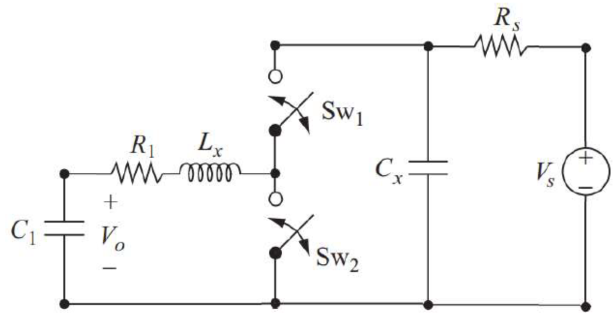
- Simulate a bi-directional DC/DC converter.

Data:

- Vs = 1000 V (DC) (Rs=1 mOhm)
- L = 50 uH (R1=1 mOhm)
- Cx = 50 uF
- C1 = 5 F (initally charged to 500 V)
- f = 10 kHz
- Start with D = 0.5



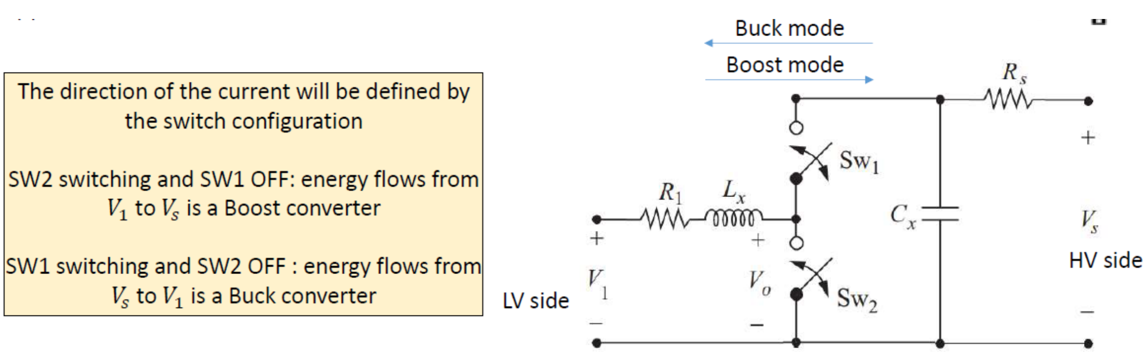
a) Define D = 0.8 and then D = 0.3 and plot the power exchanged and C1 voltage

b) Show the bidirectionality : Exchange C1 and Vs, with Vs=500 and C1 charged to 1000V, and repeat point a)

Question 1: Define D = 0.8 and then D = 0.3 and plot the power exchanged and C1 voltage

Answer 1:

A bidirectional DC-DC converter enables power flow in both directions between two DC sources, typically used in applications where energy needs to be transferred back and forth, like battery management systems, regenerative braking in electric vehicles, and energy storage systems.



The converter has a bidirectional power flow which means it can operate in both buck (step-down) and boost (step-up) modes, depending on the control of the switches. Buck mode is used when energy flows from a higher voltage source to a lower voltage load (charging a battery), while boost mode is used when energy flows from a lower voltage source to a higher voltage load (discharging a battery to power a DC bus).

Buck mode:

a) **D = 0.5 (Start with D = 0.5 in the text of the Lab)**

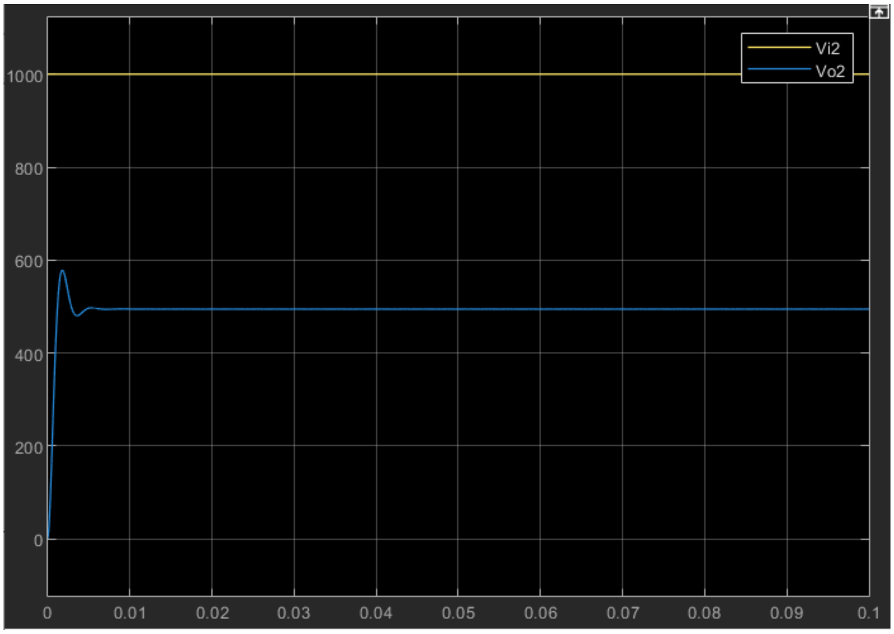


Figure 1 Output/Input Voltage

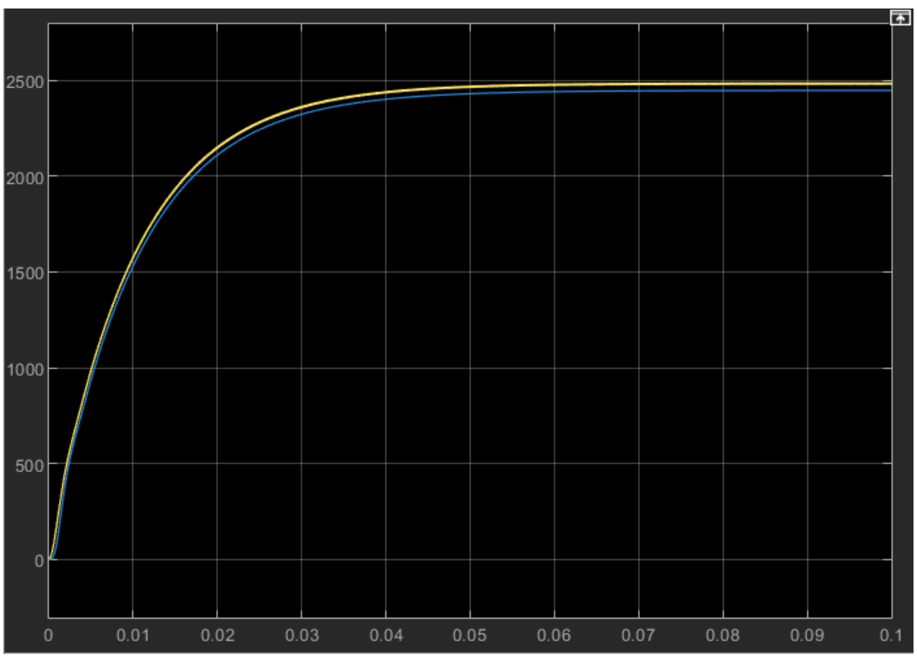


Figure 2. Output/Input Power

b) D = 0.8

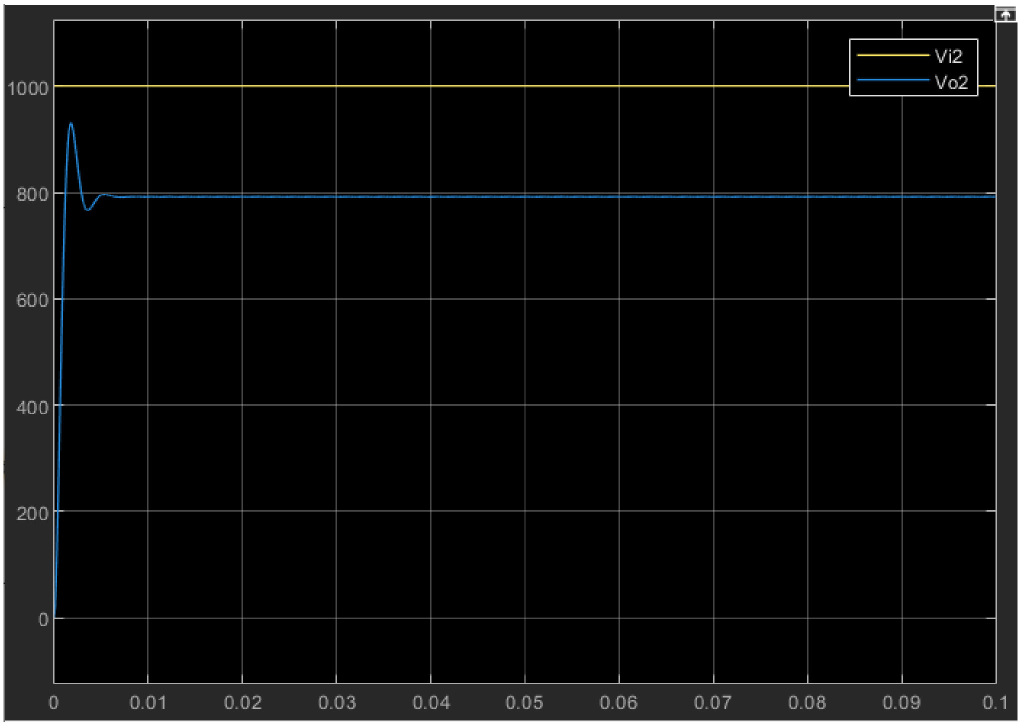


Figure 3 Output/Input Voltage

