        function obj = myRectangle(l,w)
            if nargin > 0
                obj.length = l;
                obj.width = w;
            end
        end
        function area = calcarea(obj)
            area = obj.length * obj.width;
        end
    end
end
```

Create a function that takes an object of `myRectangle` as an input.

```
function z = getarea(r)
%#codegen
z = calcarea(r);
end
```

Create an object of `myRectangle`.

```
v = myRectangle(1,2)
```

```
v = 

  myRectangle with properties:

    length: 1
     width: 2
```

Create a `coder.ClassType` object based on `v`.

```
t = coder.typeof(v)
```

```
t = 

coder.ClassType
   1×1 myRectangle
      length: 1×1 double
      width : 1×1 double
```

`coder.typeof` creates a `coder.ClassType` object that has the same properties names and types as `v` has.

Generate code for `getarea`. Specify the input type by passing the `coder.ClassType` object, `t`, to the `-args` option.

```
codegen getarea -args {t} -report
```

Create Type by Using coder.newtype

Create a `coder.ClassType` object for an object of the value class `mySquare` by using `coder.newtype`.

Create value class `mySquare` that has one property, `side`.

```
classdef mySquare
    properties
```

```
            side;
        end
        methods
            function obj = mySquare(val)
                if nargin > 0
                    obj.side = val;
                end
            end
            function a = calcarea(obj)
                a = obj.side * obj.side;
            end
        end
    end
```

Create a `coder.ClassType` type for `mySquare`.

```
t = coder.newtype('mySquare')
```

Specify the type of `side`.

```
t.Properties.side = coder.typeof(2)
```

Tips

- After you create a `coder.ClassType`, you can modify the types of the properties. For example:

  ```
  t = coder.typeof(myClass)
  t.Properties.prop1 = coder.typeof(int16(2));
  t.Properties.prop2 = coder.typeof([1 2 3]);
  ```
- After you create a `coder.ClassType`, you can add properties. For example:

  ```
  t = coder.typeof(myClass)
  t.Properties.newprop1 = coder.typeof(int8(2));
  t.Properties.newprop2 = coder.typeof([1 2 3]);
  ```
- When you generate code, the properties of the `coder.ClassType` object that you pass to `codegen` must be consistent with the properties in the class definition file. However, if the class definition file has properties that your code does not use, the `coder.ClassType` object does not have to include those properties. The code generator removes properties that you do not use.

See Also

`coder.ArrayType` | `coder.CellType` | `coder.Constant` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.Type` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

Introduced in R2017a

coder.MexConfig

Package: coder

Code acceleration configuration object for use with `fiaccel`

Description

A `coder.MexConfig` object contains all the configuration parameters that the `fiaccel` function uses when accelerating fixed-point code via a generated MEX function. To use this object, first create it using the lowercase `coder.mexconfig` function and then, pass it to the `fiaccel` function using the `-config` option.

Construction

`cfg = coder.mexconfig` creates a `coder.MexConfig` object, `cfg`, for `fiaccel` MEX function generation.

Properties

`CompileTimeRecursionLimit`

For compile-time recursion, control the number of copies of a function that are allowed in the generated code. To disallow recursion in the MATLAB code, set `CompileTimeRecursionLimit` to 0. The default compile-time recursion limit is high enough for most recursive functions that require compile-time recursion. If code generation fails because of the compile-time recursion limit, and you want compile-time recursion, try to increase the limit. Alternatively, change your MATLAB code so that the code generator uses run-time recursion

Default: *integer*, `50`

`ConstantFoldingTimeout`

Maximum number of constant folder instructions

Specify, as a positive integer, the maximum number of instructions to be executed by the constant folder.

Default: 10000

DynamicMemoryAllocation

Dynamic memory allocation for variable-size data

By default, when this property is set to 'Threshold' , dynamic memory allocation is enabled for all variable-size arrays whose size is greater than DynamicMemoryAllocationThreshold and fiaccel allocates memory for this variable-size data dynamically on the heap. Set this property to 'Off' to allocate memory statically on the stack. Set it to'AllVariableSizeArrays' to allocate memory for all variable-size arrays dynamically on the heap . You must use dynamic memory allocation for all unbounded variable-size data.

This property, DynamicMemoryAllocation, is enabled only when EnableVariableSizing is true. When you set DynamicMemoryAllocation to `Threshold', it enables the DynamicMemoryAllocationThreshold property.

Default: Threshold

DynamicMemoryAllocationThreshold

Memory allocation threshold

Specify the integer size of the threshold for variable-size arrays above which fiaccel allocates memory on the heap.

Default: 65536

EnableAutoExtrinsicCalls

Specify whether fiaccel treats common visualization functions as extrinsic functions. When this option is enabled, fiaccel detects calls to many common visualization functions, such as plot, disp, and figure. It calls out to MATLAB for these functions. This capability reduces the amount of time that you spend making your code suitable for code generation. It also removes the requirement to declare these functions extrinsic using the coder.extrinsic function.

Default: true

EchoExpressions

Show results of code not terminated with semicolons

Set this property to `true` to have the results of code instructions that do not terminate with a semicolon appear in the MATLAB Command Window. If you set this property to `false`, code results do not appear in the MATLAB Command Window.

Default: `true`

EnableRuntimeRecursion

Allow recursive functions in the generated code. If your MATLAB code requires run-time recursion and this parameter is `false`, code generation fails.

Default: `true`

EnableDebugging

Compile generated code in debug mode

Set this property to `true` to compile the generated code in debug mode. Set this property to `false` to compile the code in normal mode.

Default: `false`

EnableVariableSizing

Variable-sized arrays support

Set this property to `true` to enable support for variable-sized arrays and to enable the `DynamicMemoryAllocation` property. If you set this property to `false`, variable-sized arrays are not supported.

Default: `true`

ExtrinsicCalls

Extrinsic function calls

An extrinsic function is a function on the MATLAB path that the generated code dispatches to MATLAB software for execution. `fiaccel` does not compile or generate code for extrinsic functions. Set this property to `true` to have `fiaccel` generate code for the call to a MATLAB function, but not generate the function's internal code. Set this property to `false` to have `fiaccel` ignore the extrinsic function and not generate code for the call to the MATLAB function. If the extrinsic function affects the output of `fiaccel`, a compiler error occurs.

`ExtrinsicCalls` affects how MEX functions built by `fiaccel` generate random numbers when using the MATLAB `rand`, `randi`, and `randn` functions. If extrinsic calls are enabled, the generated mex function uses the MATLAB global random number stream to generate random numbers. If extrinsic calls are not enabled, the MEX function built with `fiaccel` uses a self-contained random number generator.

If you disable extrinsic calls, the generated MEX function cannot display run-time messages from `error` or `assert` statements in your MATLAB code. The MEX function reports that it cannot display the error message. To see the error message, enable extrinsic function calls and generate the MEX function again.

Default: `true`

`GenerateReport`

Code generation report

Set this property to `true` to create an HTML code generation report. Set this property to `false` to not create the report.

Default: `false`

`GlobalDataSyncMethod`

MEX function global data synchronization with MATLAB global workspace

Set this property to `SyncAlways` so synchronize global data at MEX function entry and exit and for all extrinsic calls to ensure maximum consistency between MATLAB and the generated MEX function. If the extrinsic calls do not affect global data, use this option in conjunction with the `coder.extrinsic -sync:off` option to turn off synchronization for these calls to maximize performance.

If you set this property to `SyncAtEntryAndExits`, global data is synchronized only at MEX function entry and exit. If your code contains extrinsic calls, but only a few affect global data, use this option in conjunction with the `coder.extrinsic -sync:on` option to turn on synchronization for these calls to maximize performance.

If you set this property to `NoSync`, no synchronization occurs. Ensure that your MEX function does not interact with MATLAB globals before disabling synchronization otherwise inconsistencies between MATLAB and the MEX function might occur.

Default: `SyncAlways`

`InlineStackLimit`

Stack size for inlined functions

Specify, as a positive integer, the stack size limit on inlined functions.

Default: `4000`

`InlineThreshold`

Maximum size of functions to be inlined

Specify, as a positive integer, the maximum size of functions to be inlined.

Default: `10`

`InlineThresholdMax`

Maximum size of functions after inlining

Specify, as a positive integer, the maximum size of functions after inlining.

Default: `200`

`IntegrityChecks`

Memory integrity

Set this property to `true` to detect any violations of memory integrity in code generated for MATLAB. When a violation is detected, execution stops and a diagnostic message displays. Set this property to `false` to disable both memory integrity checks and the runtime stack.

Default: `true`

`LaunchReport`

Code generation report display

Set this property to `true` to open the HTML code generation report automatically when code generation completes. Set this property to `false` to disable displaying the report automatically. This property applies only if you set the `GenerateReport` property to `true`.

Default: true

`ReportPotentialDifferences`

Specify whether to report potential behavior differences between generated code and MATLAB code. If `ReportPotentialDifferences` is `true`, the code generation report has a tab that lists the potential differences. A potential difference is a difference that occurs at run time only under certain conditions.

Default: `true`

`ResponsivenessChecks`

Responsiveness checks

Set this property to `true` to turn on responsiveness checks. Set this property to `false` to disable responsiveness checks.

Default: `true`

`SaturateOnIntegerOverflow`

Integer overflow action

Overflows saturate to either the minimum or maximum value that the data type can represent. Set this property to `true` to have overflows saturate. Set this property to `false` to have overflows wrap to the appropriate value representable by the data type.

Default: `true`

`StackUsageMax`

Maximum stack usage per application

Specify, as a positive integer, the maximum stack usage per application in bytes. Set a limit that is lower than the available stack size. Otherwise, a runtime stack overflow might occur. Overflows are detected and reported by the C compiler, not by `fiaccel`.

Default: `200000`

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

Examples

Use the lowercase coder.mexconfig function to create a coder.MexConfig configuration object. Set this object to disable run-time checks.

```
cfg = coder.mexconfig
% Turn off Integrity Checks, Extrinsic Calls,
% and Responsiveness Checks
cfg.IntegrityChecks = false;
cfg.ExtrinsicCalls = false;
cfg.ResponsivenessChecks = false;
% Use fiaccel to generate a MEX function for file foo.m
fiaccel -config cfg foo
```

See Also

`coder.ArrayType` | `coder.Constant` | `coder.EnumType` | `coder.FiType` | `coder.PrimitiveType` | `coder.StructType` | `coder.Type` | `coder.mexconfig` | `coder.newtype` | `coder.resize` | `coder.typeof` | `fiaccel`

coder.SingleConfig class

Package: coder

Double-precision to single-precision conversion configuration object

Description

A `coder.SingleConfig` object contains the configuration parameters that the `convertToSingle` function requires to convert double-precision MATLAB code to single-precision MATLAB code. To pass this object to the `convertToSingle` function, use the `-config` option.

Construction

`*scfg* = coder.config('single')` creates a `coder.SingleConfig` object for double-precision to single-precision conversion.

Properties

`OutputFileNameSuffix` — Suffix for single-precision file name
`'_single'` (default) | character vector

Suffix that the single-conversion process uses for generated single-precision files.

`LogIOForComparisonPlotting` — Enable simulation data logging for comparison plotting of input and output variables
`false` (default) | true

Enable simulation data logging to plot the data differences introduced by single-precision conversion.

`PlotFunction` — Name of function for comparison plots
`''` (default) | character vector

Name of function to use for comparison plots.

To enable comparison plotting, set `LogIOForComparisonPlotting` to true. This option takes precedence over `PlotWithSimulationDataInspector`.

The plot function must accept three inputs:

- A structure that holds the name of the variable and the function that uses it.
- A cell array to hold the logged floating-point values for the variable.
- A cell array to hold the logged values for the variable after fixed-point conversion.

`PlotWithSimulationDataInspector` — Specify use of Simulation Data Inspector for comparison plots

`false` (default) | `true`

Use Simulation Data Inspector for comparison plots.

`LogIOForComparisonPlotting` must be set to true to enable comparison plotting. The `PlotFunction` option takes precedence over `PlotWithSimulationDataInspector`.

`TestBenchName` — Name of test file

`''` (default) | character vector | cell array of character vectors

Test file name or names, specified as a character vector or cell array of character vectors. Specify at least one test file.

If you do not explicitly specify input parameter data types, the conversion uses the first file to infer these data types.

`TestNumerics` — Enable numerics testing

`false` (default) | `true`

Enable numerics testing to verify the generated single-precision code. The test file runs the single-precision code.

Methods

addFunctionReplacement	Replace double-precision function with single-precision function during single-precision conversion

Examples

Generate Single-Precision MATLAB Code

Create a `coder.SingleConfig` object.

```
scfg= coder.config('single');
```

Set the properties of the doubles-to-singles configuration object. Specify the test file. In this example, the name of the test file is `myfunction_test`. The conversion process uses the test file to infer input data types and collect simulation range data. Enable numerics testing and generation of comparison plots.

```
scfg.TestBenchName = 'myfunction_test';
scfg.TestNumerics = true;
scfg.LogIOForComparisonPlotting = true;
```

Run `convertToSingle`. Use the `-config` option to specify the `coder.SingleConfig` object that you want to use. In this example, the MATLAB function name is `myfunction`.

