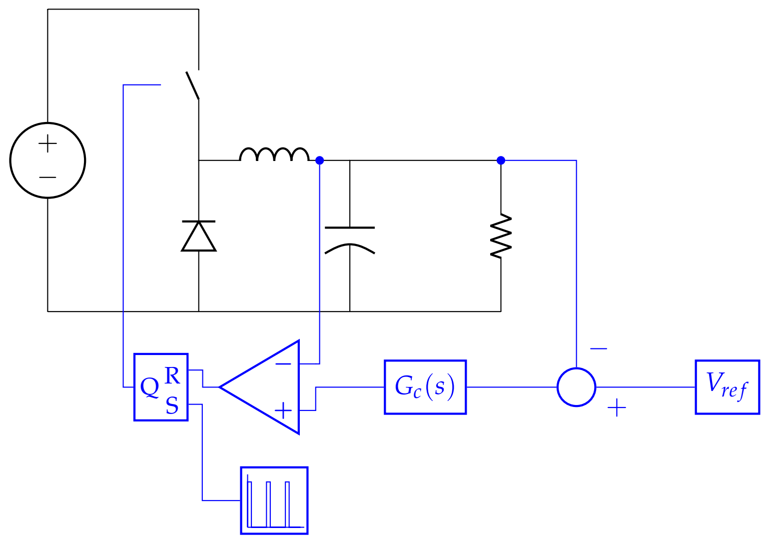
Digital Control of Power Electronics

Current Mode Control of Buck Converter



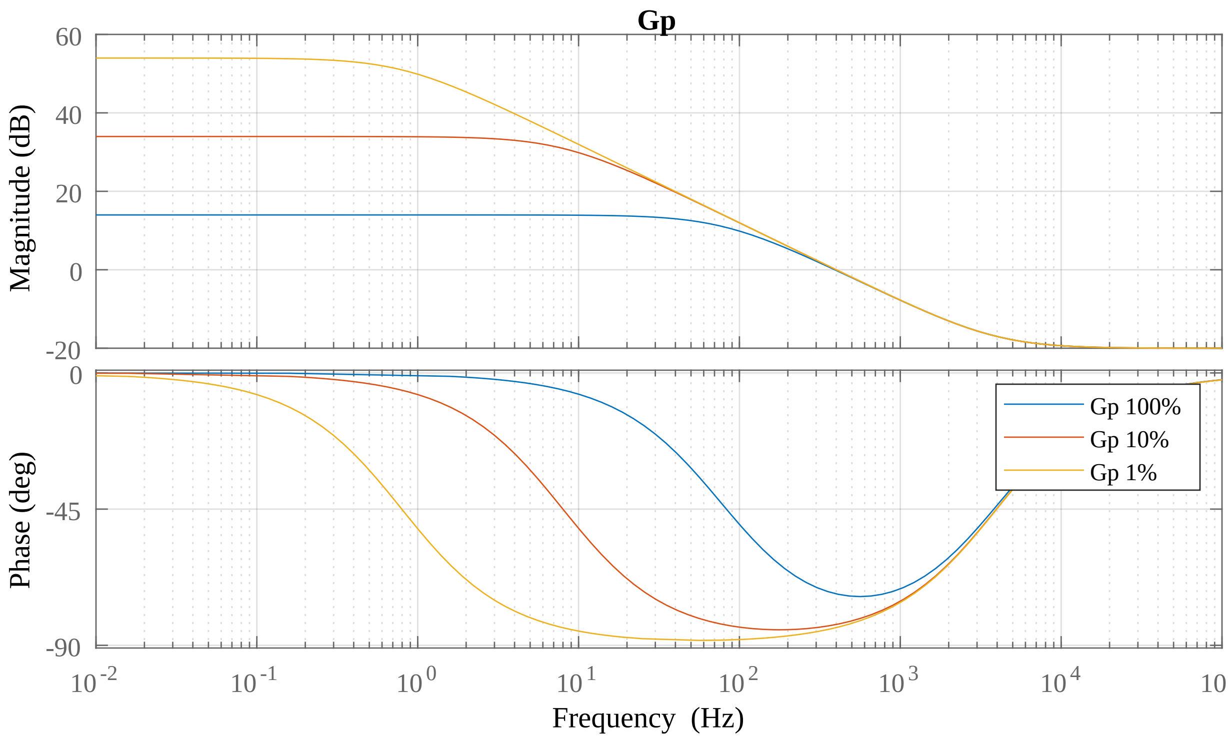
The plant for a buck converter in continuous conduction mode is shown below.

