Division of Electric Power Engineering
Chalmers University of Technology

Laboratory exercise

DC-DC SWITCH-MODE CONVERTERS
BUCK CONVERTER

OBSERVE!
The home assignment must be completed in order to be allowed to start the laboratory exercise

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Name

…………………….…………….……….
Exercise approved

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Date

Lab Board

The laboratory board is a multi-purpose board that gives the possibility to test various circuits using different magnetic boards and connections between the transistors and diodes. The board includes a switched load, but this load will not be used during this laboratory exercise. Instead, external load resistors are used that have to be connected via lab-cables.

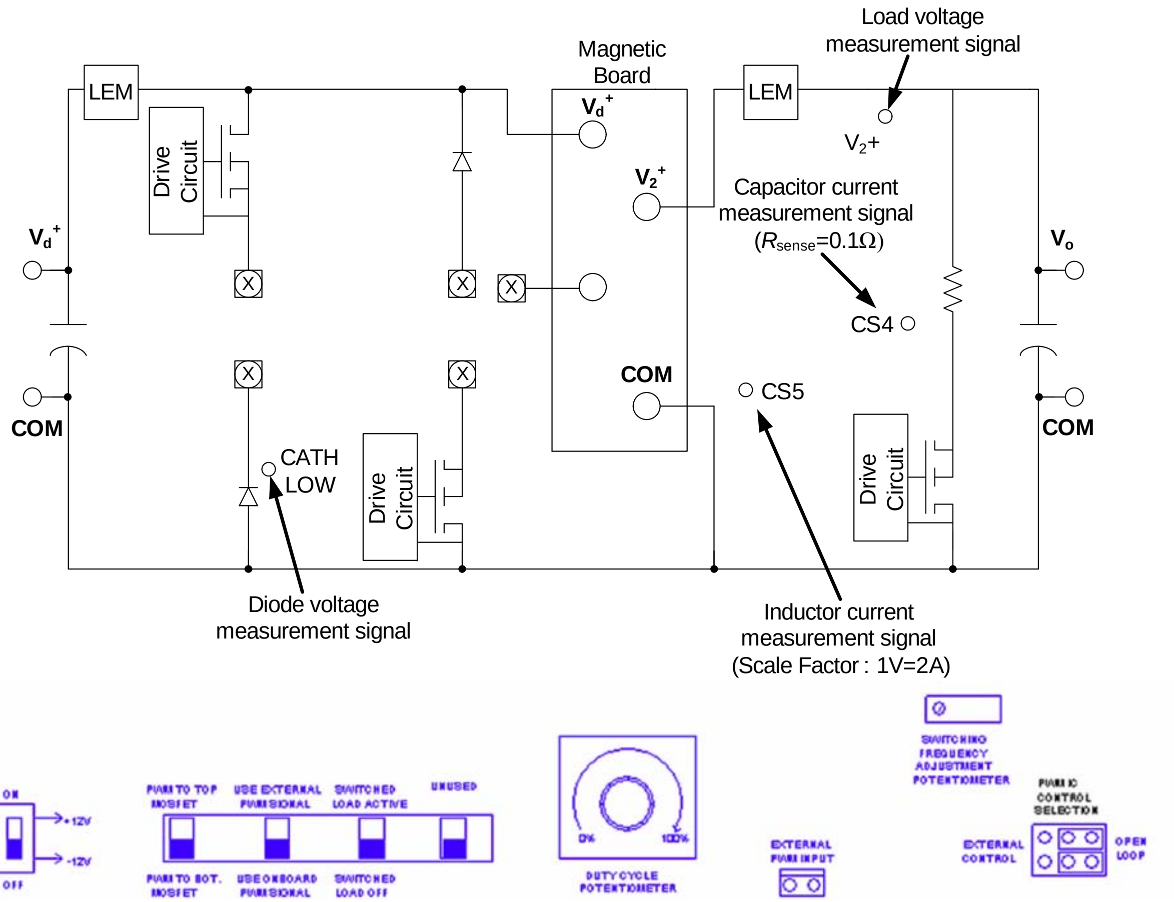


Figure 1. *Sketch of the laboratory board with no magnetic board attached.*

System parameters

Source voltage (V_d)	15V (Adjustable via external power supply)
Filter Inductance (L)	100μH (mounted on external magnetic board)
Output Capacitance (C)	680μF
Load Resistance (R_L)	10Ω to 50Ω
