

# **Filter Design Toolbox™**

## **Release Notes**

---

## How to Contact The MathWorks



[www.mathworks.com](http://www.mathworks.com) Web  
[comp.soft-sys.matlab](mailto:comp.soft-sys.matlab) Newsgroup  
[www.mathworks.com/contact\\_TS.html](http://www.mathworks.com/contact_TS.html) Technical Support



[suggest@mathworks.com](mailto:suggest@mathworks.com) Product enhancement suggestions  
[bugs@mathworks.com](mailto:bugs@mathworks.com) Bug reports  
[doc@mathworks.com](mailto:doc@mathworks.com) Documentation error reports  
[service@mathworks.com](mailto:service@mathworks.com) Order status, license renewals, passcodes  
[info@mathworks.com](mailto:info@mathworks.com) Sales, pricing, and general information



508-647-7000 (Phone)



508-647-7001 (Fax)



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

For contact information about worldwide offices, see the MathWorks Web site.

*Filter Design Toolbox™ Release Notes*

© COPYRIGHT 2005–2008 by The MathWorks, Inc.

The software described in this document is furnished under a license agreement. The software may be used or copied only under the terms of the license agreement. No part of this manual may be photocopied or reproduced in any form without prior written consent from The MathWorks, Inc.

FEDERAL ACQUISITION: This provision applies to all acquisitions of the Program and Documentation by, for, or through the federal government of the United States. By accepting delivery of the Program or Documentation, the government hereby agrees that this software or documentation qualifies as commercial computer software or commercial computer software documentation as such terms are used or defined in FAR 12.212, DFARS Part 227.72, and DFARS 252.227-7014. Accordingly, the terms and conditions of this Agreement and only those rights specified in this Agreement, shall pertain to and govern the use, modification, reproduction, release, performance, display, and disclosure of the Program and Documentation by the federal government (or other entity acquiring for or through the federal government) and shall supersede any conflicting contractual terms or conditions. If this License fails to meet the government's needs or is inconsistent in any respect with federal procurement law, the government agrees to return the Program and Documentation, unused, to The MathWorks, Inc.

### Trademarks

MATLAB and Simulink are registered trademarks of The MathWorks, Inc. See [www.mathworks.com/trademarks](http://www.mathworks.com/trademarks) for a list of additional trademarks. Other product or brand names may be trademarks or registered trademarks of their respective holders.

### Patents

The MathWorks products are protected by one or more U.S. patents. Please see [www.mathworks.com/patents](http://www.mathworks.com/patents) for more information.

<b>Summary by Version</b> .....	<b>1</b>
<b>Version 4.4 (R2008b) Filter Design Toolbox</b> .....	<b>3</b>
<b>Version 4.3 (R2008a) Filter Design Toolbox</b> .....	<b>4</b>
<b>Version 4.2 (R2007b) Filter Design Toolbox</b> .....	<b>6</b>
<b>Version 4.1 (R2007a) Filter Design Toolbox</b> .....	<b>8</b>
<b>Version 4.0 (R2006b) Filter Design Toolbox</b> .....	<b>10</b>
<b>Version 3.4 (R2006a) Filter Design Toolbox</b> .....	<b>13</b>
<b>Version 3.3 (R14SP3) Filter Design Toolbox</b> .....	<b>22</b>
<b>Version 3.2 (R14SP2) Filter Design Toolbox</b> .....	<b>34</b>
<b>Compatibility Summary for the Filter Design Toolbox Product</b> .....	<b>40</b>



## Summary by Version

This table provides quick access to what's new in each version. For clarification, see “Using Release Notes” on page 1 below.

<b>Version (Release)</b>	<b>New Features and Changes</b>	<b>Version Compatibility Considerations</b>	<b>Fixed Bugs and Known Problems</b>	<b>Related Documentation at Web Site</b>
<b>Latest Version V4.4 (R2008b)</b>	Yes Details	No	Bug Reports	Printable Release Notes: PDF  Current product documentation
V4.3 (R2008a)	Yes Details	Yes Summary	Bug Reports	No
V4.2 (R2007b)	Yes Details	Yes Summary	Bug Reports	No
V4.1 (R2007a)	Yes Details	No	Bug Reports	No
V4.0 (R2006b)	Yes Details	No	Bug Reports	No
V3.4 (R2006a)	Yes Details	Yes Summary	Bug Reports	No
V3.3 (R14SP3)	Yes Details	Yes Summary	Bug Reports	No
V3.2 (R14SP2)	Yes Details	Yes Summary	Bug Reports	No

### Using Release Notes

Use release notes when upgrading to a newer version to learn about:

- New features
- Changes
- Potential impact on your existing files and practices

Review the release notes for other MathWorks™ products required for this product (for example, MATLAB® or Simulink®) for enhancements, bugs, and compatibility considerations that also might impact you.

If you are upgrading from a software version other than the most recent one, review the release notes for all interim versions, not just for the version you are installing. For example, when upgrading from V1.0 to V1.2, review the release notes for V1.1 and V1.2.

## **What's in the Release Notes**

### **New Features and Changes**

- New functionality
- Changes to existing functionality

### **Version Compatibility Considerations**

When a new feature or change introduces a reported incompatibility between versions, the **Compatibility Considerations** subsection explains the impact.

Compatibility issues reported after the product is released appear under Bug Reports at the MathWorks Web site. Bug fixes can sometimes result in incompatibilities, so you should also review the fixed bugs in Bug Reports for any compatibility impact.

### **Fixed Bugs and Known Problems**

The MathWorks offers a user-searchable Bug Reports database so you can view Bug Reports. The development team updates this database at release time and as more information becomes available. This includes provisions for any known workarounds or file replacements. Information is available for bugs existing in or fixed in Release 14SP2 or later. Information is not available for all bugs in earlier releases.

Access Bug Reports using your MathWorks Account.

## Version 4.4 (R2008b) Filter Design Toolbox

This table summarizes what's new and changed in Version 4.4 (R2008b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	No	Bug Reports	Printable Release Notes: PDF  Current product documentation

New features and changes introduced in this version are described here.

- “Fdesign Support for Additional Filter Types” on page 3
- “OptimizeScaleValues Property Added to `dfilt` Second-order Sections Object” on page 3

### Fdesign Support for Additional Filter Types

`fdesign` now supports the following filter types:

- Raised-cosine and square-root raised-cosine
- Maxflat FIR and IIR lowpass
- Maxflat FIR highpass
- Constrained least-squares FIR lowpass, highpass, bandpass, bandstop

### OptimizeScaleValues Property Added to `dfilt` Second-order Sections Object

`OptimizeScaleValues` property added to `dfilt` second-order sections object, allows the user to control skipping multiplication-by-1. Previous versions of Filter Design Toolbox™ software always optimized scale values equal to 1. Starting in 2008b, users can configure the software so it does not to skip multiplications-by-1 between sections.

