EE6308 SMRC Assignment 3

(Note- Use MATLAB to obtain time-domain response plots and Bode plots)

I Buck Converter Data

110 V input, 48 V, 4.8 A Output

$f_s = 50$ kHz, $L = 540\,\mu H$, $C = 100\,\mu F$

Load – Resistive, $10\,\Omega$

$r_\ell = 0.3\,\Omega$, $r_s = 0.2\,\Omega$, $r_d = 0.2\,\Omega$, $r_c = 0.5\,\Omega$

$V_\gamma = 0.5$ V

1 (a) Set up the State Space Averaged (SSA) model and evaluate the Steady-state duty ratio d_o when $V_{in} = 110$ VDC, $V_o = 48$ V and $R_L = 10\,\Omega$ load.

(b) Form the LTI Small Signal State Space Model around this operating point and evaluate $\frac{\Delta \bar{V}_o(s)}{\Delta d(s)}$, $\frac{\Delta \bar{V}_o(s)}{\Delta \bar{V}_{in}(s)}$, $\frac{\Delta \bar{i}_L(s)}{\Delta d(s)}$ and $\frac{\Delta \bar{i}_L(s)}{\Delta \bar{V}_{in}(s)}$

(c) Use MATLAB and obtain the time-domain response plots for $\bar{i}_L(t)$ and $\bar{V}_o(t)$ when duty ratio is suddenly increased by 5% of d_o.

d) Obtain the time domain response plots for $\bar{i}_L(t)$ and $\bar{V}_o(t)$ when input is suddenly changed from 110 V to 100 V.

e) If V_{in} contains a 100 Hz ripple of amplitude 5 V, find the 100 Hz component amplitude in $\bar{i}_L$ and $\bar{V}_o$ under steady state by using frequency response plots of corresponding transfer fns evaluated with the help of MATLAB.

2(a) Obtain the Bode plot of $\frac{\Delta \bar{V}_o(s)}{\Delta d(s)}$ and predict whether a Type I compensator can be designed with $f_{co} = 5$ kHz & PM $= 45^\circ$.

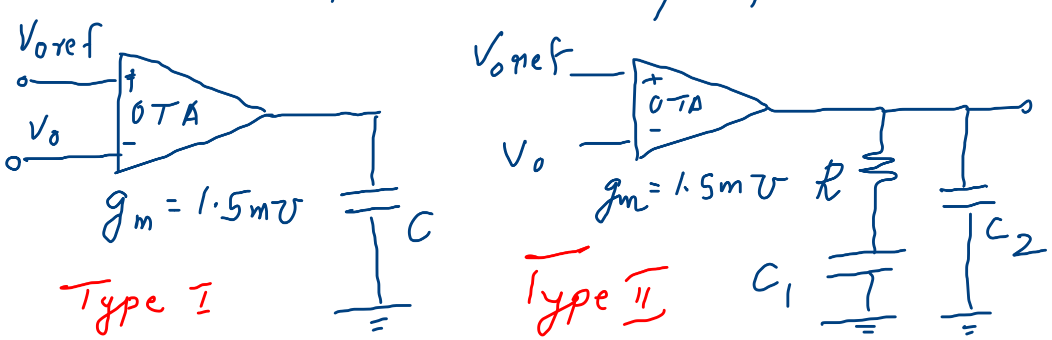
(b) Find f_{co} to be used if PM obtained by using a Type I Compensator is to be 60°.

(c) Find f_{co} to be used if PM obtained by using a Type II Compensator is to be 60°.

(d) Find f_{co} to be used if PM obtained by using a Type III Compensator is to be 60°.

(e) Design the Compensator transfer functions in (b), (c) and (d)

(f) Design circuits to obtain the Type I and Type II compensators using Transconductance amplifiers as below.



(g) Design a Opamp Circuit to get the Type III Compensator arrived at in Part(e).

3. (a) A Type I Compensator with 60° PM, designed under 2(e) is used in the converter. Obtain $\frac{\Delta \tilde{V}_o(s)}{\Delta \tilde{V}_{in}(s)}$, $\frac{\Delta V_o(s)}{\Delta V_{oref}(s)}$, $\frac{\Delta \tilde{i}_L(s)}{\Delta \tilde{V}_{in}(s)}$ and $\frac{\Delta \tilde{i}_L(s)}{\Delta V_{oref}(s)}$ for the closed loop Buck Converter.

