10. Design and analysis of Buck converter with realistic capacitance

Course: ECE1008 – Electronic Hardware Troubleshooting LAB

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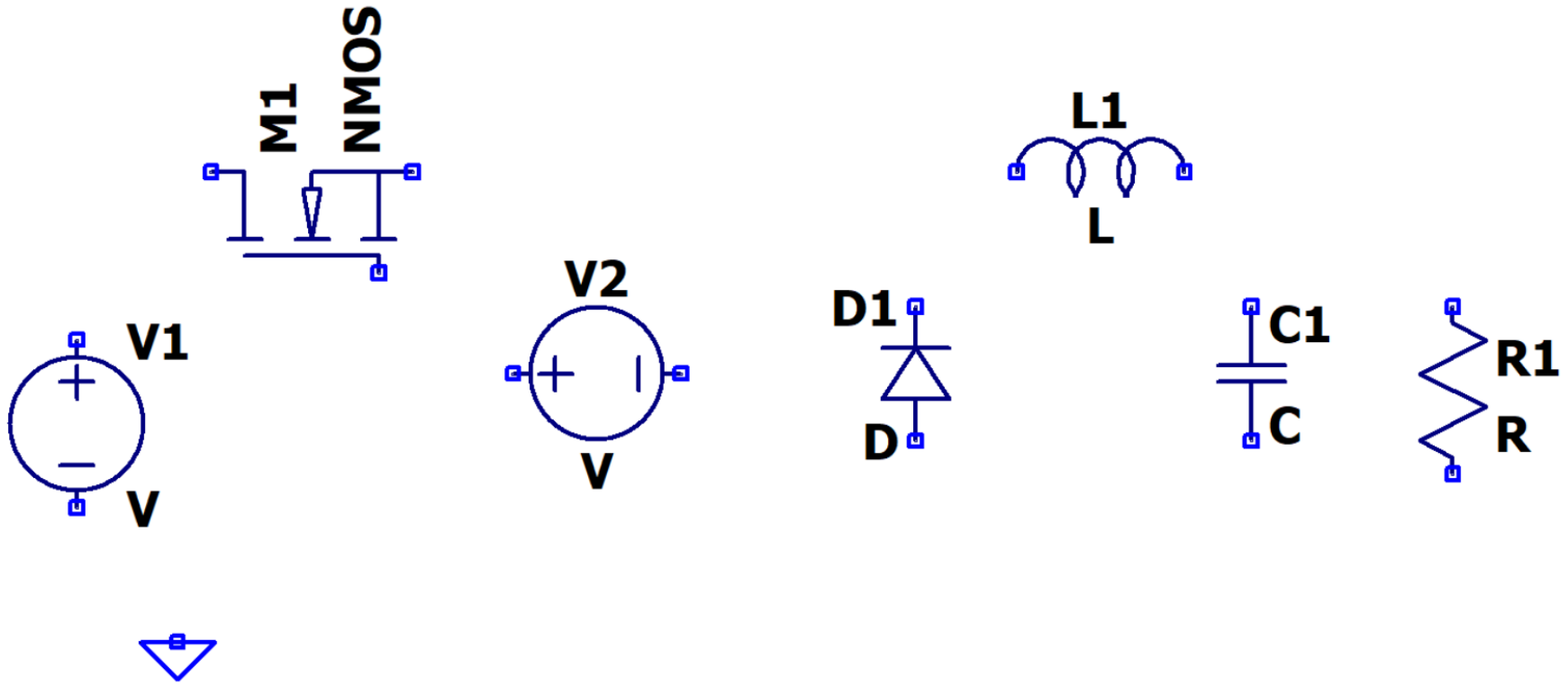
CHENNAI

Introduction

- Buck converter is used to provide
  Stable Stepped down dc voltage from a source of higher DC voltage.
- In this experiment, we will design a 12V DC to 5.7V DC signal using
  NMOS,
  Schottky diode (reverse biased)
  LC filter and a resistor.

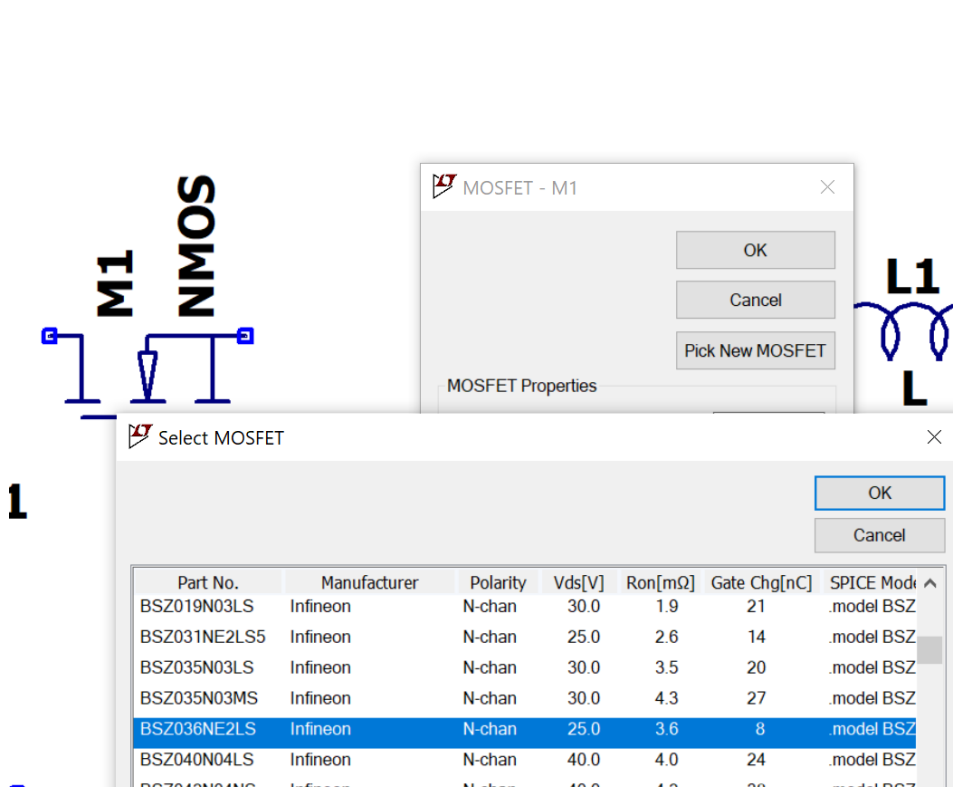
1. Steps to design:

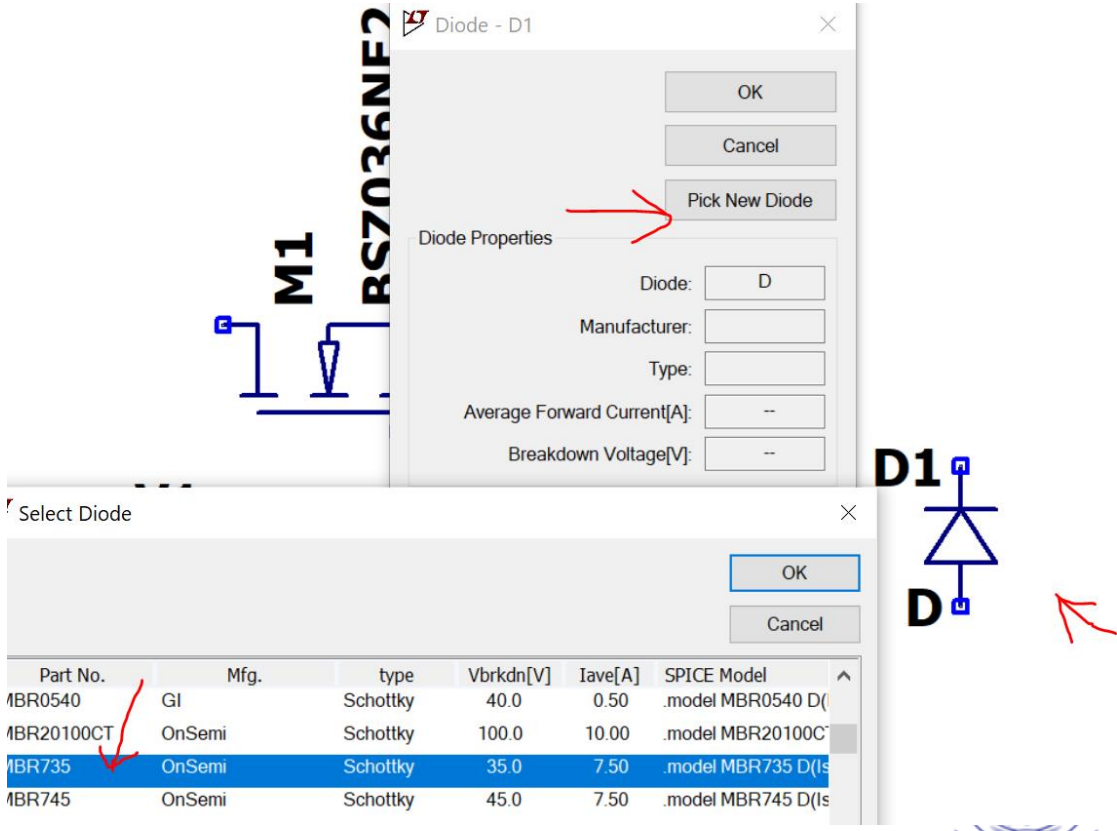
1a) Place all the components as shown below:
Note: Use CTRL+R for rotating a component.



1. Steps to design:

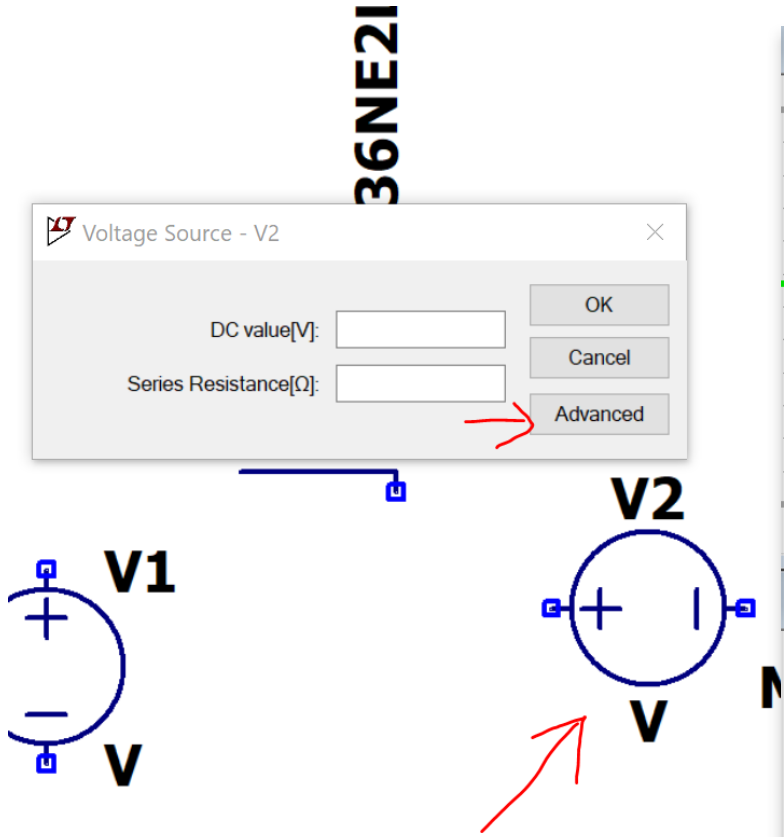
1b) Right click at NMOS and select BSZ036NE2LS
Right click at diode, and pick new diode: MBR735

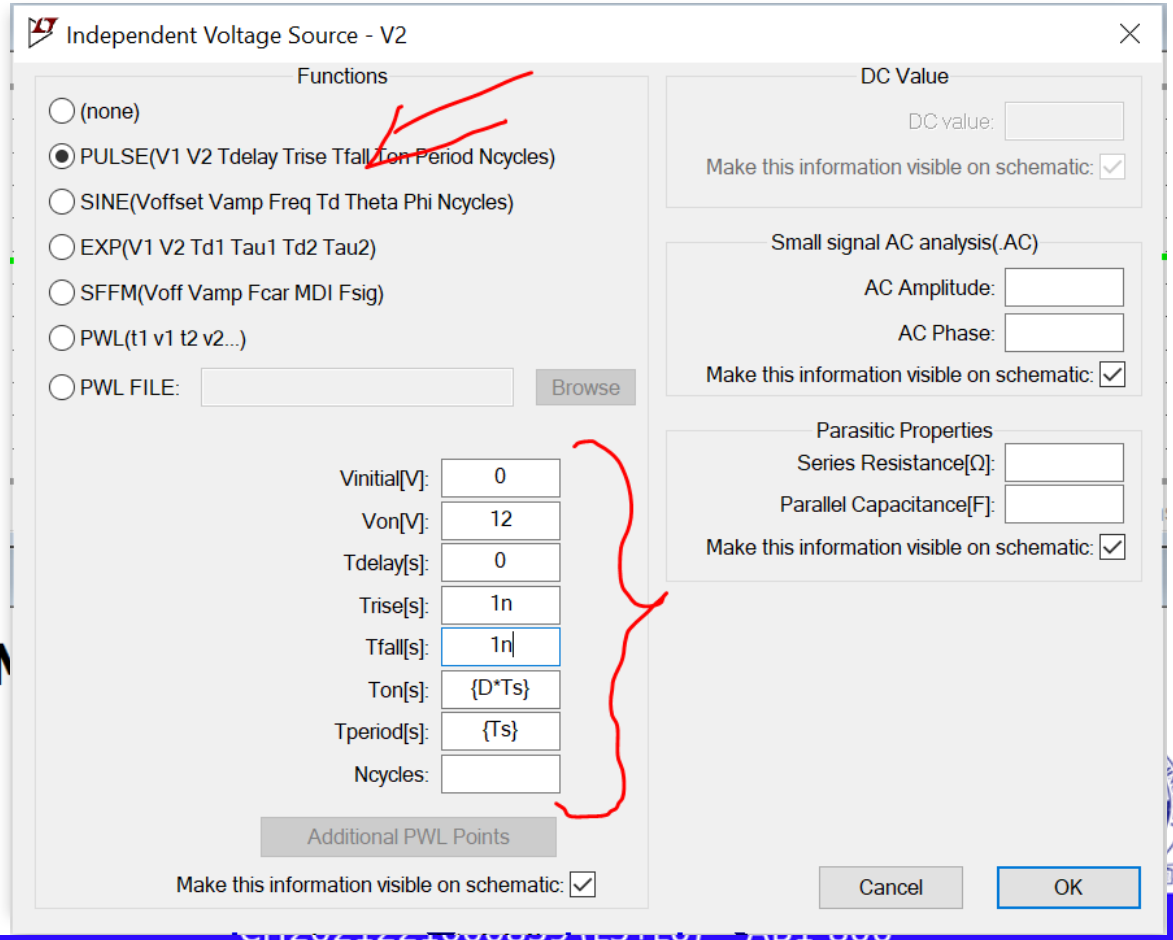




1. Steps to design:

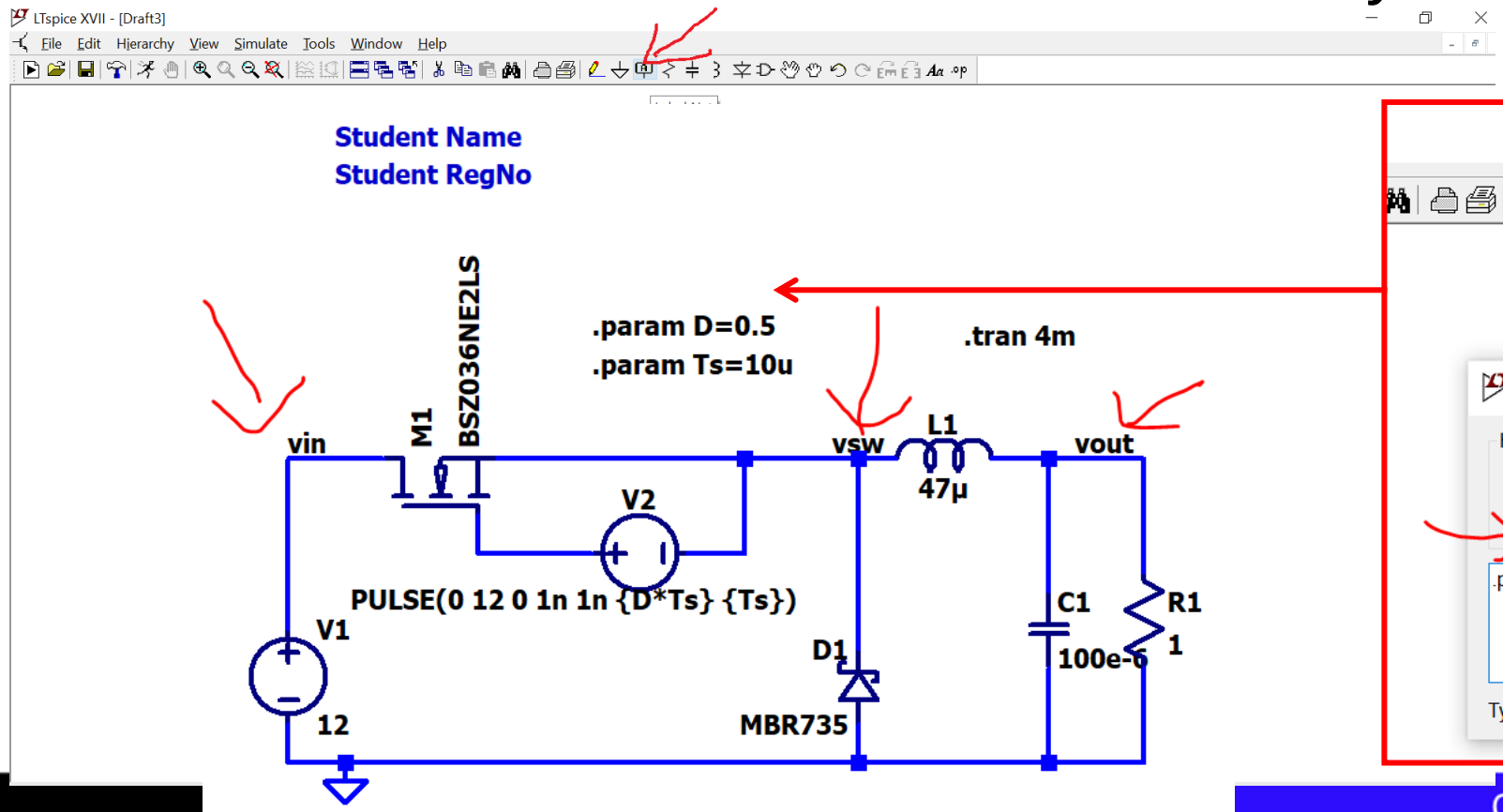
2. Set input DC voltage V1 as 12V and second Voltage source V2as Pulse source.

