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Lab 6

Electric VLSI DC-to-DC Charge Pump Regulator

Introduction:

In this lab, students created a DC-to-DC Charge Pump Regulator. The DC-to-DC Charge Pump regulator should receive an input voltage of 1V and output a voltage of 2V, while driving a 2M resistor.

Methods and Materials:

The lab was completed by following the steps outlined by the "ENCE_3501_Lab_6.pdf" and "Lab_6_Charge_Pump.pdf" handouts on the course Canvas page. The software used for this lab was Electric VLSI and LTSpice.

Schematics:

The first subsystem of a DC-to-DC Charge Pump regulator is creating a 3 Stage Charge Pump schematic as seen in Figure 1. Here, the voltage steps up three times through the cascading capacitor and resistor connections. The capacitors oscillates between charging and discharging.

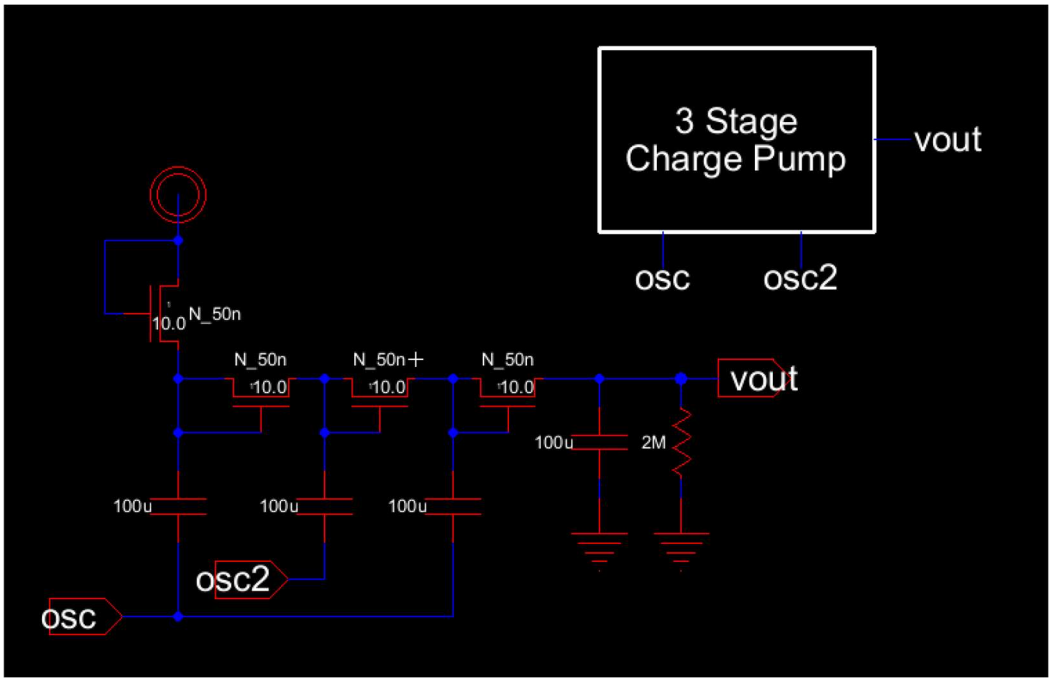

Figure 1: 3 Stage Charge Pump Schematic

Next, the behavior of the 3 stage charge pump is simulated using the schematic in Figure 2.

