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BUCK DC/DC CONVERTER

laboratory instruction – very early beta version

Power Electronics Lab, 203, building A-5

Wrocław University of Science and Technology

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1. Purpose of the exercise

The aim of the exercise is to familiarise students with a non-isolated buck DC/DC converter, both in classical and synchronous versions. The exercise is intended to familiarise students with both theoretical fundamentals and simulation and experimental models. It is also intended to draw students' attention to the phenomena occurring during operation of such a system.

2. Exercise steps

1. Using the Texas Power Stage Designer Tool (PSDT), design a buck converter circuit with the following parameters:
    a. Input voltage minimum/maximum 24 V
    b. Output voltage 18 V
    c. Output current 18 V / 22 Ω = 0,81818... A
    d. Switching frequency 40 kHz
    e. Diode voltage drop: 0.7 V
    f. Inductor current ripple: max 30%
2. Verify the inductor current waveform in PSDT. Determine at what value of load current the system will enter the range of discontinuous current mode (DCM) operation.
3. Select which parameters of the MATLAB/Simulink simulation model should be selected (R1/R2/R3, L2/L3, C2/C3, PWM duty cycle, supply voltage value) to obtain waveforms corresponding to the data from step no. 1.
4. Compare the waveforms obtained in Texas Power and in the MATLAB/Simulink simulation models.
5. Using the experimental setup with its dedicated GUI, check if the experimental results correspond to those obtained in the previous sections.
6. Using the experimental setup, check what effect the value of the output filter capacitance has on the converter signals.
7. Using the experimental setup, make the control characteristic: *output voltage* = f (*duty cycle*). Mark the part concerning the range of continuous and discontinuous currents.
8. Using the experimental setup, make a characteristic of the level of oscillation in the function of the switching frequency, *delta current I* = f(*frequency*), at duty cycle 50% for different values of the filter inductance.
9. Using the PSDT and simulation model, perform the entire procedure for the Synchronous Buck.
10. Using the experimental model and assuming the discontinuous current mode, turn on the low-side MOSFET in cmpB mode and select the point at which the transistor turns off when the current passes zero. Find the operating point at which the output voltage is higher for the Synchronous Buck converter than for the classical buck.
11. Switch on the setup in two-quadrant DC/DC converter mode (dead-band), where both MOSFETs are controlled in a complementary manner. What happens in the range of continuous currents? What happens in the range of discontinuous currents?

3. Computer-aided selection of converter parameters – Texas Power Stage Designer

A programme to select the parameters of individual DC/DC converter circuits, both isolated and non-isolated.