$$G_p(s) = \frac{v_o}{i_L} = \frac{R(1 + srC)}{(1 + sRC)} \tag{1}$$

Note, the plant has a single pole and a single zero.
The parameters of the buck converter are shown below.

$$V_{in} = 30, V_o = 15, L = 200\mu H, C = 400\mu F, r = 0.1, R = 5 \tag{2}$$

The bode plot of the plant transfer function is shown below for various load points.


Gp
Magnitude (dB)
60
40
20
0
-20
Phase (deg)
0
-45
-90
Gp 100%
Gp 10%
Gp 1%
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
Frequency (Hz)

Design the controller below, find the zero, pole and gain for a bandwidth of $f_c = 1\text{kHz}$ and phase margin of 60 degrees.

$$G_c(s) = \frac{k}{s}\frac{\left(1+\frac{s}{\omega_z}\right)}{\left(1+\frac{s}{\omega_p}\right)} \tag{3}$$

Evaluate the gain of phase of the plant at the desired bandwidth

$$|G_p(s)|_{s=j\omega} \tag{4}$$

$$\angle G_p(s)|_{s=j\omega} \tag{5}$$

$$\phi_{boost} = -90^\circ + \phi_{PM} - \angle G_p(s)|_{s=j\omega} \tag{6}$$

$$k_{boost} = \tan\left(45^\circ + \frac{\phi_{boost}}{2}\right) \tag{7}$$

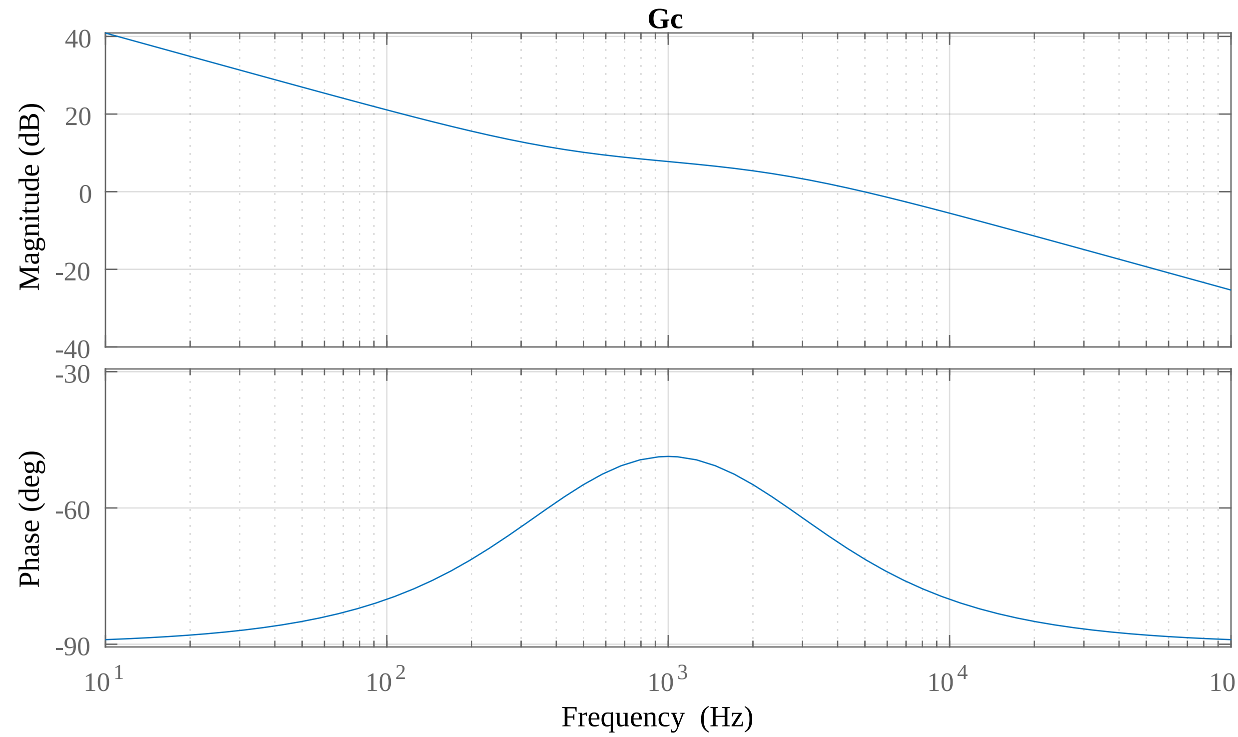
$$\omega_z = \frac{2\pi f_c}{k_{boost}} \tag{8}$$