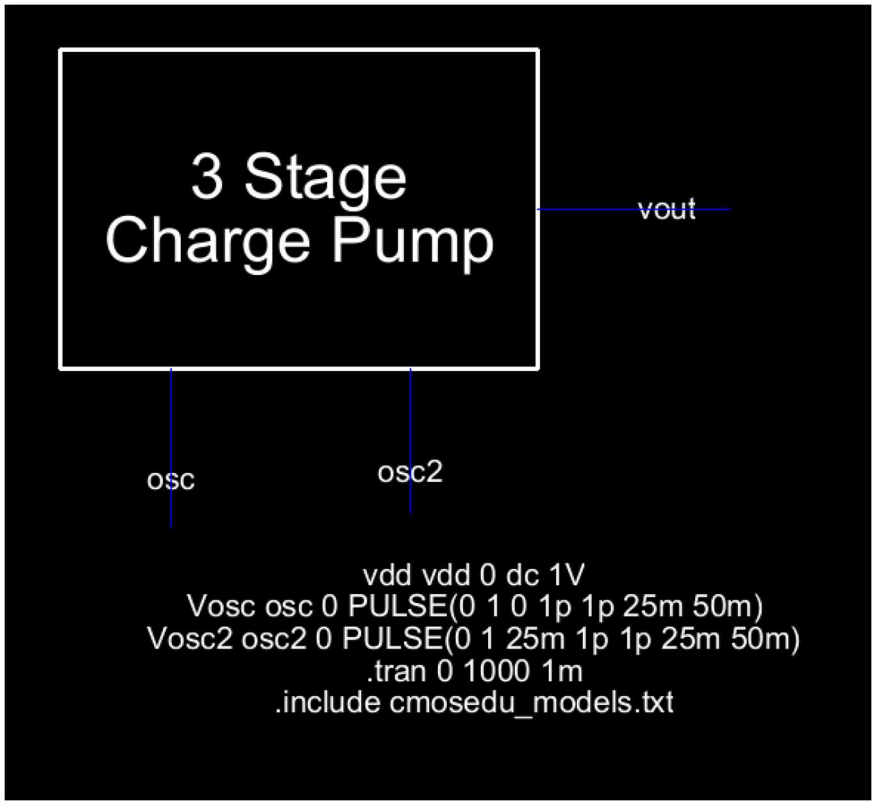

Figure 2: 3 Stage Charge Pump Simulation Schematic

The output voltage of the charge pump is seen in Figure 3. It can be observed that as the capacitors oscillate between charging and discharging, the output voltages rises until it peaks around ~2V after two minutes. The charge pump takes an input voltage of 1V and doubles it.

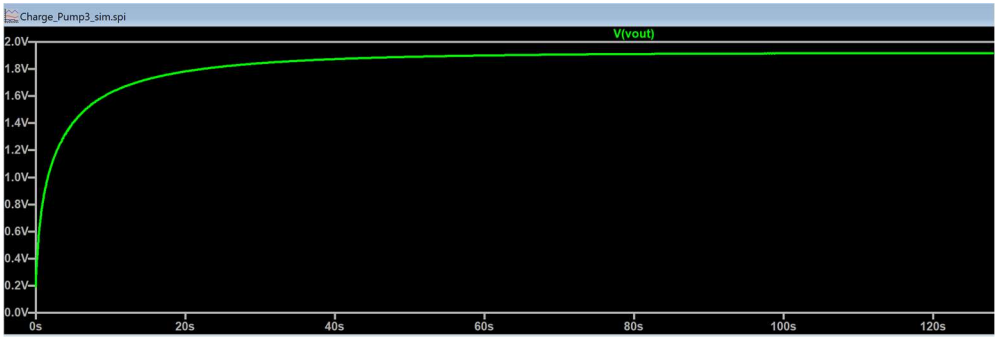

Figure 3: 3 Stage Charge Pump Simulation Result

The next subsystem of the DC-to-DC charge pump regulator is the ring oscillator which controls the charge pump subsystem. The schematic for the ring oscillator is seen in Figure 4. There is an even amount of inverters since there is an inverter inside of the NAND, making the total an odd amount.