Fig.1 Power Stage Converter Tool – higher level

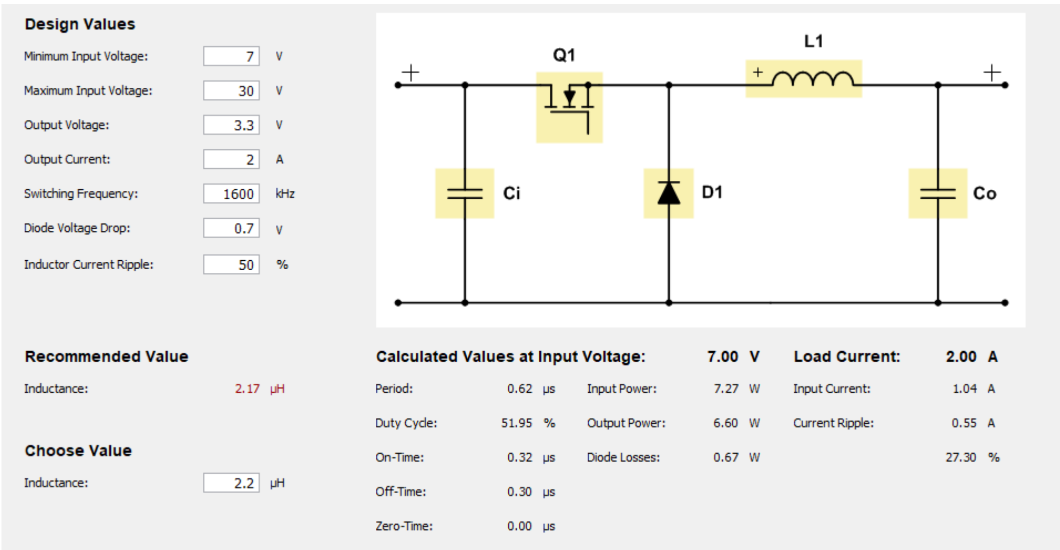

Fig.2 Power Stage Converter Tool –lower level

4. Theoretical basis

4.1. Classic buck converter

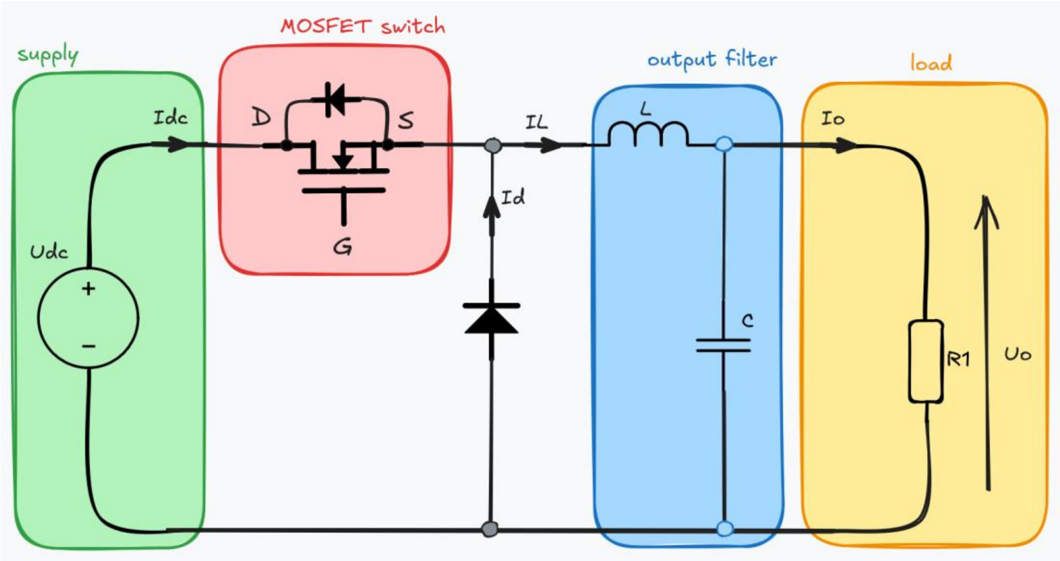

Fig.3 Classical buck converter

4.2. Synchronous buck version

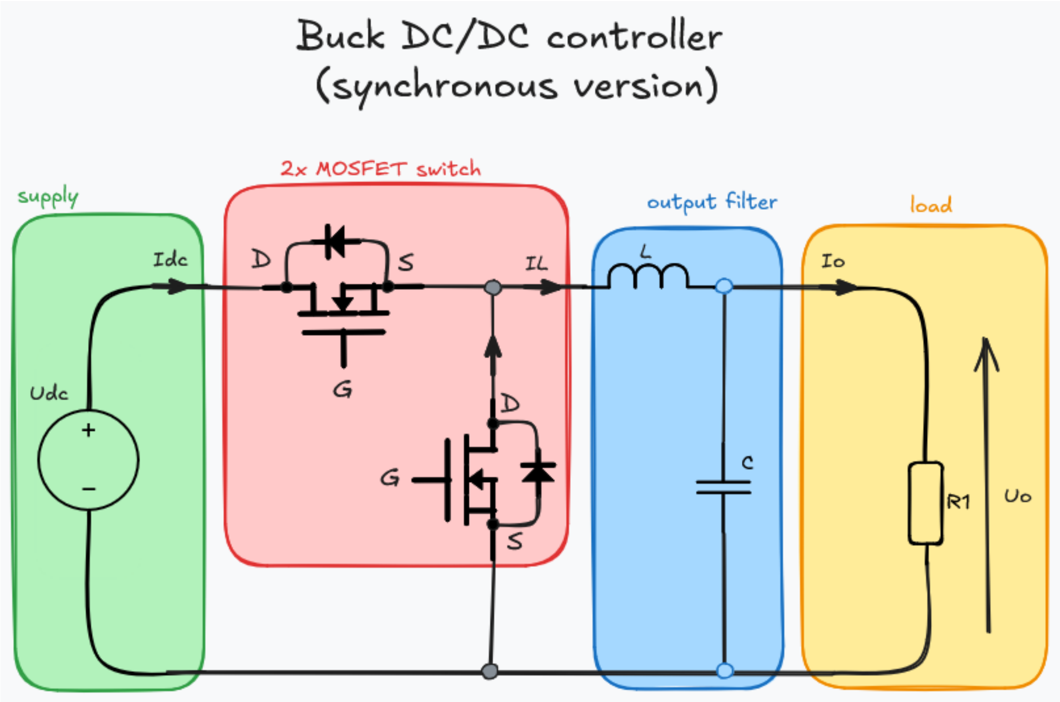

Fig.4 Synchronous buck converter

4.3. Two-quadrant DC/DC converter

The block diagram of the converter is shown in Fig. 4

5. Simulation model - MATLAB/Simulink

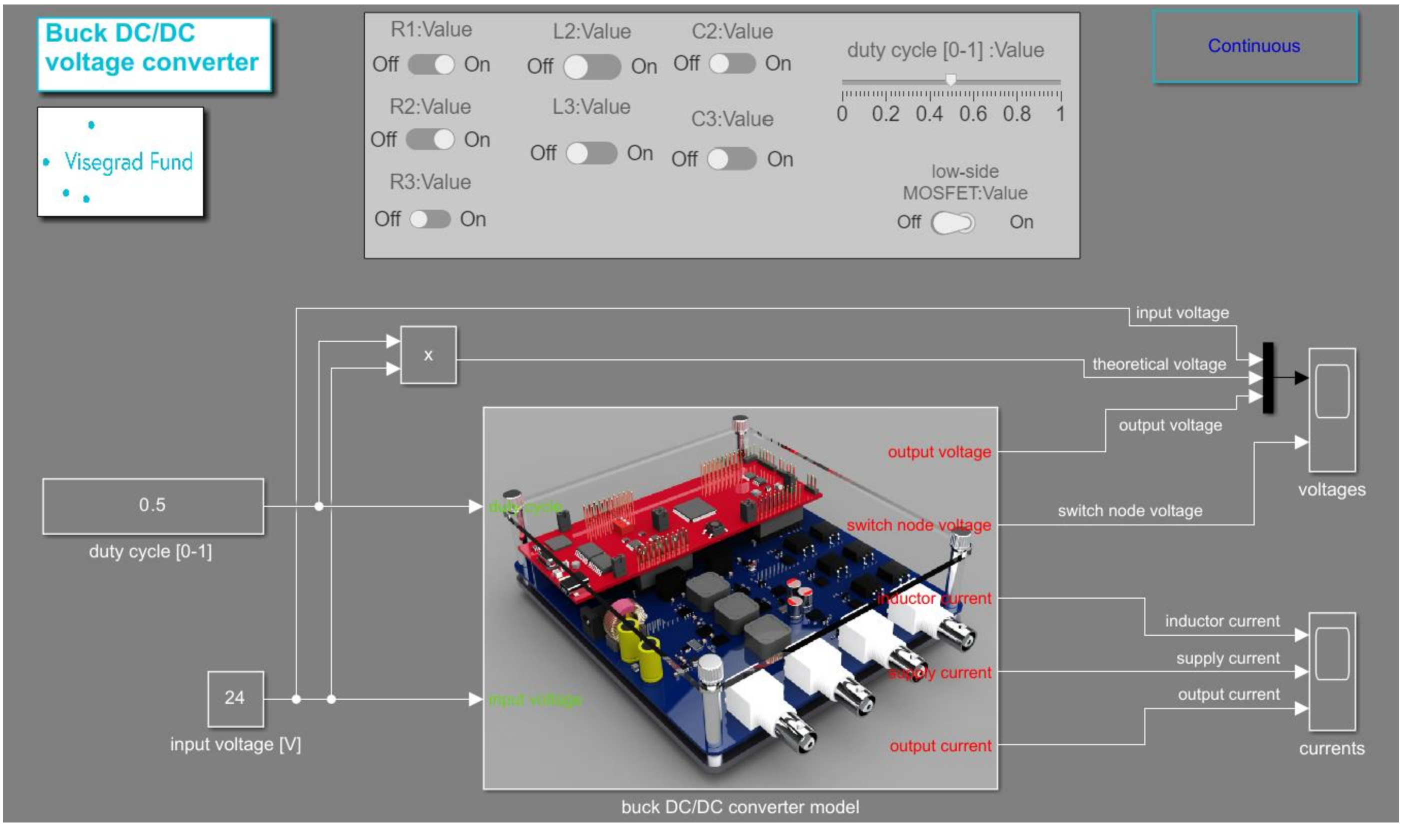

Fig.5 Simulation model – higher level

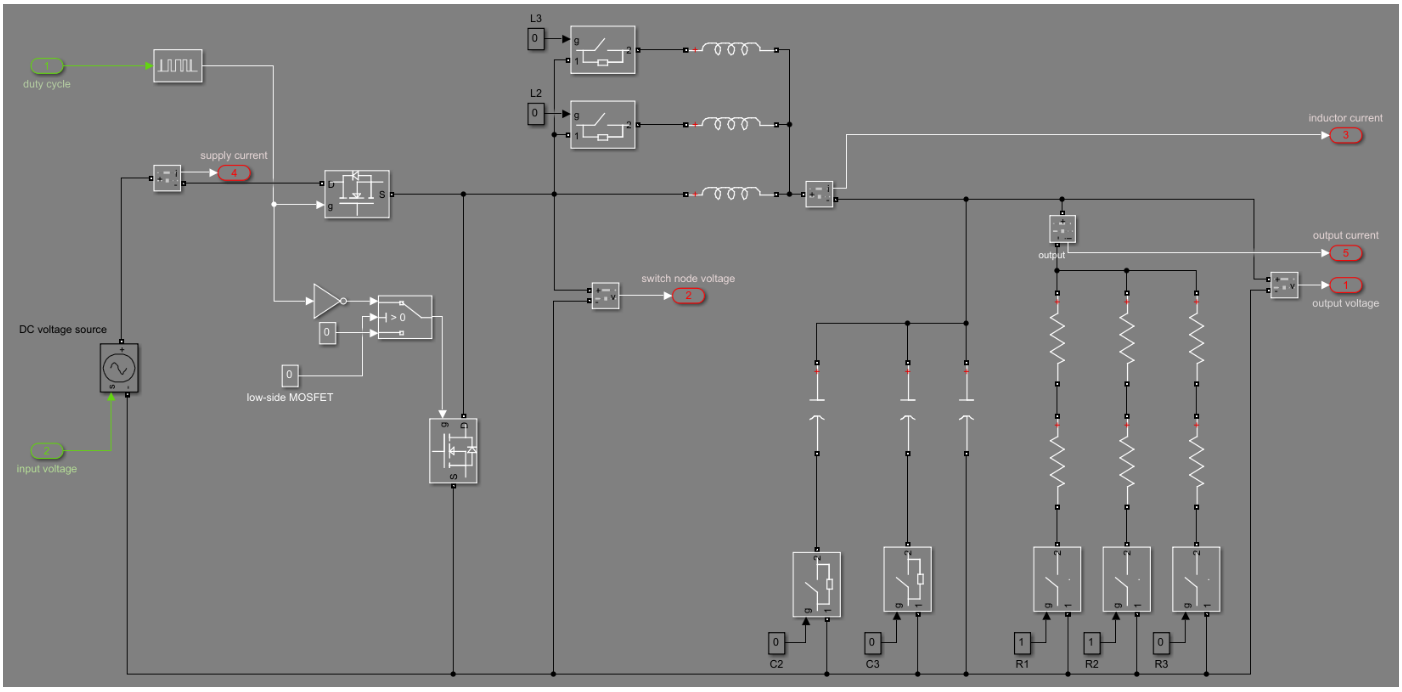

Fig. 6 Simulation mode – lower level

6. Laboratory experimental setup

A visualisation of the laboratory setup is shown in Figure 1. The model consists of a number of parts:

- the electronic part, i.e. the power electronic components that make up the voltage converter under test

