Lab 1: Power Management & Bootloading

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/hsanthanam/hsanth01-ese350

1.

$$R_1 I_1 + R_2 I_1 = V_1$$

$$I_1 = \frac{V_1}{R_1 + R_2}$$

We know that $V_1 = R_2 I_1$

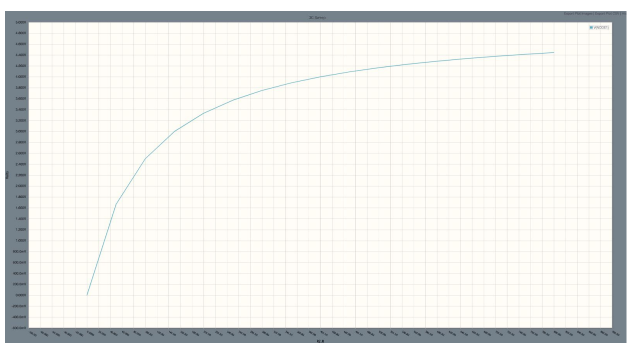
$$R_2 I_1 = \frac{R_2 V_1}{R_1 + R_2}$$

$$V_{node1} = \frac{R_2 V_1}{R_1 + R_2} = \frac{100*5}{200} = 2.5V$$

2.

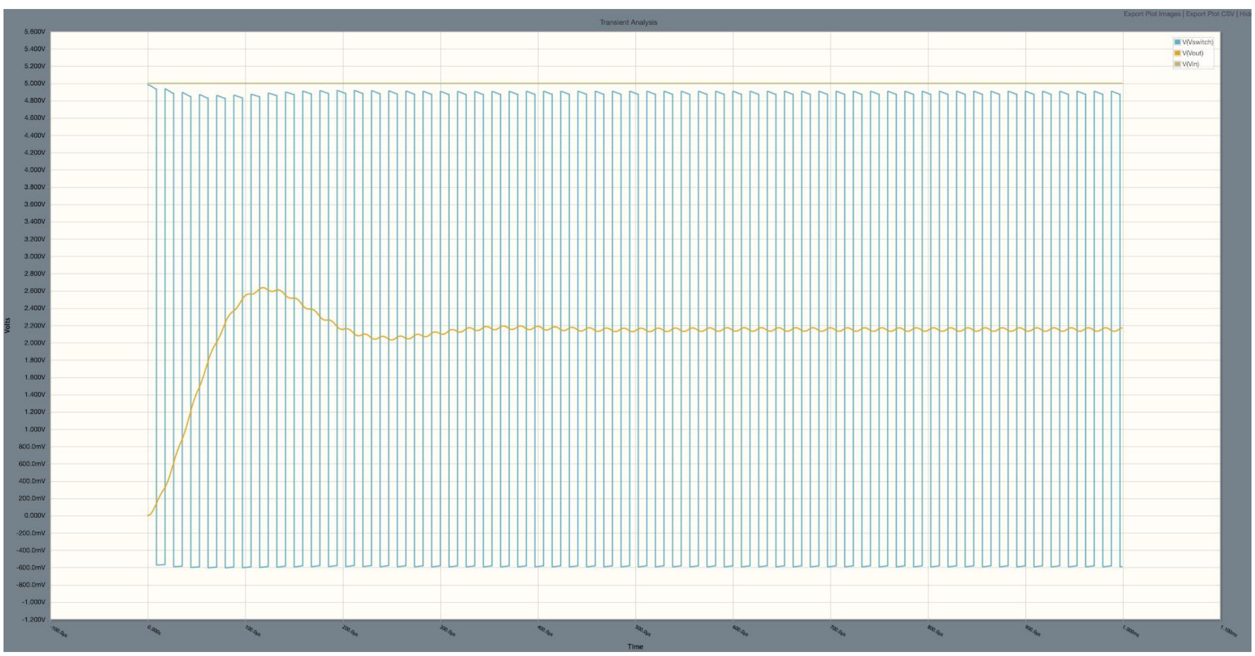
$$V_{node1} = \frac{R_2 V_1}{R_1 + R_2} = \frac{850*5}{950} = 4.47V$$

3.