## Version 4.3 (R2008a) Filter Design Toolbox

This table summarizes what's new and changed in Version 4.3 (R2008a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	Yes Summary	Bug Reports	Printable Release Notes: PDF  Current product documentation

New features and changes introduced in this version are described here.

- “Realizemdl Support for Polyphase and Farrow Sample Rate Converters” on page 4
- “Fdesign Support for Farrow Sample Rate Converters” on page 4
- “Expanded Demo: Efficient Sample Rate Conversion Between Arbitrary Factors” on page 5
- “Fdesign Support for Highpass Halfband Filters” on page 5
- “Input Quantization Added to Models Generated by the Block Method” on page 5

### Realizemdl Support for Polyphase and Farrow Sample Rate Converters

You can now create Simulink models of Polyphase and Farrow Sample Rate Converters from the command line using the `realizemdl` command with `mfilt.firsrc` and `mfilt.farrowsrc`.

### Fdesign Support for Farrow Sample Rate Converters

Multirate Farrow filters can efficiently implement arbitrary (including irrational) rate change factors. You can design Farrow sample rate converters using the new `fdesign` function `fdesign.polysrc`.



## **Expanded Demo: Efficient Sample Rate Conversion Between Arbitrary Factors**

The expanded Efficient Sample Rate Conversion Between Arbitrary Factors demo now shows you how to design Farrow sample rate converters using the new `fdesign.polysrc` function.

## **Fdesign Support for Highpass Halfband Filters**

The `fdesign` design class, `fdesign.halfband`, has a new property, `type`, that you can use to create a lowpass or highpass halfband filter.

## **Input Quantization Added to Models Generated by the Block Method**

Models generated by the block method now include a new input quantization feature.

## **Compatibility Considerations**

The new input quantization feature does not work with models generated using previous versions of the software. To restore the previous behavior, open the generated subsystem block, remove the Convert block, and reconnect the remaining block to the subsystem input.

## Version 4.2 (R2007b) Filter Design Toolbox

This table summarizes what's new and changed in Version 4.2(R2007b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	Yes	Bug Reports	Printable Release Notes: PDF  Current product documentation

New features and changes introduced in this version are described here.

- “Farrow Classes Moved into DFILT package” on page 6
- “All Multirate Filter Structures Support Complex Coefficients” on page 6
- “New Multirate Farrow Filter Capable of Sample Rate Conversion” on page 7
- “Updated Getting Started and User’s Guide” on page 7
- “Compatibility Considerations” on page 7
- “Functions Being Removed” on page 7

### Farrow Classes Moved into DFILT package

The two classes `farrow.fd` and `farrow.linearfd` have been moved into `dfilt.farrowfd` and `dfilt.farrowlinearfd`, respectively.

### All Multirate Filter Structures Support Complex Coefficients

All structures for `mfilt` multirate filters can use complex coefficients.

## New Multirate Farrow Filter Capable of Sample Rate Conversion

A new multirate filter, `mfilt.farrowsrc`, has been added to `mfilts`, allowing for Farrow decimators and interpolators, and fractional decimators and fractional interpolators where the resulting interpolation or decimation factor is not an integer.

## Updated Getting Started and User's Guide

Updates to structure of User's Guide and Getting started include sections about using `filterbuilder` and a new chapter about using integers with FIR filters

## Compatibility Considerations

- The `farrow.fd` and `farrow.linearfd` functions have been removed. For more information about the removal of these functions, see "Functions Being Removed" on page 7.

## Functions Being Removed

Function Being Removed	What Happens When You Run the Function?	Use this Function Instead	Compatibility Considerations
<code>farrow.fd</code>	Still runs	<code>dfilt.farrowfd</code>	Farrow filters are now constructed using the <code>dfilt</code> (discrete-time filter) structure. Instead of using <code>farrow.fd</code> , use <code>dfilt.farrowfd</code> . See the reference page for <code>dfilt</code> for more information.
<code>farrow.linearfd</code>	Still runs	<code>dfilt.farrowlinearfd</code>	As noted above Farrow filters are now created using the <code>dfilt</code> constructor.

## Version 4.1 (R2007a) Filter Design Toolbox

This table summarizes what's new and changed in Version 4.1(R2007a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	No	Bug Reports	Printable Release Notes: PDF  Current product documentation

New features and changes introduced in this version are described here.

- “Fdesign Support Added for Octave Band and Fractional Octave Band Filters” on page 8
- “Fdesign Support Added for Parametric Equalizer Filters” on page 9
- “Fdesign Support Added for Notch and Peak Filters” on page 9
- “Arbitrary Magnitude and Phase Added to Multirate Filters” on page 9
- “Support for Fixed-point Inputs and Tunable Parameters in Filter Design Toolbox Blocks” on page 9

### Fdesign Support Added for Octave Band and Fractional Octave Band Filters

Octave-band and fractional-octave-band filters are commonly used in acoustics, for example, in noise control to perform spectral analysis. You can design octave band and fractional octave band filters using the fdesign function `fdesign.octave`. If you prefer to design these filters using a graphical approach, try the `filterbuilder` function.

## **Fdesign Support Added for Parametric Equalizer Filters**

Parametric equalizers are digital filters used in audio for adjusting the frequency content of a sound signal. The Filter Design Toolbox provides the capability to design high-order IIR parametric equalizers. Such high-order designs provide much more control over the shape of each filter. You can design parametric equalizer filters using the `fdesign` function `fdesign.parmeq`. The same functionality can be achieved through the GUI function `filterbuilder`.

## **Fdesign Support Added for Notch and Peak Filters**

Filters that peak or notch at a certain frequency are useful to retain or eliminate a particular frequency component of a signal. You can design these peak or notch filters using the new functions `fdesign.peak` and `fdesign.notch`. The same functionality can be achieved through the GUI function `filterbuilder`.

## **Arbitrary Magnitude and Phase Added to Multirate Filters**

When designing a multirate filter, you can specify the response of the resulting filter. Arbitrary magnitude as well as arbitrary magnitude and phase are two responses that have been added to an already extensive list. To understand how to use these responses when designing multirate filters, see `fdesign.rsrc`, `fdesign.decimator`, and `fdesign.interpolator`.

