L2 - Laboratory Exercise

Given are the followings:

- A MOSFET
- A DIODE
- An INDUCTOR
- A CAPACITOR
- A FUNCTION GENERATOR
- A POWER SUPPLY
- An OSCILLOSCOPE (with CURRENT PROBE and DIFFEERENCIAL VOLTAGE PROBE)
- A LOAD RESISTOR (max 500 Ohm and ~1 A)
- A MULTIMETER
- CABLES

Exercises:

1. Build a buck converter (Figure 1.) and follow the steps:

a. Use some wires to connect the components
   - Check datasheets (Moodle files or Google) to identify what are the different pinouts of the MOSFET and DIODE
   - Pay attention to the polarity of the output capacitor when connecting it to the circuit
   - Connect the signal generator to the Gate and Source of the MOSFET (RED to GATE and BLACK to SOURCE)
   - Connect the power supply "+" to the Drain of MOSFET and the "-" to the return path of the circuit (Figure 1.)
   - Connect the load resistor to circuit (adjust its value first to **10 Ohm**)
   - Connect the Oscilloscope current probe on the cable between the inductor and the output capacitor (pay attention to current direction) – you will measure and visualize the **inductor current.** The mean value of this current, obtained by measuring it with the scope, gives a good approximate of the **load current**
   - Connect the FLUKE Multimeter in 10A current measurement mode in series with the MOSFET drain to measure the **input current**.
   - Connect the differential voltage probe parallel with the load resistor to measure the **load voltage**
   - **Input voltage** you can read later from the power supply.

b. Turn on the Function Generator, set it to *Square wave generator,* set the *Frequency* to **25 kHz**, set the *Amplitude* to the **MAX**, pull out the *Offset* and adjust it to the **middle**. Check the pulses on the Oscilloscope using the differential voltage probe – measure and visualize the gate pulses. The Function Generator should give a square wave between +/- 10V.

With the *Duty* you can adjust the **Duty cycle** (***D***) if it is pulled out. Otherwise it will be **50%** by default.

c. Turn on the **Power supply.** Select *Channel 2* and plug the supply cables of the buck converter to Channel 2 outputs.
   - Adjust the *VOLTAGE* level to 15V (***V_g=15V***)
   - Set the *CURRENT* on the power supply to around 2A (input current limit)
   - DO NOT ENABLE THE POWER SUPPLY (***OUTPUT ON/OFF***) UNTIL YOUR CIRCUIT IS CHECKED AND YOU ARE TOLD SO.

Tasks:

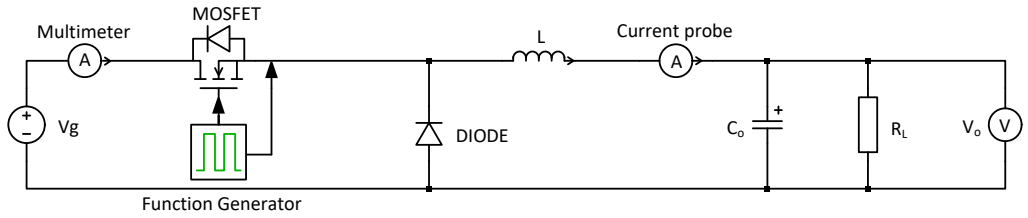

Figure 1. Buck converter

I. Calculate the estimated output voltages $\mathbf{V_{o\_est}}$ with different duty cycle values using appropriate equations.

II. Change the duty cycle from MIN to MAX, and with different duty cycle measure the input voltages, input currents, output voltages and output currents and put them into the table. Compare $\mathbf{V_{o\_meas}}$ to $\mathbf{V_{o\_est}}$. How would you explain the difference?

D	V_{in_meas} [V]	I_{in_meas} [A]	V_{o_est} [V]	V_{o_meas} [V]	I_{o_meas} [A]
D_{min}=0.22					
D=0.5					
D_{max}=0.78					

III. Using the oscilloscope visualizes the inductor current, read from the screen the required values to determine the inductance (**L**) value of the inductor. You can measure the current ripple and the time (DT_s or $(1-D)T_s$) using the CURSOR of the Oscilloscope. The current ripple equation is given.

$$\Delta I_{L\,pp} = \frac{V_g - V_o}{L} \cdot D \cdot T_S$$, where $\Delta I_{L\,pp} = 2 \cdot \Delta I_{L\,ap}$, *it is the peak-to-peak current ripple and it is twice the average-to-peak current ripple. This equation is valid when looking on the rising edge of the inductor current, when the switch is on.*

OR:

$$\Delta I_{L\,pp} = \frac{V_o}{L} \cdot (1-D) \cdot T_S$$

This equation is valid if looking at the falling edge of the inductor current, when the switch is off.

