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Matlab Cheatsheet

How to represent polynomials in Matlab?

Representation of polynomials in MATLAB Since most practical z-transforms are a ratio of polynomials, we start by explaining how MATLAB handles polynomials. In MATLAB polynomials are represented by *row* vectors containing the coefficients of the polynomial in decreasing order. For example, the polynomial

$$B(z) = 1 + 2z^{-1} + 3z^{-3}$$

is entered as `b=[1,2,0,3]`. We stress that even though the coefficient of the z^{-2} term

```
b = [1 2 0 3]
```

```
b = 1×4
     1     2     0     3
```

How to extract coefficients from polynomials?

Suppose we want to automatically get the coefficients of the following polynomial:

$H(z) = -8 + 10z^{-1} - 3z^{-2} - \frac{1}{2}z^{-3} + \frac{1}{4}z^{-4}$

```
syms z;
H = -8 + 10*z^-1 - 3*z^-2 - 1/2*z^-3 + 1/4*z^-4;
H_b = coeffs(expand(H * z^4), 'all')
```

H_b =

$$\begin{pmatrix} -8 & 10 & -3 & -\frac{1}{2} & \frac{1}{4} \end{pmatrix}$$

Representation of polynomials in MATLAB Since most practical z-transforms are a ratio of polynomials, we start by explaining how MATLAB handles polynomials. In MATLAB polynomials are represented by *row* vectors containing the coefficients of the polynomial in decreasing order. For example, the polynomial

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```
B = 1 + 2*z^-1 + 3*z^-3;
B_b = coeffs(expand(B * z^3), 'all')
```

B_b = $\begin{pmatrix} 1 & 2 & 0 & 3 \end{pmatrix}$

How to compute the roots of a polynomial?

```
b = [1 1.5 2];
z = roots(b)
```

```
z = 2×1 complex
  -0.7500 + 1.1990i
  -0.7500 - 1.1990i
```

How to compute zero-pole representation of a transfer function?

Suppose we have the transfer function of a FIR filter:

$H(z) = 1 + 4.5z^{-1} + 2z^{-2}$

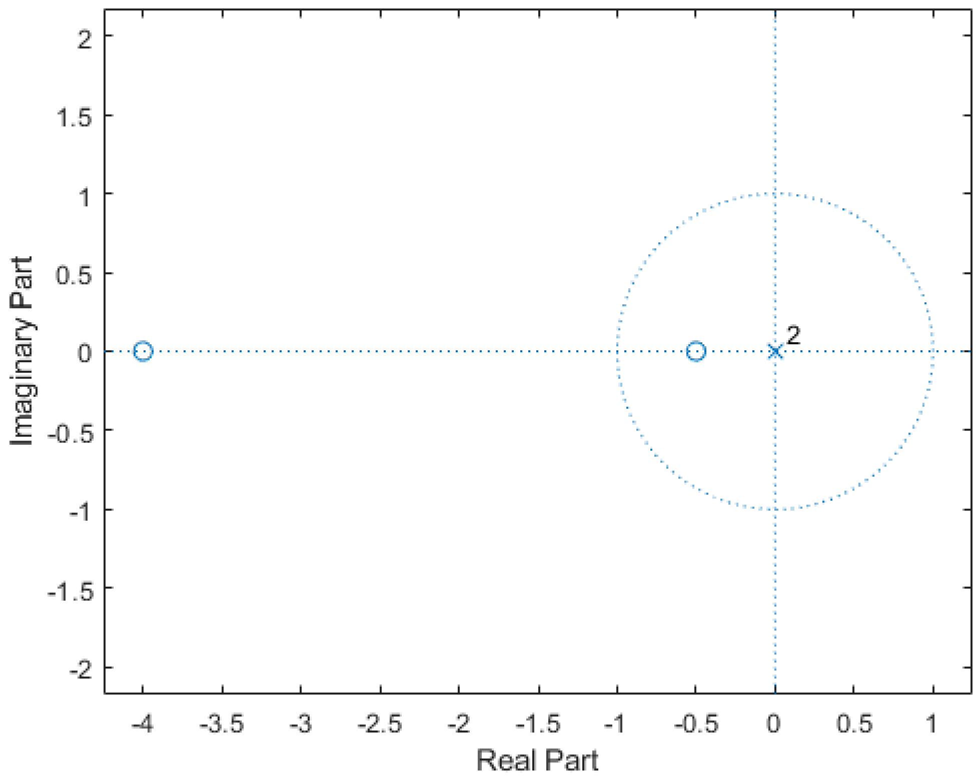
Step 1: find the zeros:

```
zeros = roots([1, 4.5, 2])
```

```
zeros = 2×1
   -4.0000
   -0.5000
```

We can see that there are two zeros at (-4, 0) and (-0.5, 0). Let us visualise it:

```
zplane([1, 4.5, 2]);
```



Step 2: use the formula $H(z) = b_0 \prod_k (1 - z_k z^{-1})$

$H(z) = 1(1 + 4z^{-1})(1 + 0.5z^{-1})$

How to compute partial fraction expansion?

Example 3.10 Partial fraction expansion using `residuez`

The following expansion:

$$X(z) = \frac{6 - 10z^{-1} + 2z^{-2}}{1 - 3z^{-1} + 2z^{-2}} = 1 + \frac{2}{1 - z^{-1}} + \frac{3}{1 - 2z^{-1}}, \tag{3.45}$$

is obtained by calling `residuez` with `b=[6,-10,2]` and `a=[1,-3,2]`. The reverse operation can be done using the same function as: `[b,a]=residuez(A,p,C)`.