Switching frequency (f_{sw})	10kHz to 100kHz
Duty ratio (D)	0 to 1

Main circuit of the buck converter

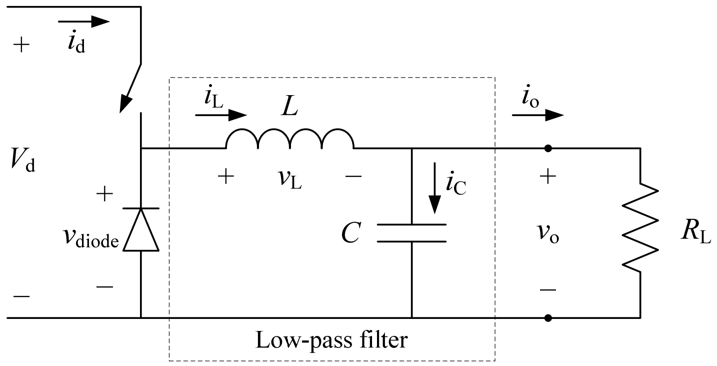


Figure 2. *Main circuit components of the buck converter.*

Home Assignment

(1) Complete the buck converter in Figure 1. Draw the necessary connections between the diode, transistor and the magnetic board. The magnetic board for the present buck lab comprises the filter inductor only. Observe that not all diodes and MOSFET's on the lab board need to be used.

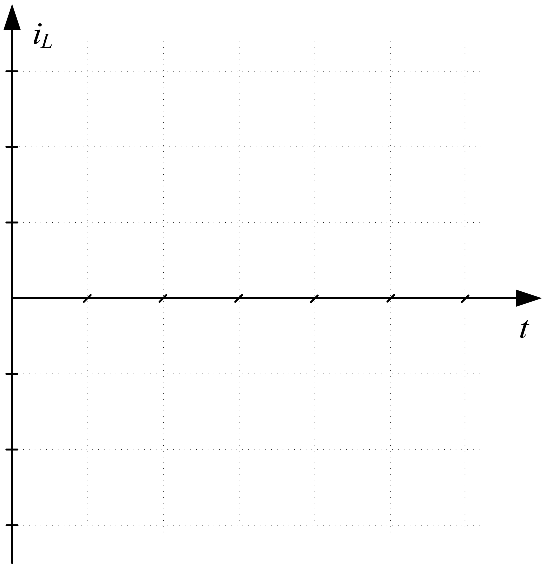
(2) Derive the expression for the input/output voltage ratio for both CCM and DCM. Use these expressions to complete the tables on page 9 for the specified values of the duty-cycles. Use $R_L = 10\Omega$ and $f_{sw} = 20kHz$.

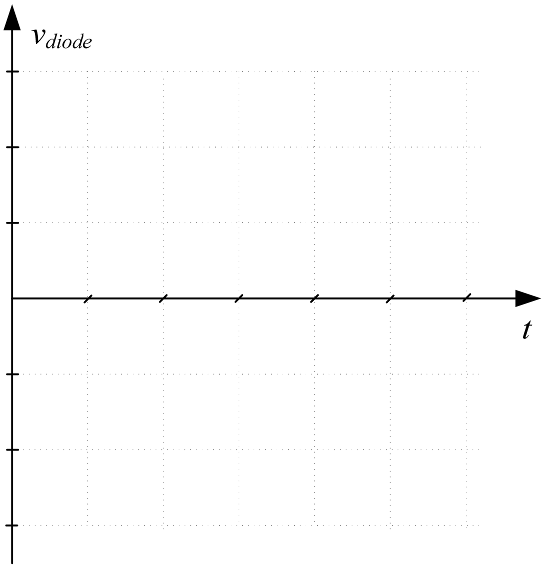
(3) The buck converter can operate in either DCM or CCM. Draw the ideal waveforms of i_L, v_{diode} and v_L for $D = 0.4$, $R_L = 10\Omega$ for two switching frequencies ($f_{sw} = 20kHz,\ \ f_{sw} = 60kHz$). Hint: One switching frequency will result in DCM operation and the other one to CCM operation.

