Lab 1: Power Converter Circuit Simulation

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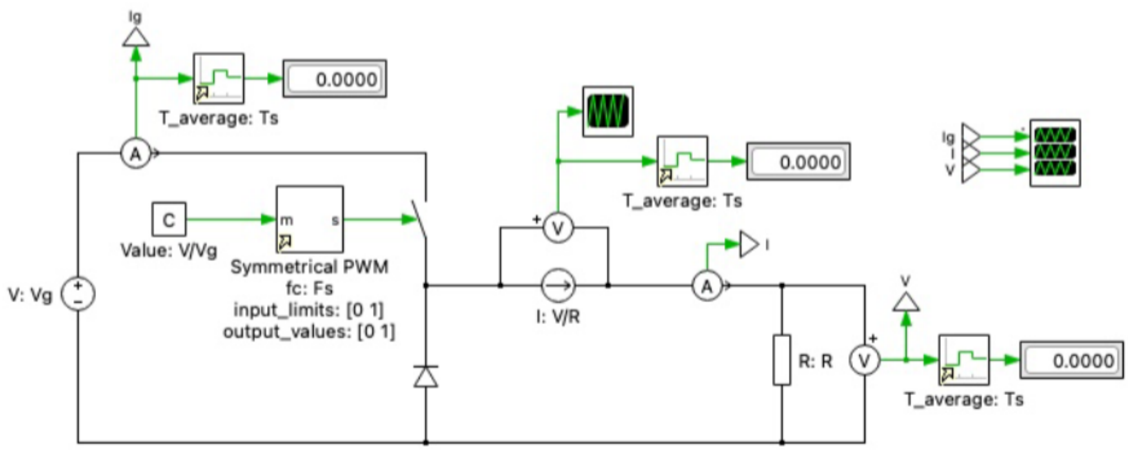
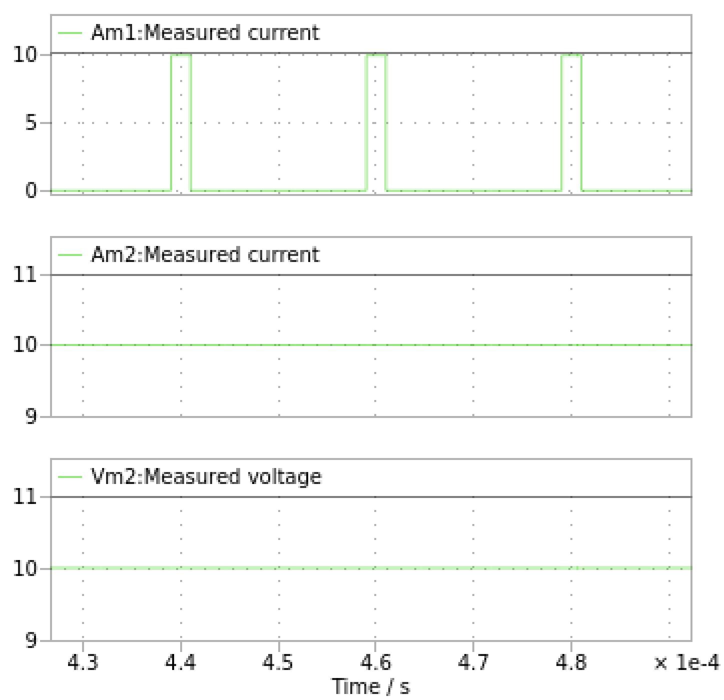
In [ ]:
```python
import matplotlib.pyplot as plt
```

Initial idealized circuit:



