University of Nottingham
UK | CHINA | MALAYSIA

EEEE3112-Power Electronic Applications and Control

Coursework 1: DC/DC converters for CPU applications

Introduction:

This coursework involves investigating the design, control, and behaviour analysis of a DC/DC converter for CPU applications.

First, let's summarize some key points. Please read them carefully

The coursework is an individual exercise where you will be tasked with designing and simulating power electronics for CPU applications and an associated control design.

All the theory and knowledge to complete the coursework are covered in lectures. Use the lectures as guidance to do your coursework. On the other hand, the coursework is designed to help strengthen your understanding of the taught topics. The taught topics and the coursework are complementary to one another.

Learning how to design and simulate a state-of-the-art converter is an essential skill for a future power electronic engineer, and the works done during the coursework are the standard steps before the construction of a laboratory prototype.

MATLAB will be used for the controller design and PLECS for the power electronics and for the simulation of the full system.

This coursework is worth 30% of the module.

Assessment will be based on a written report, submitted electronically on Moodle. The most important learning outcome of the coursework will be the application of the correct design and validation methodology. You are not expected to write a long essay but rather to be as clear as possible about how you designed the system and how you validated your design. Any additional critical comment/discussion of the results is obviously welcome!

The coursework should be written as a technical document you may be asked to submit to the management of a company and is used to decide whether to put your converter into production or not. Therefore, make sure to write the document as follows:

- If something goes wrong, for instance, you design it wrong and did not explain it properly, you will be considered responsible for it.

- Do not write the coursework as if you are answering examination questions for each of the deliverables provided.

System under study:

The power conversion system you design and simulate is a DC/DC converter for CPU applications.
System design specifications:

Assume the CPU as a resistive load.

Specification/Term	Symbol	Value
DC Supply voltage	V_{DC}	5V
Output voltage	$\overline{V}_{BN}/V_o$	1.8V
Output current	I_o	18A
Switching frequency	f_S	200kHz
Output voltage ripple	ΔV_o	1mV
Internal resistance of the filter inductor	R_L	5mΩ
ESR of the filter capacitor	ESR	0.05Ω

PART 1 – Power Electronics

Deliverables:

1.1 Choose and justify a suitable value for the inductor current ripple, ΔI_L.
1.2 Design the filter inductor L required to remove the high frequency switching noise respecting the current ripple calculated in 1.
1.3 Calculate the value of the filter capacitor.
1.4 Build a switching PLECS model of the system, including the PWM modulator and the half-bridge converter. Feed the PWM modulator with the voltage demand, V_{BN}^* and verify if your output voltage replicates the voltage demand.
1.5 Consider the bidirectional version of the converter as shown in Fig. 1 Simulate the wave forms of current, voltage and power for
   i. An ideal circuit
   ii. A circuit with losses in active and passive components

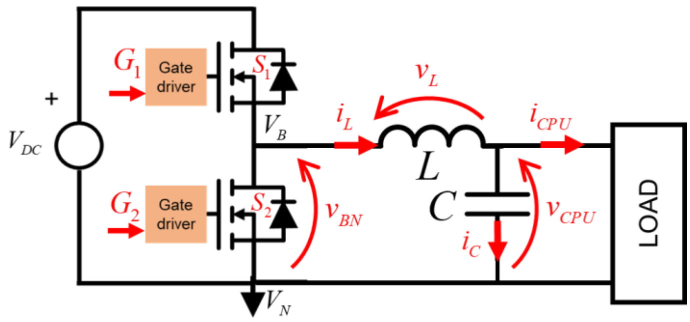

Figure 1

1.6 Consider the unidirectional version of the converter as shown in Fig.2 and simulate the wave forms of current, voltage and power for

   iii. An ideal circuit
   iv. A circuit with losses in active and passive components

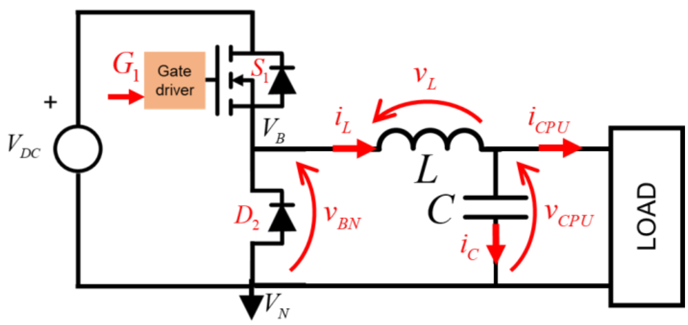

Figure 2

1.7 Report:

The report should contain the following.

- All calculations involved.
- Waveforms of current, voltage and power for all four cases.
- Details of all four cases in terms of power loss and efficiency.
- Detailed analysis of differences between the actual and the ideal case if there is any.
- If there is a difference, check if this is within the allowed limit and explain it in the report.

Page limit: 15 pages excluding title page

Part 2 – Control Systems

In this part, you are not required to write a report. Instead, your solution should be prepared using a single MATLAB Live Code file. Name that file as [First_Name_Last_Name].mlx. Use short comments to identify each part of the code and explain the essential parts only. Do not write an essay. Then, you are required to do the following:

1. Determine the transfer function of the plant based on the voltage-control mode.

2. Calculate the values of the rise time, peak time, settling time, overshoot, and steady-state error. This calculation should be done using the formulas covered in the module.

3. Use any built-in command(s) in MATLAB to determine the values mentioned in Step 2. Then, compare your findings.

4. Assume that the plant is included in the forward path of a unity feedback control system. Determine the locations of the closed-loop poles of the system. Then, find the dominant pole of the closed-loop system.

5. Investigate the effect of varying the value of the dominant pole from 0 until ∞.

6. Design a controller (or multiple controllers) for the system based on the analytical approaches covered in the module. You are required to meet the following requirements:

   A. The controller(s) should eliminate the steady-state error.

   B. The controller(s) should cause the settling time to be twice as fast as the open-loop plant.

   C. The overshoot of the controlled system should be $\leq 5\%$.

7. Compare the step response of the controlled system with the step response of the open-loop plant using a single plot.
8. Compare the root locus of the controlled system with the root locus of the open-loop plant using two subplots.
9. Use any built-in command(s) in MATLAB to determine the values of the rise time, peak time, settling time, overshoot, and steady-state error.