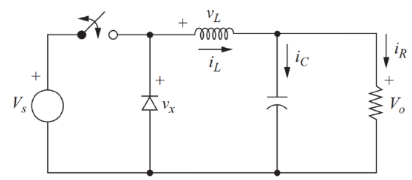
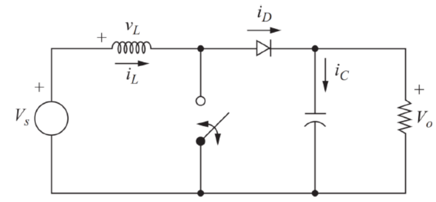
- Simulate a Buck and a Boost Converter.

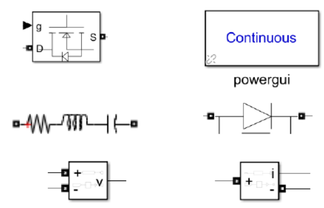
Data:

- Vs = 100 V (DC)
- L = 100 uH (r=31 mOhm)
- C = 10 uF
- R = 100 Ohm
- f = 20 kHz
- Start with D = 0.7
- Simulation time 0.1s





Electrical/Specialized Power Systems



a) Verify if the converter is in continuous or discontinuous mode.

b) Define the minimum inductor to operate in continuous mode

c) In continuous mode and D=0,7, design a capacitor to achieve 1% voltage ripple

d) Raise the curve between Vo and D (Vo for different values of D)

e) Raise the curve between efficiency and D (Vi/Vo for different values of D)

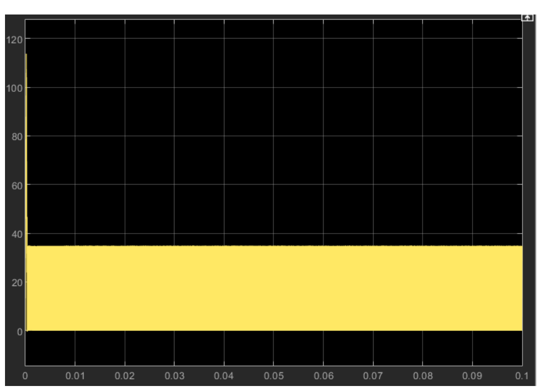
Question 1: Verify if the converter is in continious or discontinious mode.

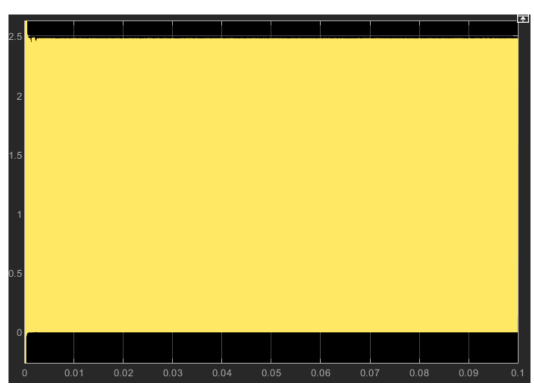
Answer 1:

In both **buck** and **boost converters**, operation can occur in two distinct modes: **continuous conduction mode** and **discontinuous conduction mode**. These modes are determined by the behavior of the inductor current over a switching cycle.

In continious current mode the current through the inductor **NEVER** falls to zero during the switching cycle. The inductor is always storing and releasing energy, meaning there is always some current flowing through it, even at the end of the switching period. **Inductor Current** is always positive, and the inductor is never fully discharged.

In discontinious current mode, the inductor current falls to zero during part of the switching cycle. This means the inductor fully discharges during each cycle before the next switching cycle begins. The inductor current reaches zero before the end of the switching period, meaning energy is not continuously transferred to the load.





We are looking at a period of 0.1 seconds. Mosfet switching frequency is 20 kHz. The switching frequency directly affects how often the MOSFET turns on and off.

