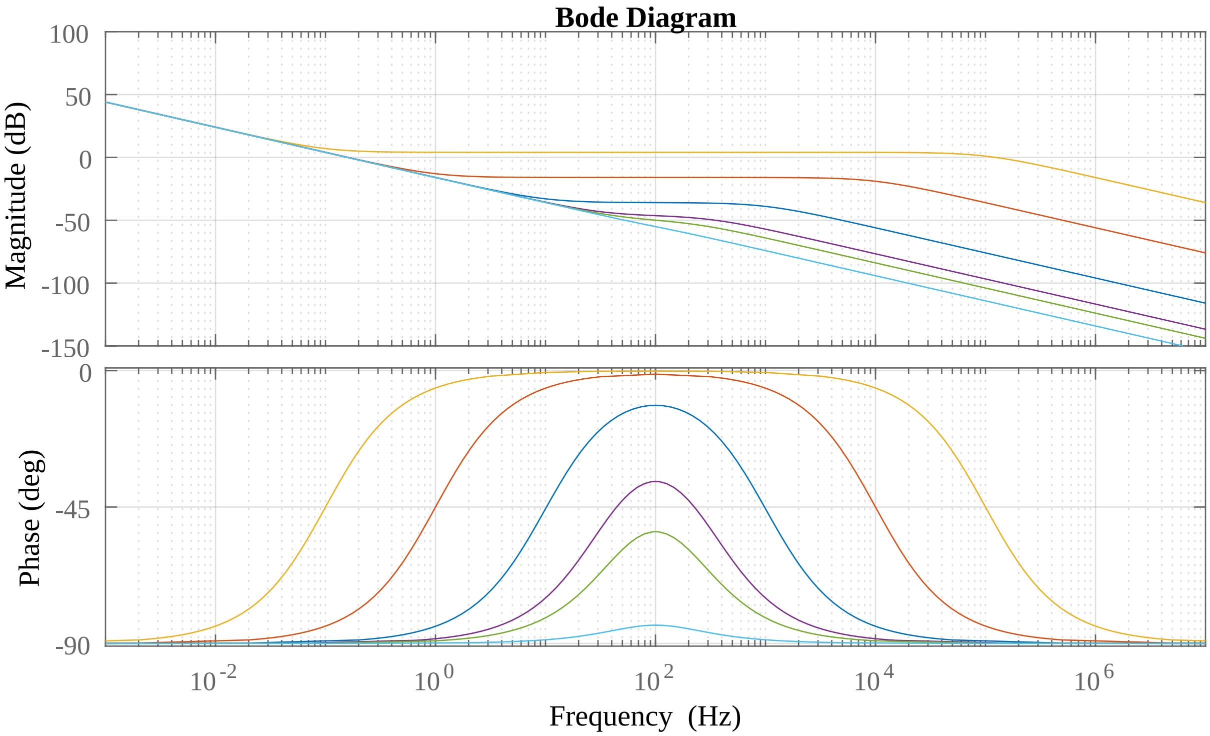
DIGITAL CONTROL OF POWER ELECTRONICS

Lead Lag Controller

The lead lag controller is shown below.

$$G_c(s) = \frac{k}{s} \frac{\frac{s}{w_z} + 1}{\frac{s}{w_p} + 1} \tag{1}$$

Note, the controller has a gain k, an integrator (pole at zero) which is needed for zero steady state error, a zero at ω_z, and a pole at ω_p.