Yes this is the expected behavior; as we saw when we increased R2 from 100ohms to 850ohms the voltage at Node1 increased from 2.5 to 4.47 volts. Node1 has an asymptote at 5V since the input voltage in the circuit is 5V. In addition, since R2 is in both the numerator and denominator it exhibits exponential-like behavior (with the tangent line at 5V).

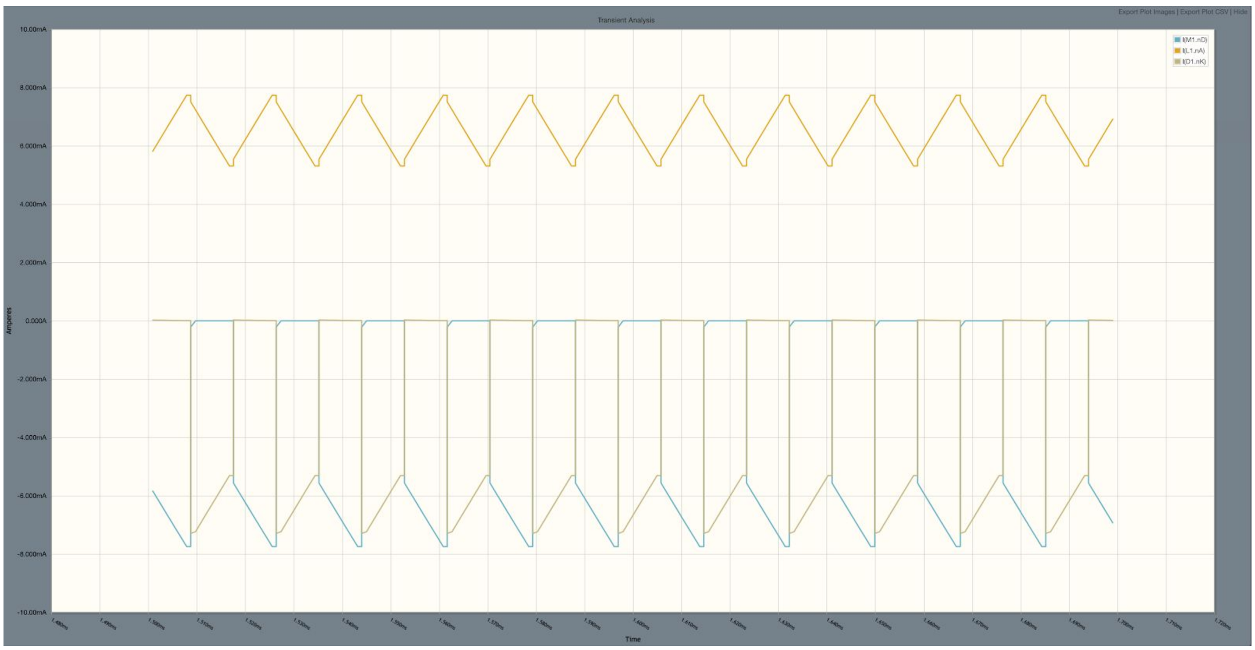
4. Voltage dividers are useful in wheatstone bridges (identifying an unknown voltage), potentiometers (adjustable resistor), and multimeters (measures voltage, current, or resistance).
5. It represents the OFF times of the MOSFET. This is p-type MOSFET; therefore, when no voltage is applied (when the CLK is LOW) it allows current to flow. When the CLK is high, the MOSFET does not allow current to flow.
6. For Vout to equal 3.3V the duty cycle should be 0.34 or 34%. For Vout to equal 2V the duty cycle should be 0.6 or 60%. Since these are p-type mosfets, the duty cycles represent the time that the mosfet is not active. Therefore, these values do make sense. Taking the complement of the duty cycles we can see that the mosfet is active for a longer period of time when Vout equals 3.3V.
    a. To do these calculations we use the expression Vout = Don * Vin
7.