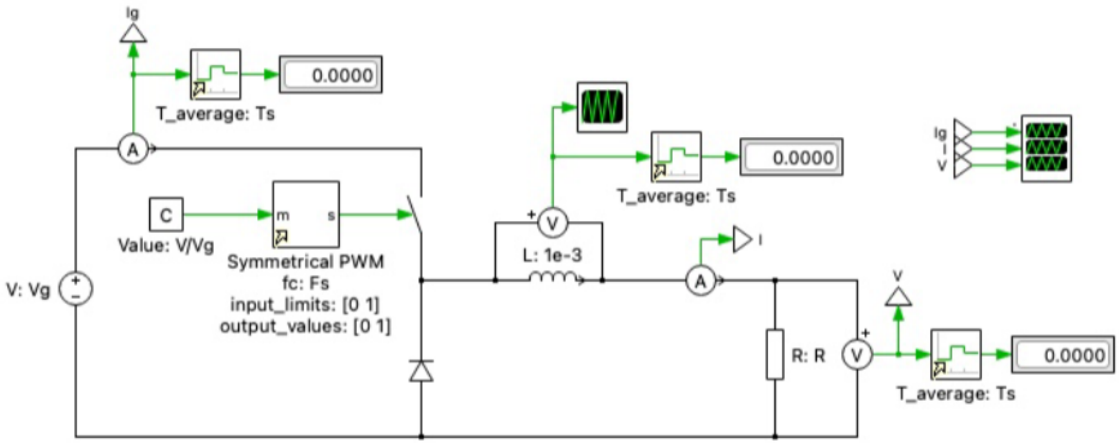
1. The output current and voltages are constant, so they have a 10A and 10V peak/average respectively. The input current has a peak of 10A and an average of 1A. The voltage across the current source has a peak of 90V and an average of 0.



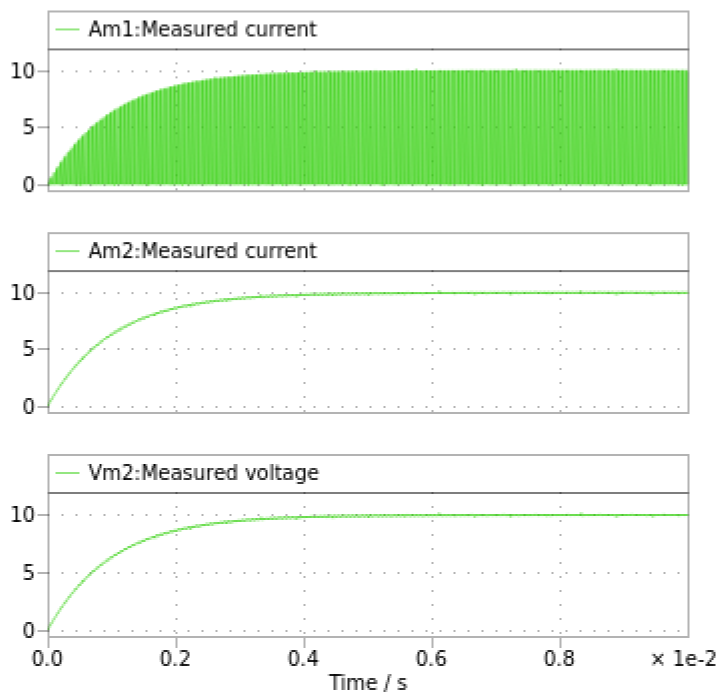
2. There is no ripple on any of the waveforms in this idealized circuit.

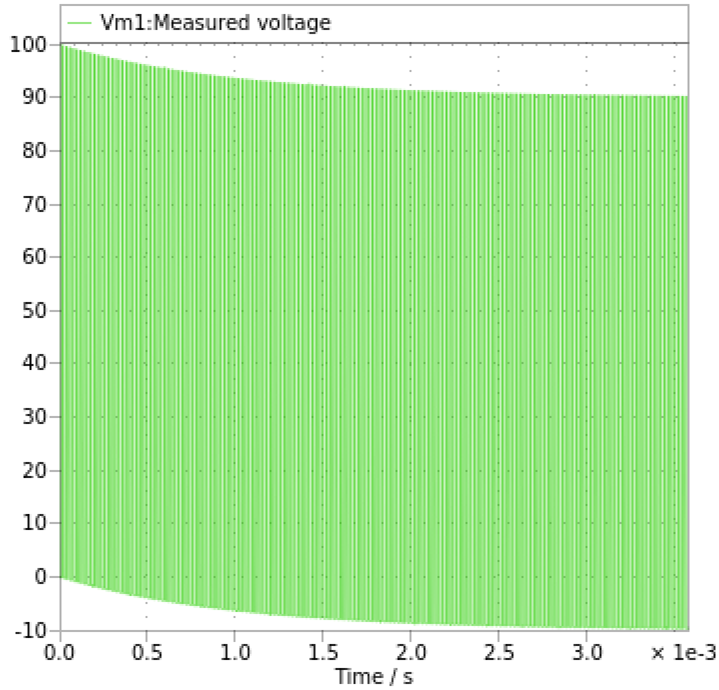
3. The resistor dissipates power, while the voltage source and current source supply power.

