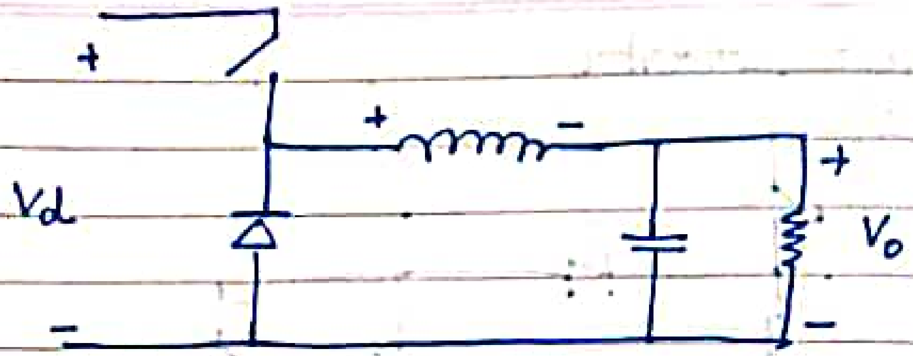
BUCK.



$\Rightarrow$ ON : $V_L = V_d - V_o$

OFF : $V_L = -V_o$

$\Rightarrow \dfrac{V_o}{V_d} = \dfrac{I_d}{I_o} = D$. $\quad I_C + I_o = I_L$

$I_L = I_o$ (average)

$\Rightarrow \Delta I_L = \dfrac{V_o(1-D)T_s}{L} = \dfrac{(V_d - V_o)DT_s}{L}$ [Select L if given ΔI_L]

$\Rightarrow I_{L(avg)} = I_{o(avg)} = V_o/R$

$I_{L,max} = \dfrac{V_o}{R} + \dfrac{V_o(1-D)T_s}{2L}$

$I_{L,min} = \dfrac{V_o}{R} - \dfrac{V_o(1-D)T_s}{2L}$

$\Rightarrow$ For CCM, $L \geq L_{min} = \dfrac{(1-D)RT_s}{2}$.

$\Rightarrow$ At the boundary :

$I_{LB} = I_{oB} = \dfrac{I_{L,peak}}{2} = \dfrac{(V_d - V_o)DT_s}{2L} = \dfrac{T_s V_d}{2L} \cdot D(1-D)$

If $I_L < I_{LB}$ or $I_o < I_{oB}$, DCM.

If $I_L \geq I_{LB}$ or $I_o \geq I_{oB}$, CCM

$I_{LB,max} = \dfrac{T_s V_d}{8L}$, $\quad I_{LB} = 4 I_{LB,max} D(1-D)$.

@ $D = 1/2$.

⇒ DCM : (constant V_o)

$$\frac{V_o}{V_d} = \frac{D}{D+\Delta_1} = \frac{I_d}{I_o}$$

$$I_o = I_{L,peak} \cdot \frac{(D+\Delta_1)}{2} = \frac{V_o T_s}{2L} \Delta_1 (D+\Delta_1) = \frac{V_d T_s D \Delta_1}{2L}$$

$$\Delta_1 = \frac{I_o}{4 I_{LB,max} D}, \quad \frac{V_o}{V_d} = \frac{D}{D+\Delta_1} = \frac{D^2}{D^2 + \frac{1}{4}(I_o / I_{LB,max})}$$

⇒ DCM : (constant V_d)

$$\frac{V_o}{V_d} = \frac{I_d}{I_o} = \frac{D}{D+\Delta_1}$$

$$I_{LB} = I_{OB} = \frac{I_{L,peak}}{2} = \frac{T_s V_o}{2L}(1-D)$$

$$I_{LB,max} = \frac{T_s V_o}{2L} \quad @ \quad D=0$$

$$I_{LB} = I_{LB,max}(1-D)$$

Boundary

$$I_o = I_{L,peak} \frac{(D+\Delta_1)}{2} = \frac{V_o T_s}{2L} \cdot \Delta_1 (D+\Delta_1)$$

$$D = \frac{V_o}{V_d} \left(\frac{I_o / I_{LB,max}}{1 - V_o/V_d} \right)^{1/2}$$

⇒ Output voltage Ripple : [look at I_L & compare with I_o]

