10/23/2024

ECE 5610
Lab 5

Buck-Boost Converter

Objective

The objective of this experiment is to study the characteristics of a simple buck-boost 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.

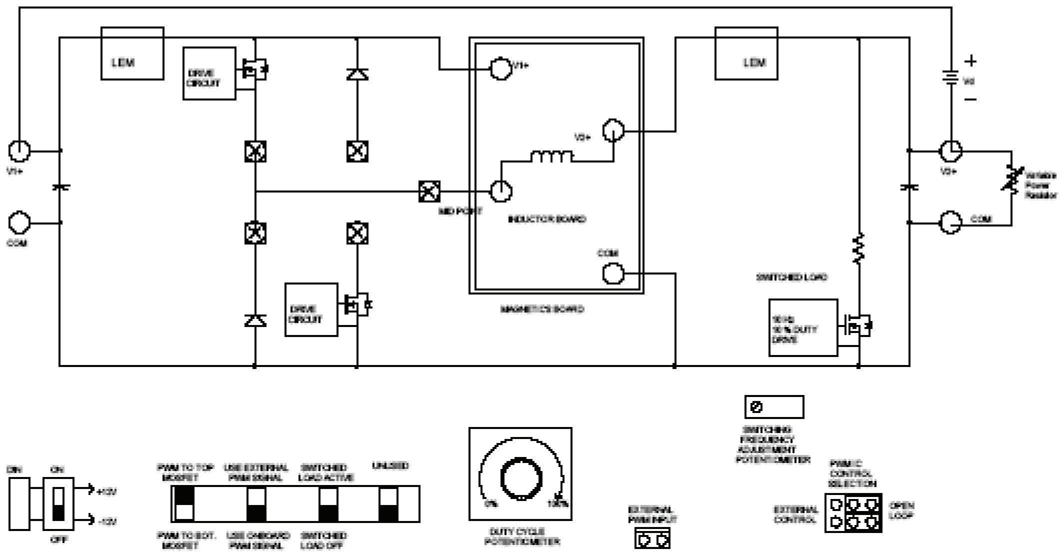


Figure 4.1: Schematic of Buck-Boost Converter

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.

Note2: Care must be taken while conducting the buck-boost converter experiment. Students need to make sure that the load is always connected at the output of the constructed buck-boost converter.

5.1 Preparing the setup

Make the connections on the power-pole board as shown in Fig. 4.1

- Use the magnetic board BB board for the buck-boost 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 OFF position.

5.2 Checks before powering the circuit

- Check the circuit connections as per the schematic.
- Have your circuit checked by your ***Lab TA***.

5.3 Powering the circuit

- Switch ON the signal supply. The green LED should illuminate.
- Adjust the duty ratio to 10%.
- Set the load resistance R_L = 20 Ω.
- Adjust the switching frequency to 100 kHz.
- Apply input voltage V_d of 10 V at terminals *V1+* and *V2+*.

5.4 Measurement and waveforms

start @ scope B5

Take the following measurements:

5.4.1 Varying duty ratio

< 53% duty = buck
> 53% = boost

- Set the duty ratio to 10%, switching frequency at 100 kHz and R_L = 20Ω.
- Vary the duty ratio from 10% to 60% (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.

5.4.2 Varying switching frequency

- Set the duty ratio to 60%, switching frequency at 100 kHz and R_L = 15Ω.
- Measure the peak-peak inductor current ripple.
- Observe and make a copy of the inductor current (*CS5*) waveform.
- Repeat the above procedure for different switching frequencies (40 kHz, 60 kHz, and 80 kHz).

5.4.3 Determining the efficiency

- Set duty ratio at 60%.
- Set load resistance R_L = 15Ω.
- Measure the RMS output current I_o.
- Measure the RMS input current I_i.
- Measure the RMS output voltage.
- Measure the RMS input voltage.
- Calculate the efficiency of the buck-boost converter for different frequencies (60 kHz and 100 kHz) using the above measurements.

5.4.4 Varying Load

- Set the duty ratio to 40%, R_L= 20 Ω and switching frequency to 40 kHz.
- Keep increasing the load resistance until the converter enters into the discontinuous conduction mode, and note the value of load resistance.

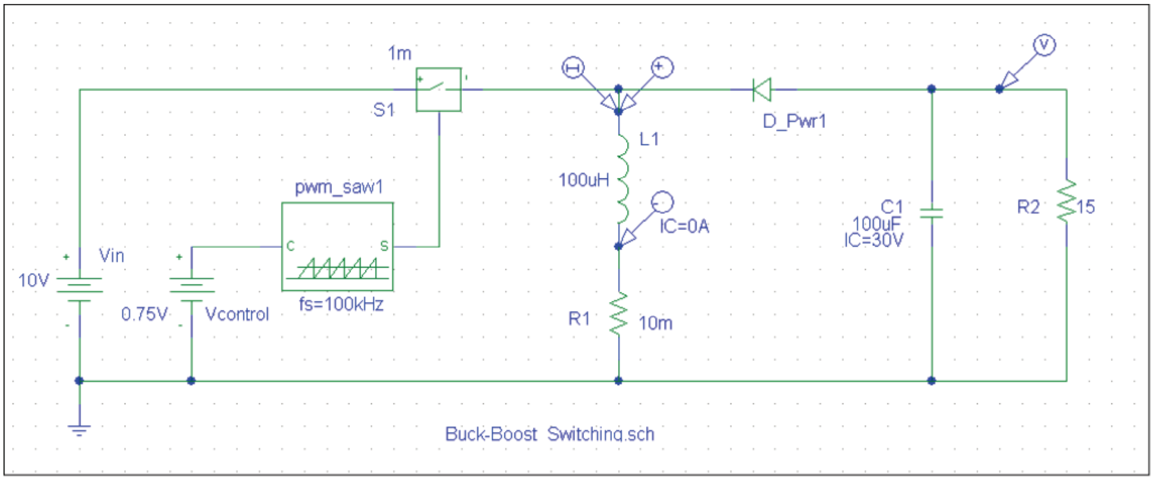
5.5 Lab report

The lab report should have a brief abstract detailing what has been done in this 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 5.4.1. Also plot the theoretically calculated results on the same graph and provide your comments.
2. Attach a copy of the inductor current (*CS5*) waveform obtained in section 5.4.2.
3. Plot the peak-peak ripple in the inductor current versus switching frequency using data obtained in section 5.4.2. Plot the theoretical results on the same graph. Compare these two plots.
4. Comment on the difference in efficiency figures obtained for two switching frequencies.
5. Attach a copy of the inductor current waveforms obtained in section 5.4.4. Compare the theoretically calculated R_{crit} (the load resistance at which the converter operates in critical conduction mode) with the observed value.

5.6 Spice simulation of Buck-Boost converter

We will use this simulation to observe switching waveforms in a near-ideal buck-boost converter operating at a fixed duty cycle. Open the file **Buck-Boost Switching.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 book.

4. Plot i_{diode} and i_C waveforms. What is the average of i_C. Compare the i_C waveform with the ripple in i_{diode}.

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

6. Calculate the inductance value of L, when Δi_L is 1/3rd of the input current. Verify these computed results with the results obtained from the simulation.

7. Change the output power in this circuit to one-half of 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 being operated at the boundary of CCM and DCM.