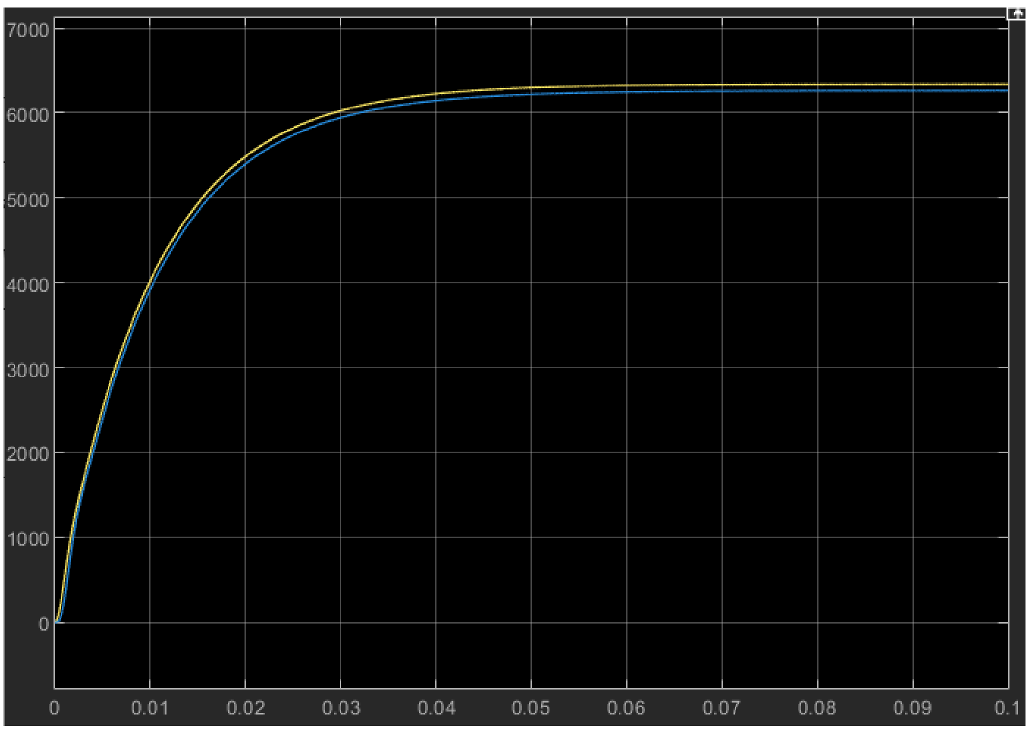


Figure 4 Output/Input Power

c) D = 0.3

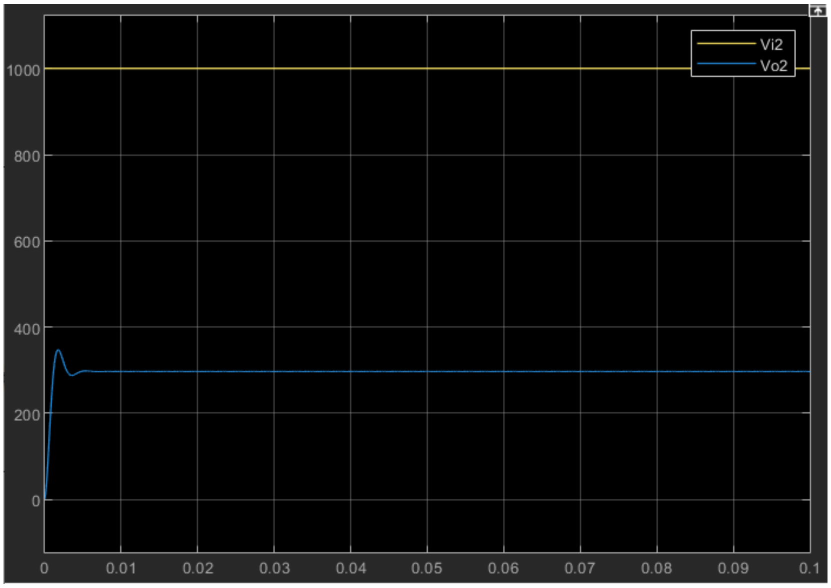


Figure 5. Output/Input Voltage

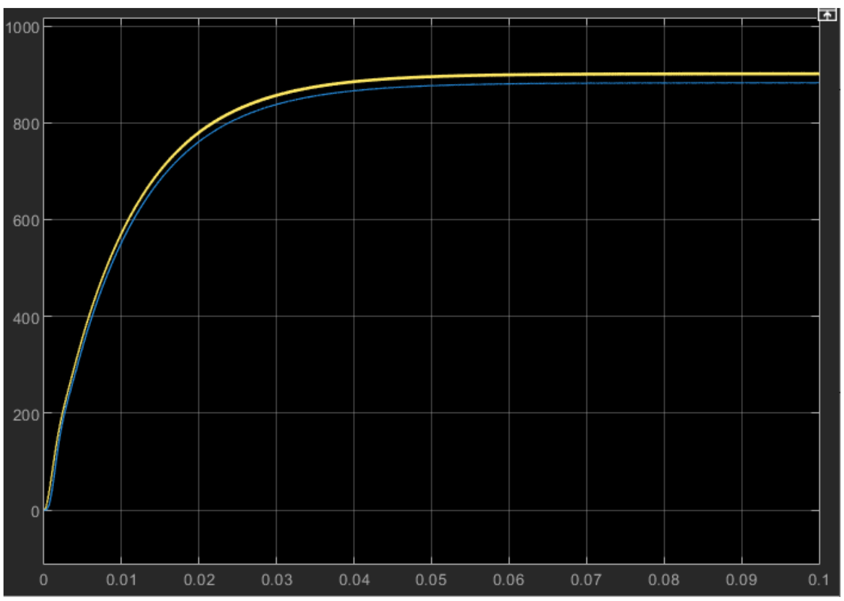


Figure 6 Output/Input Power

As can be seen on the graphs the output voltage is lower depending on the value of D.