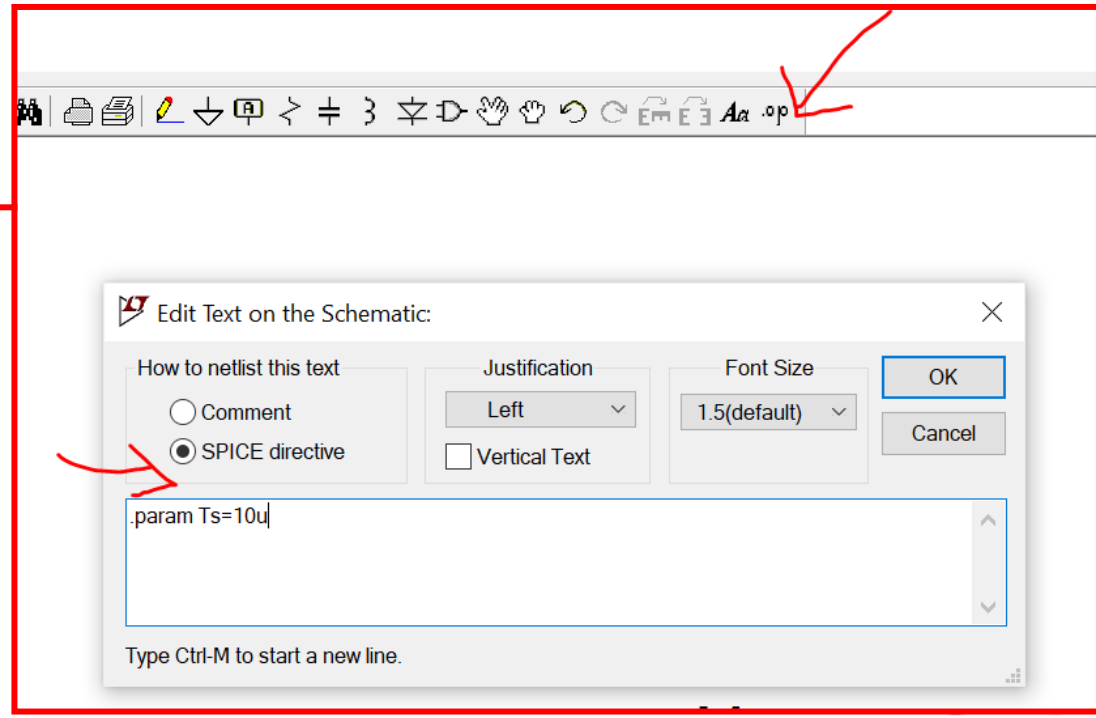




1. Steps to design:

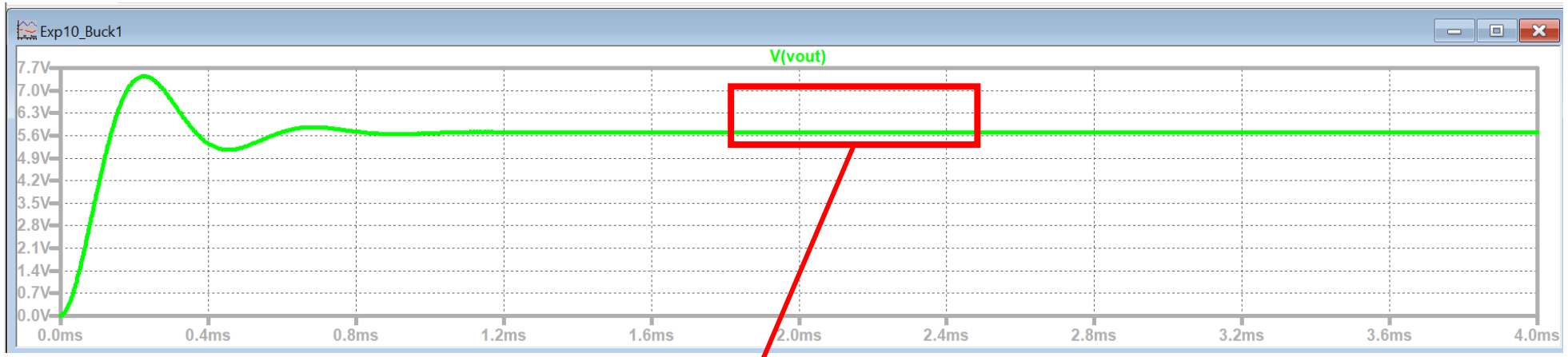
Add labelnets Vin, VSW, Vout.
EditText on schematic -> Spice directive
Include parameters D and Ts (pulse source's duty cycle time duration.)
Edit Simulation command -> Transient analysis -> 4m

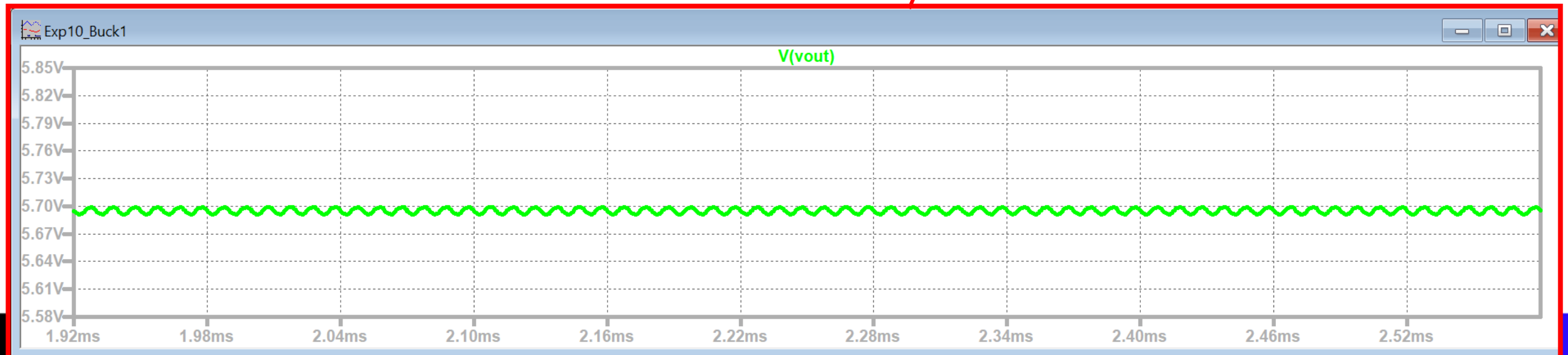




Task 1a: Measure the output (vout) fluctuations in steady state

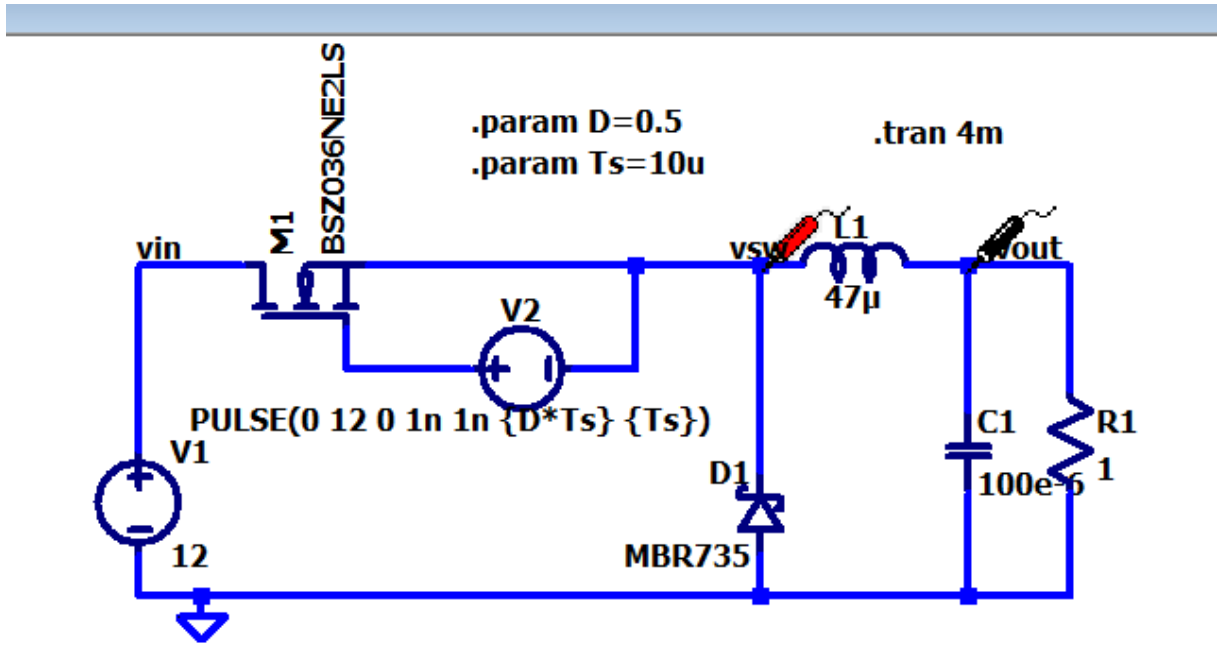
- Simulation > Edit simulation command
  .tran 4m
- Run

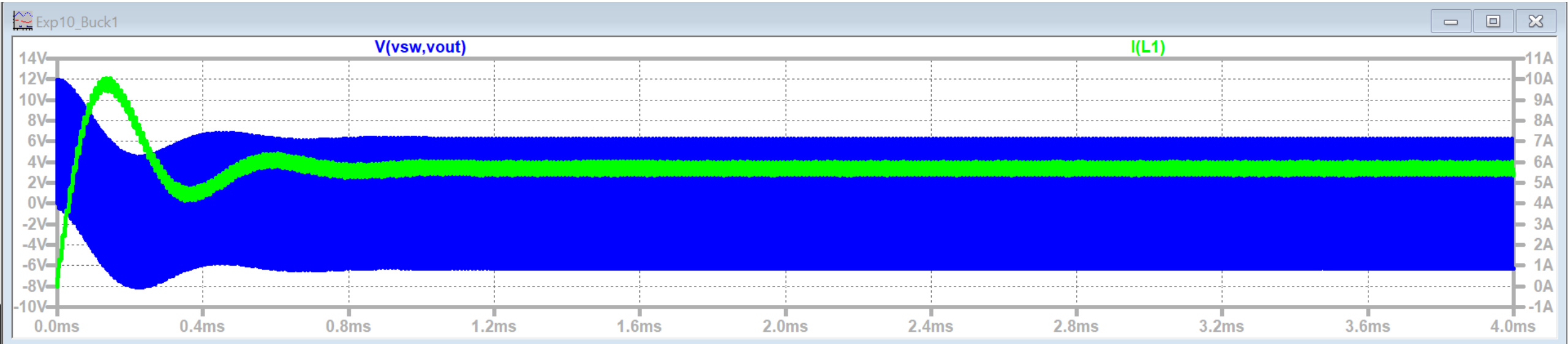




Task 1b: Measure the voltage, current across inductor in steady state

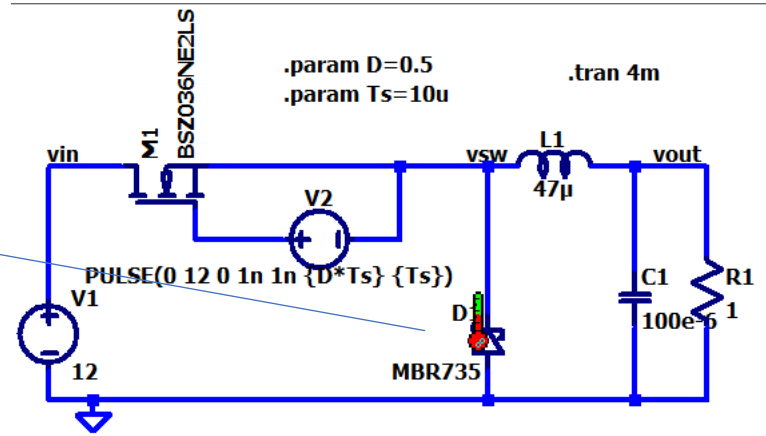
- Click at Inductor's vsw end, hold the mouse and move to vout and release the mouse click This will measure voltage across the inductor.
- Measure the inductor current too.

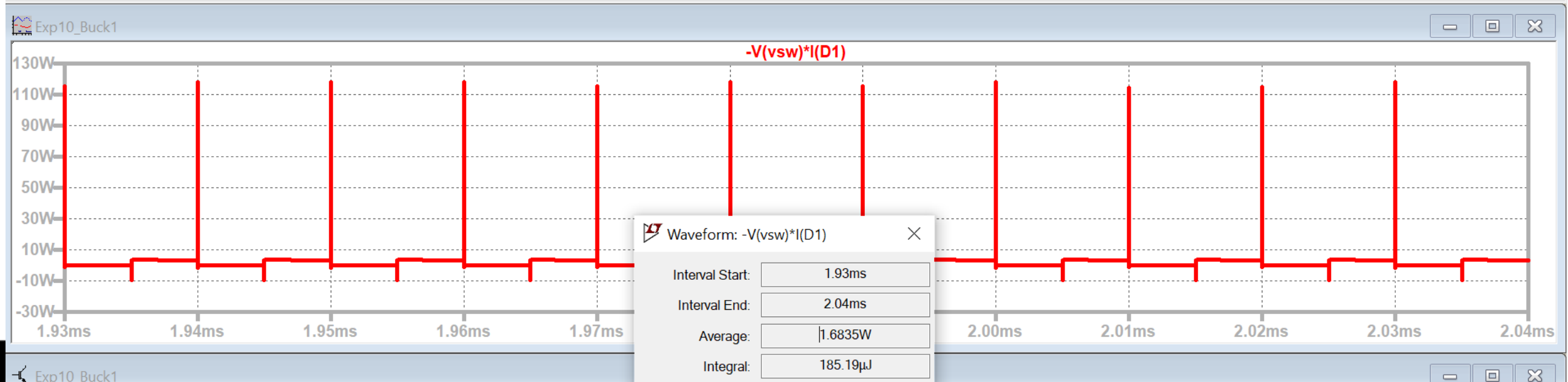




Task 1c: Measure the instantaneous power and average power at components

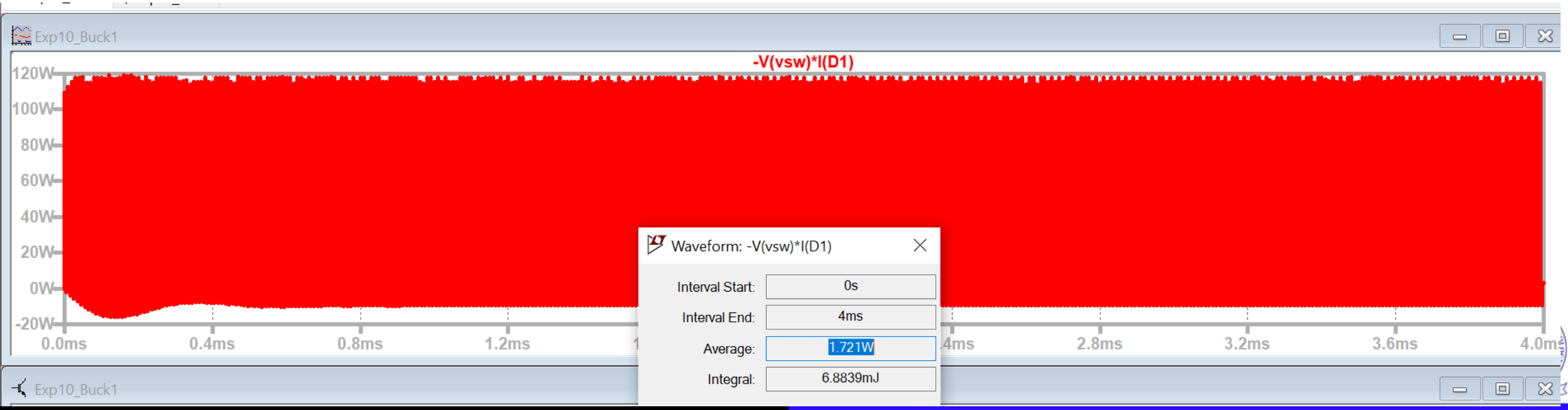
- Press alt key and click on Diode
- Zoom in the plot and
  Hold CTRL key and click on the variable
  in plot (power)
  The pop-up window will display average power.