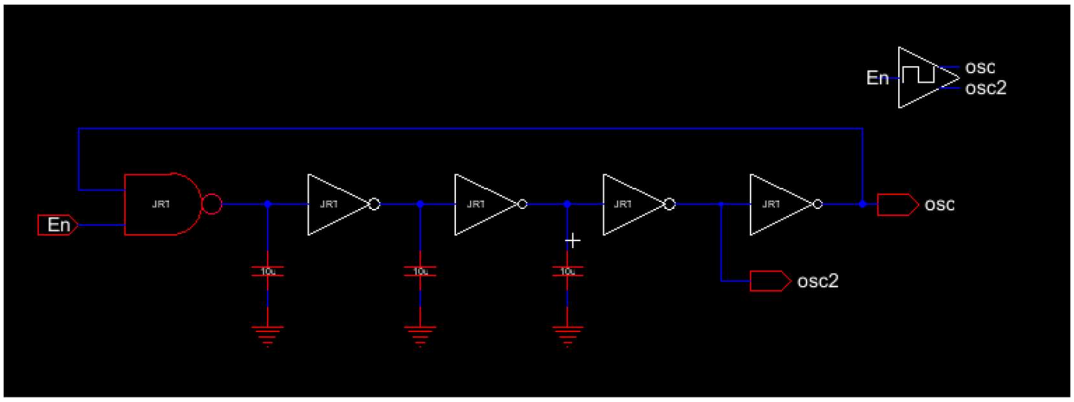

Figure 4: Ring Oscillator Schematic

Next, the behavior of the ring oscillator is simulated using the schematic seen in Figure 5.

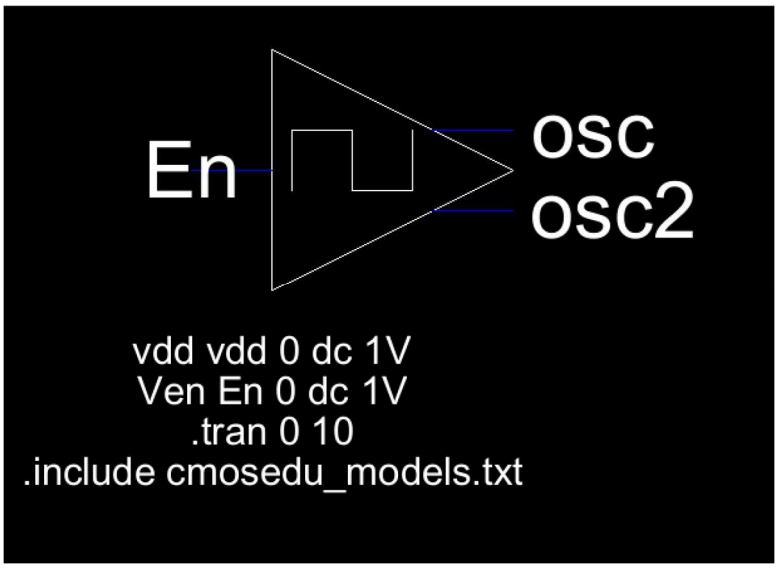

Figure 5: Ring Oscillator Simulation Schematic

The results of the ring oscillator are seen in Figure 6. It can be observed that two oscillating signals are outputted from the ring oscillator, with one signal being the opposite of the other.

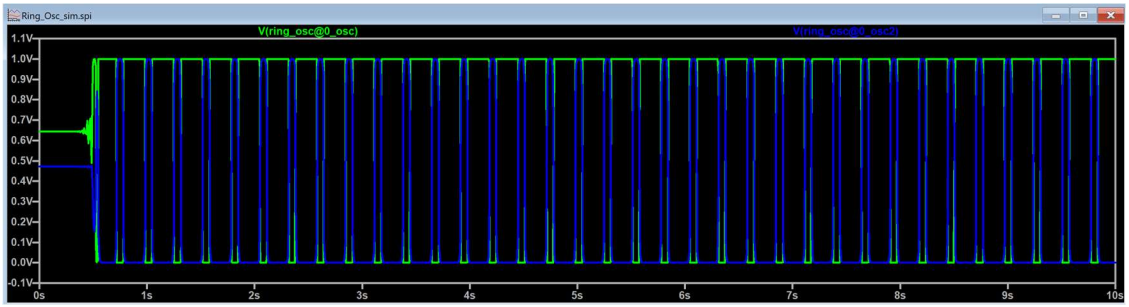

Figure 6: Ring Oscillator Simulation Result

The last subsystem of the DC-to-DC Charge Pump Regulator is the voltage regulation circuit to clean noisy signals. The schematic for the voltage regulation circuit is seen in Figure 7.

