

# MATLAB Version 4.0

(for Windows)

## Functions Reference

## 1. Language

### 1.1 General purpose commands.

#### 1.1.1 Managing commands and functions.

help	On-line documentation.
what	Directory listing of M-, MAT- and MEX-files.
type	List M-file.
lookfor	Keyword search through the HELP entries.
which	Locate functions and files.
demo	Run demos.
path	Control MATLAB's search path.

#### 1.1.2 Managing variables and the workspace.

who	List current variables.
whos	List current variables, long form.
load	Retrieve variables from disk.
save	Save workspace variables to disk.
clear	Clear variables and functions from memory.
pack	Consolidate workspace memory.
size	Size of matrix.
length	Length of vector.
disp	Display matrix or text.

#### 1.1.3 Working with files and the operating system.

cd	Change current working directory.
dir	Directory listing.
delete	Delete file.
getenv	Get environment value.
!	Execute operating system command.
unix	Execute operating system command & return result.
diary	Save text of MATLAB session.

#### 1.1.4 Controlling the command window.

cedit	Set command line edit/recall facility parameters.
clc	Clear command window.
home	Send cursor home.
format	Set output format.
echo	Echo commands inside script files.
more	Control paged output in command window.

#### 1.1.5 Starting and quitting from MATLAB.

quit	Terminate MATLAB.
startup	M-file executed when MATLAB is invoked.
matlabrc	Master startup M-file.

#### 1.1.6 General information.

info	Information about MATLAB and The MathWorks, Inc.
subscribe	Become subscribing user of MATLAB.
hostid	MATLAB server host identification number.
whatsnew	Information about new features not yet documented.

## 1.2 Language constructs and debugging.

### 1.2.1 MATLAB as a programming language.

script	About MATLAB scripts and M-files.
function	Add new function.
eval	Execute string with MATLAB expression.
feval	Execute function specified by string.
global	Define global variable.
nargchk	Validate number of input arguments.
lasterr	Last error message.

### 1.2.2 Control flow.

if	Conditionally execute statements.
else	Used with IF.
elseif	Used with IF.
end	Terminate the scope of FOR, WHILE and IF statements.
for	Repeat statements a specific number of times.
while	Repeat statements an indefinite number of times.
break	Terminate execution of loop.
return	Return to invoking function.
error	Display message and abort function.

### 1.2.3 Interactive input.

input	Prompt for user input.
keyboard	Invoke keyboard as if it were a Script-file.
menu	Generate menu of choices for user input.
pause	Wait for user response.
uimenu	Create user interface menu.
uicontrol	Create user interface control.

### 1.2.4 Debugging commands.

dbstop	Set breakpoint.
dbclear	Remove breakpoint.
dbcont	Resume execution.
dbdown	Change local workspace context.
dbstack	List who called whom.
dbstatus	List all breakpoints.
dbstep	Execute one or more lines.
dbtype	List M-file with line numbers.
dbup	Change local workspace context.
dbquit	Quit debug mode.

## 1.3 Low-level file I/O functions.

### 1.3.1 File opening and closing.

fopen	Open file.
fclose	Close file.

### 1.3.2 Unformatted I/O.

fread	Read binary data from file.
fwrite	Write binary data to file.

### 1.3.3 Formatted I/O.

fscanf	Read formatted data from file.
fprintf	Write formatted data to file.
fgetl	Read line from file, discard newline character.
fgets	Read line from file, keep newline character.

### 1.3.4 File positioning.

ferror	Inquire file I/O error status.
feof	Test for end-of-file.
fseek	Set file position indicator.
ftell	Get file position indicator.
frewind	Rewind file.

### 1.3.5 String conversion.

sprintf	Write formatted data to string.
sscanf	Read string under format control.

## 1.4 Character string functions.

### 1.4.1 General.

strings	About character strings in MATLAB.
abs	Convert string to numeric values.
setstr	Convert numeric values to string.
isstr	True for string.
blanks	String of blanks.
deblank	Remove trailing blanks.
str2mat	Form text matrix from individual strings.
eval	Execute string with MATLAB expression.

### 1.4.2 String comparison.

strcmp	Compare strings.
findstr	Find one string within another.
upper	Convert string to uppercase.
lower	Convert string to lowercase.
isletter	True for letters of the alphabet.

### 1.4.3 String to number conversion.

num2str	Convert number to string.
int2str	Convert integer to string.
str2num	Convert string to number.
sprintf	Convert number to string under format control.
sscanf	Convert string to number under format control.