- the measurement part, i.e. the circuits providing the measurement of the necessary signals,

- a control part, i.e. a circuit with a signal processor,

- the part containing the other modules

6.1. Power electronics part

The power electronics part (blue) consists of a series of electronic components that constitute a buck (step-down) DC/DC converter. This circuit consists of:

- two N-MOSFET transistors, both controlled by a suitable driver, providing hardware dead-time, i.e. each transistor is controlled independently by the signal processor outputs, but the driver will not allow both transistors to switch on at the same time,

- input filter,

- three parallel connected inductors with identical inductances of **470 µH**, one of which is switched on permanently and two of which can be connected to the circuit by software,

- three capacitors connected in parallel with identical capacitance of **10 µF**, one of which is permanently connected and two of which can be connected to the circuit via software,

- three parallel connected branches of two **33 Ω** resistors each, constituting the load of the circuit under test. Each branch of the load can be switched on by software.

6.2. Measurement part

The circuit allows the following signals to be visualised on an oscilloscope via BNC connectors:

- output voltages,
- switch node voltages,
- coil current,
- input current.

In addition, the following signals are available for the ADC of the signal processor:

- output voltages,
- coil current,
- input current.
- input voltage,
- temperature measurement of the three load branches.

The location of the measurements is shown in Figure 7.

