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Class Project 2

جامعة خليفة
Khalifa University

ECE661 Power Electronics (Fall-2022)

Class Project 2 (Due date Dec 7, 2022)

A boost converter has following specifications:

V_{in} = 12 V, V_o = 24 V, Load = 100 ohm, Fs = 20 kHZ
L = 10e-3 H, dc resistance of inductor = 0.1 ohm, C_o = 12.5e-6 F,

The input voltage may vary from 8V to 16V, whereas the load resistance varies from 50 ohm to 200 ohm.

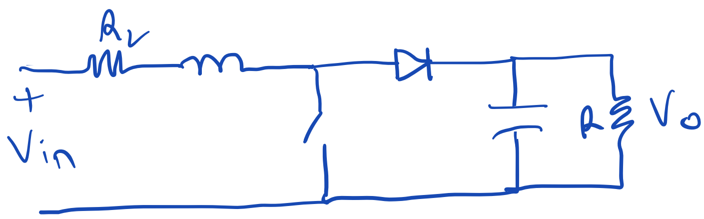
A. Design the PI controller parameters for the closed-loop system such that desired output voltage is obtained while satisfying following criteria:
   1) Output voltage lies in the range of 23.5V to 24.5V
   2) Settling time < 50 ms
   3) Maximum overshoot < 26.4V

B. To verify the performance, show the steady-state output voltage, settling time and overshoot at the startup for the following cases:
   1) Vin = 12V, Load = 50, 100, and 200 Ohm
   2) Vin = 8V, Load = 50, 100, and 200 Ohm
   3) Vin = 16V, Load = 50, 100, and 200 Ohm
   4) Vin = 12V, Load = 1000 Ohm

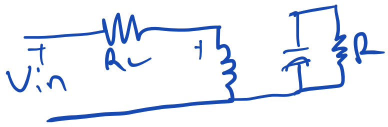
C. Discuss the system operation based on the above four points.

Note: Use the following parameters in powergui block for better results:

Simulation type = discrete, sample time = 1e-7



Switch on



KVL:

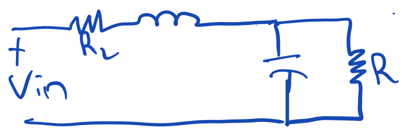
$$-V_{in} + i_L R_L + L\frac{di_L}{dt} = 0$$

$$i_c = i_o = \frac{V_o}{R}$$

$$[d(t)]\, L\frac{di_L}{dt} = (V_{in} - i_L R_L)\, [d(t)] \quad \text{— ①}$$

$$[d(t)]\, C\frac{dV_o}{dt} = -\frac{V_o}{R}\, [d(t)] \quad \text{— ②}$$

Switch off



KVL

$$-V_{in} + i_L R_L + L\frac{di_L}{dt} + V_o = 0$$

$$i_L = C\frac{dV_o}{dt} + \frac{V_o}{R}$$

$$[1-d(t)]\, L\frac{di_L}{dt} = (V_{in} - i_L R_L - V_o)\, [1-d(t)] \quad \text{— ③}$$

$$[1-d(t)]\, C\frac{dV_o}{dt} = \left(i_L - \frac{V_o}{R}\right) [1-d(t)] \quad \text{— ④}$$

① + ③ $\qquad d'(t) = 1 - d(t)$

$$\frac{di_L}{dt} = \frac{1}{L}\left(V_{in} - i_L R_L - V_o d'(t)\right) \quad \text{— ⑤}$$

③ + ④

$$\frac{dV_o}{dt} = \frac{1}{C}\left(i_L d'(t) - \frac{V_o}{R} \right) \quad \text{— ⑥}$$

Linearization

$d' = D' + \tilde{d}'$, $i_L = I_L + \tilde{i}_L$, $V_o = V_o + \tilde{v}_o$

$$\begin{bmatrix} \frac{d\tilde{i}_L}{dt} \\ \frac{d\tilde{v}_o}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R_L}{L} & -\frac{D'}{L} \\ \frac{D'}{C} & -\frac{1}{RC} \end{bmatrix} \begin{bmatrix} \tilde{i}_L \\ \tilde{v}_o \end{bmatrix} + \begin{bmatrix} -\frac{V_o}{L} & \frac{1}{L} \\ \frac{i_L}{C} & 0 \end{bmatrix} \begin{bmatrix} \tilde{d}' \\ \tilde{v}_{in} \end{bmatrix}$$

