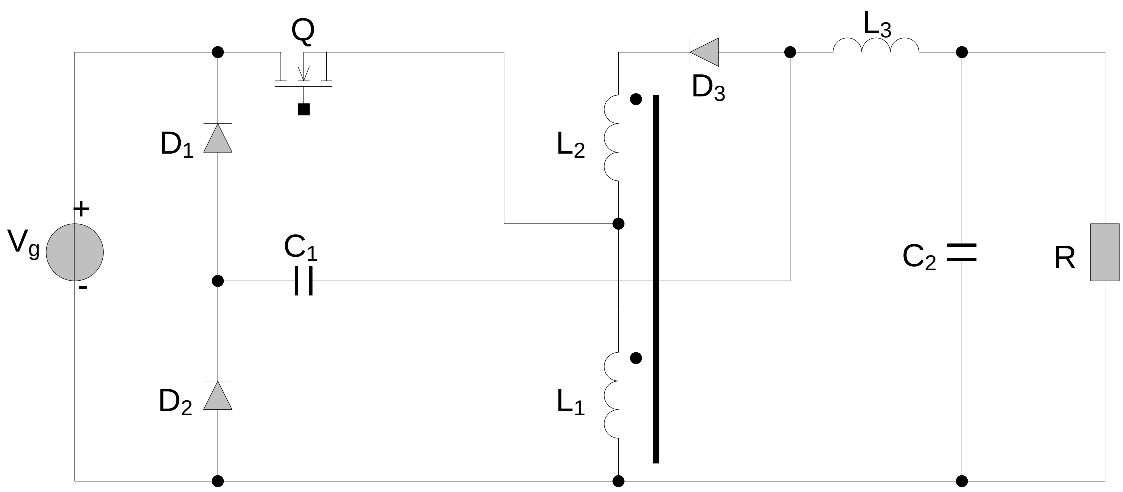
PROJECT STATEMENTS

AIM

Each team, as assigned in class, will *design* a CCM operated dc-dc converter, *including* the *control circuit*, and will compare the theoretical predictions to the simulation results. On request, practical implementation can be performed, but practical implementation is not compulsory.

DESIGN SPECIFICATIONS

A nonisolated dc-dc converter employing two *coupled inductors* will be analyzed. The inductors are assumed to be perfectly coupled, while N_1 and N_2 denote the corresponding number of turns.
It is assumed that there exists a feedback loop that regulates the dc output voltage against variations in the supply voltage and load by modifying the duty cycle.



As *design specifications* the following values are supposed to be known:

- Minimum input voltage - V_{gmin}
- Maximum input voltage - V_{gmax}
- The dc output voltage – V_o
- The maximum allowed output voltage ripple - ΔV_o
- Minimum output power – P_{omin}
- Maximum output power – P_{omax}
- The switching frequency – f_s

DESIGN STEPS

1. Under the small ripple assumption for the capacitive voltages and inductor currents, choose the direction of these variables such that they result to be positive.
2. With respect to transistor conduction states determine the conduction state of the three diodes.
3. *DC analysis*. Derive the dc capacitor voltages, the static conversion ratio and dc inductor currents in the *ideal* case - lossless converter - in terms of supply, V_g, transistor duty cycle, D load R and transformer ratio $n = \frac{N_2}{N_1}$. – *Matlab file, symbolic calculation*. Check whether the directions for the variables specified at part 1 are correctly chosen.
4. Graphically draw the static conversion ratio dependency against the duty cycle for different values of the turns ratio n, together with that of the corresponding classical converter – buck,

boost or buck-boost. Identify what type of applications is this converter suited – *Matlab file, symbolic calculation*.