Added inductor circuit:



4. On start up it takes a while for the output current, output voltage, and input current to reach their steady state values. There is also ripple across all the waveforms due to the inductor not being an ideal lossless component (as the inductor cannot instantaneously change current values). The voltage across the inductor is initially net positive as the inductor is charging and then becomes net zero after the inductor reaches steady state.





5. It takes about ~0.4e-2s for the waveforms to reach steady state from looking at plots.

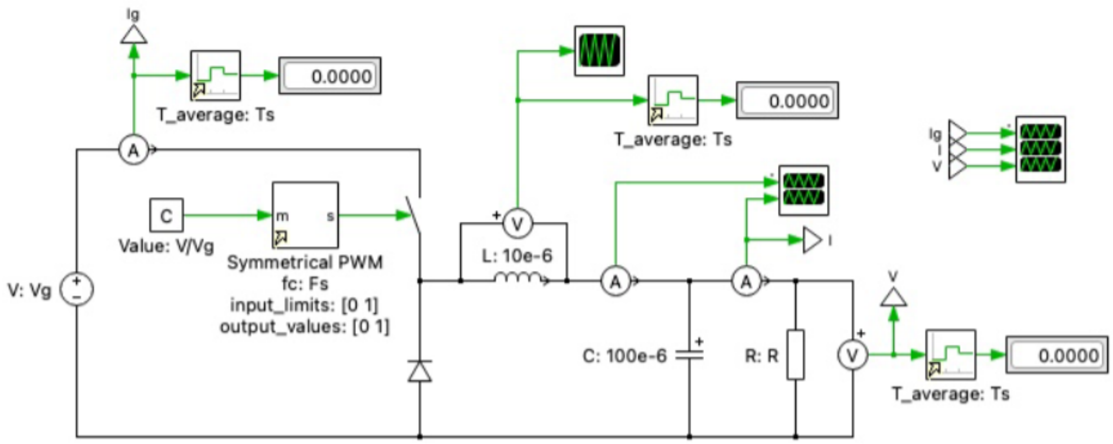
6. The average voltage across the inductor is 10V in steady state.

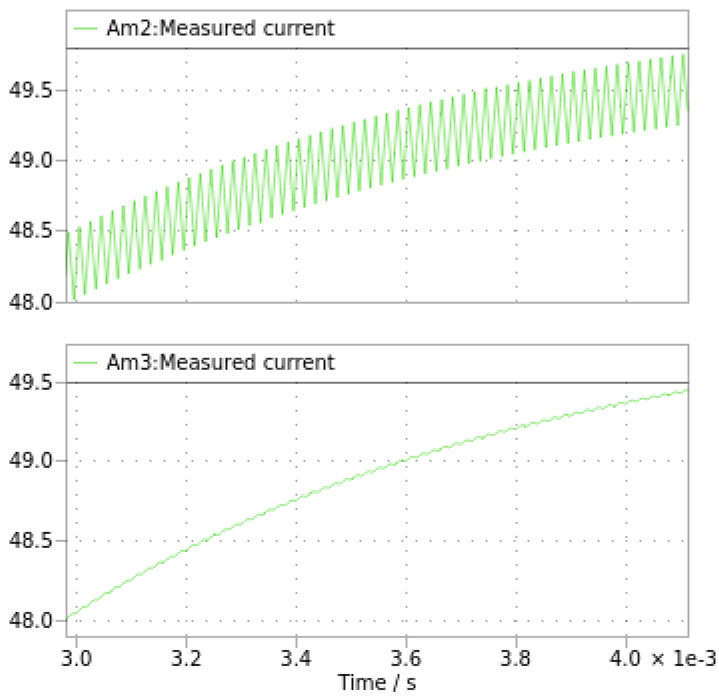
7. The voltage conversion ratio is calculated by (output voltage)/(input voltage).