$$\{V_o\} = [0 \quad 1] \begin{bmatrix} \tilde{i}_L \\ \tilde{v}_o \end{bmatrix}$$

$$G_p = C(sI - A)^{-1}B + D$$

$$\begin{bmatrix} \frac{\tilde{v}_o}{\tilde{d}'} & \frac{\tilde{v}_o}{\tilde{v}_{in}} \end{bmatrix} = \begin{bmatrix} \frac{L i_L s - D' v_o + i_L R_L}{LCs^2 + (CR_L + \frac{L}{R})s + D'^2 + \frac{R_L}{R}} & \frac{D'}{LCs^2 + (CR_L + \frac{L}{R})s + D'^2 + \frac{R_L}{R}} \end{bmatrix}$$

$$g(s) = \frac{G_c G_p}{1 + G_c G_p}$$

A)

$$\frac{\tilde{v}_o}{\tilde{v}_{in}} = \frac{D'}{LCs^2 + (CR_L + \frac{L}{R})s + D'^2 + \frac{R_L}{R}}$$

$D' = 1 - D$

$V_o = \frac{V_{in}}{D'}$

$D' = \frac{V_{in}}{V_o}$

$8 \leq V_{in} \leq 16$ && $23.5 \leq V_o \leq 24.5 \Rightarrow V_o = 24\,V$

$50 \leq R \leq 200$,

$OP < 26.4\,V$

$\%OP = \frac{26.4 - 24.5}{24.5} < \underline{7.76\%}$

<u>For R = 50</u>

$$G_p = \frac{0.5}{1.25\times10^{-7}s^2 + 0.0002s + 0.252}$$

$K_p = ?$

$$g(s) = \frac{K_p G_p}{1 + K_p G_p}$$

$$g(s) = \frac{4\times10^6 K_p}{s^2 + 1600s + 4\times10^6(K_p + 0.504)}$$

$$s = \frac{-1600 \pm \sqrt{1600^2 - 16\times10^6(K_p + 0.504)}}{2}$$

$K_p = 0$, $\quad -800 \pm 1173j$

$K_p = 0.5$, $\quad -800 \pm 1837.4j$

$K_p = 1$, $\quad -800 \pm 2318.6j$

Using Control System Designer (MATLAB)

Using the following Parameters to find Ki & Kp

V_{in} = 12 V, V_o = 24 V, Load = 100 ohm, Fs = 20 kHZ

L = 10e-3 H, dc resistance of inductor = 0.1 ohm, C_o = 12.5e-6 F,

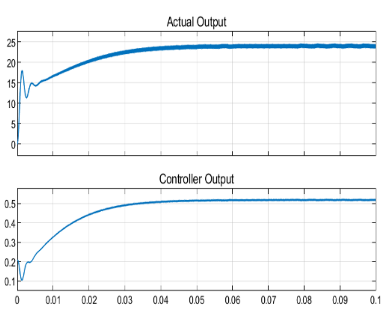
Choosing $T_s = 20ms$ & $\%OP = 5\%$

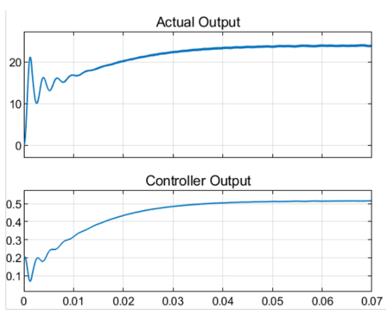
$$C = \frac{0.67737(s+316.4)}{s} \leftarrow \text{real zero}$$