```
b = [ 6 -10  2];
a = [ 1  -3  2];
```

```
% Partial fraction expansion using residuez
[A,p,C] = residuez(b, a)
```

```
A = 2×1
     3
     2
p = 2×1
     2
     1
C = 1
```

```
% Reverse operation
[b, a] = residuez(A, p, C)
```

```
b = 1×3
     6   -10     2
a = 1×3
     1    -3     2
```

How to perform polynomial multiplication?

Polynomial multiplication in MATLAB The convolution theorem (3.52) shows that polynomial multiplication is equivalent to convolution. Therefore, to compute the product

$$B(z) = (1 + 2z^{-2})(1 + 4z^{-1} + 2z^{-2} + 3z^{-3})$$
$$= 1 + 4z^{-1} + 4z^{-2} + 11z^{-3} + 4z^{-4} + 6z^{-5},$$

we use the function

```
>> b=conv([1 0 2],[1 4 2 3])
b =
     1     4     4    11     4     6
```

to find the coefficients of $B(z)$.

How to convert a transfer function $H(z)$ to its frequency response $H(e^{j\omega})$?

Suppose we have the following transfer function:

$$H(z) = \frac{0.05634(1 + z^{-1})(1 - 1.0166z^{-1} + z^{-2})}{(1 - 0.683z^{-1})(1 - 1.4461z^{-1} + 0.7957z^{-2})}$$

We can express the numerator and denominator as polynomial convolutions:

```
b0 = 0.05634;
b1 = [1  1];
b2 = [1 -1.0166 1];
```

```
a1 = [1 -0.683];
a2 = [1 -1.4461 0.7957];

b = b0*conv(b1,b2);
a = conv(a1,a2);
```

We can use the freqz function to get the frequency response as a vector. The second output variable w is the angular frequencies.

```
[H,w] = freqz(b,a);
```

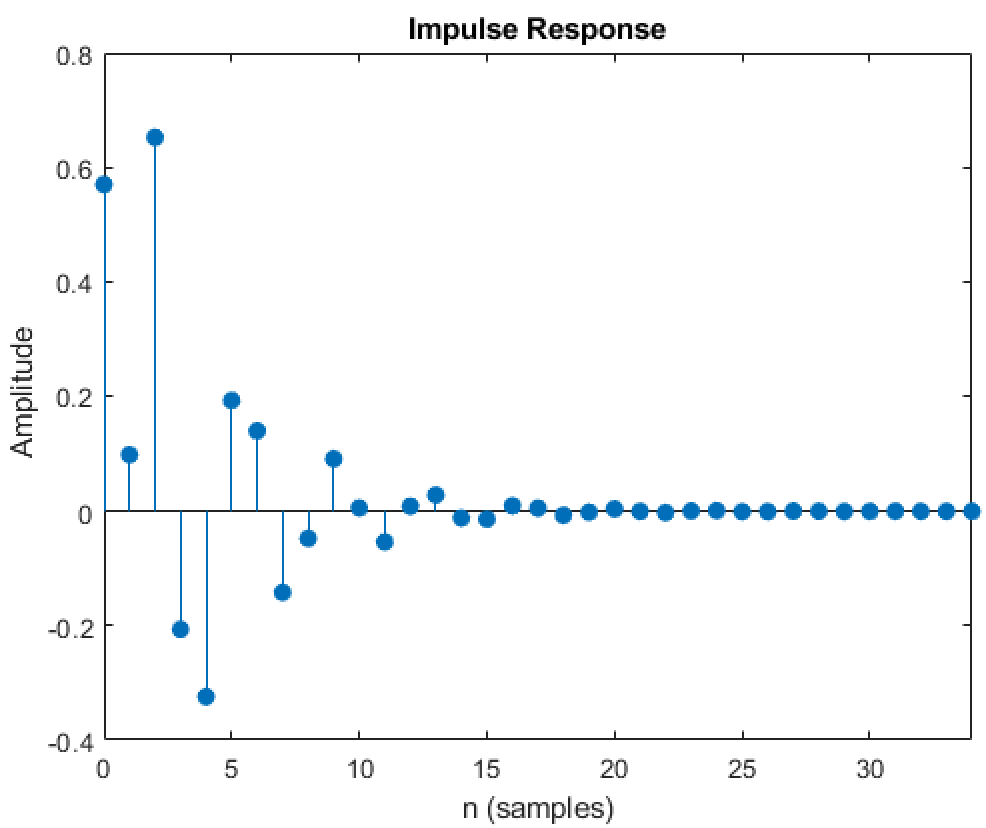
How to plot the impulse reponse from a transfer function?

Suppose we have the following transfer function:

$$H(z) = \frac{0.57 + 0.23z^{-1} + z^{-2}}{1 + 0.23z^{-1} + 0.57z^{-2}}$$

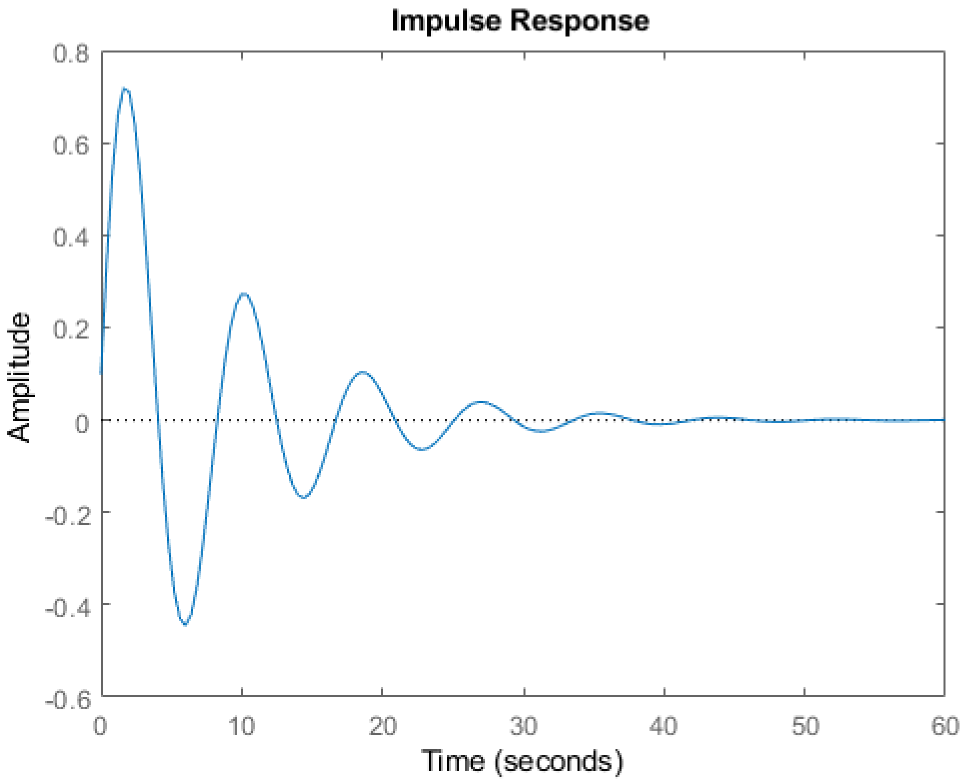
We can use the impz function:

```
b = [0.57, 0.23, 1];
a = [1, 0.23, 0.57];
impz(b, a);
```



Alternatively,

```
b = [0.57, 0.23, 1];
a = [1, 0.23, 0.57];
h = tf(b, a);
impulseplot(h);
```



How to compute the group delay?

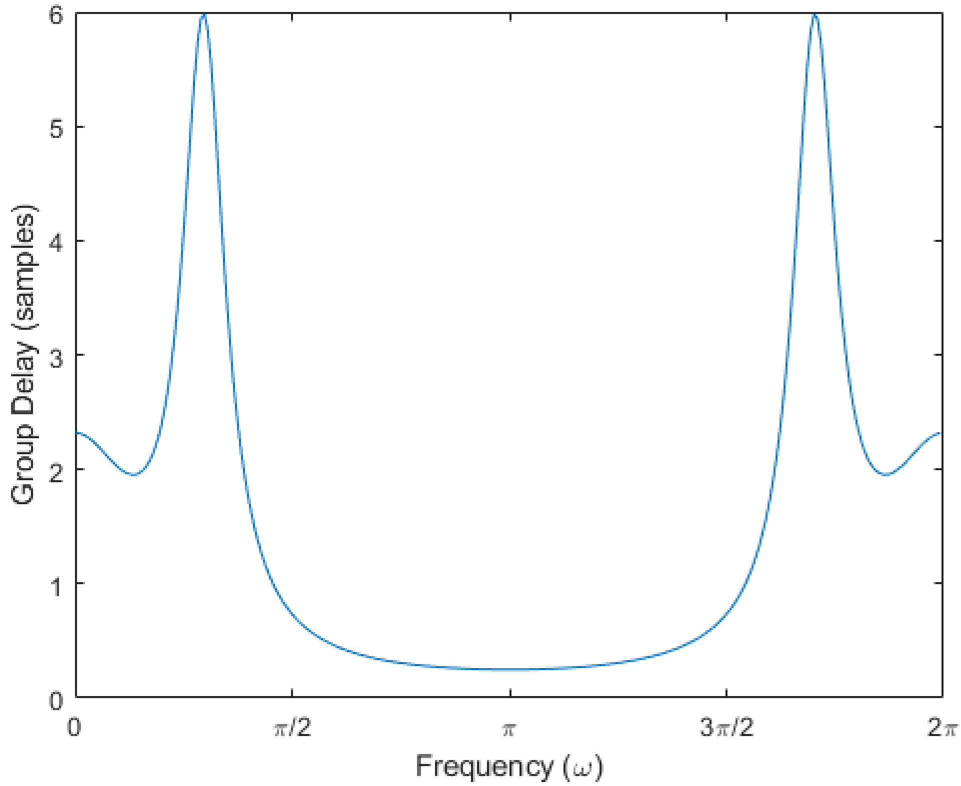
Suppose we have the following transfer function:

$$H(z) = \frac{1 + 1.655z^{-1} + 1.655z^{-2} + z^{-3}}{1 - 1.57z^{-1} + 1.264z^{-2} - 0.4z^{-3}},$$

