1. The output DC voltage $V_o$ of a step-down (buck) converter is maintained at 5V by controlling the duty cycle $D$. The input dc voltage $V_d$ to the converter varies in the range of 10 - 40 V. The switching frequency $f_s$ of the converter is 20 kHz. The minimum load current, $I_o$, of the converter is 1A. Assuming ideal devices and components,

(i) find the minimum inductance required for operation of the converter in continuous-conduction mode.

\[ L = 109.3 \, \mu H \]

The converter operates with a DC input voltage of $V_d = 12.6V$. It delivers 10A DC to the load.

(ii) Find the maximum and minimum inductor currents.

\[ I_{L_{\text{max}}} = 10.69 A, \quad I_{L_{\text{min}}} = 9.31 A \]

(iii) Obtain the filter capacitance $C$ required to keep the output voltage ripple factor $\frac{\Delta V_o}{V_o} \leq 1\%$.

\[ C = 172 \, \mu F \]

(iv) Calculate the RMS ripple current in the $L$ and $C$. How is it affected by load current?

\[ \Delta I_L = 1.097A \]

(v) Derive an expression of for the output voltage ripple, $\Delta V_o$, of a buck converter operating in discontinuous-conduction mode. Hence calculate the output voltage ripple of the buck converter, when the load current is 0.4 A.

\[ \Delta V_o = \left[ DT_s (V_d - V_o) - LI_o \right] \left[ DT_s (V_d - V_o) V_o - LI_o V_o + (V_d - V_o) \left( DT_s (V_d - V_o) - LI_o \right) \right] \]

\[ 2LCV_o (V_d - V_o) \]

\[ [D = 0.3018, \quad \Delta V_o = 21.5 \, \text{mV}] \]
2. The output DC voltage $V_o$ of a boost (step-up) converter is maintained at 24 V by controlling the duty cycle $D$. The input DC voltage $V_d$ to the converter varies in the range of 8 – 16 V. The switching frequency $f_s$ of the converter is 20 kHz. The maximum load of the converter is 5 W. Assuming ideal devices and components,

(i) find the inductance $L$ required for operation of the converter in discontinuous-conduction mode up to the maximum load.

$$[L = 213 \, \mu H]$$

The boost converter operates with a DC input voltage of $V_d = 12$V. The load current supplied by the converter is 0.75 A.

(ii) Find the maximum and minimum inductor and diode currents.

$$[i_{L_{\text{max}}} = 2.2042\, \text{A}, \ i_{L_{\text{min}}} = 0.7958\, \text{A}]$$

(iii) Obtain the filter capacitance $C$ required to keep the output voltage ripple $\frac{\Delta V_o}{V_o} \leq 1\%$.

$$[C = 78.1 \, \mu F]$$

(iv) Calculate the RMS ripple current in the capacitor for $V_d = 12$V. Note that the diode also carries this ripple current.

$$[\Delta I_{DRMS} = 0.805 \, \text{A}]$$

(v) Derive an expression for the output voltage ripple, $\Delta V_o$, of a boost converter operating in discontinuous-conduction mode. Hence calculate the output voltage ripple of this converter when the load current is 100 mA.

$$\left[ \Delta V_o = \frac{(DT_s - LI_o)^2}{2LC(V_d - V_o)}; \ D = 0.266; \ \Delta V_o = 0.032 \, \text{V} \right]$$

3. A buck-boost converter is to supply a maximum power of 75 W at −50 V from a 40 V dc source. The output voltage ripple must be no more than 1%. The switching frequency $f_s$ is 40 kHz. Assume that the converter operates at the boundary of continuous/discontinuous conduction mode when 75W is supplied.

(i) Calculate the duty cycle $D$.

$$[D = 0.55]$$

(ii) Calculate the required size of the inductance $L$ and capacitance $C$.

$$[L = 82.3 \, \mu H, \ C = 41.67 \, \mu F]$$

(iii) Determine the average, maximum and minimum inductor currents.

$$[I_{oB} = 3.374 \, \text{A}, \ i_{L_{\text{max}}} = 6.748 \, \text{A}, \ i_{L_{\text{min}}} = 0 \, \text{A}]$$

(iv) Sketch the diode current waveform and find its average value.

$$[I_D = 1.5 \, \text{A}]$$
4. The output voltage, $V_o$, of a buck-boost converter is maintained at $-15$ V, while the input voltage $V_d$, varies in the range of 8 - 40 V. The switching frequency, $f_s$, of the converter is 20 kHz and the capacitor $C = 470$ μF.

(i) Assume that the converter will operate at the boundary of continuous conduction mode when the output power is 2 W. Find the minimum value of the inductance $L$ required.

$[L_{min} = 1.49 \text{ mH}]$

(ii) The inductor $L$ is selected to have 150 μH, in order to operate the converter in the discontinuous-conduction mode, when the input voltage is 12V and the output current, $I_o$, is 250 mA. Calculate the duty cycle, $D$, with which the converter will now operate.

$[D = 0.395]$

(iii) Calculate the rms values of the diode current and the diode ripple current. Hence calculate the rms ripple current through the capacitor.

$[I_{D_{rms}} = 0.498 \text{ A}, \ I_{D_{ripple\_rms}} = 0.43 \text{ A}, \ I_{C_{rms}} = 0.43 \text{ A}]$

(iv) Derive an expression for the output voltage ripple $\Delta V_o$, (peak - peak), and hence calculate the $\Delta V_o$ for this operating condition.

$[\Delta V_o = 18.8 \text{ mV}]$