- Duty cycle of 10%: 10V/100V = 0.1
- Duty cycle of 50%: 50V/100V = 0.5

8. Because an inductor doesn't change current levels instantaneously, the first few periods of the circuit involve all waveforms reaching a steady state as the inductor charges to steady state with each cycle. Another product of this non-instant current level change is the existence of ripple across most of the waveforms as the inductor is charged by the voltage source and discharged by the output load. With 10uH, all waveforms reach steady state faster, but the ripple on all waveforms also increases.

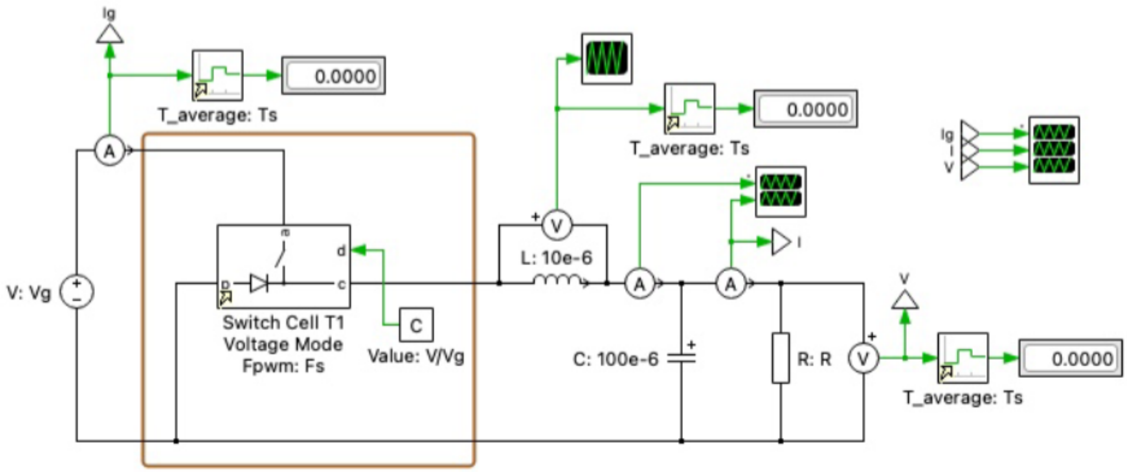
Added capacitor circuit:



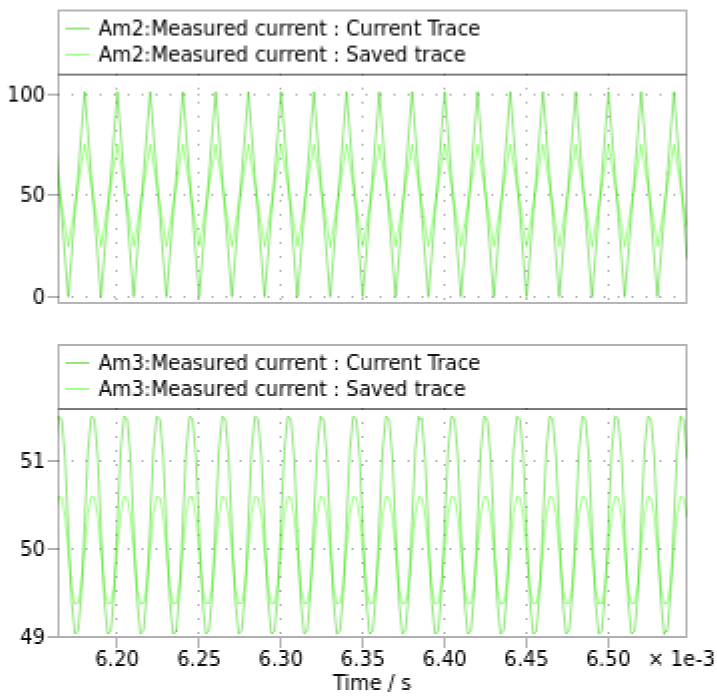


9. There is far less ripple in the current after the capacitor than before. I would consider the current before the capacitor to have large ripple characteristics, while the current after the capacitor has low ripple characteristics. This makes sense, as the capacitor can help supply the output load when the load is disconnected from the input source, smoothing out the waveform.