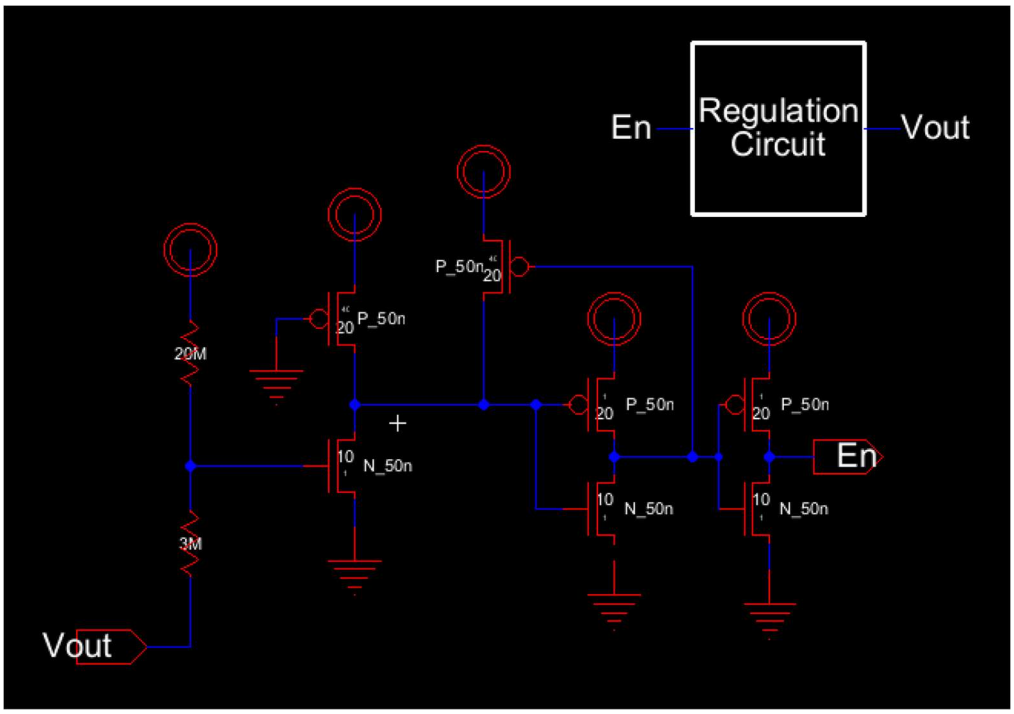

Figure 7: Voltage Regulation Schematic

The voltage regulation circuit is simulated to ensure it can output a stable voltage. The simulation schematic is seen in Figure 8.

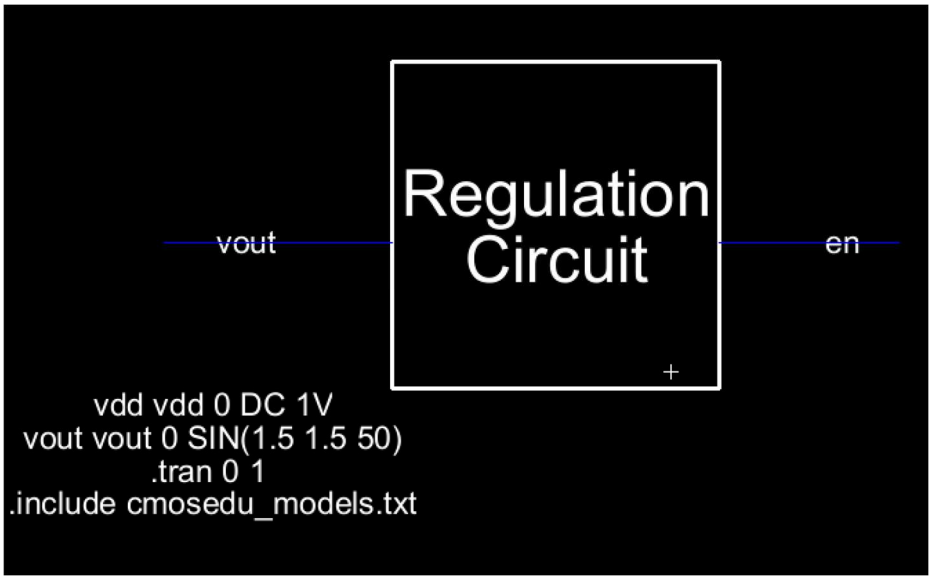

Figure 8: Voltage Regulation Simulation

The results of the simulation can be seen in Figure 9. It can be observed that there is a noisy input signal which is simulated with a sine wave, and the output signal is stable square wave.

