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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 = 1x4
    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 =

$$\left(-8 \quad 10 \quad -3 \quad -\frac{1}{2} \quad \frac{1}{4}\right)$$

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

B_b = (1 2 0 3)

How to compute the roots of a polynomial?

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

```
z = 2x1 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:

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

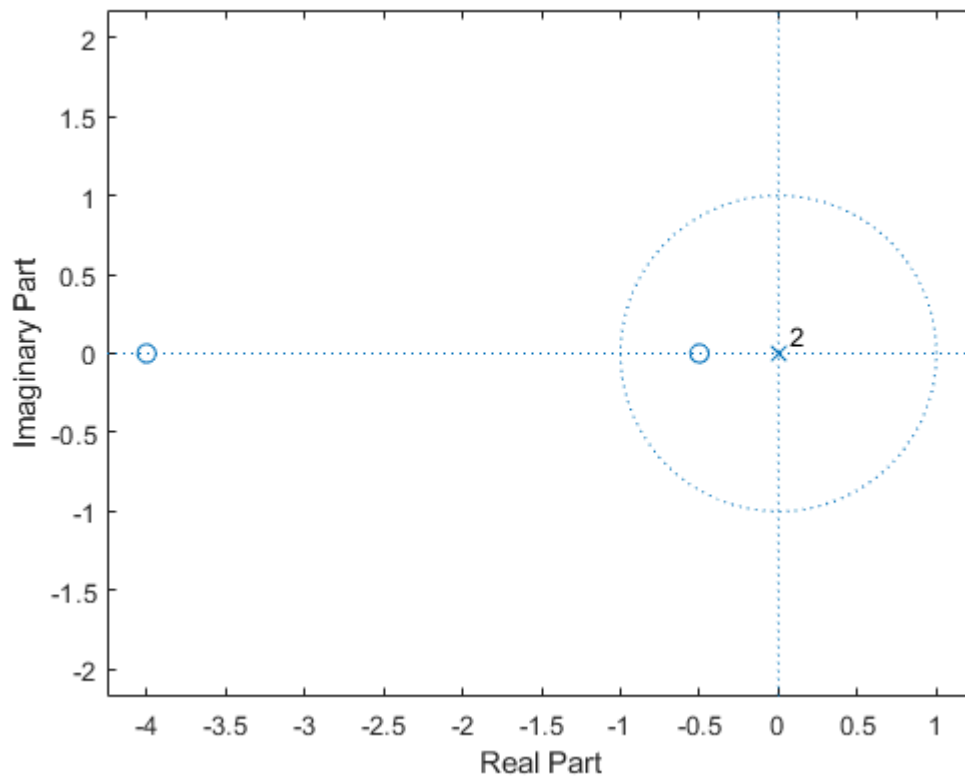
Step 1: find the zeros:

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

```
zeros = 2x1
-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:

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

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 = 2x1
```

```

      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

$$\begin{aligned}
 B(z) &= (1 + 2z^{-2})(1 + 4z^{-1} + 2z^{-2} + 3z^{-3}) \\
 &= 1 + 4z^{-1} + 4z^{-2} + 11z^{-3} + 4z^{-4} + 6z^{-5},
 \end{aligned}$$