(b) Obtain time-domain response plots using MATLAB for $\tilde{V}_o(t)$ and $\tilde{i}_L(t)$ when V_{oref} is suddenly changed from 48 V to 40 V.

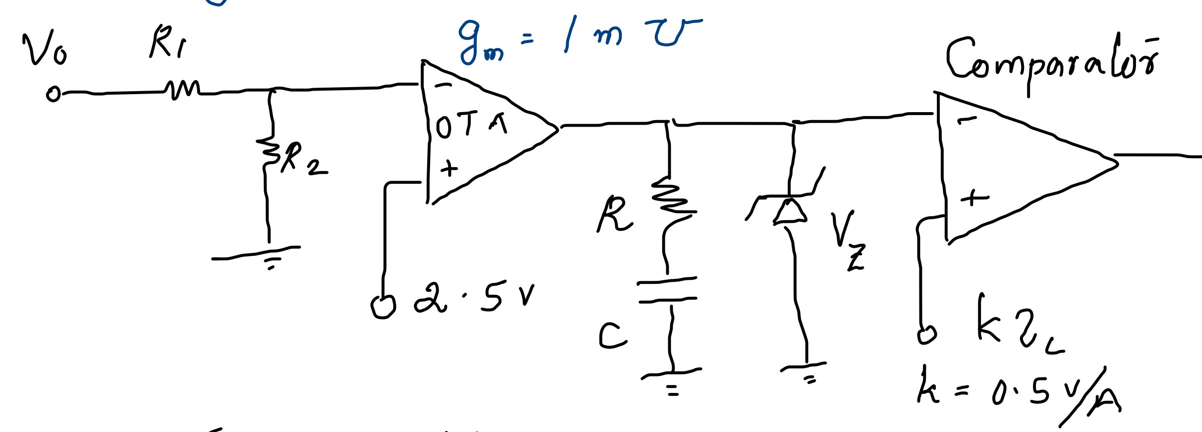
(c) Obtain time-domain response plots for $\tilde{V}_o(t)$ and $\tilde{i}_L(t)$ when V_{in} is suddenly changed from 110 V to 100 V and compare with plots in 1(d). Comment on the result.

(d) Find the 100 Hz ripple amplitude in $\bar{i}_L$ and $\bar{v}_o$ if there is a 5V amplitude 100 Hz component in V_{in}. Compare the result with the values found under 1(c) and comment.

4(a) This Buck Converter is controlled using Current Mode Control. The peak of i_L will be limited to 6 A under all conditions. The current sensor used to sense i_L has a gain of 0.5 V/A.

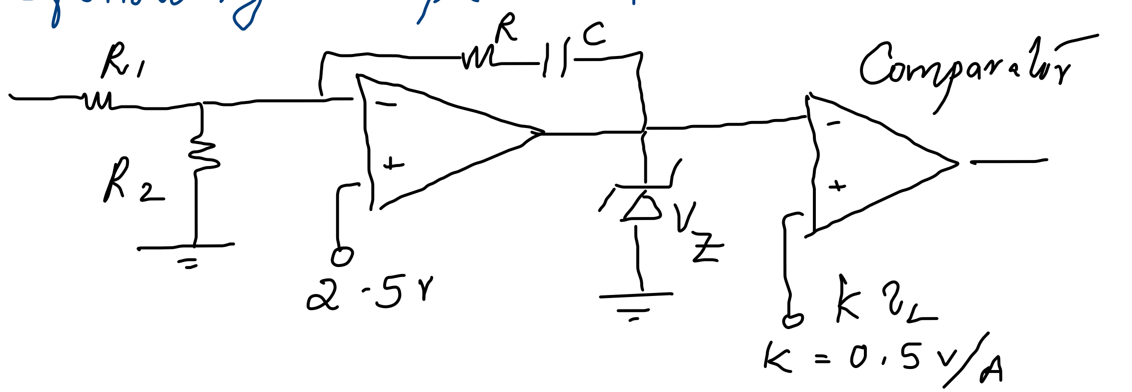
Design a PI Controller for outer voltage control loop if the closed loop system is expected to have a rise time of 1 ms.

(b) Find the component values in the following implementation of PI Controller



Resistors should be in 1 kΩ – 100 kΩ range.

c) Find the component values if the following implementation is used.



