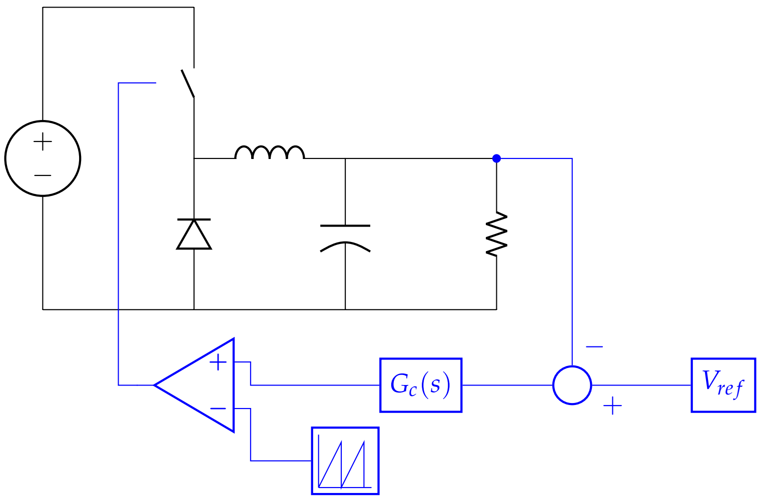
DIGITAL CONTROL OF POWER ELECTRONICS

Voltage Mode Control of Buck Converter



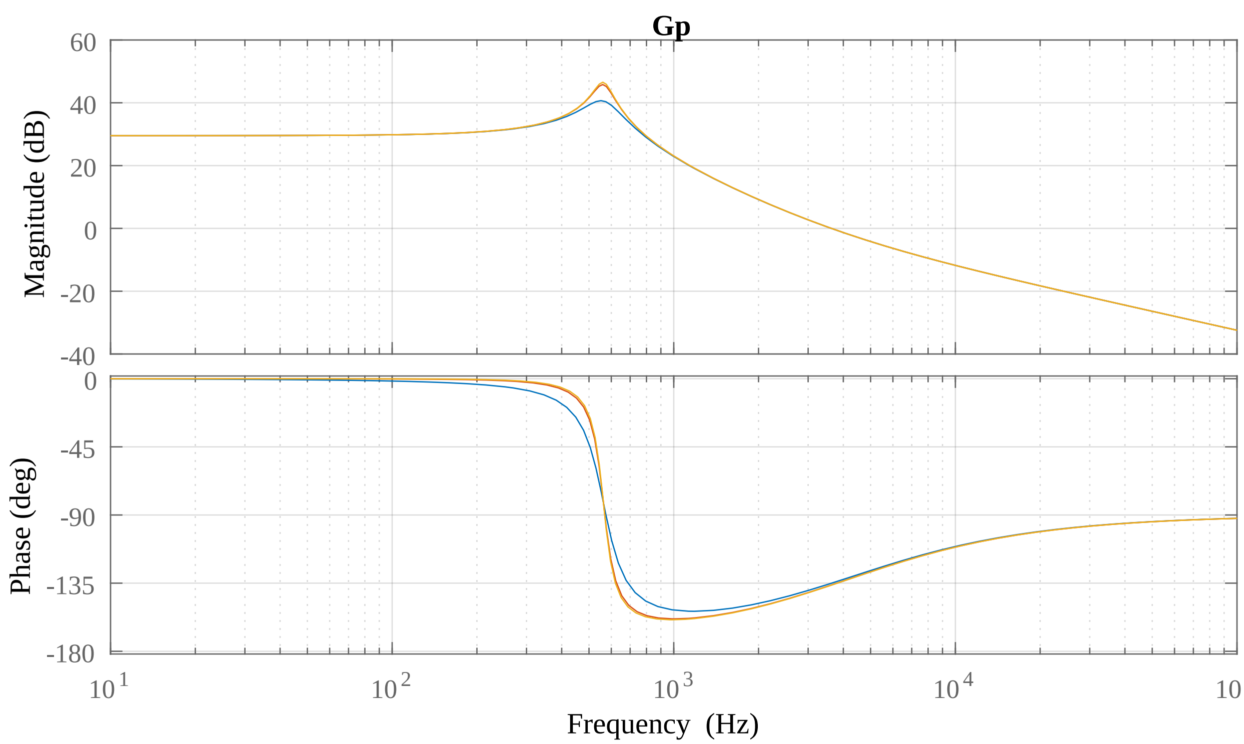
The plant for a buck converter in continuous conduction mode is shown below.

$$\frac{v_o}{d} = \frac{V_{in}}{LC} \frac{1 + srC}{s^2 + s\left(\frac{1}{RC} + \frac{r}{L}\right) + \frac{1}{LC}} \tag{1}$$

The parameters of the buck converter are shown below.