Select desired phase margin ϕ_{PM}, bandwidth f_c, and solve for f_z, f_p, and k_c.

$$\phi_{boost} = -90^\circ + \phi_{PM} - \angle G_{PS} \tag{2}$$

$$k_{boost} = \tan\left(45^\circ + \frac{\phi_{boost}}{2}\right) \tag{3}$$

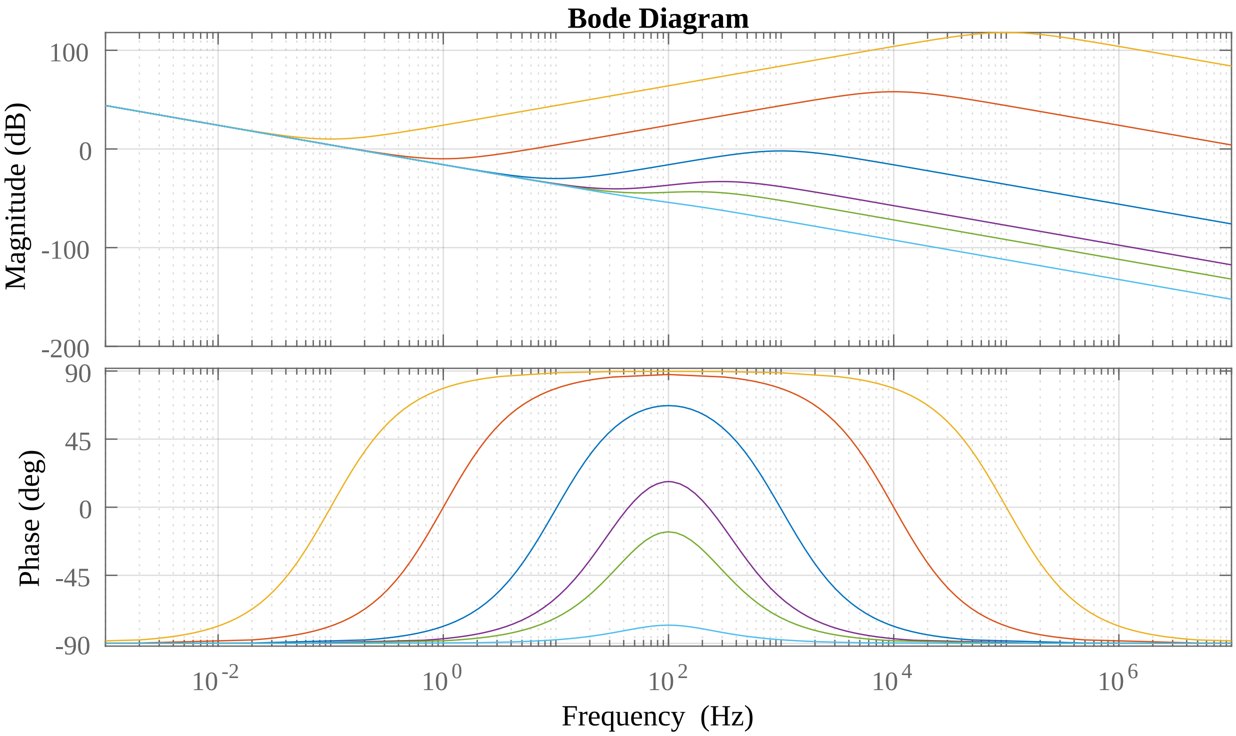
$$|G_c|_{f_c} = \frac{1}{|G_{PS}|_{f_c}} \tag{4}$$

$$f_z = \frac{f_c}{k_{boost}} \tag{5}$$

$$f_p = f_c k_{boost} \tag{6}$$

$$k_c = |G_c|_{f_c} \frac{2\pi f_z}{k_{boost}} \tag{7}$$

$$G_c(s) = \frac{k}{s} \frac{(\frac{s}{w_z} + 1)^2}{(\frac{s}{w_p} + 1)^2} \tag{8}$$