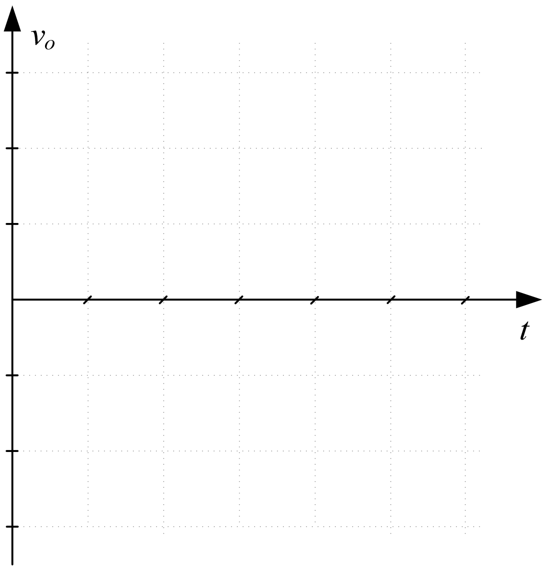
(4) Calculate the corner frequency of the low-pass filter with the rule given during the lecture. For which switching frequency has this filter been designed?

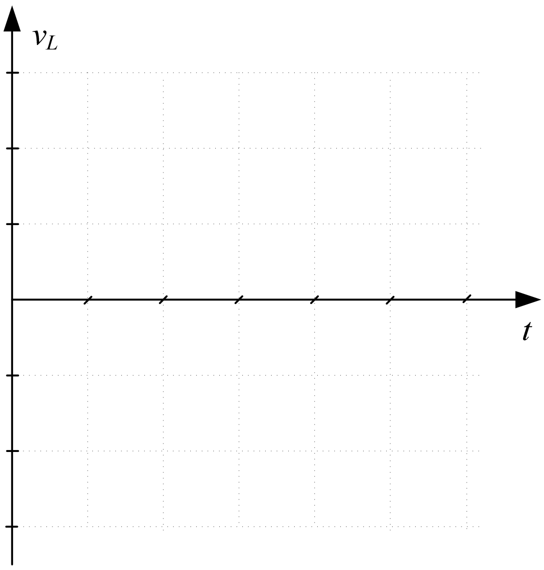
(5) If the load is assumed to be purely resistive, derive an expression for the duty cycle D that sets the boundary condition between CCM and DCM as a function of the load resistance(R_L).

Theoretical waveforms, CCM:

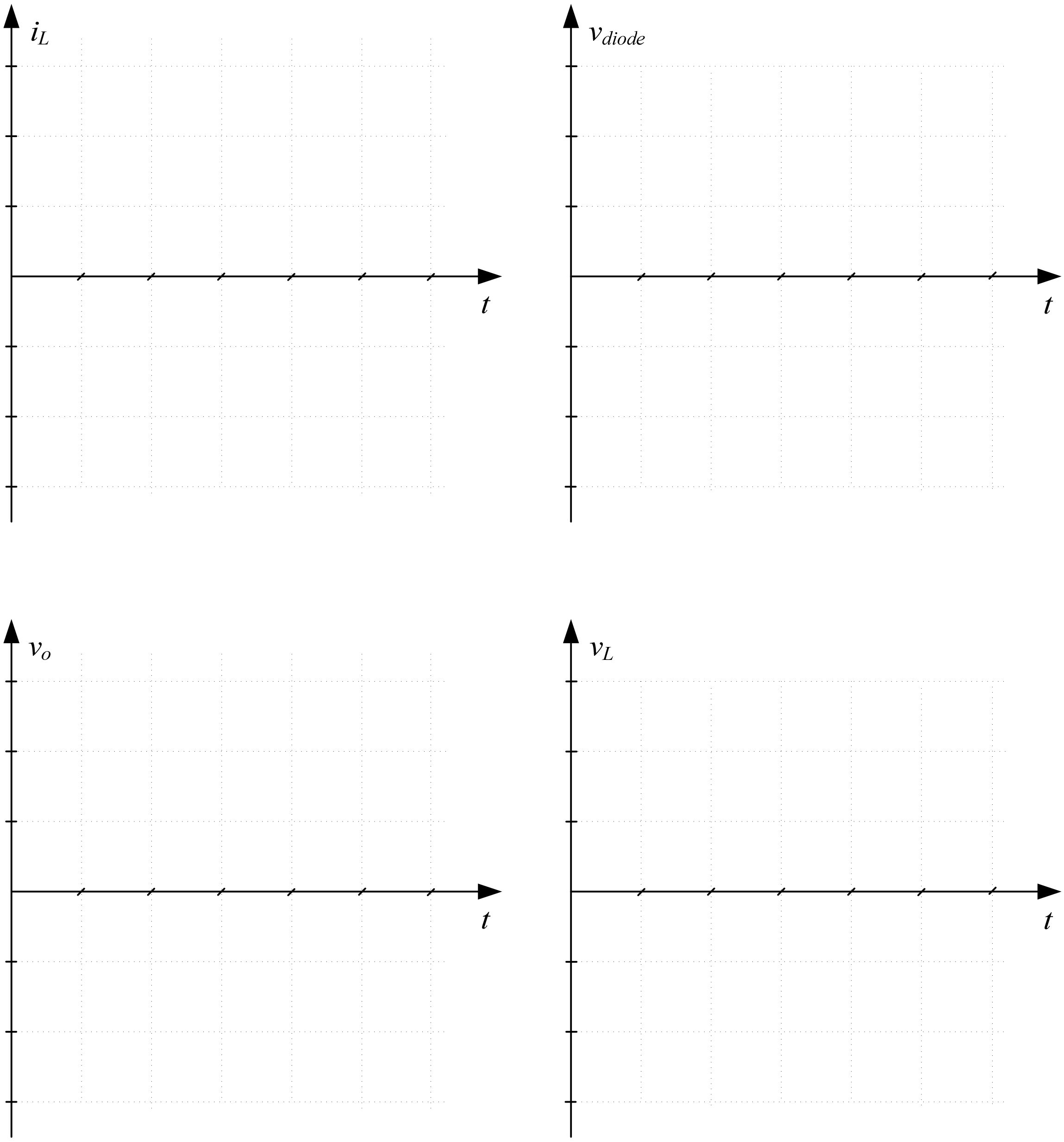








Theoretical waveforms, DCM:



How to prepare the board before the laboratory exercise:

There are a few steps that you have to follow before you can start your lab:

1. Study the circuit and locate the main components of the buck converter. Apply the magnetic board consisting of the inductor. Locate the correct test points for current and voltage measurements (see appendix A and B).

2. Check that the switches (S30) are set in the following positions:

    S30:1 – TOP FET.
    S30:2 – PWM INT.
    S30:3 – LOAD OFF.
    S30:4 – Not used.

3. Check that the signal-supply switch (S90) is in OFF position. Connect the ±12V control supply voltage (two black transformers) to the board.