```
b = [1, 1.655, 1.655, 1];
a = [1, -1.57, 1.264, -0.4];
[gd, w] = grpdelay(b, a, 255, 'whole');

plot(w, gd);
set(gca,'XTick',0:pi/2:2*pi)
set(gca,'XTickLabel',{'0','\pi/2','\pi','3\pi/2','2\pi'})
xlabel('Frequency (\omega)')
```

```
ylabel('Group Delay (samples)')
xlim([0, 2*pi]);
```

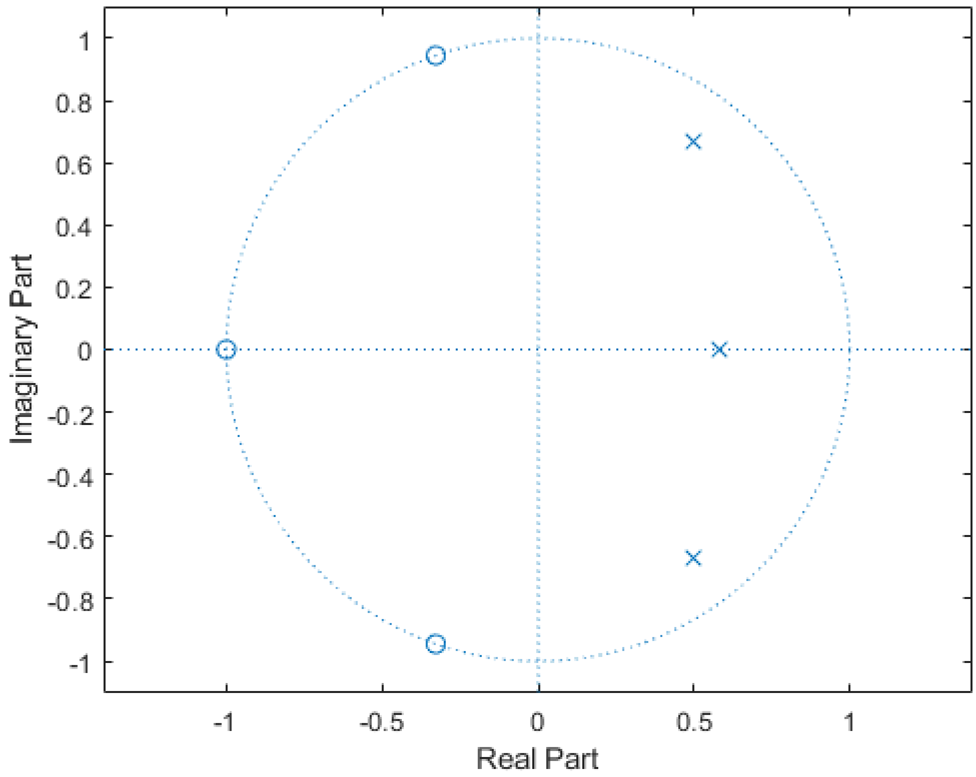


How to plot the zeros and poles?

Suppose we have the following transfer function:

$$H(z) = \frac{1 + 1.655z^{-1} + 1.655z^{-2} + z^{-3}}{1 - 1.57z^{-1} + 1.264z^{-2} - 0.4z^{-3}},$$