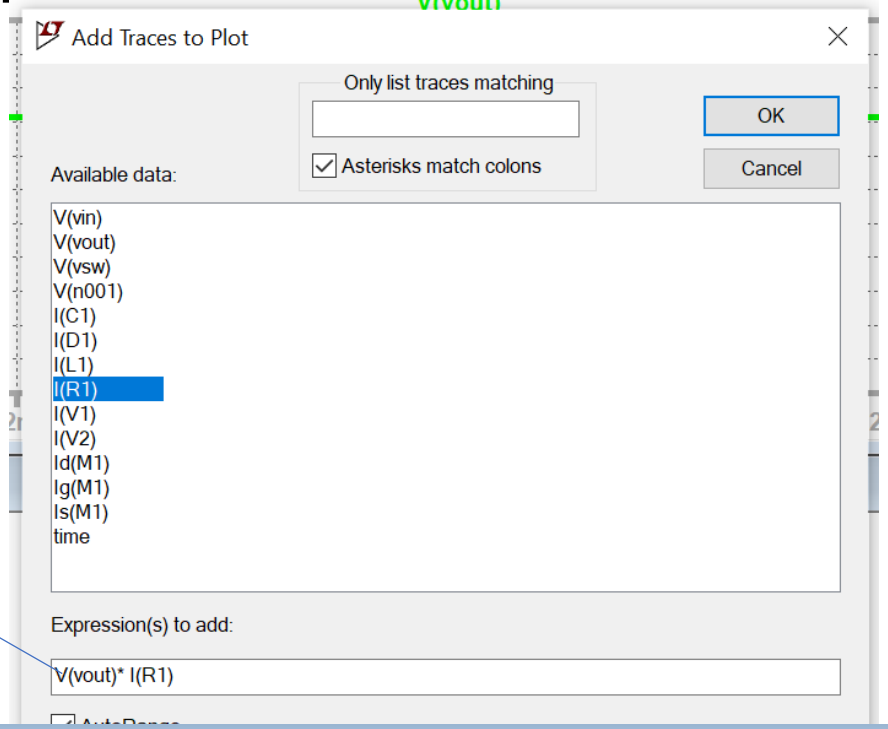
Task 1c: Measure the instantaneous power and average power at components

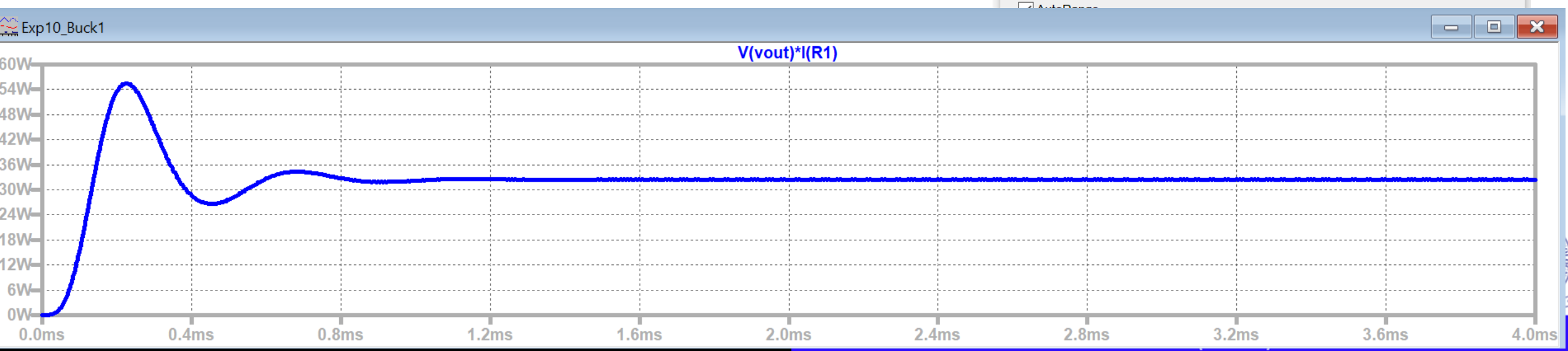
- To calculate average for whole period:
  Zoom to fit the plot and find average:



Task 1d: Measure the instantaneous power and average power at output

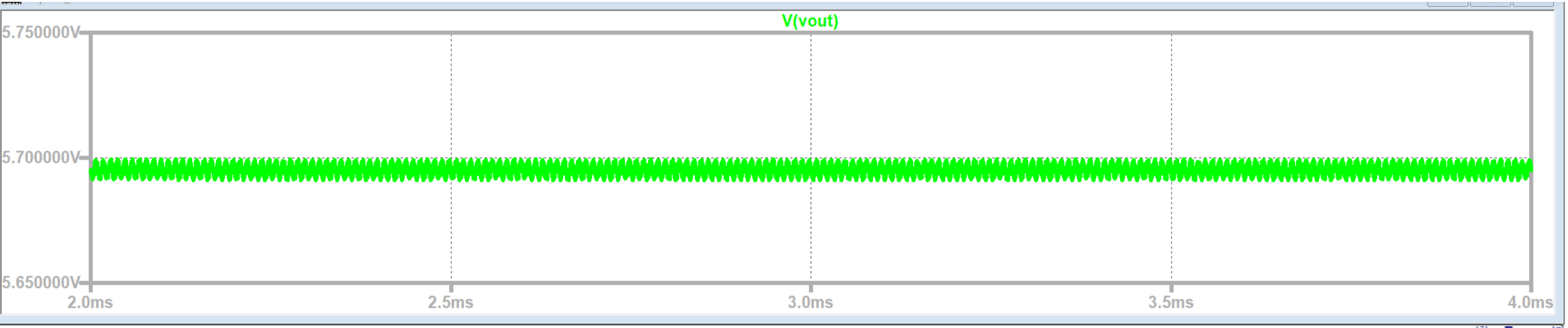
- Alternatively, for instantaneous power at load resistor,
  Right click at plot -> Add trace->
  In expression: Type V(vout)*I(R1)





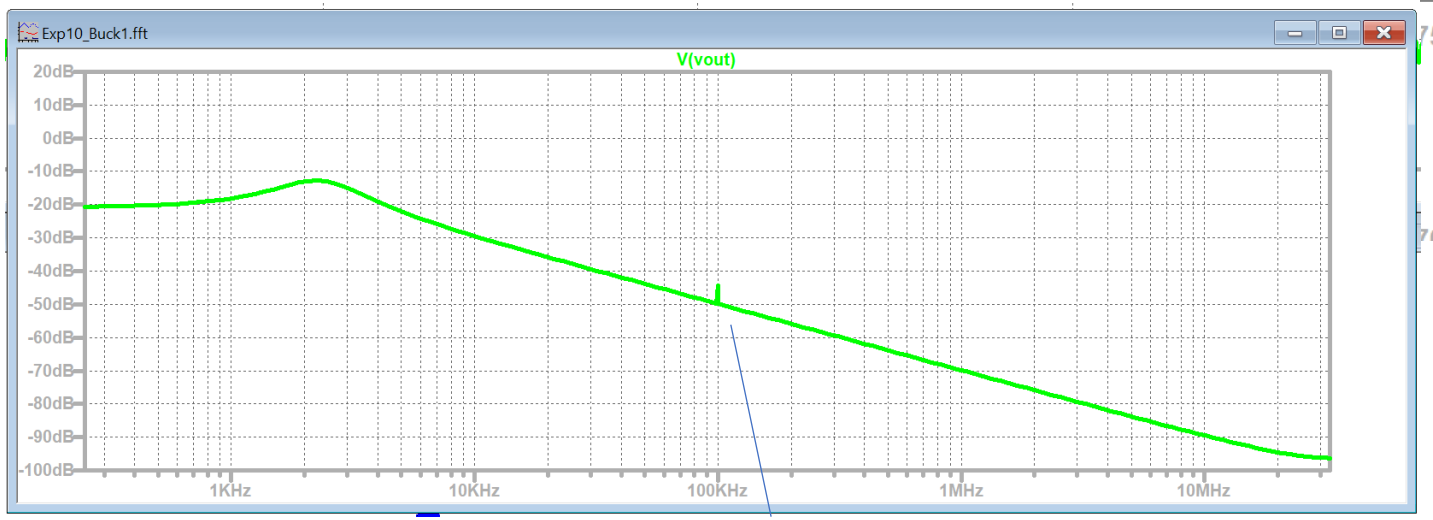
Task 2a: Select FFT of the signal (output voltage)

- Select the region on the plot by clicking on y-tick marks and x tick marks
  x: 2ms to 3ms and y: 5.6V to 5.7V

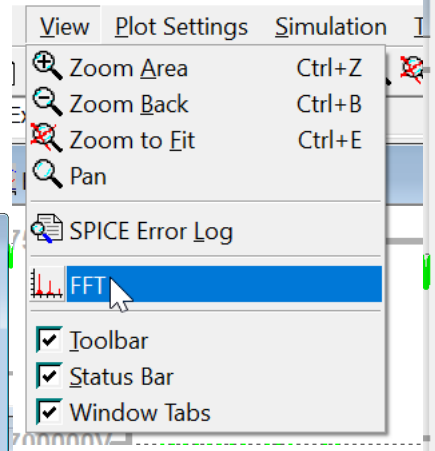


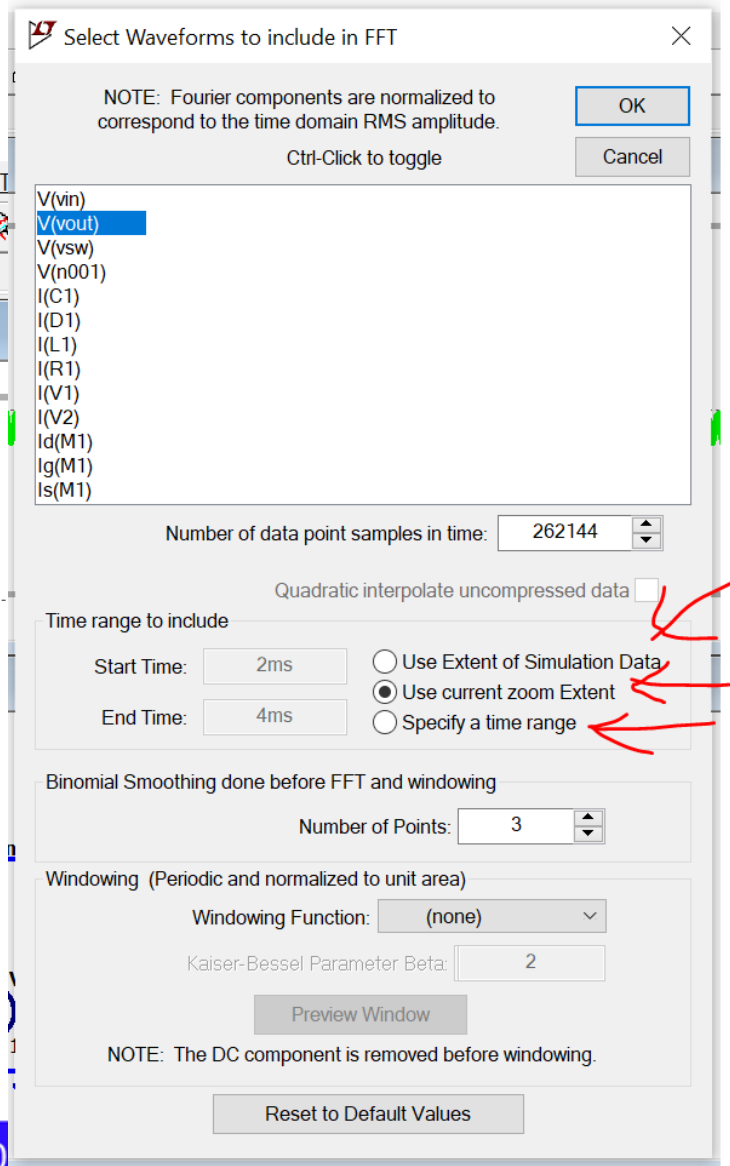
Task 2a: Select FFT of the signal (output voltage)

- Select the plot window, and View-> FFT
- Select extent of simulation data



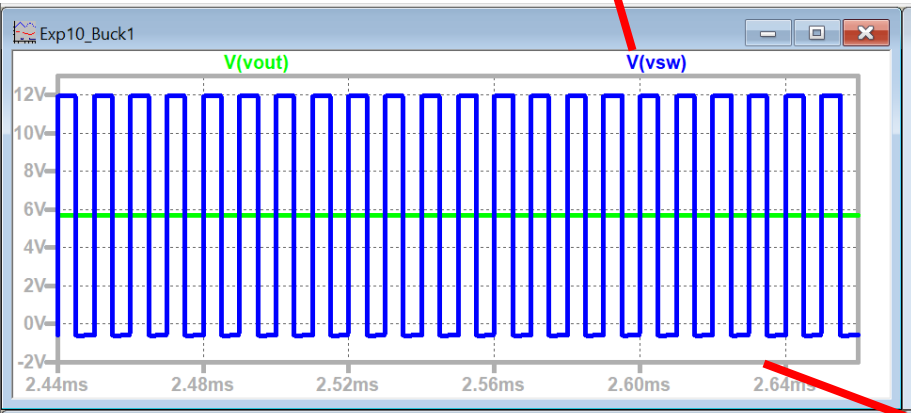
Switching frequency

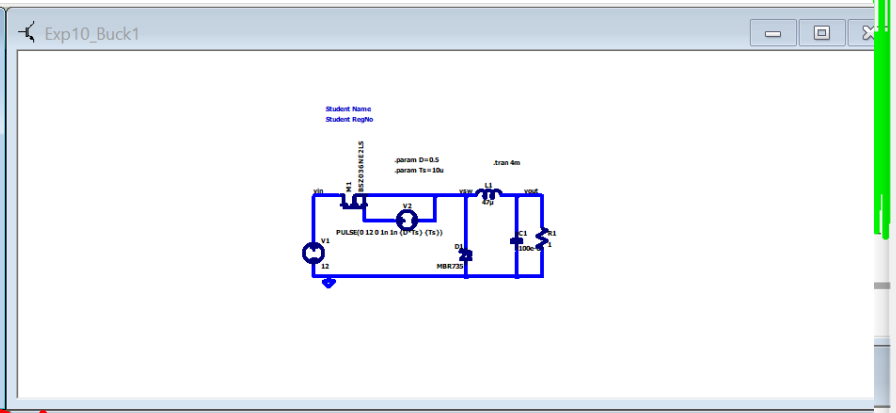


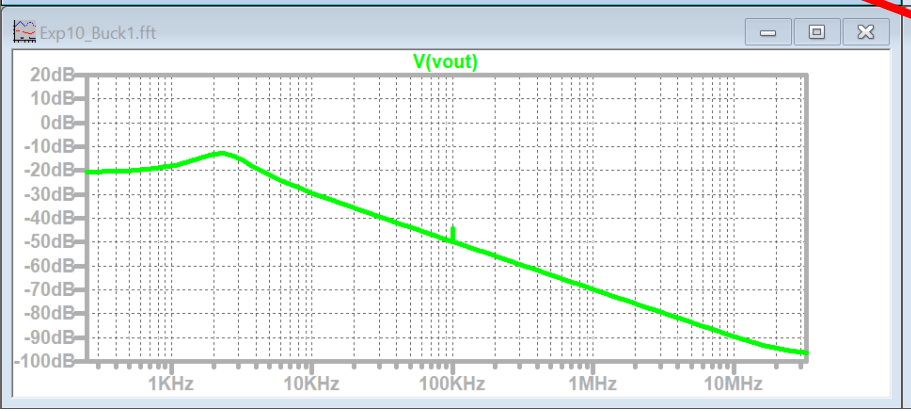


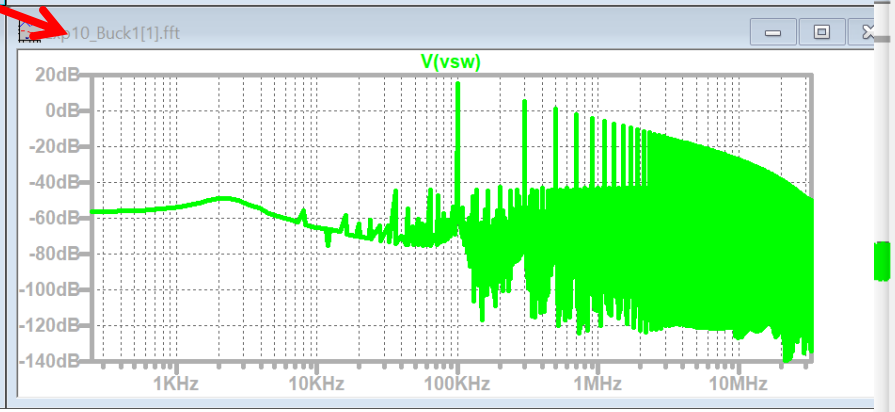
Task 2b: Select FFT of the signal (Switch voltage)