4. Switch on the signal supply, check that the green LED is turned on.

5. Turn the duty cycle down to a minimum by turning the duty-cycle knob (RV63).

6. Set the load resistance to 10Ω.

7. Apply the main input voltage source of 15V to the terminals V_1+ and COM.

It is not allowed to turn on the power supply until a lab-assistant has checked all connections!

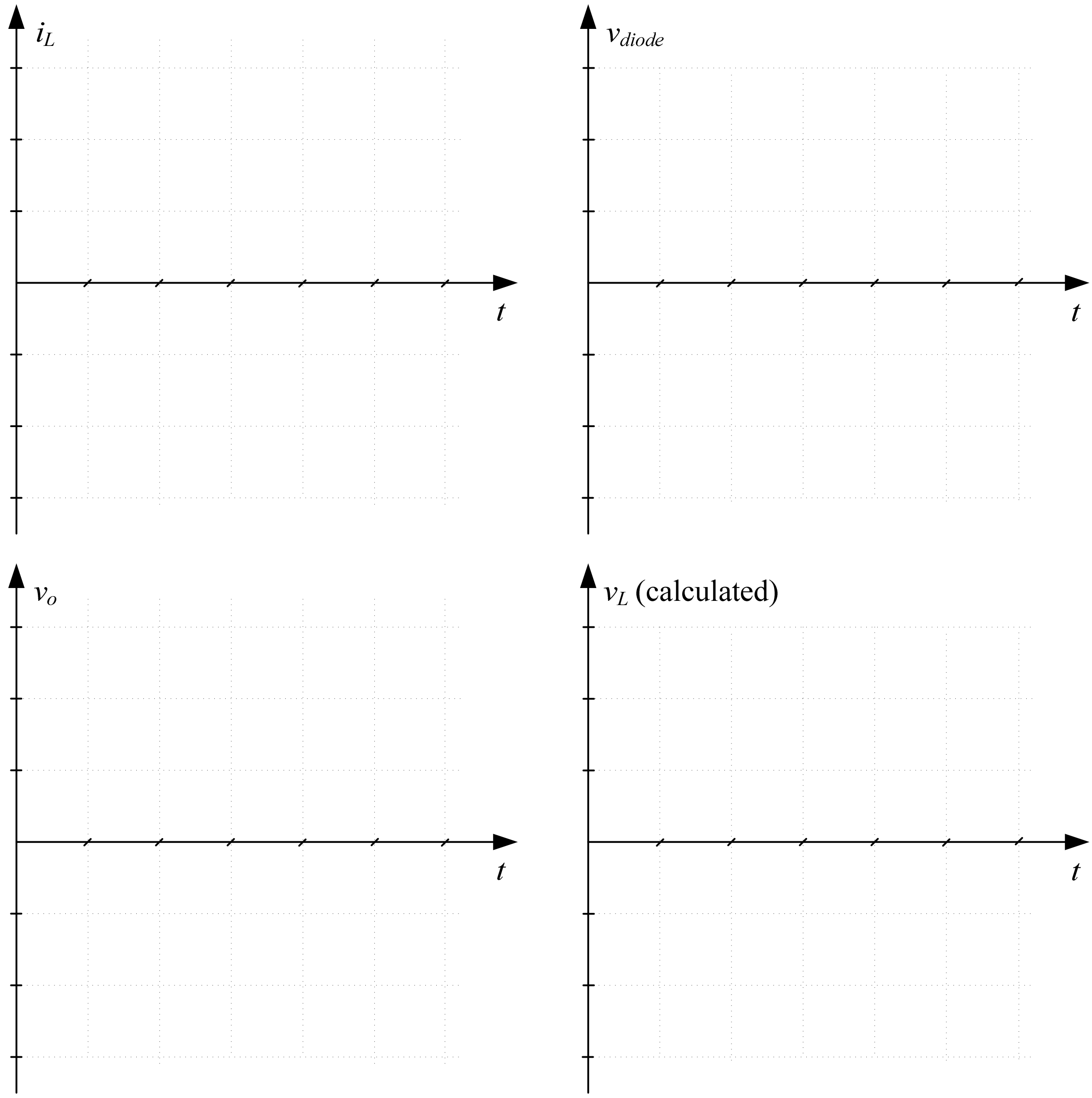
Check Appendix for measurement pins!