### 1.4.4 Hexadecimal to number conversion.

hex2num	Convert hex string to IEEE floating point number.
hex2dec	Convert hex string to decimal integer.
dec2hex	Convert decimal integer to hex string.

## 2. Matrices

### 2.1 Elementary matrices and matrix manipulation.

#### 2.1.1 Elementary matrices.

zeros	Zeros matrix.
ones	Ones matrix.
eye	Identity matrix.
rand	Uniformly distributed random numbers.
randn	Normally distributed random numbers.
linspace	Linearly spaced vector.
logspace	Logarithmically spaced vector.
meshgrid	X and Y arrays for 3-D plots.
:	Regularly spaced vector.

#### 2.1.2 Special variables and constants.

ans	Most recent answer.
eps	Floating point relative accuracy.
realmax	Largest floating point number.
realmin	Smallest positive floating point number.
pi	3.1415926535897....
i, j	Imaginary unit.
inf	Infinity.
NaN	Not-a-Number.
flops	Count of floating point operations.
nargin	Number of function input arguments.
nargout	Number of function output arguments.
computer	Computer type.
isieee	True for computers with IEEE arithmetic.
why	Succinct answer.
version	MATLAB version number.

#### 2.1.3 Time and dates.

clock	Wall clock.
cputime	Elapsed CPU time.
date	Calendar.
etime	Elapsed time function.
tic, toc	Stopwatch timer functions.

### 2.2 Matrix functions - numerical linear algebra.

#### 2.2.1 Matrix manipulation.

diag	Create or extract diagonals.
flipr	Flip matrix in the left/right direction.
flipud	Flip matrix in the up/down direction.
reshape	Change size.
rot90	Rotate matrix 90 degrees.
tril	Extract lower triangular part.
triu	Extract upper triangular part.
:	Index into matrix, rearrange matrix.

#### 2.2.2 Matrix analysis.

cond	Matrix condition number.
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norm	Matrix or vector norm.
rcond	LINPACK reciprocal condition estimator.
rank	Number of linearly independent rows or columns.
det	Determinant.
trace	Sum of diagonal elements.
null	Null space.
orth	Orthogonalization.
rref	Reduced row echelon form.

### 2.2.3 Linear equations.

\ and /	Linear equation solution; use "help slash".
chol	Cholesky factorization.
lu	Factors from Gaussian elimination.
inv	Matrix inverse.
qr	Orthogonal-triangular decomposition.
qrdelete	Delete a column from the QR factorization.
qrinsert	Insert a column in the QR factorization.
nls	Non-negative least-squares.
pinv	Pseudoinverse.
lsqov	Least squares in the presence of known covariance.

### 2.2.4 Eigenvalues and singular values.

eig	Eigenvalues and eigenvectors.
poly	Characteristic polynomial.
hess	Hessenberg form.
qz	Generalized eigenvalues.
rsf2csf	Real block diagonal form to complex diagonal form.
cdf2rdf	Complex diagonal form to real block diagonal form.
schur	Schur decomposition.
balance	Diagonal scaling to improve eigenvalue accuracy.
svd	Singular value decomposition.

### 2.2.5 Matrix functions.

expm	Matrix exponential.
expm1	M-file implementation of expm.
expm2	Matrix exponential via Taylor series.
expm3	Matrix exponential via eigenvalues and eigenvectors.
logm	Matrix logarithm.
sqrtm	Matrix square root.
funm	Evaluate general matrix function.

## 2.3 Specialized matrices.

compan	Companion matrix.
gallery	Several small test matrices.
hadamard	Hadamard matrix.
hankel	Hankel matrix.
hilb	Hilbert matrix.
invhilb	Inverse Hilbert matrix.
kron	Kronecker tensor product.
magic	Magic square.
pascal	Pascal matrix.
rosser	Classic symmetric eigenvalue test problem.
toeplitz	Toeplitz matrix.
vander	Vandermonde matrix.
wilkinson	Wilkinson's eigenvalue test matrix.

## 3. Mathematical Functions

### 3.1 Elementary math functions.

FUNCTION Function M-files.

New functions may be added to MATLAB's vocabulary if they are expressed in terms of other existing functions. The commands and functions that comprise the new function must be put in a file whose name defines the name of the new function, with a filename extension of '.m'. At the top of the file must be a line that contains the syntax definition for the new function. For example, the existence of a file on disk called STAT.M with:

```
function [mean,stdev] = stat(x)
n = length(x);
mean = sum(x) / n;
stdev = sqrt(sum((x - mean).^2)/n);
```

defines a new function called STAT that calculates the mean and standard deviation of a vector. The variables within the body of the function are all local variables.

