CAMBRIDGE UNIVERSITY ENGINEERING DEPARTMENT

Part IIA Laboratory Report

3B3 DC-DC Converters

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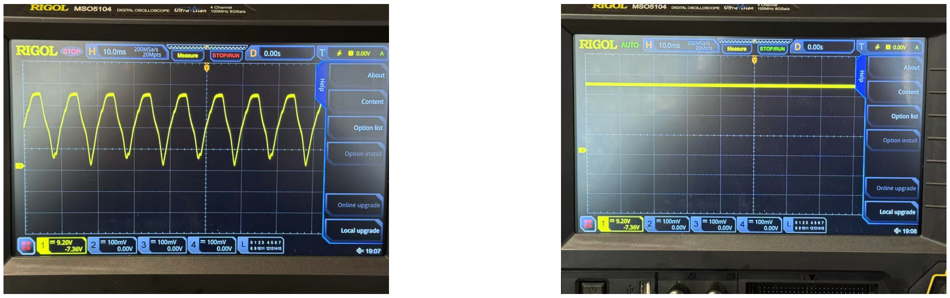
Exercise 1: Diode Bridge AC-DC Rectifier

The scope readings for exercise 1 are shown by Figure 1.



(a) Reading of 1-2 (b) Reading of 1-3

Figure 1: Scope readings of Exercise 1

Exercise 2: DC-DC Buck Converter

The testing schematic of the DC-DC Buck Converter is shown by Figure 2.

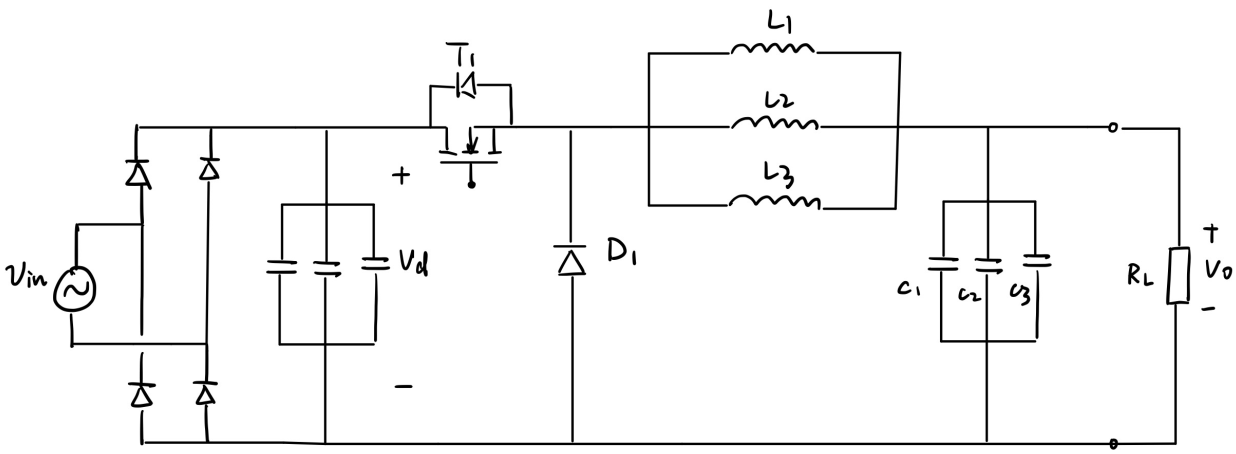


Figure 2: Schematic of DC-DC Buck Converter

The measurements are carried by four channels of the oscilliscope.

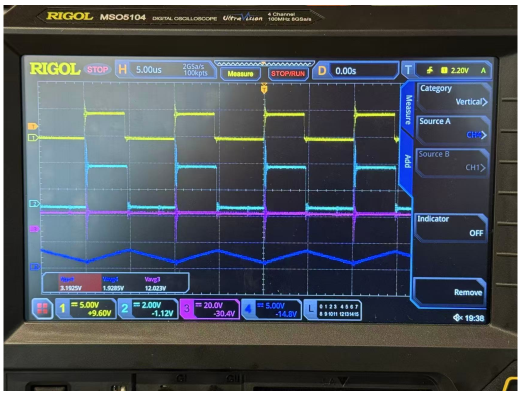
1. CH1: Gate pulse voltage v_G

2. CH2: Diode voltage v_D

3. CH3: Output DC voltage V_o

4. CH4: Inductor current i_L

Note that CH4 measures the current via a current probe and shows the reading in V on display.