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

Note, the plant has a complex pole pair and one zero.



Design the controller below, find the zero, pole and gain for a bandwidth of $f_c = 5$kHz and phase margin of 60 degrees.

$$G_c(s) = \frac{k}{s} \frac{\left(1 + \frac{s}{\omega_z}\right)^2}{\left(1 + \frac{s}{\omega_p}\right)^2} \tag{3}$$

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

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

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

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

$$k_{boost} = \tan\left(45^\circ + \frac{\phi_{boost}}{4}\right) \tag{7}$$

$$k = \frac{1}{|G_{PS}(s)|_{s=j\omega}} \tag{8}$$

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

$$\omega_p = 2\pi f_c k_{boost} \tag{10}$$

```
clear

s=tf('s')
opts = bodeoptions('cstprefs');
opts.FreqUnits = 'Hz';
Vin = 30
L = 200e-6
C = 400e-6
r = 0.1
R = 5
Gps = Vin/(L*C) * (1+s*C*r) / (s^2 + s*(r/L + 1/(R*C)) + 1/(L *C) )

fc = 5e3 % select bandwidth
pm = 60 % select phase margin
kfb = 1 % gain in feedback voltage measurement
Gpwm = 1 % gain of the modulator

[gain phase] = bode(Gps,2*pi*fc)
phiboost = -90 + pm - phase
kboost = tand(45 + phiboost/4)
gaincontroller = 1 / (kfb * Gpwm * gain)
fz = fc/kboost
fp = fc*kboost
kc = gaincontroller * 2*pi*fz/kboost
wz = 2*pi*fz
wp = 2*pi*fp
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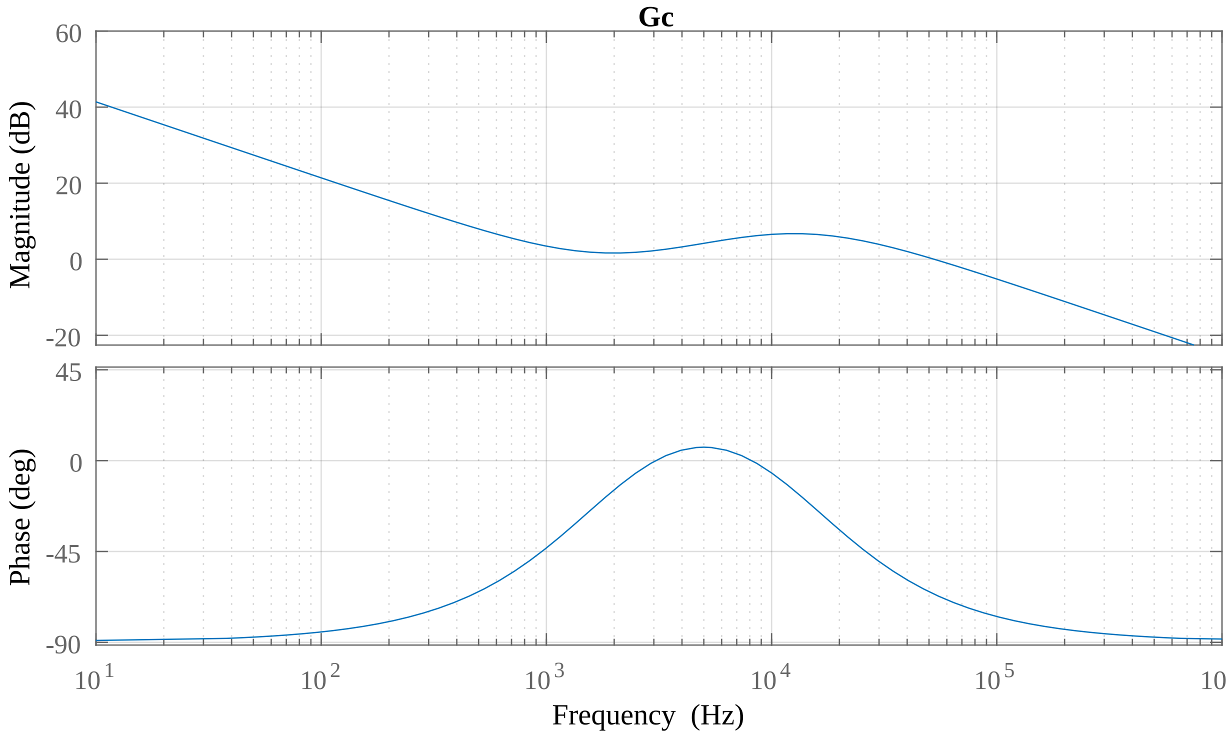
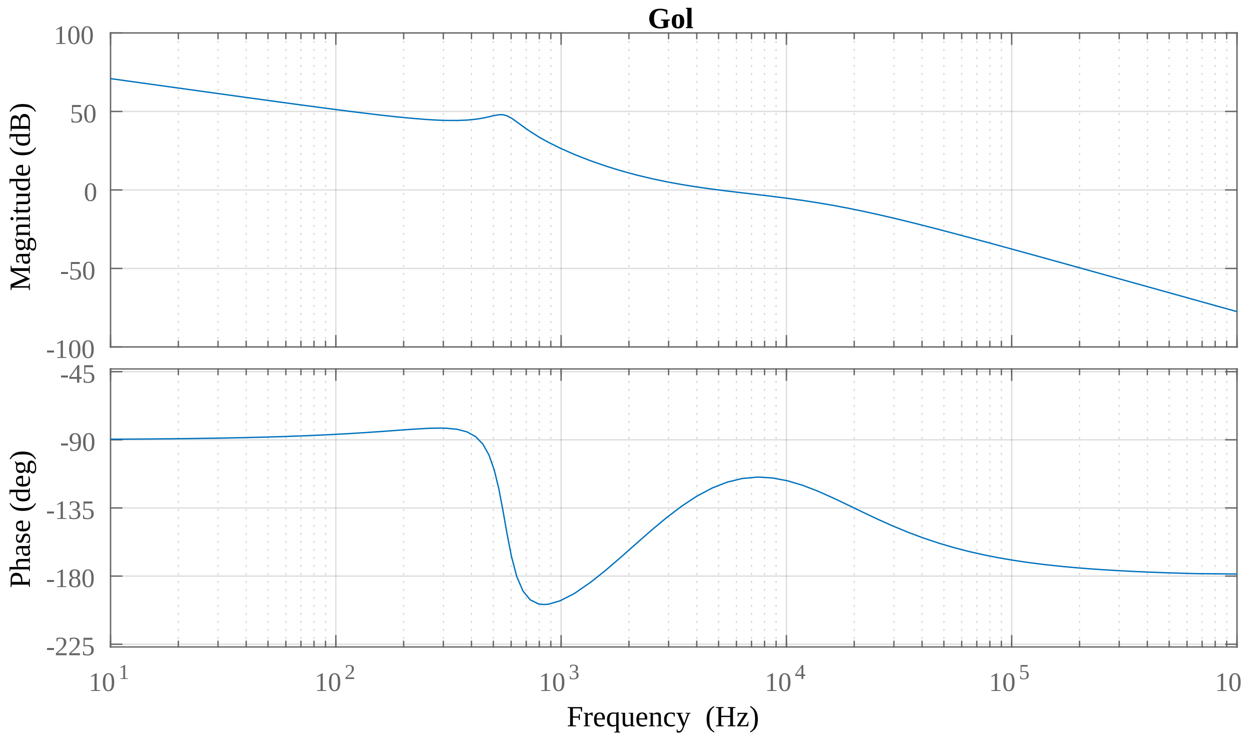