See SCRIPT for procedures that work globally on the workspace.

#### 3.1.1 Operators and special characters.

Char	Name	HELP topic
+	Plus	arith
-	Minus	arith
*	Matrix multiplication	arith
.*	Array multiplication	arith
^	Matrix power	arith
.^	Array power	arith
\	Backslash or left division	slash
/	Slash or right division	slash
./	Array division	slash
kron	Kronecker tensor product	kron
:	Colon	colon
( )	Parentheses	paren
[ ]	Brackets	paren
.	Decimal point	punct
..	Parent directory	punct
...	Continuation	punct
,	Comma	punct
;	Semicolon	punct
%	Comment	punct
!	Exclamation point	punct
'	Transpose and quote	punct
=	Assignment	punct
==	Equality	relop
< >	Relational operators	relop
&	Logical AND	relop
	Logical OR	relop
~	Logical NOT	relop
xor	Logical EXCLUSIVE OR	xor

#### Logical characteristics.

exist	Check if variables or functions are defined.
any	True if any element of vector is true.

all	True if all elements of vector are true.
find	Find indices of non-zero elements.
isnan	True for Not-A-Number.
isinf	True for infinite elements.
finite	True for finite elements.
isempty	True for empty matrix.
issparse	True for sparse matrix.
isstr	True for text string.
isglobal	True for global variables.

### 3.1.2 Trigonometric.

sin	Sine.
sinh	Hyperbolic sine.
asin	Inverse sine.
asinh	Inverse hyperbolic sine.
cos	Cosine.
cosh	Hyperbolic cosine.
acos	Inverse cosine.
acosh	Inverse hyperbolic cosine.
tan	Tangent.
tanh	Hyperbolic tangent.
atan	Inverse tangent.
atan2	Four quadrant inverse tangent.
atanh	Inverse hyperbolic tangent.
sec	Secant.
sech	Hyperbolic secant.
asec	Inverse secant.
asech	Inverse hyperbolic secant.
csc	Cosecant.
csch	Hyperbolic cosecant.
acsc	Inverse cosecant.
acsch	Inverse hyperbolic cosecant.
cot	Cotangent.
coth	Hyperbolic cotangent.
acot	Inverse cotangent.
acoth	Inverse hyperbolic cotangent.

### 3.1.3 Exponential.

exp	Exponential.
log	Natural logarithm.
log10	Common logarithm.
sqrt	Square root.

### 3.1.4 Complex.

abs	Absolute value.
angle	Phase angle.
conj	Complex conjugate.
imag	Complex imaginary part.
real	Complex real part.

### 3.1.5 Numeric.

fix	Round towards zero.
floor	Round towards minus infinity.
ceil	Round towards plus infinity.
round	Round towards nearest integer.
rem	Remainder after division.
sign	Signum function.

### 3.1.6 Function functions - nonlinear numerical methods.

ode23	- Solve differential equations, low order method.
ode23p	- Solve and plot solutions.
ode45	- Solve differential equations, high order method.
quad	- Numerically evaluate integral, low order method.
quad8	- Numerically evaluate integral, high order method.
fmin	- Minimize function of one variable.
fmins	- Minimize function of several variables.
fzero	- Find zero of function of one variable.
fplot	- Plot function.

## 3.2 Data analysis and Fourier transform functions.

### 3.2.1 Basic operations.

max	Largest component.
min	Smallest component.
mean	Average or mean value.
median	Median value.
std	Standard deviation.
sort	Sort in ascending order.
sum	Sum of elements.
prod	Product of elements.
cumsum	Cumulative sum of elements.
cumprod	Cumulative product of elements.
trapz	Numerical integration using trapezoidal method.

### 3.2.2 Finite differences.

diff	Difference function and approximate derivative.
gradient	Approximate gradient.
del2	Five-point discrete Laplacian.

### 3.2.3 Correlation.

corrcoef	Correlation coefficients.
cov	Covariance matrix.
subspace	Angle between subspaces.

### 3.2.4 Filtering and convolution.

filter	One-dimensional digital filter.
filter2	Two-dimensional digital filter.
conv	Convolution and polynomial multiplication.
conv2	Two-dimensional convolution.
deconv	Deconvolution and polynomial division.