## **Support for Fixed-point Inputs and Tunable Parameters in Filter Design Toolbox Blocks**

The blocks in the Filter Design Toolbox library of Signal Processing Blockset™ now support fixed-point and integer data types on their input and output ports. In addition, parameters of these blocks that do not change filter order or structure are now tunable. This feature is fully described in the "Signal Processing Blockset User's Guide".

## Version 4.0 (R2006b) Filter Design Toolbox

This table summarizes what's new and changed in Version 4.0 (R2006b):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	No	Bug Reports	Printable Release Notes: PDF  Current product documentation

New features and changes introduced in this version are described here.

- “Blocks for Designing Filters Added to Signal Processing Blockset (Filter Design Toolbox Required)” on page 11
- “Support for Automatically Converting Floating-Point Filters to Fixed-Point Based on Input Data” on page 11
- “New filterbuilder Function for Interactive Filter Design” on page 12
- “Fixed-Point Farrow Filter Support” on page 12
- “Fractional Delay Filter Design with fdesign.fracdelay” on page 12
- “New freqrespest Function for Using Filtering to Estimate the Filter Frequency Response from Measured Data” on page 12
- “Parallel Filter Objects Support Multirate filters” on page 12
- “Coupled-Allpass Designs Available for All fdesign Objects” on page 12

## **Blocks for Designing Filters Added to Signal Processing Blockset (Filter Design Toolbox Required)**

This release adds a block library to the Signal Processing Blockset product. The new library contains blocks that design single- and multirate filters using the new `filterbuilder` filter design dialog boxes. If you have a license for Filter Design Toolbox, you can use the new blocks to design and implement filters in simulations. Users who do not have Fixed-Point Toolbox™ licenses can run models that contain the new blocks, but they cannot change the filter designs in the blocks.

## **Support for Automatically Converting Floating-Point Filters to Fixed-Point Based on Input Data**

Two new aspects of analysis allow you to convert filters from floating-point to fixed-point format automatically:

- Scaled doubles logging

`mfilt` and `dfilt` objects now support the scaled double data type. Scaled doubles data types act like fixed-point data types, allowing you to work with both fixed-point and scaled doubles in the same calculation. Allowing this overcomes the limitation that math is permitted only between the same data types. The value `ScaledDouble` has been added to the `DataType` property of the `numericType` object. The following values have also been added to the `DataTypeMode` property of the `numericType` object:

- Scaled double: `binary point scaling`
  - Scaled double: `slope and bias scaling`
  - Scaled double: `unspecified scaling`
- A new method, `autoscale`, automatically converts an input filter from floating-point format to fixed-point format based on the results of filtering a set of data. `autoscale` attempts to scale the filter to prevent overflows in all filter computations.

The combination of these new capabilities provides the conversion support.

## **New filterbuilder Function for Interactive Filter Design**

A new function, `filterbuilder`, provides a graphical tool for designing single- and multirate filters in both floating-point and fixed-point forms. For more information, refer to `filterbuilder`.

## **Fixed-Point Farrow Filter Support**

We upgraded the Farrow filters to provide fixed-point support. Similar to the fixed point for all other `dfilt` objects.

## **Fractional Delay Filter Design with `fdesign.fracdelay`**

Add the new method `fdesign.fracdelay` for designing filters that offer fractional delays. To support designing filters with `fdesign.fracdelay`, we added a lagrange design method.

## **New `freqrespest` Function for Using Filtering to Estimate the Filter Frequency Response from Measured Data**

Use this new method to estimate the frequency response of a `dfilt` or `mfilt` object. `freqrespest` uses filtering to estimate the filter response. To support this new method, we added `freqrespopts`, an object that contains the parameters for `freqrespest`.

## **Parallel Filter Objects Support Multirate filters**

With the addition of this feature, you can create parallel structures composed of multirate filters. This extends the parallel filter capability using `dfilt.parallel` by letting you use multirate filters as the input filters. To create parallel filter objects from two or more multirate filters, the individual filters must have the same rate change factors.

## **Coupled-Allpass Designs Available for All `fdesign` Objects**

All specification objects now support coupled-allpass filter designs as structures.



## Version 3.4 (R2006a) Filter Design Toolbox

This table summarizes what's new and changed in Version 3.4 (R2006a):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	Yes Summary	Bug Reports	Printable Release Notes: PDF

New features and changes introduced in this version are described here.

- “Farrow Filters” on page 13
- “IIR Polyphase Decimators and Interpolators” on page 14
- “Single-Rate Allpass Discrete-time and Multirate Filters” on page 14
- “iirlinphase Method for Designing Linear Phase IIR Filters” on page 14
- “Arbitrary Magnitude and Phase Filter Specification Object” on page 15
- “iirlinphase/elliptic Design for Hilbert Transformers” on page 15
- “CIC Filters Provide Full Precision and Specify All Options” on page 15
- “Nearest Round Mode for dfilt and mflt Objects” on page 17
- “Cost Method” on page 17
- “New Online Help for fdesign.structure” on page 17
- “Info Method Updated to Include Filter Measurements” on page 20
- “Measurement Display Changes” on page 20
- “realizemdl Creates Additional Multirate Polyphase Filters” on page 20
- “Filter Design Object Now Called Filter Specification Object in the Documentation” on page 21

### Farrow Filters

The toolbox now provides Farrow filter capability with `farrow`. Using `farrow` you create filters based on the structure and a few options. After you create

your filter, various analysis functions, like `cost` and `fvtool`, help you determine your filter's fitness. `realizemdl` works with Farrow filters to produce blocks for Simulink models as well.

## **IIR Polyphase Decimators and Interpolators**

Now the toolbox provides design tools for IIR polyphase decimators and interpolators using `fdesign.decimator` and `fdesign.interpolator`.

## **Single-Rate Allpass Discrete-time and Multirate Filters**

Eight new filter function enable you to design both single-rate and multirate allpass filters, including wave digital filters.

- `dfilt.allpass`
- `dfilt.wdfallpass`
- `dfilt.cascadeallpass`
- `dfilt.cascadewdfallpass`
- `mfilt.iirdecim`
- `mfilt.iirwdfdecim`
- `mfilt.iirinterp`
- `mfilt.iirwdfinterp`

## **iirlinphase Method for Designing Linear Phase IIR Filters**

The new `iirlinphase` method added in this release designs quasi-linear phase IIR filters from a halfband filter specification objects. Use the form

```
hd = design(d, 'iirlinphase');
```

when `d` is a halfband specification object. Returned filter object `hd` is an IIR filter with linear phase in the passband.