Buck converter with type 1 switch cell:



10. The block above can be approximated by an ideal transformer, as both blocks accomplish a voltage step down from the input to the output of the circuit. Both components are modelled as lossless, so the components accomplish the same step down (although with AC for the transformer and DC for the switch cell).

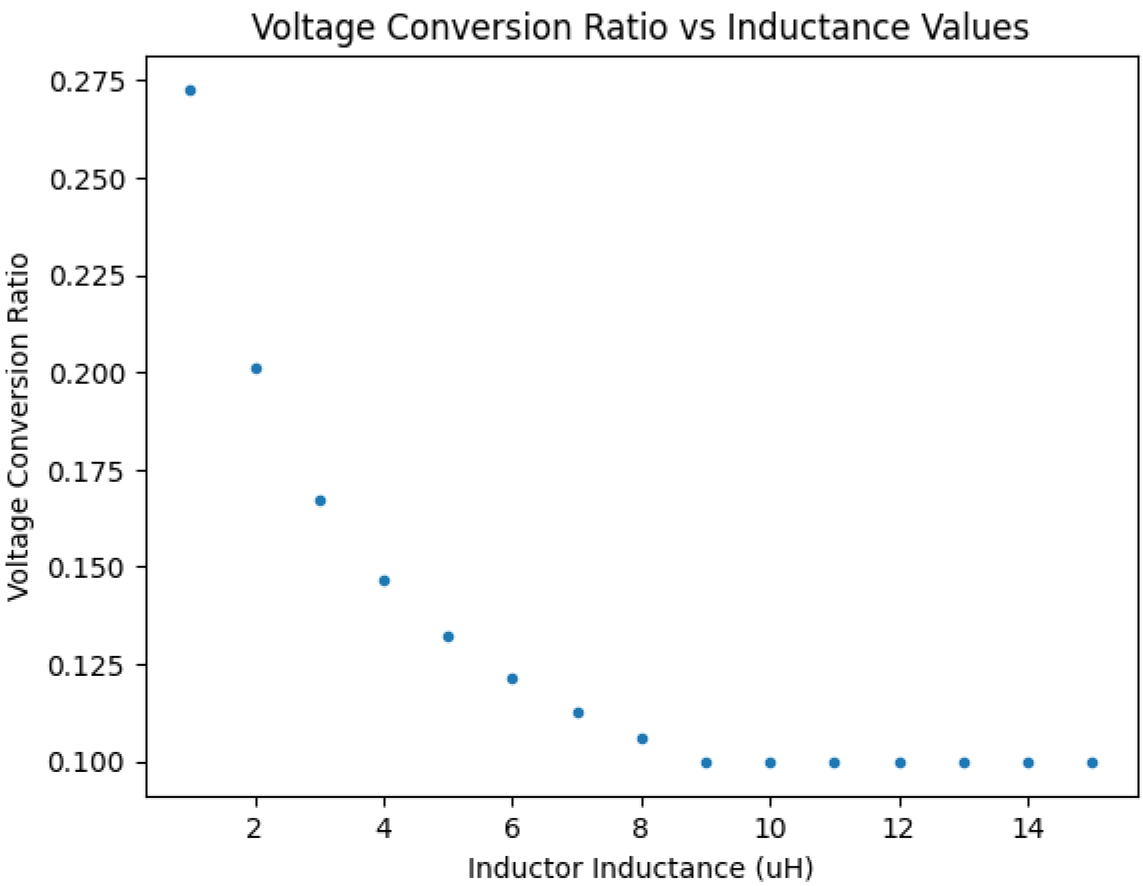


11. In the plot above, the trace with less ripple is the circuit with the lower inductance value, while the trace with larger ripple is the circuit with the higher inductance value. The larger inductor takes longer to reach a steady state current than the smaller inductor. The voltage across the output load also takes longer to settle to a steady state. This makes sense as the inductor with larger inductance will take longer to charge to supply the desired output voltage of the circuit. The larger inductor also has less current swing than the smaller inductor. This makes sense as the larger inductance creates a larger resistance to changes in current.