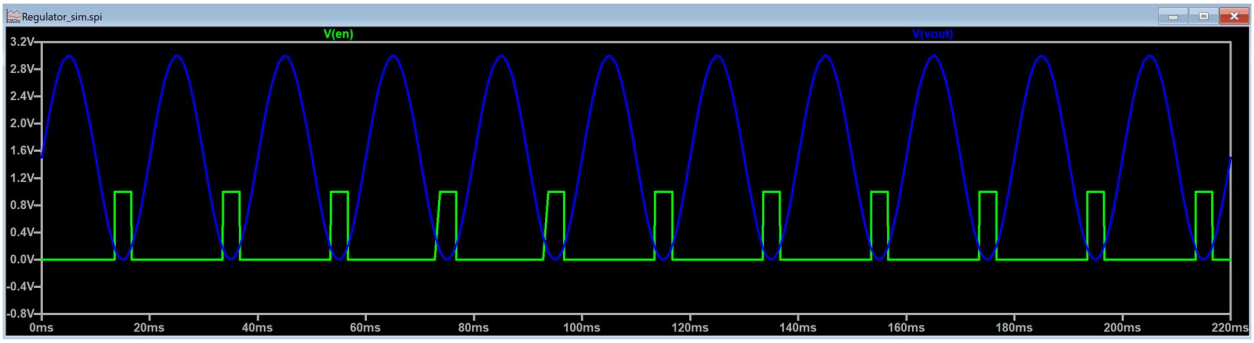

Figure 9: Voltage Regulation Simulation Result

Lastly, all three subsystems are put together to create the DC-to-DC Charge Pump regulator which is seen in Figure 10.

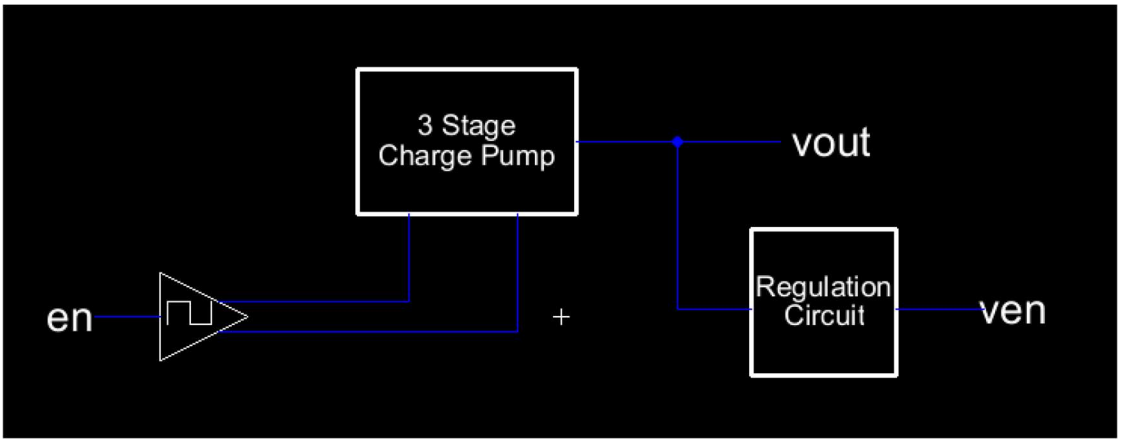

Figure 10: DC-to-DC Charge Pump Regulator Schematic

Unfortunately, a simulation for the DC-to-DC Charge Pump regulator as not achieved.