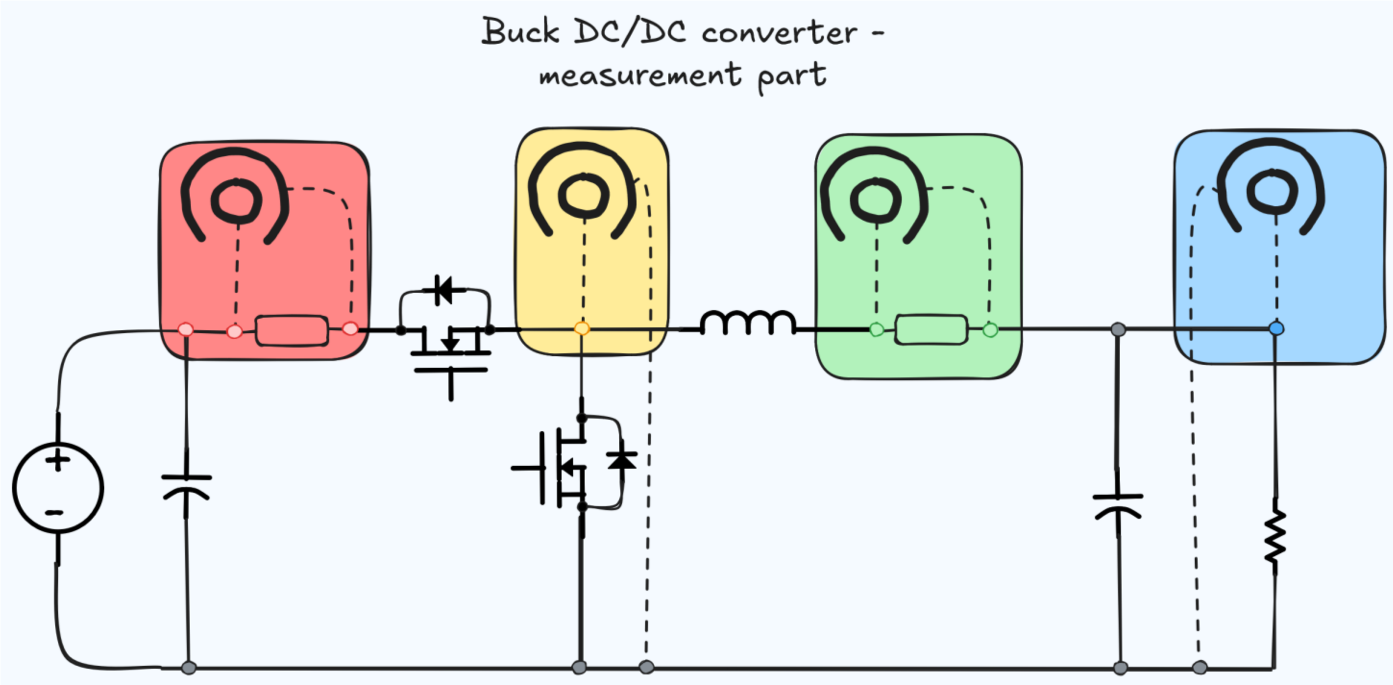

Fig. 7 BNC configuration

6.3. Część sterująca

The control part (red) is the prototype DPS system [Texas Instruments LAUNCHXL-F29069M](), including 32-bit [digital signal processor TMS320F28069M]().