```
b = [1, 1.655, 1.655, 1];
a = [1, -1.57, 1.264, -0.4];
zplane(b, a);
```



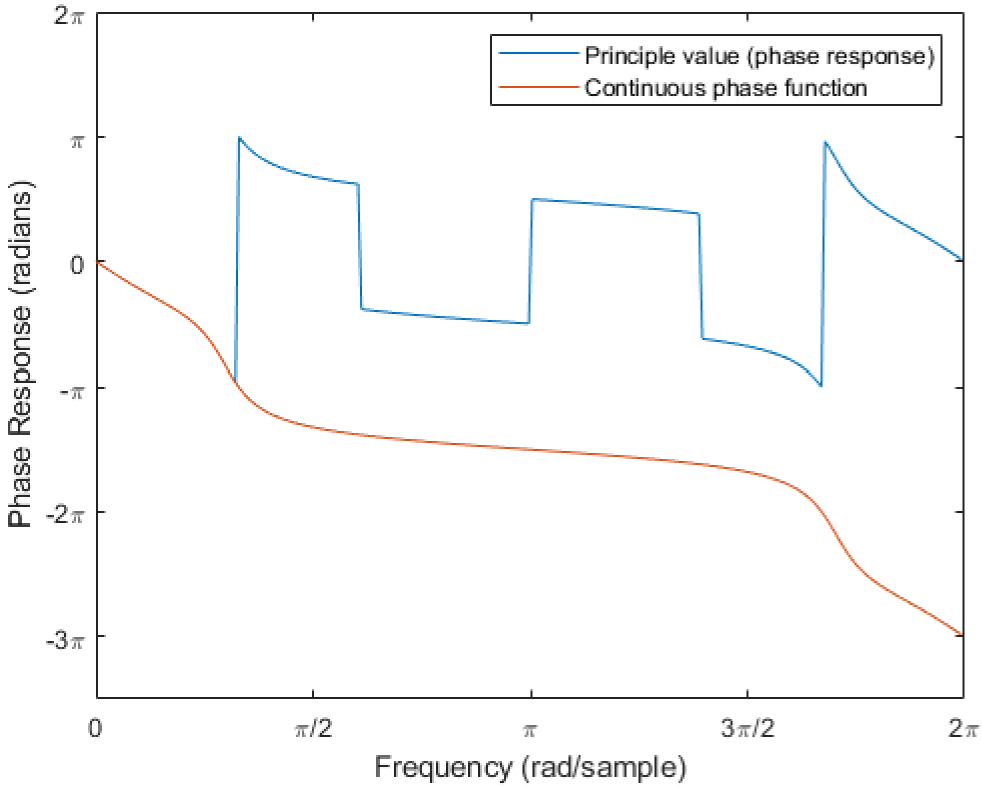
How to plot phase response (principle value) and continuos phase function?

Suppose we have the following transfer function:

$$H(z) = \frac{1 + 1.655z^{-1} + 1.655z^{-2} + z^{-3}}{1 - 1.57z^{-1} + 1.264z^{-2} - 0.4z^{-3}},$$

```
b = [1, 1.655, 1.655, 1];
a = [1, -1.57, 1.264, -0.4];