8.
    a. Initially, there is a strong BEMF created when current goes from 0 to a larger value through the inductor. This backwards force causes a dip in the voltage at Vswitch, and that's what we observe in the graph above.
    b. When Vin is connected, current flows through the inductor creating a voltage drop across the inductor, which leads to the inductor storing energy. The voltage drop across the inductor begins to decrease and charge the capacitor. Once the inductor no longer is connected to the input

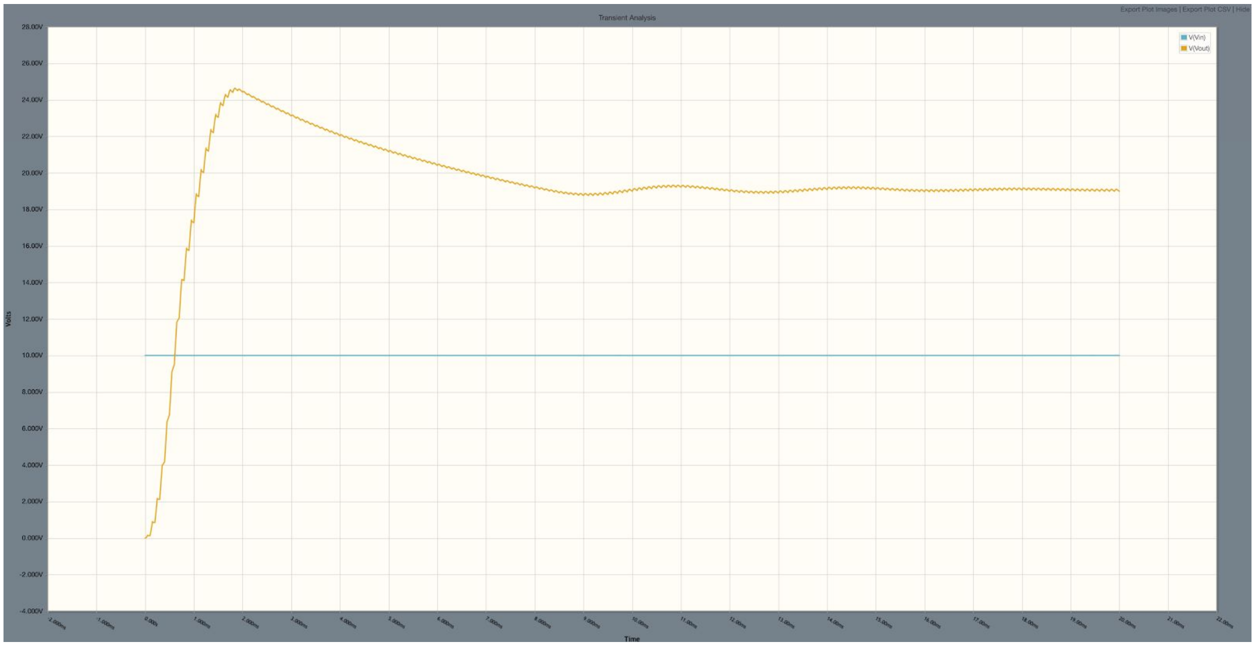
voltage, the capacitor discharges as needed. This process continues to repeat as the output voltage increases and decreases. That is why we see an increase in Vout followed by a decrease (this cycle keeps repeating). When the clock is firing an output of high the input voltage is not connected which causes voltage to discharge from the capacitor. When the clock is on low the capacitor is being charged. This fits into why we see the oscillatory behavior (when the capacitor is discharging we see an increase which is dictated by the clock going to high, the opposite is also true).

9.