$$\phi_{boost} = -90^\circ + \phi_{PM} - \angle G_{PS} \tag{9}$$

$$k_{boost} = \tan\left(45^\circ + \frac{\phi_{boost}}{4}\right) \tag{10}$$

$$|G_c|_{f_c} = \frac{1}{|G_{PS}|_{f_c}} \tag{11}$$

$$f_z = \frac{f_c}{k_{boost}} \tag{12}$$

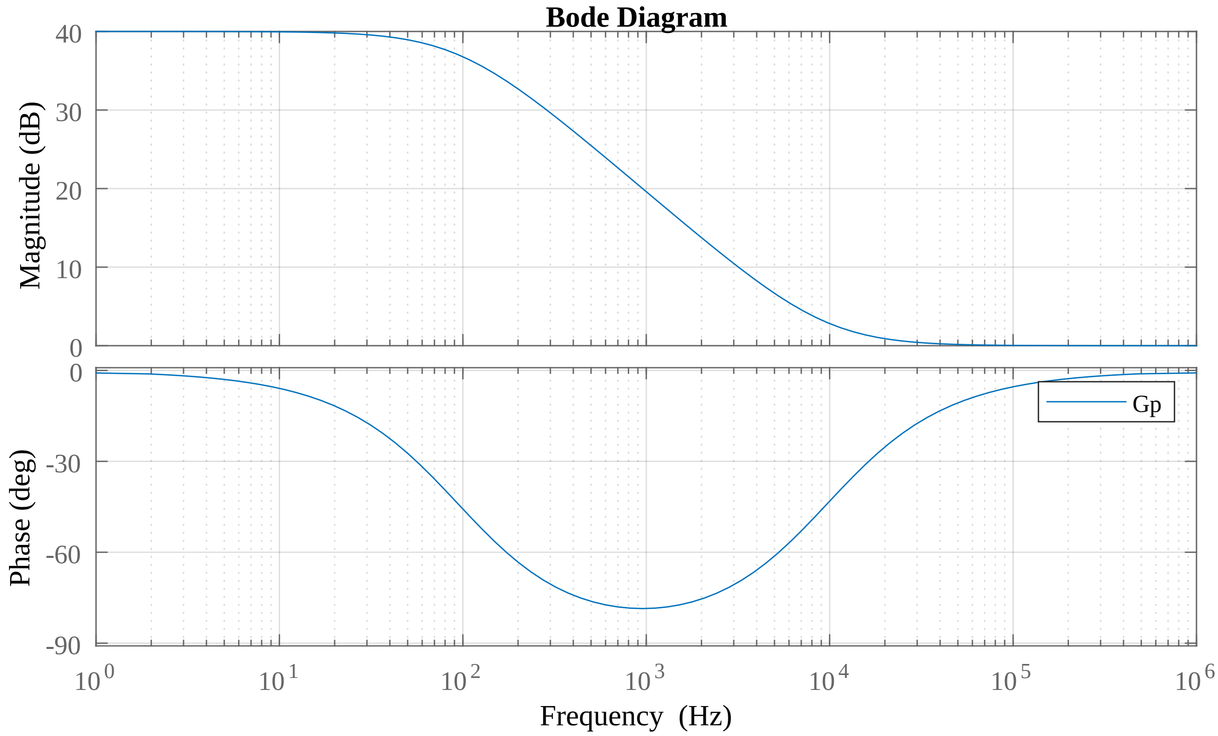
$$f_p = f_c k_{boost} \tag{13}$$

$$k_c = |G_c|_{f_c} \frac{2\pi f_z}{k_{boost}} \tag{14}$$

Lets assume we have the following plant

$$G_p(s) = \frac{(s+60000)}{(s+600)} \tag{15}$$

Design a lead lag controller for the plant with a bandwidth of 1000Hz and a phase margin of 60 degrees. The bode plot of the plant is shown below in blue. Find the gain and phase of the plant at 1000Hz.