After the set-up has been checked by the laboratory assistant, turn the power supply on and set the switching frequency to 20kHz.

Task 1:

Select an appropriate value for the duty cycle so that you are operating the converter in CCM. Draw the measured traces of the inductor current (i_L). Furthermore, measure and draw the voltage across diode (v_{diode}) and the load voltage (v_o). From these two measurements, calculate and draw the time trace of the inductor voltage (v_L).

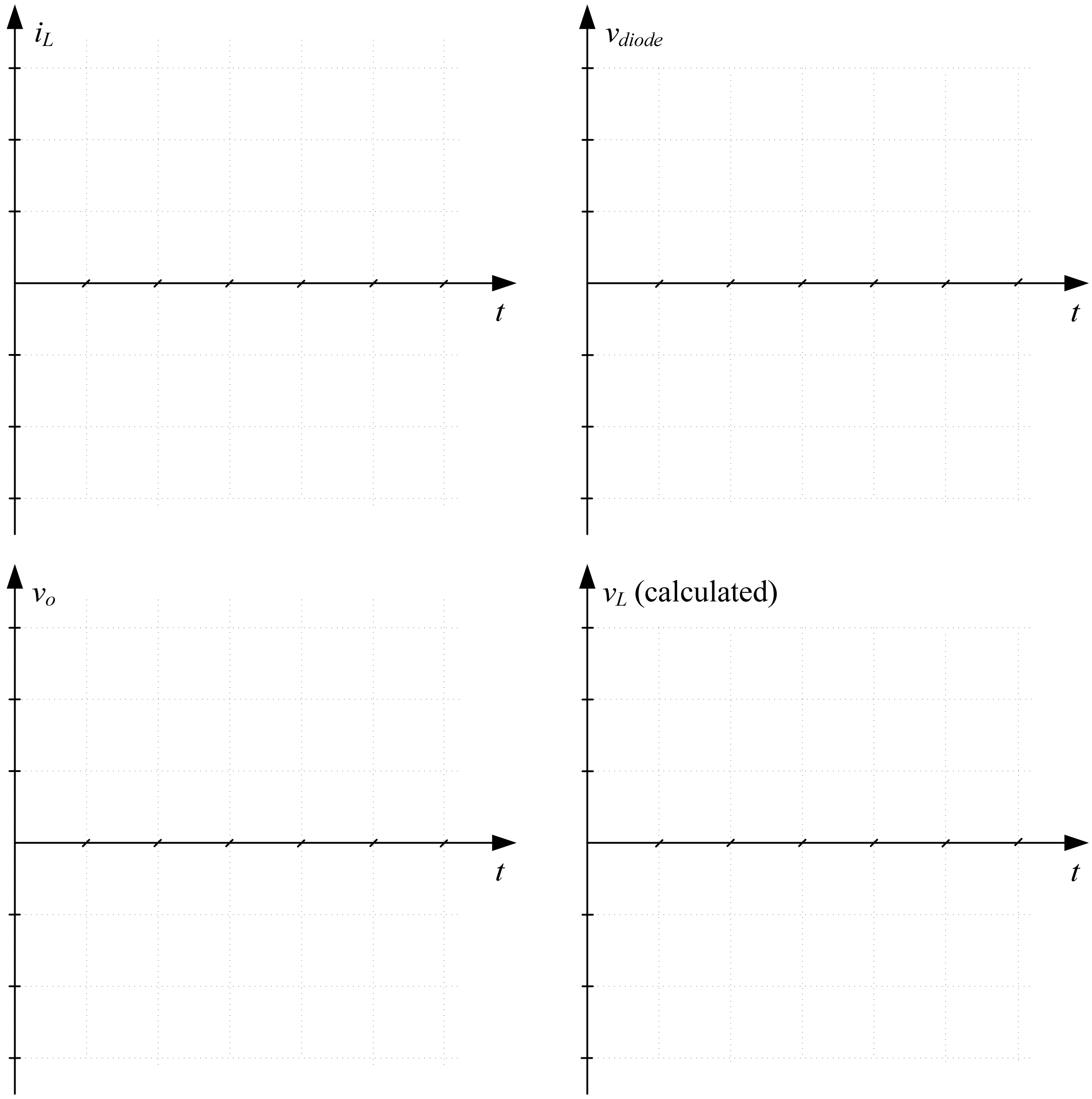
OBS! All measurements must be referred to ground.