## Arbitrary Magnitude and Phase Filter Specification Object

The new `arbmagnphase` specification object added in this release designs filters where you define the filter magnitude response and the phase response explicitly. Use the form

```
d = fdesign.arbmagnphase();
```

`d` is a filter specification object where the magnitude and phase responses are specified as a complex frequency response you provide.

## iirlinphase/elliptic Design for Hilbert Transformers

When you use `fdesign.hilbert` to create a Hilbert transformer specification object, the toolbox provides new `ellip` and `iirlinphase` design methods to implement the filter from the specification object as an elliptic filter or as a quasilinear phase IIR filter.

## CIC Filters Provide Full Precision and Specify All Options

CIC filters, such as those created by `fdesign.decimator` and `fdesign.interpolator`, now supports full precision and three word and fraction length modes for the property `FilterInternals`.

- `FullPrecision` mode automatically sets the CIC filter word lengths and fraction lengths to maintain the maximum precision in the filtering process. (new)
- `MinWordLengths` mode lets you set the output word length for the filter.
- `SpecifyWordLengths` mode lets you specify the word lengths for all sections of the filter and for the output. But you cannot set the fraction lengths.
- `SpecifyPrecision` mode lets you set all fraction lengths and word lengths for the filter sections and for the output. (new)

For more information, refer to the reference pages for `fdesign.decimator` and `fdesign.interpolator` in the Filter Design Toolbox documentation.

The following example uses the `SpecifyPrecision` mode. Use a decimation factor of 5 and differential delay equal to 1.

```
d=fdesign.decimator(5,'cic',1) % M=5, D=1.

d =

    MultirateType: 'Decimator'
    DecimationFactor: 5
    Response: 'CIC'
    Specification: 'Fp,Ast'
    Description: {'Passband Frequency';'Aliasing Attenuation(dB)'}
    DifferentialDelay: 1
    NormalizedFrequency: true
        Fpass: 0.01
        Astop: 60

hm=design(d) % Use the default multisection design method.

hm =

    FilterStructure: 'Cascaded Integrator-Comb Decimator'
    Arithmetic: 'fixed'
    DifferentialDelay: 1
    NumberOfSections: 2
    DecimationFactor: 5
    PersistentMemory: false

    InputWordLength: 16
    InputFracLength: 15

    FilterInternals: 'FullPrecision'

hm.FilterInternals='specifyPrecision'

hm =

    FilterStructure: 'Cascaded Integrator-Comb Decimator'
    Arithmetic: 'fixed'
    DifferentialDelay: 1
```

```
NumberOfSections: 2
DecimationFactor: 5
PersistentMemory: false

InputWordLength: 16
InputFracLength: 15

FilterInternals: 'SpecifyPrecision'
SectionWordLengths: [21 21 21 21]
SectionFracLengths: [15 15 15 15]
OutputWordLength: 21
OutputFracLength: 15
```

## Nearest Round Mode for `dfilt` and `mfilt` Objects

`dfilt` and `mfilt` objects include an additional mode for rounding the results of calculations —`nearest`. Results round to the nearest representable value in the chosen format. Changing this behavior makes `round` for `dfilt` and `mfilt` objects consistent with `round` in Simulink.

For more information about rounding, refer to `fi` in the Fixed Point Toolbox documentation, since the new rounding modes derive from the `fi` object used by fixed-point filters.

## Compatibility Considerations

The new `round` mode behavior now matches MATLAB `round` as well.

## Cost Method

After you create a filter, you can use `cost` to determine the arithmetic cost when you filter data. `cost` returns estimates of the add, multiplies, and other operations that occur when you use the filter.

## New Online Help for `fdesign.structure`

With the addition of more `fdesign` methods and specification objects, the toolbox changes the way you get help about a specific design method—the command-line help is now adaptive, recognizing the object and the design method in the help syntax.

The command-line help adapts to the filter specification object you have and the design method you intend to use, and provides help specifically for that combination of specification and method. For example, if you are designing a highpass filter and plan to use the `butter` design method, here is the new way to get help:

```
d = fdesign.highpass('fst,fp,ast,ap',0.45,0.55,1,60)
```

```
designmethods(d)
```

```
Design Methods for class fdesign.highpass (Fst,Fp,Ast,Ap):
```

```
butter  
cheby1  
cheby2  
ellip  
equiripple  
ifir  
kaiserwin
```

```
help(d,'butter') % New help command syntax with object and method.
```

```
DESIGN Design a Butterworth IIR filter.
```

```
HD = DESIGN(D, 'butter') designs a Butterworth filter specified by the  
FDESIGN object D.
```

```
HD = DESIGN(..., 'FilterStructure', STRUCTURE) returns a filter with the  
structure STRUCTURE. STRUCTURE is 'df2sos' by default and can be any of  
the following.
```

```
'df1sos'  
'df2sos'  
'df1tsos'  
'df2tsos'
```

```
HD = DESIGN(..., 'MatchExactly', MATCH) designs a Butterworth filter  
and matches the frequency and magnitude specification for the band  
MATCH exactly. The other band will exceed the specification. MATCH
```

can be 'stopband' or 'passband' and is 'stopband' by default.

```
% Example #1 - Compare passband and stopband MatchExactly.
h      = fdesign.highpass('Fst,Fp,Ast,Ap', .7, .9, 60, 1);
Hd     = design(h, 'butter', 'MatchExactly', 'passband');
Hd(2) = design(h, 'butter', 'MatchExactly', 'stopband');

% Compare the passband edges in FVTool.
fvtool(Hd);
axis([.89 .91 -2 0]);
```

Suppose you decide to use an equiripple design method instead. Again, the `help` command with the specification object `d` and the method `equiripple` provides help for that combination.

```
help (d,'equiripple') % New help command syntax with object and method.
```

DESIGN Design a Equiripple FIR filter.

HD = DESIGN(D, 'equiripple') designs a Equiripple filter specified by the FDESIGN object D.

HD = DESIGN(..., 'FilterStructure', STRUCTURE) returns a filter with the structure STRUCTURE. STRUCTURE is 'dffir' by default and can be any of the following.

```
'dffir'
'dffirt'
'dfsymfir'
'dfasymfir'
'fftfir'
```

HD = DESIGN(..., 'DensityFactor', DENS) specifies the grid density DENS used in the optimization. DENS is 16 by default.