Use the multimeter, differential voltage probe and the current probe to measure the voltages and currents for calculations.

2. Build a boost converter (Figure 2.) and follow the steps:

a. Use some wires to connect the components
   - Check datasheet (Moodle files or Google) to identify what are the different pinouts of the MOSFET and DIODE
   - Pay attention to the polarity of the output capacitor when connecting it to the circuit
   - Connect the signal generator to the Gate and Source of the MOSFET (RED to GATE and BLACK to SOURCE)
   - Connect the power supply "+" to one leg of the inductor and the "-" to the return path of the circuit (Figure 2.)
   - Connect the load resistor to circuit (adjust its value first to **75 Ohm**)
   - Connect the Oscilloscope current probe on the cable after the inductor (pay attention to current direction) – you will measure and visualize the **inductor current**. The mean value of this current corresponds to the **input current**.
   - Connect the FLUKE Multimeter in 10A current measurement mode in series with the load resistor to measure the **load current**.
   - Connect the differential voltage probe parallel with the Load Resistor to measure the **output voltage**.
   - The **input voltage** will be read from the power supply.

b. Turn on the Function Generator, set it to *Square wave generator,* set the *Frequency* to **50 kHz**, set the *Amplitude* to the **MAX**, pull out the *Offset* and adjust it to the **middle**. Check the pulses on the Oscilloscope using the differential voltage probe – measure and visualize the gate pulses. The Function Generator should give a square wave between +/- 10V.
   With the *Duty* you can adjust the **Duty cycle** (***D***) if it is pulled out. Otherwise it will be **50%** by default.

c. Turn on the **Power supply.** Select *Channel 2* and plug the supply cables of the buck converter to Channel 2 outputs.
   - Adjust the *VOLTAGE* level to 10V (***V_g=10V***)
   - Set the *CURRENT* on the power supply to around 3A (input current limit)
   - DO NOT ENABLE THE POWER SUPPLY (***OUTPUT ON/OFF***) UNTIL YOUR CIRCUIT IS CHECKED AND YOU ARE TOLD SO.

Tasks:

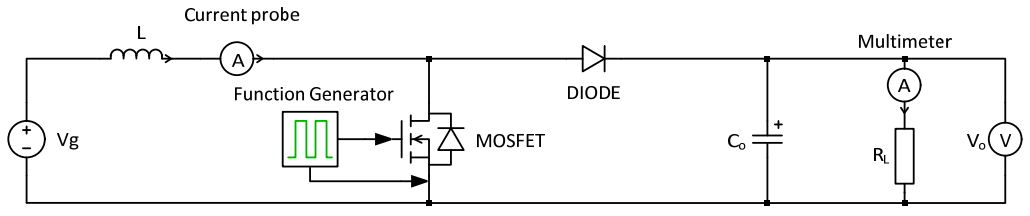

Figure 2. Boost converter

I. Calculate the estimated output voltages $\mathbf{V_{o\_est}}$ with different duty cycle values based using the appropriate equations.

II. Change the duty cycle from MIN to MAX, and with different duty cycle measure the input voltages, input currents, output voltages and output currents and put them into the table.

D	V_{in_meas} [V]	I_{in_meas} [A]	V_{o_est} [V]	V_{o_meas} [V]	I_{o_meas} [A]	Efficiency [%]
D_{min}=0.22						
D=0.5						
D_{max}=0.78						

III. Using the initial conditions of the setup at D = 0.5 (50%) what size of capacitor should be used to obtain a voltage ripple on the output capacitor (Δv_{Cpp}) of 1% of the output voltage (V_o). The voltage ripple equation is given:

$$\Delta v_{C_{pp}} = \frac{V_o}{R_L \cdot C_o} \cdot D \cdot T_S$$

IV. Calculate the efficiency of your own-built converter.

a. How would you calculate/measure it? Use the given Literature to find the solution.

You can use the multimeter to measure input and output voltages, and also the differential voltage probe and the current probe to measure the voltages and currents for calculations.

Conclusion and results

Each small group should write a few-page report summarizing the exercises and the results (what, why and how did you do), put the name of the group members on the front page and send it to me (Lajos Török) paper based or by email to *lat@et.aau.dk* – I am expecting 6 small reports.