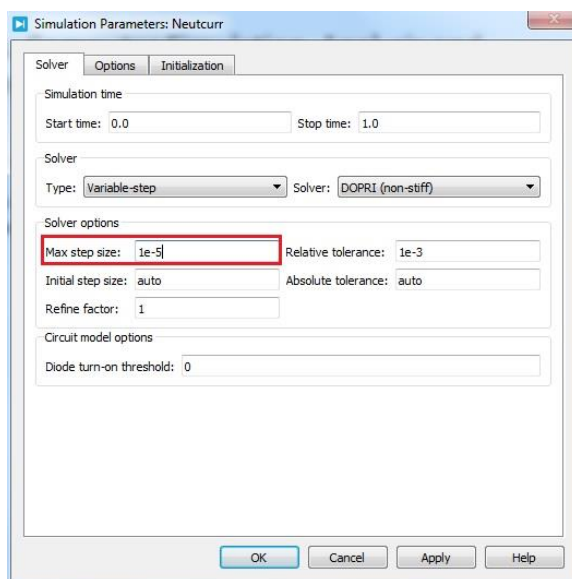


# Power Electronics: Computer Simulation, Analysis and Education Using PLECS

As announced in the course material, simulations are graded and they have an effect on the final grade of the course. The weight is 25 %.

## General instructions for using PLECS


To ensure smooth waveforms in the simulations, the max step size value needs to be changed from auto to  $1e-5$ . This option can be found from Simulation -> Simulation parameters. The max step size is in solver tab as shown below.



The simulation takes some time to reach steady state operation. In the beginning of the simulation, transients can be seen in the waveforms. Therefore, make sure you simulate the circuit long enough to reach steady state operation. The simulation time can be adjusted from the same menu as the max step size.

Some circuits use parameters as component values. These can be adjusted from Simulation -> Simulation parameters -> Initialization.

Values in PLECS are peak values. Often the problems request RMS (root mean square) values so you need calculate them separately.

Fourier analysis can be used from the scope block by pressing . Remember to adjust your center frequency accordingly to obtain correct results.

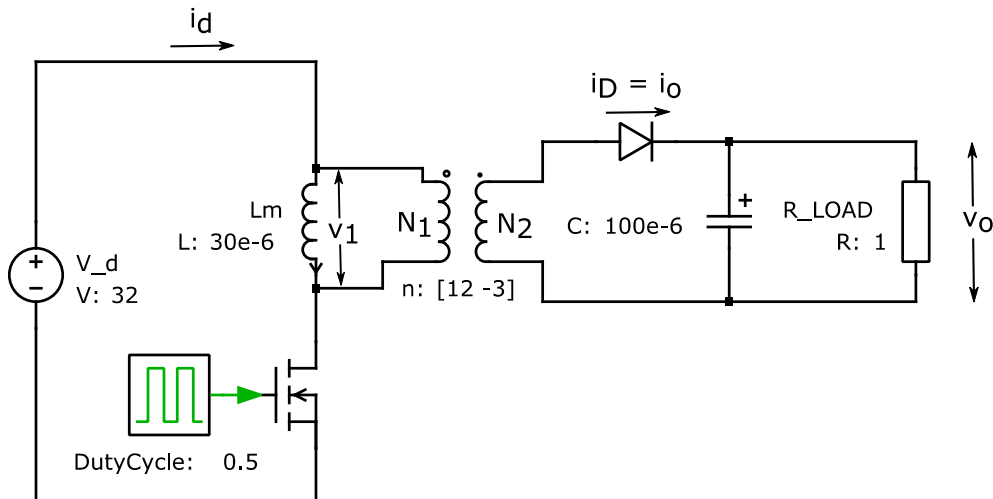
Problems often request you to different include waveforms. In your images, zoom in and only include some periods of the waveform in your image (max 10 periods). Do not include the whole simulation waveform since it is impossible to see the interesting phenomena that way.

Often it is beneficial to add multiple waveforms to the same scope screen. This can be done with the Signal multiplexer block.

To export waveforms to your document, you can copy the image to your clipboard from the scope by going to Edit -> Copy. Another option is to export the image as Bitmap or CSV through File -> Export -> as Bitmap or as CSV. With Bitmap set the quality to 100, use anti-aliasing, and set resolution to 150 dpi to obtain nice and clear figures. CSV files can be imported for example to MATLAB and plotted there.

