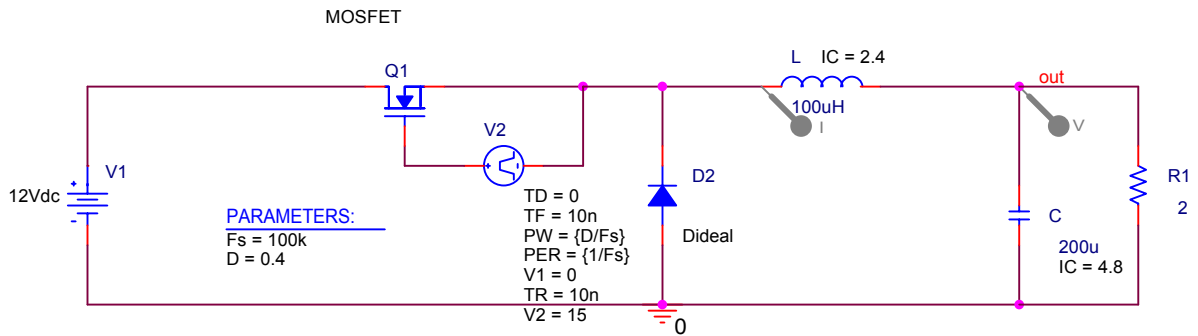


4. Buck Converter

Circuit and its paramaters:

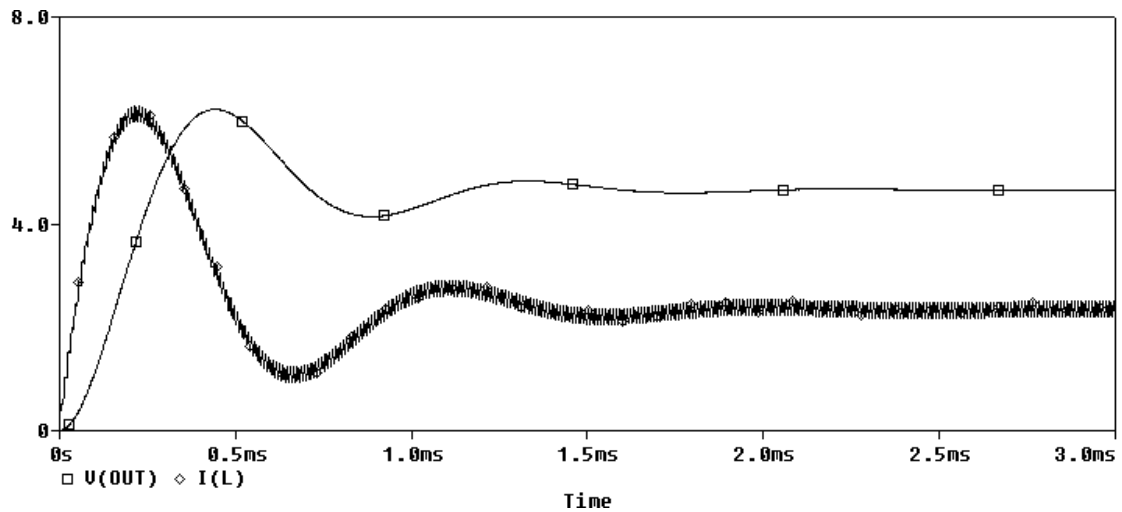


Basic Formula:

$$\frac{V_o}{V_g} = D \quad I_g = I_s \quad I_o = I_L \quad I_s = DI_L \quad I_D = (1-D)I_L$$

Pspice simulation:

(The whole scenario)



Calculation:

Circuit Parameters:

$$V_g := 12 \quad D := 0.4 \quad L := 100 \cdot 10^{-6} \quad C := 200 \cdot 10^{-6} \quad f := 100 \cdot 10^3 \quad R := 2$$

$$V_o := D \cdot V_g \quad V_o = 4.8$$

$$V_L(t) := \begin{cases} (V_g - V_o) & \text{if } 0 < t < D \cdot T \\ (-V_o) & \text{otherwise} \end{cases}$$

$$T := \frac{1}{f}$$

$$\Delta i_L := \frac{1}{L} \cdot (V_g - V_o) \cdot D \cdot T$$

$$\Delta i_L = 0.288$$

$$I_o := \frac{V_o}{R}$$

$$I_o = 2.4$$

$$I_L := I_o$$

$$I_L = 2.4$$

$$i_{Lmin} := I_L - \frac{\Delta i_L}{2}$$

$$i_{Lmin} = 2.256$$

$$i_{Lmax} := I_L + \frac{\Delta i_L}{2}$$

$$i_{Lmax} = 2.544$$

The waveforms are a piecewise linear. Collect numbers for plotting.

