ECE 5610
Lab 2

Buck Converter

Objective

The objective of this experiment is to study the characteristics of a simple buck converter. The circuit will be operated under continuous conduction mode (CCM) and open loop conditions (no feedback). Our main goal will be to compare the theoretical results with the experimental results.

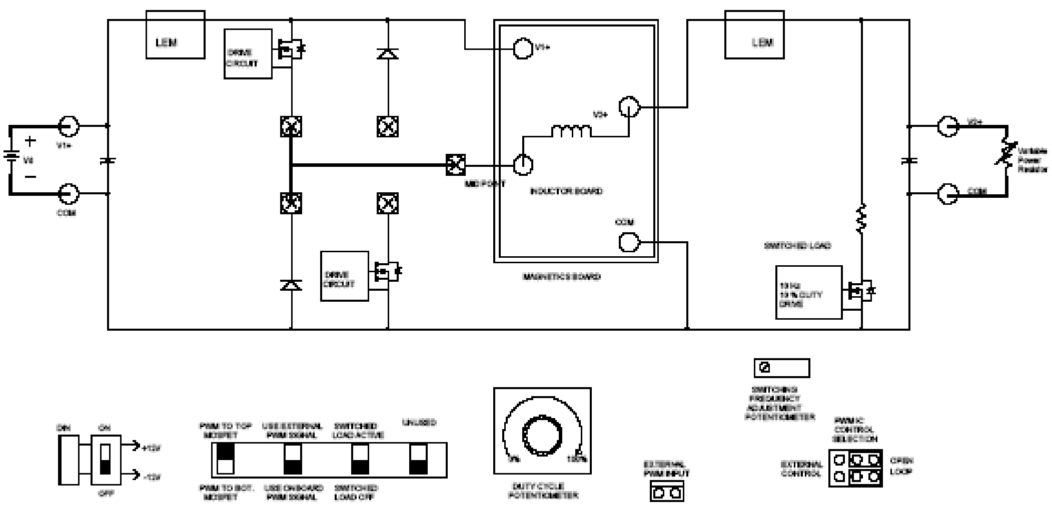


Figure 2.1: Schematic of Buck Converter

Note 1: The oscilloscope channels share the same signal GND. Therefore, it is recommended to take precautions while measuring two quantities having separate reference potentials. Students are advised to use the circuit connections shown in Figure 3 of Lab 1 if you need to take two measurements simultaneously in the oscilloscope.

2.1 Preparing the setup

Make the connections on the power-pole board as shown in Fig. 2.1.
• Use the magnetic board BB board for the buck converter circuit. The inductor is 100 μH.
• Use a variable load resistor (R_L) as a load.
• Use onboard PWM signals.
• Connect the ±12 signal supply at the *DIN* connector. Signal supply switch S90 should be in the OFF position.

2.2 Checks before powering the circuit

• Check the circuit connections as per the schematics.
• Have your circuit checked by your ***Lab TA.***

2.3 Powering the circuit

• Switch ON the signal supply. The green LED should illuminate.
• Adjust the duty ratio to 50%.
• Set the load resistance R_L = 10 Ω.

• Adjust the switching frequency to 100 kHz.
• Apply input voltage V_d of 15 V at terminals *V1+* and *COM*.

2.4 Measurement and Waveforms

Take the following measurements,

2.4.1 Varying duty ratio

• Set the duty ratio to 50%, switching frequency at 100 kHz and R_L = 10 Ω.
• Vary the duty ratio from 10% to 90% (in steps of 10%).
• Measure the average output voltage for the corresponding duty ratios.
• Calculate the theoretical average output voltage for the corresponding duty ratios.

2.4.2 Varying switching frequency

• Set the duty ratio to 50%, switching frequency at 100 kHz and R_L = 10 Ω.
• Measure the peak-peak output ripple voltage.
• Observe and make a copy of the output ripple voltage, the output current (*CS5*) and capacitor current (*CS4*) waveforms.
• Repeat the above procedure for different switching frequencies (40 kHz, 60 kHz, and 80 kHz). *Make sure that duty ratio is maintained at 50%*.

2.4.3 Varying the load

• Set the switching frequency to 100 *kHz* and duty ratio at 50%.
• Set the load resistance R_L = 10 Ω.
• Increase the load impedance and observe and make a copy of the output current waveform.
• Keep increasing the load impedance until the buck converter enters into discontinuous current mode operation. Note down the average output current value when the converter starts entering discontinuous current mode of operation.
• Observe and make a copy of the output voltage, voltage across the MOSFET and diode, output current, and capacitor current *[use oscilloscope connections as shown in Figure 2 of Lab 1]*.

