Buck converter prototype

Group project of the computer aided prototyping laboratory

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1. Aim of the project

The aim of the project is to develop a virtual and physical prototype of a buck converter with technical documentation.

2. Description and details of the buck converter

The structure of the system that have to be designed is shown in Fig. 1

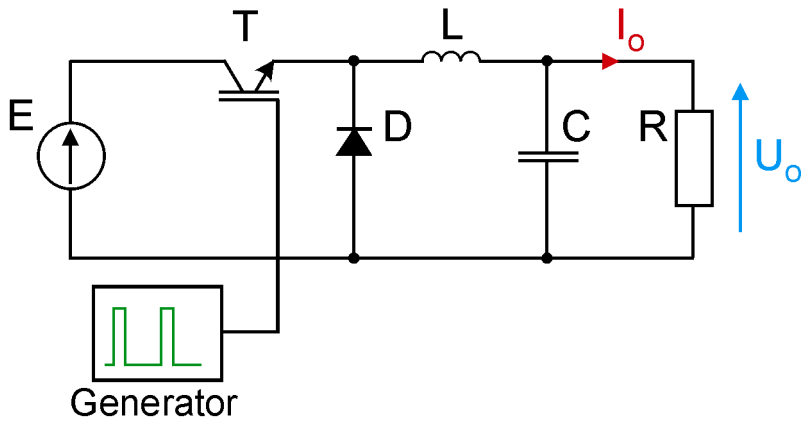

Fig.1. Buck converter

All necessary details and parameters that have to be considered in the development are shown in Tab.1

Table 1. Project numbers and input data of the buck converter design

		Project number											
Variable	**Description [unit]**	**P-1**	**P-2**	**P-3**	**P-4**	**P-5**	**P-6**	**P-7**	**P-8**	**P-9**	**P-10**	**P-11**	**P-12**
Input voltage	E [V]	28	26	24	24	26	28	26	24	28	24	28	26
Max. load current	$I_{o\,max}$ [A]	1	2	3	3	1	2	2	1	3	2	3	1
Transistor switching frequency	f_s [kHz]	40	50	30	45	55	38	42	35	52	47	41	38
Choke inductance	L [mH]	2	8.5	1.5	2.5	3.7	5	1	6	4	1	9	3
Core material													
Core coefficient	AL [nH]												

3. Work organization

The laboratory group has to be divided into 2 work teams WT_A and WT_B. Each work team is divided into 3 workgroups in which each is responsible for a task in prototype process of the buck converter.

Each WT has to design and build one converter prototype. Team work is demanded – each of the workgroup WG_1, WG_2, WG_3 is carrying out the task which was assigned to the group. The division of WT and WG as well as the assignment of the responsibilities of the project parts will be done in the first lecture.

4. Project range and division into tasks

The buck prototype design includes:

Workgroup WG_1:

- Preparing the simulation model in LTSpice, which includes the power electronic part as well as the control unit part.
- Adaptation of the simulation model to obtain a model of the real system, matching simulation and experimental results by introducing parasitic elements into the simulation model.
- Designing, building and testing of the control part based on NE555 timer on prototype PCB.
- Taking oscilloscope measurements.
- Preparing the part of the technical documentation.

Workgroup WG_2:

- Disassembly of elements from the prototype board, checking if they are functional and assembly of elements on the printed circuit (in class, tools will be available)
- The design of PCB board in EAGLE software.
- Preparation of output files for making a final PCB. Printing on transparent foil copper view for PCB laminate exposure. The circuit board will be chemically etched.
- Writing G-code software for drilling selected holes in PCB board.
- Assembling and soldering the elements of the converter on final PCB board.
- Preparing the part of the technical documentation.

Workgroup WG_3:

- Design and calculations of a choke.
- Simulation model in FEMM of the choke.
- Designing the coil bobbin of the choke using 3D software (i.e. Google SketchUp, Autodesk 123D Design) and preparation of the valid STL file.
- Generating BFB file for printing the choke bobbin using 3D printer.
- Winding of the coil and inductance measurement.
- Writing G-code software for drawing descriptions of the selected elements on the PCB board.
- Preparing the part of the technical documentation
- Colleting of all documentation parts of the other groups together and standardize all documents into one format of the technical documentation.

Assessment rules

The prototype has to be built and the report has to be prepared. A working prototype and an almost finished technical documentation have to be delivered until the last class.

join assessment is given for the whole work team. The highest grade M_{AX} is:

- M_{AX}=5.0 – the prototype is working according to requirements, the documentation is complete and right written.
- M_{AX}=4.5 – the prototype is done but not working properly, the documentation is right prepared as well as complete.

The assessment is given based on two parts A and B that are explained in Table 3 and Table 3 due to the expression (1).

$$O_{CE} = M_{AX}\left(\frac{A}{21}\cdot 0.75 + \frac{B}{27}\cdot 0.25\right) \quad (1)$$

The final determined due to (1) results using the score range given in Table 1.