Any differences between the theoretical results the measurements?

Task 2:

Keep the switching frequency at 20kHz and select an appropriate value for the duty cycle so that the converter is operating in DCM. Draw the measured traces of the inductor current (i_L). Furthermore, measure and draw the voltage across diode (v_{diode}) and the load voltage (v_o). From these two measurements, calculate and draw the time trace of the inductor voltage (v_L).



Any differences between the theoretical results and the measurements?

Task 3:

Keep the switching frequency at 20kHz and measure the input and output voltage of the converter by using a multimeter (*measure directly on the laboratory board in order to get a good accuracy of the measurement!*). Compare the measured results with the previously obtained theoretical results and comment. Calculate the efficiency for each value of the Duty-Cycle.

Output voltages and efficiency, CCM

	Calculated output voltage	**Measured output voltage**	**Measured input voltage**	**Input power**	**Output power**	**Efficiency**
D=0.7						
D=0.8						
D=0.9						

Output voltages and efficiency, DCM

	Calculated output voltage	**Measured output voltage**	**Measured input voltage**	**Input power**	**Output power**	**Efficiency**
D=0.2						
D=0.3						
D=0.4						

Any differences between the theoretical results and the measurements? Any comments on the efficiency?

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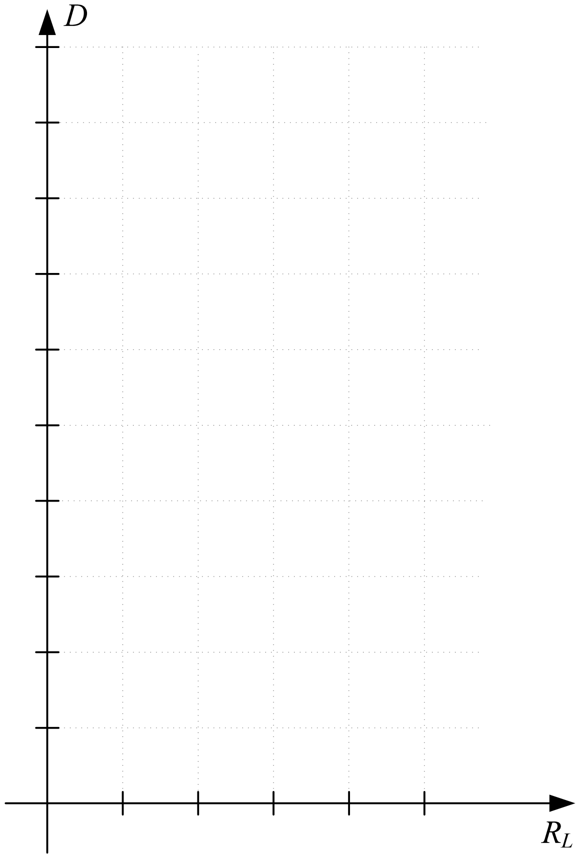
Task 4:

For a load Resistance of 10, 20, 30, 40 and 50Ω, find the boundary condition and plot the obtained duty cycles as a function of the load resistance (R_L). Can you show the region of CCM and DCM in the plot and why?



Any difference from the theoretical graph?