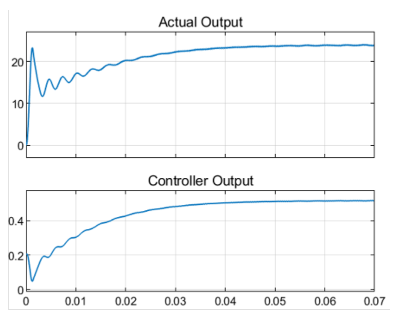
$K_p = 0.67737$, $K_i = 214.32$

B) 1) $V_{in} = 12V$

R = 50Ω   100Ω   200Ω



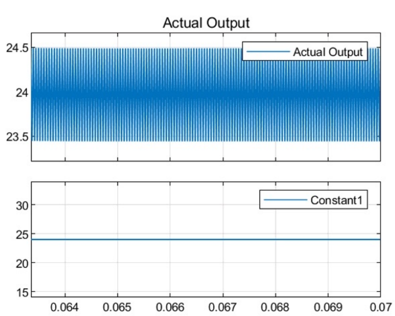


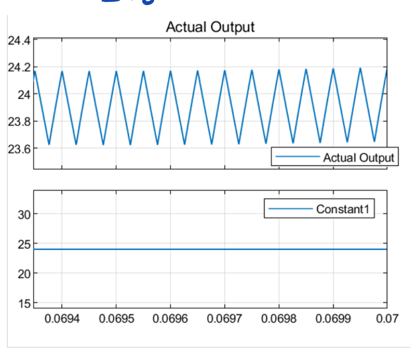


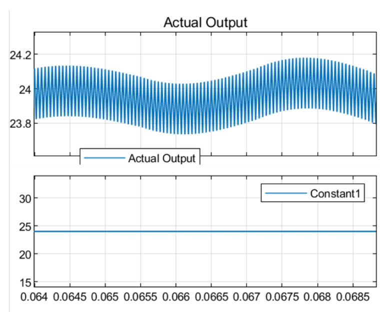
$T_s = 0.03s$
$\%OP = 0$
$\Delta V_o > 1$

$T_s = 0.03s$
$\%OP = 0\%$
$\Delta V_o < 1$

$T_s = 0.03s$
$\%OP = 0\%$
$\Delta V_o < 1$

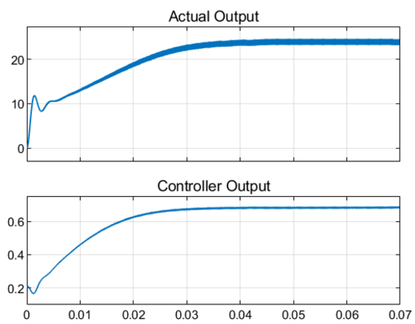


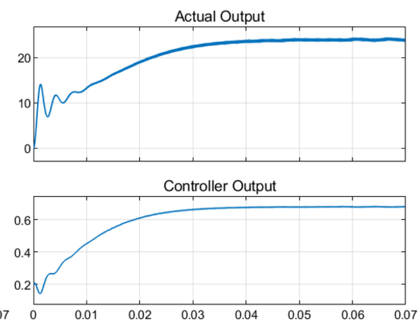


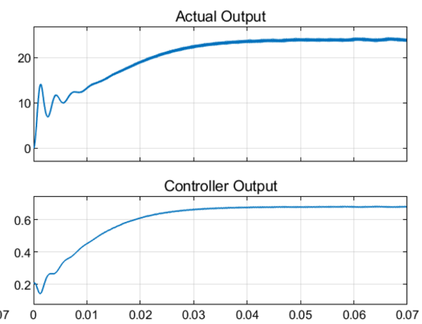


2) $V_{in} = 8V$

$R = 50\Omega$ $\qquad$ 100Ω $\qquad$ 200Ω



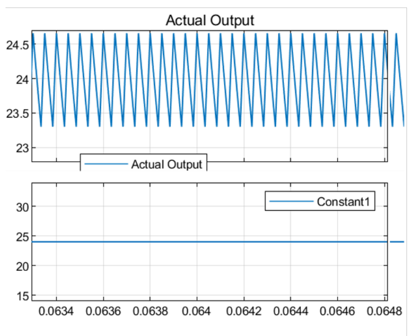


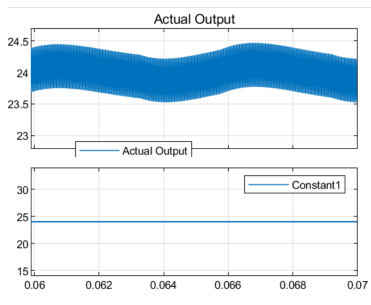


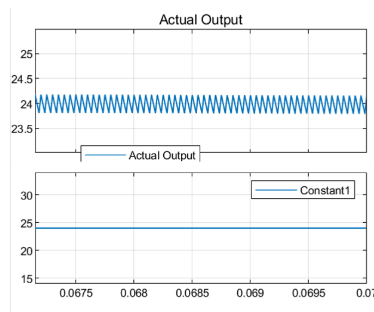
$T_s = 0.03\,s$
$\%OP = 0$
$\Delta V_o > 1$