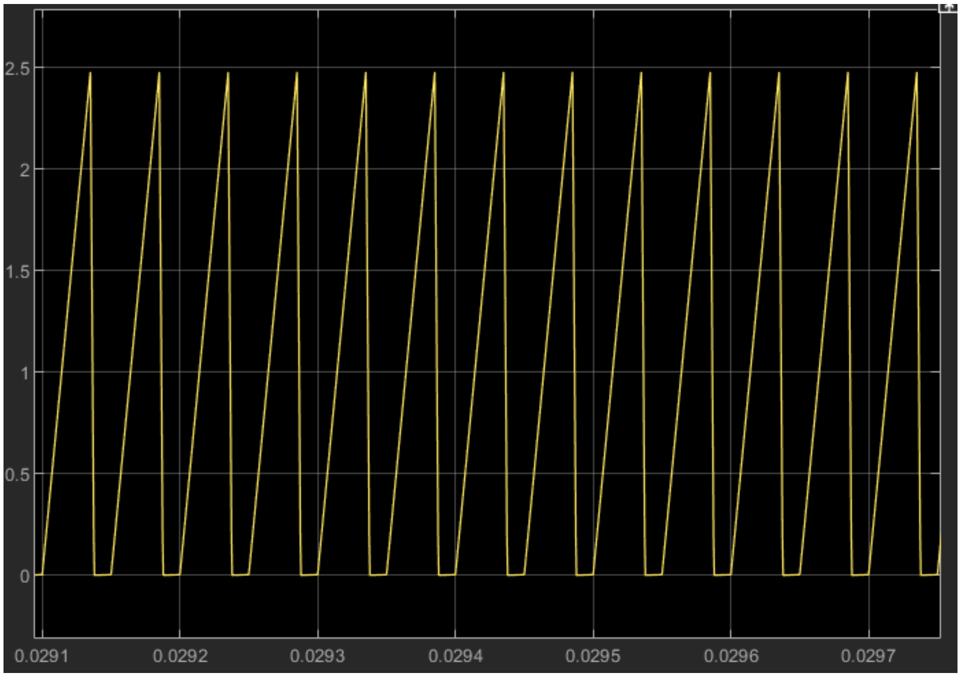


Figure 1. BUCK Inductor Current -Zoomed

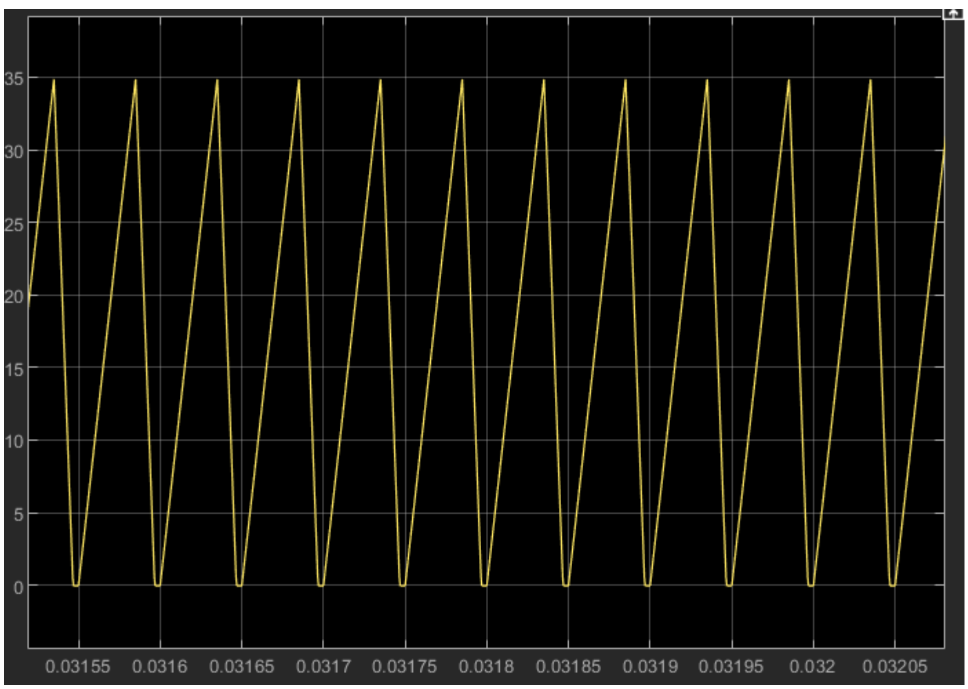


Figure 2. BOOST Inductor Current Zoomed

The inductor current in both converters falls to zero. That means that both BUCK and BOOST converters work in discontinious mode.