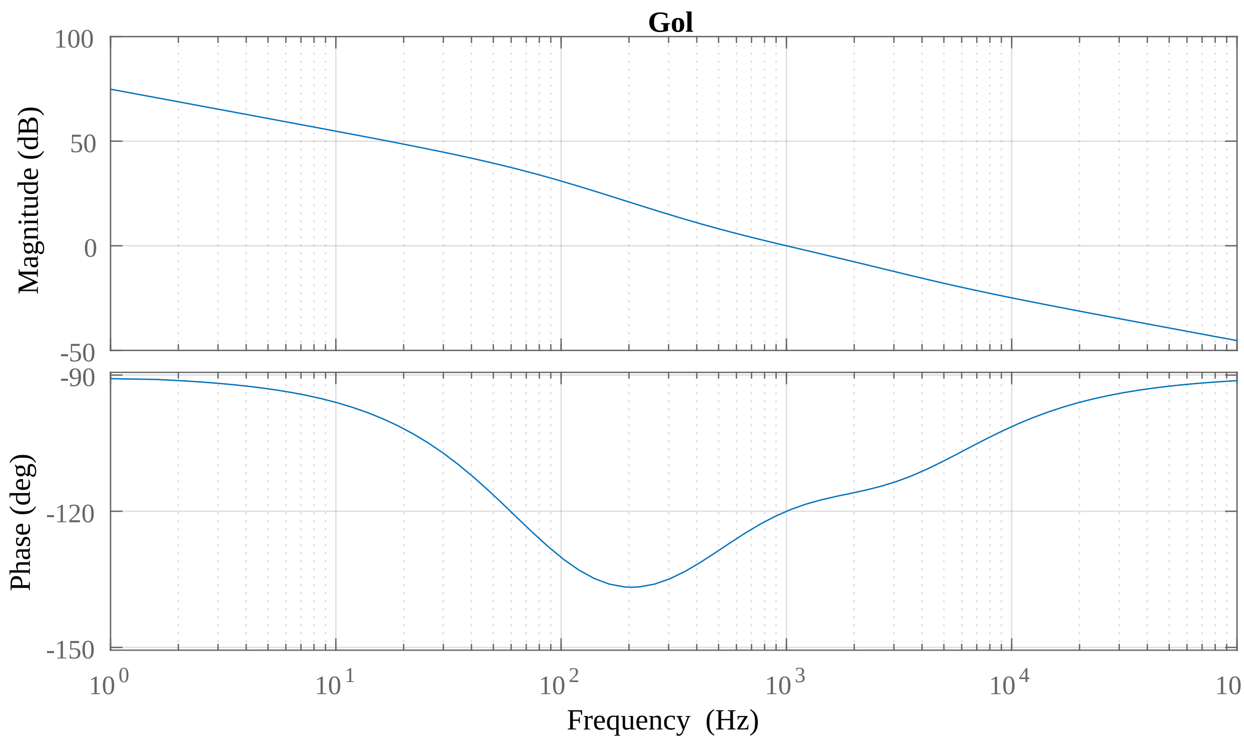
$$\omega_p = 2\pi f_c k_{boost} \tag{9}$$