### 3.2.5 Fourier transforms.

fft	Discrete Fourier transform.
fft2	Two-dimensional discrete Fourier transform.
ifft	Inverse discrete Fourier transform.
ifft2	Two-dimensional inverse discrete Fourier transform.
abs	Magnitude.
angle	Phase angle.
unwrap	Remove phase angle jumps across 360 degree boundaries.
fftshift	Move zeroth lag to center of spectrum.
cplxpair	Sort numbers into complex conjugate pairs.
nextpow2	Next higher power of 2.

### 3.3 Polynomial and interpolation functions.

#### 3.3.1 Polynomials.

roots	Find polynomial roots.
poly	Construct polynomial with specified roots.
polyval	Evaluate polynomial.
polyvalm	Evaluate polynomial with matrix argument.
residue	Partial-fraction expansion (residues).
polyfit	Fit polynomial to data.
polyder	Differentiate polynomial.
conv	Multiply polynomials.
deconv	Divide polynomials.

#### 3.3.2 Data interpolation.

interp1	1-D interpolation (1-D table lookup).
interp2	2-D interpolation (2-D table lookup).
interpft	1-D interpolation using FFT method.
griddata	Data gridding.

### 3.4 Specialized math functions.

#### 3.4.1 Sparse matrix functions.

besselj	Bessel function of the first kind.
bessely	Bessel function of the second kind.
besseli	Modified Bessel function of the first kind.
besselk	Modified Bessel function of the second kind.
beta	Beta function.
betainc	Incomplete beta function.
betaln	Logarithm of beta function.
ellipj	Jacobi elliptic functions.
ellipke	Complete elliptic integral.
erf	Error function.
erfc	Complementary error function.
erfcx	Scaled complementary error function.
erfinv	Inverse error function.
gamma	Gamma function.
gcd	Greatest common divisor.
gammainc	Incomplete gamma function.
lcm	Least common multiple.
gammaln	Logarithm of gamma function.
log2	Dissect floating point numbers.
pow2	Scale floating point numbers.
rat	Rational approximation.
rats	Rational output.
cart2sph	Transform from Cartesian to spherical coordinates.
cart2pol	Transform from Cartesian to polar coordinates.
pol2cart	Transform from polar to Cartesian coordinates.
sph2cart	Transform from spherical to Cartesian coordinates.

#### 3.4.2 Elementary sparse matrices.

speye	Sparse identity matrix.
sprandn	Sparse random matrix.
sprandsym	Sparse symmetric random matrix.
spdiags	Sparse matrix formed from diagonals.

### 3.4.3 Full to sparse conversion.

sparse	Create sparse matrix from nonzeros and indices.
full	Convert sparse matrix to full matrix.
find	Find indices of nonzero entries.
spconvert	Convert from sparse matrix external format.

### 3.4.4 Working with nonzero entries of sparse matrices.

nnz	Number of nonzero entries.
nonzeros	Nonzero entries.
nzmax	Amount of storage allocated for nonzero entries.
spones	Replace nonzero entries with ones.
spalloc	Allocate memory for nonzero entries.
issparse	True if matrix is sparse.
spfun	Apply function to nonzero entries.

### 3.4.5 Visualizing sparse matrices.

spy	Visualize sparsity structure.
gplot	Plot graph, as in "graph theory".

### 3.4.6 Reordering algorithms.

colmmd	Column minimum degree.
symmmd	Symmetric minimum degree.
symrcm	Reverse Cuthill-McKee ordering.
colperm	Order columns based on nonzero count.
randperm	Random permutation vector.
dmperm	Dulmage-Mendelsohn decomposition.

### 3.4.7 Norm, condition number, and rank.

normest	Estimate 2-norm.
condest	Estimate 1-norm condition.
sprank	Structural rank.

### 3.4.8 Operations on trees.

treelayout	Lay out a tree or forest.
treeplot	Plot a picture of a tree.
etree	Elimination tree of a matrix.
etreeplot	Plot the elimination tree.

### 3.4.9 Miscellaneous.

symbfact	Symbolic factorization analysis.
spparms	Set parameters for sparse matrix routines.
spaugment	Form least squares augmented system.

## 4. Graphical Functions

### 4.1 General purpose graphics functions.

#### 4.1.1 Figure window creation and control.

figure	Create Figure (graph window).
gcf	Get handle to current figure.
clf	Clear current figure.
close	Close figure.

#### 4.1.2 Axis creation and control.

subplot	Create axes in tiled positions.
axes	Create axes in arbitrary positions.
gca	Get handle to current axes.
cla	Clear current axes.
axis	Control axis scaling and appearance.
caxis	Control pseudocolor axis scaling.
hold	Hold current graph.