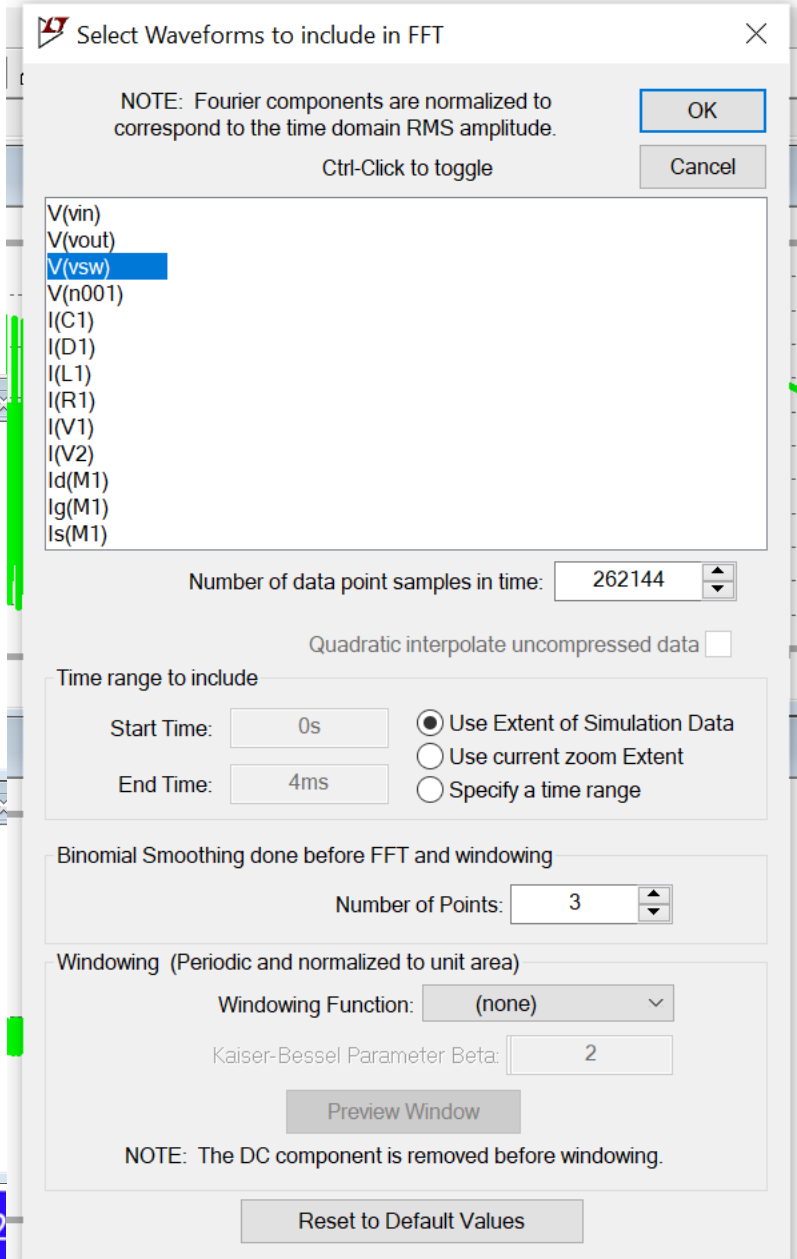
- Select the vsw in FFT and plot for entire range
  Notice the frequency and its harmonics.





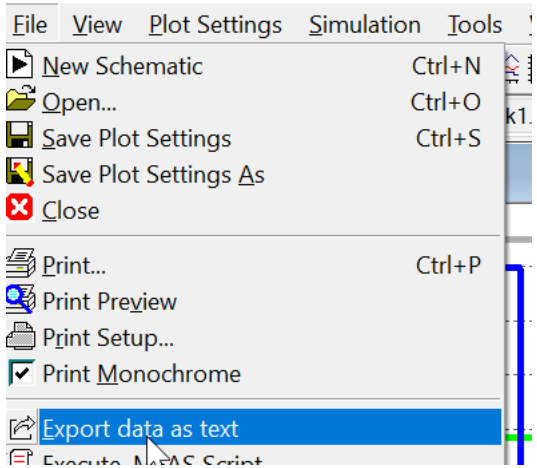


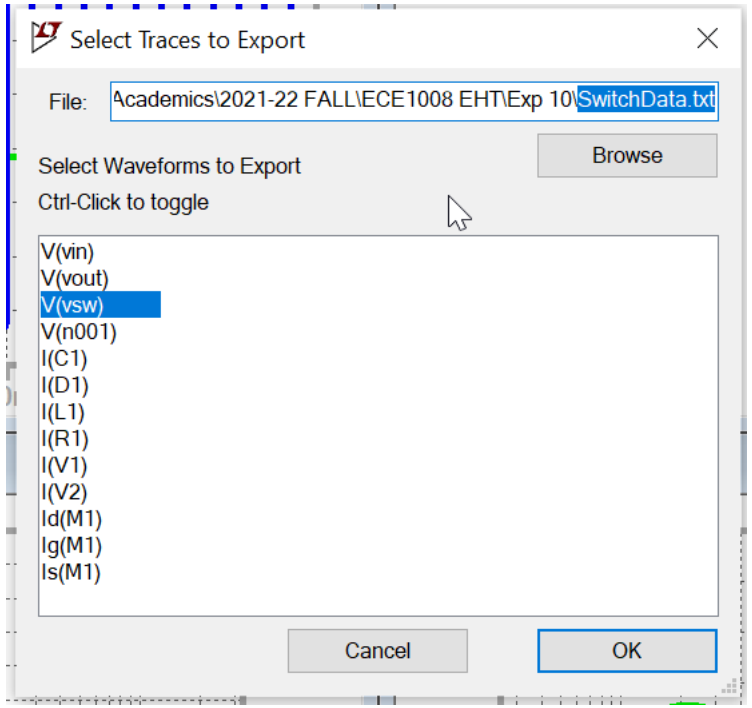


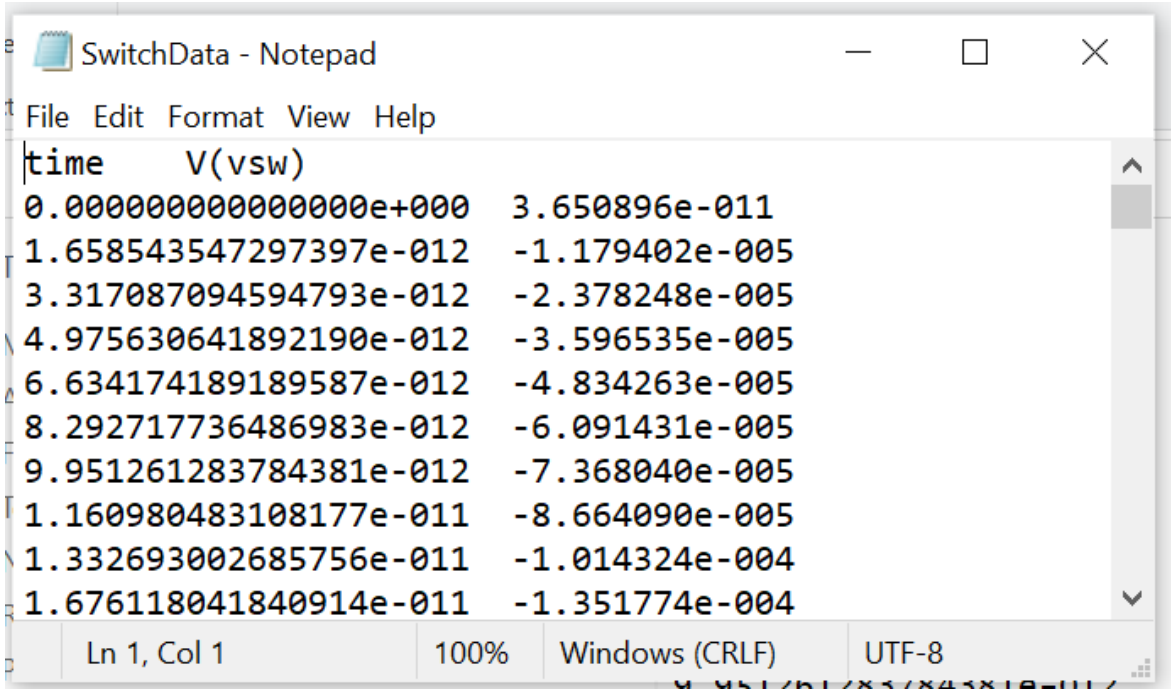


Task 2c: Export switch voltage plot data

- File -> Export -> Select vsw(switch voltage)

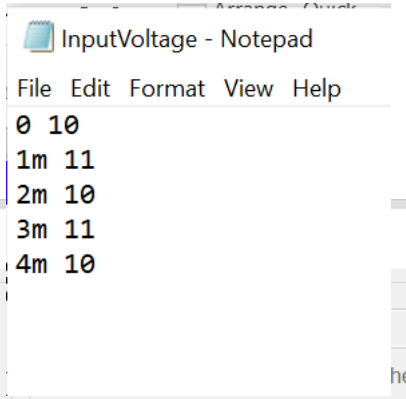


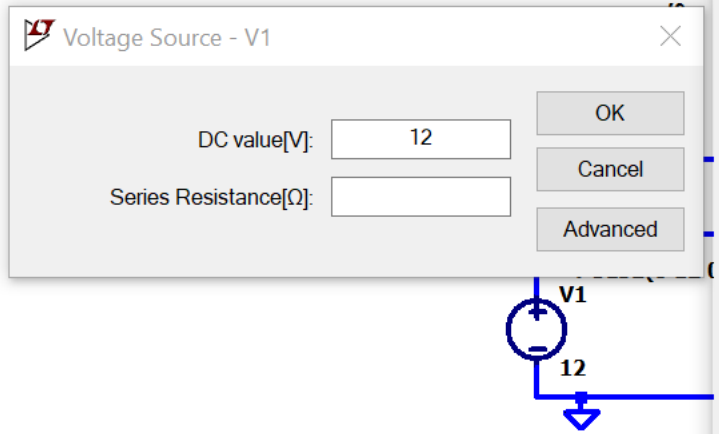


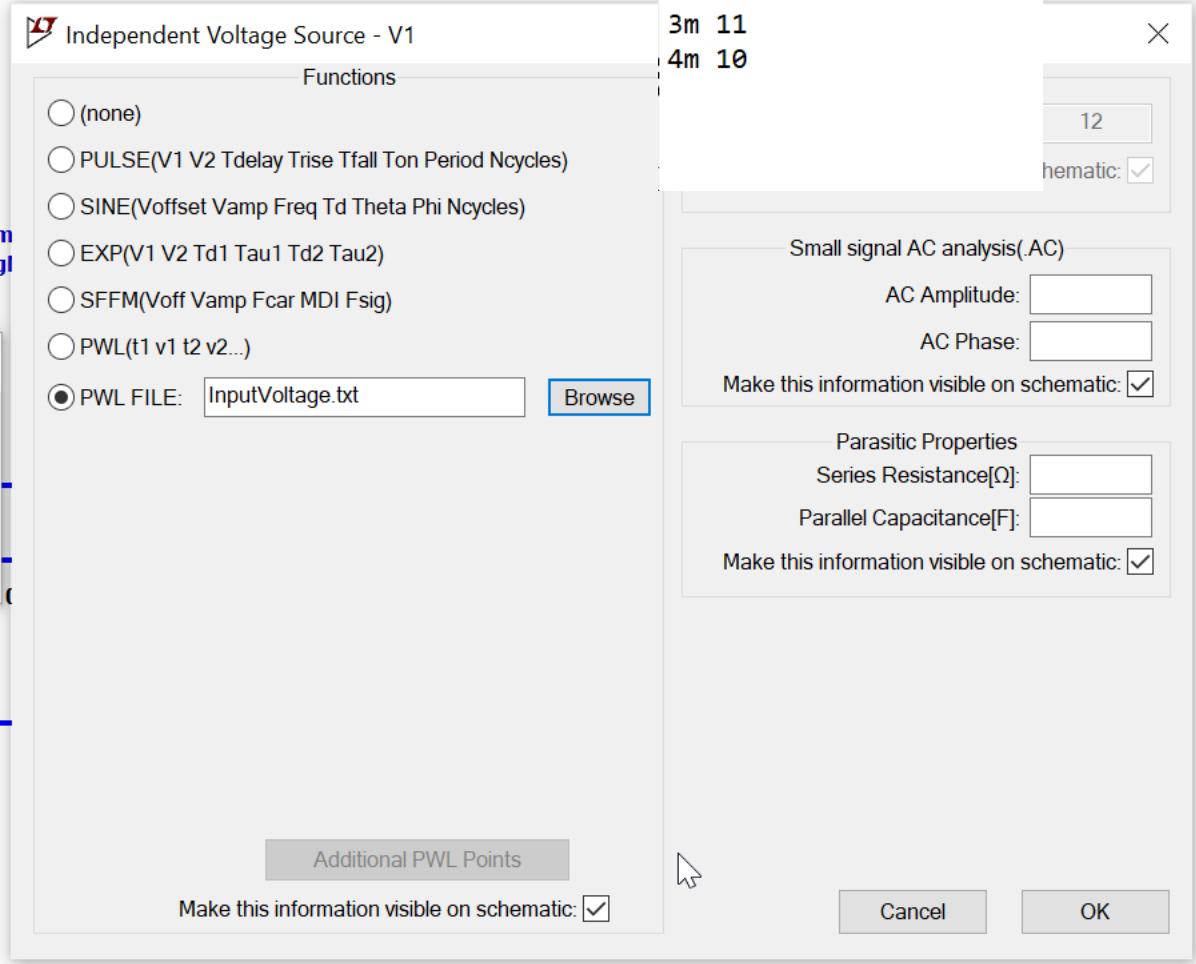


Task 3: Import txt file as source

- Save a new text file with extension .txt with the data:
- Right click at input voltage source Select pwl(piece wise linear file)