Question 2: Define the minimum inductor to operate in continious mode.

Answer 2:

To ensure a buck or boost converter operates in continuous conduction mode , the inductor current must never reach zero during the switching cycle. This requires that the inductor be large enough to maintain continuous current flow, even during the minimum current point in the cycle.

For ensuring continuous conduction this equation needs to be satisfied:

$$I_L \geq \frac{\Delta I_L}{2}$$

FOR BUCK:

$$V_o = V_s \cdot D = 100\ V\ \cdot 0.7 = 70\ V$$

$$I_L = I_o = \frac{V_o}{R} = \frac{70}{100} = 0.7\ A$$

$$\Delta I_L = \frac{V_o \cdot (1 - D)}{L \cdot f}$$

$$L \geq \frac{V_o \cdot (1 - D)}{2 \cdot I_o \cdot f} = \frac{70 \cdot (1 - 0.7)}{2 \cdot 0.7 \cdot 20 \cdot 10^3} = 7{,}5 \cdot 10^{-4} = 750 \cdot 10^{-6}$$

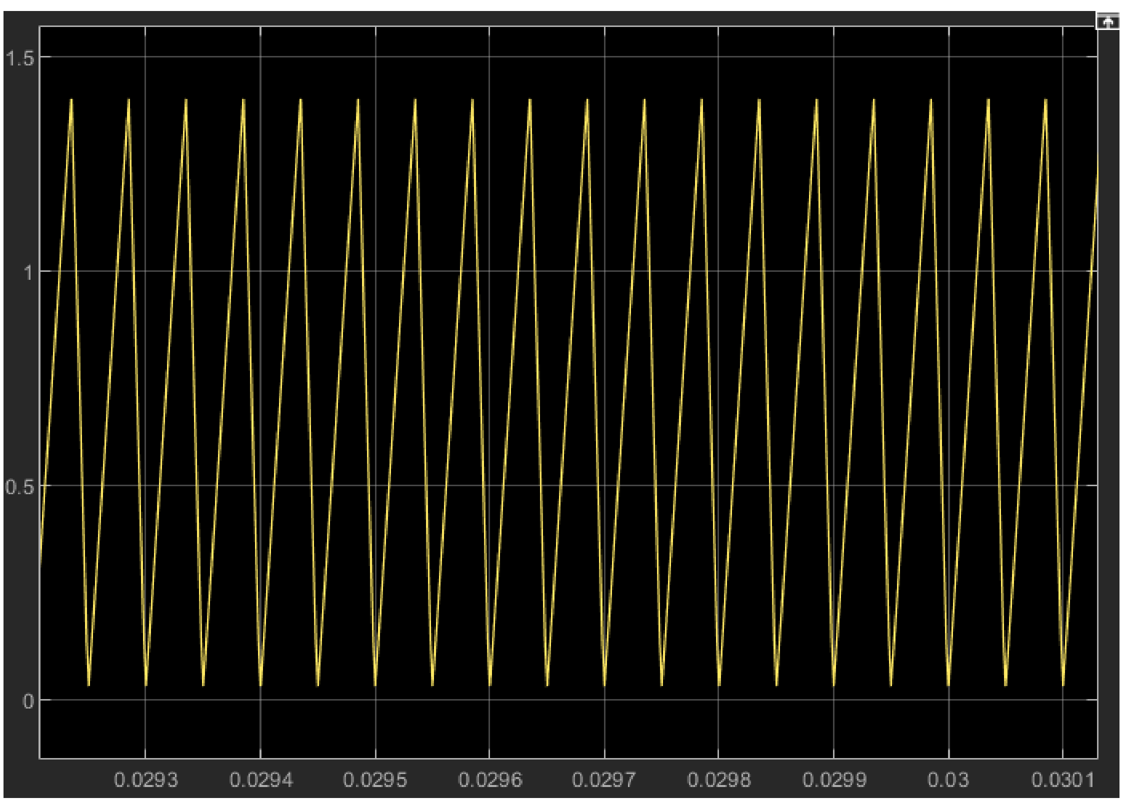


Figure 3. Inductor current continious mode

FOR BOOST:

$$V_o = \frac{V_s}{1-D} = \frac{100}{1-0.7} = 333.33\ V$$

$$I_o = \frac{V_o}{R} = \frac{333.33}{100} = 3.3333\ A$$

$$I_o = I_L \cdot (1-D) => \ I_L = \frac{I_o}{1-D} = \frac{3.3333}{1-0.7} = 11.111\ A$$

$$\Delta I_L = \frac{V_s \cdot D}{L \cdot f} = \frac{V_o \cdot D \cdot (1-D)}{L \cdot f}$$

$$L \geq \frac{V_o \cdot D \cdot (1-D)}{2 \cdot I_L \cdot f} = \frac{333.33 \cdot 0.7 \cdot (1-0.7)}{2 \cdot 11.111 \cdot 20 \cdot 10^3} = 1.575 \cdot 10^{-4} = 157.5 \cdot 10^{-6}$$

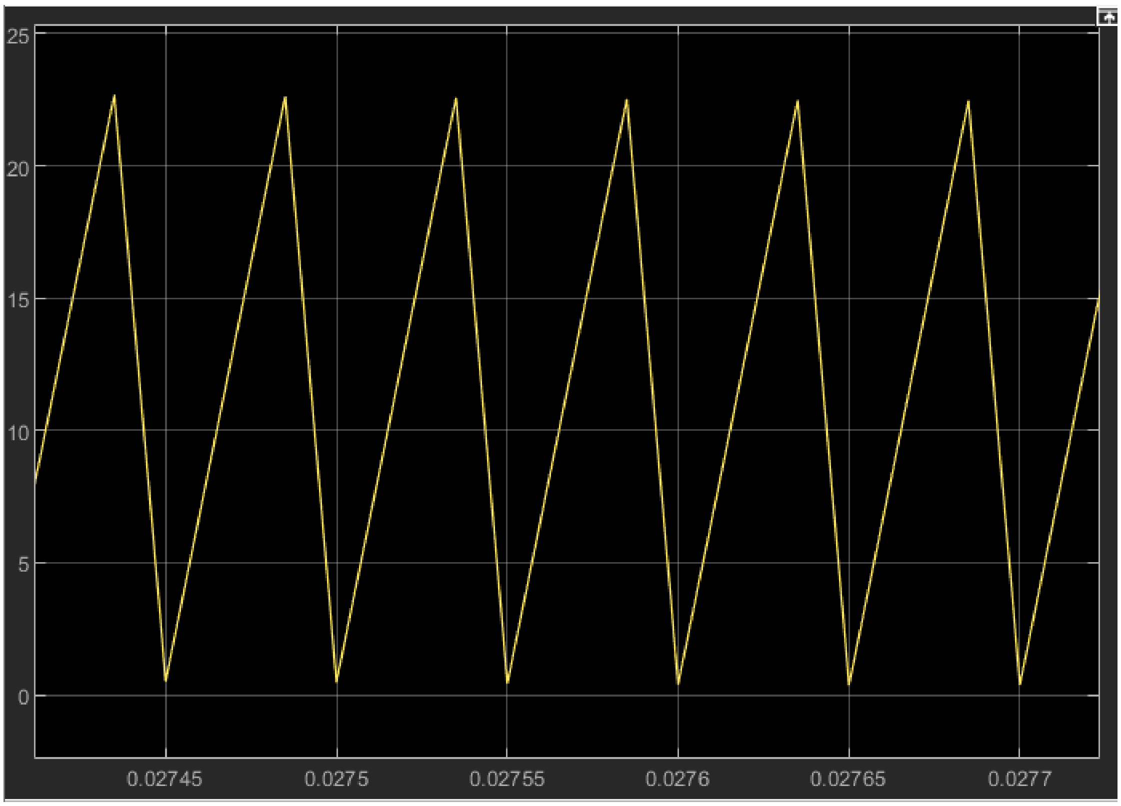


Figure 4. Inductor current continious mode

As can be seen on graphs, with these new calculated values of L, inductor current never reaches zero.

