

Implement a physical Buck Converter

1. Introduction

My goal with this project was to implement a physical Buck converter that can be controlled using a PWM signal that can handle some limits specified by my teacher.

Specifications:

- Max Current: $I = 9A$;
- Max current ripple: $\Delta I = 25\% \text{ of } 9A = 2.25 A$;
- Max voltage ripple $\Delta V = 200mV$;
- Max voltage allowed by component selection: $V_{max} = 30V$;

2. Calculations

Physical project

$V_{in} = 24V$	$\mu = \frac{12}{24} = 0.5$
$V_{out} = 12V$	
$i_{out_max} = 9A$	$L = 220 \mu H = 12.2 \cdot 10^{-4} H$
$D_{il} = 25\% \text{ of } 9A = 2.25$	$D_{il} = \frac{V_{in} - V_{out}}{L} \cdot \frac{\mu}{I} \Rightarrow f = \frac{(V_{in} - V_{out}) \cdot 0.5}{L \cdot D_{il}}$
$\Delta_{ac} = 200mV$	$f = \frac{(24 - 12) \cdot 0.5}{12 \cdot 2 \cdot 10^{-4} \cdot 2.25} = \frac{6}{2.2 \cdot 2.25} \cdot 10^4 = 12.121 \text{ kHz} \approx 12.121 \text{ kHz}$
$P = 12.121 \text{ kHz}$	

$$D_{uc} = \frac{D_{il}}{8fC} \Rightarrow C = \frac{2.25}{8 \cdot 12 \cdot 10^3 \cdot 0.2} = 0.117 \cdot 10^{-3} = 0.117 \cdot 10^{-6} F = 0.117 \text{ mF}$$
$$P_{avg} = g \cdot 0.5 = 4.5W \quad i_{max} = g + \frac{2.25}{2} = 10.125$$
$$J = UR \Rightarrow R = \frac{U}{J} = \frac{12}{9} = 1.33 \Omega$$

3. Component selection

When choosing the components I tried to find equality between price and quality.
For the inductor I chose one that has an inductance of 220 uH, a max current rating of 10A.

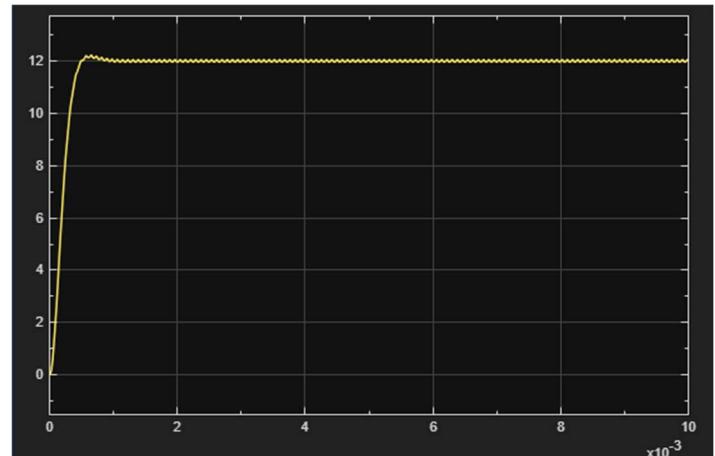
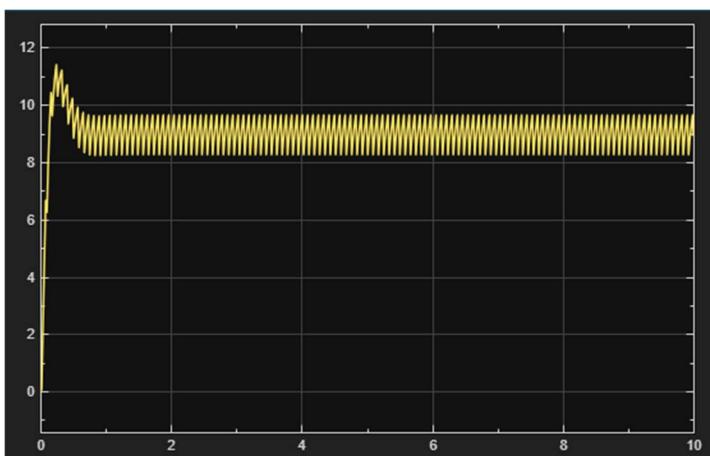
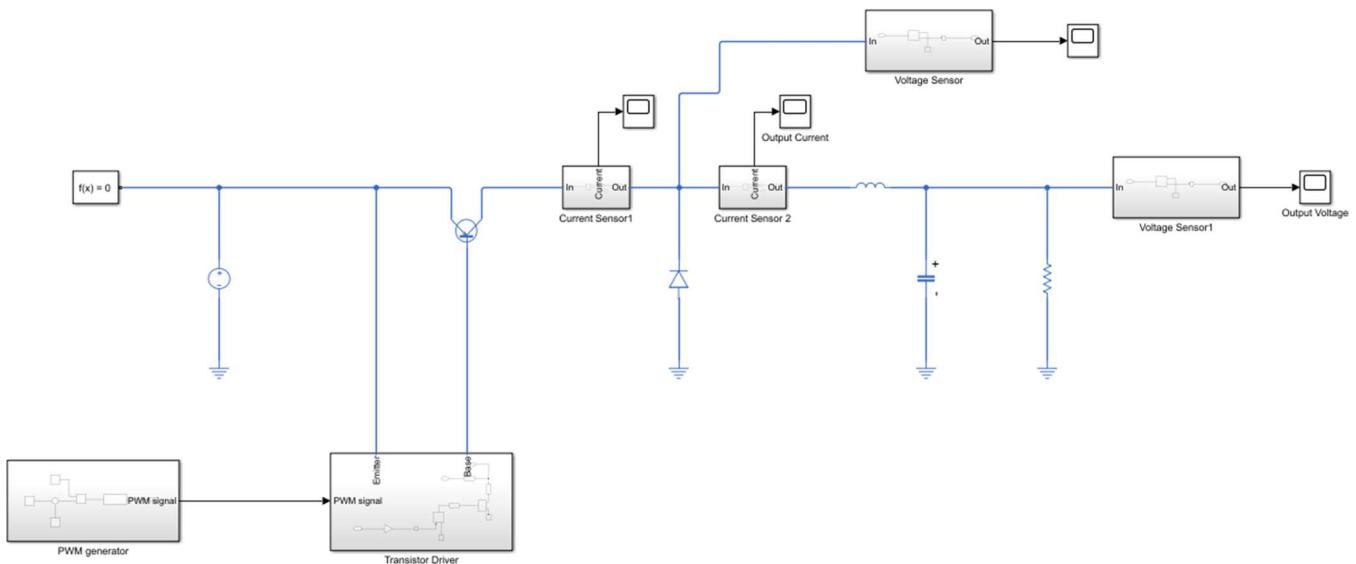
The diode is rated at 200V and 6A, the fastest switching one I could find.