HD = DESIGN(..., 'MinPhase', MPHASE) designs a minimum-phase filter when MPHASE is TRUE. MPHASE is FALSE by default.

HD = DESIGN(..., 'MinOrder', 'any') designs a minimum-order filter. The order of the filter can be even or odd. This is the default.

```
HD = DESIGN(..., 'MinOrder', 'even') designs an minimum-even-order
filter.

HD = DESIGN(..., 'MinOrder', 'odd') designs an minimum-odd-order filter.

% Example #1 - Design a lowpass Equiripple filter in a transposed
structure.
    h = fdesign.highpass('Fst,Fp,Ast,Ap');
    Hd = design(h, 'equiripple', 'FilterStructure', 'dffirt');
```

Notice that the content is different for the different methods. This makes it easier for you to know the options that apply to any combination of specification object and design method.

## Info Method Updated to Include Filter Measurements

When you request information about a filter, the information now includes measurements of the filter characteristics based on the filter specifications. These are the same results that `measure` provides.

## Measurement Display Changes

`measure` now shows more information and more specific information for any referred object. Now the display provides full text descriptions of the measured values, such as Sampling Frequency (instead of `Fs`) and Stopband Edge instead of `Fstop`. You should find this a more clear presentation of the filter information.

## realizemdl Creates Additional Multirate Polyphase Filters

From the command line, you can use `realizemdl` to create realizations for `firdecim`, `firtdecim`, `firinterp`, and `linearinterp` filters. You can also apply `realizemdl` to the new IIR single-rate and multirate filters:

- `dfilt.allpass`
- `dfilt.wdfallpass`
- `dfilt.cascadeallpass`



- `dfilt.cascadewdfallpass`
- `mfilt.iirdecim`
- `mfilt.iirwdfdecim`
- `mfilt.iirinterp`
- `mfilt.iirwdfinterp`

## **Filter Design Object Now Called Filter Specification Object in the Documentation**

When you use `fdesign.response`, MATLAB returns an object, usually called `d`, that contains the specifications for a filter design. In the documentation, the returned object is now called a *specification object*.

For clarity, we renamed the filter design object to filter specification object, because the object specifies the filter specifications, such as the magnitude response parameters. The specification object is not a filter, but an intermediate step in the filter design process that uses `fdesign.response` and `design`.

## Version 3.3 (R14SP3) Filter Design Toolbox

This table summarizes what's new in Version 3.3 (R14SP3):

<b>New Features and Changes</b>	<b>Version Compatibility Considerations</b>	<b>Fixed Bugs and Known Problems</b>	<b>Related Documentation at Web Site</b>
Yes Details below	Yes Summary	Bug Reports	Printable Release Notes: PDF

New features and changes introduced in this version are

- “New Approach and Methods for Designing Filters” on page 23
- “New Way to Get Help for Filter Designs” on page 26
- “New Demo Programs to Introduce fdesign Filter Design Approach” on page 28
- “Fdesign Now Provides Arbitrary Magnitude Filter Response Design” on page 28
- “Fdesign Now Provides Hilbert and Differentiator Filter Response Design” on page 28
- “Fdesign Objects Now Use a Default Design Method When Available” on page 29
- “butter and ellip Half-Band Design Methods Added for IIR Fdesign Objects” on page 29
- “Added multistage Filter Design Method” on page 29
- “limitcycle Method Restored to the Toolbox” on page 29
- “normalizefreq Method Added to the Toolbox” on page 30
- “New measure Method for Filters” on page 30
- “With Fdesign Objects, New Passband Zoom View Option” on page 30
- “With Fdesign Objects, New Filter Specification Mask View Option” on page 30

- “Fdesign Object Display No Longer Shows Fs When the Design Object Uses Normalized Frequency” on page 31
- “For cicinterp Objects, Changed the Order of the Properties in the Display” on page 31
- “For IIR Design Objects, Property Fcutoff is Now Called F3dB” on page 32
- “Changes to the Displays in MATLAB for Filters” on page 32
- “Obsolete Functions and Methods in This Release” on page 32
- “block Method for mfilter.firfracdecim Filter Objects No Longer Works” on page 33

## New Approach and Methods for Designing Filters

To unify and take advantage of the object-based nature of the filters in the toolbox, this release introduces a new design approach for filters using filter design objects and new design methods. In the new process, your filter design tasks begin with identifying the filter response you need for your application.

Here is the new process.

- 1** Determine the response type for your filter.
- 2** Choose the appropriate `fdesign.response` method to create a filter specifications object.
- 3** Select the specifications to use to define your filter object. Here you can select minimum order designs, IIR or FIR designs, or designs that specify the filter order as well as the frequency and magnitude specifications, among many choices.
- 4** Use `designmethods` to find out which design algorithms apply to your specifications object. Select the design method to use.
- 5** Use `designopts` with your design object to review the input arguments for your specifications object and your selected design method.
- 6** Now design your filter using your filter design object, the design method you chose, and the input arguments you require.

The result of this process is a filter object that meets your requirements in response shape or form and designed by the method you selected.

Based on three design methods and a new help method, you now design filters starting with the desired response and moving to the final filter. These new methods are:

Method	Description
<code>design</code>	Design a filter from the specifications using either a default method or a specified method.
<code>designmethods</code>	Find out which design methods apply to your current design object, including dependence on the specifications.
<code>designopts</code>	Find out which input arguments apply to your design method and design object.

Here is a short example that demonstrates the new design flow.

This `fdesign.lowpass` syntax uses the default response specification `'Fp,Fst,Ap,Ast'`, where `Fp` is the passband edge, `Fst` is the stopband edge, `Ap` specifies the ripple in the passband, and `Ast` defines the desired stopband attenuation.

```
d = fdesign.lowpass % Select the response.
designmethods(d) % Determine the design methods available.
hd = design(d) % Design the filter using the default method (equiripple).

d =

    Response: 'Lowpass'
 Specification: 'Fp,Fst,Ap,Ast'
  Description: {4x1 cell}
 NormalizedFrequency: true
           Fpass: 0.45
           Fstop: 0.55
           Apass: 1
           Astop: 60
```

Design Methods for class `fdesign.lowpass` (Fp,Fst,Ap,Ast):

```
butter
cheby1
cheby2
ellip
equiripple
ifir
kaiserwin
multistage
```

```
hd =
```

```
    FilterStructure: 'Direct-Form FIR'
        Arithmetic: 'double'
          Numerator: [1x43 double]
 PersistentMemory: false
```

For more information about a particular design method, use the new help capability with your specification object and the design method as input arguments to `help`.