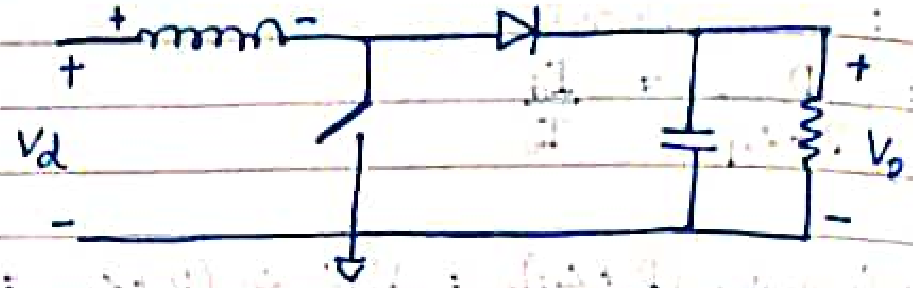
CCM

$$\Delta V_o = \frac{1}{2} \frac{\Delta I_L}{2} \frac{T_s}{2} \cdot \frac{1}{C} \Rightarrow \Delta V_o = \frac{T_s V_o}{8LC}(1-D) T_s$$

$$\frac{\Delta V_o}{V_o} = \frac{1}{8} \frac{T_s^2 (1-D)}{LC} = \frac{\pi^2}{2}(1-D)\left(\frac{f_c}{f_s}\right)^2$$

$$f_s = 1/T_s, \quad f_c = \frac{1}{2\pi\sqrt{LC}}$$

BOOST



$\Rightarrow$ ON $\Rightarrow$ $V_L = V_d$

OFF $\Rightarrow$ $V_L = -(V_o - V_d)$.

$\Rightarrow$ $\frac{V_o}{V_d} = \frac{1}{1-D} = \frac{I_d}{I_o}$ $\quad$ $I_C + I_O = I_D$.

$I_d = I_L$, $I_D = I_o$ (avg)

$I_D = (1-D) I_L$

$\Rightarrow$ $\Delta I_L = \frac{V_d . D T_s}{L} = \frac{(V_o - V_d)(1-D) T_s}{L}$

$I_{L(avg)} = \frac{I_o}{1-D} = \frac{V_o}{R(1-D)} = \frac{V_d}{R(1-D)^2}$

$I_{L,max} = \frac{V_d}{R(1-D)^2} + \frac{V_d . D T_s}{2L}$

$I_{L,min} = \frac{V_d}{R(1-D)^2} - \frac{V_d . D T_s}{2L}$

$\Rightarrow$ For CCM, $L \geq L_{min} = \frac{T_s . D . (1-D)^2 . R}{2}$

$\Rightarrow$ Boundary $\boxed{\text{Constant } V_o}$

$I_{LB} = \frac{T_s V_o}{2L} D(1-D)$

$I_{LB,max} = \frac{T_s V_o}{8L}$ @ $D = 1/2$

$I_{LB} = 4 I_{LB,max} D(1-D)$

$$I_{OB} = \frac{T_s V_o}{2L} D(1-D)^2$$

$$I_{OB,max} = \frac{2}{27}\frac{T_s V_o}{L} \quad @ \quad D = \frac{1}{3}$$

$$I_{OB} = \frac{27}{4} D(1-D)^2 I_{OB,max}$$

⇒ DCM : (constant V_o)

$$\frac{V_o}{V_d} = \frac{\Delta_1 + D}{\Delta_1} = \frac{I_d}{I_o}$$

$$I_L = I_d = \frac{V_d D T_s}{2L}(D+\Delta_1)$$

$$I_o = \frac{T_s V_d}{2L} D\Delta_1$$

$$D = \left[\frac{4}{27}\frac{V_o}{V_d}\left(\frac{V_o}{V_d}-1\right)\frac{I_o}{I_{OB,max}}\right]^{1/2}$$