#### 4.1.3 Handle Graphics objects.

figure	Create figure window.
axes	Create axes.
line	Create line.
text	Create text.
patch	Create patch.
surface	Create surface.
image	Create image.
uicontrol	Create user interface control.
uimenu	Create user interface menu.

#### 4.1.4 Handle Graphics operations.

set	Set object properties.
get	Get object properties.
reset	Reset object properties.
delete	Delete object.
drawnow	Flush pending graphics events.
newplot	M-file preamble for NextPlot property.

#### 4.1.5 Hardcopy and storage.

print	Print graph or save graph to file.
printopt	Configure local printer defaults.
orient	Set paper orientation.

#### 4.1.6 Movies and animation.

moviein	Initialize movie frame memory.
getframe	Get movie frame.
movie	Play recorded movie frames.

#### 4.1.7 Miscellaneous.

ginput	Graphical input from mouse.
rbbox	Rubberband box.
ishold	Return hold state.
whitebg	Set graphics window defaults for white background.

graymon	Set graphics window defaults for gray-scale monitors.
terminal	Set graphics terminal type.
uiputfile	Put up dialog box for saving files.
uigetfile	Put up dialog box which queries for file names.
uisetcolor	Put up dialog box which returns an RGB value.
uisetfont	Put up dialog box which queries for a font.

## 4.2 Two dimensional graphics.

### 4.2.1 Elementary X-Y graphs.

plot	Linear plot.
loglog	Log-log scale plot.
semilogx	Semi-log scale plot.
semilogy	Semi-log scale plot.
fill	Draw filled 2-D polygons.

### 4.2.2 Specialized X-Y graphs.

polar	Polar coordinate plot.
bar	Bar graph.
stem	Discrete sequence or "stem" plot.
stairs	Stairstep plot.
errorbar	Error bar plot.
hist	Histogram plot.
rose	Angle histogram plot.
compass	Compass plot.
feather	Feather plot.
fplot	Plot function.
comet	Comet-like trajectory.

### 4.2.3 Graph annotation.

title	Graph title.
xlabel	X-axis label.
ylabel	Y-axis label.
text	Text annotation.
gtext	Mouse placement of text.
grid	Grid lines.

## 4.3 Three dimensional graphics.

### 4.3.1 Line and area fill commands.

plot3	Plot lines and points in 3-D space.
fill3	Draw filled 3-D polygons in 3-D space.
comet3	3-D comet-like trajectories.

### 4.3.2 Contour and other 2-D plots of 3-D data.

contour	Contour plot.
contour3	3-D contour plot.
clabel	Contour plot elevation labels.
contourc	Contour plot computation (used by contour).
pcolor	Pseudocolor (checkerboard) plot.
quiver	Quiver plot.

### 4.3.3 Surface and mesh plots.

mesh	3-D mesh surface.
meshc	Combination mesh/contour plot.

meshz	3-D Mesh with zero plane.
surf	3-D shaded surface.
surfc	Combination surf/contour plot.
surfl	3-D shaded surface with lighting.
waterfall	Waterfall plot.

#### 4.3.4 Volume visualization.

slice	Volumetric visualization plots.
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#### 4.3.5 Graph appearance.

view	3-D graph viewpoint specification.
viewmtx	View transformation matrices.
hidden	Mesh hidden line removal mode.
shading	Color shading mode.
axis	Axis scaling and appearance.
caxis	Pseudocolor axis scaling.
colormap	Color look-up table.

#### 4.3.6 Graph annotation.

title	Graph title.
xlabel	X-axis label.
ylabel	Y-axis label.
zlabel	Z-axis label for 3-D plots.
text	Text annotation.
gtext	Mouse placement of text.
grid	Grid lines.

#### 4.3.7 3-D objects.

cylinder	Generate cylinder.
sphere	Generate sphere.

## 5. Toolbox

### 5.1 Signal Processing Toolbox.

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 \$Revision: 1.22 \$ \$Date: 1993/11/17 22:38:35 \$

#### Waveform generation.

diric - Dirichlet (periodic sinc) function.  
 sawtooth - Sawtooth function.  
 sinc - Sinc or  $\sin(\pi x)/(\pi x)$  function  
 square - Square wave function.

#### Filter analysis and implementation.

abs - Magnitude.  
 angle - Phase angle.  
 conv - Convolution.  
 fftfilt - Overlap-add filter implementation.  
 filter - Filter implementation.  
 filtfilt - Zero-phase version of filter.  
 filtic - Determine filter initial conditions.  
 freqs - Laplace transform frequency response.  
 freqspace - Frequency spacing for frequency response.  
 freqz - Z-transform frequency response.  
 grpdelay - Group delay.  
 impz - Impulse response (discrete).  
 unwrap - Unwrap phase.  
 zplane - Discrete pole-zero plot.