$$t := \begin{pmatrix} 0 \\ D \cdot T \\ D \cdot T \\ T \end{pmatrix} \quad V_L := \begin{pmatrix} V_g - V_o \\ V_g - V_o \\ -V_o \\ -V_o \end{pmatrix} \quad i_L := \begin{pmatrix} i_{Lmin} \\ i_{Lmax} \\ i_{Lmax} \\ i_{Lmin} \end{pmatrix} \quad i_s := \begin{pmatrix} i_{Lmin} \\ i_{Lmax} \\ 0 \\ 0 \end{pmatrix} \quad i_D := \begin{pmatrix} 0 \\ 0 \\ i_{Lmax} \\ i_{Lmin} \end{pmatrix}$$

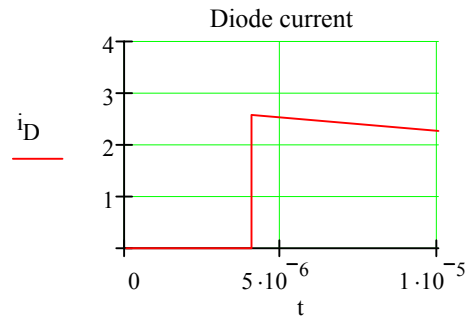
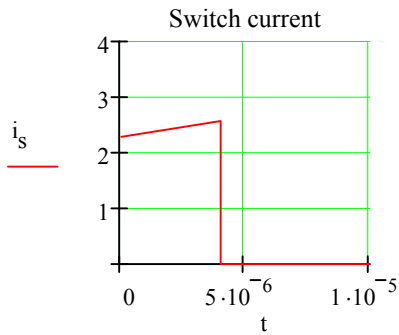
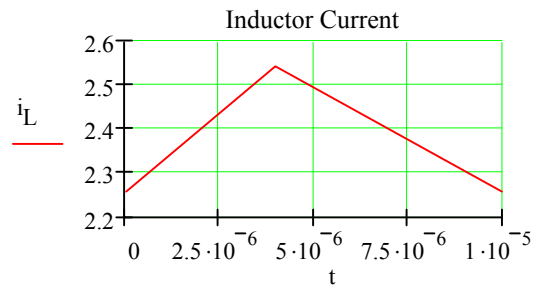
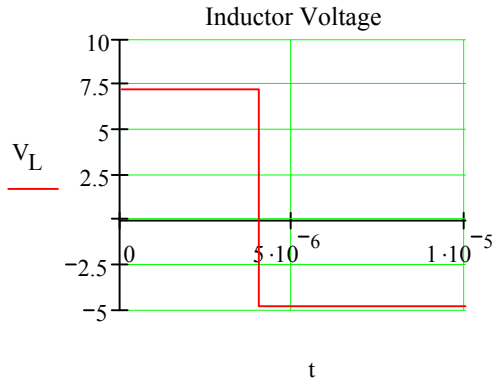
$$i_c := \begin{pmatrix} i_{Lmin} - I_o \\ i_{Lmax} - I_o \\ i_{Lmax} - I_o \\ i_{Lmin} - I_o \end{pmatrix}$$

$$i_{cmax} := i_{Lmax} - I_o$$

$$i_{cmax} = 0.144$$

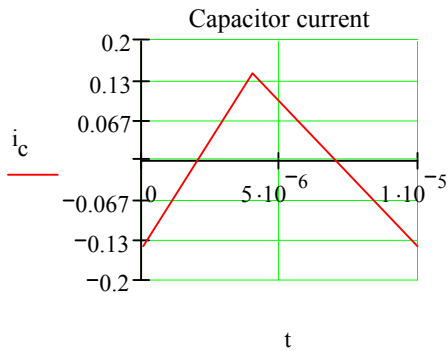
$$i_{cmin} := i_{Lmin} - I_o$$

$$i_{cmin} = -0.144$$



$$I_s := D \cdot I_L \quad I_s = 0.96$$

$$I_D := (1 - D) \cdot I_L \quad I_D = 1.44$$



$$\Delta v_o := \frac{1}{C} \cdot \frac{1}{2} \cdot \frac{T}{2} \cdot \frac{\Delta i_L}{2} \quad \Delta v_o = 1.8 \times 10^{-3}$$