5. Sketch the main *theoretical* waveforms in CCM: magnetizing inductor voltage and current, the currents in the primary and secondary, uncoupled inductor voltage and current, capacitors currents and voltages, semiconductor currents and voltages.
6. *AC analysis*. Inductor current and capacitor voltage *ripple* symbolic calculation in terms of dc supply V_g, dc output voltage V_o, output power P_o, transformer ratio n, magnetizing inductor, L_M, uncoupled inductor L_3, capacitor values, C_1, C_1 and switching frequency f_s. First express the ripples in the traditional way, then replace the duty cycle from the static conversion ratio in terms of V_g and V_o and the load resistor in terms of V_o and P_o – *Matlab file, symbolic calculation*
7. *Literally* express the semiconductor *dc* and *rms* current stresses and *voltage stresses*, in the *ideal* case in terms of V_g, V_o, P_o, n and circuit parameters both using the approximate formula and with the exact formulas provided in Annex A, see course chapters – *Matlab file, symbolic calculation*.
8. Derive the *CCM operation condition* and the *unconditioned* CCM operation conditions - *Matlab file, symbolic calculation*.
9. *Design* the *reactive elements* in the *ideal* case analyzing the *worst case* situation – *Matlab file*. It is the students' choice for reasonable values regarding the supply voltage, output voltage, output power and switching frequency.
10. *Simulate* the converter in the *ideal* case – *Caspoc or similar simulation*. Don't forget to make the elements as close as possible to the ideal ones. Verify the correctness of the main waveforms represented at part 5 and the values calculated at part 3, 6 and 7. Check the voltage stresses, the dc, rms current values and the ripples associated to the reactive elements. Develop also a *Matlab file* to estimate the theoretical values.
11. *Choose* the *semiconductor* devices and the *capacitors* from datasheets.
12. Determine the *range* the duty cycle modifies in the *real* case according to the chosen semiconductor losses and considering also the *output capacitor ESR – Matlab file*.
13. For an arbitrary chosen operating point – the pair V_g-P_o – calculate using the result at part 12 the necessary duty cycle, then simulate the converter with the real devices and check whether the peak-to-peak output voltage ripple is within the specified range. If negative, redesign the converter or propose an appropriate solution. The Caspoc file immediately results simply polishing the one corresponding to the ideal case.
14. For a fixed, arbitrary chosen input voltage represent the *static conversion ratio* against the duty cycle in two situations: ideal converter and lossy converter *neglecting the inductor currents ripples*. The curves will be depicted *on the same Matlab figure*.
15. Device *losses* and *efficiency* calculation. *Literally* determine the *device loss*es, then calculate the efficiency in the two ways, as shown in the course, for the operating point at part 13. Represent the efficiency as a surface against the supply voltage and output power – *Matlab file*.
16. Arbitrarily choose a pair V_g-P_o and depict the efficiency agains the duty cycle dependency.
17. Develop the *control* circuit schematic using ICs – SG3524 and IR2110 in the "Project Work" topic on the Virtual Campus.
18. Defend your project in front of the whole subgroup using a *Powerpoint* or *Acrobat* file – 12 minutes presentation + 5 minutes for questions. All team members will equally speak according to the way they decide to share the presentation.

TEAM WRITTEN REPORT – Microsoft Word file

The team written report should contain at least the following:

1. Converter equivalent schematic using the *perfect coupling* transformer model. An explanation for choosing the directions of capacitor voltages and inductor currents to result positive.
2. A justification for the diodes conduction states.
3. Separate circuits for the two topological states. Volt-second balance and charge balance equations in the ideal case. For on and off magnetizing inductor voltages and capacitor currents first write the equations using the superposition principle, voltage divider and current divider rules or writing KVL and KCL laws and solving the linear system. DC final analysis results, no intermediate results. The ideal static conversion ratio – final formula only.
4. Static conversion ratio representation against the duty cycle with the turns ratio as a parameter – only the Matlab figure.
5. Main theoretical waveforms – no explanations required.
6. Ripple calculation in terms of dc supply voltage, dc output voltage, output power converter parameters and switching frequency – initial relationships and final results from Matlab
7. Semiconductor voltage and current stresses - final results
8. Inequalities for CCM operation and final result in the canonical form (parameter K in terms of circuit elements and K_{crit} as a function of duty cycle) – initial formulas and final results.
9. Initial relationships for inductors and capacitors design and final Matlab numerical results.
10. Power stage simulation for the ideal converter - one Caspoc file is expected together with a table containing the comparison between the Matlab prediction and the simulated results.
11. The symbolic inequalities and the numerical results for the main parameters of the devices. The semiconductor chosen for the datasheets and their lossy parameters. The same for the capacitors.
12. Only D_{min} și D_{max} as numerical values resulted from Matlab.
13. Specify the chosen operating point, the calculated duty cycle and some explanations related to the output voltage ripple.
14. Static conversion ratio representation in the two mentioned situations – Matlab figure.
15. The final equations for the individual device losses in terms of Vg, V_o P_o, n, fs and reactive elements parameters, together with the theoretical $\eta = f(V_g, P_o)$ graphical dependency.
16. Only the Matlab figure that represents the efficiency against the duty cycle dependency.
17. The control circuit schematic using the dedicated ICs and finally the overall schematic including the control and the power stage.

Remarks

1. All project parts are compulsory.
2. The students of a team will develop *a single report* written in *Microsoft Word* or delivered as a *pdf file* and will deliver *a single set of files*. Scanned handwritten pages are not allowed.
3. Caspoc imported scopes are welcome both in the report and in the presentation file.
4. You can use any symbolic calculation program that could replace Matlab – for example, Mathcad or Mathematica. Similarly, the use of Caspoc is not mandatory. You can use LTSpice, PSIM, PLECS, or any circuit simulation program.