```
convertToSingle -config scfg myfunction
```

- “Generate Single-Precision MATLAB Code”

See Also

`coder.config` | `convertToSingle`

Topics

“Generate Single-Precision MATLAB Code”

Introduced in R2015b

DataTypeWorkflow.Converter class

Package: DataTypeWorkflow

Create fixed-point converter object

Description

A `DataTypeWorkflow.Converter` object contains the methods and parameters needed to collect simulation and derived data, propose and apply data types to the model, and analyze results. This class performs the same fixed-point conversion tasks as the Fixed-Point Tool.

Construction

`Converter = DataTypeWorkflow.Converter(systemToScale)` creates a converter object for the `systemToScale`. The converter object contains the methods and parameters needed to collect simulation and derived data, propose and apply data types to the model, and analyze results.

`Converter = DataTypeWorkflow.Converter(referencedModelSystem, 'TopModel', topModel)` creates a converter object with referenced model `referencedModel` specified as the system to scale. The top model `topModel` is used during the range collection phase of conversion.

Input Arguments

`systemToScale` — Name of system to scale
character vector

The name of the model or subsystem to scale, specified as a character vector.

Example: `converter = DataTypeWorkflow.Converter('ex_fixed_point_workflow');`

`referencedModelSystem` — Name of referenced model or system inside a referenced model
character vector

The name of the referenced model or the subsystem within a referenced model to convert to fixed point, specified as a character vector.

`topModel` — Name of top level model
character vector

The name of the top-level model which references `referencedModel`, specified as a character vector. `topModel` is used during the range collection phase of conversion.

Properties

`CurrentRunName` — Current run in the converter object
character vector

Name of the current run stored in the converter object, specified as a character vector.

Example: `converter.CurrentRunName = 'FixedPointRun'`

Data Types: `char`

`RunNames` — Names of all runs
cell array of character vectors

Names of runs stored in the converter object, specified as a cell array of character vectors.

Data Types: `cell`

`SelectedSystemToScale` — Name of model or subsystem
character vector

Name of the model or subsystem to scale, specified as a character vector.

Data Types: `char`

`ShortcutsForSelectedSystem` — Available system shortcuts
cell array of character vectors

Names of the system settings shortcuts available for the selected system, specified as a cell array of character vectors. You can create additional configurations from within the Fixed-Point Tool. For more information, see "Use Shortcuts to Manage Runs".

Data Types: `cell`

Methods

applyDataTypes	Apply proposed data types to model
applySettingsFromRun	Apply system settings used in previous run to model
applySettingsFromShortcut	Apply settings from shortcut to model
compareResults	Compare two `DataTypeWorkflow.Result` objects
compareRuns	Compare two runs of converter's selected system
deriveMinMax	Derive range information for model
proposeDataTypes	Propose data types for system
results	Find results for selected system in converter object
proposalIssues	Get results which have comments associated with them
saturationOverflows	Get results where saturation occurred
simulateSystem	Simulate converter's system
wrapOverflows	Get results where wrapping occurred

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

Alternatives

The `DataTypeWorkflow.Converter` class offers a command-line approach to using the Fixed-Point Tool. See `fxptdlg` for more information.

See Also

`DataTypeWorkflow.ProposalSettings`

Topics

"Convert a Model to Fixed Point Using the Command Line"
"The Command-Line Interface for the Fixed-Point Tool"

DataTypeWorkflow.DiffRunResult class

Package: DataTypeWorkflow

Results from comparing two simulation runs

Description

The `DataTypeWorkflow.DiffRunResult` class manages the results from comparing two simulation runs. A `DataTypeWorkflow.DiffRunResult` object contains a `DataTypeWorkflow.DiffSignalResult` object for each signal compared.

Construction

The `DataTypeWorkflow.Converter.compareRuns` method returns a handle to a `DataTypeWorkflow.DiffRunResult` object.

Properties

`count` — Number of compared signal results
scalar

Number of compared signal results, stored as an `int32`.

Data Types: `int32`

`dateCreated` — Date of object creation
serial date number

Date of object creation, stored in serial date number format. For more information, see `now` in the MATLAB documentation.

Data Types: `double`

`matlabVersion` — Version of MATLAB used
character vector

Version of MATLAB used to create instance of `DataTypeWorkflow.DiffRunResult`, stored as a character vector.

Data Types: `char`

`runName1` — Name of first run
character vector

Name of first run compared, specified as a character vector.

Data Types: `char`

`runName2` — Name of second run
character vector

Name of second run compared, specified as a character vector.

Data Types: `char`

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

See Also

`DataTypeWorkflow.Converter.compareRuns` | `DataTypeWorkflow.DiffSignalResult` | `Simulink.sdi.DiffRunResult`

Topics

"Convert a Model to Fixed Point Using the Command Line"

DataTypeWorkflow.DiffSignalResult class

Package: DataTypeWorkflow

Results from comparing two signals

Description

The `DataTypeWorkflow.DiffSignalResult` object manages the results from comparing two signals. A `DataTypeWorkflow.DiffSignalResult` object contains the value differences of the signals, the tolerance data, and the data after any specified synchronization methods are performed.

Construction

The `DataTypeWorkflow.Converter.compareResults` method returns a handle to a `DataTypeWorkflow.DiffSignalResult` object, which contains the comparison results.

Properties

`diff` — Value differences after synchronizing data
`timeseries` object

A MATLAB `timeseries` object specifying the value differences after synchronizing the two time series data.

`match` — Whether the two timeseries objects match
`0` | `1`

A boolean indicating if the two timeseries objects match according to the specified tolerance and time synchronization options.

Data Types: `logical`

`result1` — Result object to compare
`DataTypeWorkflow.Result` object

DataTypeWorkflow.Result object that is being compared.

result2 — Result object to compare
DataTypeWorkflow.Result object

DataTypeWorkflow.Result object that is being compared.

sync1 — Time series 1 after synchronization has been applied
timeseries object

A MATLAB timeseries object specifying time series 1 after synchronization has been applied.

sync2 — Time series 2 after synchronization has been applied
timeseries object

A MATLAB timeseries object specifying time series 2 after synchronization has been applied.

tol — Absolute tolerance value at each synchronized time point
timeseries object

A MATLAB timeseries object specifying the actual absolute tolerance value at each synchronized time point.

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

See Also

DataTypeWorkflow.Converter.compareResults | DataTypeWorkflow.Result | Simulink.sdi.DiffSignalResult

Topics

"Convert a Model to Fixed Point Using the Command Line"

DataTypeWorkflow.ProposalSettings class

Package: DataTypeWorkflow

Proposal settings object for data type proposals

Description

The `DataTypeWorkflow.ProposalSettings` class manages the properties related to how data types are proposed for a model.

Construction

`propSettings = DataTypeWorkflow.ProposalSettings` creates a proposal settings object. A proposal settings object manages properties related to how data types are proposed for a model, including default floating point data type, and safety margins for the proposed data types.

Properties

`DefaultWordLength` — Default word length for floating point signals
16 | scalar

Default word length for floating-point signals, specified as a double. Use this setting when the `ProposeFractionLength` property is set to `true`.

Data Types: `double`

`DefaultFractionLength` — Default fraction length for floating-point signals
4 | scalar

Default fraction length for floating-point signals, specified as a double. Use this setting when the `ProposeWordLength` property is set to `true`.

Data Types: `double`

ProposeFractionLength — Propose fraction lengths for specified word length
true (default) | false

Set to true to propose fraction lengths for the default word length specified in the DefaultWordLength property. Setting this property to true automatically sets the ProposeWordLength property to false.

Data Types: logical

ProposeForInherited — Propose fixed-point data types for objects with an inherited output data type
true (default) | false

Specify whether to propose fixed-point data types for objects in the system with inherited output data types.

Data Types: logical

ProposeForFloatingPoint — Propose fixed-point data types for objects with a floating-point output data type
true (default) | false

Specify whether to propose fixed-point data types for objects in the system with floating-point output data types.

Data Types: logical

ProposeSignedness — Propose signedness for objects in the system
true (default) | false

Specify whether to propose signedness for objects in the system.

The software bases the signedness proposal on collected range information and block constraints. Signals that are always strictly positive get an unsigned data type proposal, gaining an additional bit of precision. If you set this property to false, the software proposes a signed data type for all results that currently specify a floating-point or an inherited output data type unless other constraints are present. If a result specifies a fixed-point output data type, the software will propose a data type with the same signedness as the currently specified data type unless other constraints are present.

Data Types: logical

ProposeWordLength — Propose word lengths for specified default fraction lengths
false (default) | true

Set to true to propose word lengths for the default fraction length specified in the DefaultFractionLength property. Setting this property to true automatically sets the ProposeFractionLength property to false.

Data Types: logical

SafetyMargin — Safety margin for simulation minimum and maximum values
0 (default) | scalar

The simulation minimum and maximum values are adjusted by the percentage designated by this parameter. This allows you to specify a range different from that obtained from the simulation run.

Example: A value of 55 specifies that a range at least 55 percent larger is desired. A value of –15 specifies that a range of up to 15 percent smaller is acceptable.

Data Types: double

UseDerivedMinMax — Whether to use derived ranges to propose data types
true (default) | false

Specify whether to use derived ranges for data type proposals.

Data Types: logical

UseSimMinMax — Whether to use simulation ranges to propose data types
true (default) | false

Specify whether to use simulation ranges for data type proposals.

Data Types: logical

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Alternatives

The properties of the `DataTypeWorkflow.ProposalSettings` class can also be controlled from the **Automatic data typing for selected system** pane in the Fixed-Point Tool. See `fxptdlg` for more information.

See Also

`DataTypeWorkflow.Converter`

Topics

"Convert a Model to Fixed Point Using the Command Line"

DataTypeWorkflow.Result class

Package: DataTypeWorkflow

Object containing run result information

Description

The `DataTypeWorkflow.Result` class manages the results of simulation, derivation, and data type proposals.

Construction

The `DataTypeWorkflow.Converter.results` method returns a handle to a `DataTypeWorkflow.Result` object.

Properties

`Comments` — Comments associated with the signal
cell array of character vectors

Any comments associated with the signal, stored as a cell array of character vectors.

Data Types: `cell`

`CompiledDataType` — Data type used during simulation
character vector

Character vector containing the data type used during simulation.

Data Types: `char`

`DerivedMax` — Derived maximum value
scalar

The derived maximum value for the signal or internal data based on specified design maximums.

Data Types: `double`

`DerivedMin` — Derived minimum value
scalar

The derived minimum value for the signal or internal data based on specified design minimums.

Data Types: `double`

`ProposedDataType` — Proposed data type
character vector

Character vector containing the data type proposed for the signal or internal data type associated with this result.

Data Types: `char`

`ResultName` — Name of signal
character vector

The name of the signal or internal data associated with this result, stored as a character vector.

Data Types: `char`

`RunName` — Name of run associated with result
character vector

Name of run associated with result, specified as a character vector.

Data Types: `char`

`Saturations` — Number of saturations that occurred
scalar

The number of occurrences where the signal or internal data associated with this result saturated at the maximum or minimum of its specified data type. This field is cumulative of all the executions of the run the result is associated with.

Data Types: `double`

`SimMax` — Simulation maximum
scalar

The maximum values obtained for the signal or internal data during all of the saved executions of the run this result is associated with.

Data Types: `double`

`SimMin` — Simulation minimum
scalar

The minimum value obtained for the signal or internal data during all of the saved executions of the run this result is associated with.

Data Types: `double`

`SpecifiedDataType` — Specified data type of signal
character vector

The data type currently specified for a signal, which will take effect the next time the system is run.

Data Types: `char`

`Wraps` — Number of wraps that occurred
scalar

The number of occurrences where the signal or internal data associated with this result wrapped around the maximum or minimum of its specified data type. This field is cumulative of all the executions of the run the result is associated with.

Data Types: `double`

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

See Also

`DataTypeWorkflow.Converter` | `DataTypeWorkflow.ProposalSettings`

Topics

“Convert a Model to Fixed Point Using the Command Line”

FunctionApproximation.LUTMemoryUsageCalculator class

Package: FunctionApproximation

Calculate total memory used by lookup table blocks in a model

Description

The `FunctionApproximation.LUTMemoryUsageCalculator` class helps to calculate the total memory used by all lookup table blocks, including 1-D Lookup Table, 2-D Lookup Table, and n-D Lookup Table, used in a model.

Construction

`calculator = FunctionApproximation.LUTMemoryUsageCalculator()` creates a `FunctionApproximation.LUTMemoryUsageCalculator` object. Use the `lutmemoryusage` method to calculate the memory used by all lookup table blocks in a model.

Methods

lutmemoryusage	Calculate total memory used by lookup table blocks in a model

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

Examples

Calculate the Total Memory Used by Lookup Tables in a Model

Use the `FunctionApproximation.LUTMemoryUsageCalculator` class to calculate the total memory used by lookup table blocks in a model.

Create a `FunctionApproximation.LUTMemoryUsageCalculator` object.

```
calculator = FunctionApproximation.LUTMemoryUsageCalculator
```

Use the `lutmemoryusage` method to get the total memory used by the lookup table blocks in the `sldemo_fuelsys` model.

```
load_system('sldemo_fuelsys')
lutmemoryusage(calculator, 'sldemo_fuelsys')
```

```
ans =

  6×1 table




    sldemo_fuelsys/fuel_rate_control/airflow_calc/Pumping Constant
    sldemo_fuelsys/fuel_rate_control/control_logic/Throttle.throttle_estimate/Throttle
    sldemo_fuelsys/fuel_rate_control/control_logic/Speed.speed_estimate/Speed Estimatio
    sldemo_fuelsys/fuel_rate_control/control_logic/Pressure.map_estimate/Pressure Estim
    sldemo_fuelsys/fuel_rate_control/airflow_calc/Ramp Rate Ki
    Total
```

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`approximate` | `compare` | `displayallsolutions` | `displayfeasiblesolutions` | `lutmemoryusage` | `solutionfromID` | `solve` | `totalmemoryusage`

Topics

"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

FunctionApproximation.LUTSolution class

Package: FunctionApproximation

Optimized lookup table data or lookup table data approximating a math function

Description

A `FunctionApproximation.LUTSolution` object contains optimized lookup table data or lookup table data approximating a math function. To create a `FunctionApproximation.LUTSolution` object, use the `solve` method on a `FunctionApproximation.Problem` object. To generate a subsystem containing the lookup table approximate or the optimized lookup table, use the `approximate` method of the `FunctionApproximation.LUTSolution` object.

You can save a `FunctionApproximation.LUTSolution` object to a MAT-file and restore the solution later.

Construction

`solution = solve(problem)` solves the problem defined by the `FunctionApproximation.Problem` object, `problem`, and returns the approximation or optimization, `solution`, as a `FunctionApproximation.LUTSolution` object.

Input Arguments

`problem` — Function to approximate, or lookup table to optimize
`FunctionApproximation.Problem` object

Function to approximate, or lookup table to optimize, and the constraints to consider during the optimization, specified as a `FunctionApproximation.Problem` object.

Properties

ID — ID of the solution
scalar integer

ID of the solution, specified as a scalar integer.

This property is read-only.

Data Types: double

Feasible — Whether the approximation meets the constraints
true | false

Whether the approximation or optimization specified by the FunctionApproximation.LUTSolution object, solution, meets the constraints specified in the FunctionApproximation.Problem object, problem, and its associated FunctionApproximation.Options.

This property is read-only.

Data Types: logical

AllSolutions — All solutions, including infeasible solutions
vector of FunctionApproximation.LUTSolution objects

All solutions found during the approximation, including infeasible solutions, specified as a vector of FunctionApproximation.LUTSolution objects.

This property is read-only.

FeasibleSolutions — All solutions that meet the constraints
vector of FunctionApproximation.LUTSolution objects

All solutions meeting the specified constraints, specified as a vector of FunctionApproximation.LUTSolution objects.

This property is read-only.

PercentReduction — Reduction in memory of lookup table
scalar

If the original FunctionApproximation.Problem object specified a lookup table block to optimize, the PercentReduction property indicates the reduction in memory from the original lookup table. If the original `FunctionApproximation.Problem` object specified a math function or function handle, the `PercentReduction` is `-Inf`.

This property is read-only.

Data Types: `double`

`SourceProblem` — Problem object approximated by the solution
`FunctionApproximation.Problem` object

`FunctionApproximation.Problem` object that the `FunctionApproximation.LUTSolution` object approximates.

This property is read-only.

`TableData` — Lookup table data
struct

Struct containing data related to lookup table approximation. The struct has the following fields.

- `BreakpointValues` - Breakpoints of the lookup table
- `BreakpointDataTypes`- Data type of the lookup table breakpoints
- `TableValues` - Values in the lookup table
- `TableDataType` - Data type of the table data
- `IsEvenSpacing` - Boolean value indicating if the breakpoints are evenly spaced.

This property is read-only.

Methods

approximate	Generate a Lookup Table block from a `FunctionApproximation.LUTSolution`
compare	Compare numerical results of `FunctionApproximation.LUTSolution` to original function or lookup table
displayallsolutions	Display all solutions found during function approximation
displayfeasiblesolutions	Display all feasible solutions found during function approximation
solutionfromID	Access a solution found during the approximation process
totalmemoryusage	Calculate total memory used by a lookup table approximation

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation. Problem` | `FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.Options`

Functions
`approximate` | `compare` | `solve`

Topics
"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

FunctionApproximation.Options class

Package: FunctionApproximation

Specify additional options to use with `FunctionApproximation.Problem` object

Description

The `FunctionApproximation.Options` object contains additional options for defining a `FunctionApproximation.Problem` object.

Construction

`options = FunctionApproximation.Options()` creates a `FunctionApproximation.Options` object to use as an input to a `FunctionApproximation.Problem` object. The output, `options`, uses default property values.

`options = FunctionApproximation.Options(Name,Value)` creates a `FunctionApproximation.Options` object with property values specified by one or more `Name,Value` pair arguments. `Name` must appear inside single quotes (`''`). You can specify several name-value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Properties

`AbsTol` — Tolerance of difference between original and approximate
non-negative scalar

Maximum tolerance of the absolute value of the difference between the original output value and the output value of the approximation, specified as a non-negative scalar.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64` | `fi`

`AllowUpdateDiagram` — Whether to allow updating of the model diagram during the approximation process
1 (default) | 0

Whether to allow updating of the model diagram during the approximation process, specified as a logical. This property is only relevant for `FunctionApproximation.Problem` objects that specify a Lookup Table block, or a Math Function block as the item to approximate.

Data Types: `logical`

`BreakpointSpecification` — Spacing of breakpoint data
`ExplicitValues` (default) | `EvenSpacing` | `EvenPow2Spacing`

Spacing of breakpoint data, specified as one of the following values.

Breakpoint Specification	Description
`ExplicitValues`	Lookup table breakpoints are specified explicitly. Breakpoints can be closer together for some input ranges and farther apart in others.
`EvenSpacing`	Lookup table breakpoints are evenly spaced throughout.
`EvenPow2Spacing`	Lookup table breakpoints use power-of-two spacing. This breakpoint specification boasts the fastest execution speed because a bit shift can replace the position search.

For more information on how breakpoint specification can affect performance, see “Effects of Spacing on Speed, Error, and Memory Usage”.

Data Types: `char`

`Display` — Whether to display details of each iteration of the optimization
1 (default) | 0

Whether to display details of each iteration of the optimization, specified as a logical. A value of `1` results in information in the command window at each iteration of the approximation process. A value of `0` does not display information until the approximation is complete.

Data Types: `logical`

`Interpolation` — Method when an input falls between breakpoint values
`Linear` (default)

When an input falls between breakpoint values, the lookup table interpolates the output value using neighboring breakpoints. A linear interpolation method fits a line between the adjacent breakpoints, and returns the point on that line corresponding to the input.

Data Types: `char`

`RelTol` — Relative tolerance of difference between original and approximate
non-negative scalar

Maximum tolerance of the relative difference between the original output value and the output value of the approximation, specified as a non-negative scalar.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64` | `fi`

`WordLengths` — Word lengths permitted in the lookup table approximate
[1:128] (default) | integer scalar | integer vector

Specify the word lengths that can be used in the lookup table approximate based on your intended hardware. For example, if you intend to target an embedded processor, you can restrict the data types in your lookup table to native types, 8, 16, and 32.

Example: `options.WordLengths = [8,16,32];`

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64` | `fi`

Copy Semantics

Value. To learn how value classes affect copy operations, see Copying Objects (MATLAB).

Algorithms

When you set `BreakpointSpecification` to `'ExplicitValues'`, during the approximation process, the algorithm also attempts to find a solution using `'EvenSpacing'` and `'EvenPow2Spacing'`. Likewise, when you set `BreakpointSpecification` to `'EvenSpacing'`, the algorithm also attempts to find a solution using `'EvenPow2Spacing'`. If you set the property to `'EvenPow2Spacing'`, the algorithm only attempts to find a solution using this spacing.

In cases where the `BreakpointSpecification` property is set to `'EvenSpacing'`, but the `InputUpperBounds` or `InputLowerBounds` property of the `FunctionApproximation.Problem` object is equal to the range of the `InputTypes`, the algorithm does not attempt to find a solution using `'EvenPow2Spacing'`.

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`approximate` | `compare` | `displayallsolutions` | `displayfeasiblesolutions` | `lutmemoryusage` | `solutionfromID` | `solve` | `totalmemoryusage`

Topics

"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

FunctionApproximation.Problem class

Package: FunctionApproximation

Object defining the function to approximate, or the lookup table to optimize

Description

The `FunctionApproximation.Problem` object defines the math function to approximate with a lookup table, or the lookup table block to optimize. After defining the problem, use the `solve` method to generate a `FunctionApproximation.LUTSolution` object that contains the approximation.

Construction

`approximationProblem = FunctionApproximation.Problem()` creates a `FunctionApproximation.Problem` object with default property values. When no `function` input is provided, the `FunctionToApproximate` property is set to `'sin'`.

`approximationProblem = FunctionApproximation.Problem(function)` creates a `FunctionApproximation.Problem` object to approximate the function, Math Function block, or lookup table specified by `function`.

Input Arguments

`function` — Function to approximate, or lookup table block to optimize
`'sin'` (default) | math function | function handle | Math Function block | Lookup Table block

Function to approximate, or the lookup table block to optimize, specified as a function handle, a math function, a Math Function block, or one of the lookup table blocks (for example, 1-D Lookup Table, n-D Lookup Table).

If you specify one of the lookup table blocks, the `solve` method generates an optimized lookup table.

If you specify a math function, a function handle, or a Math Function block, the `solve` method generates a lookup table approximation of the input function.

Function handles must be on the MATLAB search path, or approximation fails.

The MATLAB math functions supported for approximation are:

- `1/.x`
- `10.^x`
- `2.^x`
- `acos`
- `acosh`
- `asin`
- `asinh`
- `atan`
- `atan2`
- `atanh`
- `cos`
- `cosh`
- `exp`
- `log`
- `log10`
- `log2`
- `sin`
- `sinh`
- `sqrt`
- `tan`
- `tanh`
- `x.^2`

Note Math functions and function handles must be vectorized. For more information, see “Vectorization” (MATLAB).

Data Types: `char` | `function_handle`

Properties

`FunctionToApproximate` — Function to approximate, or lookup table block to optimize

`'sin'` (default) | math function | function handle | Math Function block | Lookup Table block

Function to approximate, or the lookup table block to optimize, specified as a function handle, a math function, a Math Function block, or one of the lookup table blocks (for example, 1-D Lookup Table, n-D Lookup Table).

If you specify one of the lookup table blocks, the `solve` method generates an optimized lookup table.

If you specify a math function, a function handle, or a Math Function block, the `solve` method generates a lookup table approximation of the input function.

Function handles must be on the MATLAB search path, or approximation fails.

The MATLAB math functions supported for approximation are:

- `1/.x`
- `10.^x`
- `2.^x`
- `acos`
- `acosh`
- `asin`
- `asinh`
- `atan`
- `atan2`
- `atanh`
- `cos`
- `cosh`

- `exp`
- `log`
- `log10`
- `log2`
- `sin`
- `sinh`
- `sqrt`
- `tan`
- `tanh`
- `x.^2`

Note Math functions and function handles must be vectorized. For more information, see "Vectorization" (MATLAB).

Data Types: `char` | `function_handle`

`NumberOfInputs` — Number of inputs to function approximation
1 | 2 | 3

Number of inputs to approximated function. This property is inferred from the `FunctionToApproximate` property, therefore it is not a writable property.

Data Types: `double`

`InputTypes` — Desired data types of inputs to function approximation
`numerictype` object | vector of `numerictype` objects | `Simulink.Numerictype` object | vector of `Simulink.Numerictype` objects

Desired data types of the inputs to the approximated function, specified as a `numerictype`, `Simulink.Numerictype`, or a vector of `numerictype` or `Simulink.Numerictype` objects. The number of `InputTypes` specified must match the `NumberOfInputs`.

Example: `problem.InputTypes = ["numerictype(1,16,13)", "numerictype(1,16,10)"];`

`InputLowerBounds` — Lower limit of range of inputs to function to approximate
scalar | vector

Lower limit of range of inputs to function to approximate, specified as a scalar or vector. If you specify `inf`, the `InputLowerBounds` used during the approximation is derived from the `InputTypes` property. The dimensions of `InputLowerBounds` must match the `NumberOfInputs`.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64` | `fi`

`InputUpperBounds` — Upper limit of range of inputs to function to approximate
scalar | vector

Upper limit of range of inputs to function to approximate, specified as a scalar or vector. If you specify `inf`, the `InputUpperBounds` used during the approximation is derived from the `InputTypes` property. The dimensions of `InputUpperBounds` must match the `NumberOfInputs`.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64` | `fi`

`OutputType` — Desired data type of the function approximation output
`numerictype` | `Simulink.Numerictype`

Desired data type of the function approximation output, specified as a `numerictype` or `Simulink.Numerictype`. For example, to specify that you want the output to be a signed fixed-point data type with 16-bit word length and best-precision fraction length, set the `OutputType` property to `"numerictype(1,16)"`.

Example: `problem.OutputType = "numerictype(1,16)";`

`Options` — Additional options and constraints to use in approximation
`FunctionApproximation.Options` object

Additional options and constraints to use in approximation, specified as a `FunctionApproximation.Options` object.

Methods

solve	Solve for optimized solution to function approximation problem

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create Problem Object to Approximate a Function Handle

Create a `FunctionApproximation.Problem` object, specifying a function handle that you want to approximate.

