```
clear all
load('HDD_freqresp.mat');
```

PART (A)

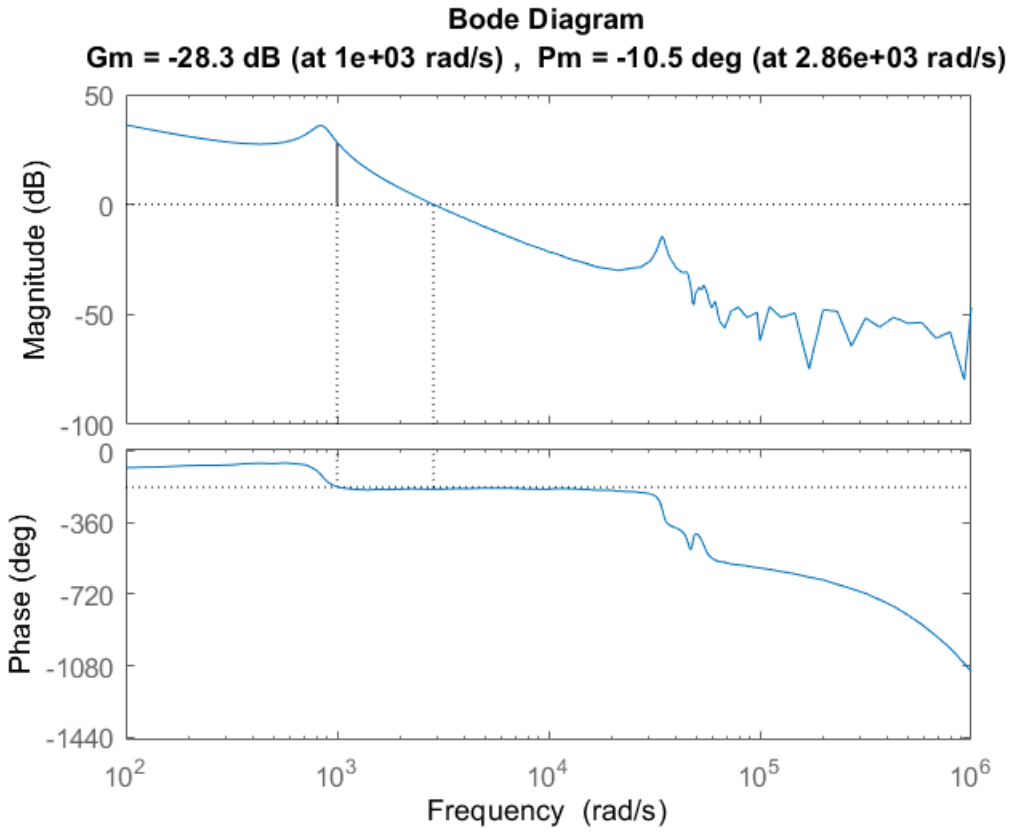
```
Ts = 1/50000;
s = tf('s');
G = HDD_freqresp;
```