[gd, w] = grpdelay(b, a, 255, 'whole');
[H, w] = freqz(b, a, 255, 'whole');
plot(w, angle(H), w, contphase(gd, w));
legend('Principle value (phase response)','Continuous phase function')
set(gca,'XTick',0:pi/2:2*pi)
set(gca,'XTickLabel',{'0','\pi/2','\pi','3\pi/2','2\pi'})
set(gca,'YTick', -3*pi:pi:3*pi)
set(gca,'YTickLabel',{'-3\pi', '-2\pi', '-\pi', '0','\pi','2\pi', '3\pi'})
xlabel('Frequency (rad/sample)')
ylabel('Phase Response (radians)')
xlim([0, 2*pi]);
ylim([-3.5*pi, 2*pi]);
```

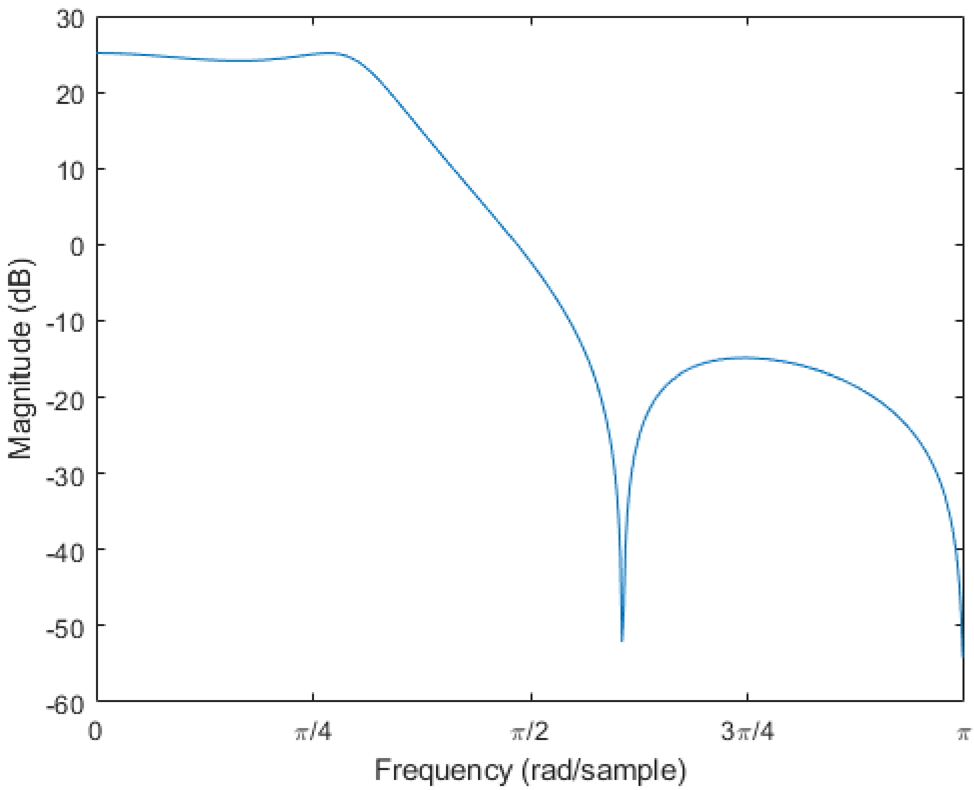


How to plot the magnitude response?

Suppose we have the following transfer function:

$$H(z) = \frac{1 + 1.655z^{-1} + 1.655z^{-2} + z^{-3}}{1 - 1.57z^{-1} + 1.264z^{-2} - 0.4z^{-3}},$$

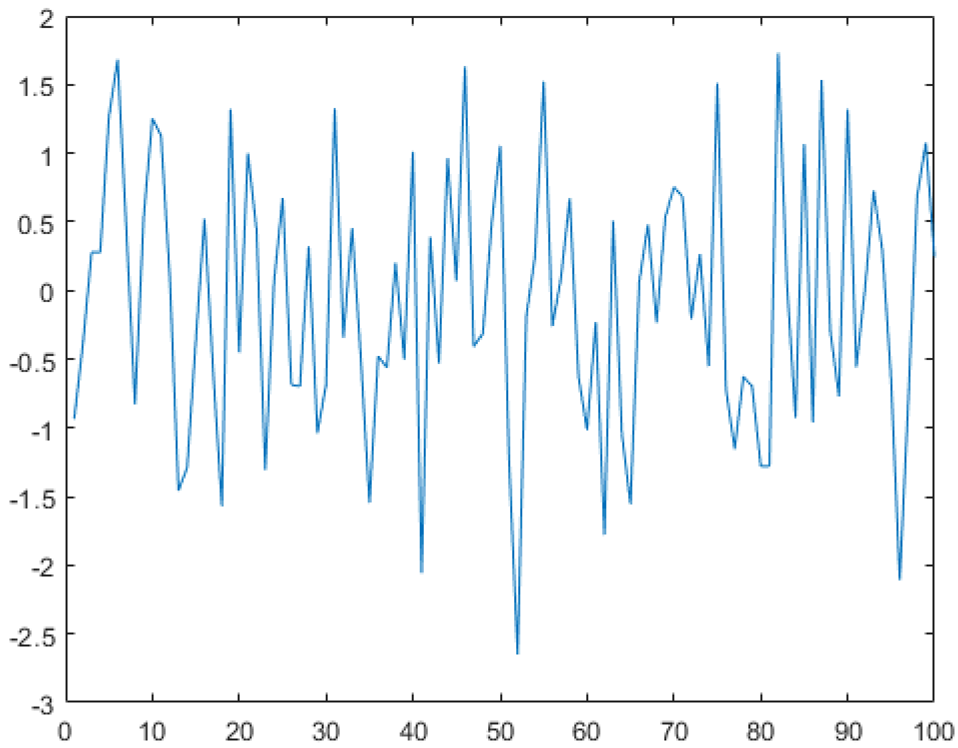
```
b = [1, 1.655, 1.655, 1];
a = [1, -1.57, 1.264, -0.4];
[H, w] = freqz(b, a);
plot(w, pow2db(H.*conj(H)));
set(gca,'XTick', 0:pi/4:pi)
set(gca,'XTickLabel', {'0','\pi/4','\pi/2','3\pi/4','\pi'})
xlabel('Frequency (rad/sample)')
ylabel('Magnitude (dB)')
xlim([0, pi]);
```



How to generate white Gaussian noise?

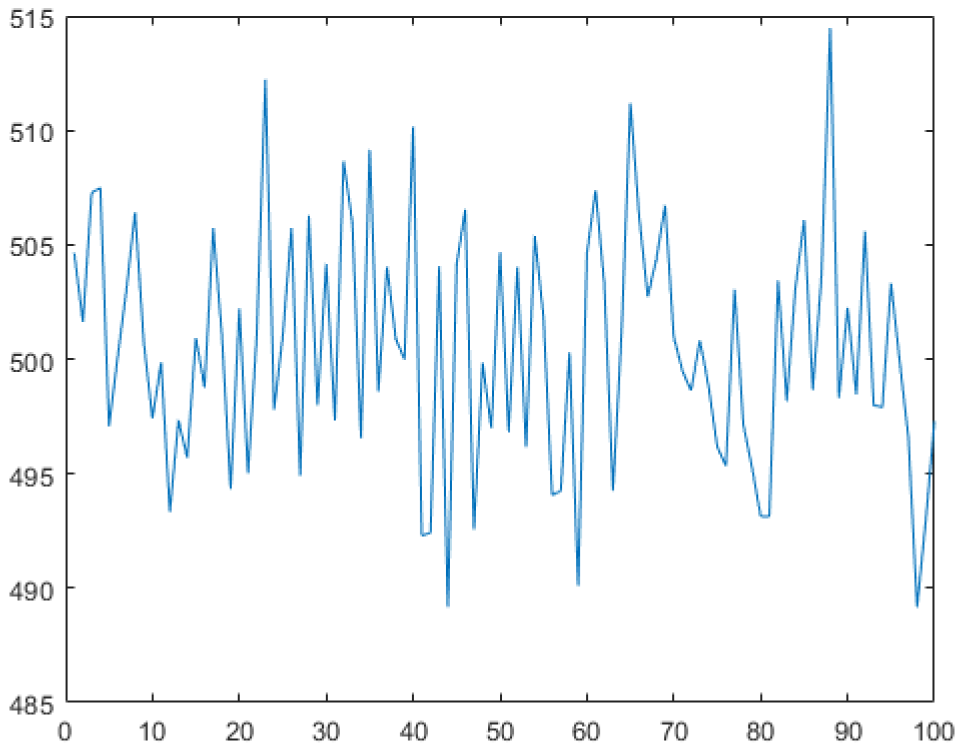
Use the function wgn.