12.

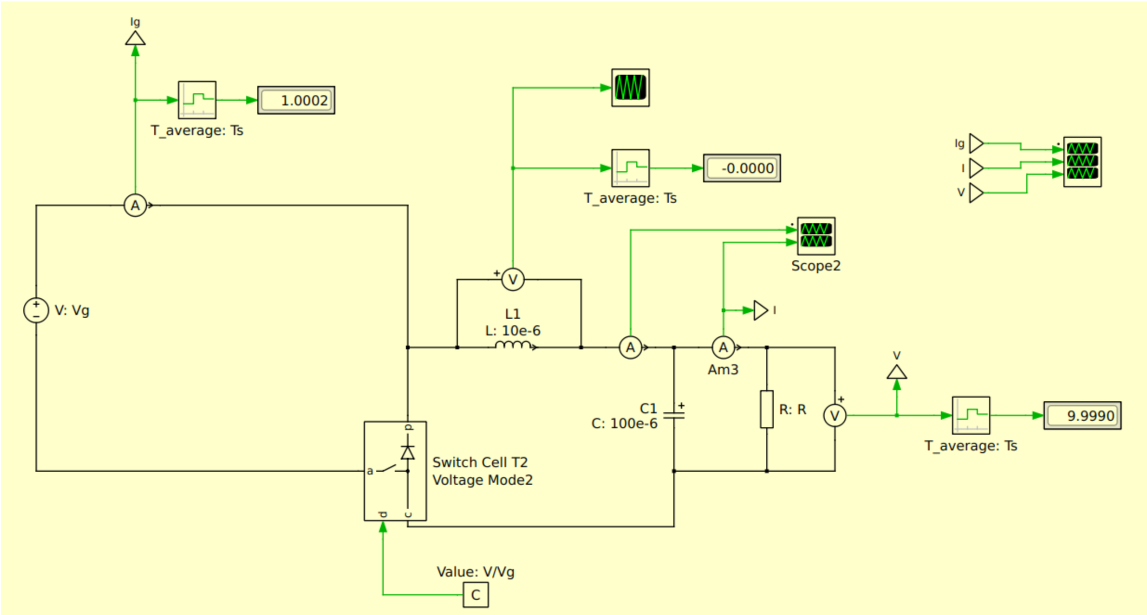
```
In [ ]: input_voltage = 100 #V
inductances = [1,2,3,4,5,6,7,8,9,10,11,12,13,14,15]
output_voltages = [27.26,20.12,16.74,14.66,13.21,12.13,11.28,10.58,10.01,9.9
voltage_ratios = []
for voltage in output_voltages:
    ratio = voltage/input_voltage
    voltage_ratios.append(ratio)

plt.plot(inductances,voltage_ratios, '.')
plt.xlabel("Inductor Inductance (uH)")
plt.ylabel("Voltage Conversion Ratio")
plt.title("Voltage Conversion Ratio vs Inductance Values")
```

```
Out[ ]: Text(0.5, 1.0, 'Voltage Conversion Ratio vs Inductance Values')
```