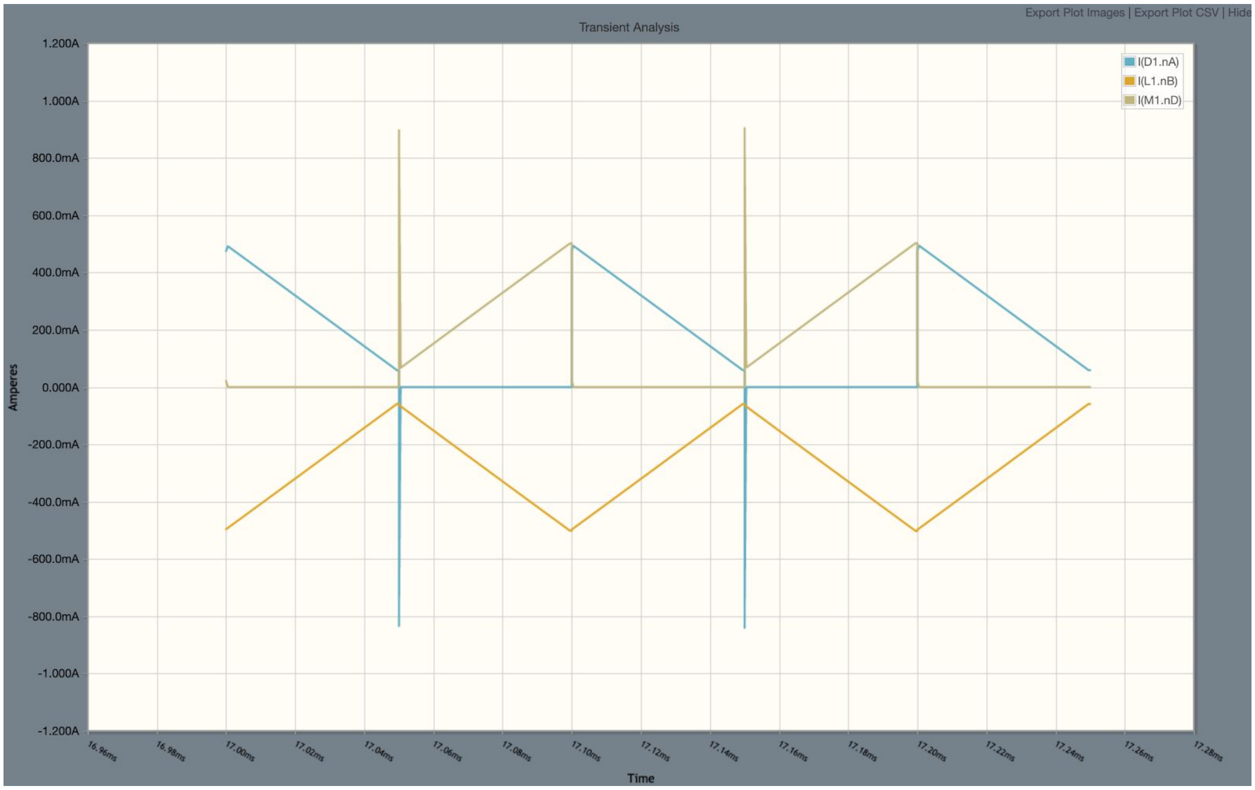
10. According to KCL, the sum of all currents entering or exiting a node must sum to zero. In this case, the three currents in the graph above enter/exit node next to Vswitch (same voltage as Vswitch). Therefore the three currents must sum to zero. This is what we see in the above graph. When all three currents are added together the sum will clearly be equal to zero.

11.



12. The expression for Vout is Vout = Vin/(1 - D). Since we are using an N-channel MOSFET in our boost converter, the duty cycle is 0.5. Plugging this into the equation we get 20 Volts. In the graph we can clearly see that Vout settles to a voltage slightly under 20V. This makes sense as energy can be lost to a number of factors such as heat (from current flowing through the MOSFET or even through the wires). Overall this is very close to the voltage we expect to see at Vout.
13. The capacitor used for the Boost Converter has a capacitance which is much larger than the capacitor used for the Buck converter (133 nF). In addition, the inductor used in the buck converter has a larger inductance value compared to the inductor in the boost converter. When analyzing the capacitance and inductance values of the buck and boost converter, we will notice that for the buck converter the RLC portion is an underdamped circuit. On the other hand, the RLC portion of the boost converter is overdamped. Overdamped circuits are known to take longer to reach equilibrium, and that is why the boost converter takes longer to reach its equilibrium value.

14.



15. KCL dictates that the current entering and exiting any node should equal zero. This is what we observe in the graph above. At any point along the x-axis, if we summed all the currents we would get a value equivalent to zero.

