Lab 1: Power Management

ESE350: Embedded Systems & Microcontroller Laboratory
University of Pennsylvania

In this document, you'll fill out your responses to the questions listed in the Lab 1 Manual. Please fill out your name and link your Github repository below to begin. Be sure that your code on the repo is up-to-date before submission!

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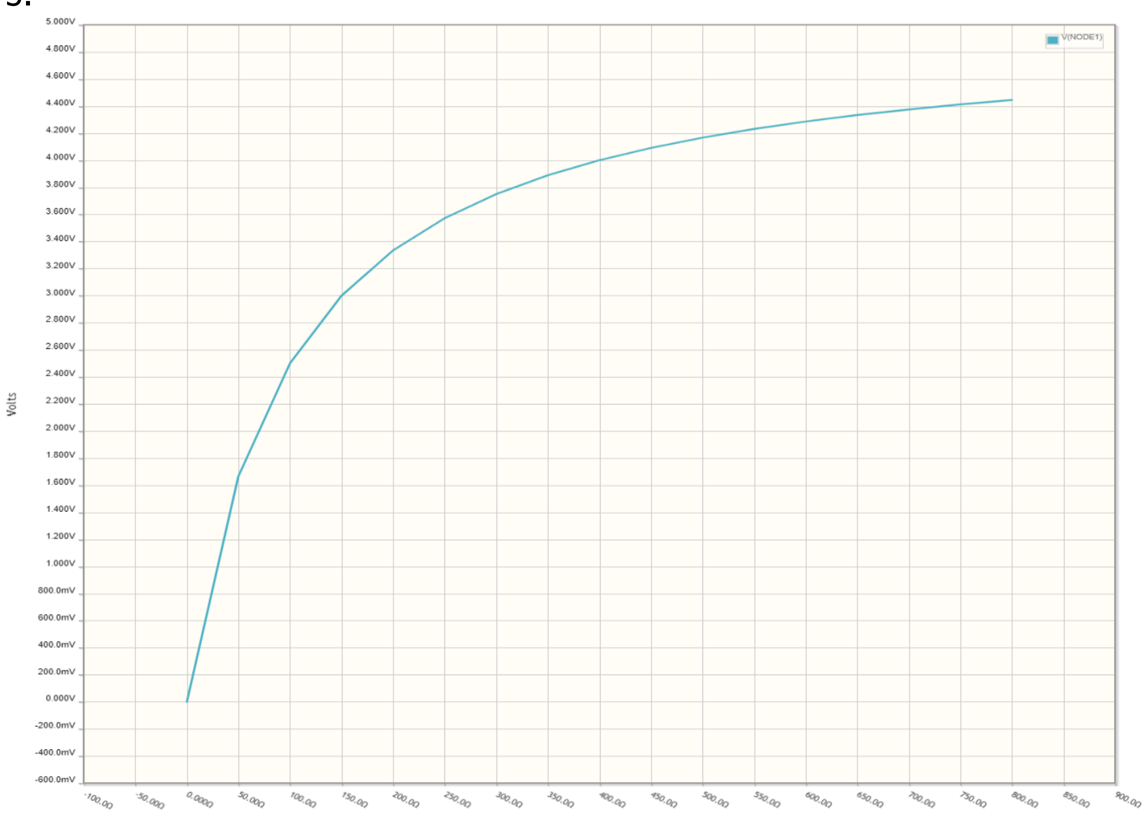
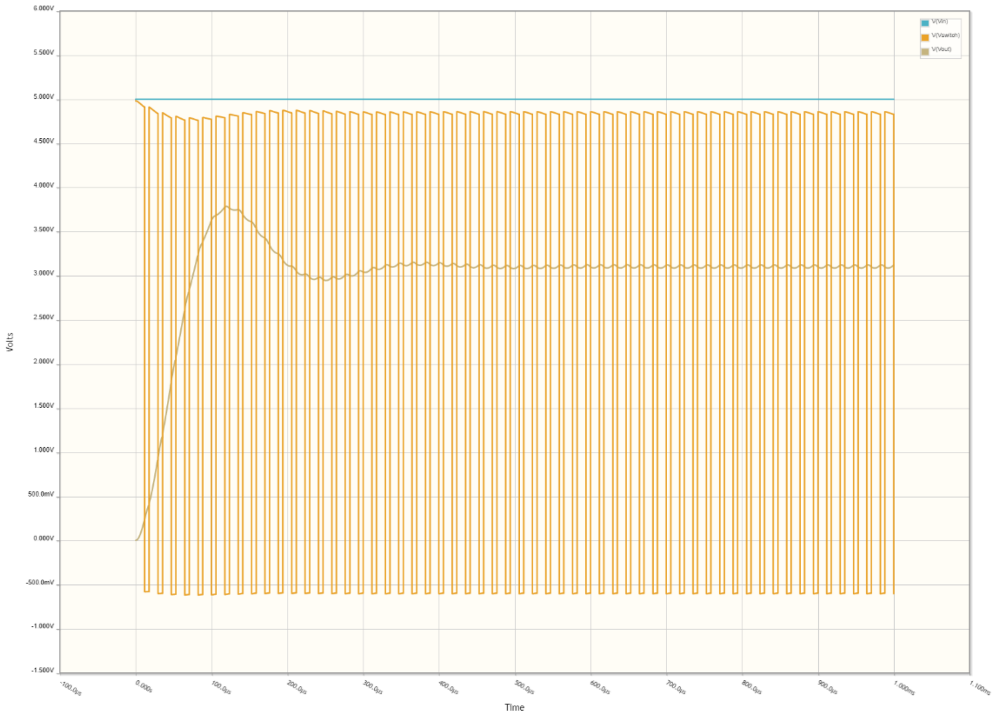
GitHub Repository: https://github.com/Lawrencez99/lab1_zrz.git