```
problem = FunctionApproximation.Problem(@(x,y) sin(x)+cos(y))
```

```
problem = 

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x,y)sin(x)+cos(y)
           NumberOfInputs: 2
               InputTypes: ["numerictype('double')"    "numerictype('double')"]
         InputLowerBounds: [-Inf -Inf]
         InputUpperBounds: [Inf Inf]
               OutputType: "numerictype('double')"
                  Options: [1×1 FunctionApproximation.Options]
```

The `FunctionApproximation.Problem` object, *problem*, uses default property values.

Set the range of the function inputs to be between zero and `2*pi`.

```
problem.InputLowerBounds = [0,0];
problem.InputUpperBounds = [2*pi, 2*pi]
```

```
problem = 

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x,y)sin(x)+cos(y)
           NumberOfInputs: 2
               InputTypes: ["numerictype('double')"    "numerictype('double')"]
         InputLowerBounds: [0 0]
         InputUpperBounds: [6.2832 6.2832]
```

```
              OutputType: "numerictype('double')"
                 Options: [1×1 FunctionApproximation.Options]
```

Create Problem Object to Approximate a Math Function

Create a `FunctionApproximation.Problem` object, specifying a math function to approximate.

```
problem = FunctionApproximation.Problem('log')
```

```
problem =

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x)log(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(1,16,10)"
         InputLowerBounds: 0.6250
         InputUpperBounds: 15.6250
               OutputType: "numerictype(1,16,13)"
                  Options: [1×1 FunctionApproximation.Options]
```

The math functions have appropriate input range, input data type, and output data type property defaults.

Create Problem Object to Optimize a Lookup Table Block

Create a `FunctionApproximation.Problem` object to optimize an existing lookup table.

```
load_system('sldemo_fuelsys');
problem = FunctionApproximation.Problem('sldemo_fuelsys/fuel_rate_control/airflow_calc/
```

```
problem =

  FunctionApproximation.Problem with properties

    FunctionToApproximate: 'sldemo_fuelsys/fuel_rate_control/airflow_calc/Pumping Const
           NumberOfInputs: 2
               InputTypes: ["numerictype('single')"    "numerictype('single')"]
         InputLowerBounds: [50 0.0500]
         InputUpperBounds: [1000 0.9500]
               OutputType: "numerictype('single')"
                  Options: [1×1 FunctionApproximation.Options]
```

The software infers the properties of the `Problem` object from the model.

Algorithms

Infinite Upper and Lower Input Bounds

When a `Problem` object specifies infinite input ranges and the input type is non-floating-point, during the approximation, the software infers upper and lower ranges based on the range of the input data type. The resulting `FunctionApproximation.LUTSolution` object specifies the bounds that the algorithm used during the approximation, not the originally specified infinite bounds.

Upper and Lower Input Bounds and Input Data Type Range

If the `InputLowerBounds` or `InputUpperBounds` specified for a `Problem` object fall outside the range of the specified `InputTypes`, the algorithm uses the range of the data type specified by `InputTypes` for the approximation.

In cases where the `BreakpointSpecification` property of the `FunctionApproximation.Options` object is set to `'EvenSpacing'`, but the `InputUpperBounds` or `InputLowerBounds` property of the `FunctionApproximation.Problem` object is equal to the range of the `InputTypes`, the algorithm does not attempt to find a solution using `'EvenPow2Spacing'`.

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options`

Functions
`approximate` | `compare` | `solve`

Topics

“Optimize Lookup Tables for Memory-Efficiency Programmatically”
“Optimize Lookup Tables for Memory-Efficiency”

Introduced in R2018a

fxpOptimizationOptions class

Specify options for data type optimization

Description

The `fxpOptimizationOptions` object enables you to specify options and constraints to use during the data type optimization process.

Construction

`opt = fxpOptimizationOptions()` creates a `fxpOptimizationOptions` object with default values.

Properties

`MaxIterations` — Maximum number of iterations to perform
50 (default) | scalar integer

Maximum number of iterations to perform, specified as a scalar integer. The optimization process iterates through different solutions until it finds an ideal solution, reaches the maximum number of iterations, or reaches another stopping criteria.

Example: `opt.MaxIterations = 75;`

Data Types: `double`

`MaxTime` — Maximum amount of time for the optimization to run (in seconds)
600 (default) | scalar

Maximum amount of time for the optimization to run, specified in seconds as a scalar number. The optimization runs until it reaches the time specified, an ideal solution, or another stopping criteria.

Example: `opt.MaxTime = 1000;`

Data Types: `double`

`Patience` — Maximum number of iterations where no new best solution is found
10 (default) | scalar integer

Maximum number of iterations where no new best solution is found, specified as a scalar integer. The optimization continues as long as the algorithm continues to find new best solutions.

Example: `opt.Patience = 15;`

Data Types: `double`

`Verbosity` — Level of information displayed at the command line during the optimization
`'Moderate'` (default) | `'High'` | `'Silent'`

The level of information displayed at the command line during the optimization process, specified as either `'High'`, `'Moderate'`, or `'Silent'`.

- `'Silent'` - Nothing is displayed at the command line until the optimization process is finished
- `'Moderate'` - Information is displayed at each major step of the optimization process, including when the process is in the preprocessing, modeling, and optimization phases.
- `'High'` - Information is displayed at the command line at each iteration of the optimization process, including whether a new best solution was found, and the cost of the solution.

Example: `opt.Verbosity = 'High';`

Data Types: `char` | `string`

`AllowableWordLengths` — Word lengths that can be used in your optimized system under design
`[1:128]` (default) | scalar integer | vector of integers

Specify the word lengths that can be used in your optimized system under design. Use this property to target the neighborhood search of the optimization process. The final result of the optimization uses word lengths in the intersection of the `AllowableWordLengths` and word lengths compatible with hardware constraints specified in the **Hardware Implementation** pane of your model.

Example: `opt.AllowableWordLenghts = [8:11,16,32];`

Data Types: `double`

`AdvancedOptions` — Additional options for optimization

struct

Additional optimization options. `AdvancedOptions` is a struct containing two additional properties that can affect the optimization.

Property	Description
`PerformNeighborhoodSearch`	• `1` (default) - Perform a neighborhood search for the optimized solution. • `0` - Do not perform a neighborhood search. This can increase the speed of the optimization process, but also increases the chances of finding a less ideal solution.
`EnforceLooseCoupling`	Some blocks have a parameter that forces inputs to share the same data type, or forces the output to share the same data type as the input. • `1` (default) - Allow the optimizer to relax this restriction on all blocks in the system under design. Relaxing this restriction enables the optimizer to provide better fitting data types. • `0` - Do not allow the optimizer to relax this restriction on blocks in the system under design.

Methods

addTolerance	Specify numeric tolerance for optimized system
showTolerances	Show tolerances specified for a system

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

Examples

Create an fxpOptimizationOptions object with default values

Create an `fxpOptimizationObject` with default property values.

```
options = fxpOptimizationOptions();
```

Edit the properties after creation using dot syntax.

```
options.Patience = 15;
options.AllowableWordLengths = [8,16,32]
```

```
options = 

  fxpOptimizationOptions with properties:

           MaxIterations: 50
                 MaxTime: 600
                Patience: 15
               Verbosity: High
    AllowableWordLengths: [8 16 32]

   Advanced Options
         AdvancedOptions: [1x1 struct]
```

See Also

Classes
`OptimizationResult` | `OptimizationSolution`

Functions
`addTolerance` | `explore` | `fxpopt` | `showTolerances`

Topics

"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

OptimizationResult class

Result after optimizing fixed-point system

Description

An `OptimizationResult` object contains the results after optimizing a fixed-point system. If the optimization process succeeds in finding a new fixed-point implementation, you can use this object to explore the different implementations that met the specified tolerances found during the process. Use the `explore` method to open the Simulation Data Inspector and view the behavior of the optimized system.

Construction

`result = fxpopt(model, sud, options)` optimizes the data types in the system specified by `sud` in the model, `model`, with additional options specified in the `fxpOptimizationOptions` object, `options`.

Input Arguments

`model` — Model containing system under design
character vector

Name of the model containing the system that you want to optimize.

Data Types: `char`

`sud` — System whose data types you want to optimize
character vector

System whose data types you want to optimize, specified as a character vector containing the path to the system.

Data Types: `char`

`options` — Additional optimization options
`fxpOptimizationOptions` object

`fxpOptimizationOptions` object specifying additional options to use during the data type optimization process.

Properties

`FinalOutcome` — Message specifying whether a new optimal solution was found
character vector

Message specifying whether a new optimal solution was found. If the optimization process finds a new solution, the message returned is `'Fixed-point implementation that met the tolerances found.'` If the optimization does not find a new solution, the message is, `'Fixed-point implementation that met the tolerances not found.'`

Data Types: `char`

`OptimizationOptions` — `fxpOptimizationOptions` object associated with the result
`fxpOptimizationOptions` object

The `fxpOptimizationOptions` object used as an input to the `fxpopt` function used to generate the `OptimizationResult`.

`Solutions` — Vector of `OptimizationSolution` objects
`OptimizationSolution` object | vector of `OptimizationSolution` objects

A vector of `OptimizationSolution` objects found during the optimization process. If the optimization finds a feasible solution, the vector is sorted by cost, with the lowest cost (most optimal) solution as the first element of the vector. If the optimization does not find a feasible solution, the vector is sorted by maximum difference from the original design.

Methods

explore	Explore fixed-point implementations found during optimization process

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

See Also

Classes
`OptimizationSolution` | `fxpOptimizationOptions`

Functions
`addTolerance` | `explore` | `fxpopt` | `showTolerances`

Topics

"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

OptimizationSolution class

Optimized fixed-point implementation of system

Description

An `OptimizationSolution` object is a fixed-point implementation of a system whose data types were optimized using the `fxpopt` function.

Construction

`solution = explore(result)` opens the Simulation Data Inspector. If the optimization found a solution, it returns the `OptimizationSolution` object with the lowest cost out of the vector of `OptimizationSolution` objects contained in the `OptimizationResult` object, `result`. If the optimization did not find a solution, it returns the `OptimizationSolution` object with the smallest `MaxDifference`.

You can also access a `OptimizationSolution` object by indexing the `Solutions` property of an `OptimizationResult` object. For example, to access the solution with the second lowest cost contained in the `OptimizationResult` object, `result`, enter

```
solution = result.Solutions(2)
```

Input Arguments

`result` — `OptimizationResult` containing the solution
`OptimizationResult` object

The `Solutions` property of the `OptimizationResult` object is a vector of `OptimizationSolution` objects found during the optimization process. If the optimization found a feasible solution, the vector is sorted by cost, with the lowest cost (most optimal) solution as the first element of the vector. If the optimization did not find a feasible solution, the vector is sorted by `MaxDifference`, with the solution with the smallest `MaxDifference` as the first element.

Properties

`Cost` — Sum of word lengths used in the system under design
scalar integer

Sum of all word lengths used in the solution in the system under design. The most optimal solution is the solution with the smallest cost.

Data Types: `double`

`Pass` — Whether the solution meets specified criteria
1 | 0

Whether the solution meets the criteria specified by the associated `fxpOptimizationOptions` object, specified as a logical.

Data Types: `logical`

`MaxDifference` — Maximum absolute difference between baseline solution run
scalar

The maximum absolute difference between the baseline the solution.

Data Types: `double`

`RunID` — Run identifier
scalar integer

Unique numerical identification for the run used by the Simulation Data Inspector. For more information, see "Inspect and Compare Data Programmatically" (Simulink).

Data Types: `double`

`RunName` — Name of the run
character vector

Name of the run in Simulation Data Inspector.

Data Types: `char`

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects (MATLAB).

See Also

Classes
`OptimizationResult` | `fxpOptimizationOptions`

Functions
`addTolerance` | `explore` | `fxpopt` | `showTolerances`

Topics
"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

Methods — Alphabetical List

isHeterogeneous

Class: coder.CellType
Package: coder

Determine whether cell array type represents a heterogeneous cell array

Syntax

```
tf = isHeterogeneous(t)
```

Description

`tf = isHeterogeneous(t)` returns `true` if the `coder.CellType` object `t` is heterogeneous. Otherwise, it returns `false`.

Examples

Determine Whether Cell Array Type Is Heterogeneous

Create a `coder.CellType` object for a cell array whose elements have different classes.