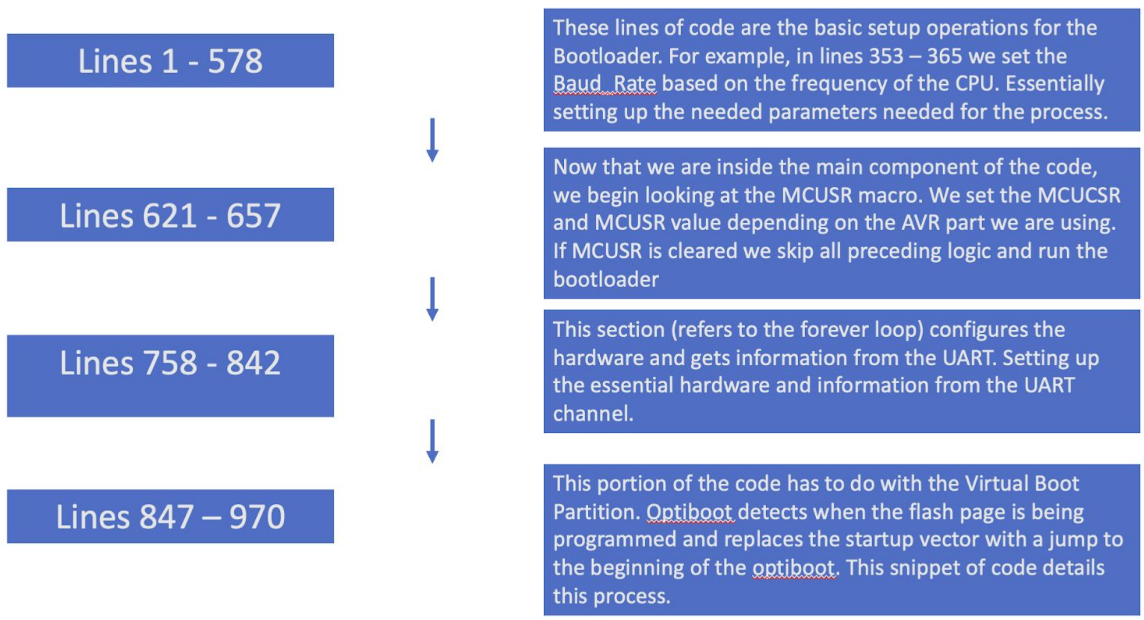
16.

Jack	USB	Power Source?	NODE1	NODE2	NODE3
0V	5V	USB	0V	5V	3.3V
10V	0V	Jack	5V	5V	3.3V
10V	5V	Jack	5V	5V	3.3V
5V	5V	USB	4.315V	4.315V	3.3V

17. Using a voltage divider is critical to maintaining the functions of the op-amp. If the supplied voltage at Vin is greater than the voltage supplied at the rails, we risk permanently damaging the op-amp. Therefore, by using a voltage divider, we can

decrease the voltage at the positive terminal of the op-amp and keep the voltage within the voltage supplied by the rails.

18. Optiboot is a bootloader for the Arduino Board we will be using. A bootloader is a piece of software that boots operating systems. Moreover, optiboot runs on device startup and configures the device before the main program begins. The 328P on the Arduino already has optiboot on it, which allows us to communicate with the arduino directly via a USB cable (without using a programmer).
19. Optiboot Profile: (divided into three sections: broad overview flow chart, followed by additional important lines of code, and other miscellaneous information)