```
N = 100;
n = [1:N];
x = wgn(N,1,0);
plot(n, x)
```



Create a vector of 1000 random values drawn from a normal distribution with a mean of 500 and a standard deviation of 5.

```
std_dev = 5;
mu = 500;
w = std_dev.*randn(N,1) + mu;
plot(n, w)
```




```
% Calculate the sample mean, standard deviation, and variance.
stats = [mean(w) std(w) var(w)]
```

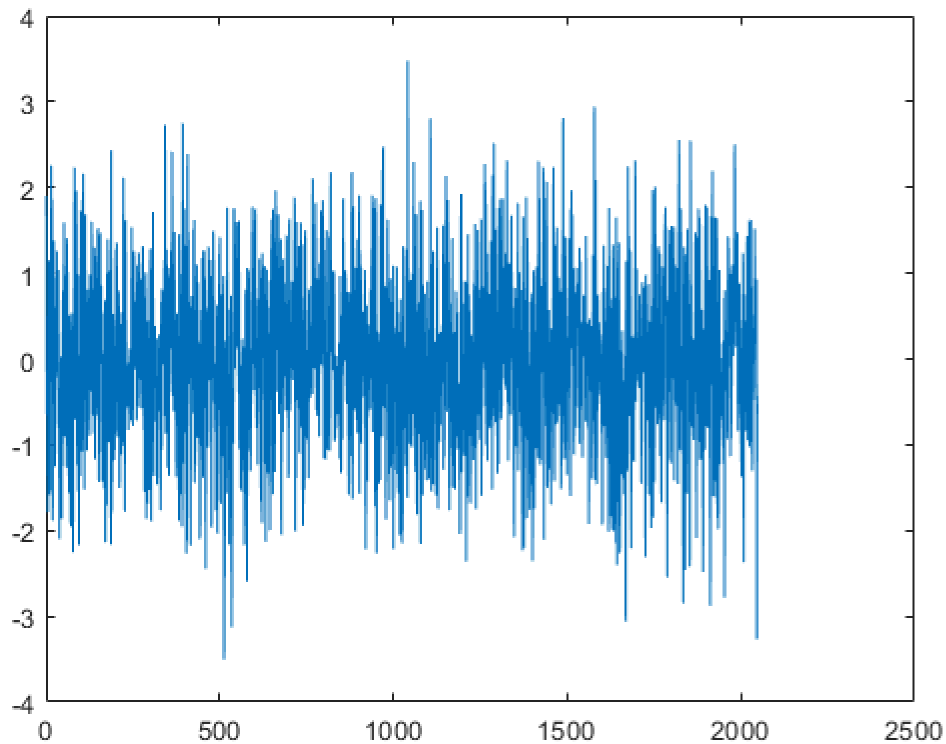
```
stats = 1×3
  500.4948    5.1767   26.7987
```

The mean and variance are not 500 and 25 exactly because they are calculated from a sampling of the distribution.

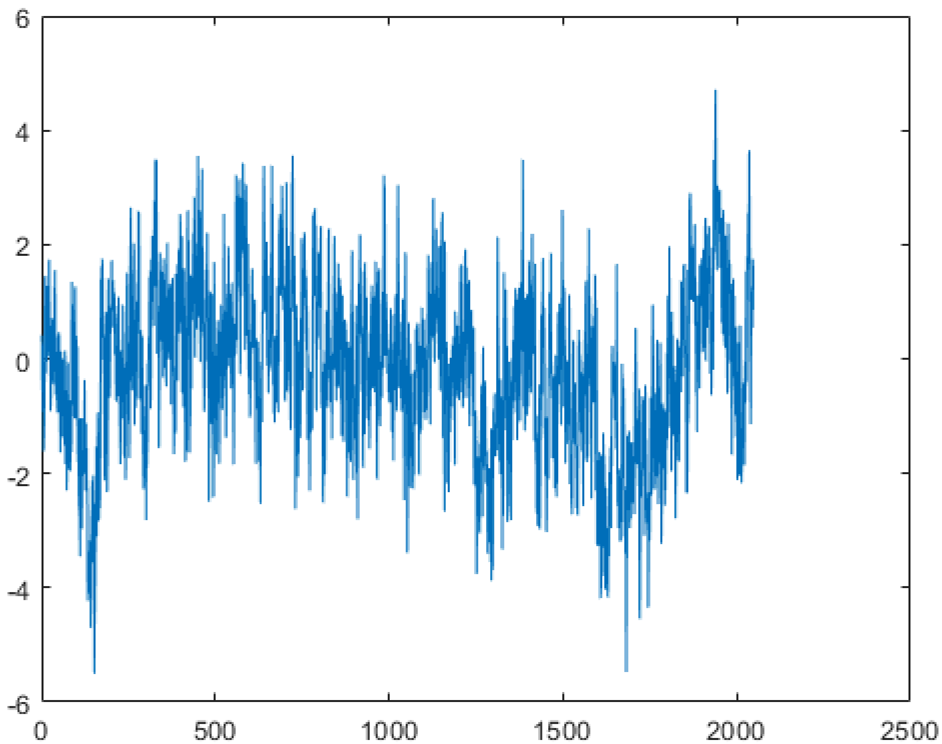
How to generate coloured noise?