This help example gets more information about using the `equiripple` method to design a lowpass filter.

```
help(d,'equiripple') % Get help on using equiripple with your lowpass filter.
```

DESIGN Design a Equiripple FIR filter.

HD = DESIGN(D, 'equiripple') designs a Equiripple filter specified by the FDESIGN object H.

HD = DESIGN(..., 'FilterStructure', STRUCTURE) returns a filter with the structure STRUCTURE. STRUCTURE is 'dffir' by default and can be any of the following.

```
'dffir'
'dffirt'
```

```
'dfsymfir'
'fftfir'
```

HD = DESIGN(..., 'DensityFactor', DENS) specifies the grid density DENS used in the optimization. DENS is 16 by default.

HD = DESIGN(..., 'MinPhase', MPHASE) designs a minimum-phase filter when MPHASE is TRUE. MPHASE is FALSE by default.

HD = DESIGN(..., 'MinOrder', 'any') designs a minimum-order filter. The order of the filter can be even or odd. This is the default.

HD = DESIGN(..., 'MinOrder', 'even') designs an minimum-even-order filter.

HD = DESIGN(..., 'MinOrder', 'odd') designs an minimum-odd-order filter.

HD = DESIGN(..., 'StopbandShape', SHAPE) designs a filter whose stopband has the shape defined by SHAPE. SHAPE can be 'flat', '1/f', or 'linear'. SHAPE is 'flat' by default.

HD = DESIGN(..., 'StopbandDecay', DECAY) specifies the decay to use when 'StopbandShape' is not set to 'flat'. When the shape is '1/f' this specifies the power that 1/f is raised. When shaped is 'linear' this specifies the slope of the stopband in dB/rad/s.

% Example #1 - Design a lowpass Equiripple filter in a transposed structure.

```
h = fdesign.lowpass('Fp,Fst,Ap,Ast');
Hd = design(h, 'equiripple', 'FilterStructure', 'dffirt');
```

## New Way to Get Help for Filter Designs

Getting help about filter design and filter design methods is now dynamic and depends on the design object and method. When you want help about designing a filter, use `help` with both the filter specification object and the method to use to design the filter. Here is an example.

```
d = fdesign.bandpass(0.25,0.35,0.55,0.65,50,0.05,50)
designmethods(d)

d =
```

```

        Response: 'Bandpass'
    Specification: 'Fst1,Fp1,Fp2,Fst2,Ast1,Ap,Ast2'
    Description: {7x1 cell}
    NormalizedFrequency: true
        Fstop1: 0.25
        Fpass1: 0.35
        Fpass2: 0.55
        Fstop2: 0.65
        Astop1: 50
        Apass: 0.05
        Astop2: 50

```

Design Methods for class `fdesign.bandpass (Fst1,Fp1,Fp2,Fst2,Ast1,Ap,Ast2)`:

```

butter
cheby1
cheby2
ellip
equiripple
kaiserwin

```

```
help(d,'kaiserwin')
```

DESIGN Design a Kaiser Windowed FIR filter.

HD = DESIGN(D, 'kaiserwin') designs a Kaiser Windowed filter specified by the FDESIGN object H.

HD = DESIGN(..., 'FilterStructure', STRUCTURE) returns a filter with the structure STRUCTURE. STRUCTURE is 'dffir' by default and can be any of the following.

```

'dffir'
'dffirt'
'dfsymfir'
'dfasymfir'
'fftfir'

```

HD = DESIGN(..., 'ScalePassband', SCALE) scales the first passband so that it has a magnitude of 0 dB after windowing when SCALE is TRUE.

SCALE is TRUE by default.

```
% Example #1 - Design a bandpass Kaiser Windowed FIR filter.  
h = fdesign.bandpass('Fst1,Fp1,Fp2,Fst2,Ast1,Ap,Ast2');  
Hd = design(h, 'kaiserwin', 'ScalePassband', false);
```

## **New Demo Programs to Introduce fdesign Filter Design Approach**

This release adds many new tutorial demos that introduce you to using `fdesign` for your filter design tasks. To access the new demos, enter

`demos`

at the Command prompt. When the Help system opens, select `Filter Design > Tutorial Demos` from the Help Navigator tree in the left pane.

Alternatively, use the `demo` command with input arguments:

```
demo('toolbox','filter design')
```

to open the Demos directory showing the Filter Design Toolbox demos.

## **Fdesign Now Provides Arbitrary Magnitude Filter Response Design**

The designs available for `fdesign` now include arbitrary magnitude response filters. You use `fdesign.arbmag` with input arguments to specify a vector of frequency points and response values at those points to define a custom filter response curve.

## **Fdesign Now Provides Hilbert and Differentiator Filter Response Design**

The designs available for `fdesign` now include differentiator and Hilbert magnitude response filters. You use `fdesign.differentiator` or `fdesign.hilbert` with input arguments to specify a differentiator or Hilbert filter design object.



## Fdesign Objects Now Use a Default Design Method When Available

`design` now applies a default design method if you do not provide the design method as an input. Usually the default method is `equiripple` for FIR filters and `ellip` for IIR filters.

## butter and ellip Half-Band Design Methods Added for IIR Fdesign Objects

For designing IIR halfband filters with `fdesign` and `design`, we added both `butter` and `ellip` to the available design methods.

## Added multistage Filter Design Method

In addition to single-stage filters, you can now design multistage filters from lowpass filter design objects by applying the `multistage` design method to the object.

For example, after you create a lowpass filter object, use `multistage` to create the filter as a multistage filter.

```
d=fdesign.lowpass(0.25,0.35,0.05,50);  
hd = design(d,'multistage')
```

```
hd =
```

```
FilterStructure: Cascade  
  Stage(1): Direct-Form FIR Polyphase Decimator  
  Stage(2): Direct-Form FIR Polyphase Decimator  
  Stage(3): Direct-Form FIR Polyphase Interpolator  
  Stage(4): Direct-Form FIR Polyphase Interpolator  
PersistentMemory: false
```

## limitcycle Method Restored to the Toolbox

The function `limitcycle` is now available to test your fixed-point IIR filters for the limit cycle behavior.

## **normalizefreq Method Added to the Toolbox**

To let you convert your filters to use normalized frequency specifications, rather than absolute frequency, the toolbox adds `normalizefreq` for filter objects.