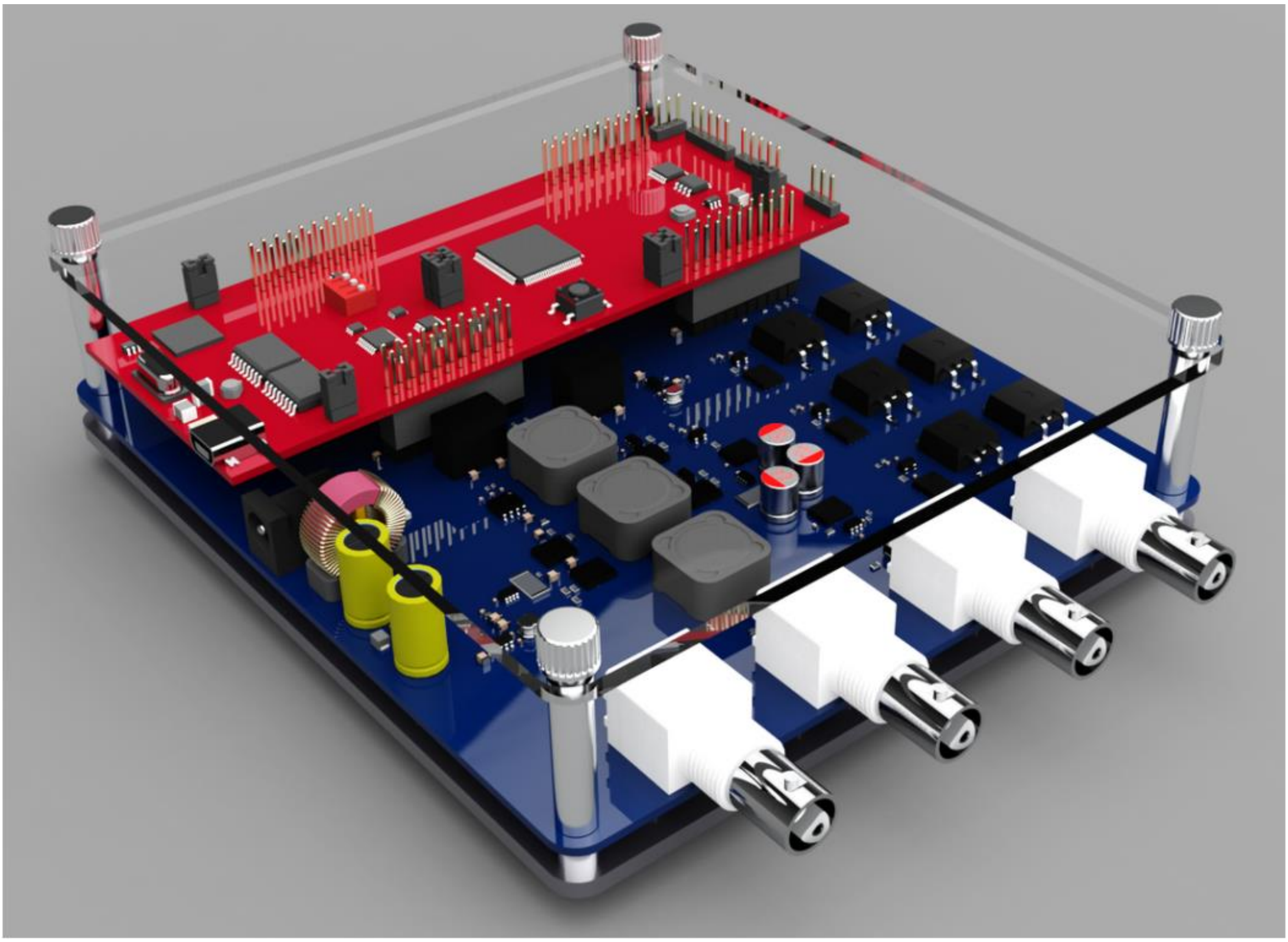

Fig. 8 Visualization of experimental setup

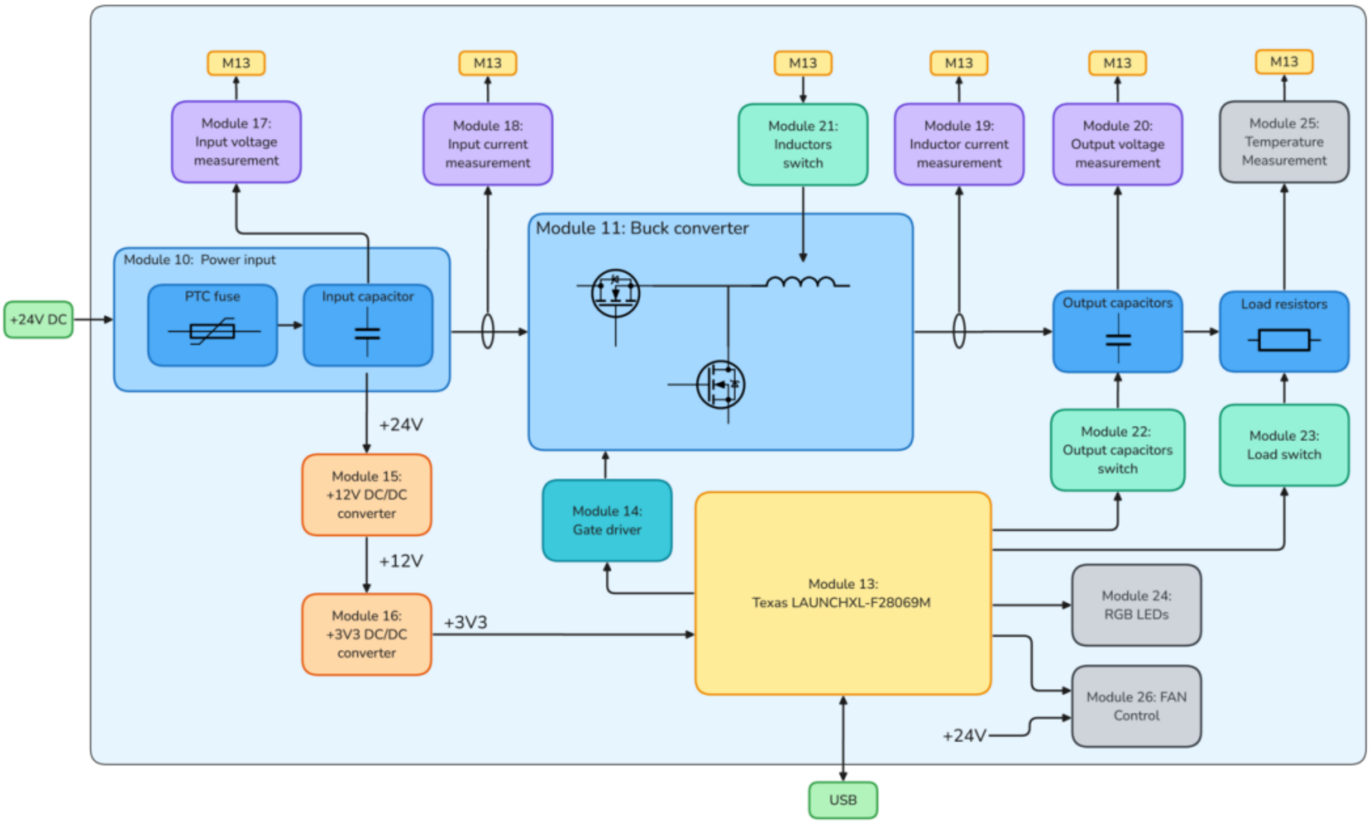

Fig. 9 Functional block diagram of experimental setup