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);
```

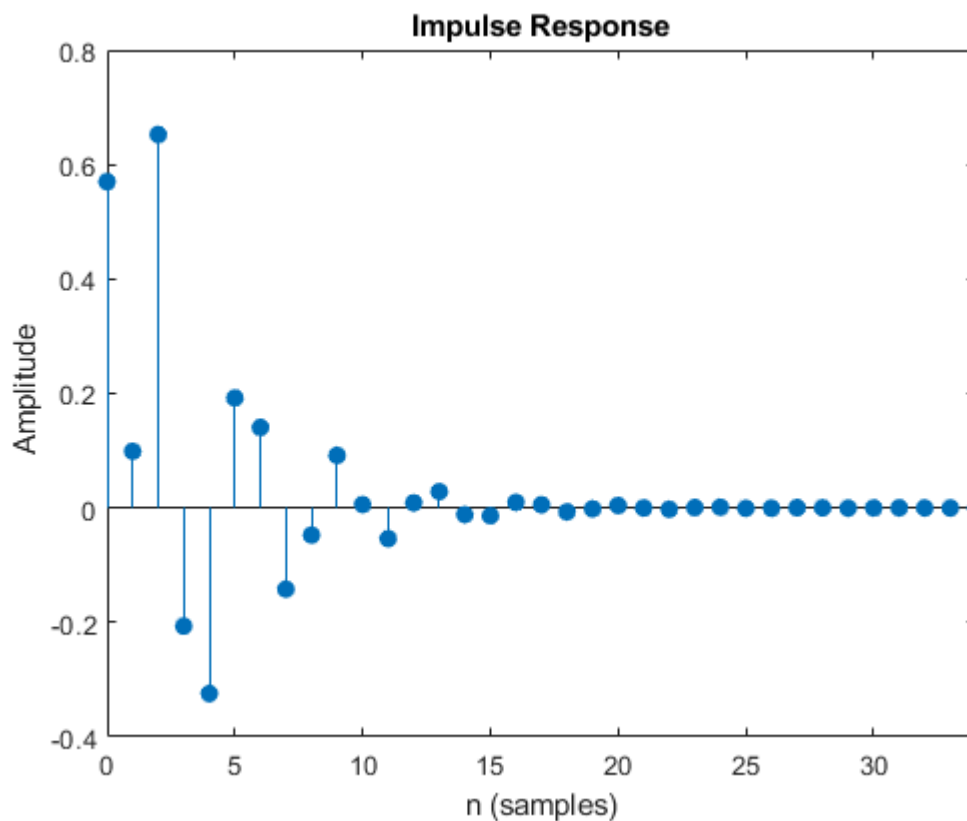
How to plot the impulse response from a transfer function?

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:

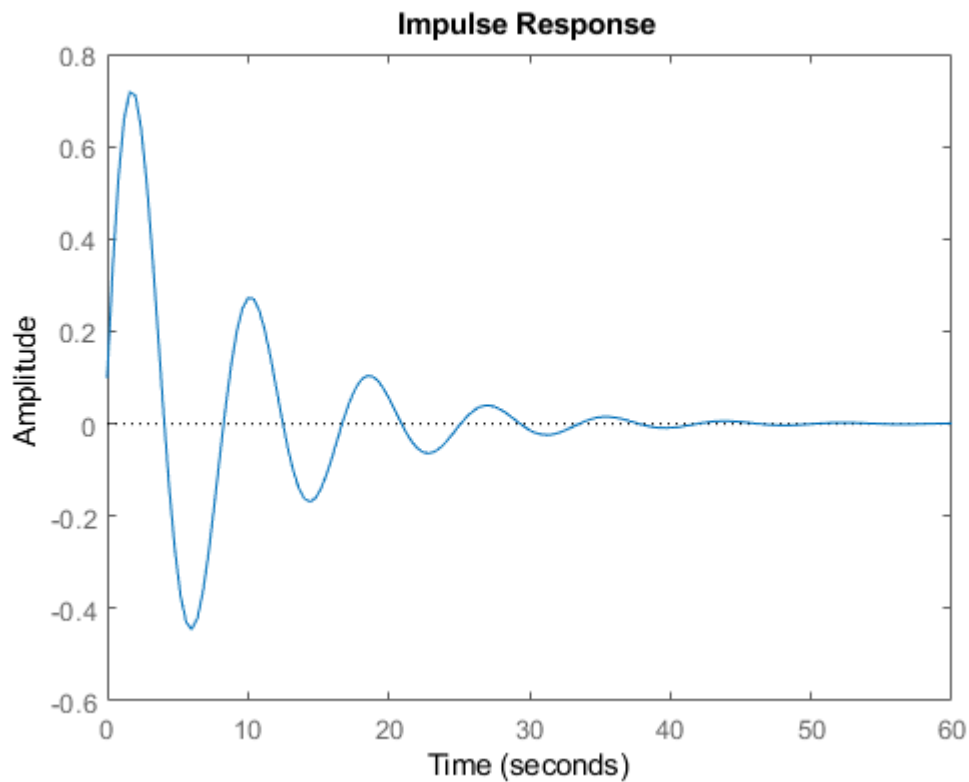
```
b = [0.57, 0.23, 1];  
a = [1, 0.23, 0.57];  
impz(b, a);
```



Alternatively,

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