2.4.4 Determining efficiency

• Set duty ratio at 50% and load resistance R_L = 10 Ω.
• Measure the RMS output current I_o.
• Measure the RMS input current I_i.
• Measure the RMS output voltage *V2+*.
• Measure the RMS input voltage V_d.
• Calculate the efficiency of the buck converter for different frequencies (60 kHz and 100 kHz) using the above measurements.

2.5 Lab report

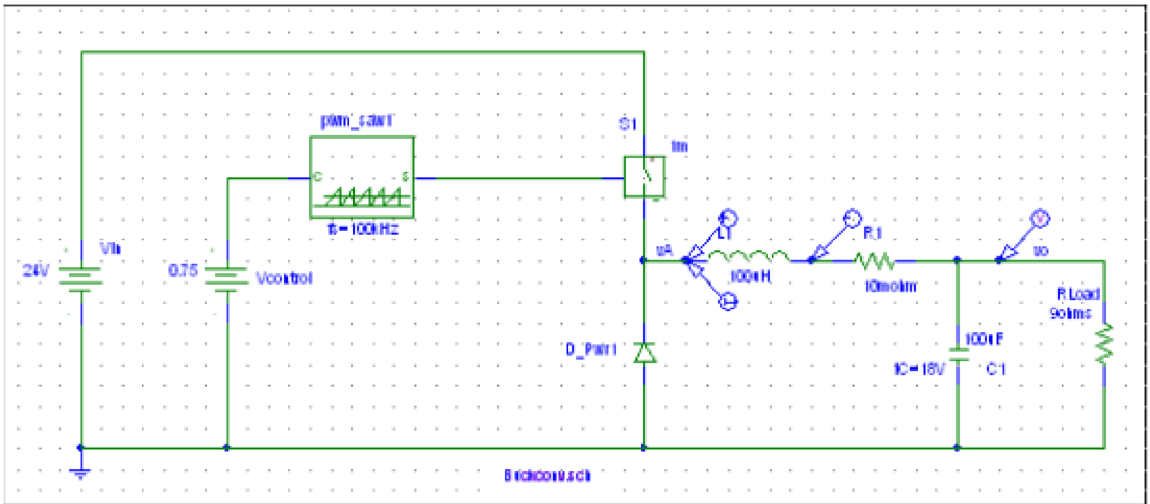
The lab report should have a brief abstract detailing what has been done in the experiment. The remaining part of the report should consist of the information asked below along with any discussion you feel necessary.

1. Attach a graph showing the output voltage (*V2+*) versus duty ratio using data obtained in section 2.4.1. Also plot the theoretically calculated results on the same graph. Compare these two plots and comment on how the buck converter works as a variable dc step down transformer. Enclose output voltage & voltage across diode waveforms for duty ratio 50%.
2. Attach a copy of the output/inductor current (*CS5*) and the capacitor current (*CS4*) waveforms obtained in section 2.4.2. Explain the relation between these two currents. Comment on the ripple in the inductor current for these two frequencies.
3. Plot the peak-peak ripple in the output voltage versus switching frequency using data obtained in section 2.4.2. Plot the theoretical results on the same graph. Compare the two plots.
4. Attach a copy of the inductor current waveforms obtained in section 2.4.3. Compare the theoretically calculated R_{crit} with the observed value.

5. Comment on the difference in efficiency results obtained for two switching frequencies.

2.6 Spice simulation of the Buck converter

We will use this simulation to observe switching waveforms in a near-ideal buck converter operating at a fixed duty cycle. Open the file **Buckconv.sch**. Take a moment to examine the circuit, and then perform the following measurements.



Assignments:

1. Plot the waveforms during the last 10 switching cycles for i_L, v_L and v_o. You need to make sure the circuit has reached steady state. Depending on the operating conditions, you may need to simulate the circuit for a much longer time (way more than 10 switching cycles).

2. Plot the average value of v_L.

3. Plot i_L and measure the peak-peak ripple Δi_L and compare it with the equation in the text book.

4. Plot i_C waveform. What is the average of i_C. Compare the i_C waveform with the ripple in i_L.

5. Plot the input current waveform and calculate its average. Compare that to the value calculated theoretically.

6. Calculate the inductance value of L, if Δi_L should be 1/3rd of the load current. Verify these computed results with the results obtained from the simulation.

7. Change the output power in this circuit to one-half its original value. Measure the peak-peak ripple Δi_L and compare it with that in assignment 3. Comment on this comparison.

8. Calculate R_{crit} and verify whether the converter is operating on the boundary of CCM and DCM.