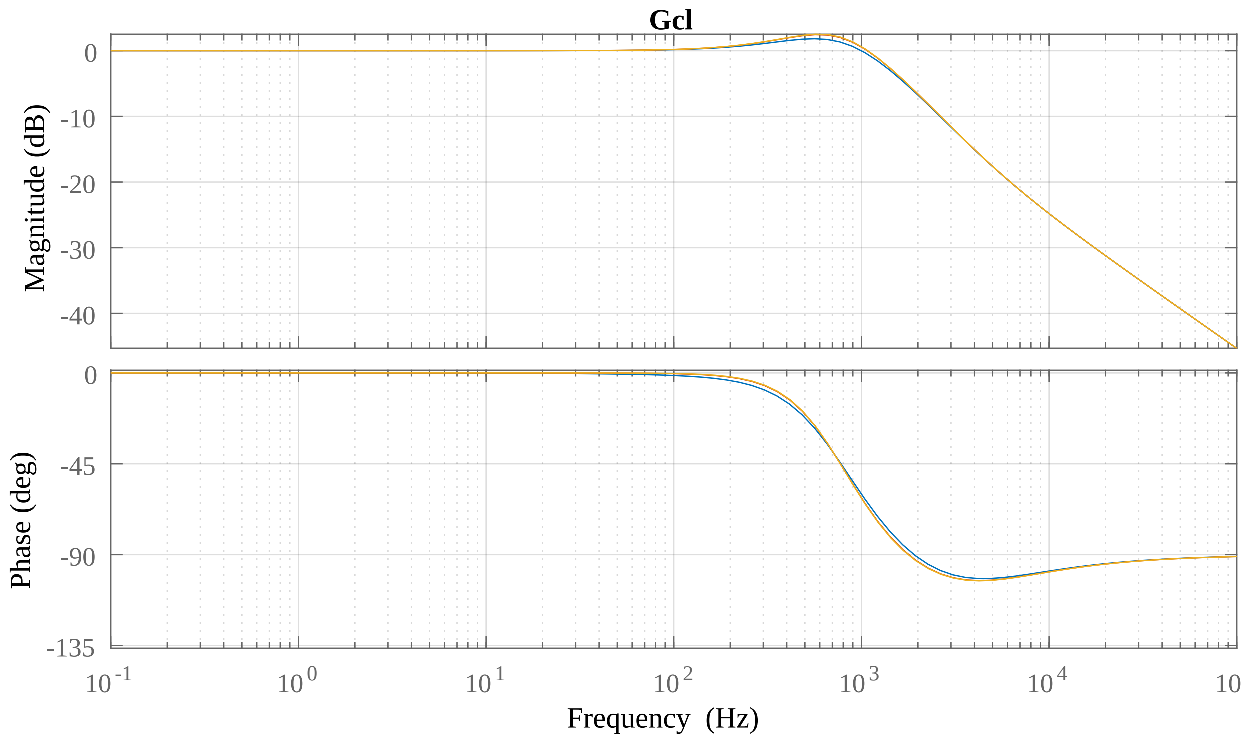
$$k = \frac{\omega_z}{|G_p(s)|_{s=j\omega}} \tag{10}$$