Now adding time delay approximation,

```
sys1 = exp(-Ts*s/2);
```

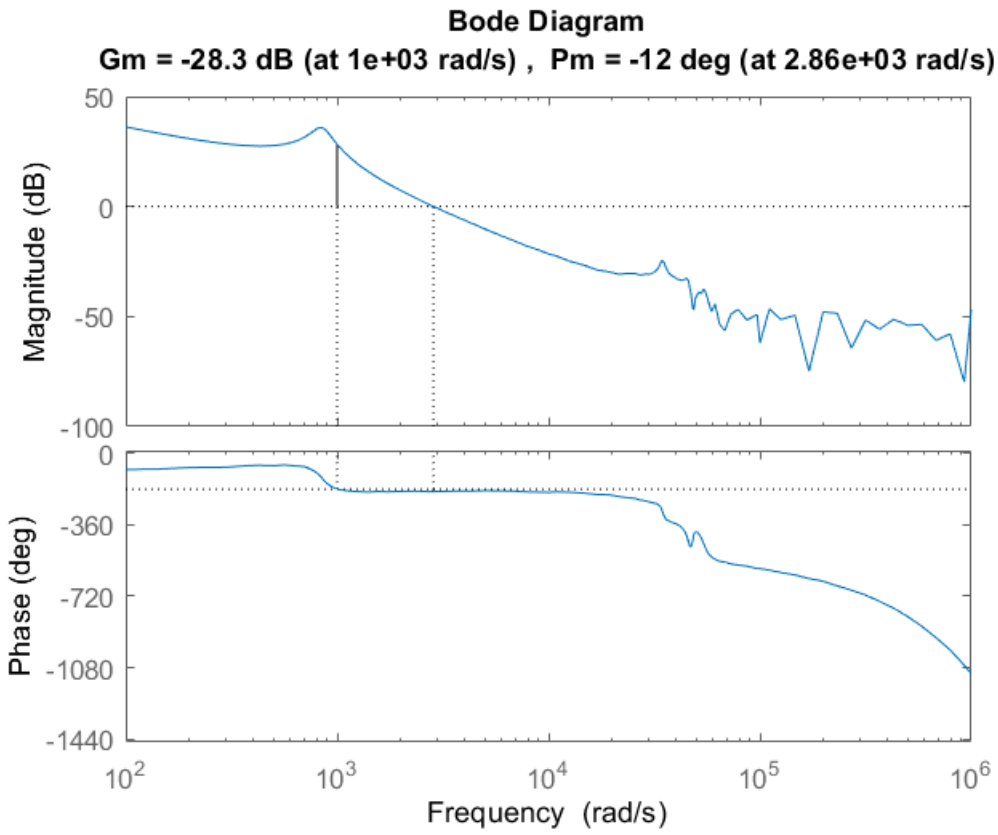
Add PI compensator. the zero is placed at 0.1 x wc = 2*pi*100 rad/s

```
tf_intx = G*sys1*(s+100*2*pi)/s;
margin(tf_intx)
```



Since the bode plot was crossing the x-axis 2 times, I added a notch filter at the second crossing to obtain a single crossing at w = 1 KHz or 2*pi*1000 rad/s.

```
n = notch(10,5000,34300);
tf_intx = tf_intx*n;
margin(tf_intx)
```



Calculate the phase of the system at 1 KHz to add a lead compensator.

```
[m,phase,wout] = bode(tf_intx,2*pi*1000)
```

```
m = 0.1970
phase = 171.0884
wout = 6.2832e+03
```

```
phase_req = -135-phase
```

```
phase_req = -306.0884
```

```
L = lead(phase_req,2*pi*1000)
```

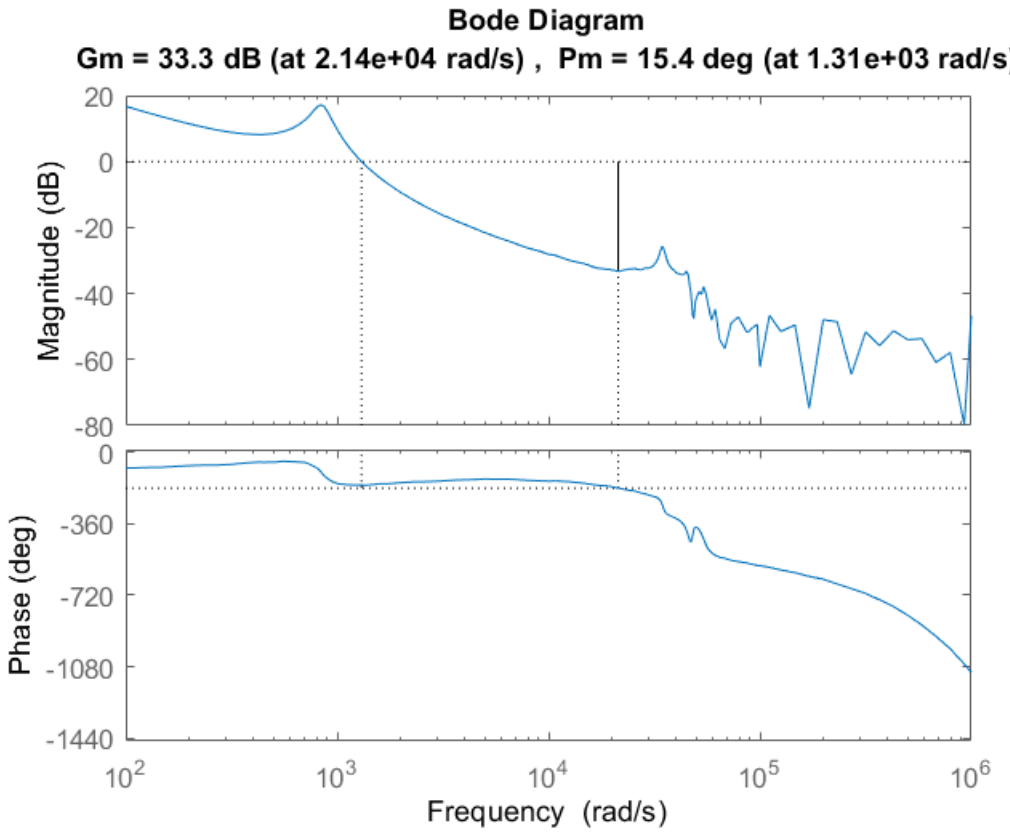
```
L =

    s + 2047
  ------------
  s + 1.929e04

Continuous-time transfer function.
```