1. According to the Kirchhoff's current law, $I = I_{R1} = I_{R2}$.
   By Kirchhoff's second law (KVL),
   $V_1 = V_{R1} + V_{R2} = R1 * I_{R1} + R2 * I_{R2} = R_1 * I + R_2 * I = (R_1 + R_2) * I$
   $\Rightarrow I = V_1 / (R_1 + R_2)$
   $\Rightarrow V_{NODE1} = V_2 = R_2 * I = V_1 * R_2 / (R_1 + R_2) = 5 * 100 / (100+100) = 2.5V$
2. If R_2 was 850 ohm, $V_{NODE1} = V_1 * R_2 / (R_1 + R_2) = 5 * 850 / (100+850) = 4.47V$
3.

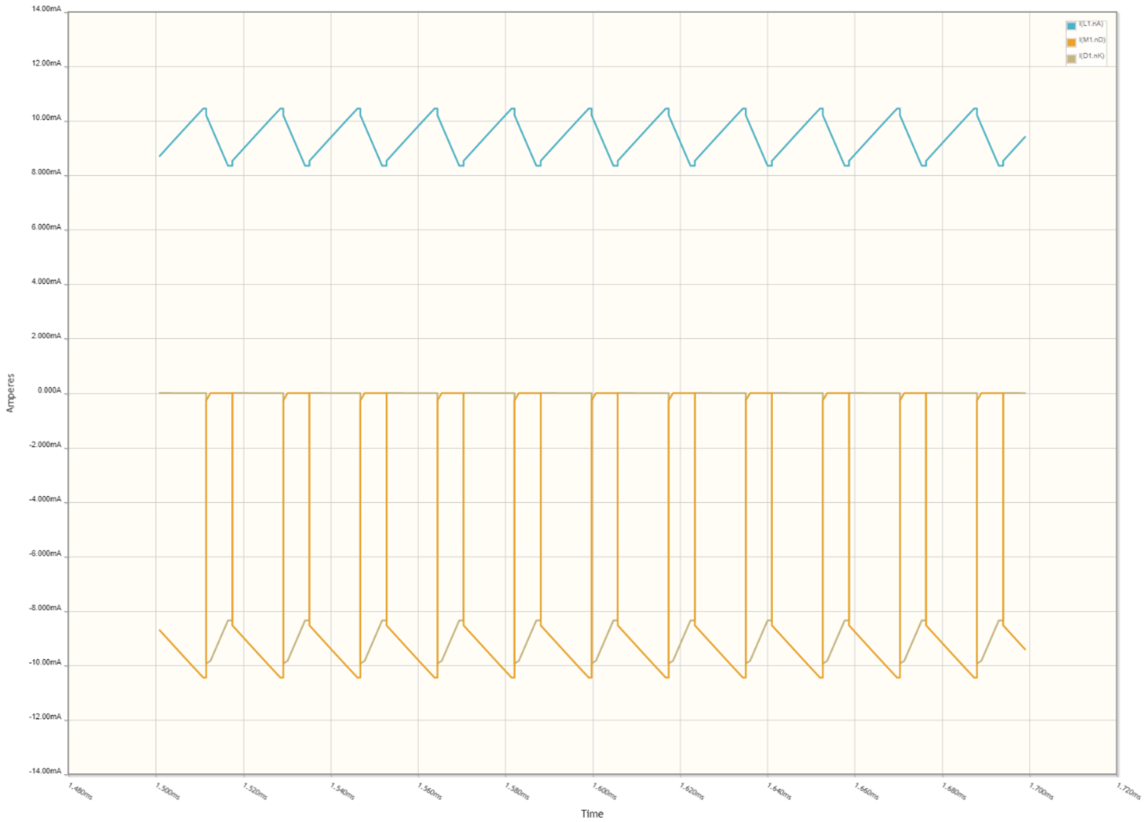


The image is as expected according to the equation we derived from question 1. As R_2 getting larger, more voltage will be occupied by R_2 as the currents through the circuit are the same.

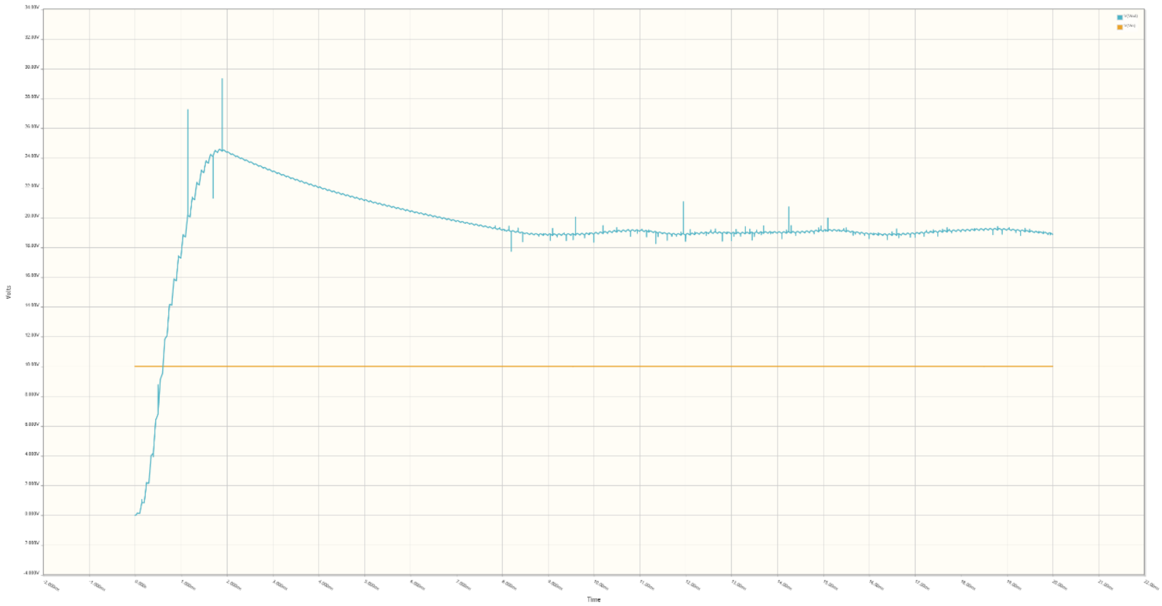
4. Scenario1: a voltage divider can be used to measure the resistance of a sensor. A voltage divider is created by adding a resistor in series with the sensor, then we can calculate the resistance of the sensor.
   Scenario2: a voltage divider can be used as a level shifter, especially when the load is small. A Voltage divider for example can level the voltage down from a microcontroller with 5 v output to prevent damage to a 3v sensor connected to it.
   Scenario3: A voltage divider can be used as a potentiometer, so that we can have a variable voltage from a fixed voltage source.
5. The duty cycle setting for the CLK1 part represent the high time of the pulse. The MOSFET become active when the pulse is low, as it is a p channel MOSFET.
6. Assume Vout is 3.3V, Vout = Vin/(1-D) => 5 = 3.3/(1-D) => D = 0.34
   Assume Vout is 2V, D = 0.6
   So in order for Vout to be 3.3V, duty cycle of 0.34 should be selected and for Vout to be 2V, duty cycle of 0.6 should be selected. It makes sense, because the duty cycle decided the percentage of time per period the inductor will store energy from the source voltage, and thus decide the output voltage. But since the efficiency is not 100%, the duty cycle should be a little bit smaller than the value listed above.
7.



