SI100B – Electrical Engineering, 2023 Spring

Homework #4

Notes:

1. The submission deadline is **2023-05-21 23:59**. Late assignments will incur a **20-point** deduction per day.
2. You must work on this homework individually. Any plagiarism will result in a zero grade for this assignment.
3. You can either type your answers in a word document and save it as a **pdf file** or write them by hand and scan them as a **pdf file**.
4. The simulation files that support your analysis should be named according to the problems. They should be submitted **separately from the pdf file** (You can upload multiple files at once on Blackboard).

Problem 1. Buck-Boost Converter (80 points)

A buck-boost converter is a DC-DC converter that can step up or down the input voltage depending on the duty ratio of the switch. The circuit diagram is shown below. In this problem, you will analyze and design a buck-boost converter with the given specifications.

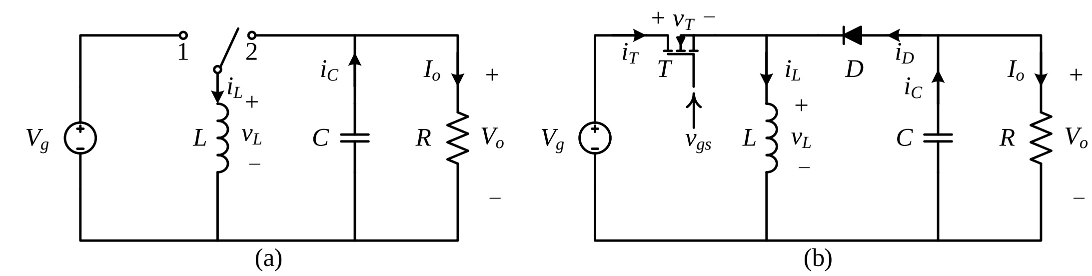

Fig. 1-1 Buck-boost converter circuit. (a) Ideal. (b) Implementation using MOSFET and diode

1) Sketch the waveforms of the following quantities in one switching cycle of the Buck-Boost converter shown in Fig. 1-1(b): v_{gs}, v_T, v_L, i_L, i_T, i_D and i_C. **(20 points)**
   (Hint: The gate-source voltage that controls the MOSFET T is denoted as v_{gs}. You can assume that the output voltage V_o is constant in this problem. However, you cannot neglect the ripple of the inductor current i_L. Pay attention to the voltage and current reference directions marked in Fig. 1-1(b).)
2) Find the expressions for the output voltage V_o and **average** inductor current I_L as functions of the duty ratio D, input voltage V_g, and load resistance R. **(10 points)**
   (Hint: To simplify the analysis of the Buck-Boost converter, you may assume that the inductor current ripple and capacitor voltage ripple are small. Then write the KVL and KCL equations for the two operation modes and apply the volt-second balance and charge balance principles.)
3) Plot the curves of V_o and I_L versus D for $0 \leqslant D \leqslant 1$ using MATLAB or any other software. **Include the plots in your submitted pdf file.** **(10 points)**
4) Based on the given specifications:

Input voltage V_g	50V
Output voltage V_o	–30V
Load resistance R	10Ω
Switching frequency f_s	20kHz

Output capacitance C	470μF

a) Find **the duty cycle *D*** that satisfies the output voltage specification and find **the corresponding value of I_L**. **(10 points)**

b) Choose the **inductance *L*** such that the inductor current ripple Δi_L is 5% of I_L. **(5 points)**

5) Use Simulink to create a simulation of the circuit with the parameters listed and derived in (4). **Include the simulation circuit and results in your submitted pdf file. (15 points)**
(Note: The simulation results should show the waveforms of V_g, V_o, v_{gs}, v_T, v_L, i_L, i_T, i_D, i_C in steady state. Make sure the voltage and current reference directions in the simulation circuit match the ones marked in Fig. 1-1(b). Use appropriate legends to label your simulated waveforms.)

6) To improve the performance of the Buck-Boost converter under input voltage disturbances, we can use a PID controller to regulate the output voltage. The control system measures the output voltage and compares it with a reference value. The error signal is then used to adjust the duty cycle of the switch. Draw **a feedback block diagram** for the Buck-Boost converter with a PID controller. **(10 points)**

Problem 2. Dynamic Systems and Control (20 points)

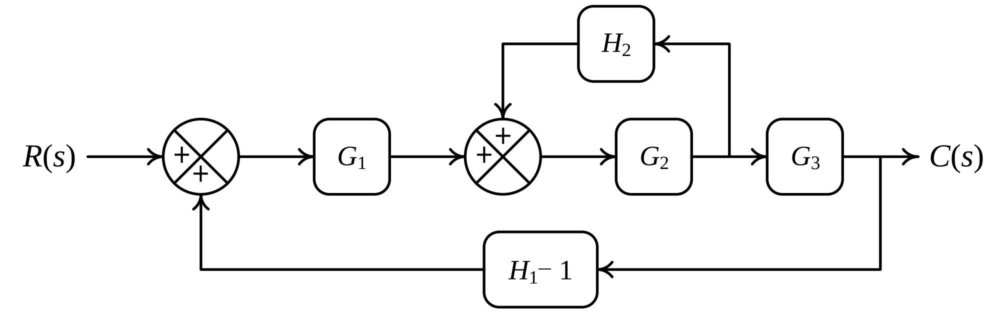

Fig. 2-1

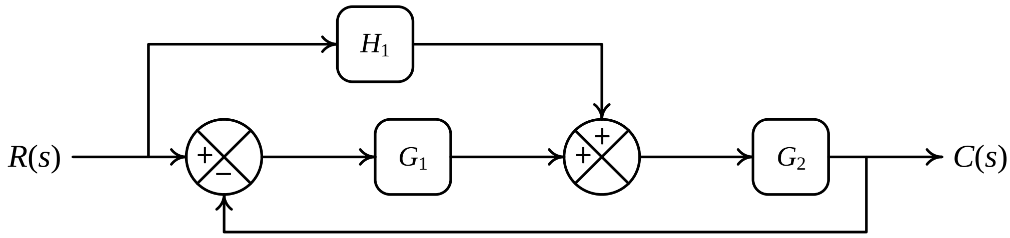

Fig. 2-2

1) Derive the transfer function $G(s) = \dfrac{C(s)}{R(s)}$ of the signal-flow graph in Fig. 2-1. **(10 points)**

2) Derive the transfer function $G(s) = \dfrac{C(s)}{R(s)}$ of the signal-flow graph in Fig. 2-2. **(10 points)**