Layouts:

The first subsystem to layout is the 3 stage charge pump which is seen in Figure 11. Hand calculations were done between Rana and I and we determined that to create the 100uF capacitors, they would have to be 2 meters. For this reason, it was decided to just use artwork instead. The same is true for the resistor. Since the passive components had to be represented using artwork, no simulations were possible for the layouts.

R Calc

2M = 855 Ohm/sq * (L/W)

Assume W = 1

L = 2339, too big to layout.

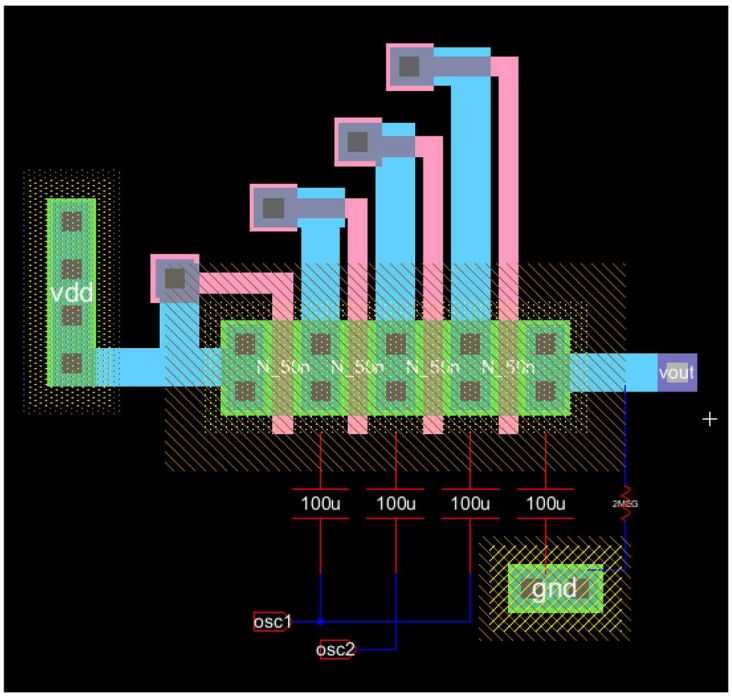

Figure 11: 3 Stage Charge Pump Layout

The next subsystem that was laid out is the ring oscillator which is seen in Figure 12. Just like the previous layout, the capacitors are too large to layout at this scale.

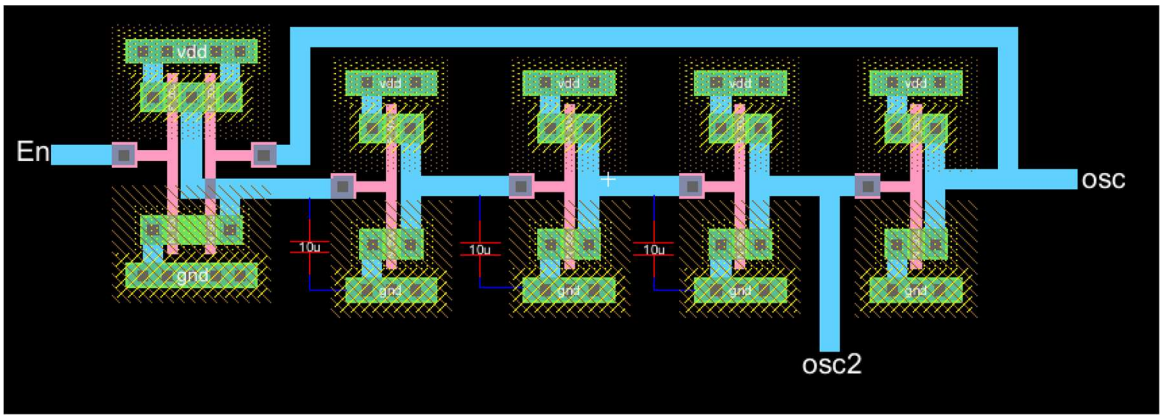

Figure 12: Ring Oscillator Layout

The third and final subsystem to be laid out is the voltage regulator which is seen in Figure 13. Just like the previous layouts, the passive components are too large to layout at this scale.