## 1. Flyback dc-dc Converter

File: Flyback.plecs  
Single-output flyback converter



**Nominal Values:**  $V_d = 32\text{ V}$ ,  $V_o = 4\text{ V}$   
 switch duty-ratio  $D = 0.4$ ,  $f_s = 200\text{ kHz}$ ,  
 $C = 100\text{ }\mu\text{F}$ ,  $R_{load} = 1\text{ }\Omega$   
 Transformer:  $N_1/N_2 = 4$ ,  
 Magnetizing inductance  $L_m = 30\text{ }\mu\text{H}$ ,  
 Neglect the leakage inductances.

### Problems

1. Obtain waveforms for  $v_1$ ,  $i_d$ , and  $i_D$ .
2. Plot  $v_1$ ,  $i_{sw}$ , and  $i_D$  during a switching transition.
3. Calculate the average values of  $i_d$  and  $i_D$  in Problem 1 and verify that

$$\frac{I_d}{I_o} = \frac{V_o}{V_d}$$

4. Obtain the waveform for the switch voltage  $v_{sw}$ . Verify the results with the following equation:

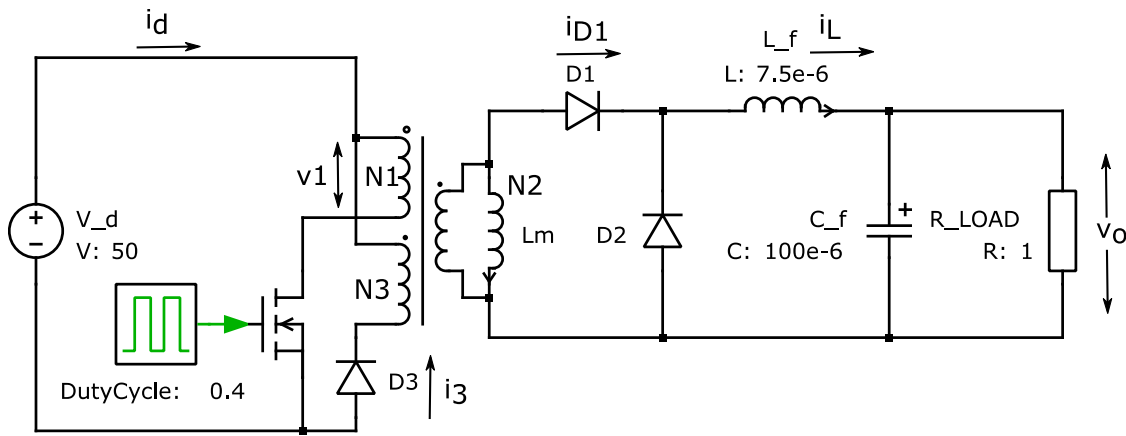
$$v_{sw} = \frac{V_d}{1 - D}$$

5. Change the load resistance to  $50\text{ }\Omega$  and repeat Problems 1 and 2 after a steady state is reached.

## 2. Forward dc-dc Converter

File: Forward.plecs

Single-transistor forward converter



### Nominal values:

$$V_d = 50 \text{ V}, V_o = 4.5 \text{ V}, \frac{N_1}{N_2} = 4, \frac{N_1}{N_3} = 1$$

$$f_s = 200 \text{ kHz}, L_m = 100 \text{ } \mu\text{H}, L_f = 7.5 \text{ } \mu\text{H}$$