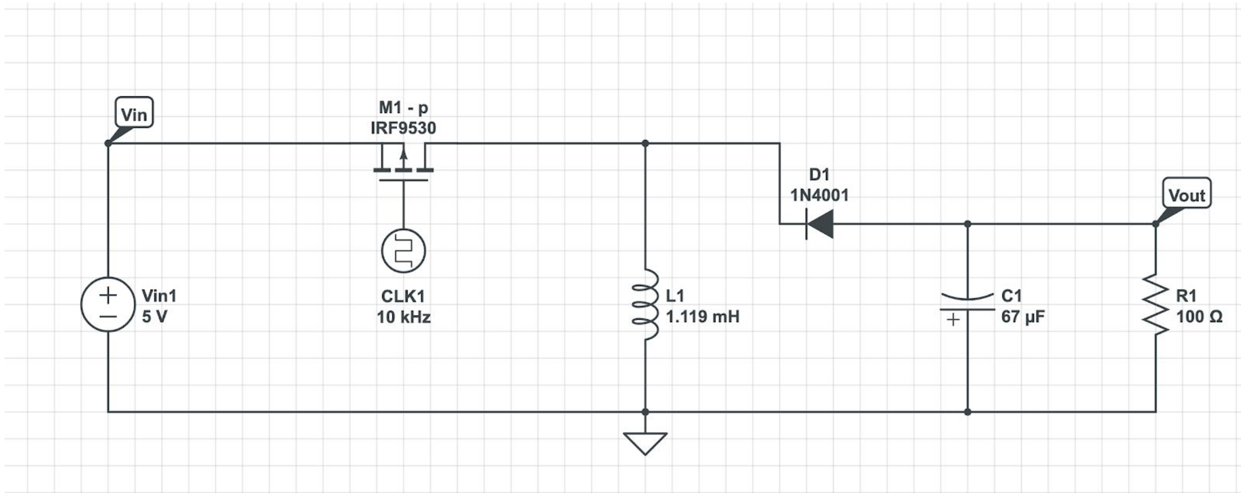
Other important lines of code in optiboot.c

- Line 580 marks the begin of the most important section of code
  - Preceding lines mainly detail the setup
    - i.e. Baud Rate and other needed values
- Example of If statements – lines 738-746 define outputs such as the LED pin or TX pin
- Line 748 states that if the LED flashes then it signals the start of the bootloader
  - Line 753 also indicates that the bootloader is starting by turning on the LED
- After Line 748-756 we enter the main forever loop which is described in the main flowchart
- As specified on line 758, if WDT is reset we exit the forever loop which begins on line 759
- In addition once we enter the main forever loop, we stay inside of it until we receive a reset command or are ready to move into the application code
  - The If/Else statements inside of the forever loop check what character is received I will either jump into the application or I will reset the timer and attempt to read the next character from the UART
    - These If/Def statements can be found in lines