## **New measure Method for Filters**

A new method, `measure`, lets you measure the response of filters after you design them. `measure` returns the response values at a variety of frequencies in the filter magnitude response.

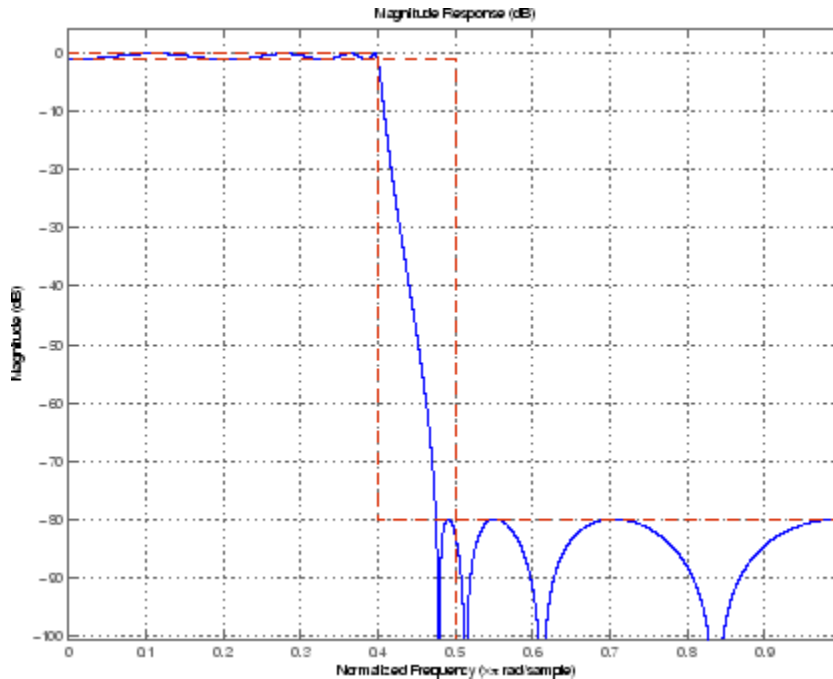
## **With Fdesign Objects, New Passband Zoom View Option**

Selecting the **View > Passband** option from the menu bar automatically zooms the display to focus on the passband for the filter shown. Using an `fdesign` object to design your filter enables the Passband Zoom option in FVTool.

## **With Fdesign Objects, New Filter Specification Mask View Option**

When you use FVTool or FDATool to display a filter response for a filter you design with an `fdesign` object, you see new masks that outline the filter passband, stopband, and transition regions as specified by your filter object.

The following graphic shows the mask for a lowpass filter. To display the specification mask, use a filter design object to construct your filter, and then display the filter in FVTool. Select **View > Specification Mask** from the menu bar in FVTool to see the specification mask.



## **Fdesign Object Display No Longer Shows Fs When the Design Object Uses Normalized Frequency**

In this release, the default filter display no longer shows the sampling frequency  $F_s$  when you specify the filter to use normalized frequency instead of absolute frequency.

## **For cicinterp Objects, Changed the Order of the Properties in the Display**

Reordered the listing of the filter properties in the default display of CIC filters. The new arrangement better matches the display organization for single rate filters.

## For IIR Design Objects, Property Fcutoff is Now Called F3dB

The filter property Fcutoff is now called F3dB to be more descriptive.

## Changes to the Displays in MATLAB for Filters

Some of the displays for filter objects, showing the properties and values, are different in this release. Some property names have changed, and some properties reordered to make the displays more logically grouped and consistent across the various objects. Among the changed displays are the CIC object property arrangements and the names of some properties for bandpass, bandstop, and general IIR filter objects.

### Compatibility Considerations

If you depend on the displays in your code or scripts or programs, be sure to modify your work to accommodate the new display names and arrangements.

## Obsolete Functions and Methods in This Release

The following methods are now obsolete.

### Compatibility Considerations

As you see in the table, new methods replace them, providing the same or expanded design capability.

Obsolete Method	Replacement Method
fdesign.decim	fdesign.decimator
fdesign.interp	fdesign.interpolator
fdesign.src	fdesign.rsrc

The obsolete methods continue to work, but they may be removed in the future.

## **block Method for mfilt.firfracdecim Filter Objects No Longer Works**

Changes in the FIR Sample Rate Change block in the Signal Processing Blockset software required that the `block` method for `firfracdecim` filters be made obsolete. You cannot use `block` to create a Simulink block from an `firfracdecim` filter object. To create a block from the `firfracdecim` object, convert the object to an `firsrc` object, and then use `block`.

```
hm = mfilt.firfracdecim(4,7); convert(hm,'firsrc') block(hm)
```

### **Compatibility Considerations**

Programs that use the `block` method for `firfracdecim` require that you convert your `mfilt.firfracdecim` multirate filter to `firsrc` form using the `convert` method.

## Version 3.2 (R14SP2) Filter Design Toolbox

This table summarizes what's new in Version 3.2 (R14SP2):

New Features and Changes	Version Compatibility Considerations	Fixed Bugs and Known Problems	Related Documentation at Web Site
Yes Details below	Yes Summary	Bug Reports	Printable Release Notes: PDF

New features and changes introduced in this version are

- “Improved Fixed-Point Support for FIR Filters” on page 34
- “Version 3.4 (R2006a) Filter Design Toolbox” on page 13
- “realizemdl Creates CIC Filters” on page 35
- “Context-Sensitive Help for FDATool Returns” on page 36
- “Second-Order Section Filter View Options Available from the Command Line” on page 36
- “Function fdesign Specifies Filter Response with Specified Structure” on page 37

### Improved Fixed-Point Support for FIR Filters

Four FIR filters now support fixed-point processing using the same properties or attributes and methods (mostly) that the fixed-point multirate filters use.

- `dfilt.dfasymfir`
- `dfilt.dffir`
- `dfilt.dffirt`
- `dfilt.dfsymfir`

With the improved filter objects, the properties for your discrete-time filters now look the same as your multirate filters. Unifying the look and feel makes working with the full range of filters in the toolbox easier and more clear.

Additionally, making the switch from floating-point to fixed-point by setting `Arithmetic` to `fixed` creates a fixed-point version of your floating-point filter that uses full precision arithmetic internally. The result—a fixed-point filter that most closely matches to your floating-point prototype. If your design cannot support the resources for this fixed-point implementation, you can start to adjust the fixed-point properties as you need.