```
t = coder.typeof({'a', 1})
```

```
t = 

coder.CellType
   1x2 heterogeneous cell
      f0: 1x1 char
      f1: 1x1 double
```

Determine whether the `coder.CellType` object represents a heterogeneous cell array.

```
isHeterogeneous(t)
```

```
ans =

     1
```

Tips

- `coder.typeof` determines whether the cell array type is homogeneous or heterogeneous. If the cell array elements have the same class and size, `coder.typeof` returns a homogeneous cell array type. If the elements have different classes, `coder.typeof` returns a heterogeneous cell array type. For some cell arrays, the classification as homogeneous or heterogeneous is ambiguous. For example, the type for {1 [2 3]} can be a 1x2 heterogeneous type. The first element is double and the second element is 1x2 double. The type can also be a 1x3 homogeneous type in which the elements have class double and size 1x:2. For these ambiguous cases, `coder.typeof` uses heuristics to classify the type as homogeneous or heterogeneous. If you want a different classification, use the `makeHomogeneous` or `makeHeterogeneous` methods. The `makeHomogeneous` method makes a homogeneous copy of a type. The `makeHeterogeneous` method makes a heterogeneous copy of a type.

  The `makeHomogeneous` and `makeHeterogeneous` methods permanently assign the classification as homogeneous and heterogeneous, respectively. You cannot later use one of these methods to create a copy that has a different classification.

See Also

`coder.newtype` | `coder.typeof`

Topics

"Code Generation for Cell Arrays"
"Specify Cell Array Inputs at the Command Line"

Introduced in R2015b

isHomogeneous

Class: coder.CellType
Package: coder

Determine whether cell array type represents a homogeneous cell array

Syntax

```
tf = isHomogeneous(t)
```

Description

`tf = isHomogeneous(t)` returns `true` if the `coder.CellType` object `t` represents a homogeneous cell array. Otherwise, it returns `false`.

Examples

Determine Whether Cell Array Type Is Homogeneous.

Create a `coder.CellType` object for a cell array whose elements have the same class and size.

```
t = coder.typeof({1 2 3})
```

```
t =

coder.CellType
   1x3 homogeneous cell
      base: 1x1 double
```

Determine whether the `coder.CellType` object represents a homogeneous cell array.

```
isHomogeneous(t)
```

```
ans =

     1
```

Test for a Homogeneous Cell Array Type Before Executing Code

Write a function `make_varsize`. If the input type `t` is homogeneous, the function returns a variable-size copy of `t`.

```
function c = make_varsize(t, n)
assert(isHomogeneous(t));
c = coder.typeof(t, [n n], [1 1]);
end
```

Create a heterogeneous type `tc`.

```
tc = coder.typeof({'a', 1});
```

Pass `tc` to `make_varsize`.

```
tc1 = make_varsize(tc, 5)
```

The assertion fails because `tc` is heterogeneous.

Create a homogeneous type `tc`.

```
tc = coder.typeof({1 2 3});
```

Pass `tc` to `make_varsize`.

```
tc1 = make_varsize(tc, 5)
```

```
tc1 =

coder.CellType
   :5x:5 homogeneous cell
      base: 1x1 double
```

Tips

- `coder.typeof` determines whether the cell array type is homogeneous or heterogeneous. If the cell array elements have the same class and size, coder.typeof returns a homogeneous cell array type. If the elements have different classes, coder.typeof returns a heterogeneous cell array type. For some cell arrays, the classification as homogeneous or heterogeneous is ambiguous. For example, the type for {1 [2 3]} can be a 1x2 heterogeneous type. The first element is double and the second element is 1x2 double. The type can also be a 1x3 homogeneous type in which the elements have class double and size 1x:2. For these ambiguous cases, coder.typeof uses heuristics to classify the type as homogeneous or heterogeneous. If you want a different classification, use the makeHomogeneous or makeHeterogeneous methods. The makeHomogeneous method makes a homogeneous copy of a type. The makeHeterogeneous method makes a heterogeneous copy of a type.

The makeHomogeneous and makeHeterogeneous methods permanently assign the classification as homogeneous and heterogeneous, respectively. You cannot later use one of these methods to create a copy that has a different classification.

See Also

coder.newtype | coder.typeof

Topics

“Code Generation for Cell Arrays”
“Specify Cell Array Inputs at the Command Line”

Introduced in R2015b

makeHeterogeneous

Class: coder.CellType
Package: coder

Make a heterogeneous copy of a cell array type

Syntax

```
newt = makeHeterogeneous(t)
t = makeHeterogeneous(t)
```

Description

`newt = makeHeterogeneous(t)` creates a `coder.CellType` object for a heterogeneous cell array from the `coder.CellType` object `t`. `t` cannot represent a variable-size cell array.

The classification as heterogeneous is permanent. You cannot later create a homogeneous `coder.CellType` object from `newt`.

`t = makeHeterogeneous(t)` creates a heterogeneous `coder.CellType` object from `t` and replaces `t` with the new object.

Examples

Replace a Homogeneous Cell Array Type with a Heterogeneous Cell Array Type

Create a cell array type `t` whose elements have the same class and size.

```
t = coder.typeof({1 2 3})
```

```
t =

coder.CellType
```

```
   1x3 homogeneous cell
      base: 1x1 double
```

The cell array type is homogeneous.

Replace `t` with a cell array type for a heterogeneous cell array.

```
t = makeHeterogeneous(t)
```

```
t =

coder.CellType
   1×3 locked heterogeneous cell
      f1: 1×1 double
      f2: 1×1 double
      f3: 1×1 doublee
```

The cell array type is heterogeneous. The elements have the size and class of the original homogeneous cell array type.

Tips

- In the display of a `coder.CellType` object, the terms `locked heterogeneous` or `locked homogeneous` indicate that the classification as homogeneous or heterogeneous is permanent. You cannot later change the classification by using the `makeHomogeneous` or `makeHeterogeneous` methods.
- `coder.typeof` determines whether the cell array type is homogeneous or heterogeneous. If the cell array elements have the same class and size, `coder.typeof` returns a homogeneous cell array type. If the elements have different classes, `coder.typeof` returns a heterogeneous cell array type. For some cell arrays, the classification as homogeneous or heterogeneous is ambiguous. For example, the type for {1 [2 3]} can be a 1x2 heterogeneous type. The first element is double and the second element is 1x2 double. The type can also be a 1x3 homogeneous type in which the elements have class double and size 1x:2. For these ambiguous cases, `coder.typeof` uses heuristics to classify the type as homogeneous or heterogeneous. If you want a different classification, use the `makeHomogeneous` or `makeHeterogeneous` methods.

See Also

`coder.newtype` | `coder.typeof`

Topics

"Code Generation for Cell Arrays"
"Specify Cell Array Inputs at the Command Line"

Introduced in R2015b

makeHomogeneous

Class: coder.CellType
Package: coder

Create a homogeneous copy of a cell array type

Syntax

```
newt = makeHomogeneous(t)
t = makeHomogeneous(t)
```

Description

`newt = makeHomogeneous(t)` creates a `coder.CellType` object for a homogeneous cell array `newt` from the `coder.CellType` object `t`.

To create `newt`, the `makeHomogeneous` method must determine a size and class that represent all elements of `t`:

- If the elements of `t` have the same class, but different sizes, the elements of `newt` are variable size with upper bounds that accommodate the elements of `t`.
- If the elements of `t` have different classes, for example, `char` and `double`, the `makeHomogeneous` method cannot create a `coder.CellType` object for a homogeneous cell array.

The classification as homogeneous is permanent. You cannot later create a heterogeneous `coder.CellType` object from `newt`.

`t = makeHomogeneous(t)` creates a homogeneous `coder.CellType` object from `t` and replaces `t` with the new object.

Examples

Replace a Heterogeneous Cell Array Type with a Homogeneous Cell Array Type

Create a cell array type `t` whose elements have the same class, but different sizes.

```
t = coder.typeof({1 [2 3]})
```

```
t = 

coder.CellType
   1x2 heterogeneous cell
      f0: 1x1 double
      f1: 1x2 double
```

The cell array type is heterogeneous.

Replace `t` with a cell array type for a homogeneous cell array.

```
t = makeHomogeneous(t)
```

```
t = 

coder.CellType
   1×2 locked homogeneous cell
      base: 1×:2 double
```

The new cell array type is homogeneous.

Tips

- In the display of a `coder.CellType` object, the terms `locked heterogeneous` or `locked homogeneous` indicate that the classification as homogeneous or heterogeneous is permanent. You cannot later change the classification by using the `makeHomogeneous` or `makeHeterogeneous` methods.
- `coder.typeof` determines whether the cell array type is homogeneous or heterogeneous. If the cell array elements have the same class and size, `coder.typeof` returns a homogeneous cell array type. If the elements have different classes, `coder.typeof` returns a heterogeneous cell array type. For some cell arrays, the classification as homogeneous or heterogeneous is ambiguous. For example, the type for {1 [2 3]} can be a 1x2 heterogeneous type. The first element is double and the second element is 1x2 double. The type can also be a 1x3 homogeneous type in which the elements have class double and size 1x:2. For these ambiguous cases, `coder.typeof` uses heuristics to classify the type as homogeneous or heterogeneous.

If you want a different classification, use the makeHomogeneous or makeHeterogeneous methods.

See Also

coder.newtype | coder.typeof

Topics

"Code Generation for Cell Arrays"
"Specify Cell Array Inputs at the Command Line"

Introduced in R2015b

addApproximation

Replace floating-point function with lookup table during fixed-point conversion

Syntax

`addApproximation(approximationObject)`

Description

`addApproximation(approximationObject)` specifies a lookup table replacement in a `coder.FixptConfig` object. During floating-point to fixed-point conversion, the conversion process generates a lookup table approximation for the function specified in the `approximationObject`.

Input Arguments

`approximationObject` — Function replacement configuration object
`coder.mathfcngenerator.LookupTable` configuration object

Function replacement configuration object that specifies how to create an approximation for a MATLAB function. Use the `coder.FixptConfig` configuration object `addApproximation` method to associate this configuration object with a `coder.FixptConfig` object. Then use the `fiaccel` function `-float2fixed` option with `coder.FixptConfig` to convert floating-point MATLAB code to fixed-point MATLAB code.

Examples

Replace log function with an optimized lookup table replacement

Create a function replacement configuration object that specifies to replace the log function with an optimized lookup table.

```
logAppx = coder.approximation('Function','log','OptimizeLUTSize',...
          true,'InputRange',[0.1,1000],'InterpolationDegree',1,...
          'ErrorThreshold',1e-3,...
          'FunctionNamePrefix','log_optim_','OptimizeIterations',25);
```

Create a fixed-point configuration object and associate the function replacement configuration object with it.

```
fixptcfg = coder.config('fixpt');
fixptcfg.addApproximation(logAppx);
```

You can now generate fixed-point code using the `fiaccel` function.

- “Replace the exp Function with a Lookup Table”
- “Replace a Custom Function with a Lookup Table”

See Also

`coder.FixptConfig` | `fiaccel`

Topics

“Replace the exp Function with a Lookup Table”
“Replace a Custom Function with a Lookup Table”
“Replacing Functions Using Lookup Table Approximations”

addDesignRangeSpecification

Class: coder.FixptConfig
Package: coder

Add design range specification to parameter

Syntax

`addDesignRangeSpecification(fcnName,paramName,designMin, designMax)`

Description

`addDesignRangeSpecification(fcnName,paramName,designMin, designMax)` specifies the minimum and maximum values allowed for the parameter, `paramName`, in function, `fcnName`. The fixed-point conversion process uses this design range information to derive ranges for downstream variables in the code.

Input Arguments

`fcnName` — Function name
string

Function name, specified as a string.

Data Types: `char`

`paramName` — Parameter name
string

Parameter name, specified as a string.

Data Types: `char`

`designMin` — Minimum value allowed for this parameter
scalar

Minimum value allowed for this parameter, specified as a scalar double.

Data Types: `double`

designMax — Maximum value allowed for this parameter
scalar

Maximum value allowed for this parameter, specified as a scalar double.

Data Types: `double`

Examples

Add a Design Range Specification

```
% Set up the fixed-point configuration object
cfg = coder.config('fixpt');
cfg.TestBenchName = 'dti_test';
cfg.addDesignRangeSpecification('dti', 'u_in', -1.0, 1.0)
cfg.ComputeDerivedRanges = true;

% Derive ranges  and generate fixed-point code
fiaccel -float2fixed cfg dti
```

See Also

`coder.FixptConfig` | `coder.FixptConfig.clearDesignRangeSpecifications` | `coder.FixptConfig.getDesignRangeSpecification` | `coder.FixptConfig.hasDesignRangeSpecification` | `coder.FixptConfig.removeDesignRangeSpecification` | `fiaccel`

addFunctionReplacement

Class: coder.FixptConfig
Package: coder

Replace floating-point function with fixed-point function during fixed-point conversion

Syntax

`addFunctionReplacement(floatFn,fixedFn)`

Description

`addFunctionReplacement(floatFn,fixedFn)` specifies a function replacement in a `coder.FixptConfig` object. During floating-point to fixed-point conversion, the conversion process replaces the specified floating-point function with the specified fixed-point function. The fixed-point function must be in the same folder as the floating-point function or on the MATLAB path.

Input Arguments

`floatFn` — Name of floating-point function
`''` (default) | string

Name of floating-point function, specified as a string.

`fixedFn` — Name of fixed-point function
`''` (default) | string

Name of fixed-point function, specified as a string.

Examples

Specify Function Replacement in Fixed-Point Conversion Configuration Object

Suppose that:

- The function `myfunc` calls a local function `myadd`.
- The test function `mytest` calls `myfunc`.
- You want to replace calls to `myadd` with the fixed-point function `fi_myadd`.

Create a `coder.FixptConfig` object, `fixptcfg`, with default settings.

```
fixptcfg = coder.config('fixpt');
```

Set the test bench name. In this example, the test bench function name is `mytest`.

```
fixptcfg.TestBenchName = 'mytest';
```

Specify that the floating-point function, `myadd`, should be replaced with the fixed-point function, `fi_myadd`.

```
fixptcfg.addFunctionReplacement('myadd', 'fi_myadd');
```

Convert the floating-point MATLAB function, `myfunc`, to fixed-point.

```
fiaccel -float2fixed fixptcfg myfunc
```

`fiaccel` replaces `myadd` with `fi_myadd` during floating-point to fixed-point conversion.

See Also

`coder.FixptConfig` | `fiaccel`

addFunctionReplacement

Class: coder.SingleConfig
Package: coder

Replace double-precision function with single-precision function during single-precision conversion

Syntax

`addFunctionReplacement(doubleFn,singleFn)`

Description

`addFunctionReplacement(doubleFn,singleFn)` specifies a function replacement in a `coder.SingleConfig` object. During double-precision to single-precision conversion, the conversion process replaces the specified double-precision function with the specified single-precision function. The single-precision function must be in the same folder as the double-precision function or on the MATLAB path. It is a best practice to provide unique names to local functions that a replacement function calls. If a replacement function calls a local function, do not give that local function the same name as a local function in a different replacement function file.

Input Arguments

`doubleFn` — Name of double-precision function
`''` (default) | string

Name of double-precision function, specified as a string.

`singleFn` — Name of single-precision function
`''` (default) | string

Name of single-precision function, specified as a string.

Examples

Specify Function Replacement in Single-Precision Conversion Configuration Object

Suppose that:

- The function `myfunc` calls a local function `myadd`.
- The test function `mytest` calls `myfunc`.
- You want to replace calls to `myadd` with the single-precision function `single_myadd`.

Create a `coder.SingleConfig` object, `scfg`, with default settings.