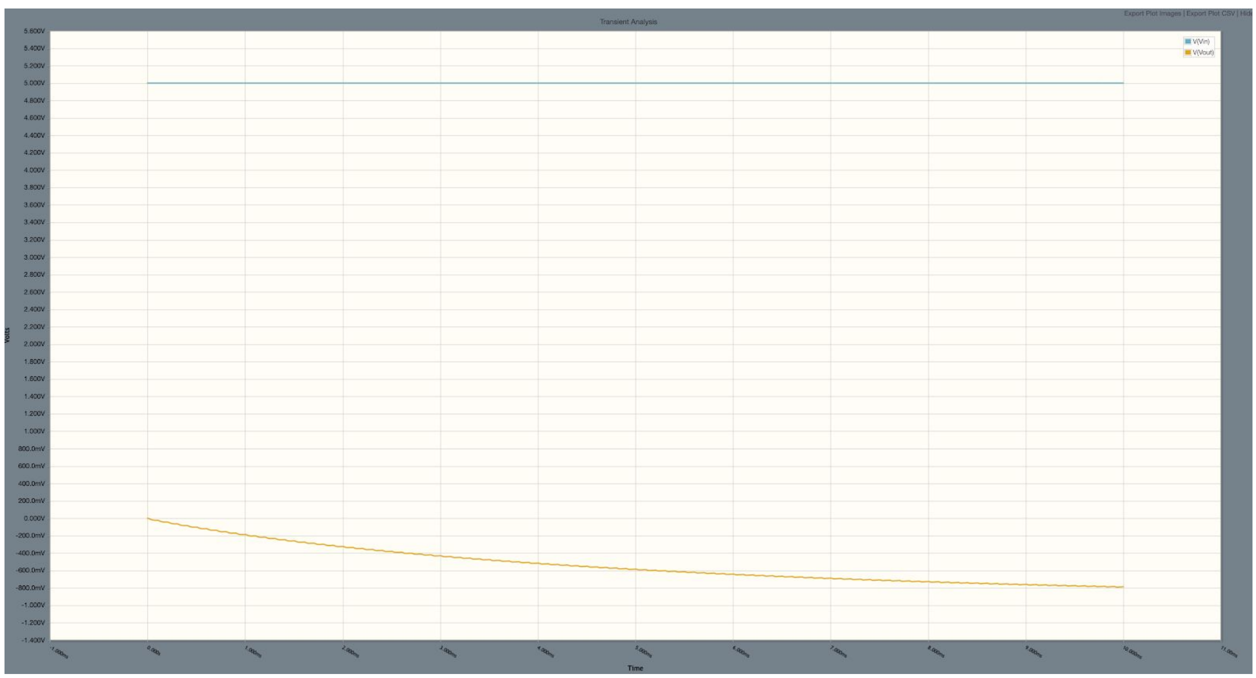
Other Important Details

- We have a makefile that defines what we want to do and what needs to be executed
- Much of the optiboot.c file is in sections defined by if/else statements. This means that a lot of the code that is run depends on the desired output (for example if we are doing a virtual boot or not).

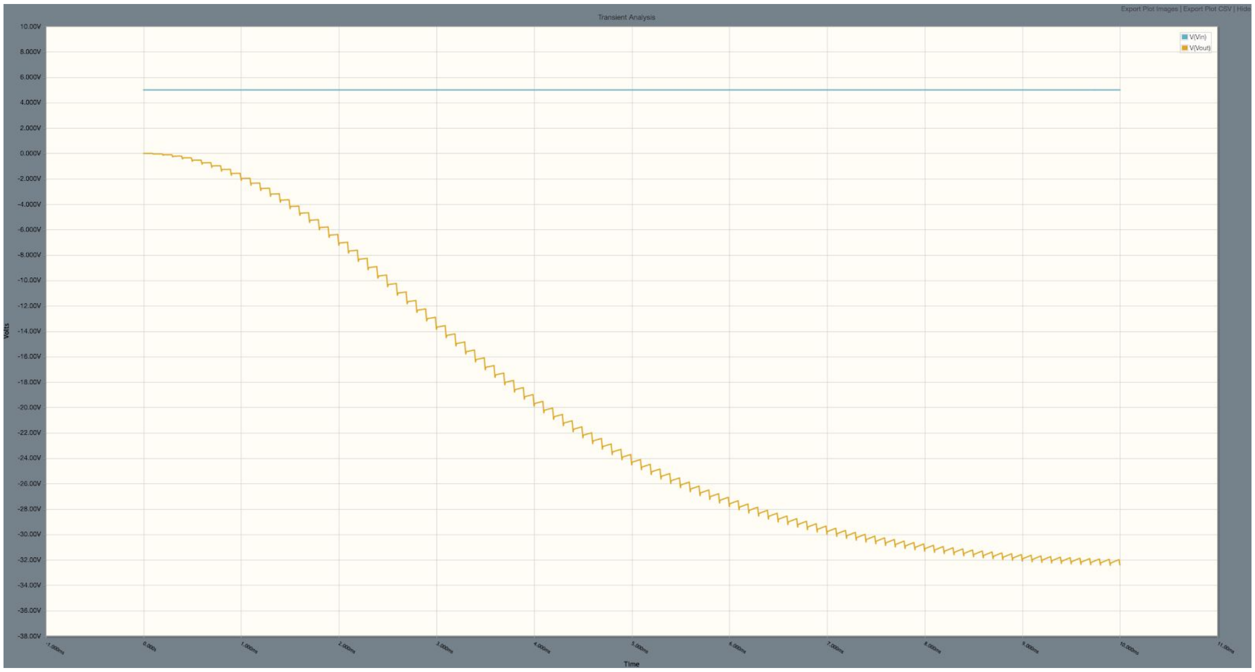
20. https://www.circuitlab.com/circuit/htaj46w85jc5/buck-boost-converter/



21.



22.


Export Plot Images | Export Plot CSV | Hide
Transient Analysis
V(Vin)
V(Vout)
Volts
Time
10.00V
8.000V
6.000V
4.000V
2.000V
0.000V
-2.000V
-4.000V
-6.000V
-8.000V
-10.00V
-12.00V
-14.00V
-16.00V
-18.00V
-20.00V
-22.00V
-24.00V
-26.00V
-28.00V
-30.00V
-32.00V
-34.00V
-36.00V
-38.00V