In an ideal bidirectional DC-DC converter, the power on the input and output sides are the same, minus any losses due to non-idealities like resistance in components and switching losses.

Boost mode:

Power flows from the low-voltage side to the high-voltage side (DC bus), stepping up the voltage. The direction of power flow is controlled by switches (MOSFETs or IGBTs), which are selectively turned on and off to control the current direction. Mosfet 2 is switching and Mosfet 1 is OFF: energy flows from $V0$ to Vs.

a) D = 0.5

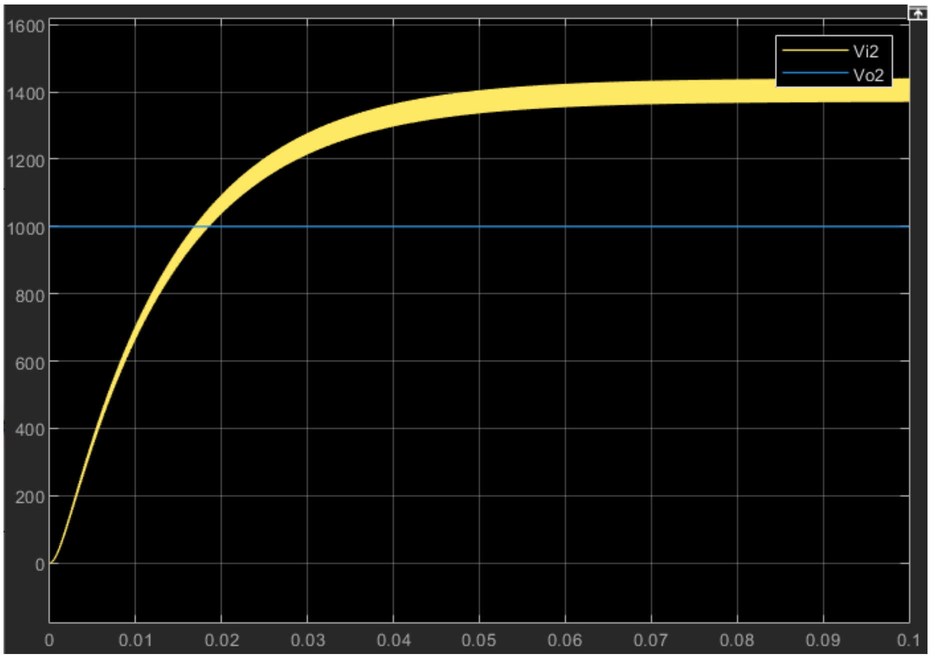


Figure 7 Output/Input Voltage

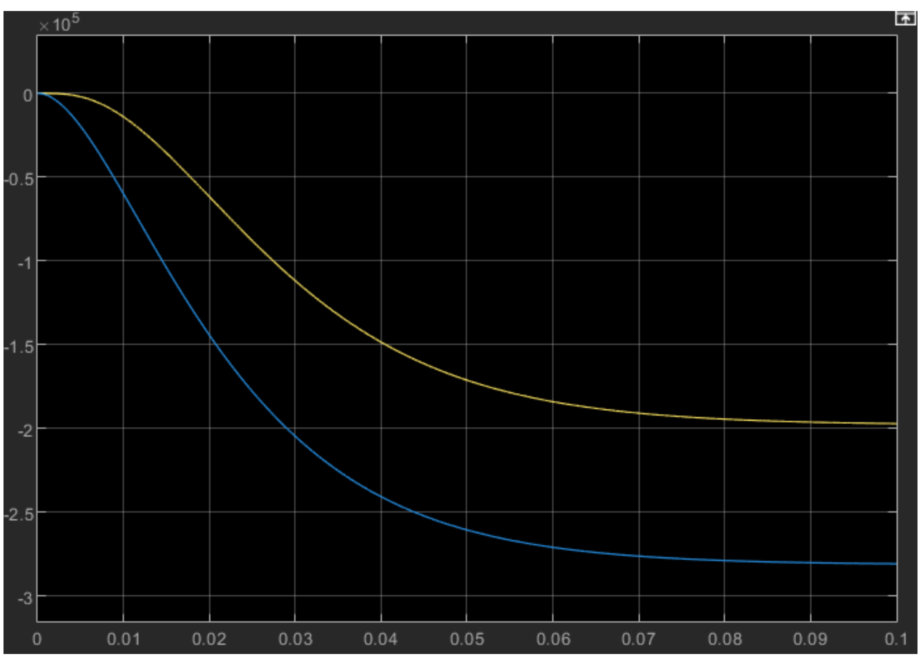


Figure 8 Output/Input Power

b) D = 0.8

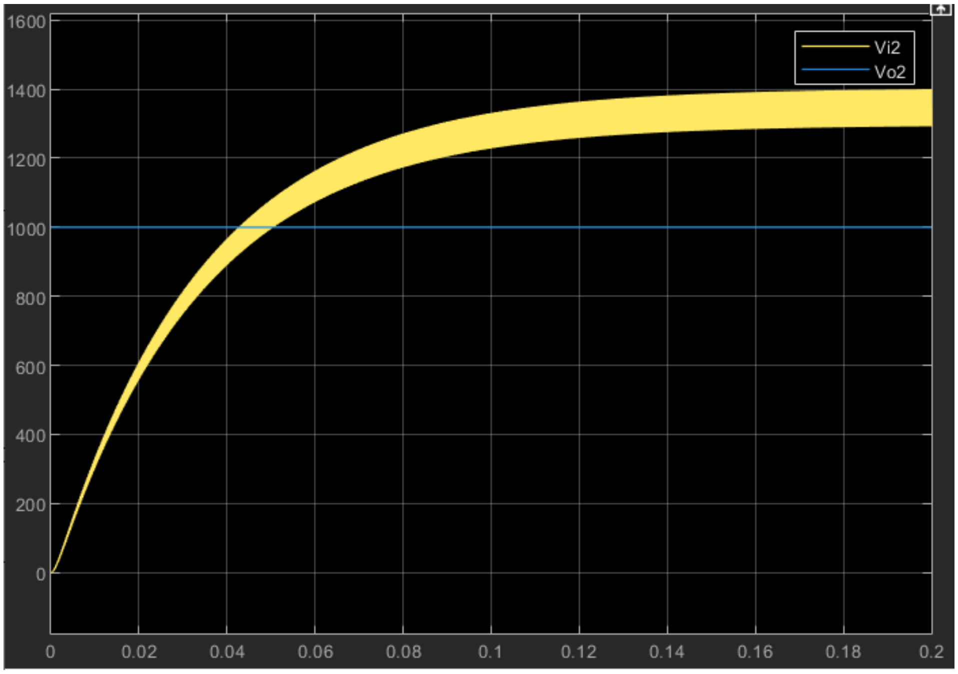


Figure 9 Output/Input Voltage