$$|G_{PS}|_{f_c} = 9.558 \tag{16}$$

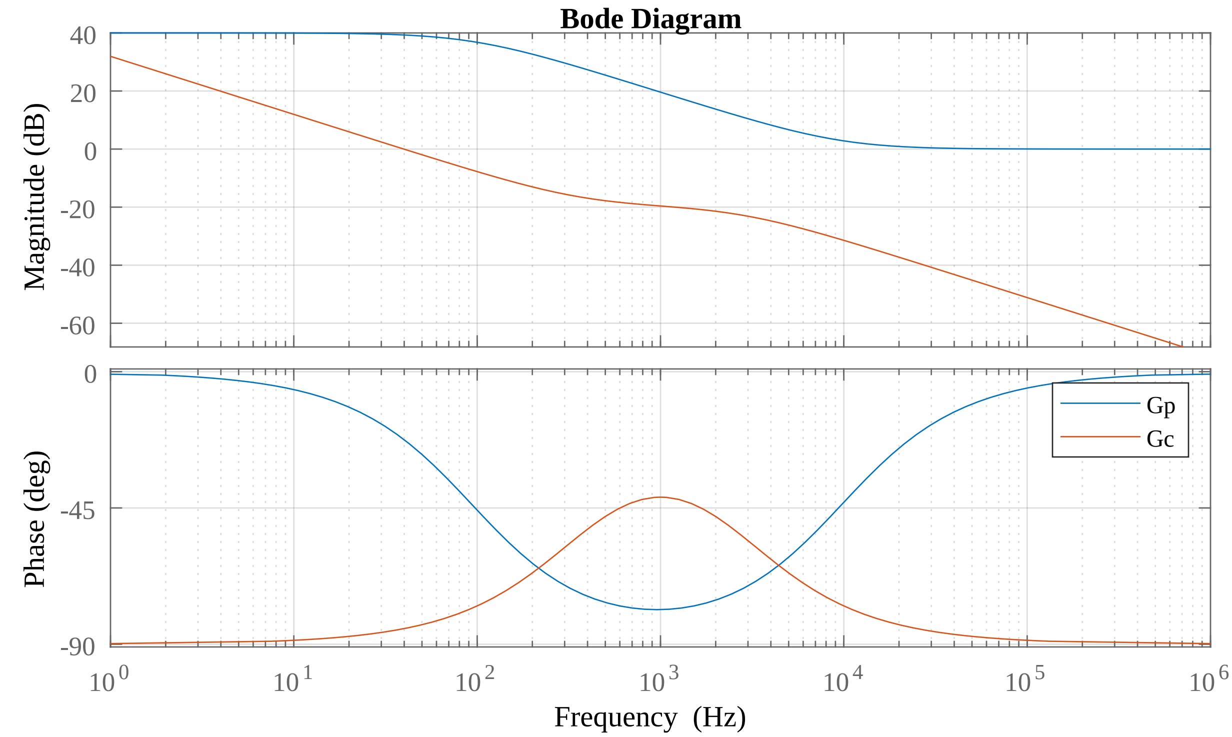
$$\angle G_{PS} = -78.567 \tag{17}$$

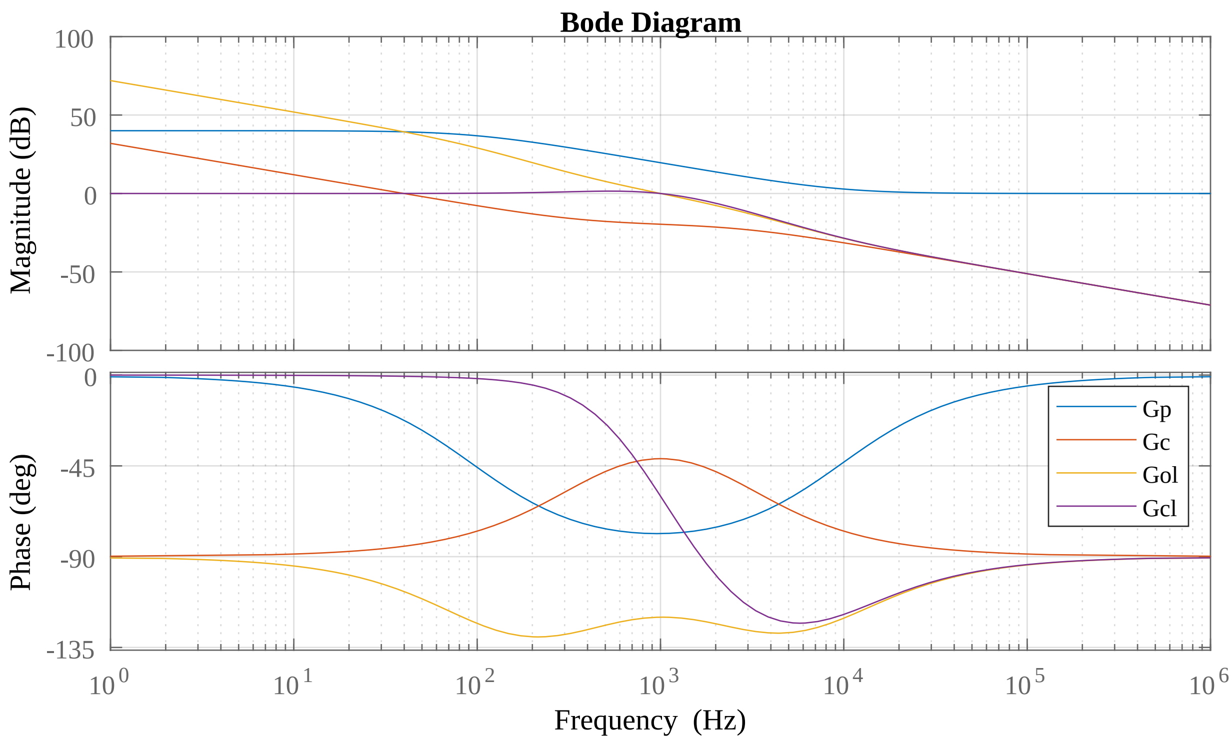