To continue to use your existing fixed-point FIR filters, you have to upgrade them to the new format. The toolbox includes a new utility for making the transition—`legacyfixptfir`. Note that this utility is not covered in the Filter Design Toolbox documentation. You can get help by entering

```
help legacyfixptfir
```

at the MATLAB prompt.

For information about converting your existing fixed-point FIR filters to the new objects, refer to “Upgrading Your Existing Fixed-Point FIR Filters to the New Properties” on page 37.

## Fixed-Point Linear and Hold Interpolators

Both `mfilt.holdinterp` and `mfilt.linearinterp` let you use fixed-point arithmetic. After you create the interpolator object, you can switch the setting for the `Arithmetic` property to `fixed` to use fixed-point interpolation.

Both also support single-precision floating-point arithmetic.

## realizemdl Creates CIC Filters

You can use `realizemdl` to construct CIC filters from basic blocks for processing signals. If you construct a CIC decimator filter, as shown in this example, `realizemdl` can make an atomic subsystem CIC filter block in the Simulink product for you.

```
hm=mfilt.cicdecim(4); realizemdl(hm)
```

A new Simulink model window opens and you see a filter block. Double-clicking on the new block shows you the CIC filter subsystem.





```

set(handle.sosviewsettings, 'view')

ans =

    'Complete'
    'Individual'
    'Cumulative'
    'UserDefined'

set(handle.sosviewsettings, 'view', 'individual')

```

In `SOSViewSettings`, the options are the same, with the same meaning, that you find in **View > SOS View Settings** in `FDATool`.

For more information about the `fvtool` properties, refer to `fvtool` in the Signal Processing Toolbox™ documentation or in the online Help system.

## Function `fdesign` Specifies Filter Response with Specified Structure

You can use `fdesign.response` to specify a filter response and specify the filter structure to use during construction.

## Upgrading Your Existing Fixed-Point FIR Filters to the New Properties

There is a utility named `legacyfixptfir` to ensure backward compatibility of your existing scripts and a function `update` to help you migrate to the new FIR filters. `legacyfixptfir` switches the preferences for your session between pre- and post-Filter Design Toolbox 3.2 FIR filters.

Here is an example of the process of converting your old FIR filters to the new form in this version of the toolbox.

Begin with an existing direct-form FIR filter `h` that you constructed with

```
h = dfilt.dffir
```

in an earlier version of the toolbox. First, use `legacyfixptfir` to retrieve `h` in the old format. Then convert `h` to the new form.

```
legacyfixptfir(true) % To get the old form of h.  
h.Arithmetic='fixed'
```

```
h =
```

```
    FilterStructure: 'Direct-Form FIR'  
      Arithmetic: 'fixed'  
      Numerator: 1  
PersistentMemory: false
```

```
    CoeffWordLength: 16  
      CoeffAutoScale: true  
      Signed: true
```

```
    InputWordLength: 16  
    InputFracLength: 15
```

```
OutputWordLength: 16  
      OutputMode: 'AvoidOverflow'
```

```
      ProductMode: 'FullPrecision'
```

```
      AccumMode: 'KeepMSB'  
AccumWordLength: 40  
      CastBeforeSum: true
```

```
      RoundMode: 'convergent'  
      OverflowMode: 'wrap'
```

```
update(h) % Convert h to the new properties.  
h
```

```
h =
```

```
    FilterStructure: 'Direct-Form FIR'  
      Arithmetic: 'fixed'  
      Numerator: 1  
PersistentMemory: false
```

```
    CoeffWordLength: 16
```

```

    CoeffAutoScale: true
        Signed: true

    InputWordLength: 16
    InputFracLength: 15

    FilterInternals: 'SpecifyPrecision'

    OutputWordLength: 16
    OutputFracLength: 13

    ProductWordLength: 32
    ProductFracLength: 29

    AccumWordLength: 40
    AccumFracLength: 29

    RoundMode: 'convergent'
    OverflowMode: 'wrap'

```

Note the changes in properties. The filter performs the same way but the attributes are now updated to the newest form.

## Filter Weights Have Been Removed from the Specifications in `fdesign`

The weights applied to the filter magnitude response are now design options. They are no longer properties of the `fdesign.typeobject`. To set them, pass them as property name/property value (PV) pairs to the appropriate filter design method, as shown in this example.

```

h = fdesign.lowpass('N,Fp,Fst',30) % Was 'N,Fp,Fst,Wp,Wst'.
                                % Removed Wp and Wst.
hd = equiripple(h, 'Wpass', 3, 'Wstop', 25); % Specify the
                                             % weights here.
hd(2) = equiripple(h, 'Wpass', 3, 'Wstop', 1);
fvtool(hd)

```

## Compatibility Summary for the Filter Design Toolbox Product

This table summarizes new features and changes that might cause incompatibilities when you upgrade from an earlier version, or when you use files on multiple versions of the product. Details about the compatibility effects appear with the description of the new feature or change in the New Features and Changes sections for the product.

<b>Version (Release)</b>	<b>New Features and Changes with Version Compatibility Impact</b>
<b>Latest Version V4.4 (R2008b)</b>	None
V4.3 (R2008a)	See the <b>Compatibility Considerations</b> subheading for “Input Quantization Added to Models Generated by the Block Method” on page 5.
V4.2 (R2007b)	See the <b>Compatibility Considerations</b> subheading for “Functions Being Removed” on page 7.
V4.1 (R2007a)	None
V4.0 (R2006b)	None
V3.4 (R2006a)	See the <b>Compatibility Considerations</b> subheading for “Nearest Round Mode for dfilt and mfilt Objects” on page 17

<b>Version (Release)</b>	<b>New Features and Changes with Version Compatibility Impact</b>
V3.3 (R14SP3)	<p>See the <b>Compatibility Considerations</b> subheading for each of these new features or changes:</p> <ul style="list-style-type: none"> <li>• “Fdesign Object Display No Longer Shows Fs When the Design Object Uses Normalized Frequency” on page 31</li> <li>• “Changes to the Displays in MATLAB for Filters” on page 32</li> <li>• “Obsolete Functions and Methods in This Release” on page 32</li> <li>• “block Method for mfilter.firfracdecim Filter Objects No Longer Works” on page 33</li> </ul>
V3.2 (R14SP2)	<p>See the <b>Compatibility Considerations</b> subheading for each of these new features or changes:</p> <ul style="list-style-type: none"> <li>• “Upgrading Your Existing Fixed-Point FIR Filters to the New Properties” on page 37</li> <li>• “Filter Weights Have Been Removed from the Specifications in fdesign” on page 39</li> </ul>