2.1-5 For each of the following transfer functions, determine and plot the poles and zeros of $H(s)$, and use the pole and zero information to predict overall system behavior. Confirm your predictions by graphing the system's frequency response (magnitude and phase).

(c) $H(s) = \dfrac{0.03s^4+1.76s^2+15.22}{s^4+2.32s^3+9.79s^2+13.11s+17.08}$

Using MATLAB,

```
num = [0.03 0 1.76 0 15.22];
den = [1 2.32 9.79 13.11 17.08];

H = tf(num,den);
Hp = pole(H)
Hz = zero(H)

subplot(3,1,1);
pzplot(H); axis([-1 1 -8 8]);
```

Command Window

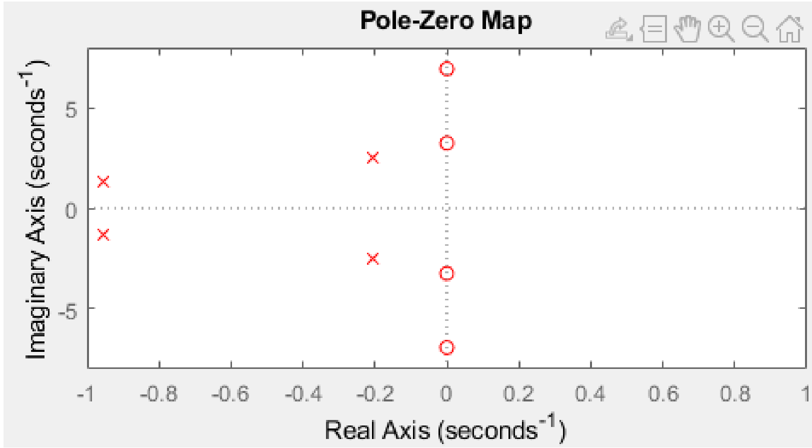
```
>> C2_1_5c

Hp =

  -0.2063 + 2.4986i
  -0.2063 - 2.4986i
  -0.9537 + 1.3446i
  -0.9537 - 1.3446i


Hz =

   0.0000 + 6.9372i
   0.0000 - 6.9372i
   0.0000 + 3.2469i
   0.0000 - 3.2469i
```



From looking at the P/Z Map we can see that

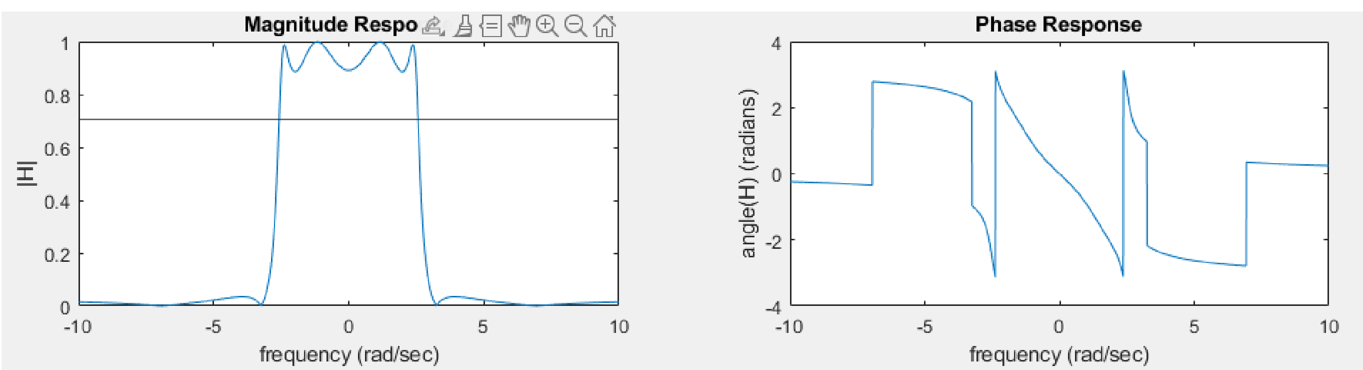
- As omega goes to infinity |H(s)| = 0
- There are some poles close to omega = 0 rad/sec (DC)

From this I would assume

- This transfer function has low pass-ish characteristics. Looking at the graph I would make a guess that it passes frequencies in the 0 – 2 rad/sec band
- Difficult to guess what type of phase response this T.F. just by looking at the P/Z Map