```
scfg = coder.config('single');
```

Set the test file name. In this example, the test file function name is `mytest`.

```
scfg.TestBenchName = 'mytest';
```

Specify that you want to replace the double-precision function, `myadd`, with the single-precision function, `single_myadd`.

```
scfg.addFunctionReplacement('myadd', 'single_myadd');
```

Convert the double-precision MATLAB function, `myfunc` to a single-precision MATLAB function.

```
convertToSingle -config scfg myfunc
```

The double-precision to single-precision conversion replaces instances of `myadd` with `single_myadd`.

See Also

Introduced in R2015b

clearDesignRangeSpecifications

Class: coder.FixptConfig
Package: coder

Clear all design range specifications

Syntax

`clearDesignRangeSpecifications()`

Description

`clearDesignRangeSpecifications()` clears all design range specifications.

Examples

Clear a Design Range Specification

```
% Set up the fixed-point configuration object
cfg = coder.config('fixpt');
cfg.TestBenchName = 'dti_test';
cfg.addDesignRangeSpecification('dti', 'u_in', -1.0, 1.0)
cfg.ComputeDerivedRanges = true;
% Verify that the 'dti' function parameter 'u_in' has design range
hasDesignRanges = cfg.hasDesignRangeSpecification('dti','u_in')
% Now remove the design range
cfg.clearDesignRangeSpecifications()
hasDesignRanges = cfg.hasDesignRangeSpecification('dti','u_in')
```

See Also

`coder.FixptConfig` | `coder.FixptConfig.addDesignRangeSpecification` | `coder.FixptConfig.getDesignRangeSpecification` |

`coder.FixptConfig.hasDesignRangeSpecification` | `coder.FixptConfig.removeDesignRangeSpecification` | `fiaccel`

getDesignRangeSpecification

Class: coder.FixptConfig
Package: coder

Get design range specifications for parameter

Syntax

```
[designMin, designMax] = getDesignRangeSpecification(fcnName,
paramName)
```

Description

`[designMin, designMax] = getDesignRangeSpecification(fcnName, paramName)` gets the minimum and maximum values specified for the parameter, `paramName`, in function, `fcnName`.

Input Arguments

`fcnName` — Function name
string

Function name, specified as a string.

Data Types: `char`

`paramName` — Parameter name
string

Parameter name, specified as a string.

Data Types: `char`

Output Arguments

designMin — Minimum value allowed for this parameter
scalar

Minimum value allowed for this parameter, specified as a scalar double.

Data Types: double

designMax — Maximum value allowed for this parameter
scalar

Maximum value allowed for this parameter, specified as a scalar double.

Data Types: double

Examples

Get Design Range Specifications

```
% Set up the fixed-point configuration object
cfg = coder.config('fixpt');
cfg.TestBenchName = 'dti_test';
cfg.addDesignRangeSpecification('dti', 'u_in', -1.0, 1.0)
cfg.ComputeDerivedRanges = true;
% Get the  design range for the 'dti' function parameter 'u_in'
[designMin, designMax] = cfg.getDesignRangeSpecification('dti','u_in')
```

```
designMin =

    -1


designMax =

     1
```

See Also

coder.FixptConfig | coder.FixptConfig.addDesignRangeSpecification | coder.FixptConfig.clearDesignRangeSpecifications |

`coder.FixptConfig.hasDesignRangeSpecification` | `coder.FixptConfig.removeDesignRangeSpecification` | `fiaccel`

hasDesignRangeSpecification

Class: coder.FixptConfig
Package: coder

Determine whether parameter has design range

Syntax

```
hasDesignRange = hasDesignRangeSpecification(fcnName,paramName)
```

Description

`hasDesignRange = hasDesignRangeSpecification(fcnName,paramName)` returns true if the parameter, `param_name` in function, `fcn`, has a design range specified.

Input Arguments

`fcnName` — Name of function
string

Function name, specified as a string.

Example: 'dti'

Data Types: `char`

`paramName` — Parameter name
string

Parameter name, specified as a string.

Example: 'dti'

Data Types: `char`

Output Arguments

hasDesignRange — Parameter has design range
true | false

Parameter has design range, returned as a boolean.

Data Types: `logical`

Examples

Verify That a Parameter Has a Design Range Specification

```
% Set up the fixed-point configuration object
cfg = coder.config('fixpt');
cfg.TestBenchName = 'dti_test';
cfg.addDesignRangeSpecification('dti', 'u_in', -1.0, 1.0);
cfg.ComputeDerivedRanges = true;
% Verify that the 'dti' function parameter 'u_in' has design range
hasDesignRanges = cfg.hasDesignRangeSpecification('dti','u_in')
```

```
hasDesignRanges =

     1
```

See Also

`coder.FixptConfig` | `coder.FixptConfig.addDesignRangeSpecification` | `coder.FixptConfig.clearDesignRangeSpecifications` | `coder.FixptConfig.getDesignRangeSpecification` | `coder.FixptConfig.removeDesignRangeSpecification` | `fiaccel`

removeDesignRangeSpecification

Class: coder.FixptConfig
Package: coder

Remove design range specification from parameter

Syntax

`removeDesignRangeSpecification(fcnName,paramName)`

Description

`removeDesignRangeSpecification(fcnName,paramName)` removes the design range information specified for parameter, `paramName`, in function, `fcnName`.

Input Arguments

`fcnName` — Name of function
string

Function name, specified as a string.

Data Types: `char`

`paramName` — Parameter name
string

Parameter name, specified as a string.

Data Types: `char`

Examples

Remove Design Range Specifications

```
% Set up the fixed-point configuration object
cfg = coder.config('fixpt');
cfg.TestBenchName = 'dti_test';
cfg.addDesignRangeSpecification('dti', 'u_in', -1.0, 1.0)
cfg.ComputeDerivedRanges = true;
% Verify that the 'dti' function parameter 'u_in' has design range
hasDesignRanges = cfg.hasDesignRangeSpecification('dti','u_in')
% Now clear the design ranges and verify that
% hasDesignRangeSpecification returns false
cfg.removeDesignRangeSpecification('dti', 'u_in')
hasDesignRanges = cfg.hasDesignRangeSpecification('dti','u_in')
```

See Also

coder.FixptConfig | coder.FixptConfig.addDesignRangeSpecification | coder.FixptConfig.clearDesignRangeSpecifications | coder.FixptConfig.getDesignRangeSpecification | coder.FixptConfig.hasDesignRangeSpecification | fiaccel

applyDataTypes

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Apply proposed data types to model

Syntax

`converter.applyDataTypes(RunName)`

Description

`converter.applyDataTypes(RunName)` applies the proposed data types for the specified run to the converter's system.

Input Arguments

`RunName` — Name of run
character vector

Name of run to apply data types to, specified as a character vector.

Example: `converter.applyDataTypes('Run1')`

Data Types: `char`

Alternatives

`DataTypeWorkflow.Converter.applyDataTypes` provides functionality similar to the Fixed-Point Tool button **Apply accepted fraction lengths** . For more information, see `fxptdlg`.

See Also

`DataTypeWorkflow.Converter.proposeDataTypes` |
`DataTypeWorkflow.ProposalSettings`

Topics

"Convert a Model to Fixed Point Using the Command Line"

applySettingsFromRun

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Apply system settings used in previous run to model

Syntax

```
converter.applySettingsFromRun(RunName)
```

Description

`converter.applySettingsFromRun(RunName)` applies the data type override and instrumentation settings used in a previous run to the model.

Input Arguments

RunName — Name of run
character vector

Name of run that has the settings to apply, specified as a character vector.

Example: `converter.applySettingsFromRun('Run1')`

Data Types: `char`

See Also

`DataTypeWorkflow.Converter.applySettingsFromShortcut`

Topics

"Convert a Model to Fixed Point Using the Command Line"

applySettingsFromShortcut

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Apply settings from shortcut to model

Syntax

`converter.applySettingsFromShortcut(shortcutName)`

Description

`converter.applySettingsFromShortcut(shortcutName)` applies the settings from the specified configuration to the model.

Input Arguments

`shortcutName` — Name of shortcut
character vector

Name of shortcut that specifies which settings to use, specified as a character vector.

Example: `converter.applySettingsFromShortcut('Range collection using double override')`

Data Types: `char`

Tips

- You can create additional configurations using the Fixed-Point Tool. For more information, see "Use Shortcuts to Manage Runs".

Alternatives

`DataTypeWorkflow.Converter.applySettingsFromShortcut` provides functionality similar to the Fixed-Point Tool button group **Configure model settings**

. For more information, see `fxptdlg`.

See Also

`DataTypeWorkflow.Converter.applySettingsFromRun` | `fxptdlg`

Topics

"Convert a Model to Fixed Point Using the Command Line"

compareResults

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Compare two `DataTypeWorkflow.Result` objects

Syntax

```
diff = converter.compareResults(result1, result2)
```

Description

`diff = converter.compareResults(result1, result2)` compares two `DataTypeWorkflow.Result` objects.

Input Arguments

`Result1` — Result object
`DataTypeWorkflow.Result` object

`DataTypeWorkflow.Result` object to compare.

`Result2` — Result object
`DataTypeWorkflow.Result` object

`DataTypeWorkflow.Result` object to compare.

Output Arguments

`diff` — `DiffSignalResult` object
`DiffSignalResult` object

A `DataTypeWorkflow.DiffSignalResult` object containing the results of the comparison.

Alternatives

The `DataTypeWorkflow.Converter.compareResults` method offers a command-line approach to using the Fixed-Point Tool. For more information, see `fxptdlg`.

See Also

`Simulink.sdi.compareSignals` | `fxptdlg`

Topics

"Convert a Model to Fixed Point Using the Command Line"

compareRuns

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Compare two runs of converter’s selected system

Syntax

```
diff = converter.compareRuns(RunName1, RunName2)
```

Description

`diff = converter.compareRuns(RunName1, RunName2)` compares the matched signals between two simulations runs, `RunName1` and `RunName2`.

Input Arguments

`RunName1` — Name of run
character vector

Name of run to compare, specified as a character vector.

Data Types: `char`

`RunName2` — Name of run
character vector

Name of run to compare, specified as a character vector.

Data Types: `char`

Output Arguments

`diff` — Difference between two runs
`DataTypeWorkflow.DiffRunResult` object

A `DataTypeWorkflow.DiffRunResult` containing the results of the comparison.

Alternatives

The `DataTypeWorkflow.Converter.compareRuns` method offers a command-line approach to using the Fixed-Point Tool. See `fxptdlg` for more information.

See Also

`Simulink.sdi.compareRuns` | `fxptdlg`

Topics

"Convert a Model to Fixed Point Using the Command Line"

deriveMinMax

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Derive range information for model

Syntax

```
converter.deriveMinMax()
```

Description

`converter.deriveMinMax()` derives the minimum and maximum values for each block based on design minimum and maximum values.

Tips

- If any issues come up during the derivation, they can be queried using the `DataTypeWorkflow.Converter.proposalIssues` method.

Alternatives

The `DataTypeWorkflow.Converter.deriveMinMax` method is equivalent to the

Derive min/max values for selected system button () in the Fixed-Point Tool. See `fxptdlg` for more information.

See Also

`DataTypeWorkflow.Converter.simulateSystem` | `fxptdlg`

Topics

“Convert a Model to Fixed Point Using the Command Line”

proposeDataTypes

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Propose data types for system

Syntax

`converter.proposeDataTypes(RunName, propSettings)`

Description

`converter.proposeDataTypes(RunName, propSettings)` proposes data types for the system based on the range results stored in `RunName` and the settings specified in `propSettings`.

Input Arguments

`RunName` — Name of run
character vector

Name of run to propose data types for, specified as a character vector.

Data Types: `char`

`propSettings` — Proposed data type settings
`DataTypeWorkflow.ProposalSettings` object

Proposed data type settings specified as a `DataTypeWorkflow.ProposalSettings` object. Use this object to specify proposal settings such as the default data type for all floating point signals.

Alternatives

`DataTypeWorkflow.Converter.proposeDataTypes` provides functionality similar to the Fixed-Point Tool button **Propose fraction lengths** 

. For more information, see `fxptdlg`.

See Also

`DataTypeWorkflow.Converter.applyDataTypes` | `DataTypeWorkflow.ProposalSettings`

Topics

"Convert a Model to Fixed Point Using the Command Line"

results

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Find results for selected system in converter object

Syntax

```
results = converter.results(RunName)
results = converter.results(RunName, filterFunc)
```

Description

`results = converter.results(RunName)` returns all results in the specified run.

`results = converter.results(RunName, filterFunc)` returns the results in the specified run which match the criteria specified by `filterFunc`.

Input Arguments

`RunName` — Name of run
character vector

Name of the run to query, specified as a character vector.

Data Types: `char`

`filterFunc` — Function to use to filter results
function handle

Function to use to filter results, specified as a function handle with a `DataTypeWorkflow.Result` object as its input.

Data Types: `function_handle`

Output Arguments

`results` — Filtered results
array of `Result` objects

Array of `DataTypeWorkflow.Result` objects from `RunName` filtered by `filterFunc`

Alternatives

The `DataTypeWorkflow.Converter.results` method offers a command-line approach to using the Fixed-Point Tool. See `fxptdlg` for more information.

See Also

`DataTypeWorkflow.Converter.proposalIssues` |
`DataTypeWorkflow.Converter.saturationOverflows` |
`DataTypeWorkflow.Converter.wrapOverflows`

Topics

"Convert a Model to Fixed Point Using the Command Line"

proposalIssues

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Get results which have comments associated with them

Syntax

```
results = converter.proposalIssues(RunName)
```

Description

`results = converter.proposalIssues(RunName)` returns all results in `RunName` that have associated comments. The comments field of the returned results can provide information related to any issues found.

Input Arguments

`RunName` — Name of run
character vector

Name of run to look for comments in, specified as a character vector.

Data Types: `char`

Output Arguments

`results` — Results that have associated comments
`DataTypeWorkflow.Result` object

A `DataTypeWorkflow.Result` object containing all signals in `RunName` with associated comments.

Alternatives

The `DataTypeWorkflow.Converter.proposalIssues` method offers a command-line approach to using the Fixed-Point Tool. See `fxptdlg` for more information.

See Also

`DataTypeWorkflow.Converter.results` | `DataTypeWorkflow.Converter.saturationOverflows` | `DataTypeWorkflow.Converter.wrapOverflows`

Topics

"Convert a Model to Fixed Point Using the Command Line"

saturationOverflows

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Get results where saturation occurred

Syntax

```
results = converter.saturationOverflows(RunName)
```

Description

`results = converter.saturationOverflows(RunName)` all results in `RunName` that saturated during simulation.

Input Arguments

`RunName` — Name of run
character vector

Name of run to look for saturations in, specified as a character vector.

Data Types: `char`

Output Arguments

`results` — Results that saturated
`DataTypeWorkflow.Result` object

`DataTypeWorkflow.Result` object containing all of the signals that saturated during the specified run.

See Also

`DataTypeWorkflow.Converter.proposalIssues` |
`DataTypeWorkflow.Converter.results` |
`DataTypeWorkflow.Converter.wrapOverflows`

Topics

"Convert a Model to Fixed Point Using the Command Line"

simulateSystem

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Simulate converter's system

Syntax