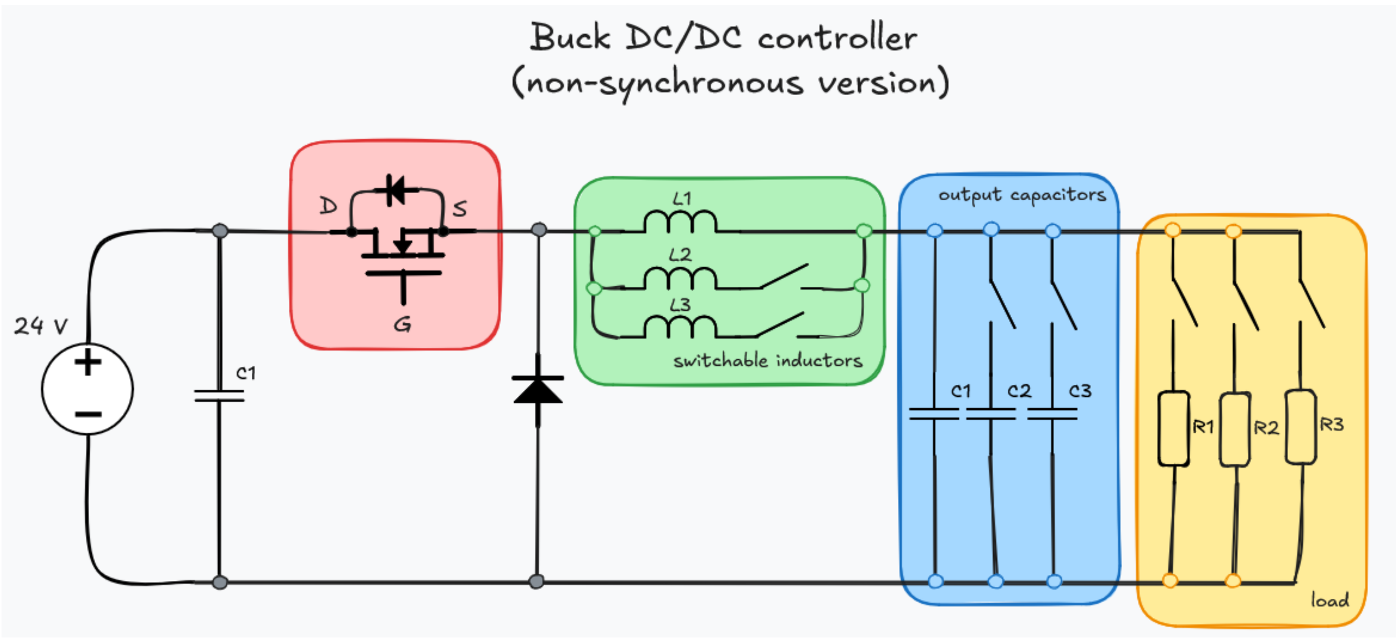

Fig. 10 Block diagram of the laboratory system

7. GUI

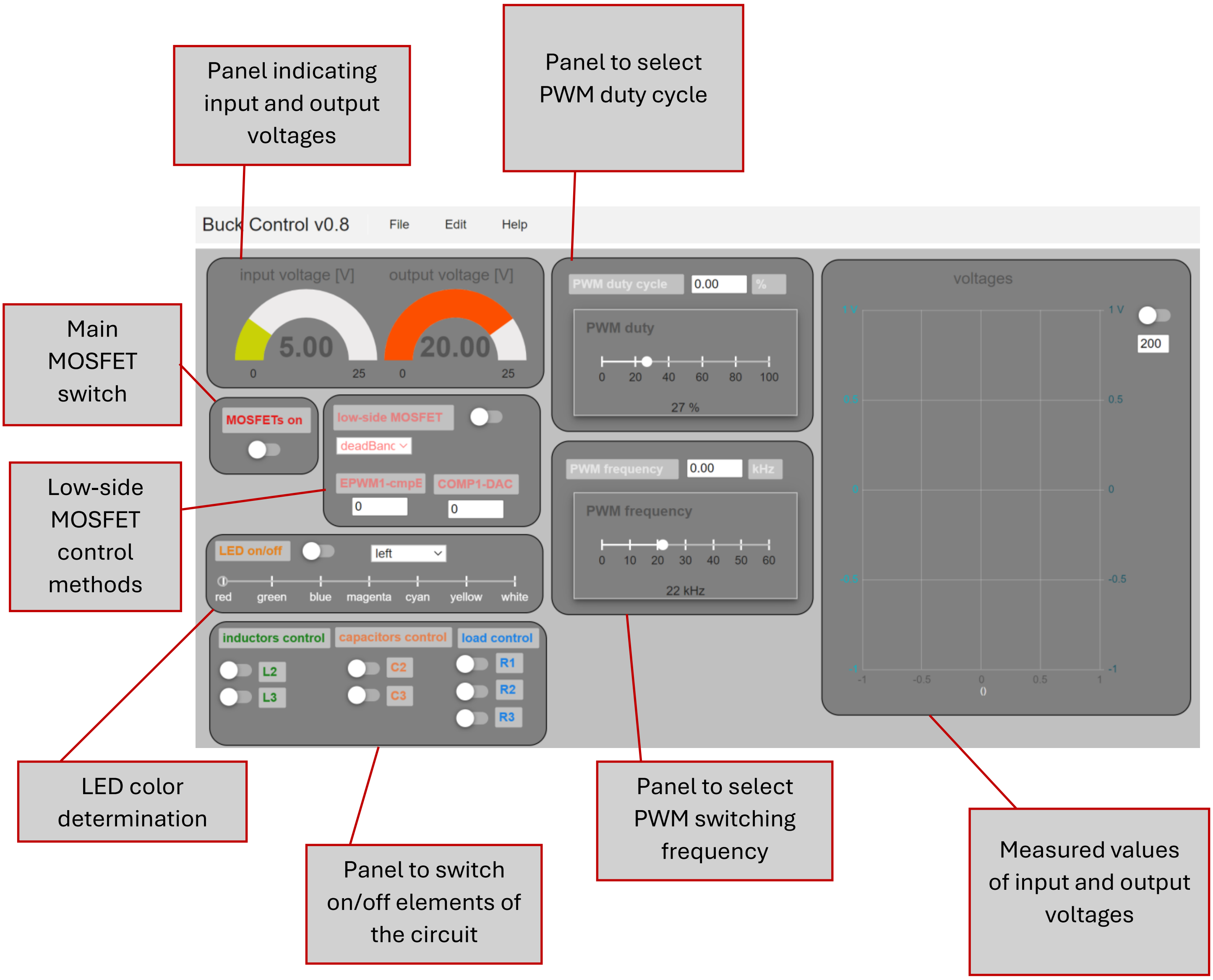

Fig. 11 Graphical user interface

8. Conclusions

The instruction described the buck / step-down DC/DC converter and the tools necessary to design and simulate the operation of the converter.

9. Bibliography

To be continued.