EE270: Homework 6

Due: Jan. 4th 2024

Problem 1

A certain buck converter operates with an input voltage of $V_g = 30\text{V}$ and an output voltage of $V = 15\text{V}$. The load resistance is $R = 20\Omega$. Other element and parameter values are $L = 50\mu\text{H}$, $C = 220\mu\text{F}$, $f_s = 50\text{kHz}$.

(a) Determine the value of R_e.

(b) Determine the quiescent duty cycle D.

(c) Sketch a Bode plot of the control-to-output transfer function $G_{vd}(s)$. Label the values of all salient features. You may neglect inductor dynamics.

Problem 2

A nonideal buck converter operates in the continuous conduction mode, with the values $V_g = 12\text{V}$, $f_2 = 100\text{kHz}$, $L = 4\mu\text{H}$, $C = 75\mu\text{F}$, and $R = 0.4\Omega$. The desired full-load output is 6V at 15A. The power stage contains the following loss elements: MOSFET on-resistance $R_{on} = 0.1\Omega$, Schottky diode forward voltage drop $V_D = 0.5\text{V}$, inductor winding resistance $R_L = 0.03\Omega$.

(a) Steady-state analysis: determine the converter steady-state duty cycle D, the inductor current ripple slopes m_1 and m_2, and the dimensionless parameter $K = 2L/RT_s$.

(b) Determine the small-signal equations for this converter, for duty-cycle control.

A current-programmed controller is now implemented for this converter. An artificial ramp is used, having a fixed slope $M_a = 0.5M_2$, where M_2 is the steady-state slope m_2 obtained with an output of 6V at 15A.

(c) Over what range of D is the current-programmed controller stable? Is it stable at rated output?

Note that the nonidealities affect the stability boundary.

(d) Determine the control-to-output transfer function $G_{vc}(s)$, using the simple approximation $\langle i_L(t)\rangle_{T_s} \approx ic(t)$. Give analytical expressions for the corner frequency and dc gain. Sketch the Bode plot of $G_{vc}(s)$.

Problem 3

A buck converter operates with current-programmed control. The element values are

$$\begin{array}{ll} V_g = 120\text{V} & D = 0.6 \\ R = 10\Omega & fs = 100\text{kHz} \\ L = 240\mu\text{H} & C = 100\mu\text{F} \end{array}$$

An artificial ramp is employed, having slope $0.15\text{A}/\mu\text{s}$.

(a) Construct the magnitude and phase asymptotes of the control-to-output transfer function $G_{vd}(s)$ for duty-cycle control. On the same plot, construct the magnitude and phase asymptotes of the control-to-output transfer function $G_{vc}(s)$ for current programmed control. Compare.

(b) Construct the magnitude asymptotes of the line-to-output transfer function $G_{vg}(s)$ for duty-cycle control. On the same plot, construct the magnitude asymptotes of the line-to-output transfer function $G_{vg-cpm}(s)$ for current-programmed control. Compare.