$$C_f = 100 \text{ } \mu\text{F}, R_{Load} = 1 \text{ } \Omega,$$

$$\text{Switch duty-ratio } D = 0.4 .$$

### Problems

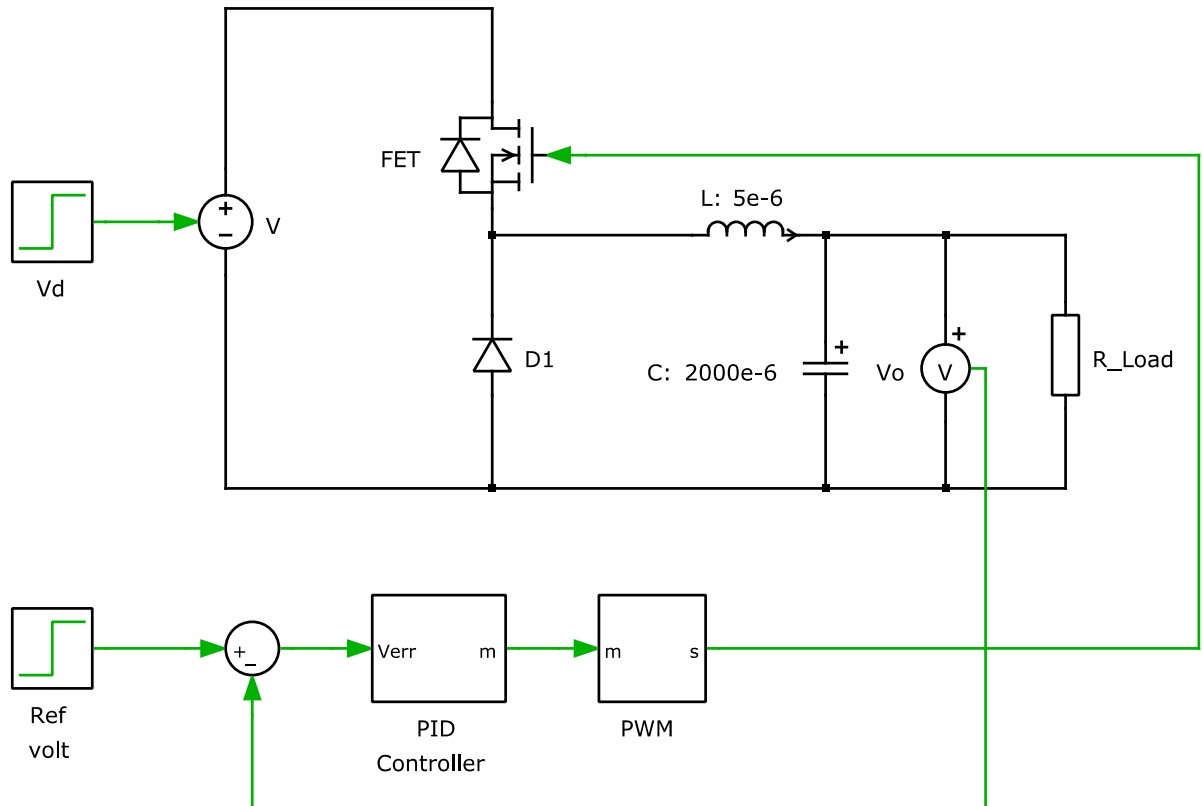
1. Obtain the waveforms for  $i_L$  and the voltage input to the output stage (i.e., the voltage across diode  $D_2$ ).
2. Obtain  $v_1$ ,  $i_{sw}$  and  $i_3$  waveforms.
3. In problem 2, show that the average value of  $v_1$  equals zero.
4. From the results of Problem 2, verify that

$$\frac{t_m}{T_s} = \frac{N_3}{N_1} D$$

where  $t_m$  is the time interval during which  $i_3$  flows, and  $T_s$  is the switching time period.

### 3. Buck Converter: Voltage-Mode Controlled

File: Buck\_Cntl.plecs



**Nominal values:**

$$V_d = 8 \text{ V}, V_o = 4 \text{ V}, f_s = 100 \text{ kHz},$$

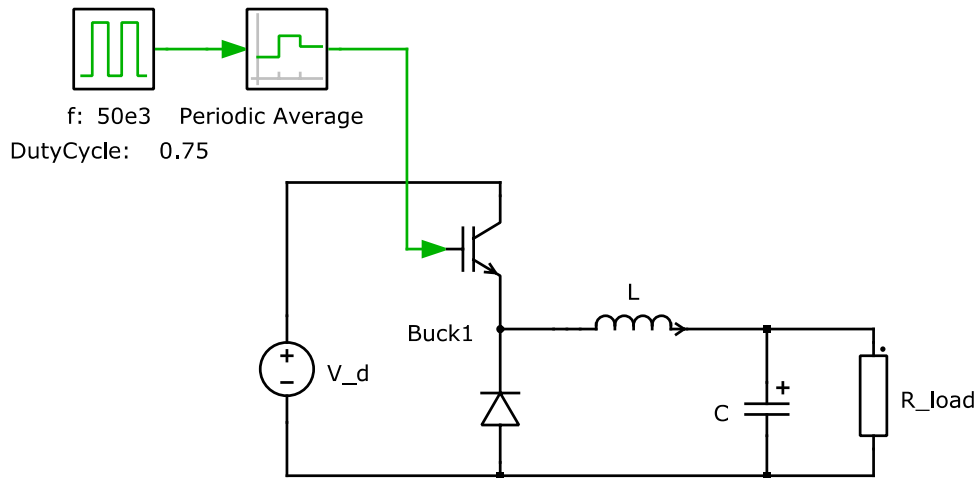
$$L = 5 \mu\text{H}, C = 2000 \mu\text{H}, R_{load} = 3 \Omega$$