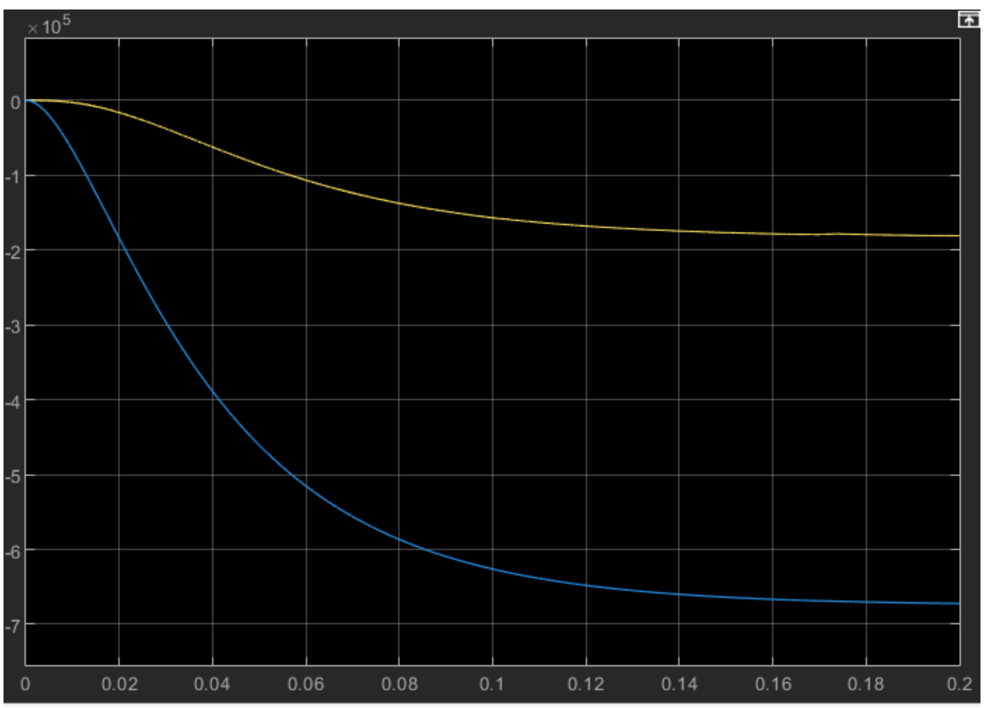


Figure 10 Output/Input Power

c) D = 0.3

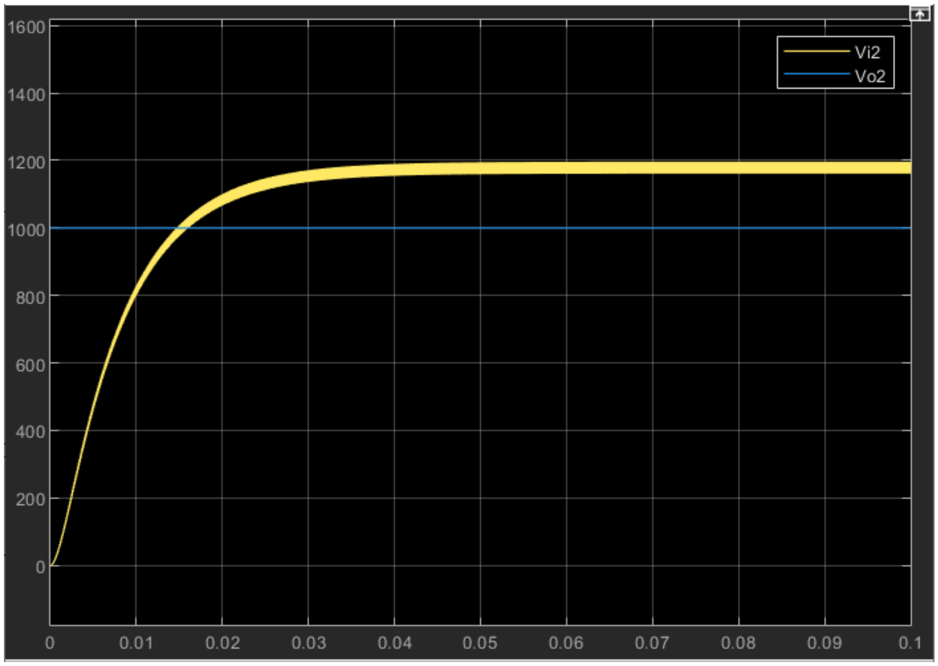


Figure 11 Output/Input Voltage

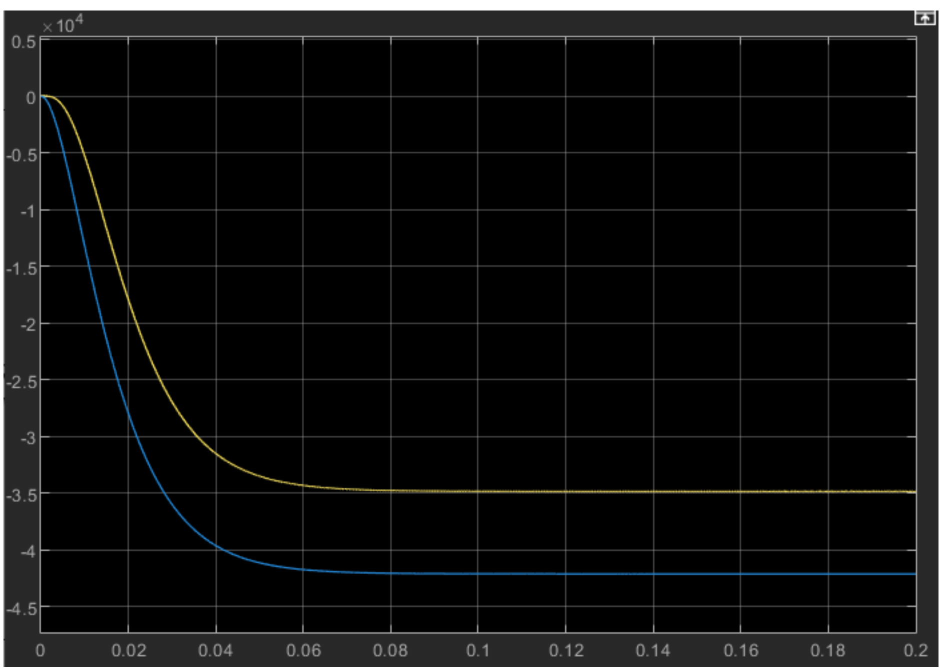


Figure 12 Output/Input Power

Question 2: Show the bidirectionality: Exchange C1 and Vs, with Vs=500 and C1 charged to 1000V, and repeat point a)

Answer 2:

a) **D = 0.5**

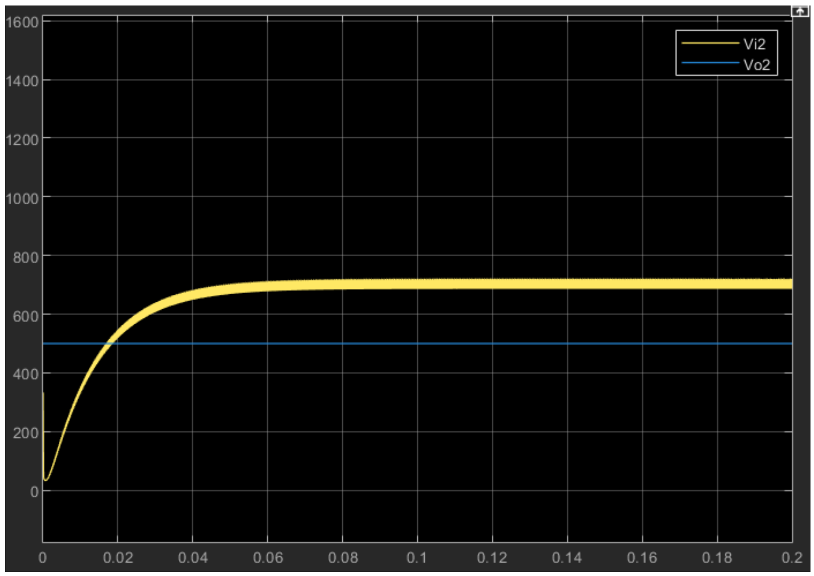


Figure 13 Output/Input Voltage

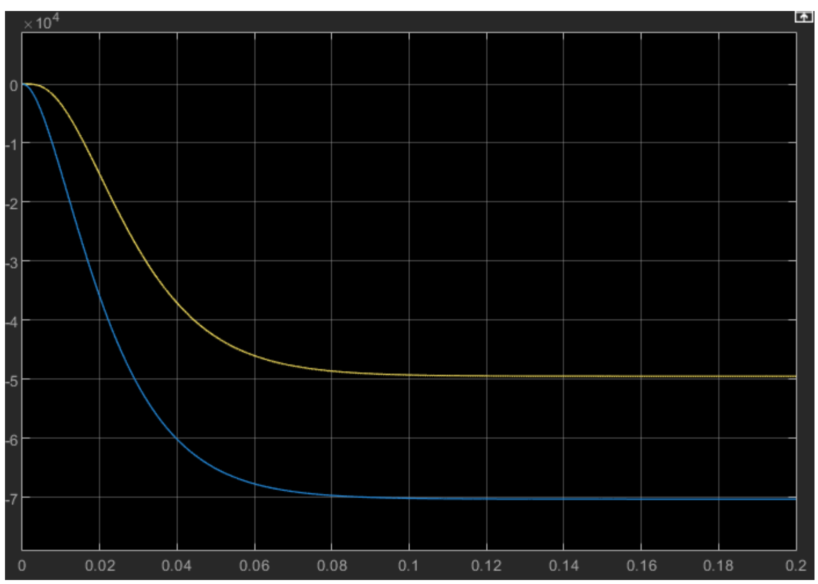


Figure 14 Output/Input Power

b) D = 0.8

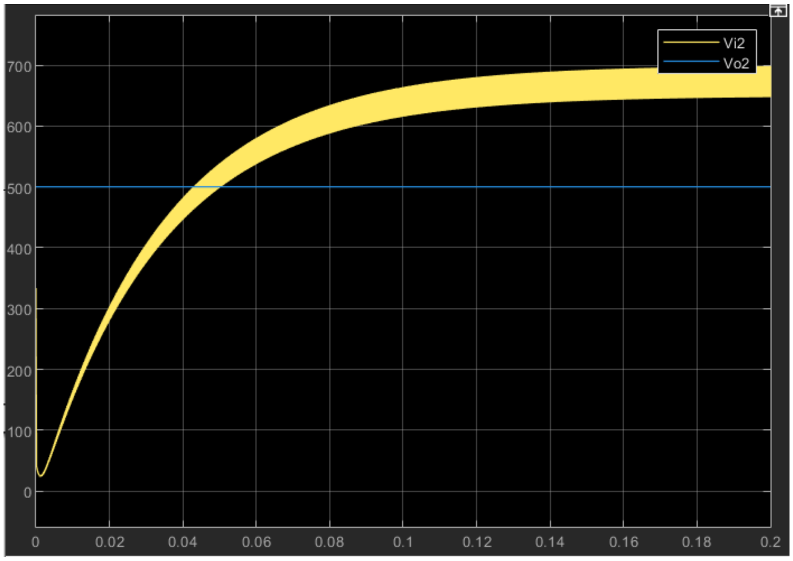


Figure 15 Output/Input Voltage

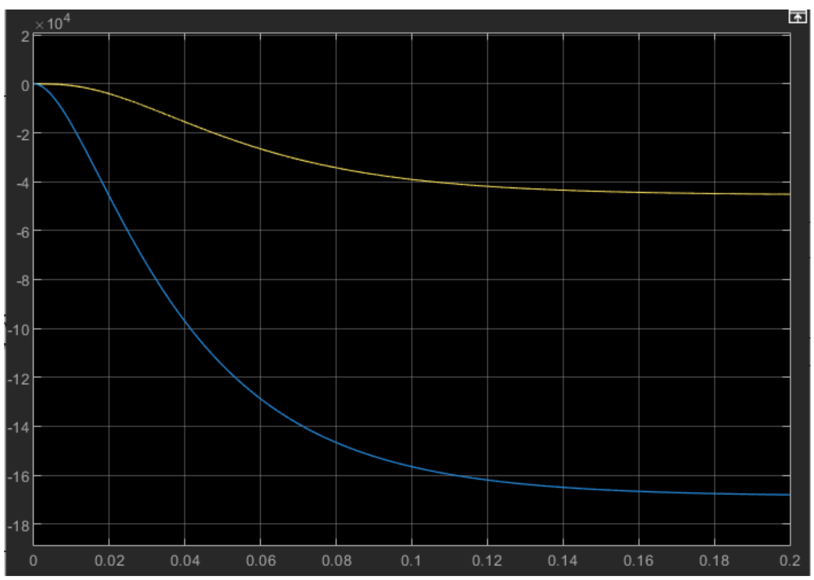


Figure 16 Output/Input Power

With a duty cycle D=0.8 in boost mode, there is a large discrepancy between the battery power (input power) and the power received by the DC grid (output power), this often indicates inefficiencies or issues in the