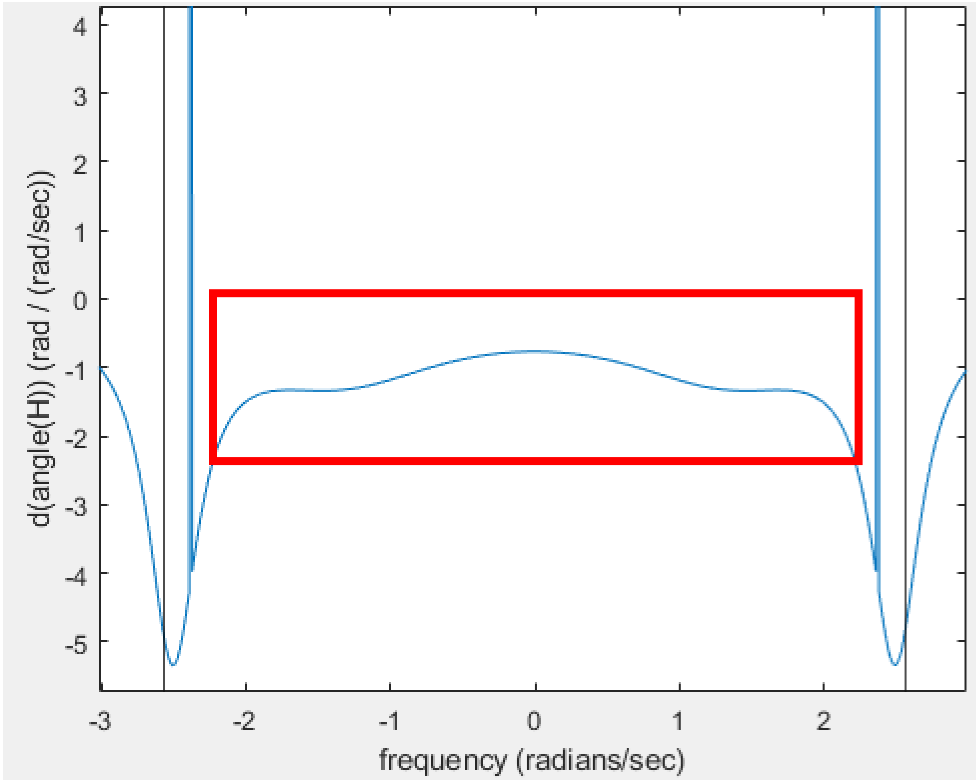
In MATLAB,

```
w = -10:0.1:10;
s = j*w;
H = (0.03.*s.^4 + 1.76.*s.^2 + 15.22) ./ (s.^4 + 2.32.*s.^3 + 9.79.*s.^2 + 13.11.*s + 17.08);
subplot(3,1,2);
plot(w,abs(H)); title("Magnitude Response"); xlabel("frequency (rad/sec)"); ylabel("|H|");
subplot(3,1,3);
plot(w,angle(H)); title("Phase Response"); xlabel("frequency (rad/sec)"); ylabel("angle(H) (degrees)");
```



From these plots we can see that:

- T.F. is a low-pass filter. From its shape it looks epileptic
- Has a ½ power point at ±2.57 rad/sec. So, our guess of the pass band being from 0 → 2 rad/sec was a somewhat good estimate
- It appears the phase response in the pass band (-2.57 rad/sec → 2.57 rad/sec) is somewhat close to linear. Plotting the first derivative of the phase response (seen on next page), we see the slope of phase is sticks close to -1 rad / (rad/sec) . This can help keep distortion less transmission in the pass band



d(angle(H)) (rad / (rad/sec))
frequency (radians/sec)
4
3
2
1
0
-1
-2
-3
-4
-5
-3
-2
-1
0
1
2

2.2-1 Consider the LTIC system with transfer function $H(s) = \frac{3s}{s^2+2s+2}$. Using Eq. (2.15), plot the delay response of this system. Is the delay response constant for signals within the system's passband?

$$t_g(\omega) = -\frac{d}{d\omega}\angle H(\omega). \tag{2.15}$$

In MATLAB,

```
step = 0.001;
w = -10:step:10; s = j.*w;
H = (3.*s) ./ (s.^2 + 2.*s + 2);

tg = (-diff(angle(H)))./step;

subplot(2,2,1); plot(w,abs(H)); xlabel("rad/sec"); title("Magnitude Resp. of H"); axis([-6 6
subplot(2,2,2); plot(w,angle(H)); xlabel("rad/sec"); title("Phase Resp. of H"); axis([-6 6 -p

w(end) = [];
subplot(2,2,[3 4]); plot(w,tg); xlabel("rad/sec"); title("Measure of Delay Variation of H");
axis([-6 6 -0.5 1.5]); xline(-2.7,'k'); xline(2.7,'k'); xline(-0.73,'k'); xline(0.73,'k');
```

In the bottom plot we can see that this systems delay varies from a max of 1.2 $\frac{rad}{rad/sec}$ to 0.33 $\frac{rad}{rad/sec}$ over the pass band $\left(0.73\ \frac{rad}{sec}\ to\ 2.7\frac{rad}{sec}\right)$. Therefore, this system **does not** have a constant delay response in the passband.