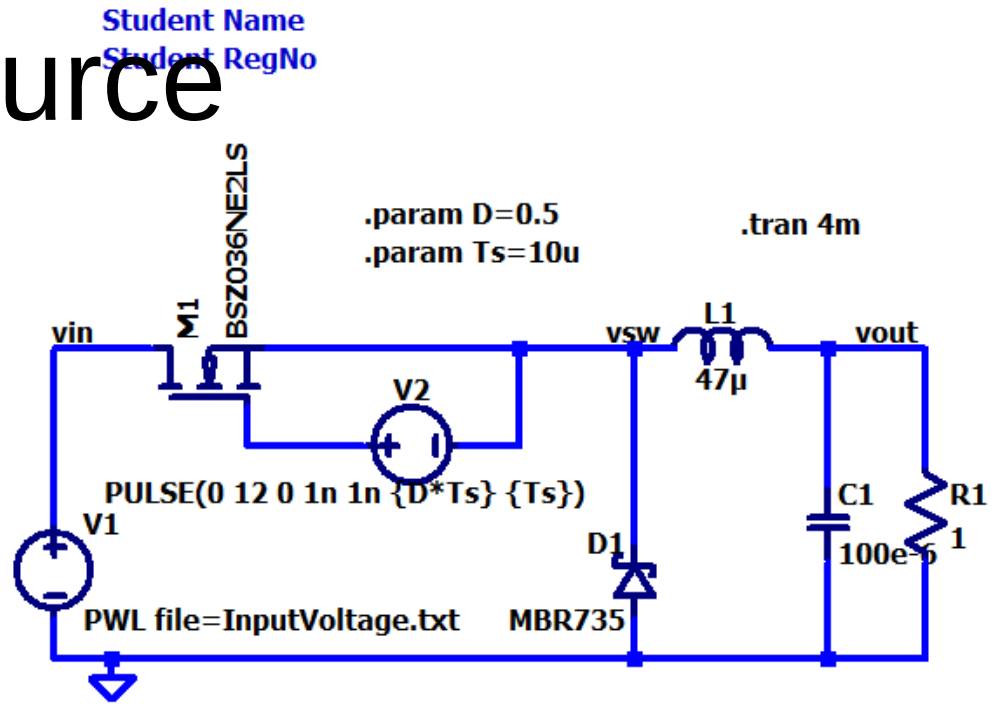


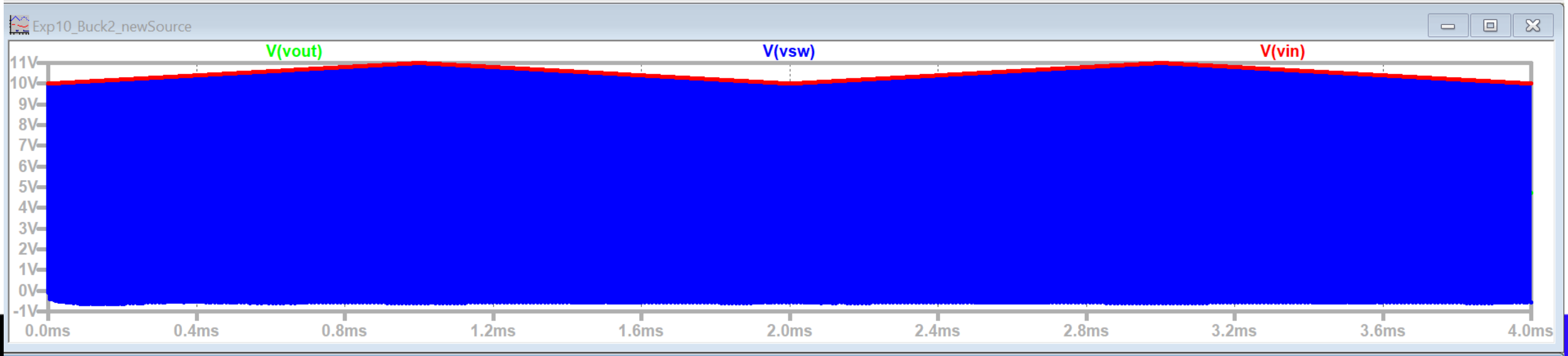




Task 3: Import txt file as source

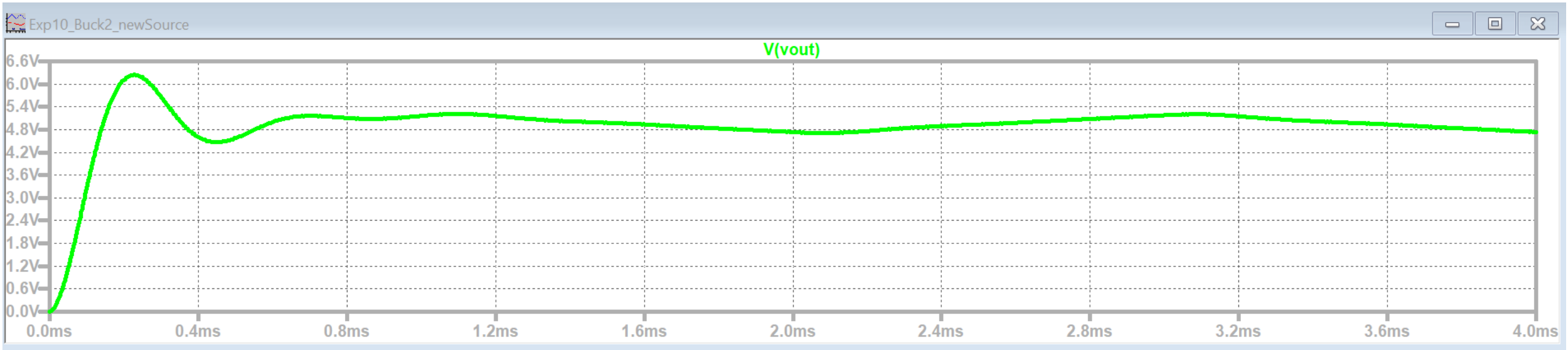
- Input voltage source is in RED
- Blue represents the switching voltage





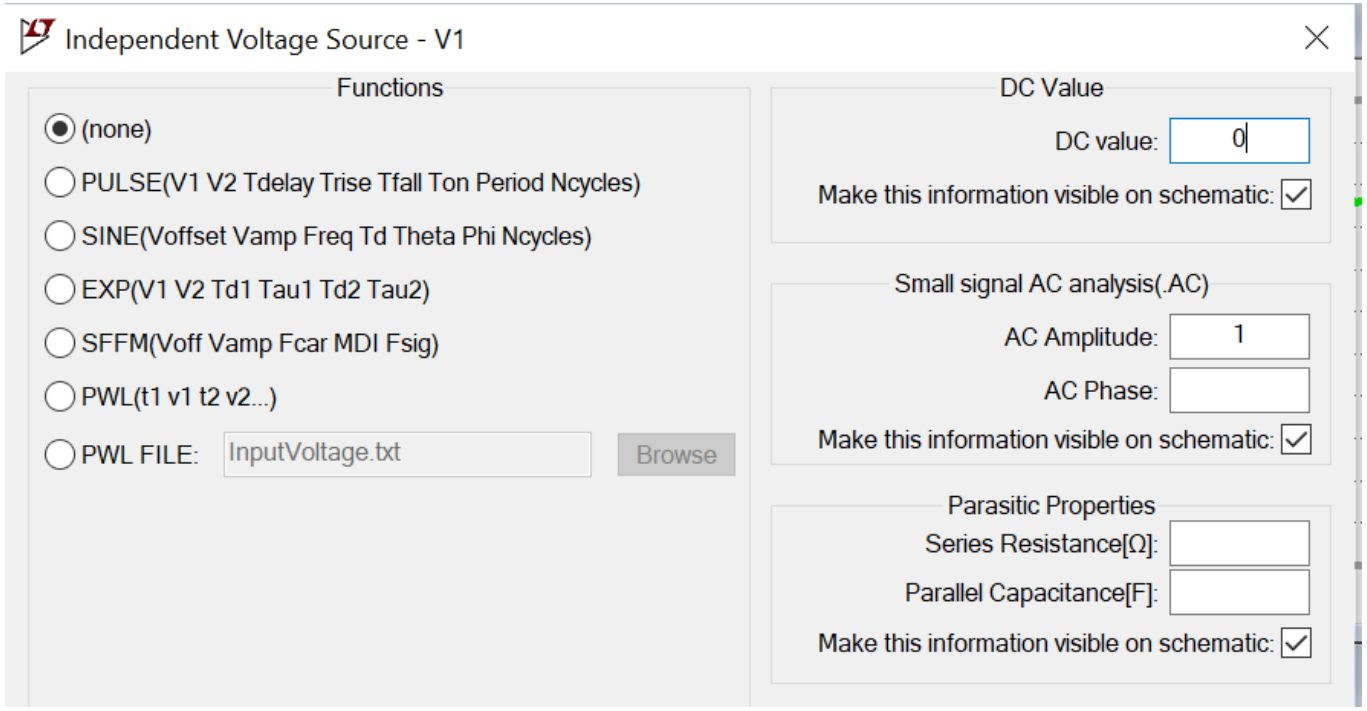
Task 3: Import txt file as source

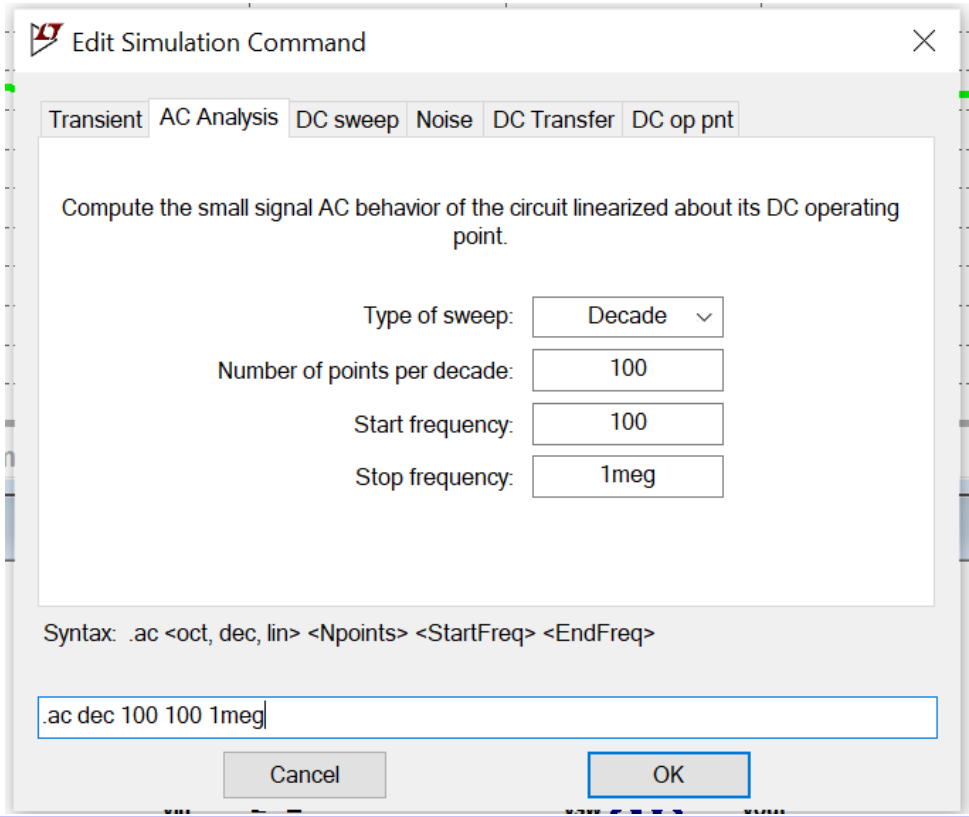
- Vout



Task 4: AC analysis

- Replace V2 pulse source to DC (12V)
- Replace V1 input voltage to DC (0V) with an ac amplitude of 1V
- Set simulation as ac analysis:

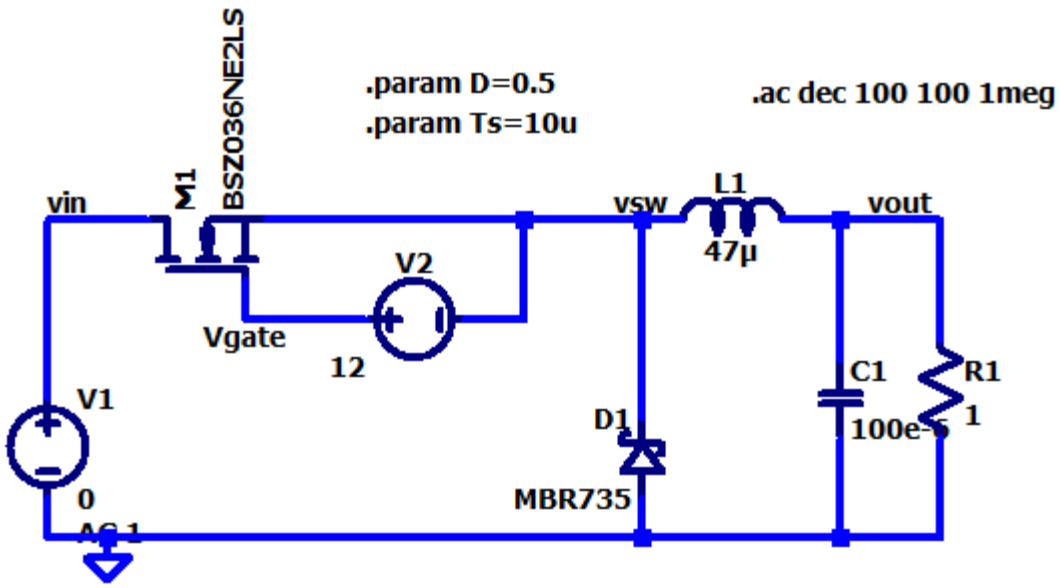


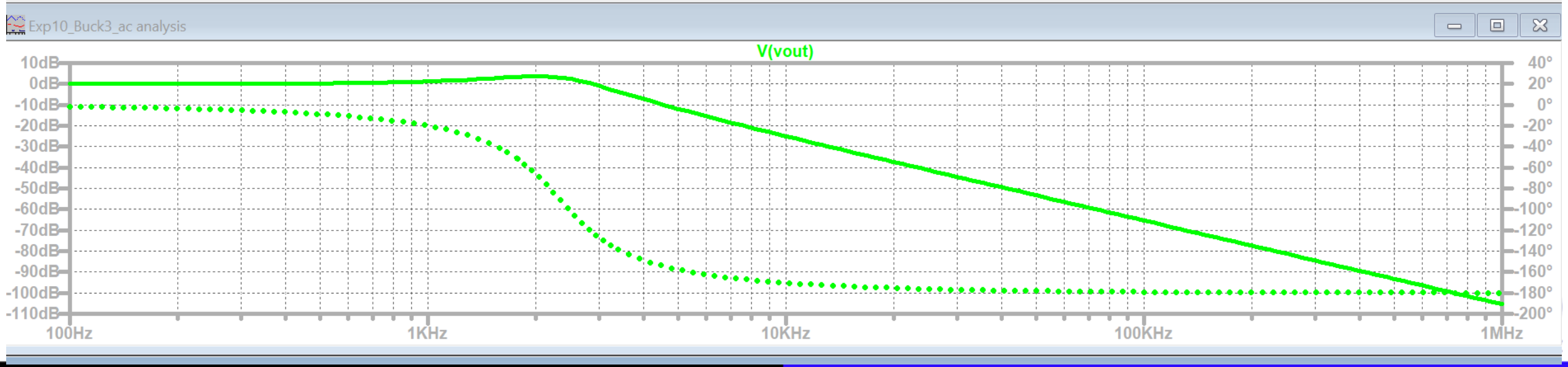


Student Name
Student RegNo

Task 4: AC analysis

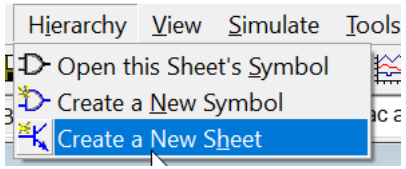
- Close to DC: unity gain
  After resonance: the drop in gain
- After DC: notice the Phase shift