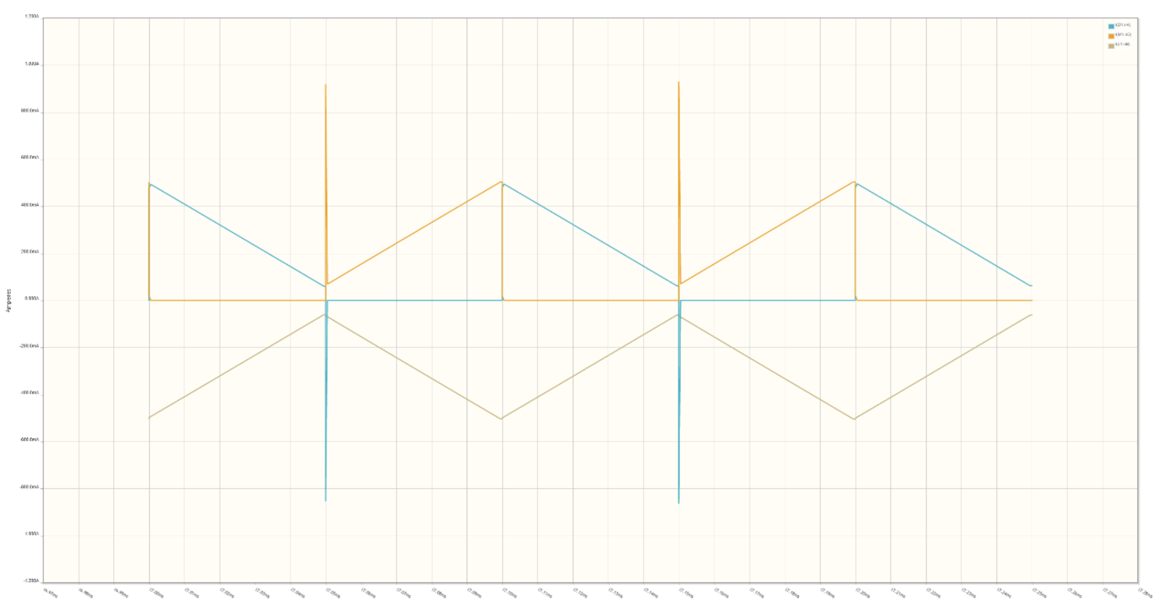
8. The dip at around 100us is because of the volt-second balance rule, that the average voltage across the inductor must be zero. The output voltage is steady state output instead of a straight horizontal line is because the inductor keeps charging and discharging as MOSFET goes on and off and the capacitor helps stabilize the voltage.
9.