#### Linear system transformations.

convmtx - Convolution matrix.  
 poly2rc - Polynomial to reflection coefficients transformation.  
 rc2poly - Reflection coefficients to polynomial transformation.  
 residuez - Z-transform partial fraction expansion.  
 sos2ss - Second-order sections to state-space conversion.  
 sos2tf - Second-order sections to transfer function

#### conversion.

sos2zp - Second-order sections to zero-pole conversion.  
 ss2sos - State-space to second-order sections conversion.  
 ss2tf - State-space to transfer function conversion.  
 ss2zp - State-space to zero-pole conversion.  
 tf2ss - Transfer function to state-space conversion.  
 tf2zp - Transfer function to zero-pole conversion.  
 zp2sos - Zero-pole to second-order sections conversion.  
 zp2ss - Zero-pole to state-space conversion.  
 zp2tf - Zero-pole to transfer function conversion.

#### IIR digital filter design.

besself - Bessel analog filter design.  
 butter - Butterworth filter design.  
 cheby1 - Chebyshev type I filter design.  
 cheby2 - Chebyshev type II filter design.  
 ellip - Elliptic filter design.  
 yulewalk - Yule-Walker filter design.

#### IIR filter order selection.

buttord - Butterworth filter order selection.  
 cheb1ord - Chebyshev type I filter order selection.  
 cheb2ord - Chebyshev type II filter order selection.  
 ellipord - Elliptic filter order selection.

#### FIR filter design.

fir1 - Window based FIR filter design - low, high, band,  
 stop.  
 fir2 - Window based FIR filter design - arbitrary response.  
 fircls - FIR filter design - arbitrary response with  
 transition bands.  
 intfilt - Interpolation FIR filter design.  
 remez - Parks-McClellan optimal FIR filter design.  
 remezord - Parks-McClellan filter order selection.

#### Transforms.

czt - Chirp-z transform.  
 dct - Discrete cosine transform.  
 dftmtx - Discrete Fourier transform matrix.  
 fft - Fast Fourier transform.  
 fftshift - Swap vector halves.  
 hilbert - Hilbert transform.  
 idct - Inverse discrete cosine transform.  
 ifft - Inverse fast Fourier transform.

#### Statistical signal processing.

cohere - Coherence function estimate.  
 corrcoef - Correlation coefficients.  
 cov - Covariance matrix.  
 csd - Cross Spectral Density.  
 psd - Power Spectral Density.  
 spectrum - psd, csd, cohere and tfe combined.  
 tfe - Transfer function estimate.  
 xcorr - Cross-correlation function.  
 xcov - Covariance function.

#### Windows.

bartlett - Bartlett window.  
 blackman - Blackman window.  
 boxcar - Rectangular window.  
 chebwin - Chebyshev window.  
 hamming - Hamming window.  
 hanning - Hanning window.  
 kaiser - Kaiser window.  
 triang - Triangular window.

#### Parametric modeling.

invfreqs - Analog filter fit to frequency response.  
 invfreqz - Discrete filter fit to frequency response.  
 levinson - Levinson-Durbin recursion.  
 lpc - Linear Predictive Coefficients using autocorrelation  
 method.  
 prony - Prony's discrete filter fit to time response.  
 stmcb - Steiglitz-McBride iteration for ARMA modeling.  
 ident - See also the Identification Toolbox.

#### Specialized operations.

cceps - Complex cepstrum.  
 decimate - Resample data at a lower sample rate.  
 deconv - Deconvolution.  
 demod - Demodulation for communications simulation.  
 interp - Resample data at a higher sample rate.  
 interp1 - General 1-D interpolation. (MATLAB Toolbox)  
 medfilt1 - 1-Dimensional median filtering.  
 modulate - Modulation for communications simulation.  
 rceps - Real cepstrum and minimum phase reconstruction.  
 resample - Resample sequence with new sampling rate.  
 spectrogram - Spectrogram, for speech signals.  
 spline - Cubic spline interpolation.  
 vco - Voltage controlled oscillator.

#### Analog lowpass filter prototypes.

besslap - Bessel filter prototype.  
 buttap - Butterworth filter prototype.  
 cheb1ap - Chebyshev type I filter prototype (passband ripple).  
 cheb2ap - Chebyshev type II filter prototype (stopband ripple).  
 ellipap - Elliptic filter prototype.