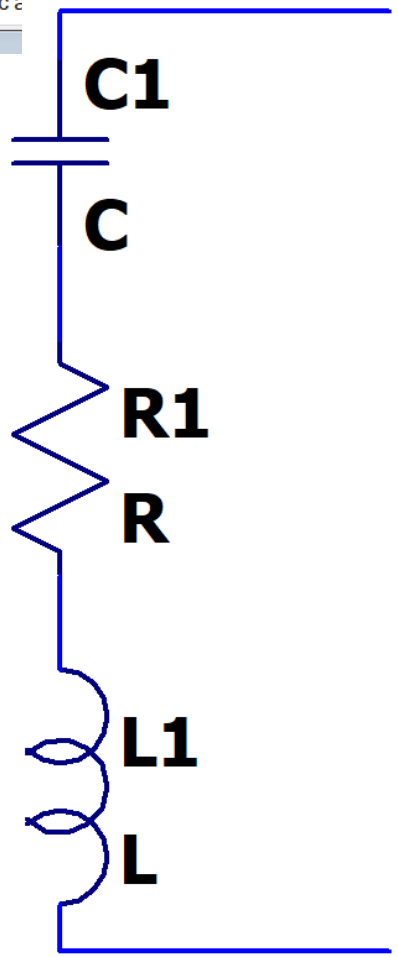


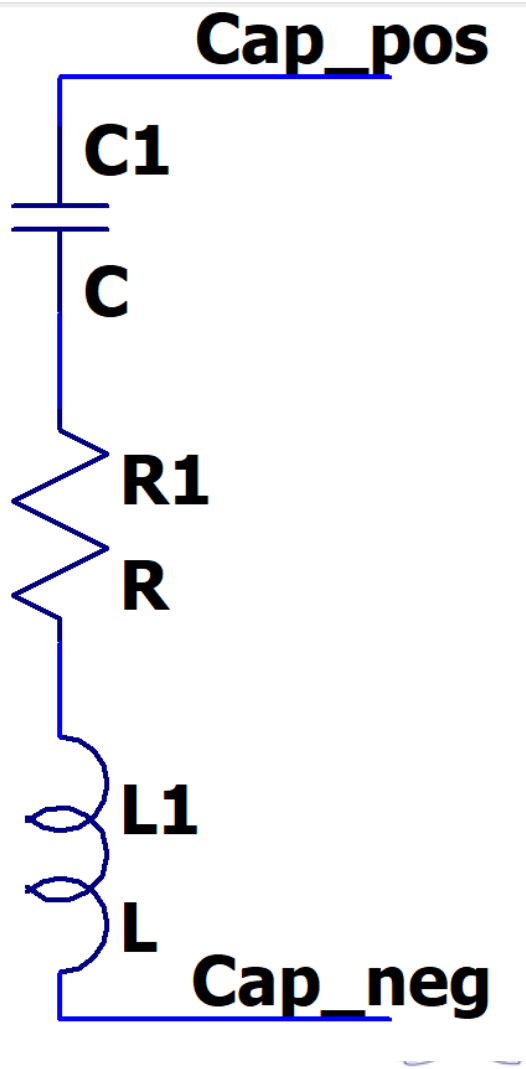


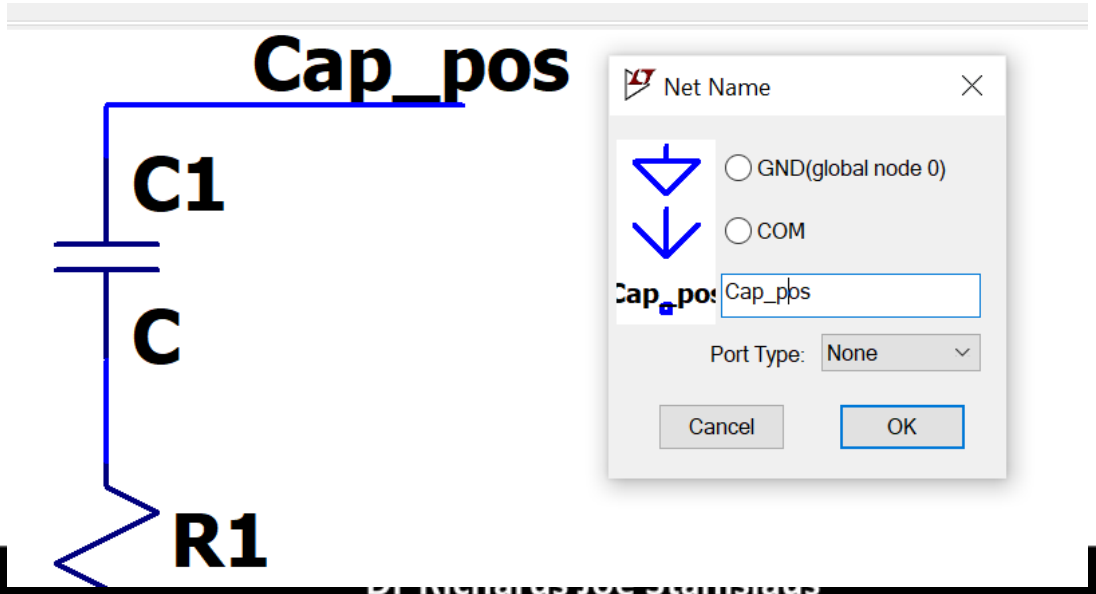
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

- Delete the 100uF capacitor.
- Go to Hierarchy -> New sheet
  Place the three passive components (C, L and R) in series.
  Add labelnets to end terminals.



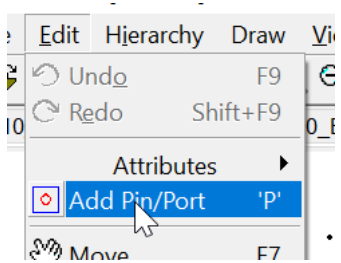


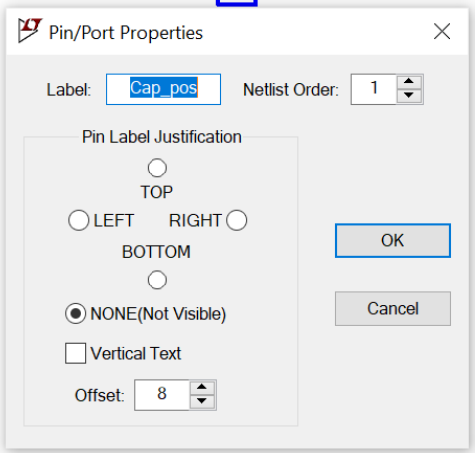


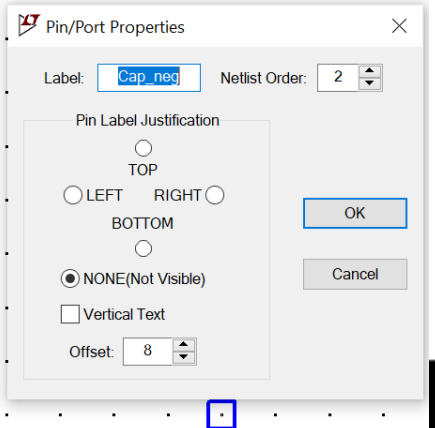


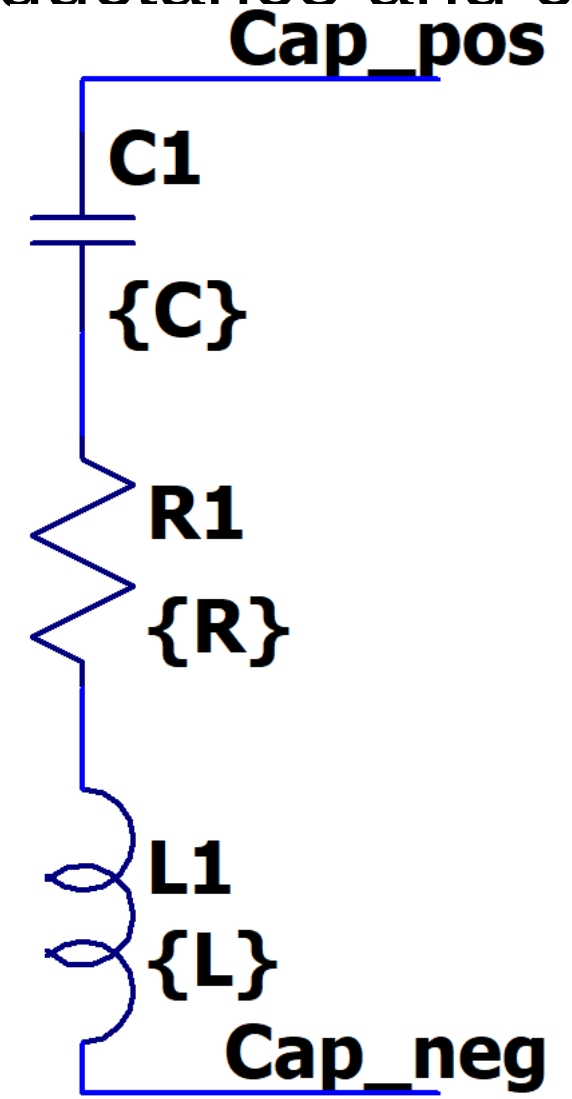
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

- Change the values as parameters: {C}, {R} and {L}
- Save as “my_cap.asc”
- Once sub-circuit is complete Hierarchy->Create New symbol
- Edit-> Add Pins/ports Use same labelnet names



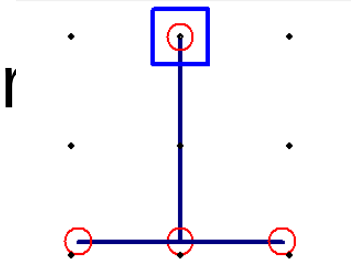


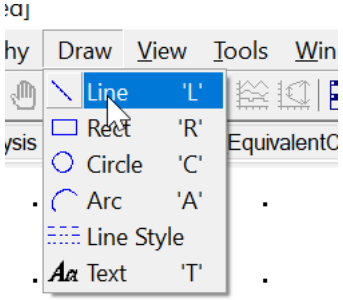


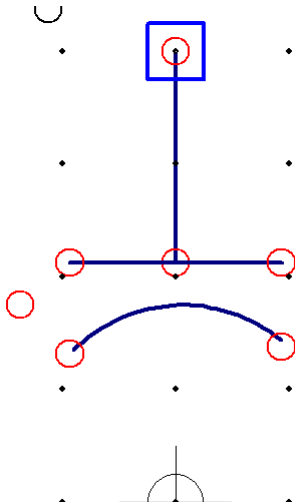


Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

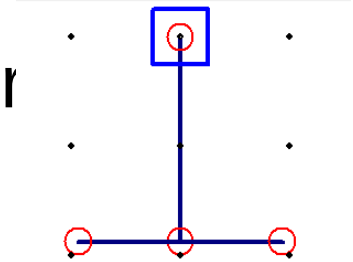
- Remember the netlist order
- To draw between the pins, Draw -> line or arc



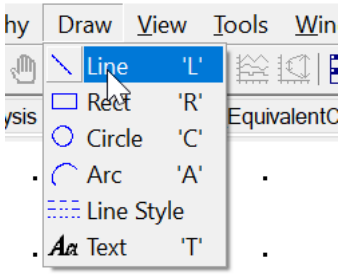




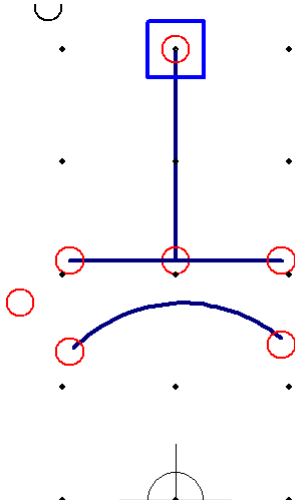
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance



- Remember the netlist order
- To draw between the pins, Draw -> line or arc



- To draw arc: select arc->



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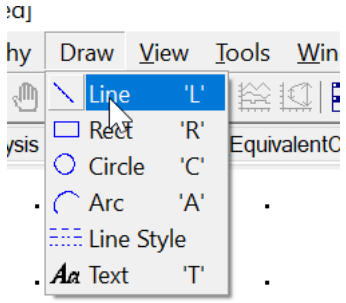
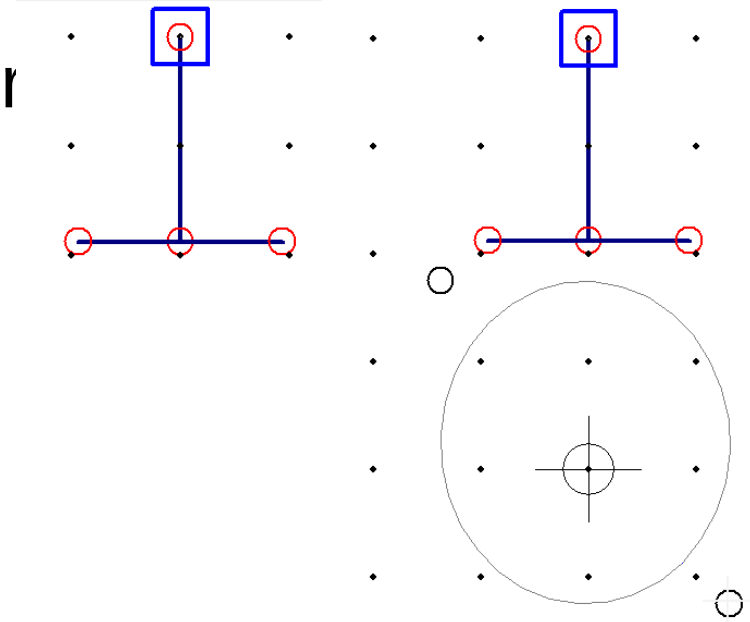
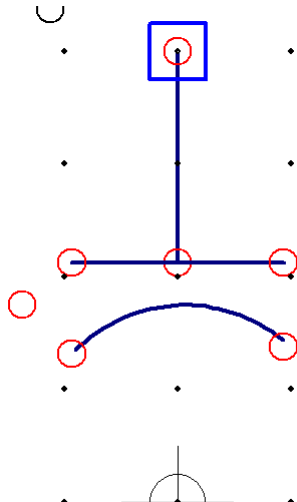
- To draw between the pins, Draw -> line or arc



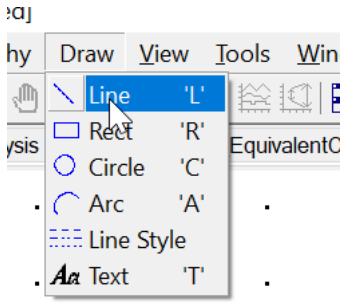


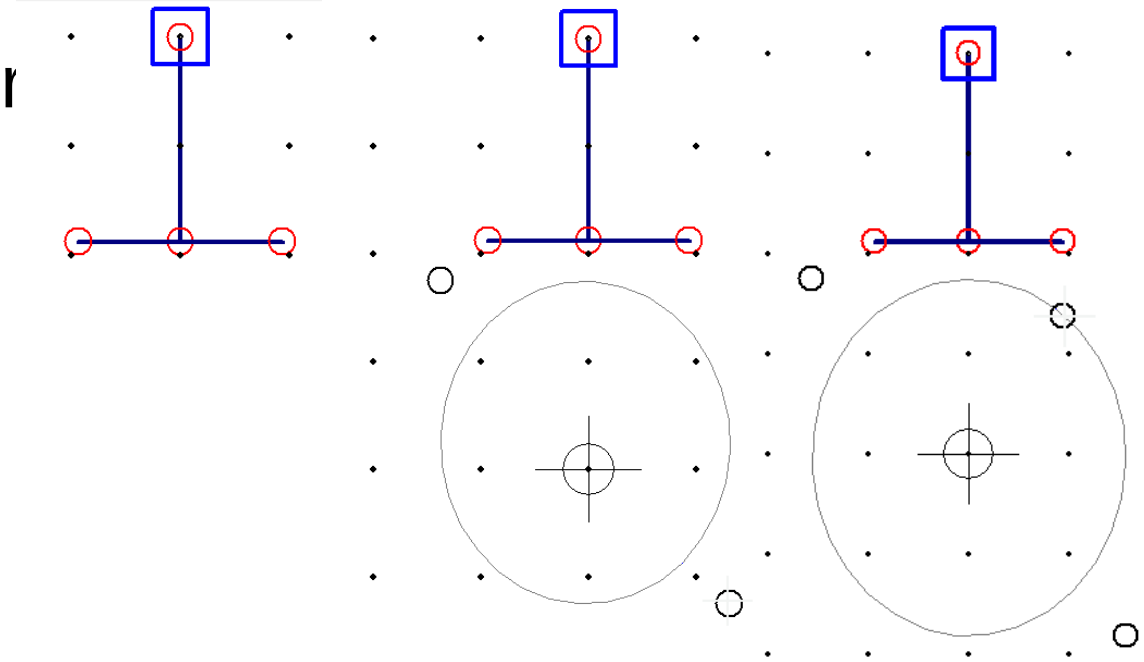
- To draw arc: select arc-> Draw an ellipse,



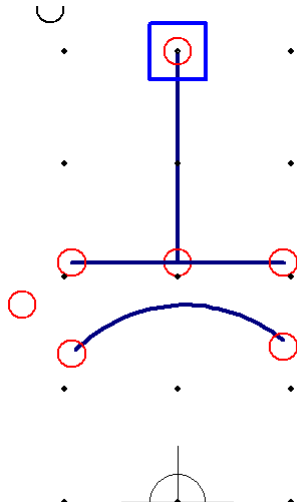
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