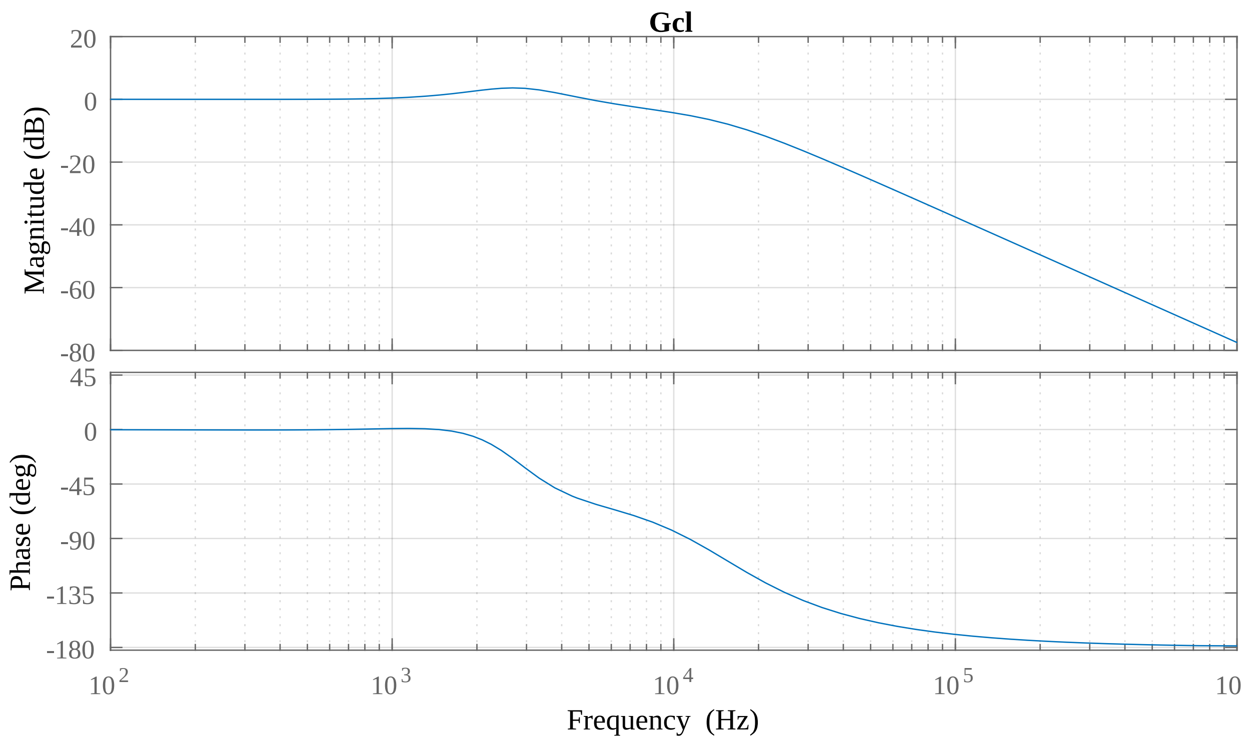
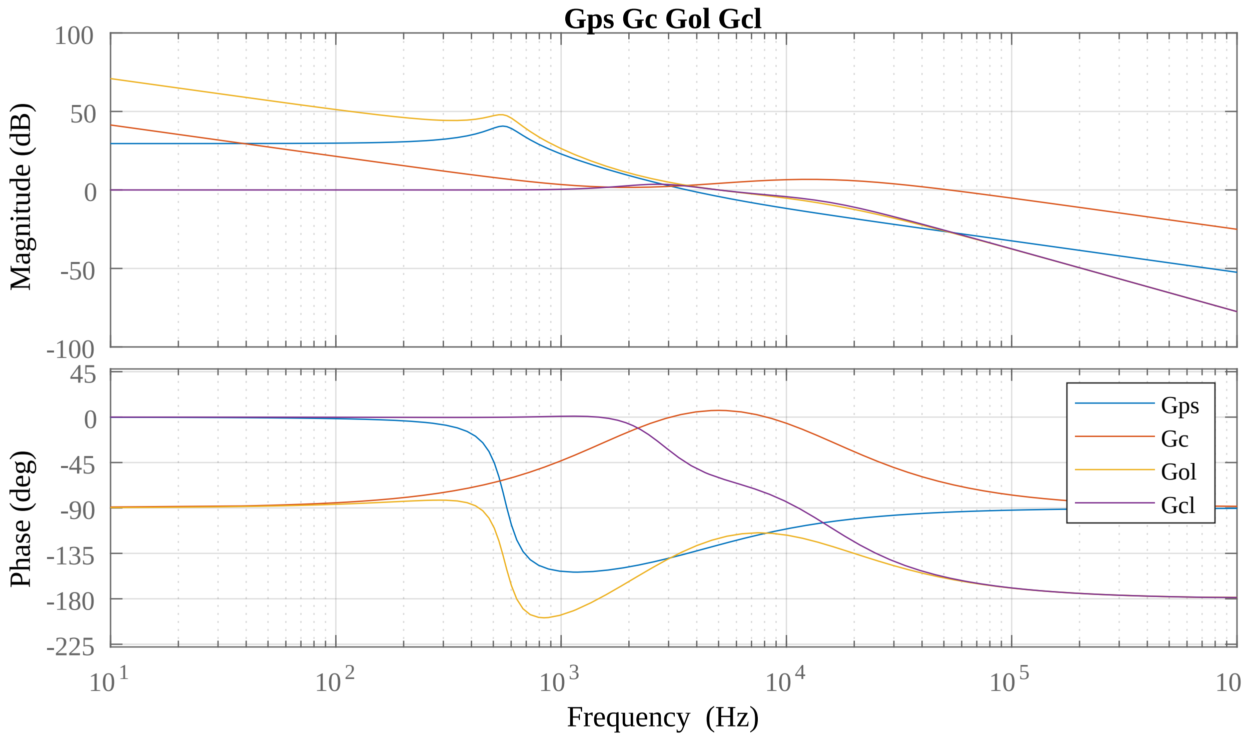
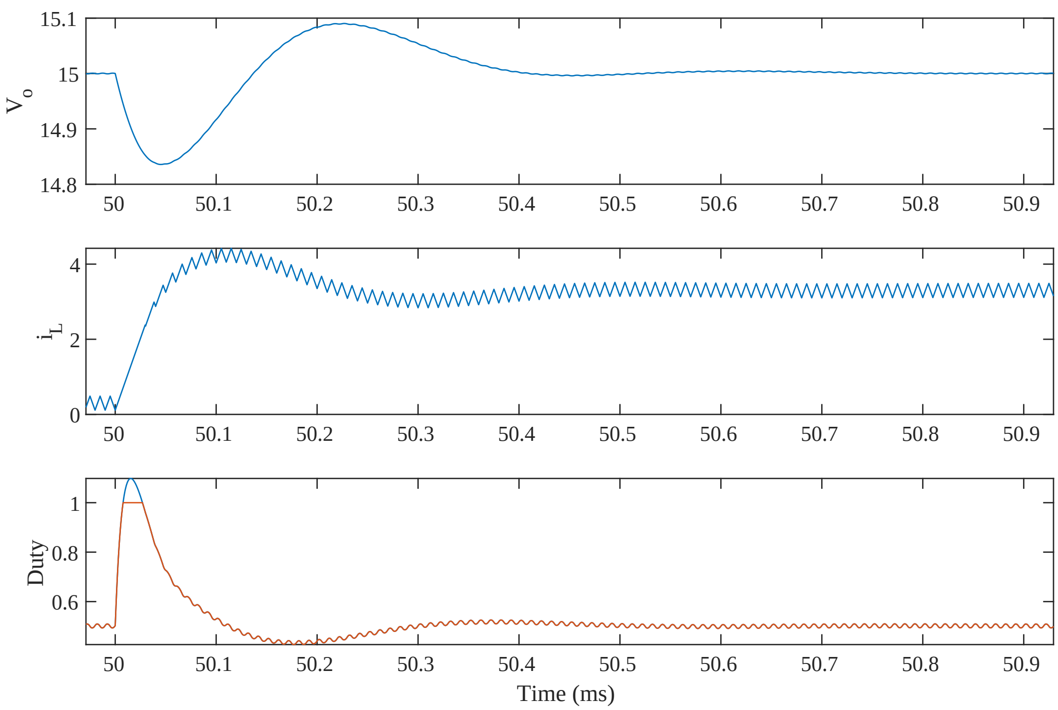
$$\omega_z = 11954 \quad \omega_p = 82556 \quad k = 7364 \tag{11}$$




Gol
Magnitude (dB)
100
50
0
-50
-100
Phase (deg)
-45
-90
-135
-180
-225
10^1
10^2
10^3
10^4
10^5
Frequency (Hz)


Gcl
Magnitude (dB)
20
0
-20
-40
-60
-80
Phase (deg)
45
0
-45
-90
-135
-180
10^2
10^3
10^4
10^5
Frequency (Hz)


Gps Gc Gol Gcl
Magnitude (dB)
Phase (deg)
Frequency (Hz)
Gps
Gc
Gol
Gcl


V_o
i_L
Duty
Time (ms)