$$fz = 378.1978 \tag{18}$$

$$fp = 2644.1 \tag{19}$$

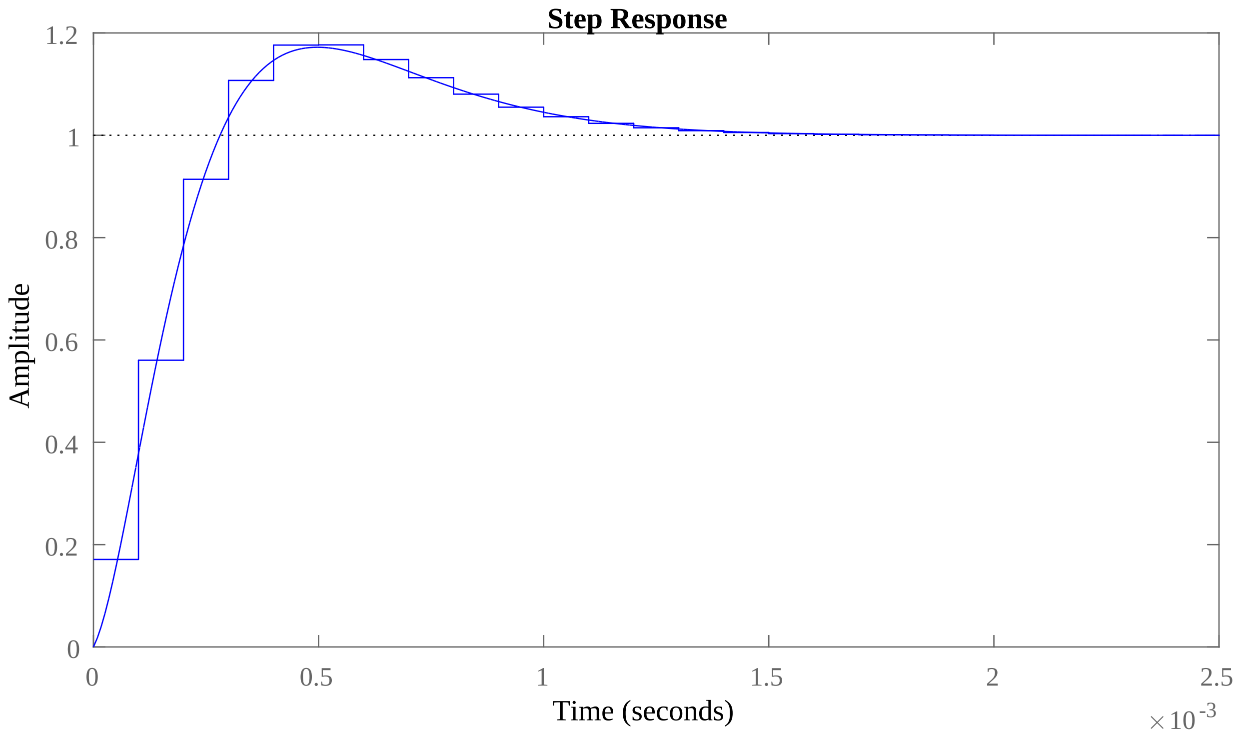
$$kc = 248.6167 \tag{20}$$