- Remember the netlist order
- To draw between the pins, Draw -> line or arc



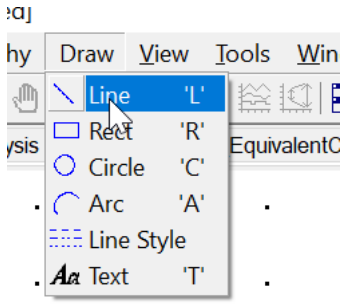


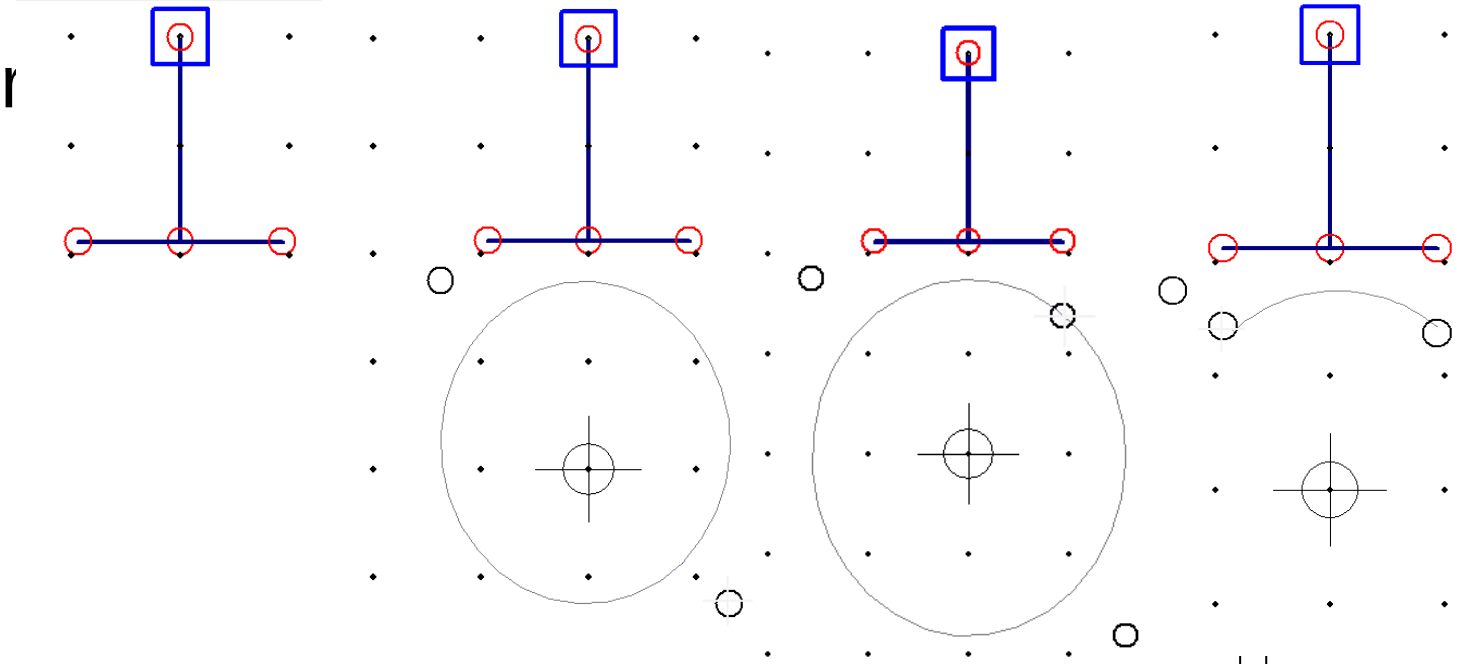
- To draw arc: select arc-> Draw an ellipse, Select the right end of arc



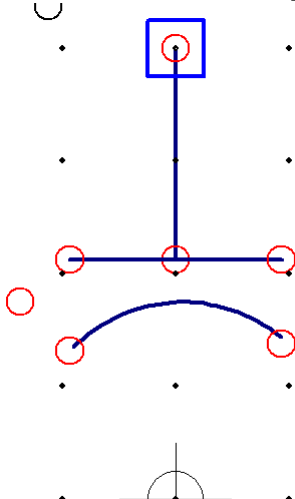
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

- Remember the netlist order
- To draw between the pins, Draw -> line or arc



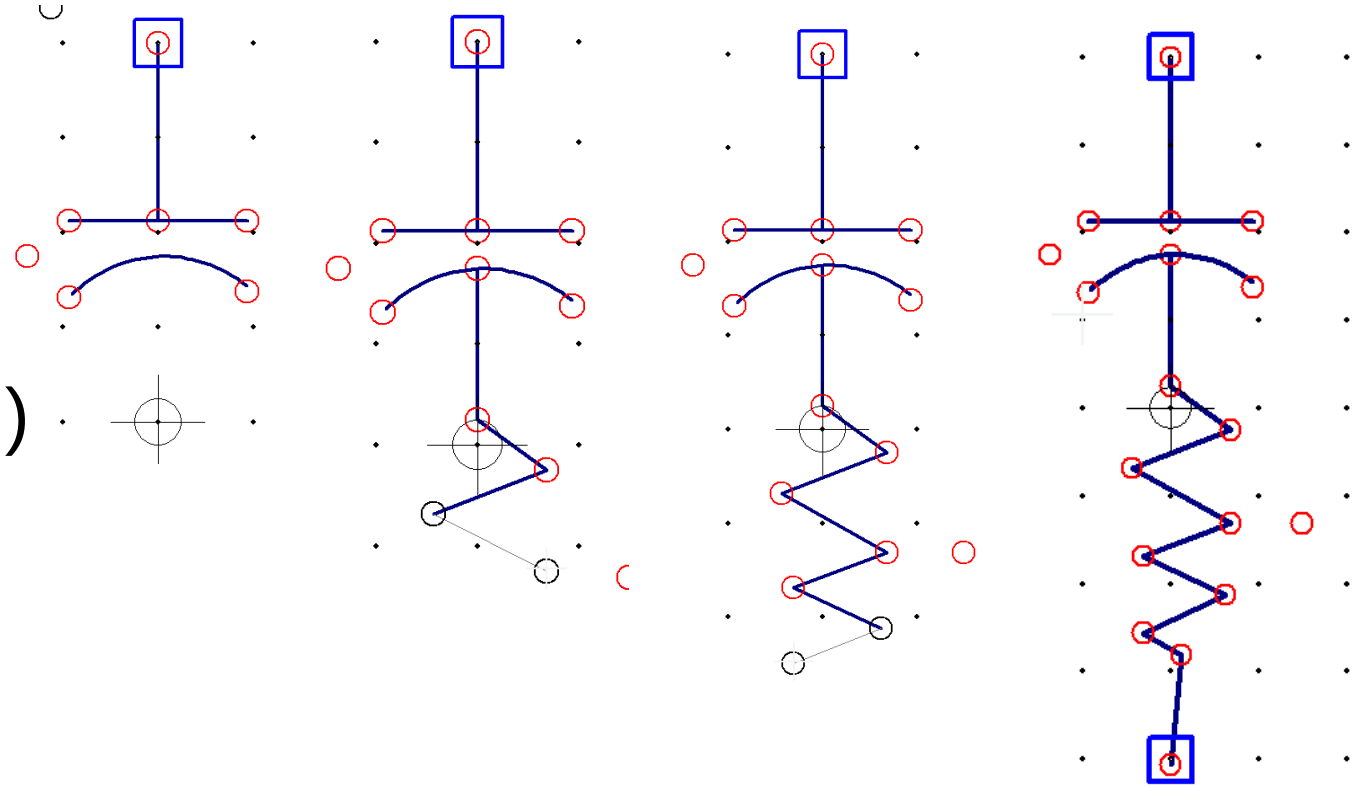


- To draw arc: select arc-> Draw an ellipse, Select the right end of arc Then select location of left end and then click.



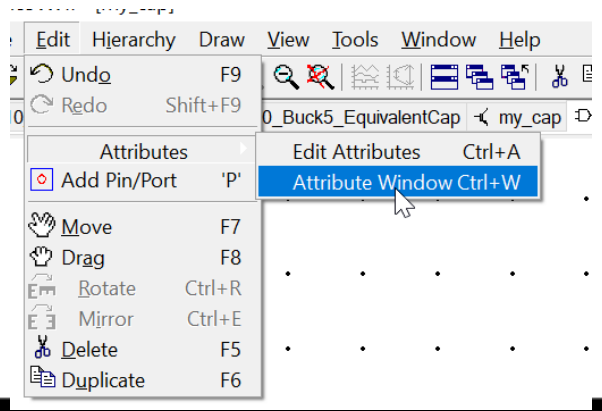
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

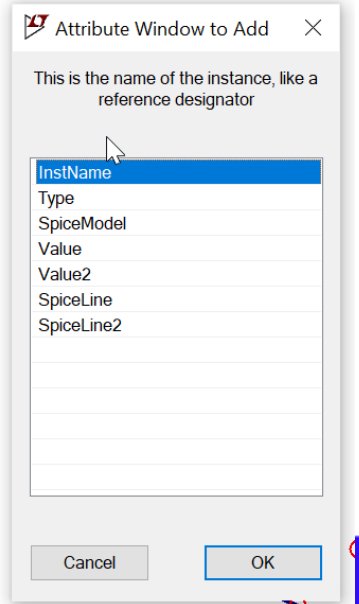
- Using Draw -> Line
  Complete the custom symbol
  as Capacitor with series resistor
- File-> Save-> my_cap.asy
  (same name with .asy for symbol)

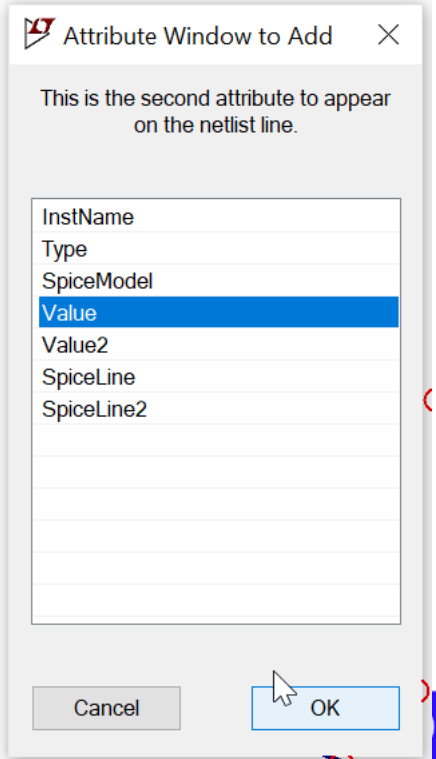


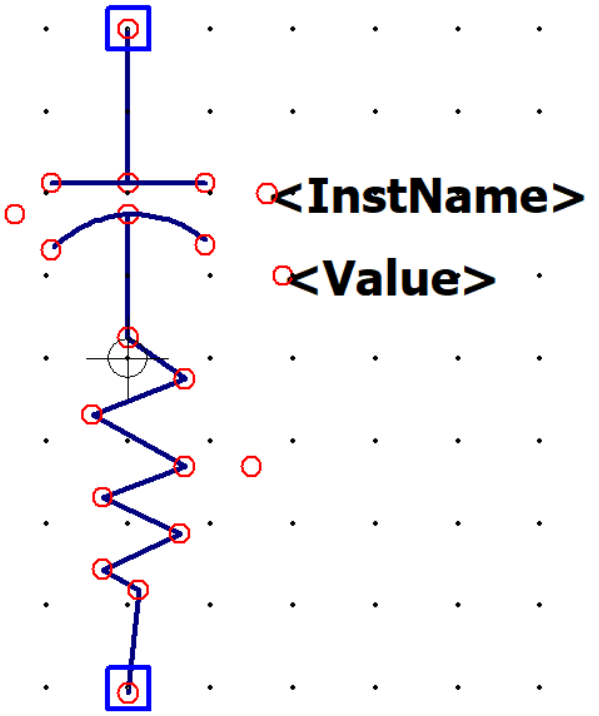
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

- Using Draw -> Line
  Complete the custom symbol
  as Capacitor with series resistor
- File-> Save-> my_cap.asy (same name with .asy for symbol)
- Edit-> Attribute window-> Inst Name
  -> Value
- Close the symbol.









Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

- Open circuit of Buck converter:
  Edit-> component ->
  Search the folder where you had saved the my_cap symbol.
  Place the my_cap symbol instead of Capacitor in the initial circuit of 4m transient simulaiton.

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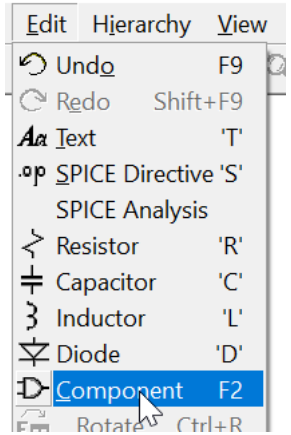
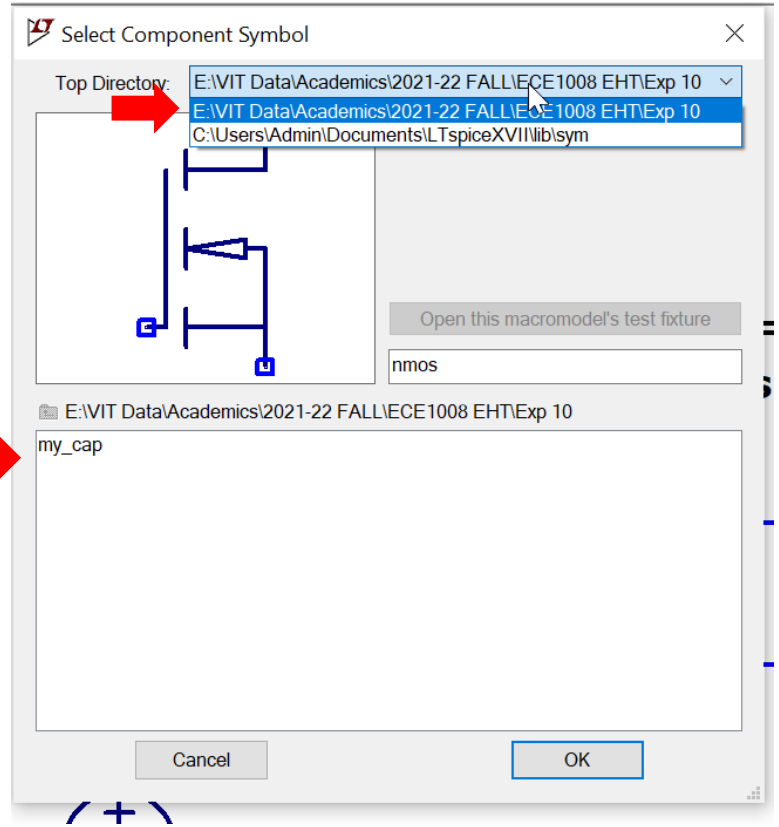
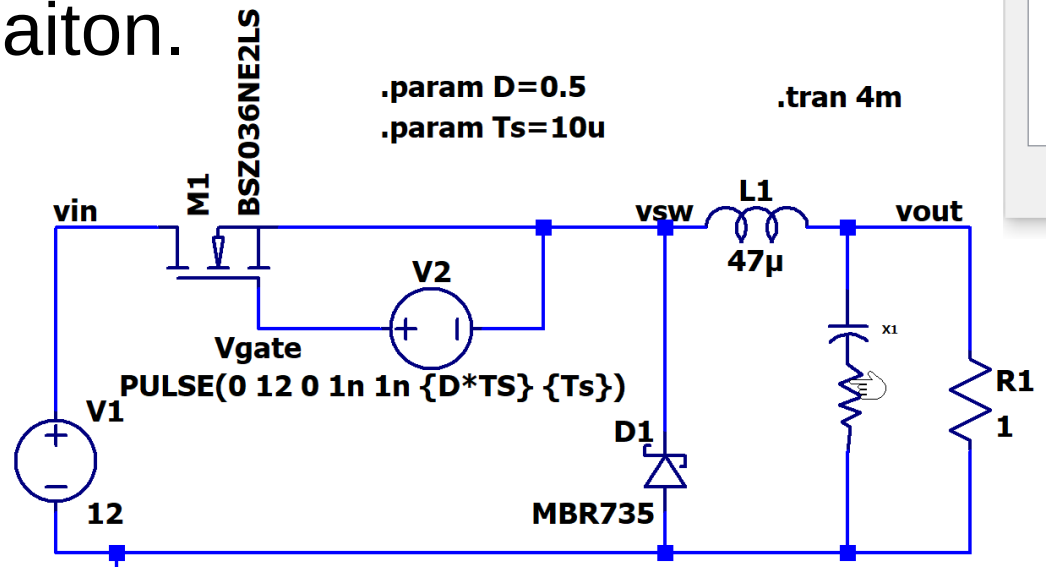