converter (high switching losses, conduction losses in switches). Also the output voltage is the same when D = 0.5 and D = 0.8. This can indicate inductor saturation. The inductor should store more energy and release it to boost the voltage. If the inductor is saturating, it loses the ability to store additional energy, leading no increase in the output voltage regardless of duty cycle.

c) D = 0.3

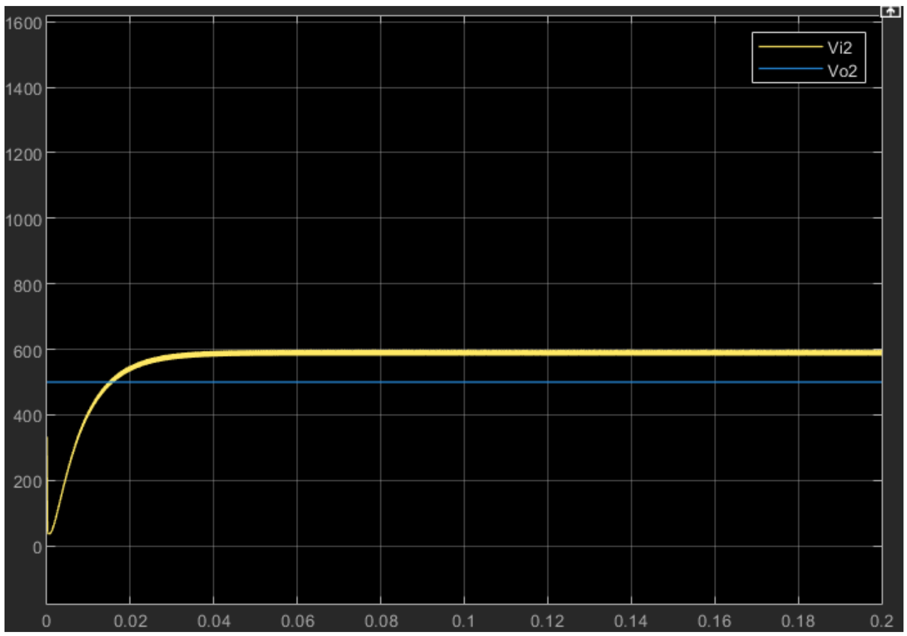


Figure 17 Output/Input Voltage

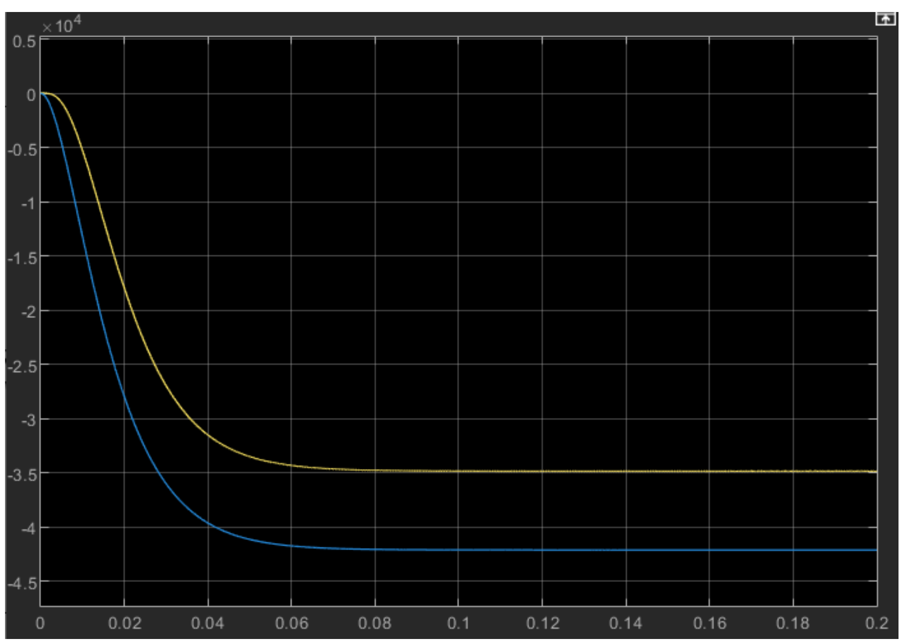


Figure 18 Output/Input Power