Table 3. Score range of final assessment

Score section	Project grade
$O_{CE} < 2.5$	2
$2.5 \le O_{CE} < 3.0$	3
$3.0 \le O_{CE} < 3.5$	3.5
$3.5 \le O_{CE} < 4.0$	4
$4.0 \le O_{CE} < 4.5$	4.5
$4.5 \le O_{CE}$	5

Moreover

1. The teacher is able to raise the grade about 0.5 points, if the prototype and the technical documentation are done before the deadline (prototype on the last lab exercise and the technical documentation within one week).
2. Besides, the teacher is able to raise the grade about further 0.5 points for groups and group members with especially engagement without any missing lab exercises.
3. The grade can be lowered if the documentation will be finished beyond the deadline.
4. The grade can be lowered in case of any missing laboratory exercise.

Attention

At the end of the report two additional pages including Table 3 and Table 4 have to be placed

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Table 3. Part A assessment - documentation contents (*max. 21 points, weighting factor 0.75*)

	Project contents Each position is graded with 1 point	**Grade**
WG1	1. Description of the buck converter principle of operation	
	2. Scheme of the LTSpice simulation model	
	3. LTSpice simulation results	
	4. Description of the control circuit principle of operation	
	5. Scheme of the control circuit	
	6. Calculations of PWM frequency for NE555, selection of elements values	
	7. Measurement of the control signals	
	8. Oscilloscope measurements of the complete buck converter	
	9. Conclusions regarding 1..8 points of WG1	
WG2	10. Complete scheme of the built buck converter	
	11. PCB layout with dimensions, calculations of the printed paths width	
	12. List of materials of the complete buck converter	
	13. G-code software for drilling the selected holes in PCB board	
	14. Description of the etching of PCB board (as WG3 conclusions)	
WG3	15. The choke simulation model in FEMM	
	16. Equations and calculations of the choke (including B-H curve)	
	17. FEMM simulation results	
	18. 3D model of the choke bobbin	
	19. Choke inductance measurement	
	20. G-code software for drawing of the descriptions of selected elements on PCB board	
	21. Conclusions (regarding 1..8 points of WG3)	
	TOTAL	

Table 4. Part B assessment - documentation check list (*max. 26 points, weighting factor 0.25*)

	Formal part Each position is graded with 1 point	**Grade**
	General	
1.	Front page	
2.	List of the students	
3.	Project number and input parameters	
4.	Table of contents	
5.	Page numbers	
	Figures	
6.	Numbers	
7.	Captions	
8.	Description of the symbols used in Figures	
9.	Satisfying size and quality	
	Charts and oscilloscope waveforms	
10.	Numbers	
11.	Captions	
12.	Axis labels	
13.	Purposefulness of the results	
14.	Explanation to each chart and waveform	
	Tables	
15.	Numbers	
16.	Captions	
17.	Units	
18.	Example of calculations	
	Equations	
19.	Numbers	
20.	Units	
21.	Description of variables	
	Other schemes and drawings	
22.	Diagrams with models	
23.	Schematic diagram	
24.	PCB printed circuit board	
25.	3D drawing of the choke bobbin	
	Miscellaneous	
26.	Conclusions	
	Total	

5. Work groups

Laboratory group

Day of the week..... hours .....

Work team	Work group	Tasks	Student names
WT_A		Project **P-.....**	
	WG_1	Simulation model in LTSpice. Adaptation of the simulation model to experimental results. Designing, building and testing of the control part based on NE555 timer on prototype PCB. Oscilloscope measurements. Preparing the part of the technical documentation.	1. 2.
	WG_2	Disassembly of elements from the prototype board. Assembling of elements on the printed circuit. The design of PCB. Output files for PCB. Printing on transparent foil copper view for PCB expose for etching. Writing G-code for drilling PCB board. Soldering the elements on final PCB board. Part of the report.	1. 2.
	WG_3	Choke design calc. FEMM simulation model. Bobbin designing, STL files, 3d printing. Coil winding. Choke inductance measurement. G-code for drawing descriptions on the PCB. Part of the report. Colleting of all documentation parts and standardize all documents into one format.	1. 2.
WT_B		Project **P-.....**	
	WG_1	Simulation model in LTSpice. Adaptation of the simulation model to experimental results. Designing, building and testing of the control part based on NE555 timer on prototype PCB. Oscilloscope measurements. Preparing the part of the technical documentation.	1. 2.
	WG_2	Disassembly of elements from the prototype board. Assembling of elements on the printed circuit. The design of PCB. Output files for PCB. Printing on transparent foil copper view for PCB expose for etching. Writing G-code for drilling PCB board. Soldering the elements on final PCB board. Part of the report.	1. 2.
	WG_3	Choke design calc. FEMM simulation model. Bobbin designing, STL files, 3d printing. Coil winding. Choke inductance measurement. G-code for drawing descriptions on the PCB. Part of the report. Colleting of all documentation parts and standardize all documents into one format.	1. 2.