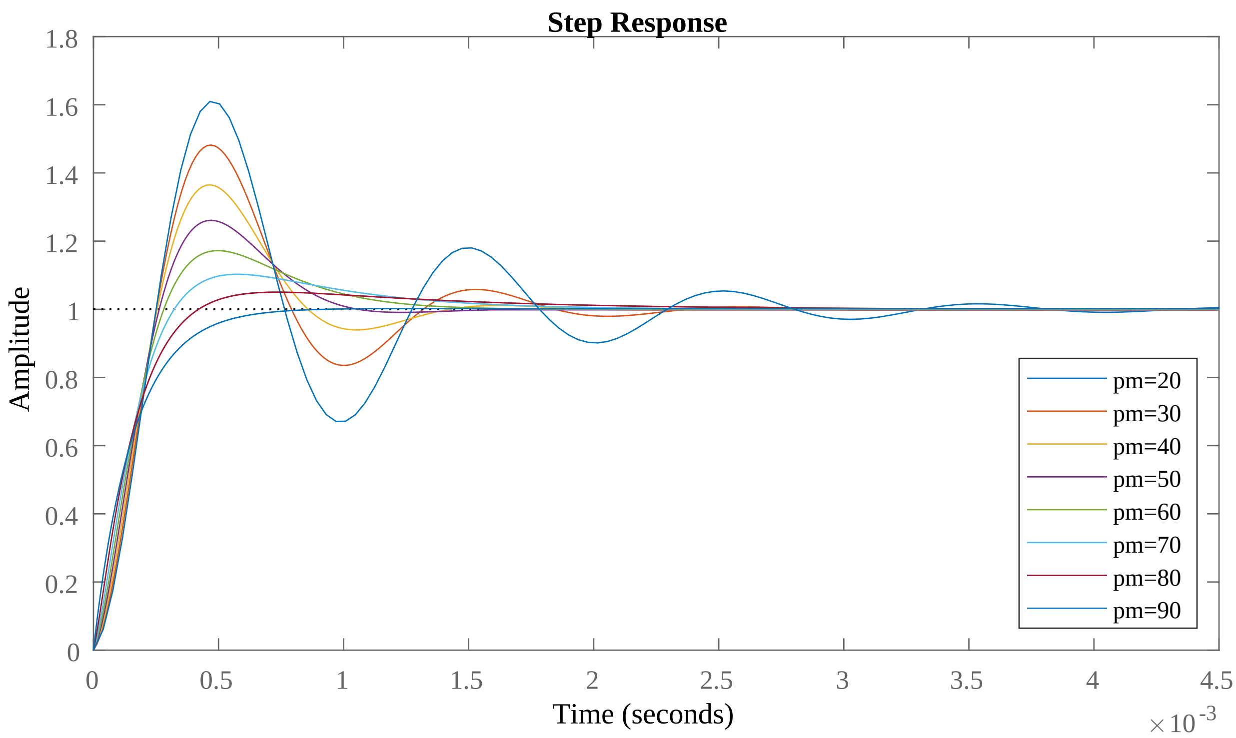
$$G_c(s) = \frac{4.13 \times 10^6 s + 9.815 \times 10^9}{2376s^2 + 3.948 \times 10^7 s} \tag{21}$$