```
impzplot(h);
```

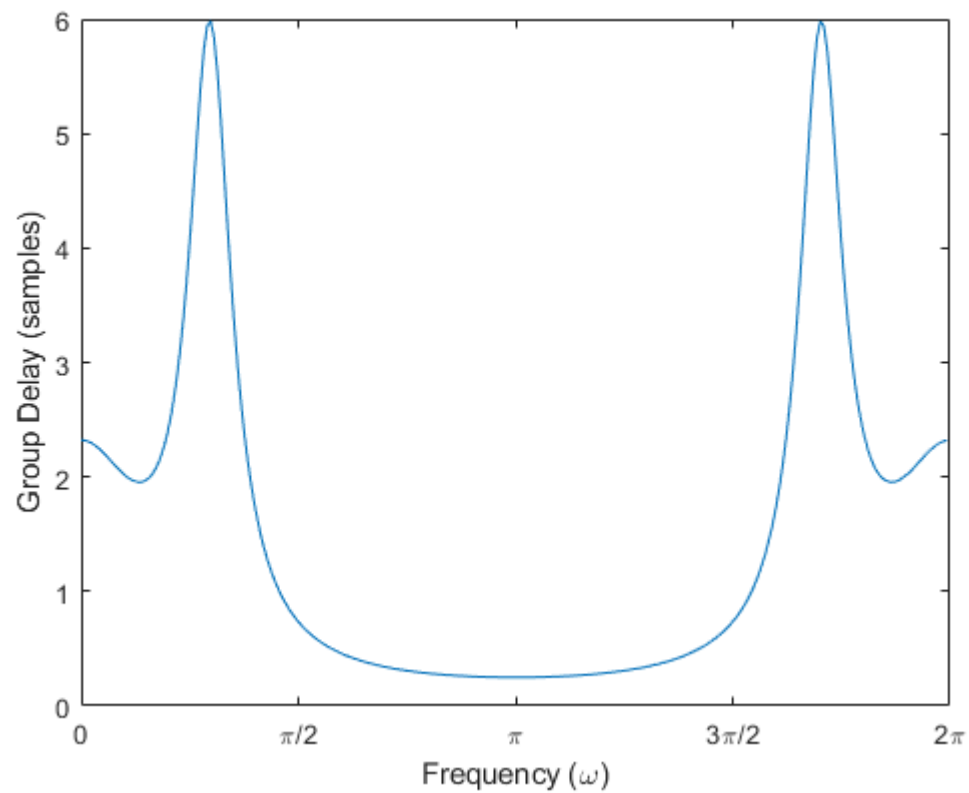


How to compute the group delay?

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]);
```

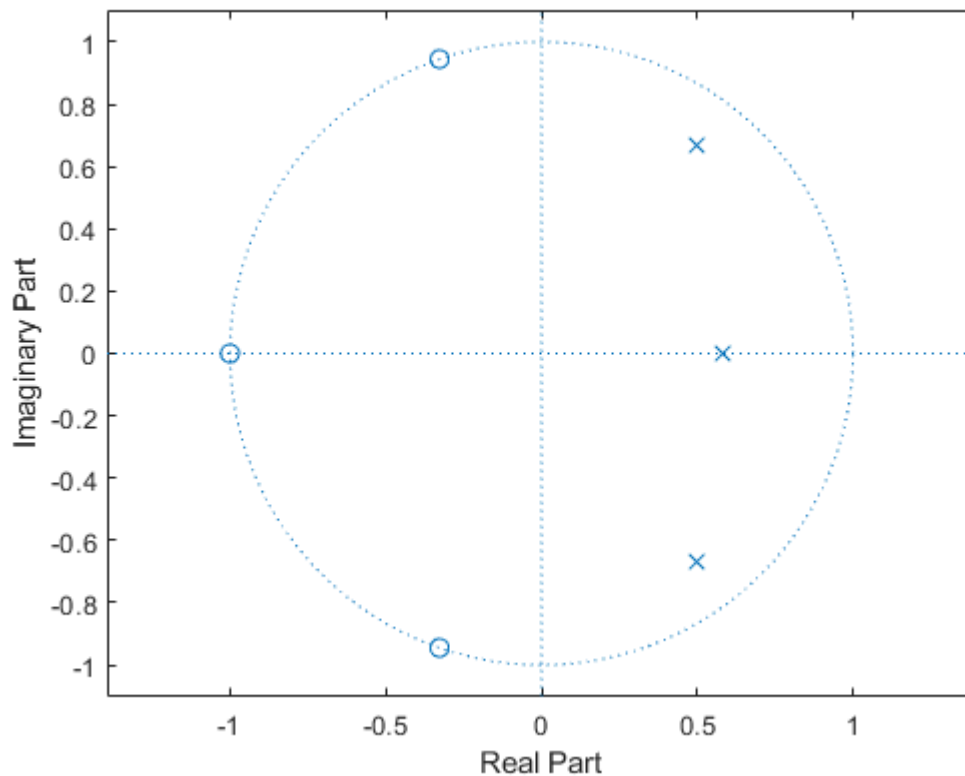


How to plot the zeros and poles?