10. According to KCL, the sum of the three currents is zero. This is as expected. As the MOSFET is ON, the inductor will charge up and current will increase. The diode will prevent the current flow from cathode to anode, so there will be zero current. the current flow out of the drain will equals to the current flow into the inductor. When the MOSFET is OFF, there will be no current at the drain. The inductor will discharge, and current will drop. The current flow out of cathode of diode will equal to the current flow into the inductor.
11.



12. The output voltage is about 20V, which is as expected. Vout = Vin/(1-D) = 10/0.5 = 20V.
13. The plot of this boost converter take much longer than the plot of the previous buck regulator is because the capacitor used in boost converter is much larger than the one used in the buck section.
14.



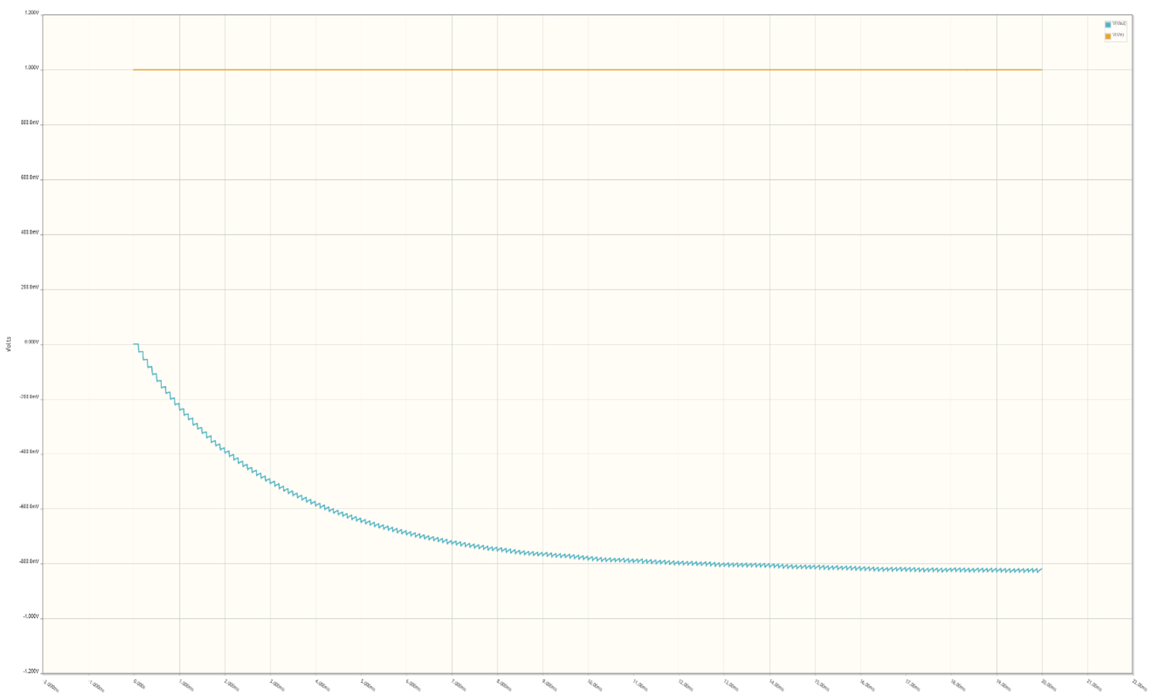
15. According to KCL, the sum of three currents is zero. The plot and relationship are as expected. When the MOSFET is OFF, the current through the drain is zero. The inductor will discharge and current will decrease. The current flow out of inductor will be the same as the current flow into the diode. When the MOSFET is ON, there will be no current flow through the diode. The inductor will charge

and the current through it will increase. The current flow out of the inductor will be the same as the current flow into the drain of the MOSFET.