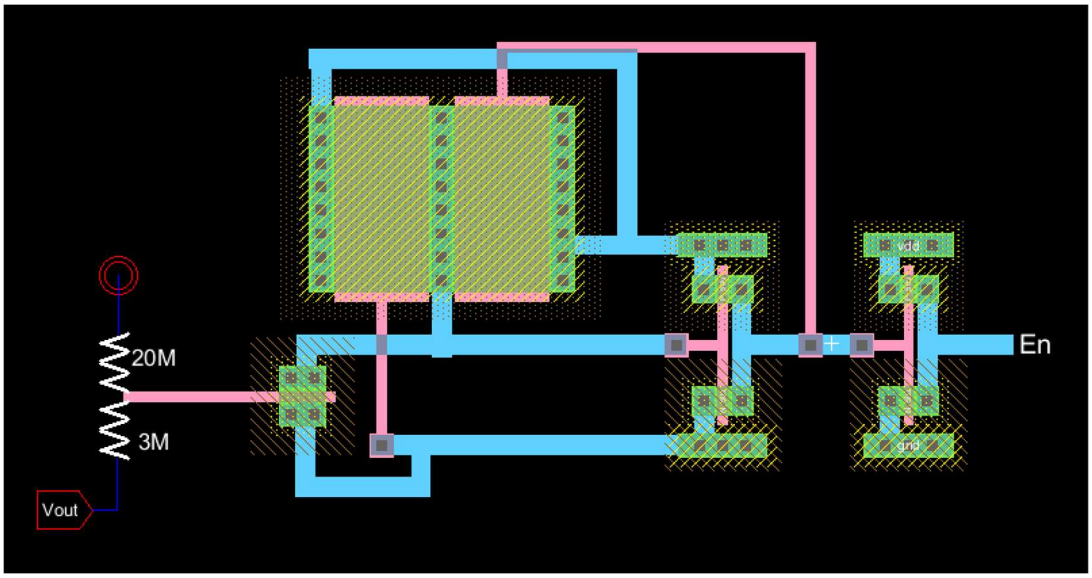

Figure 13: Voltage Regulator Layout

The very last step is to lay out all three subsystems as seen in Figure 14.

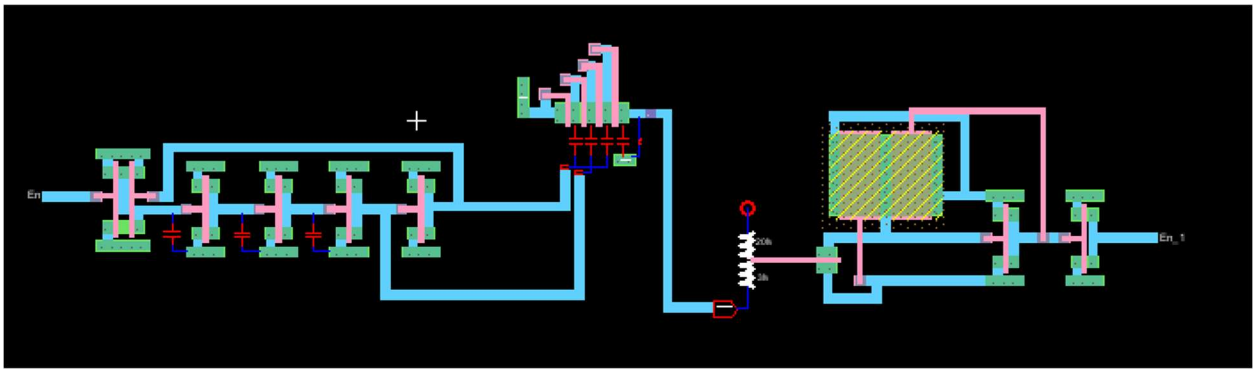

Figure 14: DC-to-DC Charge Pump Regulator

Conclusion:

All in all, students created schematics and layouts for a DC-to-DC Charge Pump regulator.