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);
```



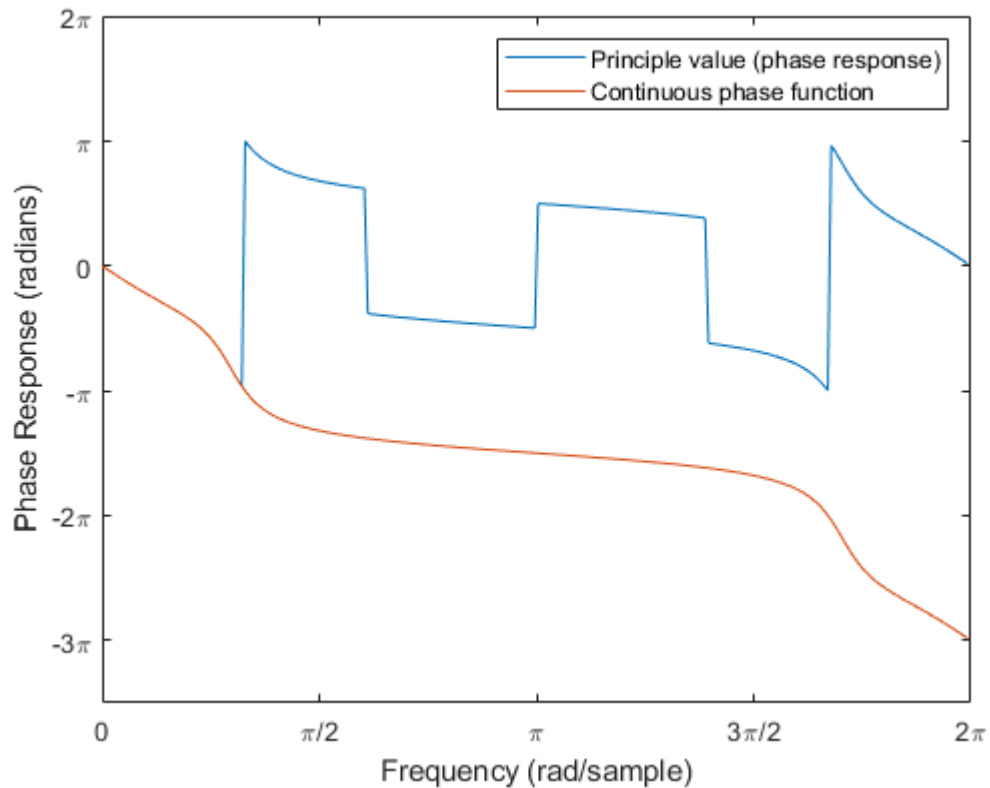
How to plot phase response (principle value) and continuous phase function?

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]);
```