```
N = 2048;

% Slight coloured noise
x1 = step(dsp.ColoredNoise('InverseFrequencyPower', 0.1, 'SamplesPerFrame', N));
plot(x1);
```




```
% Very coloured noise (Pink noise)
x1 = step(dsp.ColoredNoise('InverseFrequencyPower', 1, 'SamplesPerFrame', N));
plot(x1);
```



How to generate random value from uniform distribution?

By default, `rand` returns normalized values (between 0 and 1) that are drawn from a uniform distribution. To change the range of the distribution to a new range, (*a*, *b*), multiply each value by the width of the new range, (*b* – *a*) and then shift every value by *a*.

```
a = 50;
b = 100;
r = (b-a).*rand(4, 1) + a
```

```
r = 4×1
   52.2526
   86.1587
   67.3719
   83.0308
```

Generate a random value for the uniform distribution $\phi \sim U(0, 2\pi)$:

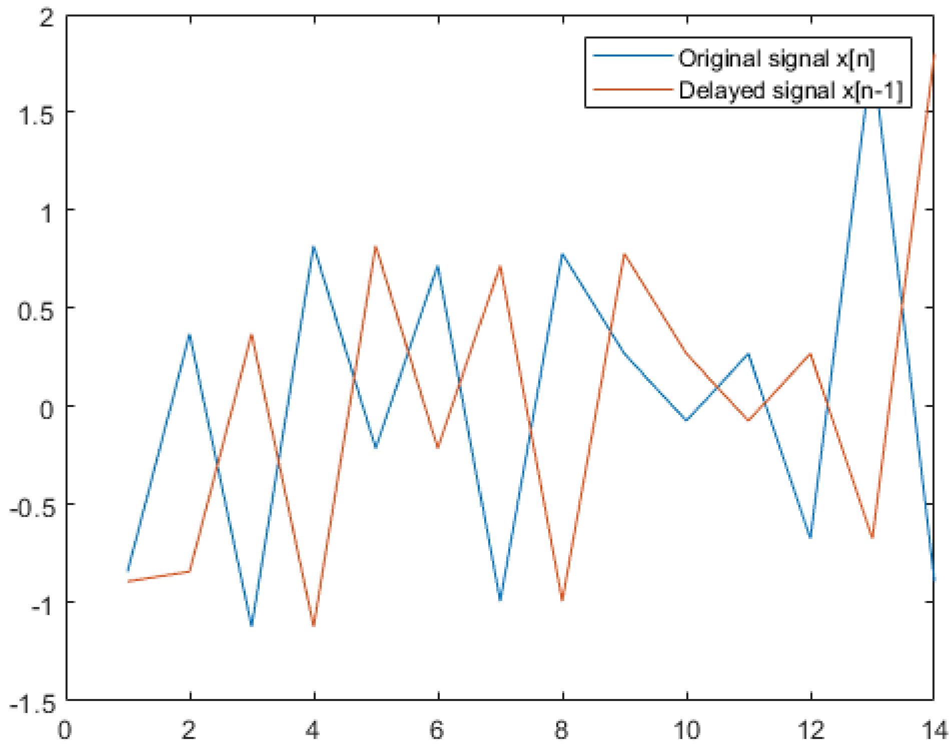
```
phi = 2*pi*rand()
```

```
phi = 2.4119
```

How to delay a signal?

Use the circshift function.

```
delay = 1;
x = [-0.84, 0.37, -1.12, 0.82, -0.21, 0.72, -0.99, 0.78, 0.27, -0.07, 0.27, -0.67, 1.80, -0.89]
N = numel(x);
n = [1:N];
plot(n, x, n, circshift(x, delay))
legend('Original signal x[n]', strcat('Delayed signal x[n-', num2str(delay), ']'))
```



Functions

```
function cph=contphase(grd,om)
% Computation of continuous phase function
% from equidistant values of group delay
  N=length(om);
  dom=om(2)-om(1);
  p(1)=0;
  for k=2:N
```

```
    p(k)=p(k-1)+dom*(grd(k-1)+grd(k))/2;
  end
  cph=-p;
end
```