(a) Reading with $V_o = 12$V

(b) Reading with $V_o = 18$V

Figure 3: Scope readings of section 2-2

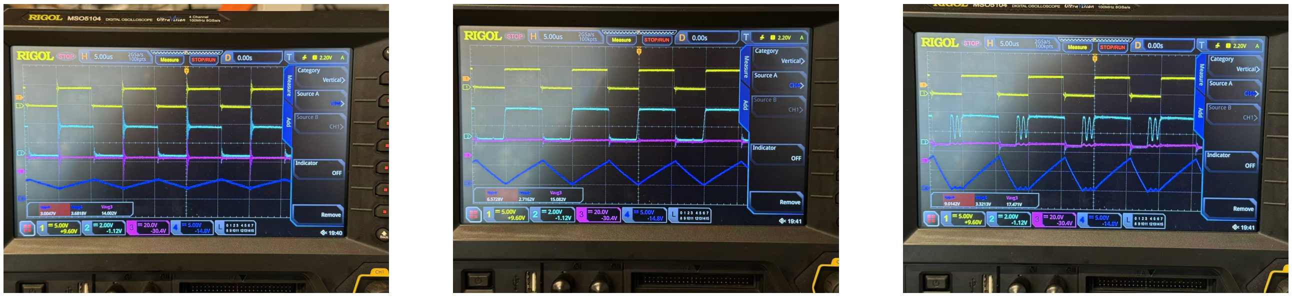
In Section 2-2, scope readings are taken with $V_o = 12$V and $V_o = 18$V. Duty ratio D = 0.45 for $V_o = 12$V, D = 0.68 for $V_o = 18$V.

According to theory, the voltage transfer ratio of a buck converter $M(D) = \frac{V_o}{V_d} = D$. So, the theoretical values of the two measurements should be $\frac{12}{30} = 0.4$ and $\frac{18}{20} = 0.6$ respectively.

We can see that the measured duty ratios are about 10% larger than the theoretical values for both cases. This is due to non-ideal parts of circuits, mainly the extra voltage drop due to the diode and the parasitic resistance of the inductor.

Thus, for both ON and OFF states of the transistor, the DC output $= V_o - \Delta V$ is kept constant actually. $V_o = DV_d$ should be larger than theoretical value of compensate this effect. As result, duty ratio is measured to be larger.

In the next session, load resistor and inductors are explored by switching more inductors on. The reading of scope is shown in Figure 4.



(a) Reading with L_3 ON

(b) Reading with L_3 and L_2 ON

(c) Reading with L_3, L_2, and L_1 ON

Figure 4: Scope readings of section 2-3

To find the load resistance $R_L = \frac{V_o}{I_o}$, output current I_o should be obtained from the readings of CH4, which measures the inductor current i_L. By making the assumption that the output smoothing capacitor is large enough that all ripple current goes into the capacitor, $I_o = i_{L\text{avg}}$. This average value can be obtained by the built-in measurements of the oscilliscope. From Figure 3a and 3b, we have $I_o = 1.9285A$ for $V_o = 12V$ and $I_o = 5.3808A$ for $V_o = 18V$. Thus, the load resistances are calculated as 6.22Ω and 3.34Ω for this two cases respectively. There is a huge discrepancy as expected. Only one measurement is taken per case and the parasitic resistance is not accounted for. We could improve this estimate of load resistance by taking multiple measurements and averaging them, or by considering the parasitic resistance of the inductor and diode voltage drop.

For now, we can only conclude that the load resistance is somewhere between 3Ω and 6Ω.

After that, interest focuses on the inductance L_1, L_2, and L_3. This can be found by considering the peak-to-peak ripple current ΔI_L.

From theory in Continuous Conduction Mode, $\Delta I_L = \frac{V_d D(1-D)}{f_s L}$, where f_s is the switching frequency, 100kHz, D is the duty ratio, fixed at 0.53, and V_D is 30V. Rearranging gives $L = \frac{V_d D(1-D)}{f_s \Delta I_L}$. By looking at the waveform of inductor current, we can see that the buck converter operates at CCM for the first two cases in Figure 4.

$L_3 = \frac{30\times0.53\times(1-0.53)}{100000\times0.346} = 217.6\mu H$. $L_2//L_3 = \frac{L_2 L_3}{L_2+L_3} = \frac{30\times0.53\times(1-0.53)}{100000\times0.222} = 339.9\mu H$. We can get

$L_2 = 567.8 \mu H$ from above two equations.

For the last case in Figure 4, the buck converter now operates in DCM. Thus, the previous formula is not applicable.

Exercise 3: DC-DC Boost Converter