MAS.S62
Problem Set - switching power supplies

Background:

This problem set is intended to give a basic understanding of how switching power supplies work, and the effect that the relative L and C values have on their behaviour. Switching power supplies are named as such, because they have have switches which control the flow of current in the circuit. This current can be directed to either a lower or higher voltage to create boost or buck converters. These topologies are shown in Figures 1 and 2. It should be noted that Figures 1 and 2 are identical, and just reversed in terms of inputs and outputs. For the boost converter, V1 is in the input, and V2 is the output, and for the buck converter V2 is the input and V1 the output. This makes sense, as the role of a boost converter is the reverse of a buck converter.

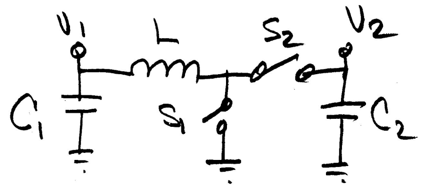

Figure 1: Boost converter topology.

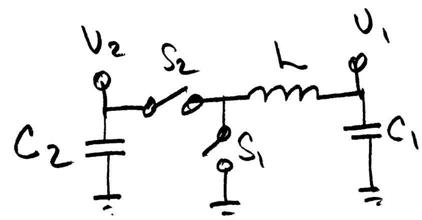

Figure 2: Buck converter topology.

For each of these topologies, S1 and S2 are switches that are opened and closed at a fast rate to control the current flow through the inductor (L). These switches are in opposite polarity to each other, so whenever S1 is open, S2 is closed, and vise versa. If both were to be closed at the same time, C2 would just be shorted to ground.

A feedback loop which monitors the output voltage is typically employed to set the switching rate, to fix the output voltage at a desired level. The switches are then implemented with transistors, to allow for fast switching under external control. Diodes can replace one of the switches in each topology, as a diode automatically stops current flow in the reverse direction. Since we always want current to flow into the output capacitor, this means we can replace S2 in the boost converter, and S1 in the Buck converter.

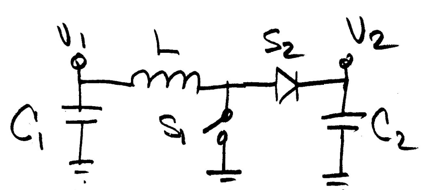

Figure 3: Boost with diode switch.

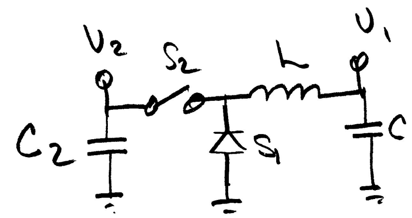

Figure 4: Buck with diode switch.

For most switching applications, the input voltage is relatively fixed, although it might have a bit of resistance associate with it, so the input capacitor (C1:boost, C2:buck) helps hold this voltage constant under the high current pulses that the switches create. The output capacitor is used to absorb these current pulses, so the larger the value, the less voltage change you will have at the output. To limit the value of these current pulses, most switching power supplies incorporate a current measurement circuit that opens the switch once current has reached a threshold. This is useful for a number of reasons.

first, the switch itself can only handle so much current, so it keeps it from getting damaged. Secondly, the inductor has a limit to how much current it can pass before the ferrite core saturates, and you are no longer storing any energy in the magnetic field. All current past this point will be dissipated in the resistance of the inductor, and be wasted energy. For the experiments done here, we will use a current limiting resistor to ensure that the current does not exceed a certain value. This resistor will be placed in series with the switch, so that it is not in the circuit when the switch is opened, allowing the inductor to operate at full efficiency when current is transferring to the output capacitor.

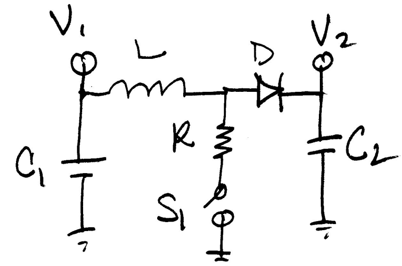

Figure 5: Boost converter circuit for lab test.

Please build the circuit shown in figure 5. The diode should be a power diode. The switch is a simple push button rated for 100mA, the inductor is an180uH power inductor, and the capacitors are both 10uF/25V electrolytic capacitors.

Questions:

1. The inductor is part # A814AY-181k by Toko. What is the max current it can handle?
2. The diode is an SB130 by Vishay. What is the max current it can handle? What is the maximum reverse voltage it can handle?
3. If the input voltage (V1) is 5V, what value should R be to protect the components?
4. Given your value of R, when you press and hold the switch, what is the max current in the inductor? When you release the switch, all of this current flows through D to C2, so this is also the max current the diode will see.
5. Theoretically, how long does it take for the inductor to reach this max current?
6. When the circuit is first powered up, how much charge (coloumbs) is on C2?
7. What is the voltage drop across the diode when the diode is on? Build the circuit and measure this voltage. Note: you will have to use an oscilloscope to measure this voltage as it happens very quickly.
8. What is the voltage across the inductor for this period? Again, measure this on your circuit.
9. Assuming the voltage across the inductor is constant for this period, how long should this period theoretically last, given your starting current? Does this match your measurements?
10. How much charge (coulombs) is theoretically transferred to the capacitor during this period?
11. Theoretically, what should be the new voltage on C2 given its initial charge, and the charge that was added? Does this match what you measured?
12. The input of an oscilloscope is typically 10M. How long will it take for the extra charge you placed onto the capacitor to drain off through the scope probe? Does this match with what you've measured?
13. When the diode switches off, there is some ringing at its input. What frequency is this at? What capacitance, paired with the inductor, would ring at this frequency? What component(s) create this capacitance?
14. Given the calculated charge and discharge times of the inductor, whats the fastest frequency you could switch this circuit at? How much current would it supply at this frequency?
15. Assuming a 10M load, what is the maximum output voltage this circuit could produce?