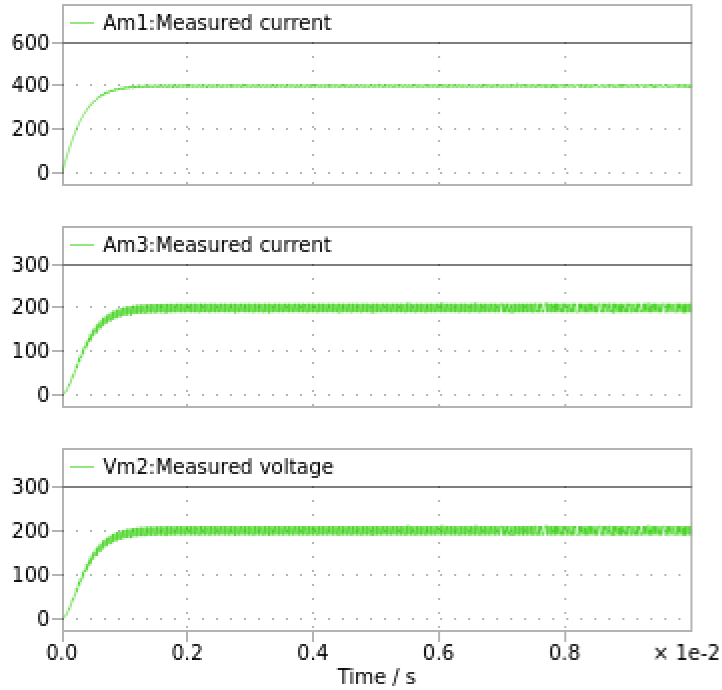


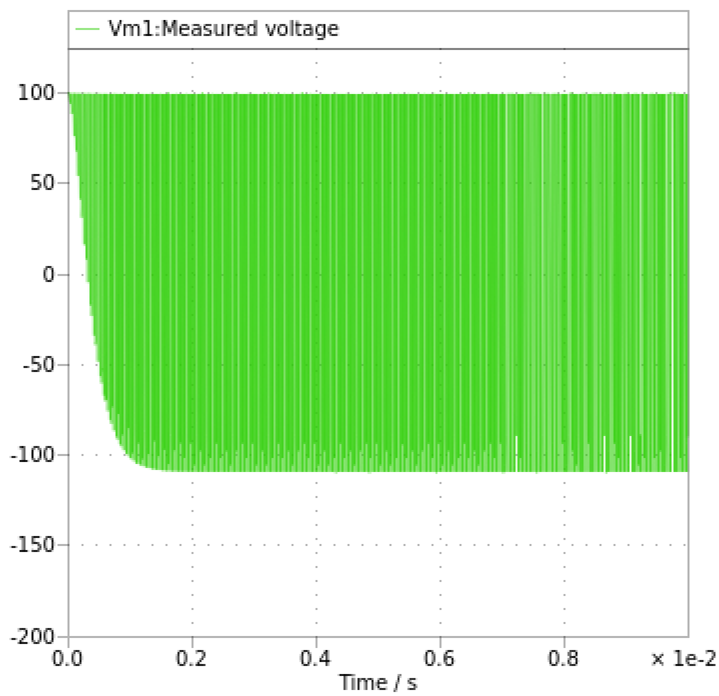
13.

Buck converter with type 2 switch cell:


Ig
T_average: Ts
1.0002
-0.0000
T_average: Ts
Ig
I
V
Scope2
V: Vg
L1
L: 10e-6
I
Am3
V
C1
C: 100e-6
R: R
T_average: Ts
9.9990
Switch Cell T2
Voltage Mode2
Value: V/Vg
C

14.





The boost waveforms have a similar behavior to the buck converter, with the output voltage and currents being stepped up instead of down for the buck converter. An increased duty cycle still increases the output voltage, although above the input voltage for the boost converter. Both converters still have a similar transient behavior before reaching steady state.

15. The voltage conversion ratio for D=50% 199.39/100 = 1.9937, or ~2.

16.

In [ ]:
```
#16
input_voltage = 100
duty_cycles = [0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9]
output_voltages = [111.09,124.93,142.70,166.36,199.39,248.72,330.16,481.92,6

voltage_ratios = []
for voltage in output_voltages:
    ratio = voltage/input_voltage
    voltage_ratios.append(ratio)

plt.plot(duty_cycles,voltage_ratios, '.')
plt.xlabel("Duty Cycle")
plt.ylabel("Voltage Conversion Ratio")
plt.title("Voltage Conversion Ratio vs Duty Cycle")
```

Out[ ]:
```
Text(0.5, 1.0, 'Voltage Conversion Ratio vs Duty Cycle')
```