II Boost Converter Data

48V input, 110V, 4 A Output

$f_s = 50\,kHz$, $L = 270\,\mu H$, $C = 330\,\mu F$

$r_l = 0.3\,\Omega$ $r_s = 0.1\,\Omega$ $r_d = 0.1\,\Omega$

$r_c = 0.1\,\Omega$ Load is resistive $= 27.5\,\Omega$

$V_\gamma = 0.5\,V$

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1 (a) Set up the State Space Averaged (SSA) model and evaluate the steady-state duty ratio d_0 when $V_{in} = 110$ VDC, $V_0 = 48$ V and $R_L = 27.5\,\Omega$ load. (You may have to iterate)

(b) Form the LTI Small Signal State Space Model around this operating point and evaluate $\frac{\Delta \bar{V}_0(s)}{\Delta d(s)}$, $\frac{\Delta \bar{V}_0(s)}{\Delta \bar{V}_{in}(s)}$, $\frac{\Delta \bar{i}_L(s)}{\Delta d(s)}$ and $\frac{\Delta \bar{i}_L(s)}{\Delta \bar{V}_{in}(s)}$

(c) Use MATLAB and obtain the time-domain response plots for $\bar{i}_L(t)$ and $\bar{V}_0(t)$ when duty ratio is suddenly increased by 5% of d_0.

d) Obtain the time domain response plots for $\bar{i}_L(t)$ and $\bar{V}_0(t)$ when input is suddenly changed from 48 V to 44 V.

e) If V_{in} contains a 100 Hz ripple of amplitude 10 V, find the 100 Hz component amplitude in $\bar{i}_L$ and $\bar{V}_0$ under steady state by using frequency response plots of corresponding transfer fns evaluated with the help of MATLAB.

2(a) Obtain the Bode plot of $\frac{\Delta \bar{V}_0(s)}{\Delta d(s)}$ and predict whether a Type I compensator can be designed with $f_{co} = 5\,kHz$ & $PM = 45°$.

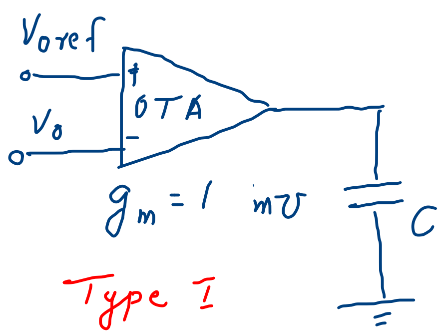
(b) Find f_{co} to be used if PM obtained by using a Type I Compensator is to be 60°

(c) Find f_{co} to be used if PM obtained by using a Type II Compensator is to be 60°.

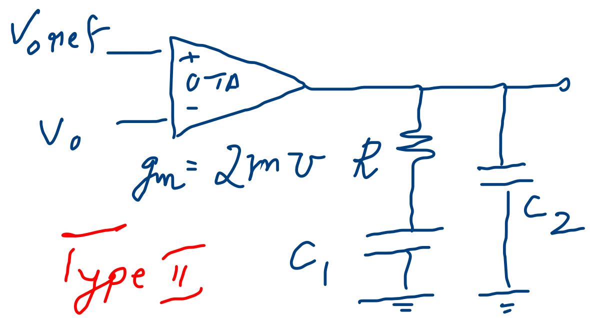
(d) Find f_{co} to be used if PM obtained by using a Type III Compensator is to be 60°

(e) Design the Compensator transfer functions in (b), (c) and (d)

(f) Design circuits to obtain the Type I and Type II compensators using Transconductance amplifiers as below.



Type I



Type II

3. (a) A Type III Compensator with 60° PM, designed under 2(e) is used in the converter. Set up the closed loop control block diagram in MATLAB/Simulink.

(b) Obtain time-domain response plots using MATLAB for $\bar{V}_o(t)$ and $\bar{i}_L(t)$ when V_{oref} is suddenly changed from 110 V to 120 V.

(c) Obtain time-domain response plots for $\bar{V}_o(t)$ and $\bar{i}_L(t)$ when V_{in} is suddenly changed from 48 V to 40 V and compare with plots in 1(d). Comment on the result.

(d) Find the 100 Hz ripple amplitude in $\bar{i}_L$ and $\bar{V}_o$ if there is a 10 V amplitude 100 Hz component in V_{in}. Compare the result with the values found under 1(e) and comment.