New transfer function is now obtained which has the desired phase margin.

```
TF = tf_intx*L;
[mag,phase,wout] = bode(TF,2*pi*1000)
```

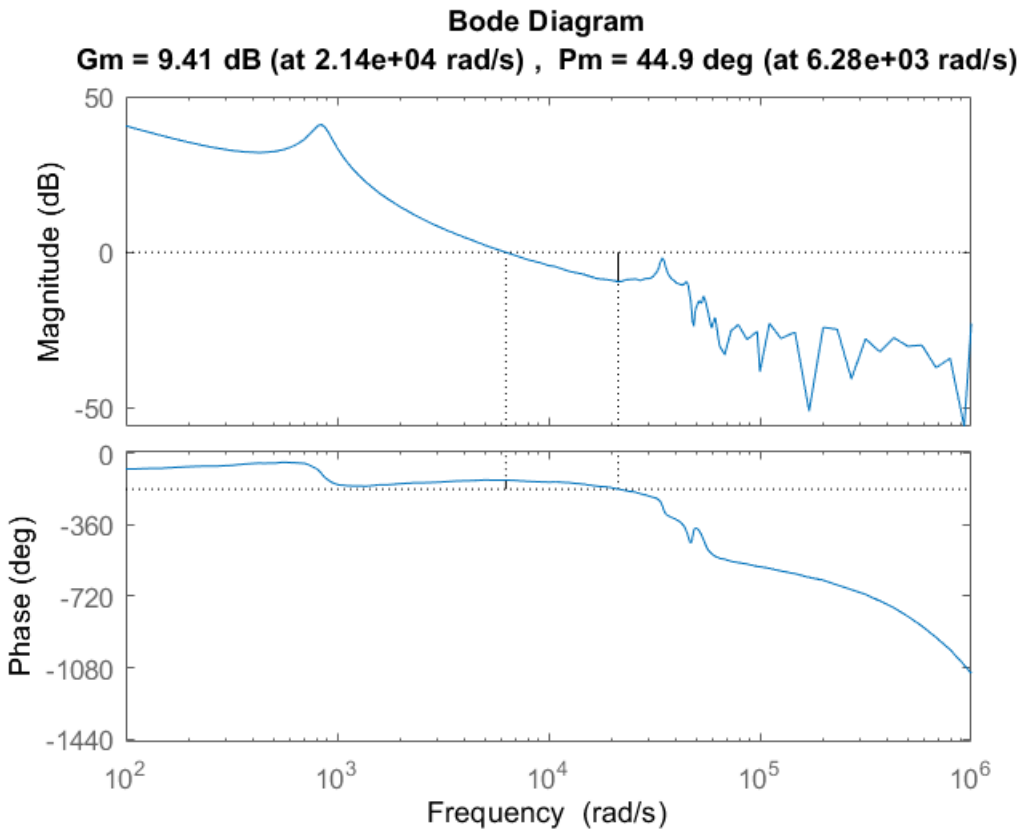
```
mag = 0.0642
phase = -135.0804
wout = 6.2832e+03
```

```
margin(TF)
```



Next, we calculate the magnitude at the desired cross-over frequency to provide an offset to the magnitude plot to achive the desired preformance.

```
tf_final = TF/mag;
margin(tf_final)
```



PART (B)