Question 3: In continuous mode and D=0,7, design a capacitor to achieve 1% voltage ripple.

Answer 3:

Request: $\frac{\Delta V_o}{V_o} < 1\%$

FOR BUCK:

$$C = \frac{1-D}{8 \cdot L \cdot \frac{\Delta V_o}{V_o} \cdot f^2} = \frac{1-0.7}{8 \cdot 750 \cdot 10^{-6} \cdot 0.01 \cdot (20 \cdot 10^3)^2} = 12.5 \cdot 10^{-6}$$

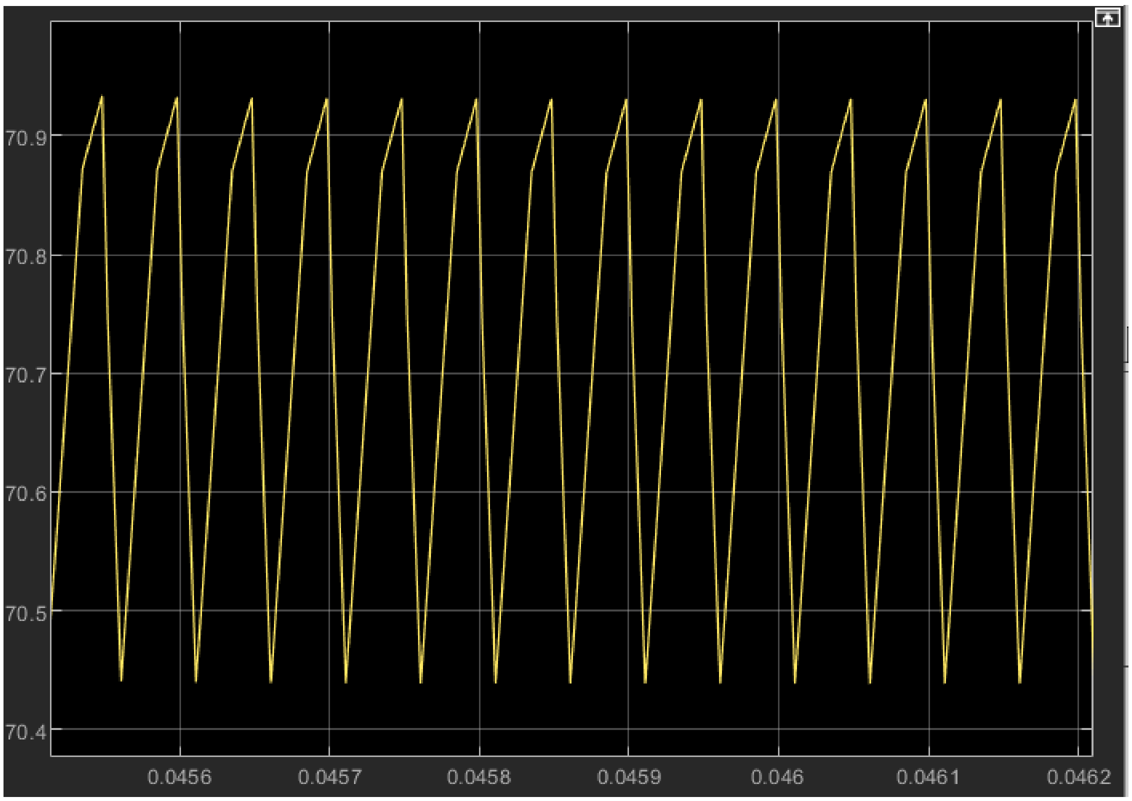


Figure 5. Buck output voltage ripple

FOR BOOST:

$$C = \frac{D}{R \cdot \frac{\Delta V_o}{V_o} \cdot f} = \frac{0.7}{100 \cdot 0.01 \cdot 20 \cdot 10^3} = 35 \cdot 10^{-6}$$