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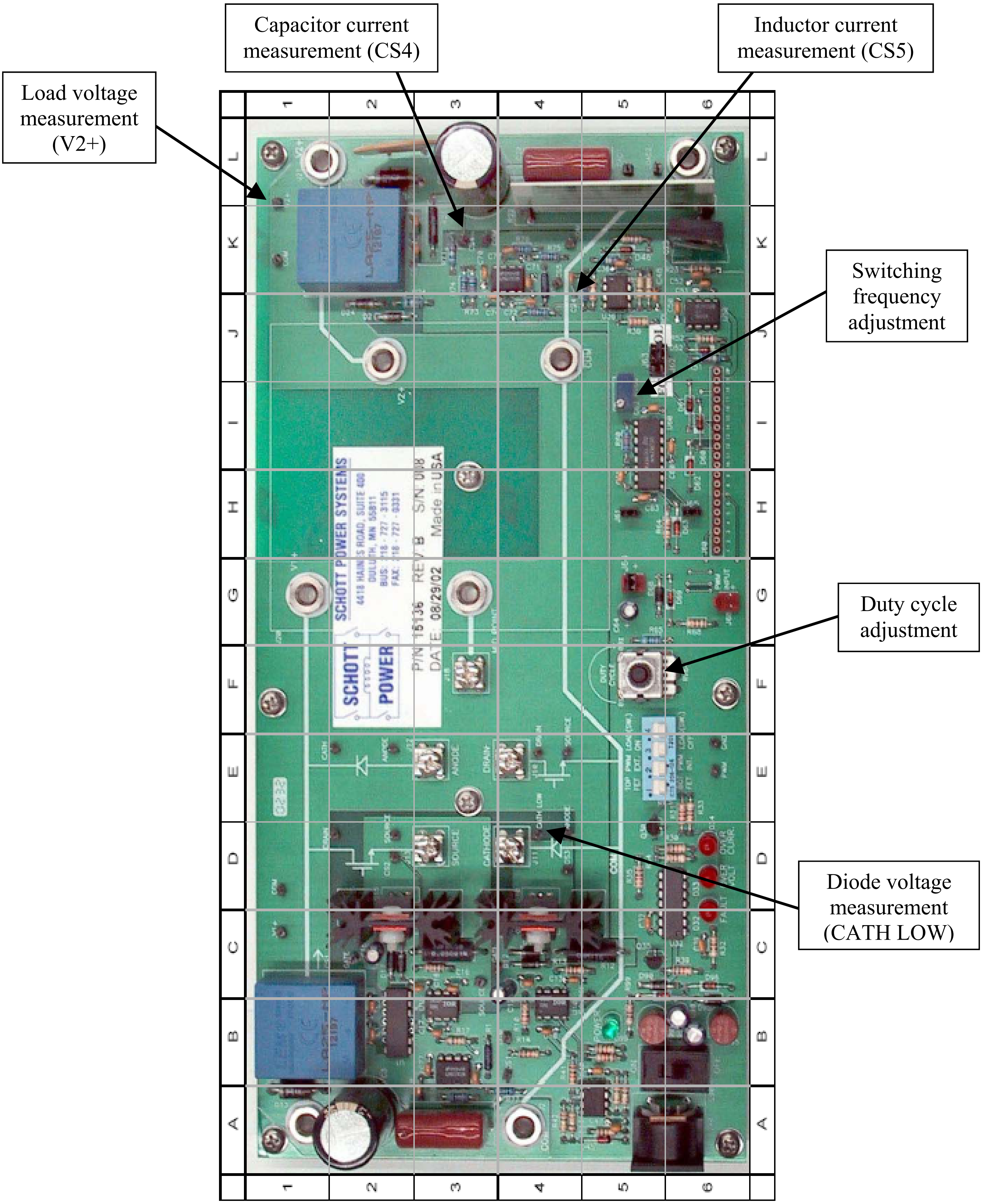
Appendix A. Lab board



Appendix B. Magnetics board