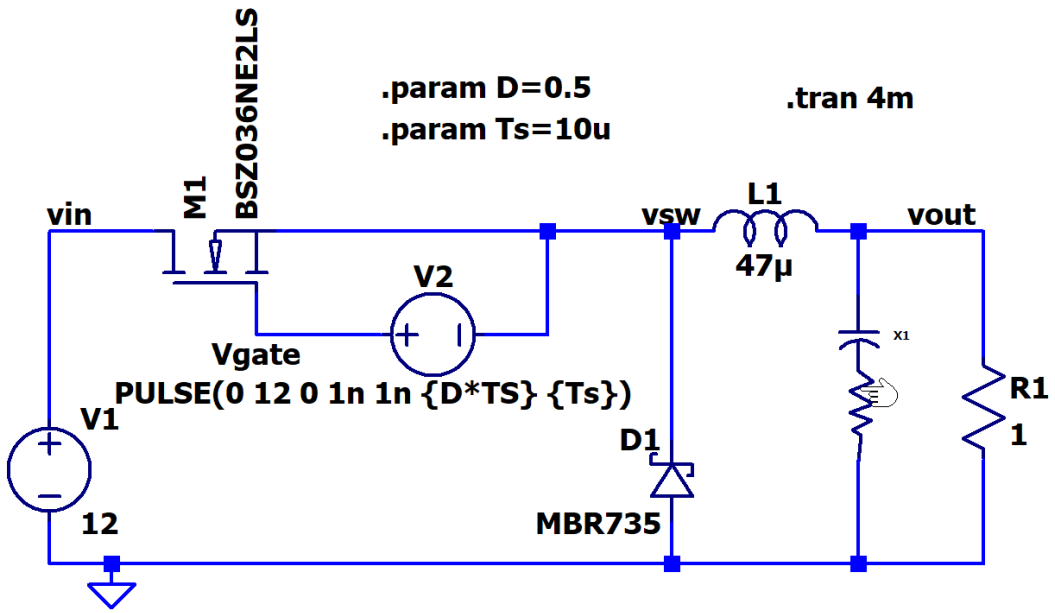


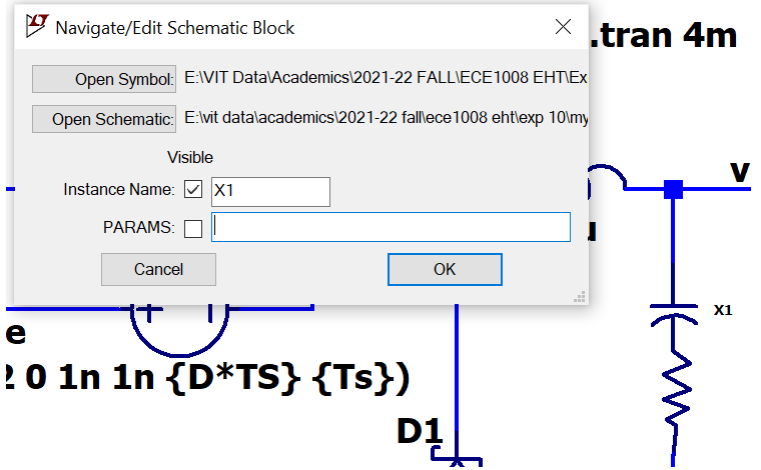
Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

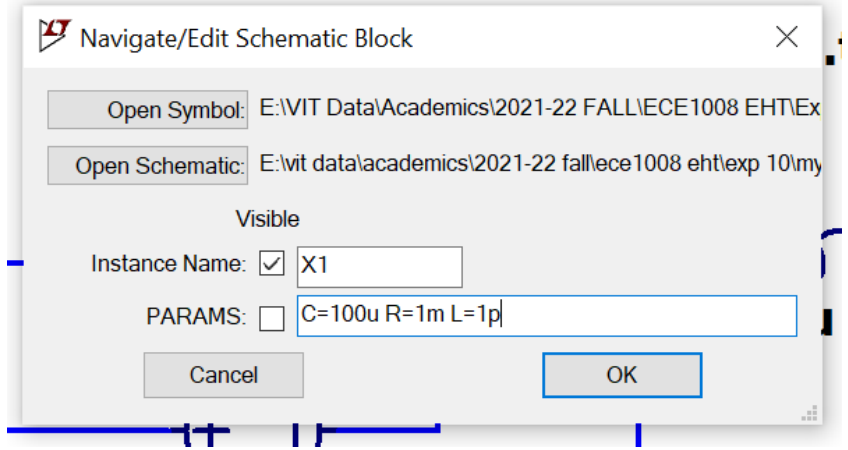
5a) Right click at the my_cap symbol and add values as
C=100u R=1m L=1p

- Simulation -> RUN

Student Name
Student RegNo

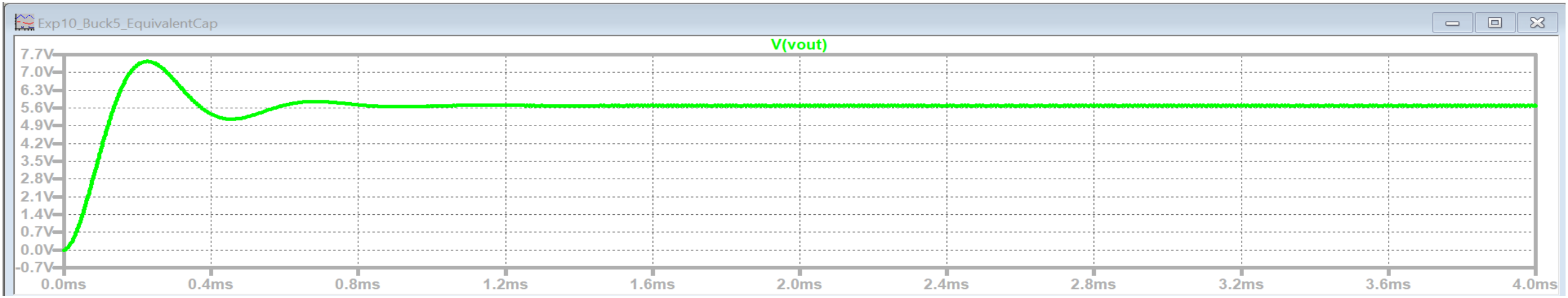






Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

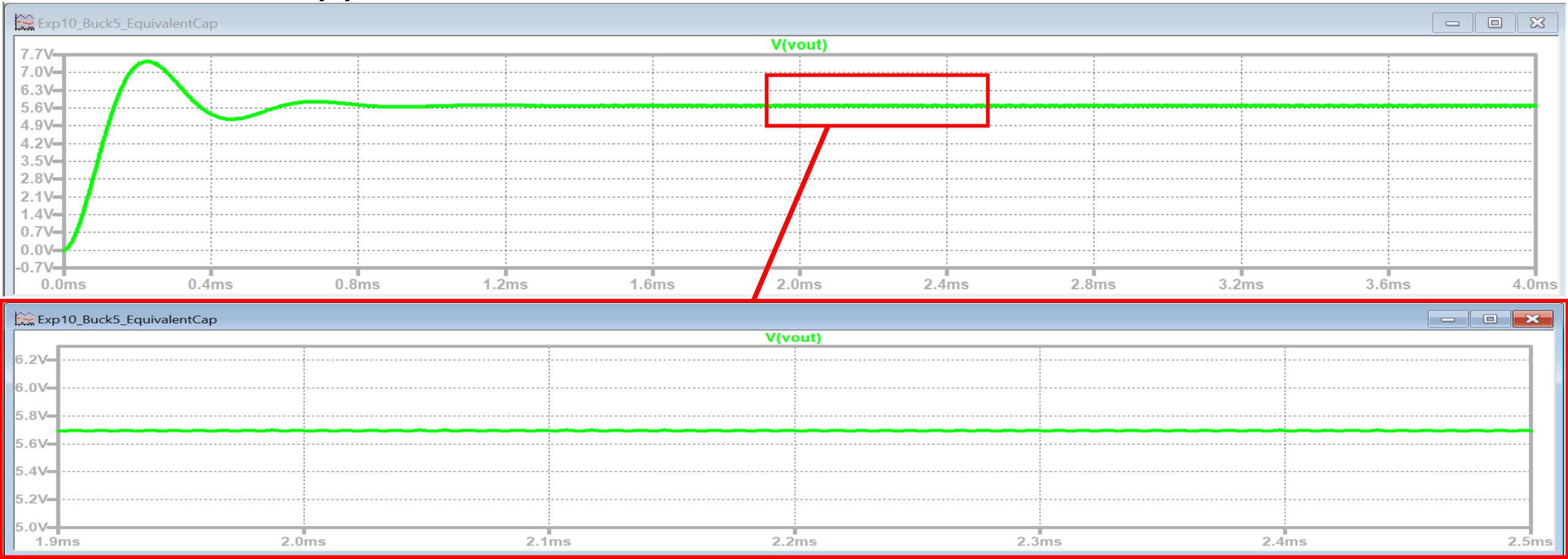
5a) C=100u R=1m L=1p (Similar to earlier circuit)



Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

5a) C=100u R=1m L=1p (Similar to earlier circuit)

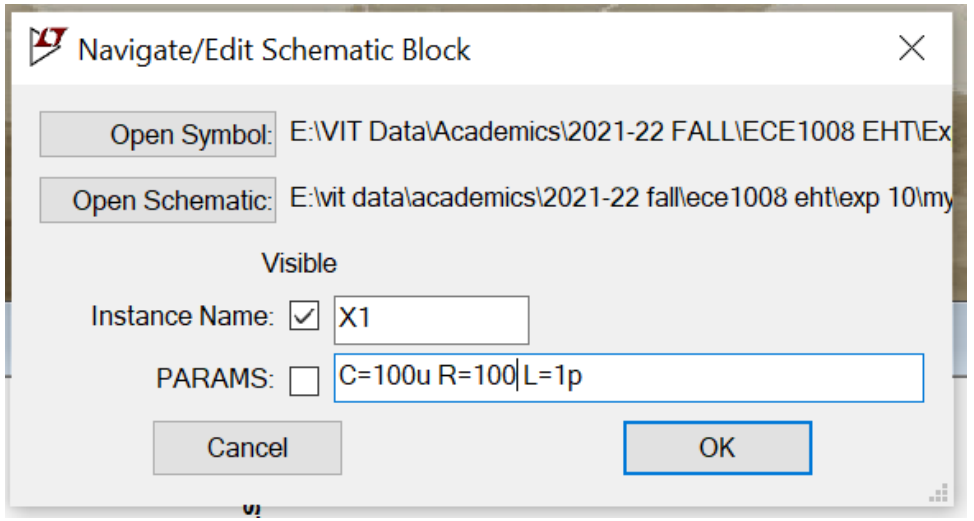
Less ripples as before.



Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

Change the resistance to 100 (unrealistic) to check if symbol works

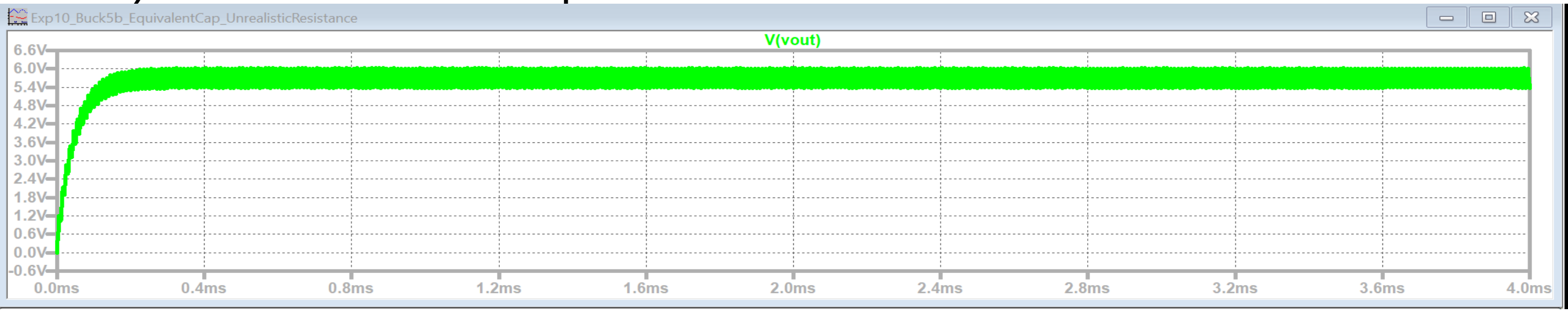
5b) C=100u **R=100** L=1p :



Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

Change the resistance to 100 (unrealistic) to check if symbol works

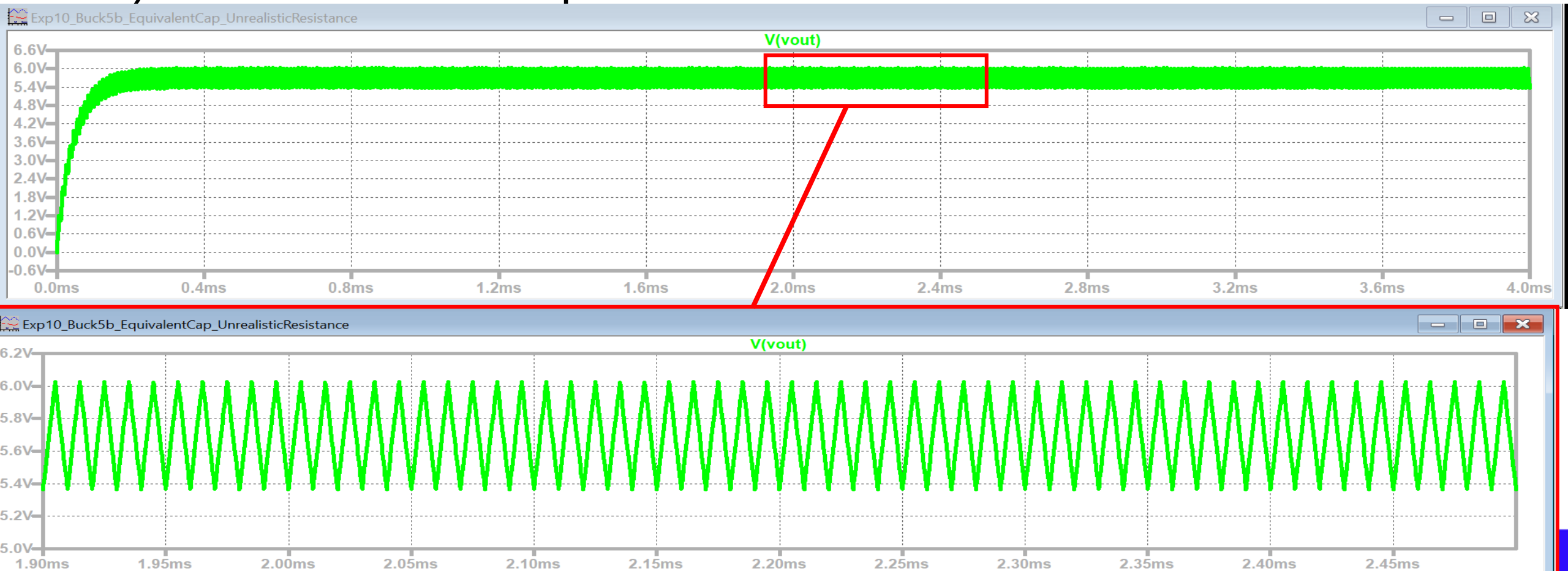
5b) C=100u **R=100** L=1p :



Task 5: To replace the ideal capacitor with model consisting of equivalent series resistance, inductance and capacitance

Change the resistance to 100 (unrealistic) to check if symbol works

5b) C=100u **R=100** L=1p :



Important NOTE

- Enter your **registration number** and **Full Name** next to

  all your circuits and
  the output plots.
- Keep the background of circuit and plot as white.

LAB record instructions:

For the lab experiment,

- Write the **Aim**.
- Complete the **Software/Hardware components used**.
- **Obtain the expression for the outputs.**
- Place the respective **circuits in LT Spice**.
- Connect the inputs and outputs. Name them and **write the same in the lab copy(inputs and outputs section)**.
- Use probe in LT spice to plot all possible combinations.
- Write a **concluding statement for each circuit**.
- **Submit** the document's soft copy **on time** in lms.vit.ac.in when available.