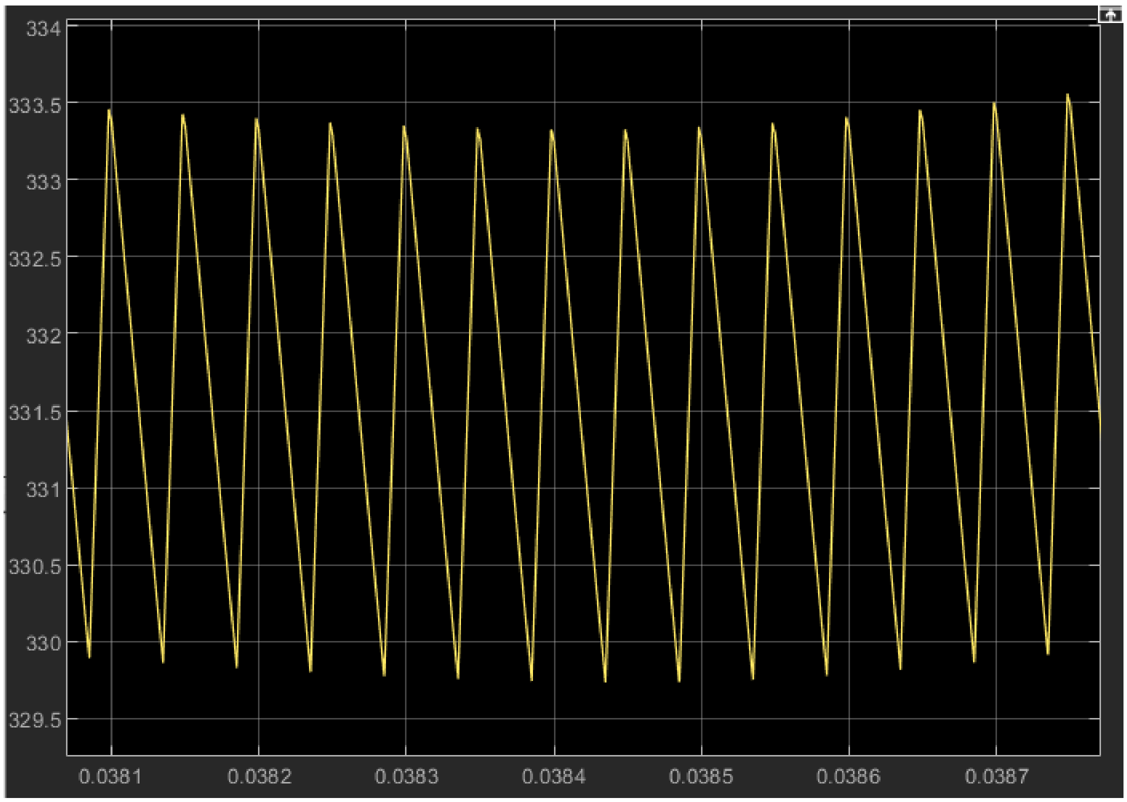


Figure 6. Boost output voltage ripple

Question 4: Raise the curve between Vo and D (Vo for different values of D).

Answer 4:

Plot the curves means creating a graphical representation of the relationship between two variables — the **output voltage** (Vo) and the **duty cycle** (D) for the buck and boost converters.

FOR BUCK:

$$V_o = V_s \cdot D$$

For the **Buck converter**, Vo increases linearly with D.

FOR BOOST:

$$V_o = \frac{V_s}{1 - D}$$

For the **Boost converter**, Vo increases non-linearly as D approaches 1, theoretically going to infinity as D→1.