```
simOut = converter.simulateSystem()
simOut = converter.simulateSystem(Name,Value)
simOut = converter.simulateSystem(ParameterStruct)
simOut = converter.simulateSystem(ConfigSet)
```

Description

`simOut = converter.simulateSystem()` simulates the converter's selected system.

`simOut = converter.simulateSystem(Name,Value)` uses additional options specified by one or more `Name,Value` pair arguments. This method accepts the same `Name,Value` pairs as the `sim` function.

`simOut = converter.simulateSystem(ParameterStruct)` simulates the converter's selected system using the parameter values specified in the structure, `ParameterStruct`.

`simOut = converter.simulateSystem(ConfigSet)` simulates the converter's selected system using the configuration settings specified in the model configuration set, `ConfigSet`.

Note

- The `SimulationMode` property must be set to `normal`. The Fixed-Point Designer software does collect simulation ranges in Rapid accelerator or Hot restart modes.
- The `SrcWorkspace` parameter must be set to either `base` or `current`.

Input Arguments

`ParameterStruct` — Structure of parameter settings
structure

Structure with fields that are the names of the configuration parameters for the simulation. The corresponding values are the parameter values.

Data Types: `struct`

`ConfigSet` — Configuration set
`Simulink.ConfigSet`

Configuration set, specified as a `Simulink.ConfigSet`, containing the values of the model parameters.

Output Arguments

`simOut` — Simulation output
`Simulink.SimulationOutput` object

`Simulink.SimulationOutput` object containing the simulation outputs: logged time, states, and signals.

Tips

- To correspond your simulation to a specific run name, before simulation, change the `CurrentRunName` property of the `DataTypeWorkflow.Converter` object.
- `DataTypeWorkflow.Converter.simulateSystem` provides functionality similar to the `sim` command, except that `simulateSystem` preserves the model-wide data type override and instrumentation settings of each run.

See Also

`sim`

Topics

"Convert a Model to Fixed Point Using the Command Line"

wrapOverflows

Class: DataTypeWorkflow.Converter
Package: DataTypeWorkflow

Get results where wrapping occurred

Syntax

`results = converter.wrapOverflows(RunName)`

Description

`results = converter.wrapOverflows(RunName)` returns all results in `RunName` that wrapped during simulation.

Input Arguments

`RunName` — Name of run
character vector

Name of run in which to look for wrap overflows, specified as a character vector.

Example: `converter.WrapOverflows('Run3')`

Data Types: `char`

Output Arguments

`results` — Result object
`DataTypeWorkflow.Result` object

`DataTypeWorkflow.Result` object containing all of the signals that wrapped during the specified run.

See Also

`DataTypeWorkflow.Converter.proposalIssues` |
`DataTypeWorkflow.Converter.results` |
`DataTypeWorkflow.Converter.saturationOverflows`

Topics

"Convert a Model to Fixed Point Using the Command Line"

convertToSingle

Convert a double-precision system to single precision

Syntax

```
ConversionReport = DataTypeWorkflow.Single.convertToSingle(
systemToConvert)
```

Description

`ConversionReport = DataTypeWorkflow.Single.convertToSingle(systemToConvert)` converts the system specified by `systemToConvert` to single precision and returns a report. Data types that are specified as Boolean, fixed point, or one of the built-in integers are not affected by conversion.

Input Arguments

`systemToConvert` — System to convert to single precision
character vector

The system to convert from double-precision to single-precision, specified as a character vector. The system must be open before using this method.

Data Types: `char`

Output Arguments

`ConversionReport` — Report containing results from the conversion
report

Report containing results from the conversion.

Examples

Convert a system to single precision

1 Open the system to convert to single precision.

```
addpath(fullfile(docroot,'toolbox','fixpoint','examples'))
ex_fuel_rate_calculation
```

2 Use the `DataTypeWorkflow.Single.convertToSingle` method to convert the system from double precision to single precision.

```
report = DataTypeWorkflow.Single.convertToSingle('ex_fuel_rate_calculation')
```

The specified system now uses single-precision data types instead of double-precision data types. Data types in the model that were specified as Boolean, fixed-point, or one of the built-in integers remain the same after conversion.

- "Convert a System to Single Precision"

Alternatives

You can also use the Single Precision Converter app to convert a system from double precision to single precision. To open the Converter, from the Simulink **Analysis** menu, select **Data Type Design** > **Single Precision Converter**. For more information, see "Getting Started with Single Precision Converter".

See Also

Single Precision Converter

Topics

"Convert a System to Single Precision"
"Getting Started with Single Precision Converter"

Introduced in R2016b

lutmemoryusage

Class: FunctionApproximation.LUTMemoryUsageCalculator
Package: FunctionApproximation

Calculate total memory used by lookup table blocks in a model

Syntax

```
memory = lutmemoryusage(calculator,model)
```

Description

`memory = lutmemoryusage(calculator,model)` calculates the memory used by all lookup table blocks in the specified model.

Input Arguments

`calculator` — `FunctionApproximation.LUTMemoryUsageCalculator` object
`FunctionApproximation.LUTMemoryUsageCalculator`

`FunctionApproximation.LUTMemoryUsageCalculator` object.

`model` — Model containing lookup table blocks
character vector

Model containing lookup table blocks, specified as a character vector.

Data Types: `char`

Output Arguments

`memory` — Memory used by the model
table

Table displaying the memory, in bits, used by each lookup table block in the specified model.

Examples

Calculate the Total Memory Used by Lookup Tables in a Model

Use the `FunctionApproximation.LUTMemoryUsageCalculator` class to calculate the total memory used by lookup table blocks in a model.

Create a `FunctionApproximation.LUTMemoryUsageCalculator` object.

```
calculator = FunctionApproximation.LUTMemoryUsageCalculator
```

Use the `lutmemoryusage` method to get the total memory used by the lookup table blocks in the `sldemo_fuelsys` model.

```
load_system('sldemo_fuelsys')
lutmemoryusage(calculator, 'sldemo_fuelsys')
```

```
ans =

  6×1 table




    sldemo_fuelsys/fuel_rate_control/airflow_calc/Pumping Constant
    sldemo_fuelsys/fuel_rate_control/control_logic/Throttle.throttle_estimate/Throttle
    sldemo_fuelsys/fuel_rate_control/control_logic/Speed.speed_estimate/Speed Estimatio
    sldemo_fuelsys/fuel_rate_control/control_logic/Pressure.map_estimate/Pressure Estim
    sldemo_fuelsys/fuel_rate_control/airflow_calc/Ramp Rate Ki
    Total
```

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Topics
"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

approximate

Class: FunctionApproximation.LUTSolution
Package: FunctionApproximation

Generate a Lookup Table block from a `FunctionApproximation.LUTSolution`

Syntax

`approximate(solution)`

Description

`approximate(solution)` generates a Simulink model containing a subsystem made up of the Lookup Table block with data and breakpoints specified by the `FunctionApproximation.LUTSolution` object, `solution`. The generated Lookup Table block is surrounded with Data Type Converter blocks.

Input Arguments

`solution` — Solution to generate lookup table from
`FunctionApproximation.LUTSolution` object

The solution to generate a lookup table from, specified as a `FunctionApproximation.LUTSolution` object.

Examples

Generate a Lookup Table Approximating a Function

Create a `FunctionApproximation.Problem` object defining the function you want to approximate.

```
problem = FunctionApproximation.Problem('tanh')
```

```
problem = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.Problem" style="font-weight:bold"

    FunctionToApproximate: @(x)tanh(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(1,16,12)"
         InputLowerBounds: -8
         InputUpperBounds: 8
               OutputType: "numerictype(1,16,15)"
                  Options: [1x1 FunctionApproximation.Options]
```

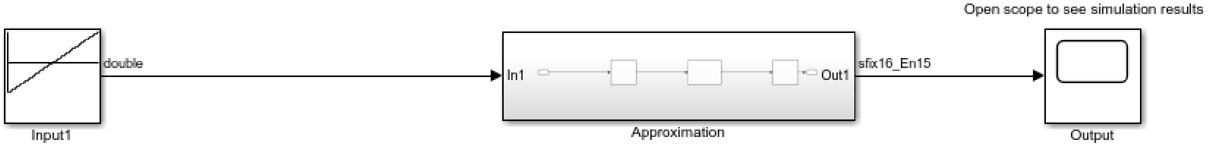
Use default values for all other options. Approximate the `tanh` function using the `solve` method.

```
solution = solve(problem)
```

```
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     0 |              64 |               0 |               2 |              16 |
|     1 |            1072 |               1 |              65 |              16 |
|     2 |             560 |               0 |              33 |              16 |
|     3 |             816 |               0 |              49 |              16 |
|     4 |             944 |               1 |              57 |              16 |
|     5 |             880 |               0 |              53 |              16 |
|     6 |             912 |               0 |              55 |              16 |
|     7 |             928 |               0 |              56 |              16 |
|     8 |             512 |               1 |              16 |              16 |

Best Solution
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     8 |             512 |               1 |              16 |              16 |


solution = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.LUTSolution" style="font-weight:b

          ID: 8
    Feasible: "true"
```

Generate a Simulink™ subsystem containing a Lookup Table block approximating the `tanh` function.

```
approximate(solution)
```



See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`approximate` | `compare` | `solve`

Topics
“Optimize Lookup Tables for Memory-Efficiency Programmatically”
“Optimize Lookup Tables for Memory-Efficiency”

Introduced in R2018a

compare

Class: FunctionApproximation.LUTSolution
Package: FunctionApproximation

Compare numerical results of `FunctionApproximation.LUTSolution` to original function or lookup table

Syntax

```
data = compare(solution)
```

Description

`data = compare(solution)` plots the difference between the data contained in the `FunctionApproximation.LUTSolution` object, `solution`, and the original lookup table, function, or Math Function block.

Input Arguments

`solution` — Solution to compare original behavior against
`FunctionApproximation.LUTSolution` object

The solution to compare original behavior against, specified as a `FunctionApproximation.LUTSolution` object.

Output Arguments

`data` — Struct containing data comparing original and the solution
struct

Struct containing data comparing the original function or lookup table and the approximation contained in the solution.

Examples

Compare Function Approximation to Original Function

Create a `FunctionApproximation.Problem` object defining the function you want to approximate.

```
problem = FunctionApproximation.Problem('tanh')
```

```
problem = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.Problem" style="font-weight:bold"

    FunctionToApproximate: @(x)tanh(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(1,16,12)"
         InputLowerBounds: -8
         InputUpperBounds: 8
               OutputType: "numerictype(1,16,15)"
                  Options: [1x1 FunctionApproximation.Options]
```

Use default values for all other options. Approximate the `tanh` function using the `solve` method.

```
solution = solve(problem)
```

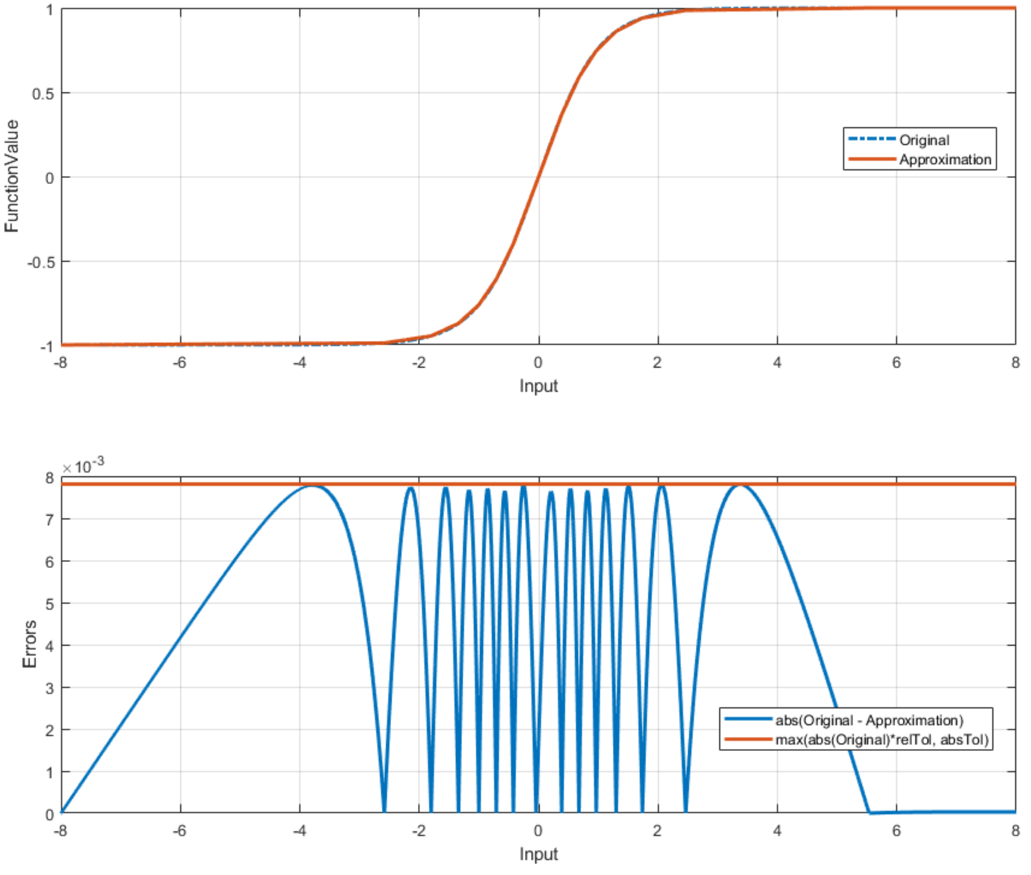
```
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     0 |              64 |               0 |               2 |              16 |
|     1 |            1072 |               1 |              65 |              16 |
|     2 |             560 |               0 |              33 |              16 |
|     3 |             816 |               0 |              49 |              16 |
|     4 |             944 |               1 |              57 |              16 |
|     5 |             880 |               0 |              53 |              16 |
|     6 |             912 |               0 |              55 |              16 |
|     7 |             928 |               0 |              56 |              16 |
|     8 |             512 |               1 |              16 |              16 |

Best Solution
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     8 |             512 |               1 |              16 |              16 |
```

```
solution = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.LUTSolution" style="font-weight:b

          ID: 8
    Feasible: "true"
```

Compare the original function and the function approximation.

```
data = compare(solution)
```

```
data = 

  struct with fields:

    Breakpoints: [65536x1 double]
       Original: [65536x1 double]
    Approximate: [65536x1 double]
```



See Also

Apps
Lookup Table Optimizer

Classes
FunctionApproximation.LUTMemoryUsageCalculator | FunctionApproximation.LUTSolution | FunctionApproximation.Options | FunctionApproximation.Problem

Functions
approximate | compare | solve

Topics
"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

displayallsolutions

Class: FunctionApproximation.LUTSolution
Package: FunctionApproximation

Display all solutions found during function approximation

Syntax

`displayallsolutions(solution)`

Description

`displayallsolutions(solution)` displays all solutions, including the non-feasible solutions, associated with a `FunctionApproximation.LUTSolution` object.

Input Arguments

`solution` — Solution object from which to display all associated solutions
`FunctionApproximation.LUTSolution` object

`FunctionApproximation.LUTSolution` object from which to display all associated solutions.

Examples

Display All Solutions Found During Lookup Table Approximation

Create a `FunctionApproximation.Problem` object defining a math function to approximate. Then, use the `solve` method to get a `FunctionApproximation.LUTSolution` object.

Display all solutions found during the approximation process using the `displayallsolutions` method.

```
problem = FunctionApproximation.Problem('sin')

problem = 

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x)sin(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(0,16,13)"
         InputLowerBounds: 0
         InputUpperBounds: 6.2832
               OutputType: "numerictype(1,16,14)"
                  Options: [1×1 FunctionApproximation.Options]

solution = solve(problem)

solution = 

  FunctionApproximation.LUTSolution with properties

          ID: 8
    Feasible: "true"

displayallsolutions(solution)

|    ID |   Memory (bits) |   ConstraintMet |       Table Size | Breakpoints WLs |    Ta
|     0 |              64 |               0 |                2 |              16 |
|     1 |             464 |               0 |               27 |              16 |
|     2 |             864 |               1 |               52 |              16 |
|     3 |              64 |               0 |                2 |              16 |
|     4 |             560 |               1 |               33 |              16 |
|     5 |             304 |               0 |               17 |              16 |
|     6 |             432 |               0 |               25 |              16 |
|     7 |             496 |               1 |               29 |              16 |
|     8 |             464 |               1 |               27 |              16 |
|     9 |             448 |               0 |               26 |              16 |
|    10 |             704 |               1 |               22 |              16 |

Best Solution
```

```
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     8 |             464 |               1 |              27 |              16 |
```

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`displayfeasiblesolutions` | `solutionfromID` | `totalmemoryusage`

Topics

"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

displayfeasiblesolutions

Class: FunctionApproximation.LUTSolution
Package: FunctionApproximation

Display all feasible solutions found during function approximation

Syntax

`displayfeasiblesolutions(solution)`

Description

`displayfeasiblesolutions(solution)` displays all feasible solutions found during the approximation process, including the best solution. Feasible solutions are defined as any solutions to the original `FunctionApproximation.Problem` object that met the constraints defined in the associated `FunctionApproximation.Options` object.

Input Arguments

`solution` — Solution object from which to display all associated feasible solutions
`FunctionApproximation.LUTSolution` object

`FunctionApproximation.LUTSolution` object from which to display all associated feasible solutions.

Examples

Display All Feasible Solutions Found During Lookup Table Approximation

Create a `FunctionApproximation.Problem` object defining a math function to approximate. Then, use the `solve` method to get a `FunctionApproximation.LUTSolution` object.

Display all feasible solutions found during the approximation process using the `displayfeasiblesolutions` method.