**Problems**

1. Using the switching model in Buck\_Cntl, apply a step increase of 0.5 V to the output voltage  $V_o$  at 0.3 s (4 V  $\rightarrow$  4.5 V). Observe the system response i.e. output voltage at 0.3 s.
2. Observe the system response when an additional load resistance of 1  $\Omega$  is added in parallel with the nominal load resistance.
3. Observe the system response when applying a step increase of 1 V in the nominal value of the input voltage  $V_d$ .

#### 4. Step-down (Buck) dc-dc Converter Using Averaged-Switch Model

File: Buck\_avg.plecs and Buck.plecs



##### Nominal values:

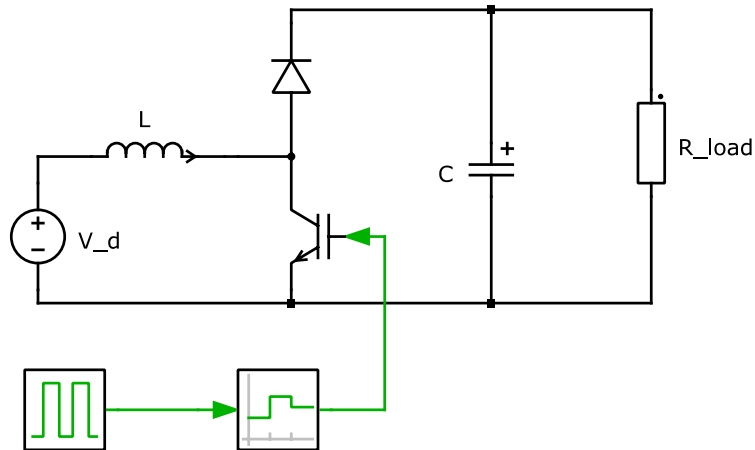
$V_d = 8\text{ V}$ ,  $L = 20\ \mu\text{H}$ ,  $C = 10\ \mu\text{F}$ ,  $R_{load} = 0.5\ \Omega$ ,  $f_s = 50\ \text{kHz}$ ,  $D = 0.75$

##### Problems:

1. Obtain the  $v_o$  and  $i_L$  waveforms with Buck\_avg.plecs.
2. Compare the above waveforms with those obtained using the Buck.plecs model.
3. At 0.3 ms, increase the output load as a step by connecting another load of resistance 0.5  $\Omega$ . Plot  $v_o$  and  $i_L$  waveforms.
4. Repeat Problem 3 using the Buck.plecs model and compare results

## 5. Step-up (Boost) dc-dc Converter Using Averaged-Switch Model

File: Boost\_avg.plecs and Boost.plecs



f: 50e3      Periodic Average

DutyCycle: 0.625

### Nominal values:

$V_d = 9\text{ V}$ ,  $L = 10\ \mu\text{H}$ ,  $C = 50\ \mu\text{F}$ ,  $R_{load} = 5\ \Omega$ ,  $f_s = 50\ \text{kHz}$ ,  $D = 0.625$

### Problems:

1. Obtain the  $v_o$  and  $i_L$  waveforms with Boost\_avg.plecs.
2. Compare the above waveforms with those obtained using the Boost.plecs model.
3. At 0.3 ms, increase the output load as a step by connecting another load of resistance 0.5  $\Omega$ . Plot  $v_o$  and  $i_L$  waveforms.
4. Repeat Problem 3 using the Boost.plecs model and compare results