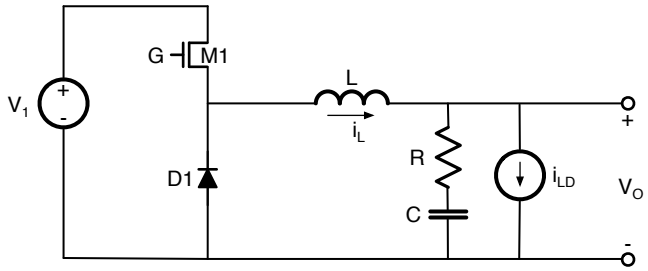
EE155/255 F17 Homework 4
Feedback Control and Electric Motor Calculations

Assigned 10/16/17
Due 10/23/17

Problem 1: Feedback Control



Consider the schematic above of a buck converter where we are explicitly modeling the effective series resistance (ESR) of the capacitor. Suppose the duty factor on FET M1 is D_M and the duty factor of diode D1 is $D_D = (1-D_M)$.

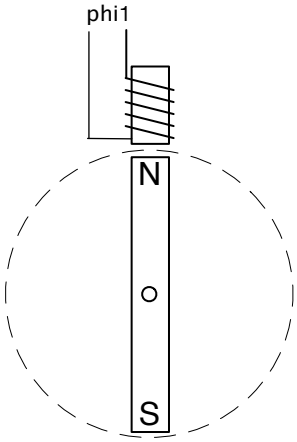
(a) Write an expression for the open-loop transfer function from D_M to V_O – the voltage across the load.

(b) For the specific values of i_{LD} = 10A, R=0.01Ω, C=100uF, L=22uF, and V_1 = 10V, design a PID controller (i.e., specify values of P, Q, and R) that gives a well-damped response (no more than 20% overshoot), zero residual error, and avoids saturating the duty factor on a 1V step in target input voltage. (Hint: You may use feed-forward control in lieu of an integral term in your controller).

(c) (Extra Credit) Simulate your controller (and the converter) in Matlab. Show the response to a step from a target of 4V to 5V and then back to 4V.

(d) (Extra Credit) Show Bode plots (phase and amplitude vs frequency) for your plant and your plant with controller. Measure the phase margin.

Problem 2: Motor Calculations



Suppose you have a single-phase brushless permanent magnet motor (as shown above). The rotor is shown in the θ=0 position. You may neglect the inductance in the motor windings.

(a) When the motor has an angular velocity of ω=1 rad/s you observe a sine wave with amplitude 1V (RMS) and frequency of 1 rad/s across the single open-circuit winding. If you increase the angular velocity to $\omega = 2$ rad/s, what voltage waveform will you see across the winding? (Express voltage as a function of time, t).

(b) You apply a torque of 2 N-m to the shaft of the motor rotating at 10 rad/s in the direction of rotation. What resistance must be applied across the winding to keep the motor at a steady speed (averaged over a cycle)? How much power is dissipated in this resistor?

(c) Driving the winding with a DC current source with current I_0 and the rotor "locked" in a stationary position, you observe a torque of 1 N-m with the rotor at θ=30 degrees. What torque do you expect with the same current and the rotor at θ=90 degrees?

(d) What torque do you expect at θ=90 degrees and a current of $2I_0$?