The transistor is a MOSFET, rated at 30V, 150A driven by a NPN and PNP pair.

The capacitor is 150 uF, 35VDC maximum rating. At the end of this document there are links with the components I used.

4. Simulation

I wanted to simulate the circuit before starting building it and for that I made a simulation in MatLab/Simulink using the SimScape toolbox.



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These are the results of the simulation with all the parasitic elements of the components added. With a 24V supply the duty cycle must be around 0.77 for the output to be 12V.

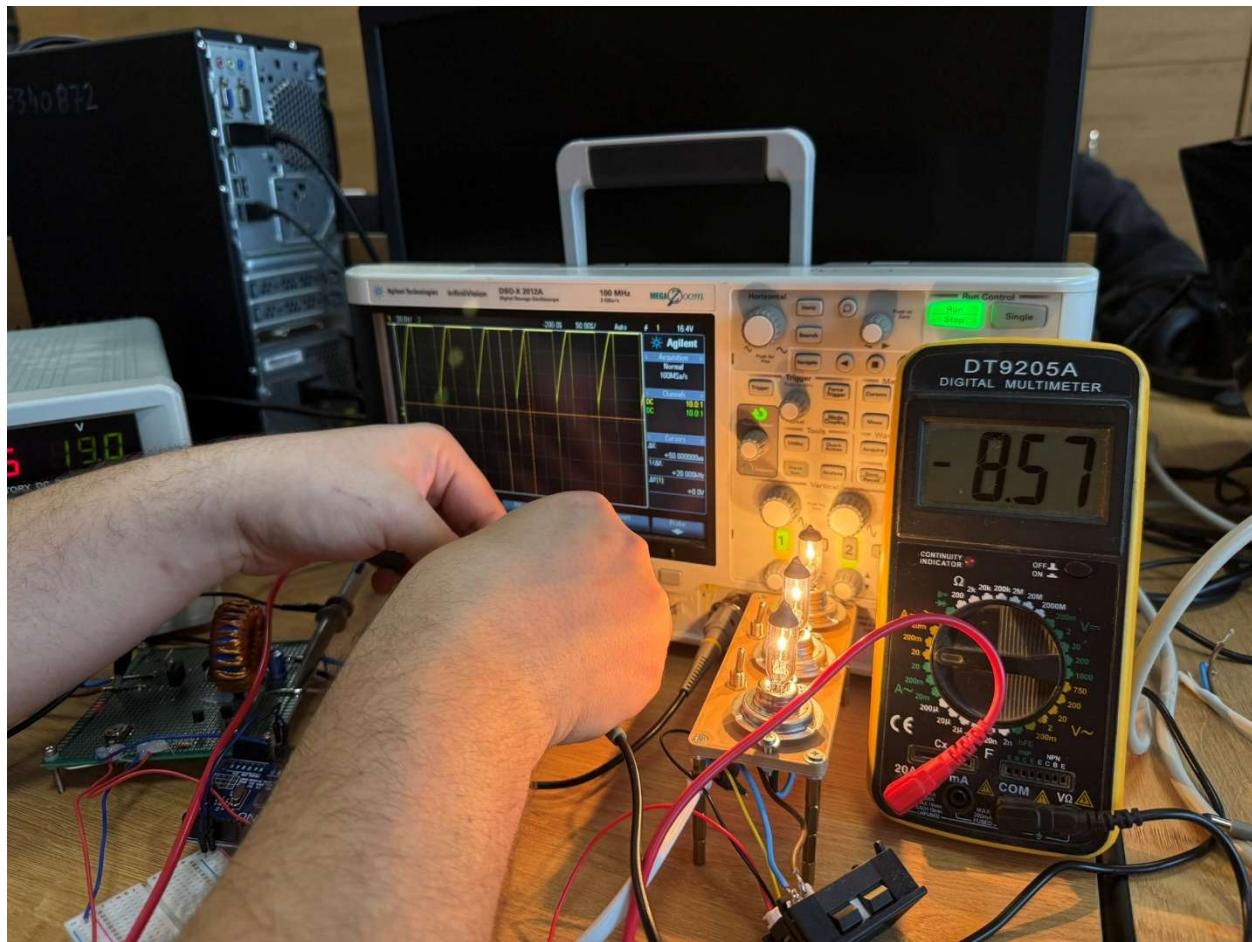
The simulated current ripple is 1.3A, within the maximum limit. And the voltage ripple is 93mv, as well within the maximum limit.

