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Lab 2: DC/DC Converters

Pre Lab

Bring the curves you took in Lab 1 to lab. Soft (electronic) copies are fine.

Choppers: A maximum power point tracker (MPPT) for a solar array works by always ensuring the voltage across the array is such that it operates at its maximum power point. Since solar energy systems are DC, the array voltage can be controlled with a chopper (DC/DC converter).

There are three types of choppers commonly used in maximum power point trackers for solar energy systems: buck, boost, and buck-boost. These choppers are also used in many other DC power applications, such as dc motor drives and UPSs.

1. Draw (or make in PSPICE) a basic circuit diagram for each chopper type

2. State what each type of chopper is used for, i.e, stepping voltage up or down.

3. Write down the equation for output voltage in terms of input voltage and duty cycle for each type.

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Lab Exercises

Buck Chopper:

1. Power up the IGBT chopper/inverter & DAC modules.
2. Make sure the DAC module is USB connected to the PC.
3. Open LVDAC-EMS and ensure that the data acquisition and control the IGBT chopper/inverter modules are checked. Then hit "OK."
4. Select Tools >> Chopper/Inverter Control.
5. Set the function to Buck Chopper (high side switching).
6. Using Q1 (on the IGBT chopper/inverter module) as the electronic switch, connect the necessary components for a buck chopper with a 300 Ω resistive load.
7. Using the LVDAC-EMS scope and metering, set up to monitor the voltage difference between Q1's gate and emitter (V_{GE}) (from "switching control input 1" to the white ground terminal on the chopper), source voltage, and load voltage. Use the metering function to observe the average of each voltages and the oscilloscope function to observe each voltage instantaneously.
    a. Make sure you turn on "continuous refresh" in both the scope and metering windows.
    b. Make sure that the voltmeters you use are set to DC.
8. Using the DC power supply, apply 20V to the input of the chopper.
9. Pick your favorite switching frequency for the chopper and press start
10. Change the duty cycle and observe what happens. Using sketches or screenshots, show the relationship between the gating signal (V_{GE}) and the output voltage.

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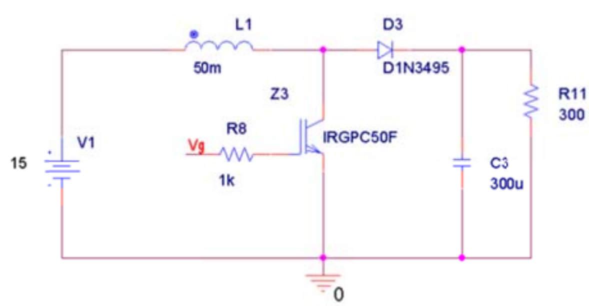
11. Record a few average output voltages for different duty cycles.

    a. Does the equation you had in the pre-lab match your results?

12. Keeping the duty cycle constant and vary the switching frequency. How does frequency affect the output voltage?

Boost Chopper

1. Change over to a boost chopper. Use the 50 mH filtering inductor. The cap will be the built-in C_{bus}. Use the same 300 Ω load and a **15 Vdc** source.



2. In addition to the voltages you monitored for the buck chopper, monitor the inductor current and voltage (average and scope) and the load current.
3. Start up the power supply and the chopper and play with the duty cycle. **Don't let the duty cycle exceed 75%**. See what happens to output voltage.
    a. Why don't we want to run the boost chopper at high duty cycles?

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4. The equation for the ripple current through the inductor when the IGBT is on (saturation mode) is $\Delta I_L = \frac{V_{in}*D}{f*L}$, where f is the switching frequency and. Use the scope to try and directly measure ΔI_L for different D values.

5. How well does the given relationship hold for your circuit? Why might the inductor ripple current be an important design parameter?

6. Using the LVDAC-EMS metering functions and Data Table function, make a table of V_{in}, V_{out}, I_{in}, I_{out}, P_{in}, P_{out}, efficiency, and duty cycle. You should be able to have the software automatically record all of those quantities except for duty cycle (Options >> Record Settings). Use a duty cycle range of 0 – 75%.

a. Use the graph function of the data table to make plots of V_{out} vs. D and Efficiency vs. D. Note: When using the graph function always plot “Points and Curves.”

b. Comment on your findings.

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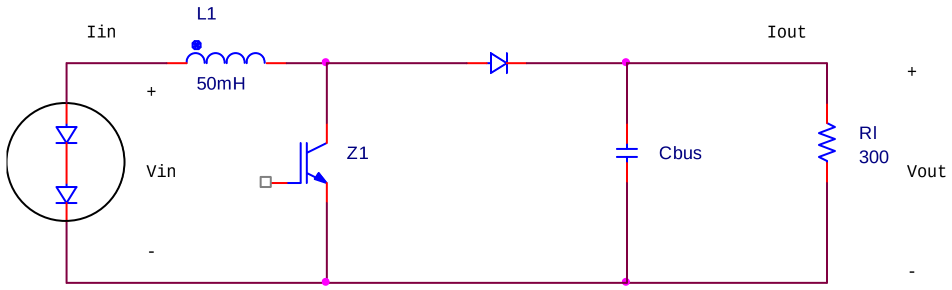
Boost Chopper w/ PV array

1. Leave the boost chopper connections in place, but this time instead of a 15 Vdc source, use a solar panel with a work light as the input.



2. Use the worklight distances you used last week when finding curves. Therefore one of your curves should be a good predictor for how this panel will behave. Use your curve to predict the maximum power point voltage.

3. Make the same measurements as in the last part (V_{in}, V_{out}, I_{in}, I_{out}, P_{in}, P_{out}, efficiency, and duty cycle). Present them as a table.
    a. How good was your estimate of maximum power point voltage?

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4. Plot load voltage vs. duty cycle and array voltage vs. duty cycle on the same plot. Also plot P_{in} vs. duty cycle.

5. Change the irradiation on the PV panel and repeat step 3. Use an irradiation level for which you have a curve. From your work from Lab 1, what's V_{OC} for this irradiation level?

6. Is the duty cycle needed for maximum power out of the PV panel the same is before?

7. Taking both of your trials into account, what do you notice about the relationship between V_{MPP} and V_{OC} for the solar panel?