#### Frequency translation.

lp2bp - Lowpass to bandpass analog filter transformation.  
 lp2bs - Lowpass to bandstop analog filter transformation.  
 lp2hp - Lowpass to highpass analog filter transformation.  
 lp2lp - Lowpass to lowpass analog filter transformation.

#### Filter discretization.

bilinear - Bilinear transformation with optional prewarping.  
 impinvar - Impulse invariance analog to digital conversion.

#### Other

conv2 - 2-D convolution.  
 cplxpair - Order vector into complex conjugate pairs.  
 detrend - Linear trend removal.  
 fft2 - 2-D fast Fourier transform.  
 fftshift - Swap quadrants of array.  
 ifft2 - Inverse 2-D fast Fourier transform.  
 polystab - Polynomial stabilization.  
 stem - Plot discrete data sequence.  
 strips - Strip plot.  
 xcorr2 - 2-D cross-correlation.

#### Demonstrations.

cztdemo - Chirp-z transform and FFT demonstration.  
 filtdemo - Filter design demonstration.  
 moddemo - Modulation/demodulation demonstration.  
 sosdemo - Second-order sections demonstration.

## 5.2 Spline Toolbox.

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#### Manipulate functions in pp-form or B-form.

fnder - Derivative of a function.  
 fnint - Indefinite integral of function.  
 fnplt - Plot a function.  
 fnval - Evaluate a function.  
 fncmb - Weighted sum of two functions in the same form.

#### Splines in pp-form.

ppbrk - Get order, breaks, and coefficients from pp-form.  
 ppcut - Cut down a pp to a given interval.  
 ppmak - Make pp-form from breaks and coefficients.  
 pppce - Pick out one polynomial piece.

#### Splines in B-form.

sp2pp - Convert from B-form to pp-form.  
 spap2 - Least-squares approximation by splines.  
 spapi - Spline interpolation.  
 spbrk - Get order, knots, and coefficients from B-form.  
 spcol - Generate the B-spline collocation matrix.  
 spcrv - Generate a spline curve.  
 spmak - Make B-form from knots and coefficients.

#### Cubic splines.

csapi - Cubic spline interpolation.  
 csape - Cubic spline interpolation with various end-conditions.

csaps - Cubic smoothing spline.  
 cscvn - Generate an interpolating parametric cubic spline curve.

#### Breaks and knots.

augknt - Provide proper knot multiplicities.  
 aveknt - Supply knot averages (e.g., for interpolation).  
 newknt - Improve break distribution.  
 optknt - Optimal knots.

#### Special linear system solver.

slvblk - Solve an almost block-diagonal linear system.  
 bkbrk - Get the relevant parts of an almost block-diagonal matrix.

#### Demonstrations and explanations.

spdemos - List of spline toolbox demonstrations.  
 ppalldem - Demonstrate form and usage of pp-form.  
 spalldem - Demonstrate form and usage of B-form.  
 bsplidem - Demonstrate B-splines.  
 spapidem - Demonstrate spline interpolation.  
 spcrvdm - Demonstrate spline curves.  
 csapidem - Demonstrate cubic spline interpolation.  
 csapsdem - Demonstrate cubic smoothing spline.  
 chebdem - Demonstrate the construction of a Chebyshev spline.  
 difeqdem - Demonstrate solution of ODE by collocation.  
 tspdem - Demonstrate tensor product splines.  
 franke - Franke's test function.

## 5.3 Control System Toolbox.

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#### Model building.

append - Append system dynamics.  
 augstate - Augment states as outputs.  
 blkbuild - Build state-space system from block diagram.  
 cloop - Close loops of system.  
 connect - Block diagram modeling.  
 conv - Convolution of two polynomials.  
 destim - Form discrete state estimator from gain matrix.  
 dreg - Form discrete controller/estimator from gain

#### matrices.

drmodel - Generate random discrete model.  
 estim - Form continuous state estimator from gain matrix.  
 feedback - Feedback system connection.  
 ord2 - Generate A,B,C,D for a second-order system.  
 pade - Pade approximation to time delay.  
 parallel - Parallel system connection.  
 reg - Form continuous controller/estimator from gain

#### matrices.

rmodel - Generate random continuous model.  
 series - Series system connection.  
 ssdelete - Delete inputs, outputs, or states from model.  
 ssselect - Select subsystem from larger system.