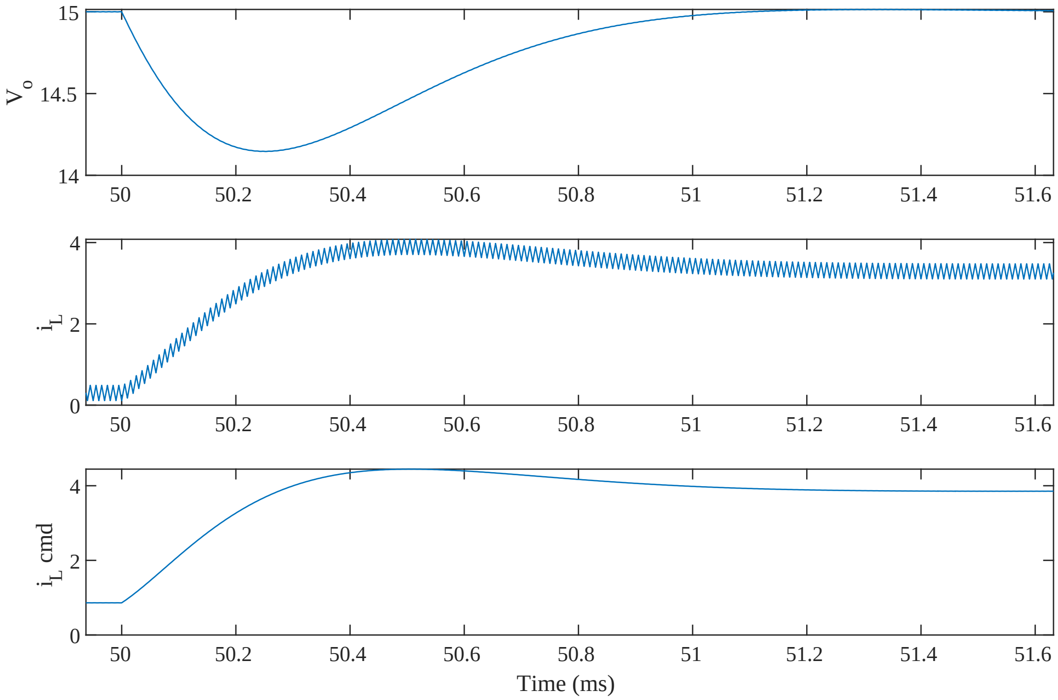
```
clear

Vin = 30
L = 200e-6
C = 400e-6
r = 0.1
R = 5

fc = 1000 % select bandwidth
pm = 60 % select phase margin
w = 2*pi*fc

gain_gps = abs(R*(1+j*w*r*C)/(1+j*w*R*C))
angle_gps = angle(R*(1+j*w*r*C)/(1+j*w*R*C))*180/pi

phiboost = -90 +pm-angle_gps
gain_need = 1/gain_gps

Kboost = tand(45+phiboost/2)
fz = fc/Kboost
fp = Kboost*fc
kc = 2*pi*fz/gain_gps

wz = 2*pi*fz
wp = 2*pi*fp
```

$$\omega_z = 2840 \quad \omega_p = 13897 \quad k = 6946 \tag{11}$$


Gc
Magnitude (dB)
40
20
0
-20
-40
Phase (deg)
-30
-60
-90
10^1
10^2
10^3
10^4
10^5
Frequency (Hz)


Gol
Magnitude (dB)
100
50
0
-50
Phase (deg)
-90
-120
-150
10^0
10^1
10^2
10^3
10^4
10^5
Frequency (Hz)


Gcl
Magnitude (dB)
0
-10
-20
-30
-40
Phase (deg)
0
-45
-90
-135
10^-1
10^0
10^1
10^2
10^3
10^4
Frequency (Hz)


15
14.5
14
V o
50
50.2
50.4
50.6
50.8
51
51.2
51.4
51.6
4
2
0
i L
4
2
0
i L cmd
Time (ms)