```
problem = FunctionApproximation.Problem('sin')

problem = 

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x)sin(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(0,16,13)"
          InputLowerBounds: 0
          InputUpperBounds: 6.2832
               OutputType: "numerictype(1,16,14)"
                  Options: [1×1 FunctionApproximation.Options]

solution = solve(problem)

solution = 

  FunctionApproximation.LUTSolution with properties

          ID: 8
    Feasible: "true"

displayfeasiblesolutions(solution)

|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     2 |             864 |               1 |              52 |              16 |
|     4 |             560 |               1 |              33 |              16 |
|     7 |             496 |               1 |              29 |              16 |
|     8 |             464 |               1 |              27 |              16 |
|    10 |             704 |               1 |              22 |              16 |

Best Solution
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     8 |             464 |               1 |              27 |              16 |
```

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`compare` | `displayallsolutions` | `solutionfromID` | `totalmemoryusage`

Topics
"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

solutionfromID

Class: FunctionApproximation.LUTSolution
Package: FunctionApproximation

Access a solution found during the approximation process

Syntax

```
other_solution = solutionfromID(solution,id)
```

Description

`other_solution = solutionfromID(solution,id)` returns the solution associated with the `FunctionApproximation.LUTSolution` object, `solution`, with the ID specified by `id`.

Input Arguments

`solution` — Solution object
`FunctionApproximation.LUTSolution` object

The solution object containing the solution you want to explore, specified as a `FunctionApproximation.LUTSolution` object.

`id` — ID of the solution
scalar integer

ID of the solution that you want to explore, specified as a scalar integer.

Data Types: `double`

Output Arguments

other_solution — FunctionApproximation.LUTSolution specified by id
FunctionApproximation.LUTSolution object

FunctionApproximation.LUTSolution object associated with the specified ID.

Examples

Examine Infeasible Function Approximation Solution

This example shows how to use the solutionfromID method of the FunctionApproximation.LUTSolution object to examine other approximation solutions.

Create a FunctionApproximation.Problem object defining a math function to approximate. Then use the solve method to get a FunctionApproximation.LUTSolution object.

```
problem = FunctionApproximation.Problem('sin')
```

```
problem = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.Problem" style="font-weight:bold"

    FunctionToApproximate: @(x)sin(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(0,16,13)"
         InputLowerBounds: 0
         InputUpperBounds: 6.2832
               OutputType: "numerictype(1,16,14)"
                  Options: [1x1 FunctionApproximation.Options]
```

```
solution = solve(problem)
```

```
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     0 |              64 |               0 |               2 |              16 |
|     1 |             560 |               1 |              33 |              16 |
|     2 |             304 |               0 |              17 |              16 |
|     3 |             432 |               0 |              25 |              16 |
```

```
|     4 |            496 |              1 |             29 |             16 |
|     5 |            464 |              1 |             27 |             16 |
|     6 |            448 |              0 |             26 |             16 |
|     7 |             64 |              0 |              2 |             16 |
|     8 |            640 |              1 |             20 |             16 |

Best Solution
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     5 |            464 |              1 |             27 |             16 |


solution = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.LUTSolution" style="font-weight:b

          ID: 5
    Feasible: "true"
```

Display all feasible solutions found during the approximation process.

```
displayfeasiblesolutions(solution)
```

```
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     1 |            560 |              1 |             33 |             16 |
|     4 |            496 |              1 |             29 |             16 |
|     5 |            464 |              1 |             27 |             16 |
|     8 |            640 |              1 |             20 |             16 |

Best Solution
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     5 |            464 |              1 |             27 |             16 |
```

Solution with ID 5 is not listed as a feasible solution in the table. Explore this solution to see why it is not feasible.

```
solution5 = solutionfromID(solution, 5)
```

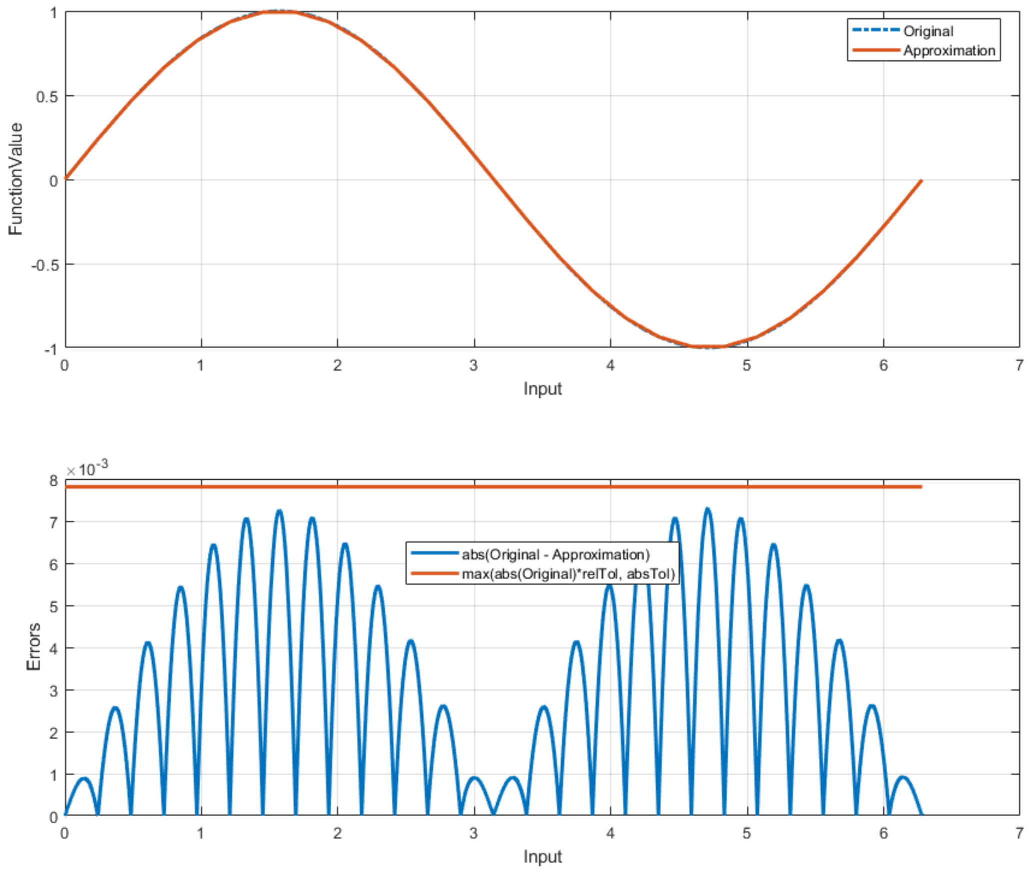
```
solution5 = 

  1x1 <a href="matlab:helpPopup FunctionApproximation.LUTSolution" style="font-weight:b

          ID: 5
```

```
    Feasible: "true"
```

Compare the numerical behavior of the solution with ID 5.

```
compare(solution5)
```

```
ans = 

  struct with fields:

    Breakpoints: [51455x1 double]
       Original: [51455x1 double]
    Approximate: [51455x1 double]
```



You can see from the plot that the solution does not meet the required tolerances.

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`displayallsolutions` | `displayfeasiblesolutions` | `totalmemoryusage`

Topics
"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

totalmemoryusage

Class: FunctionApproximation.LUTSolution
Package: FunctionApproximation

Calculate total memory used by a lookup table approximation

Syntax

```
memory = totalmemoryusage(solution,units)
```

Description

`memory = totalmemoryusage(solution,units)` returns the total memory used by the lookup table approximation specified by `solution`, in the units specified by `units`.

Input Arguments

`solution` — Solution to get memory of
`FunctionApproximation.LUTSolution` object

Solution to get memory of, specified as a `FunctionApproximation.LUTSolution` object.

`units` — Units in which to display the total memory used
`'bits'` (default) | `'bytes'` | `'GiB'` | `'KiB'` | `'MiB'`

Units in which to display the total memory used, specified as a character vector.

Data Types: `char`

Output Arguments

`memory` — total memory used by a lookup table approximation
scalar

Total memory used by a lookup table approximation, returned as a scalar.

Examples

Calculate the Total Memory Used by a Lookup Table Approximation

Create a `FunctionApproximation.Problem` object defining a math function to approximate. Then, use the `solve` method to get a `FunctionApproximation.LUTSolution` object.

Calculate the total memory used by the `FunctionApproximation.LUTSolution` object using the `totalmemoryusage` method.

```
problem = FunctionApproximation.Problem('sin')
```

```
problem = 

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x)sin(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(0,16,13)"
         InputLowerBounds: 0
         InputUpperBounds: 6.2832
               OutputType: "numerictype(1,16,14)"
                  Options: [1×1 FunctionApproximation.Options]
```

```
solution = solve(problem)
```

```
solution = 

  FunctionApproximation.LUTSolution with properties

          ID: 8
    Feasible: "true"
```

```
totalmemoryusage(solution, 'bytes')
```

```
ans =

    58
```

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`compare` | `displayallsolutions` | `displayfeasiblesolutions` | `solutionfromID`

Topics
"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

solve

Class: FunctionApproximation.Problem
Package: FunctionApproximation

Solve for optimized solution to function approximation problem

Syntax

```
solution = solve(problem)
```

Description

`solution = solve(problem)` solves the optimization problem defined by the `FunctionApproximation.Problem` object, `problem`, and returns the optimized result, `solution`, as a `FunctionApproximation.LUTSolution` object.

Input Arguments

`problem` — Optimization problem
`FunctionApproximation.Problem`

Optimization problem specified as a `FunctionApproximation.Problem` object defining the function or Math Function block to approximate, or the Lookup Table block to optimize, and other parameters and constraints to use during the optimization process.

Output Arguments

`solution` — Approximation solution
`FunctionApproximation.LUTSolution` object

Approximation solution, returned as a `FunctionApproximation.LUTSolution` object.

Examples

Approximate a Math Function

Create a `FunctionApproximation.Problem` object, specifying a math function to approximate.

```
problem = FunctionApproximation.Problem('log')
```

```
problem = 

  FunctionApproximation.Problem with properties

    FunctionToApproximate: @(x)log(x)
           NumberOfInputs: 1
               InputTypes: "numerictype(1,16,10)"
         InputLowerBounds: 0.6250
         InputUpperBounds: 15.6250
               OutputType: "numerictype(1,16,13)"
                  Options: [1×1 FunctionApproximation.Options]
```

Use default values for all other options.

Use the `solve` method to generate an approximation of the function.

```
solution = solve(problem)
```

```
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     0 |              64 |               0 |               2 |              16 |
|     1 |            1984 |               1 |             122 |              16 |
|     2 |            1024 |               0 |              62 |              16 |
|     3 |            1968 |               1 |             121 |              16 |
|     4 |              64 |               0 |               2 |              16 |
|     5 |             416 |               1 |              13 |              16 |

Best Solution
|    ID |   Memory (bits) |   ConstraintMet |      Table Size | Breakpoints WLs |    Ta
|     5 |             416 |               1 |              13 |              16 |


solution = 

  FunctionApproximation.LUTSolution with properties
```

```
         ID: 5
   Feasible: "true"
```

You can then use the `approximate` method to generate a subsystem containing the lookup table approximation.

See Also

Apps
Lookup Table Optimizer

Classes
`FunctionApproximation.LUTMemoryUsageCalculator` | `FunctionApproximation.LUTSolution` | `FunctionApproximation.Options` | `FunctionApproximation.Problem`

Functions
`approximate` | `compare`

Topics

"Optimize Lookup Tables for Memory-Efficiency Programmatically"
"Optimize Lookup Tables for Memory-Efficiency"

Introduced in R2018a

addTolerance

Class: fxpOptimizationOptions

Specify numeric tolerance for optimized system

Syntax

```
addTolerance(options,block_path,port_index,tolerance_type,
tolerance_value)
```

Description

`addTolerance(options,block_path,port_index,tolerance_type,tolerance_value)` specifies a numeric tolerance for the output signal specified by `block_path` and `port_index`, with the tolerance type specified by `tolerance_type` and value specified by `tolerance_value`.

Input Arguments

`options` — Associated `fxpOptimizationOptions` object
`fxpOptimizationOptions`

`fxpOptimizationOptions` object to add a tolerance specification.

`block_path` — Path to block for which to add tolerance
block path name

Path to the block to add a tolerance to, specified as a character vector.

Data Types: `char` | `string`

`port_index` — Index of output port of block
scalar integer

Index of output port of the block specified by `block_path` for which you want to specify a tolerance, specified as a scalar integer.

Data Types: double

tolerance_type — Type of tolerance to specify
'AbsTol' | 'RelTol'

Type of tolerance to add to the port indicated specified as either absolute tolerance, AbsTol, or relative tolerance, RelTol.

Data Types: char

tolerance_value — Difference between the original output and the output of the new design
scalar double

Acceptable level of tolerance for the signal specified by block_path and port_index.

If tolerance_type is set to 'AbsTol', then tolerance_value represents the absolute value of the maximum acceptable difference between the original output, and the output of the new design.

If tolerance_type is set to 'RelTol', then tolerance_value represents the maximum relative difference, specified as a percentage, between the original output, and the output of the new design. For example, a value of 1e-2 indicates a maximum difference of one percent between the original output, and the output of the new design.

Data Types: double

Examples

Specify required numeric tolerance for optimized system

Load the system for which you want to optimize the data types.

```
load_system('ex_auto_gain_controller');
```

Create a fxpOptimizationOptions object with default property values.

```
options = fxpOptimizationOptions;
```

To specify a required numeric tolerance to use during the optimization process, use the addTolerance method of the fxpOptimizationOptions object. To specify several tolerance constraints, call the method once per constraint. You can specify either relative, or absolute tolerance constraints.

```
addTolerance(options, 'ex_auto_gain_controller/output_signal', 1, 'AbsTol', 5e-2);
addTolerance(options, 'ex_auto_gain_controller/input_signal', 1, 'RelTol', 1e-2);
```

Use the `showTolerances` method to display all tolerance constraints added to a specified `fxpOptimizationOptions` object.

```
showTolerances(options)
```

```
                  Path                    Port_Index    Tolerance_Type    Toleranc
    ________________________________________    __________    ______________    ________

    'ex_auto_gain_controller/output_signal'        1            'AbsTol'          0.0
    'ex_auto_gain_controller/input_signal'         1            'RelTol'          0.0
```

See Also

Classes
`OptimizationResult` | `OptimizationSolution` | `fxpOptimizationOptions`

Functions
`addTolerance` | `explore` | `fxpopt` | `showTolerances`

Topics
"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

showTolerances

Class: fxpOptimizationOptions

Show tolerances specified for a system

Syntax

```
showTolerances(options)
```

Description

`showTolerances(options)` displays the absolute and relative tolerances specified for a system using the `addTolerance` method of the `fxpOptimizationOptions` class. If the `options` object has no tolerances specified, the `showTolerances` method does not display anything.

Input Arguments

options — Optimization options
`fxpOptimizationOptions` object

`fxpOptimizationOptions` object specifying options and tolerances to use during the data type optimization process.

Examples

Specify required numeric tolerance for optimized system

Load the system for which you want to optimize the data types.

```
load_system('ex_auto_gain_controller');
```

Create a `fxpOptimizationOptions` object with default property values.

```
options = fxpOptimizationOptions;
```

To specify a required numeric tolerance to use during the optimization process, use the `addTolerance` method of the `fxpOptimizationOptions` object. To specify several tolerance constraints, call the method once per constraint. You can specify either relative, or absolute tolerance constraints.

```
addTolerance(options, 'ex_auto_gain_controller/output_signal', 1, 'AbsTol', 5e-2);
addTolerance(options, 'ex_auto_gain_controller/input_signal', 1, 'RelTol', 1e-2);
```

Use the `showTolerances` method to display all tolerance constraints added to a specified `fxpOptimizationOptions` object.

