High Voltage Engineering

Problem 1 (16.66%)

A 1,2/50 μs single stage impulse generator, type b with a maximum output peak impulse voltage V_{max} = 100 kV should be designed. Already chosen components: Discharge capacitance C_1 = 10 nF, load capacitance C_2 = 1,5 nF, discharge resistance R_2 = 9500 Ω

Temperature in the HV laboratory is 15°C and air pressure p = 1027 hPa

a) Draw a graph of the impulse voltage waveform generated by the impulse generator for a charging voltage of V_0 = 95 kV using a sufficient number of calculated points (or MATLAB) of the curve V(t). Determine graphically on the basis of this graph front time T_1, time to half T_2 and the efficiency η. Please show clearly on the graph how you do this! Comment!

b) The students want to measure the impulse voltage from b) by means of a sphere gap. What should be the *precise* distance S between a pair of 12,5 cm spheres for the sphere gap to ignite (i.e. make a spark) for this voltage? State clearly how you do this!

Problem 2 (16.66%)

Test of a HV capacitor with C = 400 nF using non-destructive test methods.

a) Explain briefly the most important methods for non-destructive HV testing.

b) A Schering bridge has been used for measuring the loss angle tan δ for the capacitor at 42 kV and the result was tan δ = 0, 152. Calculate the current through the capacitor (result as a phasor, i.e. in complex polar coordinates, explain your method) during the measurement and the loss P in the capacitor. What causes such losses?

c) The losses calculated in b) are not acceptable. What should be the loss angle tan δ in order to lower the losses to 10 kW?

Problem 3 (16.66%)

A high voltage impulse voltage divider has a unit step response as shown in the figure attached to this set of exercises.

a) Calculate the response time of this voltage divider as explained in Kuffel chapter 3.6.2. Explain carefully your procedure (you can write on the sheet with the figure and hand in). General approximations are of course acceptable.

b) A front chopped 1,2/50 μs is chopped at T_c = 0,4 μs and its peak voltage was recorded to 418 kV using the above question a) voltage divider. What was the actual peak voltage?

EPSH1/PED1/WPS1

CLB/SMN

DEPARTMENT OF ENERGY TECHNOLOGY
AALBORG UNIVERSITY

Written examination in

High Voltage Engineering and Design of Switch Mode Converters

Monday 25th January 2016

09.00 – 13.00 (4 hours)

Please provide sufficient text description and reference to textbook and equations so your method of solution is clear and easy to follow. Statements and results will only give credit if explained thoroughly.

Design of Switch Mode Converters

Problem 4 (20%)

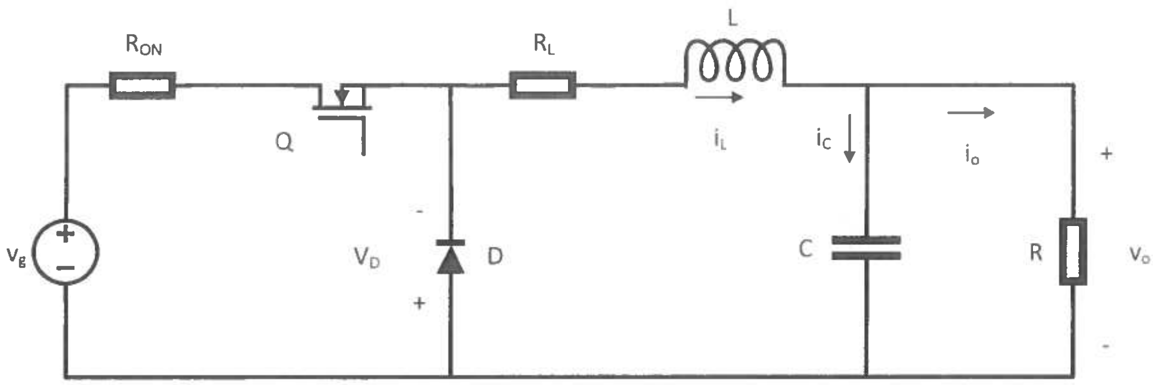


Figure 1: Diagram of the non-ideal buck converter

A non-ideal buck converter from Figure 1 operates in continuous conduction mode, with the values:

- Input voltage V_g = 15V
- Switching frequency f_{sw} = 250kHz
- Inductor L=15µH
- Output capacitor C = 75µF
- Load resistance R = 0.25Ω

The desired full-load output is:

- Vo = 5V
- Io = 25A

The power stage contains the following loss elements: MOSFET R_{ON}= 0.1Ω, Schottky diode forward voltage drop V_D = 0.5V, inductor winding resistance R_L = 0.05Ω.

Questions:

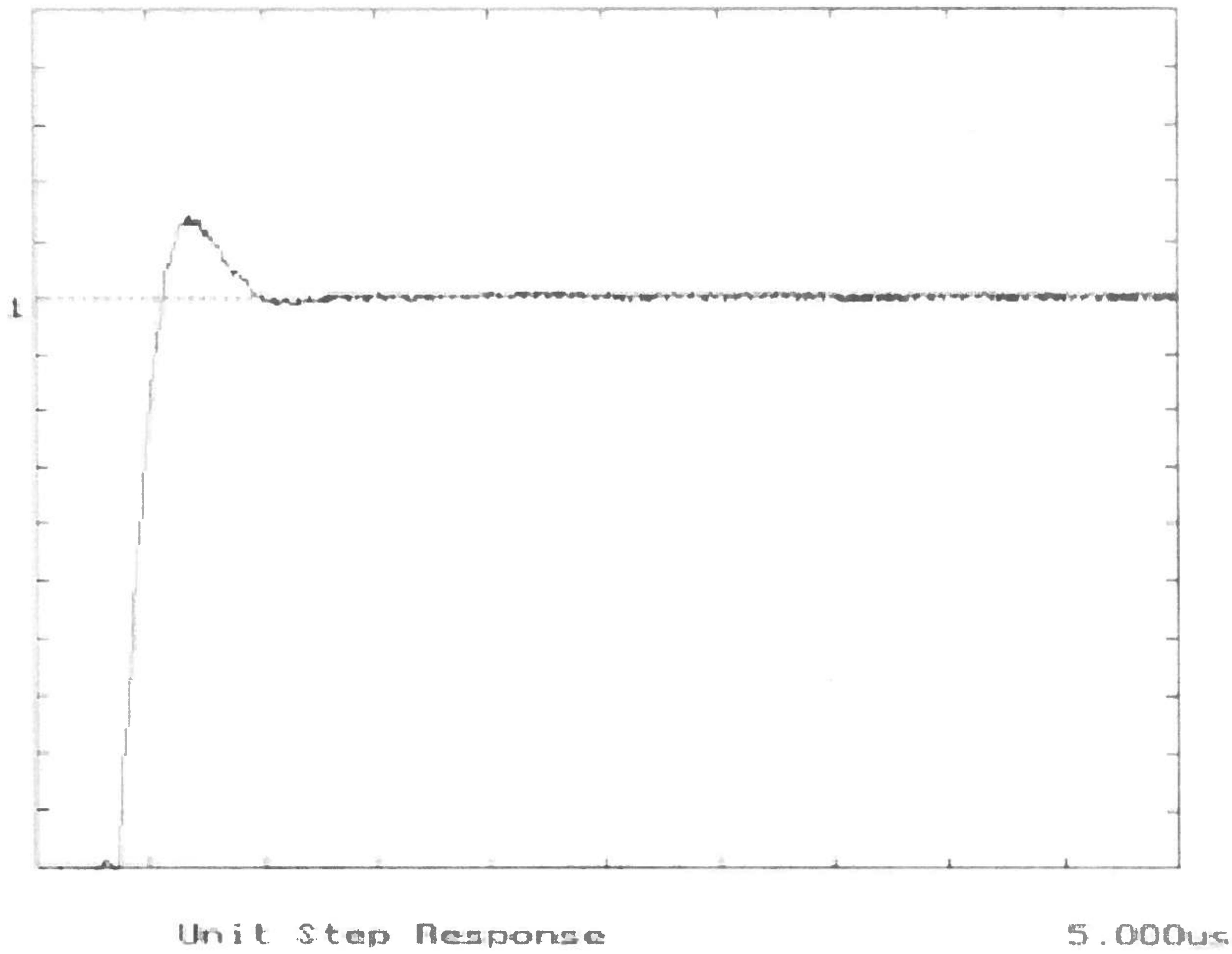
A.) Determine the converter steady state duty cycle D, then inductor current ripple slopes m_1 and m_2.

B.) Determine the small-signal equations for duty cycle control (AC components of inductor voltage, capacitor current and input current)

A current-programmed controller is implemented for this converter. An artificial ramp is used, having a fixed slope of $M_a = 0.375*M_2$, where M_2 is the steady state slope m_2 at nominal output.

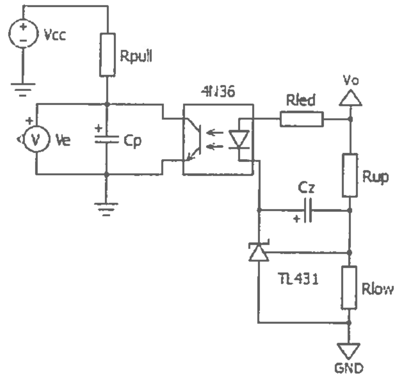
C.) Over what range of D is the current programmed control stable for $M_a = 0.375*M_2$? What about for the case $M_a = 0.5*M_2$?

D.) Determine the control-to-output transfer function using the simple approximation $i_L(t) = i_{ctrl}$.


1
Unit Step Response
5.000us

Problem 6 (20%)

Design a Type II controller, as show on the figure below using analog components (resistors, capacitors, optocoupler and TL431 shunt regulator) for a DC-DC converter having an output voltage V_o=12V. The bandwidth of the controller should be ω_{cross} = 15000 rad/s.



Tasks:

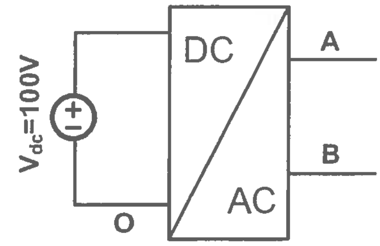
1. Define the desired value of ω_z and ω_p and motivate why did you chose it so?
2. Calculate the G_0, ω_z, ω_p and ω_0 of the controller (R_{up}, R_{low}, R_{led}, R_{pull}, C_p, C_z respectively) and show the compensator $G_c(s)$ transfer function.

Given are the followings:

- The minimum cathode voltage on the TL431 V_{Kmin}=2.5 V and the reference voltage of the TL431 IC is V_{ref}=2.5 V
- The forward voltage drop of the optocoupler at a minimum forward current i_{Fmin}=1 mA is V_{Fmin}=1.1 V
- The Current Transfer Ration of the optocoupler is CTR = 0.7
- The converter gain the cross-over frequency is: $||G_{converter}(\omega_{cross})||$ = 3 dB
- Vcc = 3.3 V

Problem 5 (10%)

Calculate and draw the differential mode (V_AB) and common mode (V_CM) voltages for a PWM converter shown below:



Draw V_CM and V_AB for the given V_Ao and V_Bo voltage measurements.