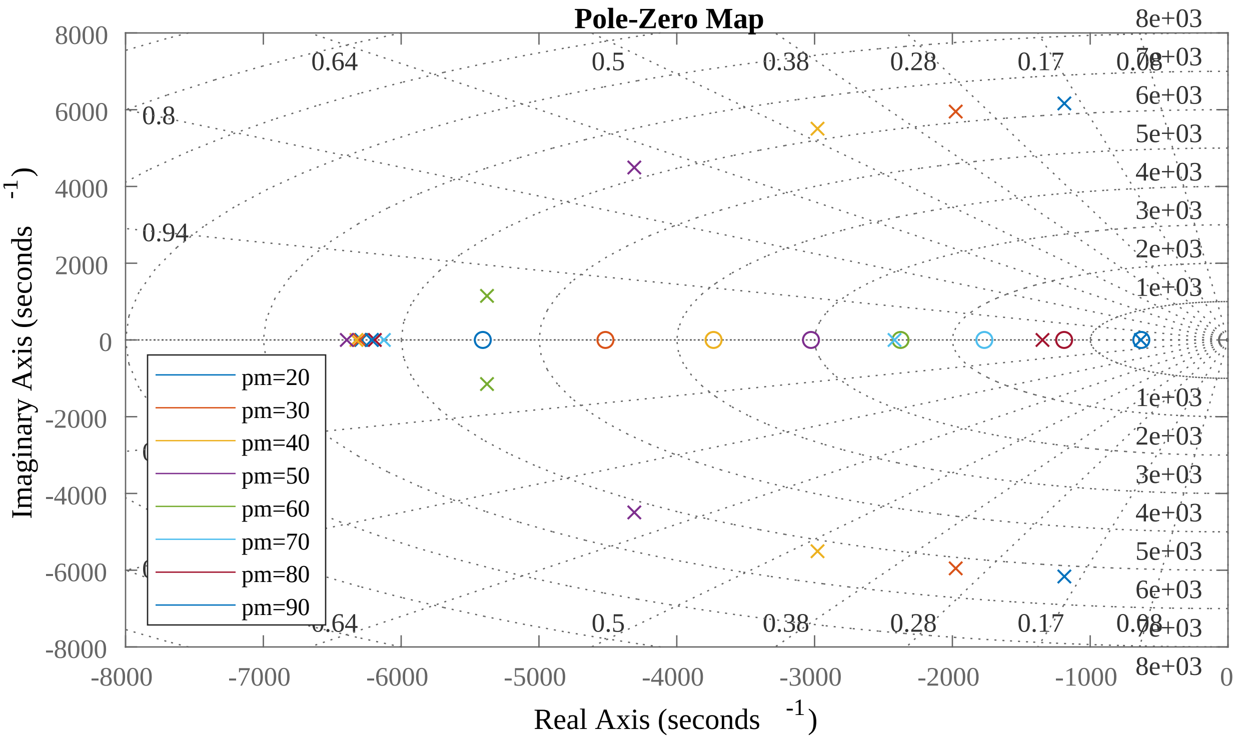




$$G_c(z) = \frac{0.05311z^2 + 0.01128z - 0.04183}{z^2 - 1.092z + 0.09249} \tag{22}$$


Step Response
Amplitude
Time (seconds)
×10^-3


Step Response
Amplitude
Time (seconds)
×10^-3
pm=20
pm=30
pm=40
pm=50
pm=60
pm=70
pm=80
pm=90


Pole-Zero Map
Imaginary Axis (seconds -1)
Real Axis (seconds -1)
pm=20
pm=30
pm=40
pm=50
pm=60
pm=70
pm=80
pm=90
8000
6000
4000
2000
0
-2000
-4000
-6000
-8000
-7000
-5000
-3000
-1000
0.64
0.5
0.38
0.28
0.17
0.08
0.8
0.94
8e+03
7e+03
6e+03
5e+03
4e+03
3e+03
2e+03
1e+03