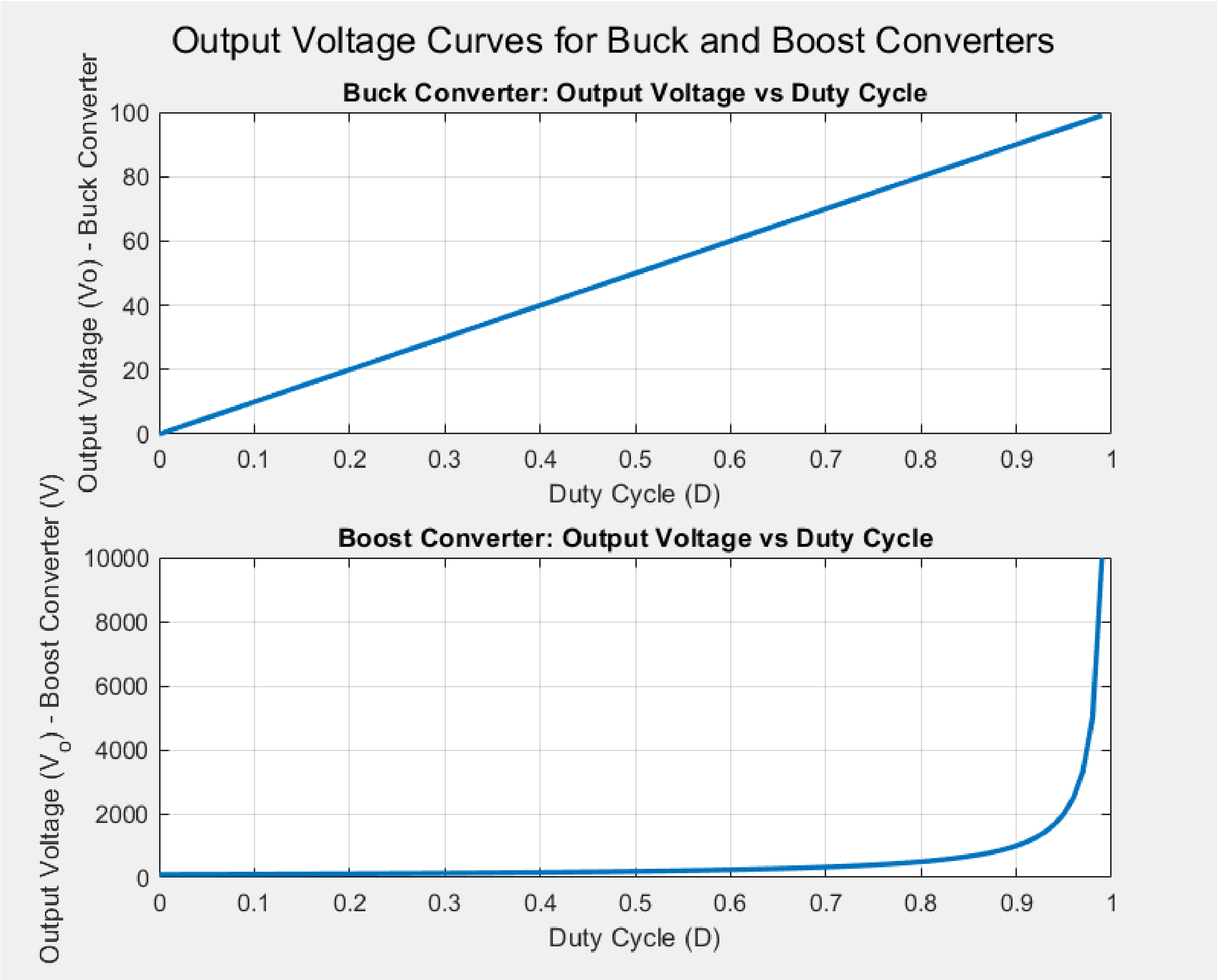


Figure 7. Output voltage Curves

Question 5: Raise the curve between efficiency and D (Vi/Vo for different values of D).