$$I_g := I_s \quad I_g = 0.96 \quad V_g = 12$$

$$I_o = 2.4 \quad V_o = 4.8$$

$$P_g := V_g \cdot I_g \quad P_g = 11.52$$

$$P_o := V_o \cdot I_o \quad P_o = 11.52$$

Due to ideal components (switch, diode, L and C) that we assume, the circuit is lossless, the efficiency is 100% and as such $P_g = P_o$.

DCM/CCM Boundary

Case I: L, f, and the other circuit parameters are kept constant, R is varied

$$i_{Lmin} := 0 \quad i_{Lmax} := \Delta i_L$$

$$i_{L1} := \begin{pmatrix} i_{Lmin} \\ i_{Lmax} \\ i_{Lmax} \\ i_{Lmin} \end{pmatrix} \quad I_L := \frac{\Delta i_L}{2} \quad I_{L1} := I_L \quad I_{omin} := (1 - D) \cdot I_L \quad I_{omin} = 0.086$$

$$R_{max} := \frac{V_o}{I_{omin}} \quad R_{max} = 55.556$$

Case II: R, f, and the other circuit parameters are kept constant, L is varied

$$R := 2 \quad I_o := \frac{V_o}{R} \quad I_o = 2.4 \quad I_L := \frac{I_o}{1 - D} \quad I_L = 4$$

$$i_{Lmin} := 0 \quad i_{Lmax} := 2 \cdot I_L \quad i_{Lmax} = 8 \quad \Delta i_L := i_{Lmax} \quad i_{Lmax} = 8$$

$$i_{L2} := \begin{pmatrix} i_{Lmin} \\ i_{Lmax} \\ i_{Lmax} \\ i_{Lmin} \end{pmatrix} \quad \Delta i_L = 8$$

$$\Delta i_L = \frac{1}{L} \cdot V_g \cdot D \cdot T \quad L_{min} := \frac{1}{\Delta i_L} \cdot V_g \cdot D \cdot T \quad L_{min} = 6 \times 10^{-6}$$

Case III: R, L, and the other circuit parameters are kept constant, f is varied

$$R := 2 \quad I_o := \frac{V_o}{R} \quad I_o = 2.4 \quad I_L := \frac{I_o}{1 - D} \quad I_{L3} := I_L \quad I_{L3} = 4$$

$$i_{Lmin} := 0 \quad i_{Lmax} := 2 \cdot I_L \quad i_{Lmax} = 8 \quad \Delta i_L := i_{Lmax} \quad i_{Lmax} = 8$$

$$\Delta i_L = 8$$

$$\Delta i_L = \frac{1}{L} \cdot \left[(V_g - V_o) \cdot D \cdot \frac{1}{f} \right] \quad f_{min} := \frac{1}{\Delta i_L} \cdot (V_g - V_o) \cdot D \cdot \frac{1}{L} \quad f_{min} = 3.6 \times 10^3$$

Collect numbers for plotting

$$t1 := \begin{pmatrix} 0 \\ \frac{D}{f_{\min}} \\ \frac{D}{f_{\min}} \\ \frac{1}{f_{\min}} \end{pmatrix} \quad i_{L3} := \begin{pmatrix} i_{L\min} \\ i_{L\max} \\ i_{L\max} \\ i_{L\min} \end{pmatrix} \quad I_{L3} := \begin{pmatrix} I_{L3} \\ I_{L3} \\ I_{L3} \\ I_{L3} \end{pmatrix} \quad I_{L2} := I_{L3} \quad I_{L1} := \begin{pmatrix} I_{L1} \\ I_{L1} \\ I_{L1} \\ I_{L1} \end{pmatrix}$$

$$T_{\max} := \frac{1}{f_{\min}} \quad T_{\max} = 2.778 \times 10^{-4}$$

Waveforms i_L and I_L :