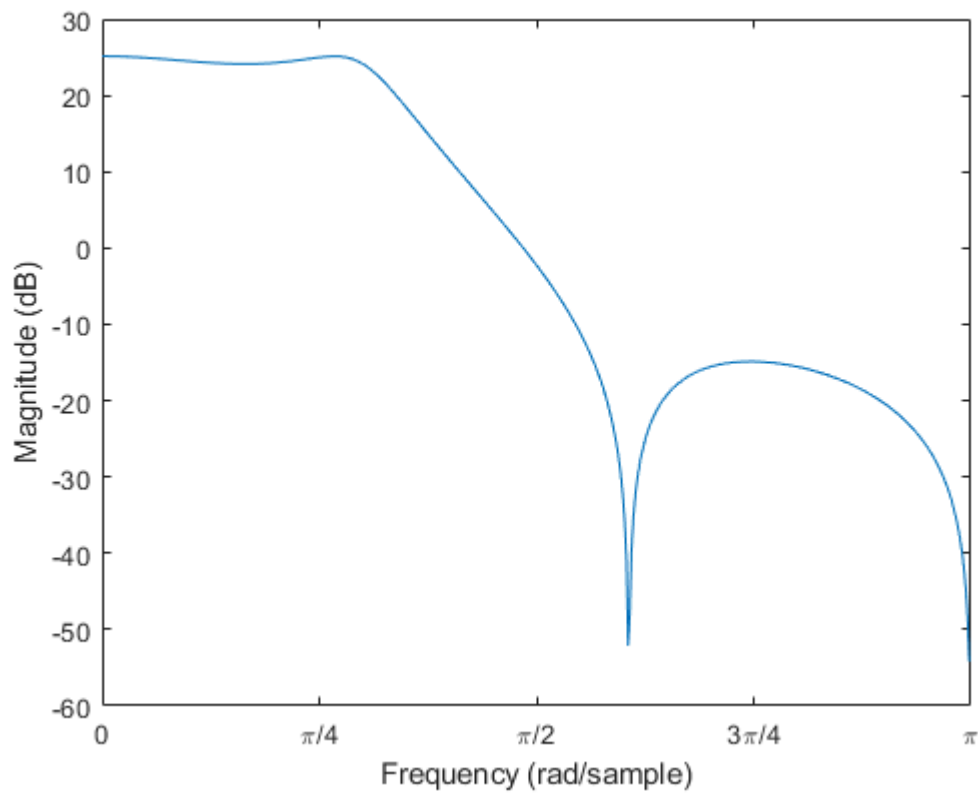



How to plot the magnitude response?

Suppose we have the following transfer function:

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

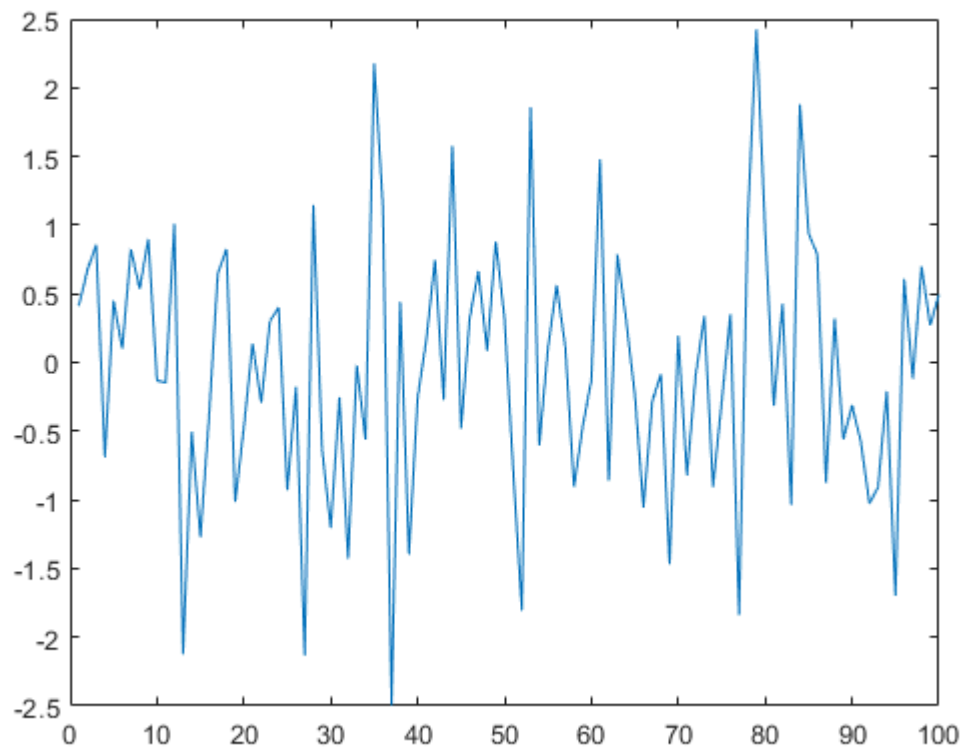
```
b = [1, 1.655, 1.655, 1];
a = [1, -1.57, 1.264, -0.4];
[H, w] = freqz(b, a);
plot(w, pow2db(H.*conj(H)));
set(gca, 'XTick', 0:pi/4:pi);
set(gca, 'XTickLabel', {'0', '\pi/4', '\pi/2', '3\pi/4', '\pi'});
xlabel('Frequency (rad/sample)');
ylabel('Magnitude (dB)');
xlim([0, pi]);
```