5. Real testing and results

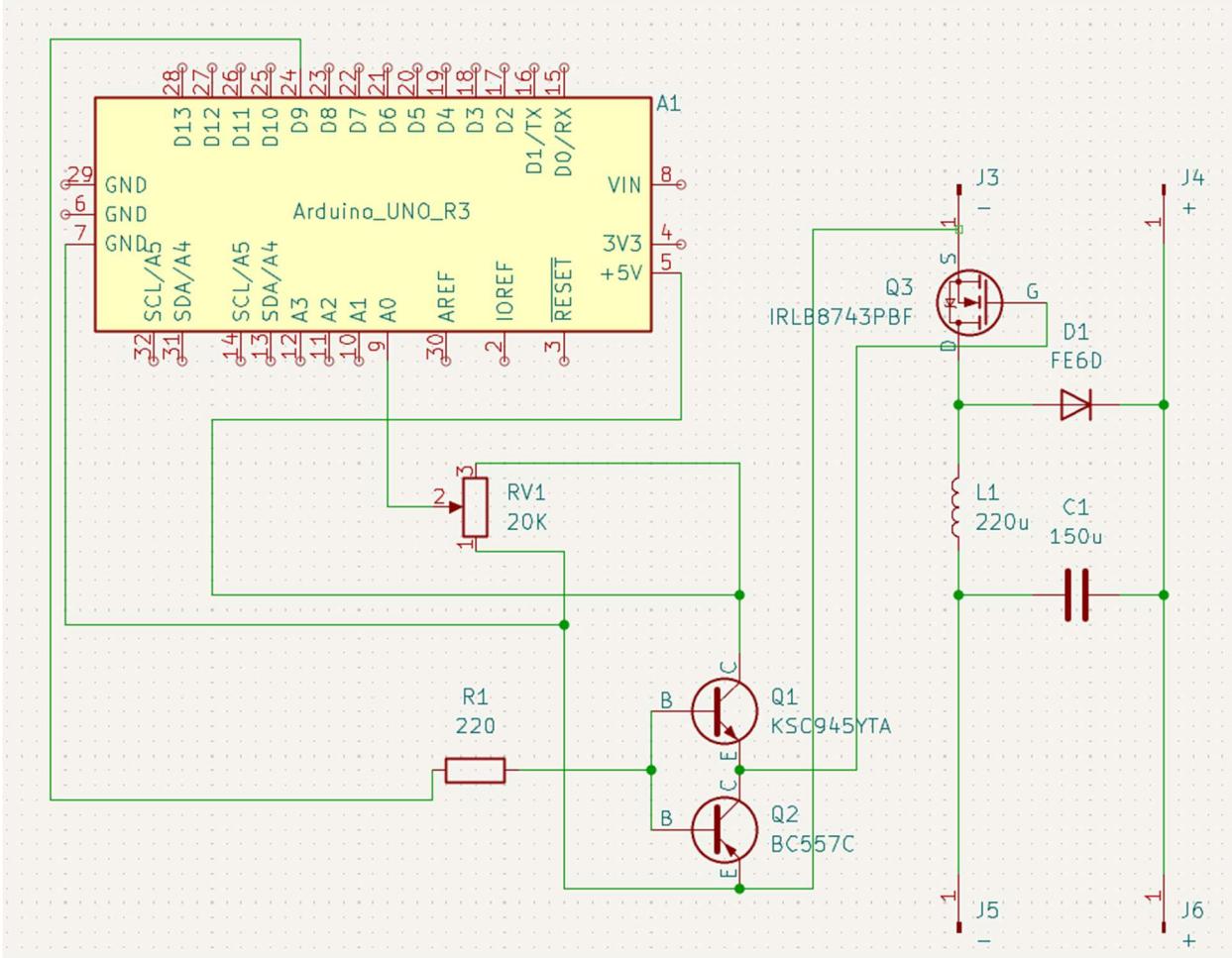
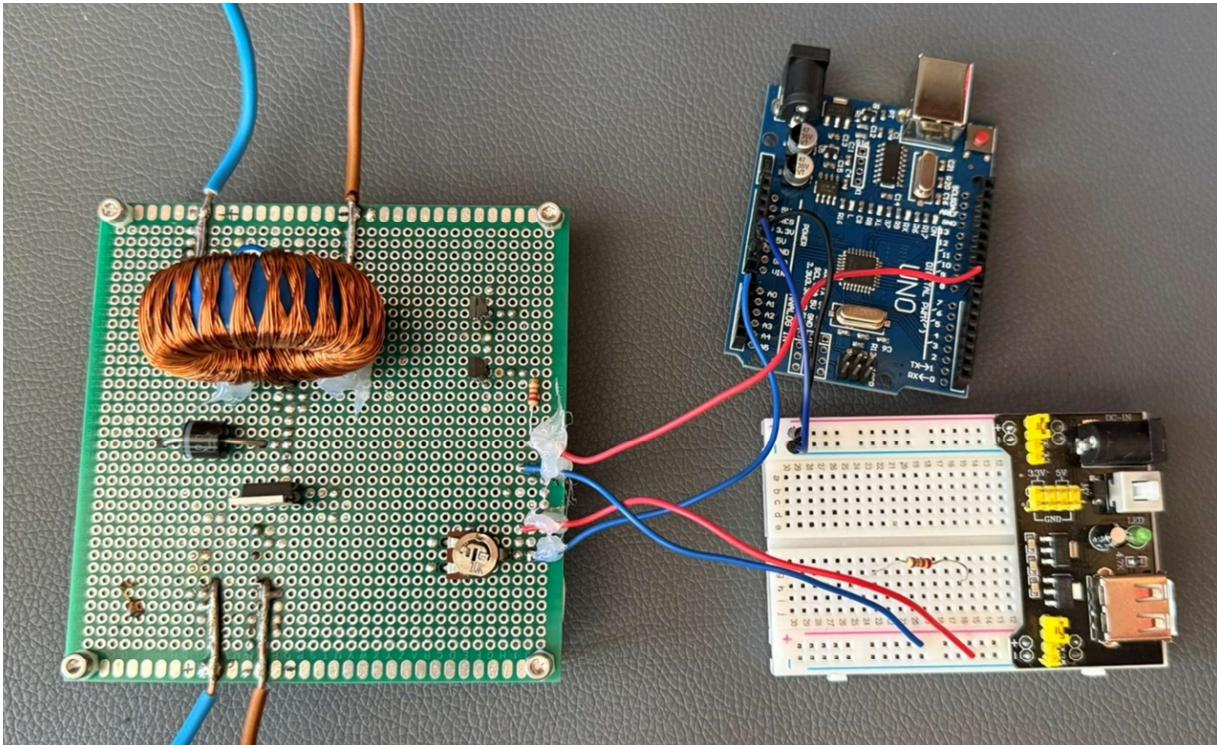
For testing the circuit, I use a PWM signal generated by an Arduino. The frequency is 12.21 kHz, and the duty cycle is adjusted using a potentiometer.

During real testing the circuit sustained 8.5A at 19V without any of the components getting hot.

On the oscilloscope we can see how the voltage rises and falls across the whole circuit.



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For this schematic I used KiCad to draw it.