Answer 5:

Efficiency for Buck Converter:

$$\eta_{buck} = \frac{V_o}{V_s} = D$$

Efficiency for Boost Converter:

$$\eta_{boost} = \frac{V_o}{V_s} = \frac{V_s}{V_s \cdot (1-D)} = \frac{1}{1-D}$$

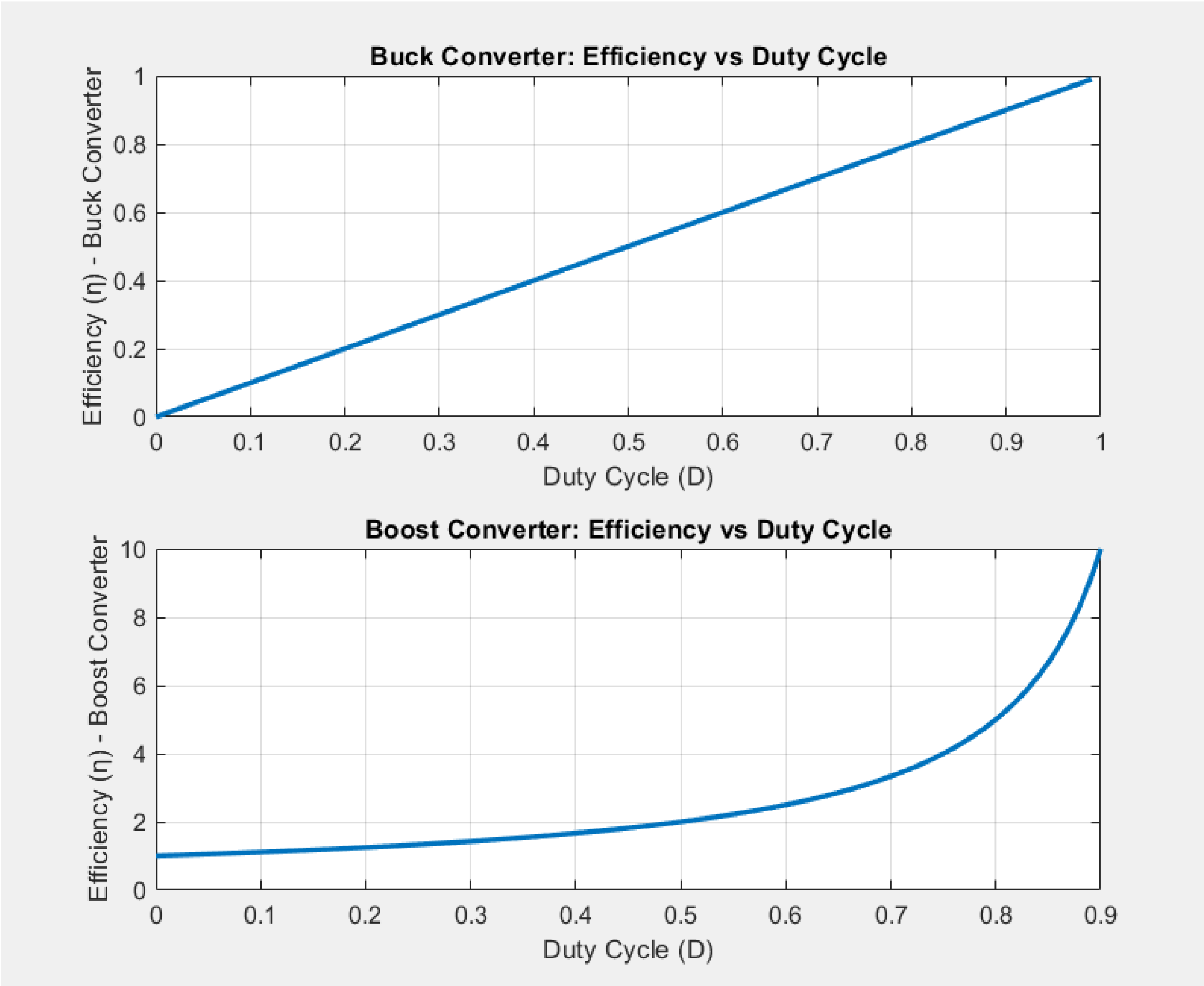


Figure 8. Efficiency for Buck And Boost converters for different values of D