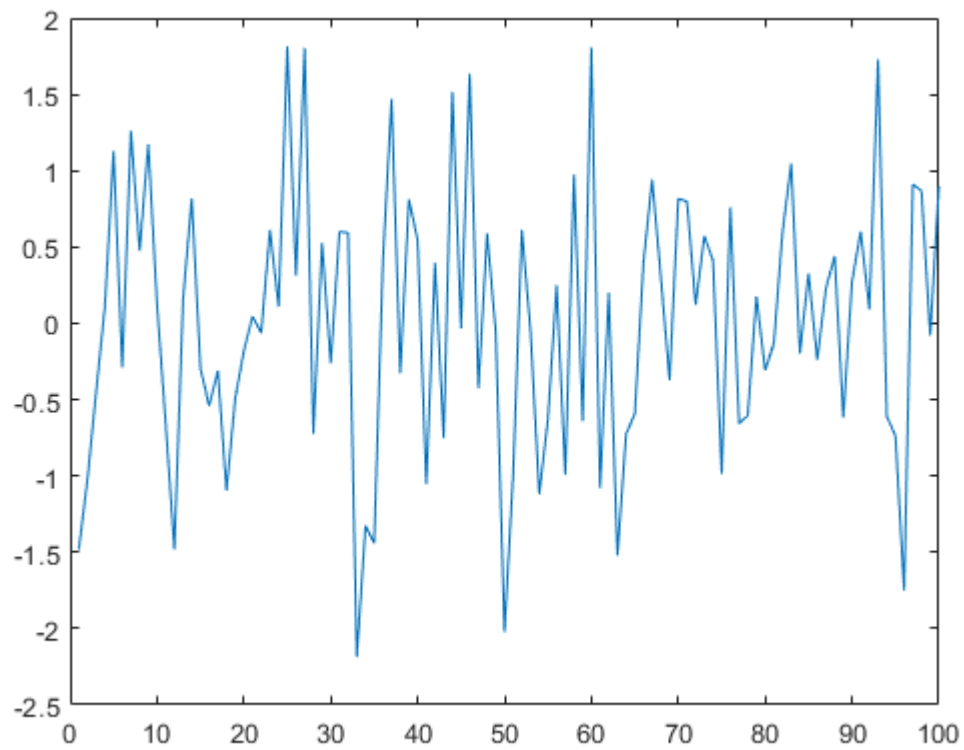
How to generate white Gaussian noise?

Use the function `wgn`.

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



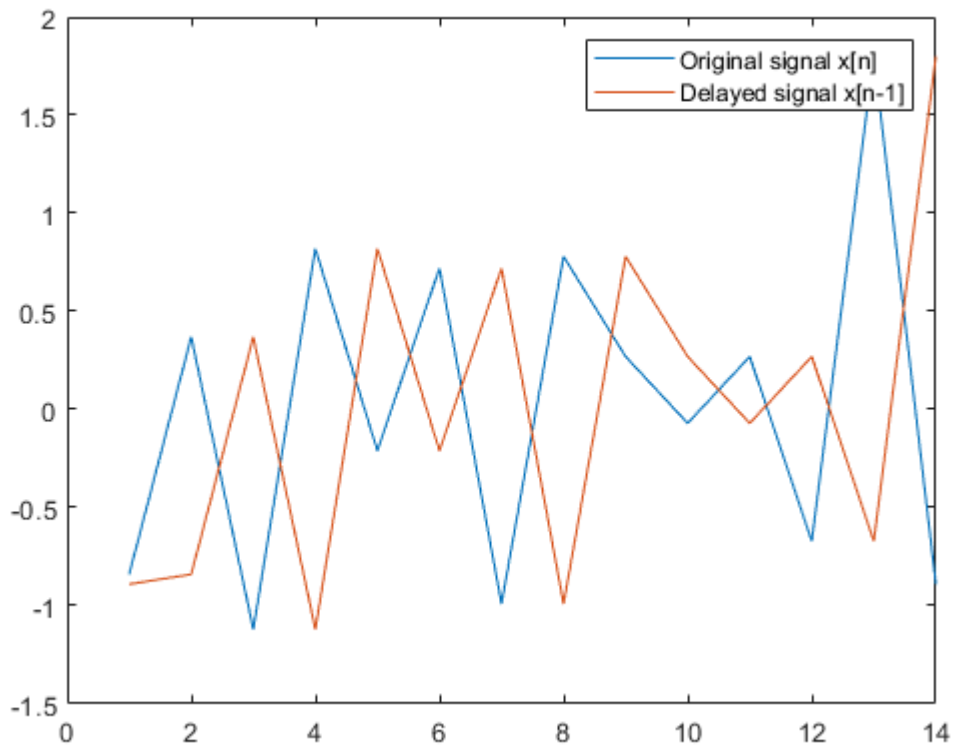
```
w = randn(N,1);  
plot(n, w)
```



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
```