#### Model conversions.

c2d - Continuous to discrete-time conversion.  
 c2dm - Continuous to discrete-time conversion with method.  
 c2dt - Continuous to discrete conversion with delay.  
 d2c - Discrete to continuous-time conversion.  
 d2cm - Discrete to continuous-time conversion with method.  
 poly - Roots to polynomial conversion.  
 residue - Partial fraction expansion.

ss2tf - State-space to transfer function conversion.  
ss2zp - State-space to zero-pole conversion.  
tf2ss - Transfer function to state-space conversion.  
tf2zp - Transfer function to zero-pole conversion.  
zp2tf - Zero-pole to transfer function conversion.  
zp2ss - Zero-pole to state-space conversion.

## Model reduction.

balreal - Balanced realization.  
dbalreal - Discrete balanced realization.  
dmodred - Discrete model order reduction.  
minreal - Minimal realization and pole-zero cancellation.  
modred - Model order reduction.

## Model realizations.

canon - Canonical form.  
ctrbf - Controllability staircase form.  
obsvf - Observability staircase form.  
ss2ss - Apply similarity transform.

## Model properties.

covar - Continuous covariance response to white noise.  
ctrb - Controllability matrix.  
damp - Damping factors and natural frequencies.  
dcgain - Continuous steady state (D.C.) gain.  
dcovar - Discrete covariance response to white noise.  
ddamp - Discrete damping factors and natural frequencies.  
ddcgain - Discrete steady state (D.C.) gain.  
dgram - Discrete controllability and observability gramians.  
dsort - Sort discrete eigenvalues by magnitude.  
eig - Eigenvalues and eigenvectors.  
esort - Sort continuous eigenvalues by real part.  
gram - Controllability and observability gramians.  
obsv - Observability matrix.  
printsys - Display system in formatted form.  
roots - Polynomial roots.  
tzero - Transmission zeros.  
tzero2 - Transmission zeros using random perturbation method.

## Time response.

dimpulse - Discrete unit sample response.  
dinitial - Discrete initial condition response.  
dlsim - Discrete simulation to arbitrary inputs.  
dstep - Discrete step response.  
filter - SISO z-transform simulation.  
impulse - Impulse response.  
initial - Continuous initial condition response.  
lsim - Continuous simulation to arbitrary inputs.  
ltitr - Low level time response function.  
step - Step response.  
stepfun - Step function.

## Frequency response.

bode - Bode plot (frequency response).  
dbode - Discrete Bode plot (frequency response).  
dnichols - Discrete Nichols plot.  
dnyquist - Discrete Nyquist plot.  
dsigma - Discrete singular value frequency plot.  
fbode - Fast Bode plot for continuous systems.  
freqs - Laplace-transform frequency response.  
freqz - Z-transform frequency response.  
ltifr - Low level frequency response function.  
margin - Gain and phase margins.  
nichols - Nichols plot.  
ngrid - Draw grid lines for Nichols plot.  
nyquist - Nyquist plot.

- sigma - Singular value frequency plot.
- Root locus.
- pzmap - Pole-zero map.
  - rlocfind - Interactive root locus gain determination.
  - rlocus - Evans root-locus.
  - sgrid - Draw continuous root locus  $\omega_n, z$  grid.
  - zgrid - Draw discrete root locus  $\omega_n, z$  grid.
- Gain selection.
- acker - SISO pole placement.
  - dlqe - Discrete linear-quadratic estimator design.
  - dlqew - General discrete linear quadratic estimator design.
  - dlqr - Discrete linear-quadratic regulator design.
  - dlqry - Discrete regulator design with weighting on outputs.
  - lqe - Linear-quadratic estimator design.
  - lqed - Discrete estimator design from continuous cost
- function.
- lqe2 - Linear quadratic estimator design using Schur method.
  - lqew - General linear-quadratic estimator design.
  - lqr - Linear-quadratic regulator design.
  - lqrd - Discrete regulator design from continuous cost
- function.
- lqry - Regulator design with weighting on outputs.
  - lqr2 - Linear quadratic regulator design using Schur method.
  - place - Pole placement.
- Equation solution.
- are - Algebraic Riccati equation solution.
  - dlyap - Discrete Lyapunov equation solution.
  - lyap - Continuous Lyapunov equation solution.
  - lyap2 - Lyapunov equation solution using diagonalization.
- Demonstrations.
- ctrldemo - Introduction to the Control Toolbox.
  - boildemo - LQG design of boiler system.
  - jetdemo - Classical design of jet transport yaw damper.
  - diskdemo - Digital control design of hard disk controller.
  - kalmdemo - Kalman filter design and simulation.

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