```
showTolerances(options)
```

```
                     Path                        Port_Index    Tolerance_Type    Toleranc
    _______________________________________    __________    ______________    ________

    'ex_auto_gain_controller/output_signal'        1            'AbsTol'           0.0
    'ex_auto_gain_controller/input_signal'         1            'RelTol'           0.0
```

See Also

Classes
`OptimizationResult` | `OptimizationSolution` | `fxpOptimizationOptions`

Functions
`addTolerance` | `explore` | `fxpopt` | `showTolerances`

Topics
"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

explore

Class: OptimizationResult

Explore fixed-point implementations found during optimization process

Syntax

```
explore(result)
solution = explore(result)
solution = explore(result, n)
```

Description

`explore(result)` opens the Simulation Data Inspector with logging data displayed for the `OptimizationResult` object specified by `result`.

`solution = explore(result)` opens the Simulation Data Inspector and returns an `OptimizationSolution` object, `solution`.

`solution = explore(result, n)` returns the n^{th} `OptimizationSolution` object contained in `result`.

Input Arguments

`result` — `OptimizationResult` to explore
`OptimizationResult`

`OptimizationResult` object to explore.

If the optimization finds a feasible solution, the vector of `OptimizationSolution` objects contained in the `result` object is sorted by cost, with the lowest cost (most optimal) solution as the first element of the vector. If the optimization does not find a feasible solution, the vector is sorted by maximum difference from the original design.

n — Index of solution to explore
scalar integer

Index of the solution to explore, specified as a scalar integer. For example, if the optimization found a solution, `solution = explore(result, 3)` returns the solution with the 3rd lowest cost.

Data Types: `double`

Output Arguments

`solution` — `OptimizationSolution` containing information related to fixed-point implementation for system
`OptimizationSolution`

`OptimizationSolution` object containing information related to the optimal fixed-point implementation for the system, including total cost of the implementation and the maximum difference between the baseline and the solution.

See Also

Classes
`OptimizationResult` | `OptimizationSolution` | `fxpOptimizationOptions`

Functions
`addTolerance` | `fxpopt` | `showTolerances`

Topics
"Optimize Fixed-Point Data Types for a System"

Introduced in R2018a

Glossary

This glossary defines terms related to fixed-point data types and numbers. These terms may appear in some or all of the documents that describe MathWorks products that have fixed-point support.

arithmetic shift
: Shift of the bits of a binary word for which the sign bit is recycled for each bit shift to the right. A zero is incorporated into the least significant bit of the word for each bit shift to the left. In the absence of overflows, each arithmetic shift to the right is equivalent to a division by 2, and each arithmetic shift to the left is equivalent to a multiplication by 2.

See also binary point, binary word, bit, logical shift, most significant bit

bias
: Part of the numerical representation used to interpret a fixed-point number. Along with the slope, the bias forms the scaling of the number. Fixed-point numbers can be represented as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{exponent}$$

See also fixed-point representation, fractional slope, integer, scaling, slope, [Slope Bias]

binary number
: Value represented in a system of numbers that has two as its base and that uses 1's and 0's (bits) for its notation.

See also bit

binary point
: Symbol in the shape of a period that separates the integer and fractional parts of a binary number. Bits to the left of the binary point are integer bits and/or sign bits, and bits to the right of the binary point are fractional bits.

See also binary number, bit, fraction, integer, radix point

binary point-only scaling

Scaling of a binary number that results from shifting the binary point of the number right or left, and which therefore can only occur by powers of two.

See also binary number, binary point, scaling

binary word

Fixed-length sequence of bits (1's and 0's). In digital hardware, numbers are stored in binary words. The way in which hardware components or software functions interpret this sequence of 1's and 0's is described by a data type.

See also bit, data type, word

bit

Smallest unit of information in computer software or hardware. A bit can have the value 0 or 1.

ceiling (round toward)

Rounding mode that rounds to the closest representable number in the direction of positive infinity. This is equivalent to the `ceil` mode in Fixed-Point Designer software.

See also convergent rounding, floor (round toward), nearest (round toward), rounding, truncation, zero (round toward)

contiguous binary point

Binary point that occurs within the word length of a data type. For example, if a data type has four bits, its contiguous binary point must be understood to occur at one of the following five positions:

.0000
0.000
00.00
000.0
0000.

See also data type, noncontiguous binary point, word length

convergent rounding

Rounding mode that rounds to the nearest allowable quantized value. Numbers that are exactly halfway between the two nearest allowable quantized values are rounded up only if the least significant bit (after rounding) would be set to `0`.

See also ceiling (round toward), floor (round toward), nearest (round toward), rounding, truncation, zero (round toward)

data type

Set of characteristics that define a group of values. A fixed-point data type is defined by its word length, its fraction length, and whether it is signed or unsigned. A floating-point data type is defined by its word length and whether it is signed or unsigned.

See also fixed-point representation, floating-point representation, fraction length, signedness, word length

data type override

Parameter in the Fixed-Point Tool that allows you to set the output data type and scaling of fixed-point blocks on a system or subsystem level.

See also data type, scaling

exponent

Part of the numerical representation used to express a floating-point or fixed-point number.

1. Floating-point numbers are typically represented as

$$real\text{-}world\ value = mantissa \times 2^{exponent}$$

2. Fixed-point numbers can be represented as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{exponent}$$

The exponent of a fixed-point number is equal to the negative of the fraction length:

$$exponent = -1 \times fraction\ length$$

See also bias, fixed-point representation, floating-point representation, fraction length, fractional slope, integer, mantissa, slope

fixed-point representation

Method for representing numerical values and data types that have a set range and precision.

1. Fixed-point numbers can be represented as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{exponent}$$

The slope and the bias together represent the scaling of the fixed-point number.

2. Fixed-point data types can be defined by their word length, their fraction length, and whether they are signed or unsigned.

See also bias, data type, exponent, fraction length, fractional slope, integer, precision, range, scaling, slope, word length

floating-point representation

Method for representing numerical values and data types that can have changing range and precision.

1. Floating-point numbers can be represented as

$$real\text{-}world\ value = mantissa \times 2^{exponent}$$

2. Floating-point data types are defined by their word length.

See also data type, exponent, mantissa, precision, range, word length

floor (round toward)

Rounding mode that rounds to the closest representable number in the direction of negative infinity.

See also ceiling (round toward), convergent rounding, nearest (round toward), rounding, truncation, zero (round toward)

fraction

Part of a fixed-point number represented by the bits to the right of the binary point. The fraction represents numbers that are less than one.

See also binary point, bit, fixed-point representation

fraction length

Number of bits to the right of the binary point in a fixed-point representation of a number.

See also binary point, bit, fixed-point representation, fraction

fractional slope

Part of the numerical representation used to express a fixed-point number. Fixed-point numbers can be represented as

$$\textit{real-world value} = (\textit{slope} \times \textit{stored integer}) + \textit{bias}$$

where the slope can be expressed as

$$\textit{slope} = \textit{fractional slope} \times 2^{\textit{exponent}}$$

The term *slope adjustment* is sometimes used as a synonym for fractional slope.

See also bias, exponent, fixed-point representation, integer, slope

full range

The broadest range available for a data type. From –∞ to ∞ for floating-point types. For integer types, the representable range is the range from the smallest to largest integer value (finite) the type can represent. For example, from -128 to 127 for a signed 8–bit integer. Also known as representable range.

guard bits

Extra bits in either a hardware register or software simulation that are added to the high end of a binary word to ensure that no information is lost in case of overflow.

See also binary word, bit, overflow

incorrect range

A range that is too restrictive and does not include values that can actually occur in the model element. A range that is too broad is not considered incorrect because it will not lead to overflow.

See also range analysis

integer

1. Part of a fixed-point number represented by the bits to the left of the binary point. The integer represents numbers that are greater than or equal to one.

2. Also called the "stored integer." The raw binary number, in which the binary point is assumed to be at the far right of the word. The integer is part of the numerical representation used to express a fixed-point number. Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{exponent}$$

See also bias, fixed-point representation, fractional slope, integer, real-world value, slope

integer length

Number of bits to the left of the binary point in a fixed-point representation of a number.

See also binary point, bit, fixed-point representation, fraction length, integer

least significant bit (LSB)

Bit in a binary word that can represent the smallest value. The LSB is the rightmost bit in a big-endian-ordered binary word. The weight of the LSB is related to the fraction length according to

$$weight\ of\ LSB = 2^{-fraction\ length}$$

See also big-endian, binary word, bit, most significant bit

logical shift

Shift of the bits of a binary word, for which a zero is incorporated into the most significant bit for each bit shift to the right and into the least significant bit for each bit shift to the left.

See also arithmetic shift, binary point, binary word, bit, most significant bit

mantissa

Part of the numerical representation used to express a floating-point number. Floating-point numbers are typically represented as

$$real\text{-}world\ value = mantissa \times 2^{exponent}$$

See also exponent, floating-point representation

model element

Entities in a model that range analysis software tracks, for example, blocks, signals, parameters, block internal data (such as accumulators, products).

See also range analysis

most significant bit (MSB)

Bit in a binary word that can represent the largest value. The MSB is the leftmost bit in a big-endian-ordered binary word.

See also binary word, bit, least significant bit

nearest (round toward)
Rounding mode that rounds to the closest representable number, with the exact midpoint rounded to the closest representable number in the direction of positive infinity. This is equivalent to the `nearest` mode in Fixed-Point Designer software.

See also ceiling (round toward), convergent rounding, floor (round toward), rounding, truncation, zero (round toward)

noncontiguous binary point
Binary point that is understood to fall outside the word length of a data type. For example, the binary point for the following 4-bit word is understood to occur two bits to the right of the word length,

$$0000\_\_.$$

thereby giving the bits of the word the following potential values:

$$2^5 2^4 2^3 2^2 \_\_.$$

See also binary point, data type, word length

one's complement representation
Representation of signed fixed-point numbers. Negating a binary number in one's complement requires a bitwise complement. That is, all 0's are flipped to 1's and all 1's are flipped to 0's. In one's complement notation there are two ways to represent zero. A binary word of all 0's represents "positive" zero, while a binary word of all 1's represents "negative" zero.

See also binary number, binary word, sign/magnitude representation, signed fixed-point, two's complement representation

overflow
Situation that occurs when the magnitude of a calculation result is too large for the range of the data type being

used. In many cases you can choose to either saturate or wrap overflows.

See also saturation, wrapping

padding

Extending the least significant bit of a binary word with one or more zeros.

See also least significant bit

precision

1. Measure of the smallest numerical interval that a fixed-point data type and scaling can represent, determined by the value of the number's least significant bit. The precision is given by the slope, or the number of fractional bits. The term *resolution* is sometimes used as a synonym for this definition.

2. Measure of the difference between a real-world numerical value and the value of its quantized representation. This is sometimes called quantization error or quantization noise.

See also data type, fraction, least significant bit, quantization, quantization error, range, slope

Q format

Representation used by Texas Instruments™ to encode signed two's complement fixed-point data types. This fixed-point notation takes the form

$$Qm.n$$

where

- *Q* indicates that the number is in Q format.
- *m* is the number of bits used to designate the two's complement integer part of the number.
- *n* is the number of bits used to designate the two's complement fractional part of the number, or the number of bits to the right of the binary point.

In Q format notation, the most significant bit is assumed to be the sign bit.

See also binary point, bit, data type, fixed-point representation, fraction, integer, two's complement

quantization — Representation of a value by a data type that has too few bits to represent it exactly.

See also bit, data type, quantization error

quantization error — Error introduced when a value is represented by a data type that has too few bits to represent it exactly, or when a value is converted from one data type to a shorter data type. Quantization error is also called quantization noise.

See also bit, data type, quantization

radix point — Symbol in the shape of a period that separates the integer and fractional parts of a number in any base system. Bits to the left of the radix point are integer and/or sign bits, and bits to the right of the radix point are fraction bits.

See also binary point, bit, fraction, integer, sign bit

range — Span of numbers that a certain data type can represent.

See also data type, full range, precision, representable range

range analysis — Static analysis of model to derive minimum and maximum range values for elements in the model. The software statically analyzes the ranges of the individual computations in the model based on specified design ranges, inputs, and the semantics of the calculation.

real-world value — Stored integer value with fixed-point scaling applied. Fixed-point numbers can be represented as

$$real\text{-}world\ value = 2^{-fraction\ length} \times stored\ integer$$

or

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{exponent}$$

See also integer

representable range The broadest range available for a data type. From –∞ to ∞ for floating-point types. For integer types, the representable range is the range from the smallest to largest integer value (finite) the type can represent. For example, from `-128` to `127` for a signed 8–bit integer. Also known as full range.

resolution *See* **precision**

rounding Limiting the number of bits required to express a number. One or more least significant bits are dropped, resulting in a loss of precision. Rounding is necessary when a value cannot be expressed exactly by the number of bits designated to represent it.

See also bit, ceiling (round toward), convergent rounding, floor (round toward), least significant bit, nearest (round toward), precision, truncation, zero (round toward)

saturation Method of handling numeric overflow that represents positive overflows as the largest positive number in the range of the data type being used, and negative overflows as the largest negative number in the range.

See also overflow, wrapping

scaled double A double data type that retains fixed-point scaling information. For example, in Simulink and Fixed-Point Designer software you can use data type override to convert your fixed-point data types to scaled doubles. You can then simulate to determine the ideal floating-point behavior of your system. After you gather that information you can turn data type override off to return to fixed-point data types, and your quantities still have their original scaling information because it was held in the scaled double data types.

scaling

1. Format used for a fixed-point number of a given word length and signedness. The slope and bias together form the scaling of a fixed-point number.

2. Changing the slope and/or bias of a fixed-point number without changing the stored integer.

See also bias, fixed-point representation, integer, slope

shift

Movement of the bits of a binary word either toward the most significant bit ("to the left") or toward the least significant bit ("to the right"). Shifts to the right can be either logical, where the spaces emptied at the front of the word with each shift are filled in with zeros, or arithmetic, where the word is sign extended as it is shifted to the right.

See also arithmetic shift, logical shift, sign extension

sign bit

Bit (or bits) in a signed binary number that indicates whether the number is positive or negative.

See also binary number, bit

sign extension

Addition of bits that have the value of the most significant bit to the high end of a two's complement number. Sign extension does not change the value of the binary number.

See also binary number, guard bits, most significant bit, two's complement representation, word

sign/magnitude representation

Representation of signed fixed-point or floating-point numbers. In sign/magnitude representation, one bit of a binary word is always the dedicated sign bit, while the remaining bits of the word encode the magnitude of the number. Negation using sign/magnitude representation consists of flipping the sign bit from 0 (positive) to 1 (negative), or from 1 to 0.

See also binary word, bit, fixed-point representation, floating-point representation, one's complement representation, sign bit, signed fixed-point, signedness, two's complement representation

signed fixed-point Fixed-point number or data type that can represent both positive and negative numbers.

See also data type, fixed-point representation, signedness, unsigned fixed-point

signedness The signedness of a number or data type can be signed or unsigned. Signed numbers and data types can represent both positive and negative values, whereas unsigned numbers and data types can only represent values that are greater than or equal to zero.

See also data type, sign bit, sign/magnitude representation, signed fixed-point, unsigned fixed-point

slope Part of the numerical representation used to express a fixed-point number. Along with the bias, the slope forms the scaling of a fixed-point number. Fixed-point numbers can be represented as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

where the slope can be expressed as

$$slope = fractional\ slope \times 2^{exponent}$$

See also bias, fixed-point representation, fractional slope, integer, scaling, [Slope Bias]

slope adjustment *See* **fractional slope**

[Slope Bias] Representation used to define the scaling of a fixed-point number.

See also bias, scaling, slope

stored integer — *See* **integer**

trivial scaling — Scaling that results in the real-world value of a number being simply equal to its stored integer value:

$$real\text{-}world\ value = stored\ integer$$

In [Slope Bias] representation, fixed-point numbers can be represented as

$$real\text{-}world\ value = (slope \times stored\ integer) + bias$$

In the trivial case, slope = 1 and bias = 0.

In terms of binary point-only scaling, the binary point is to the right of the least significant bit for trivial scaling, meaning that the fraction length is zero:

$$real\text{-}world\ value = stored\ integer \times 2^{-fraction\ length} = stored\ integer \times 2^{0}$$

Scaling is always trivial for pure integers, such as `int8`, and also for the true floating-point types `single` and `double`.

See also bias, binary point, binary point-only scaling, fixed-point representation, fraction length, integer, least significant bit, scaling, slope, [Slope Bias]

truncation — Rounding mode that drops one or more least significant bits from a number.

See also ceiling (round toward), convergent rounding, floor (round toward), nearest (round toward), rounding, zero (round toward)

two's complement representation — Common representation of signed fixed-point numbers. Negation using signed two's complement representation consists of a translation into one's complement followed by the binary addition of a one.

See also binary word, one's complement representation, sign/magnitude representation, signed fixed-point

unsigned fixed-point
Fixed-point number or data type that can only represent numbers greater than or equal to zero.

See also data type, fixed-point representation, signed fixed-point, signedness

word
Fixed-length sequence of binary digits (1's and 0's). In digital hardware, numbers are stored in words. The way hardware components or software functions interpret this sequence of 1's and 0's is described by a data type.

See also binary word, data type

word length
Number of bits in a binary word or data type.

See also binary word, bit, data type

wrapping
Method of handling overflow. Wrapping uses modulo arithmetic to cast a number that falls outside of the representable range the data type being used back into the representable range.

See also data type, overflow, range, saturation

zero (round toward)
Rounding mode that rounds to the closest representable number in the direction of zero. This is equivalent to the `fix` mode in Fixed-Point Designer software.

See also ceiling (round toward), convergent rounding, floor (round toward), nearest (round toward), rounding, truncation

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