→ Output Voltage Ripple ⇒ [compare I_D with I_o]

$$\Delta V_o = \frac{I_o D T_s}{C} = \frac{V_o}{R}\frac{DT_s}{C}$$

$$\Rightarrow \frac{\Delta V_o}{V_o} = \frac{DT_s}{RC} = \frac{DT_s}{\tau}$$

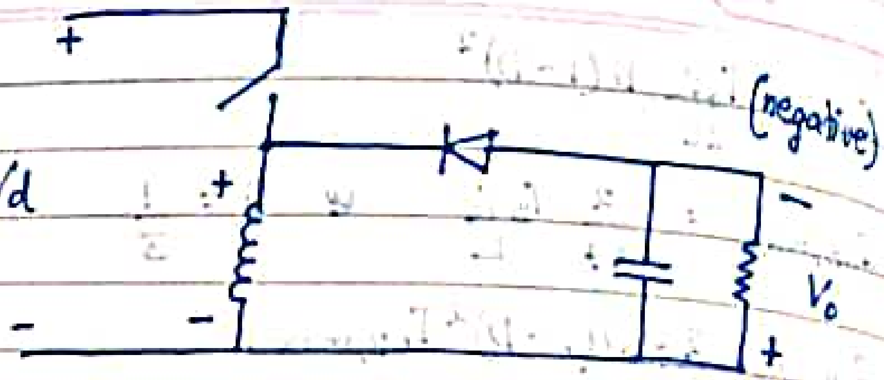
⇒ Inductor Resistance ⇒

$$P_d = P_o + P_{r,\ell} \Rightarrow V_d I_L = V_o I_D + I_L^2 r_\ell$$

$$V_o = \left(\frac{V_d}{1-D}\right)\left(\frac{1}{1 + r_\ell/[R(1-D)^2]}\right)$$ [messes up at high D]

$$\eta = \frac{1}{1 + r_\ell/[R(1-D)^2]}$$

BUCK - BOOST :



$\Rightarrow$ ON : $V_L = V_d$ BOOST
OFF : $V_L = -V_o$ BUCK

$\Rightarrow \dfrac{V_o}{V_d} = \dfrac{D}{1-D} = \dfrac{I_d}{I_o}$ $I_C + I_O = I_D$

$I_D = I_O$ (avg) , $I_d = DI_L$ $\left[\begin{matrix} D>0.5 & \uparrow \\ D<0.5 & \downarrow \end{matrix}\right]$

** $\Rightarrow I_L = I_d + I_o$; $I_o = I_L(1-D)$

$\Rightarrow \Delta I_L = \dfrac{V_d D T_s}{L} = \dfrac{V_o(1-D)T_s}{L}$

$I_{L,avg} = \dfrac{V_d \cdot D}{R(1-D)^2}$

$I_{max} = \dfrac{V_d \cdot D}{R(1-D)^2} + \dfrac{V_d D T_s}{2L}$

$I_{min} = \dfrac{V_d \cdot D}{R(1-D)^2} - \dfrac{V_d D T_s}{2L}$

$\Rightarrow$ For CCM, $L \geq L_{min} = \dfrac{(1-D)^2 R T_s}{2}$

$\Rightarrow$ Boundary (constant V_o)

$I_{LB} = \dfrac{T_s V_o}{2L}(1-D)$

$I_{LB,max} = \dfrac{T_s V_o}{2L}$ @ $D = 0$

$I_{LB} = I_{LB,max}(1-D)$

$$I_{oB} = \frac{T_S V_o}{2L}(1-D)^2$$

$$I_{oB,max} = \frac{T_S V_o}{2L} \quad @ \; D = 0$$

$$I_{oB} = I_{OB,max}(1-D)^2$$

⇒ DCM :

$$\frac{V_o}{V_d} = \frac{D}{\Delta_1} = \frac{I_d}{I_o}$$

$$I_L = I_d + I_o$$

$$I_L = \frac{V_d DT_S}{2L}(D+\Delta_1) \qquad \left[I_{L,peak} \cdot \frac{(D+\Delta_1)}{2}\right]$$

$$\Delta_1 = \sqrt{\frac{I_o}{I_{OB,max}}} , \quad D = \frac{V_o}{V_d}\sqrt{\frac{I_o}{I_{OB,max}}}$$

⇒ Output Voltage Ripple ⇒ [compare I_D with I_o]

$$\Delta V_o = \frac{I_o DT_S}{C} = \frac{V_o}{R}\frac{DT_S}{C}$$

$$\frac{\Delta V_o}{V_o} = \frac{DT_S}{RC} = \frac{DT_S}{\tau}$$