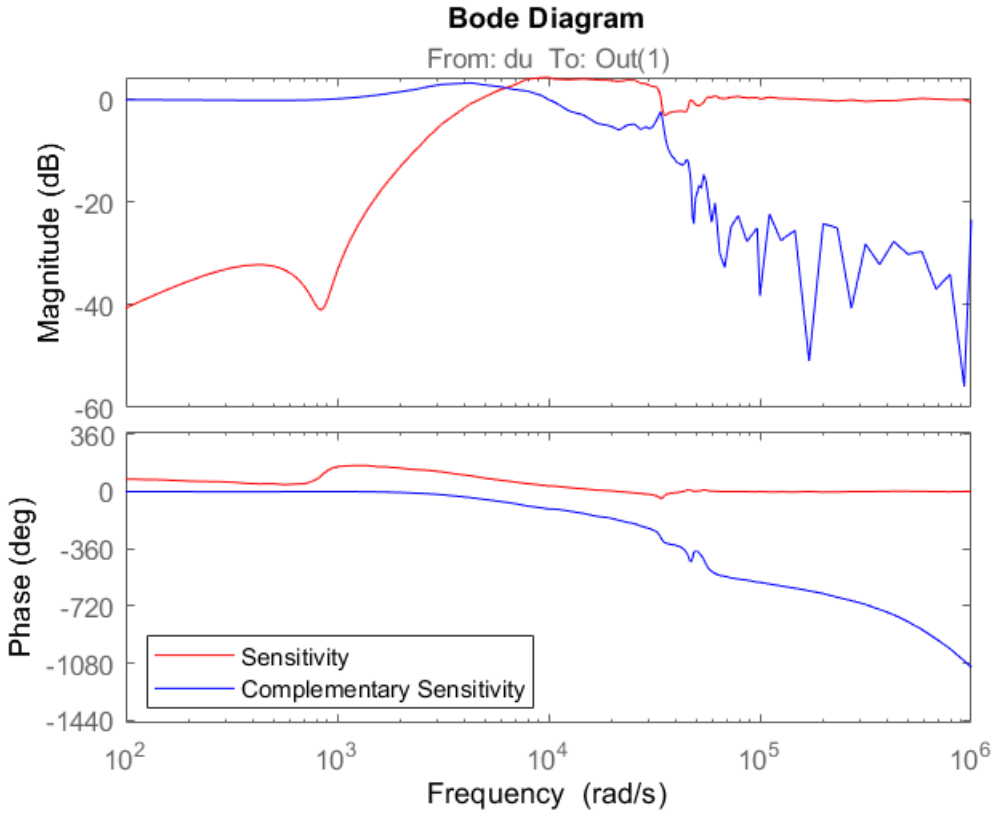
Compute the controller TF by multiplying all the above added compensators.

```
C = n*L*sys1*(s+100*2*pi)/(mag*s)
```

```
C =

                  s^4 + 7675 s^3 + 1.191e09 s^2 + 3.154e12 s + 1.513e15
  exp(-1e-05*s) * ------------------------------------------------------
                   0.06417 s^4 + 2252 s^3 + 9.507e07 s^2 + 1.456e12 s

Continuous-time transfer function.
```

Compute the Sensitivity and complementary sensitivity function using loopsens(). It can be alternatively done by the closed loop transfer funciton. S = I - CL_TF.

```
loops = loopsens(G,C);
bode(loops.Si,'r',loops.Ti,'b')
legend('Sensitivity','Complementary Sensitivity','Location','southwest')
```



Compute the peak gain of the Sensitivity funciton.

```
S_fn = loops.Si;
S_gpeak = getPeakGain(S_fn)
```

```
S_gpeak = 1.6440
```

Compute the peak gain of the Complementary Sensitivity funciton.

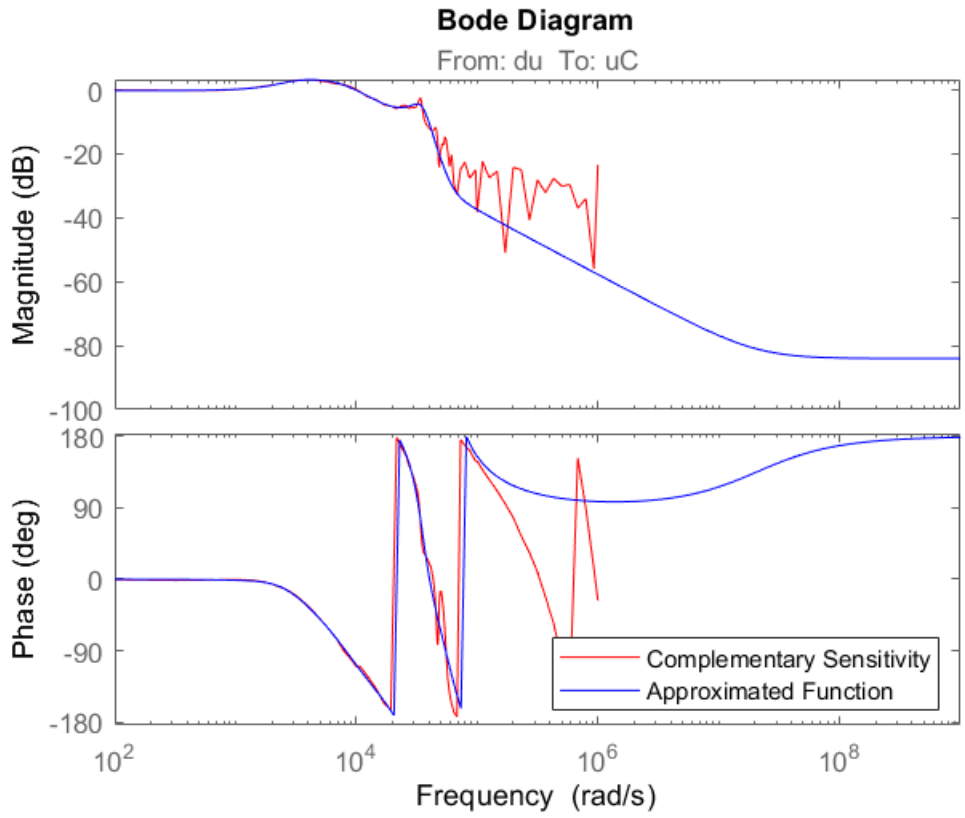
```
CS_fn = loops.Ti;
CS_gpeak = getPeakGain(CS_fn)
```

```
CS_gpeak = 1.4590
```