$T_s = 0.03\,s$
$\%OP = 0\%$
$\Delta V_o < 1$

$T_s = 0.03\,s$
$\%OP = 0\%$
$\Delta V_o < 1$

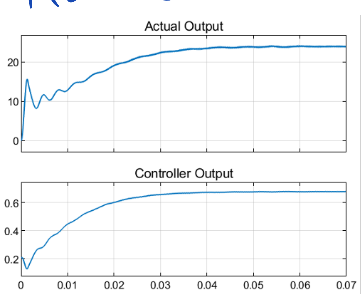


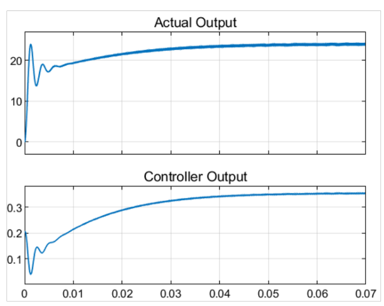


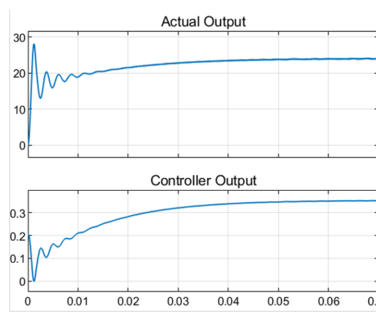


3) $V_{in} = 16V$

$R = 50\Omega$ $\qquad$ 100Ω $\qquad$ 200Ω



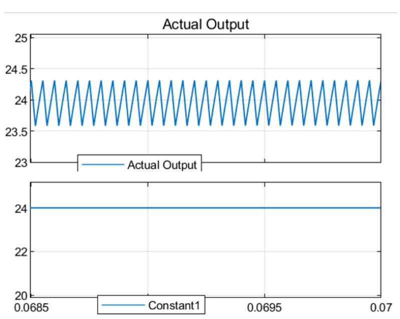


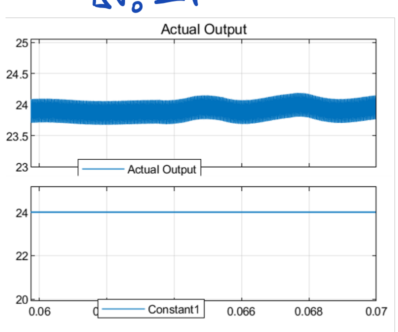


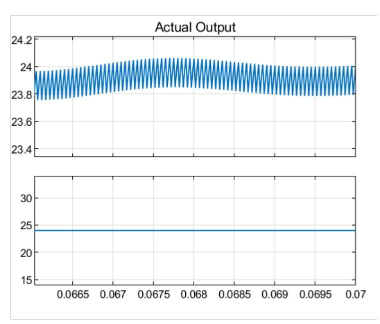
$T_s = 0.03\,s$ $\qquad$ $\Delta V_o < 1$
$\%OP = 0\%$

$T_s = 0.035\,s$
$\%OP = 0\%$
$\Delta V_o < 1$

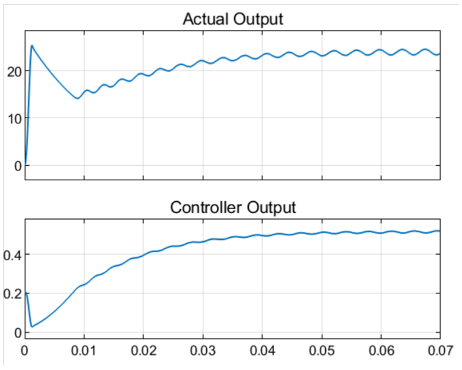
$T_s = 0.035\,s$
$\%OP = 16.7\%$
$\Delta V_o < 1$







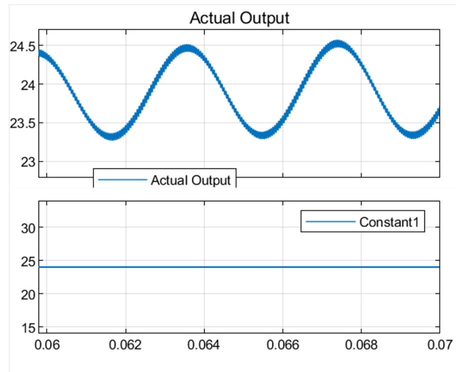
4) $V_{in} = 12V$
$R = 1000\,\Omega$



$T_s = 0.04s$

$\%OP = 8\%$

$\Delta V_o > 1$



c) Based on the result from the simulink oscilloscope, we can say that the settling time requirement is meet by using a PI controller.

However, the peak overshoot and the ripple voltage requirement is not always meet by using the PI controller.

For any input parameters, the output voltage fluctuates around the set value.