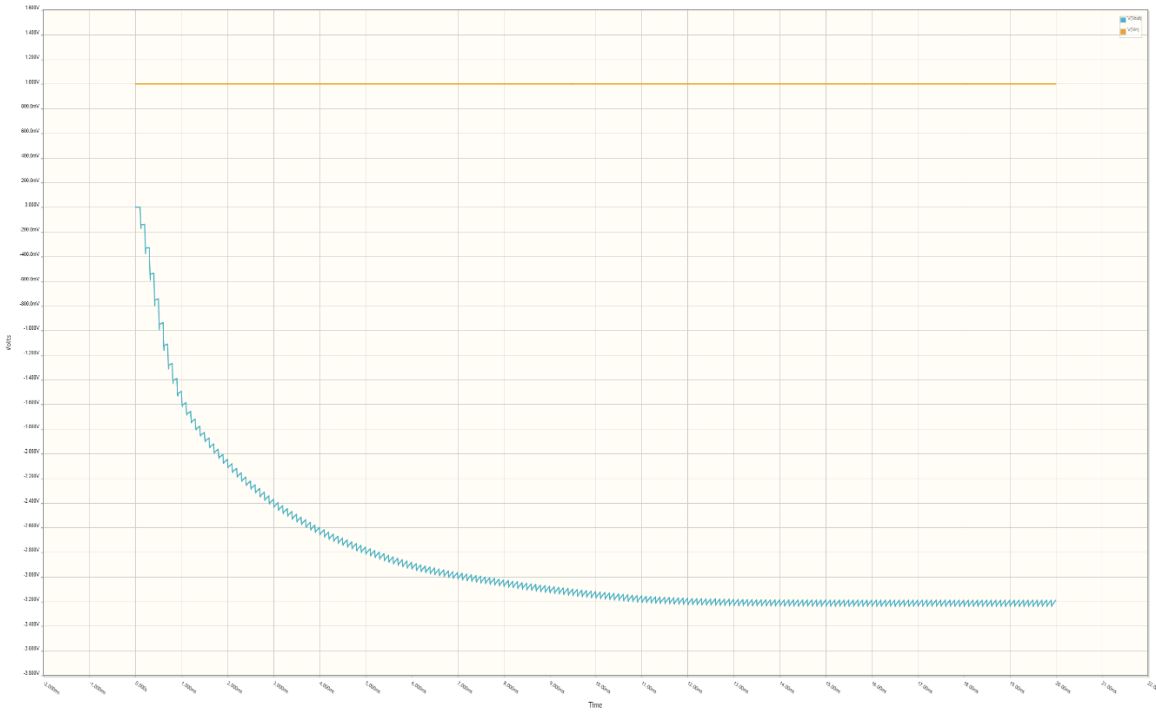
16.

Jack	USB	Power Source?	NODE1(V)	NODE2(V)	NODE3(V)
0V	5V	USB	-928.8u	4.999	3.3
10V	0V	Jack	5	5	3.3
10V	5V	Jack	5	5	3.3
3V	5V	USB	-928.8u	4.999	3.3

17. The voltage divider enables higher voltage difference between Vin and Vout without dissipate a lot more heat. Assume we connect Vin of 15V directly to the non-inverting input of op amp, in order to drop 15V to 5V as output, a lot of heat will be created in op amp. On the other hand, if we have the voltage divider in the circuit above, the op amp will only need to drop the voltage from 7.5 V to 5 V, which will result in less heat dissipated by op amp.
18. https://www.circuitlab.com/circuit/f3ktpax369y2/buck-boost-converter/
19. Settled around -800mV



20. Settled around -3.2V



21. Similarities:
    - Both BJT and MOSFET can be used as amplifier and switch.
    - Both BJT and MOSFET have three pins.

    Difference:
    - MOSFET is a metal oxide semiconductor while BJT is a bipolar junction transistor.
    - The three pins of MOSFET and BJT are different
    - The BJT depends on the current at its base terminal, while the MOSFET depends on the voltage at the oxide-insulated gate electrode.

    For high-power applications, it is better to use MOSFET. BJTs are good to use in low current applications. The choice between MOSFET and BJT need to consider factors such as cost, power level, efficiency, etc.