PART (C)

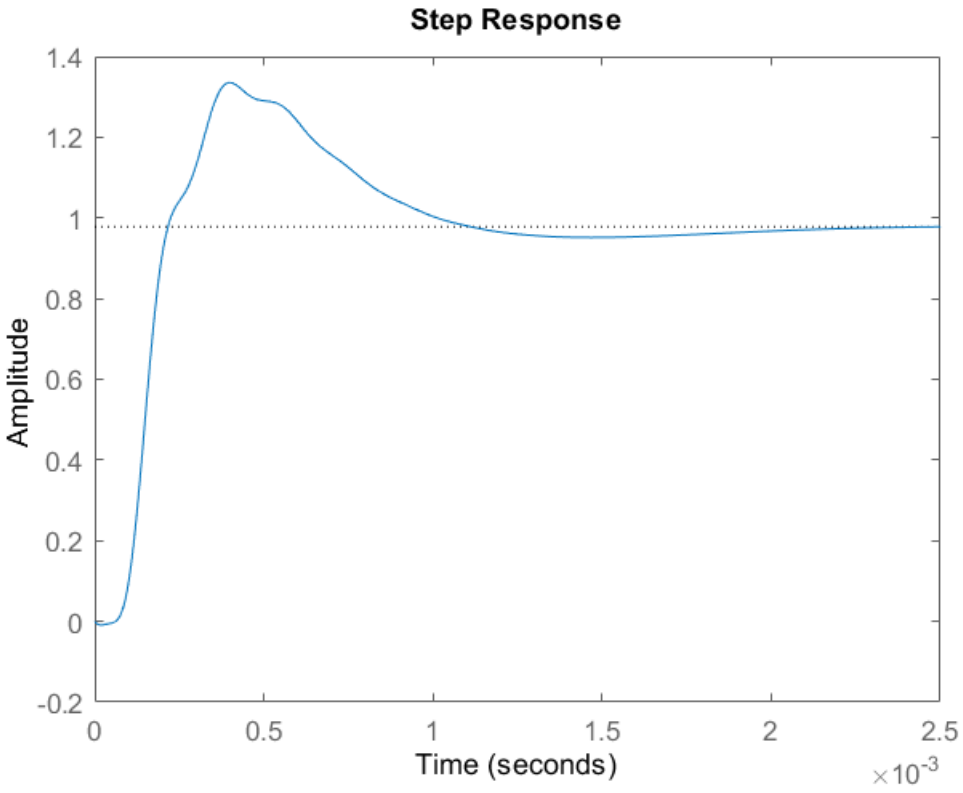
Assuming the number of states to be 8, the approximation of the FRD was obtained, and the bode plot is genereated.

```
N = 8;
B = fitfrd(CS_fn,N);
opts = bodeoptions('cstprefs');
opts.PhaseWrapping = 'on';
bode(CS_fn,'r',B,'b',opts)
legend('Complementary Sensitivity','Approximated Function','Location','southeast')
```



Step response of the approximated complementary system.

```
step(B)
```


Step Response
Amplitude
Time (seconds)
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
0
0.5
1
1.5
2
2.5
×10-3