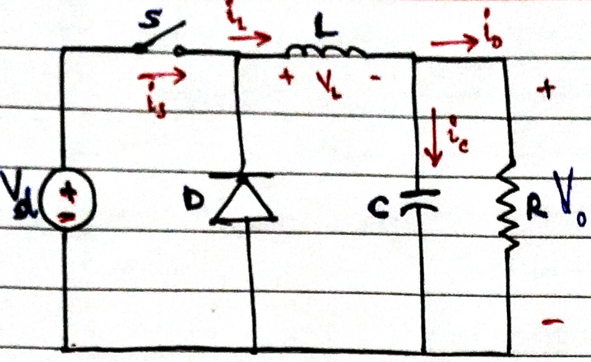
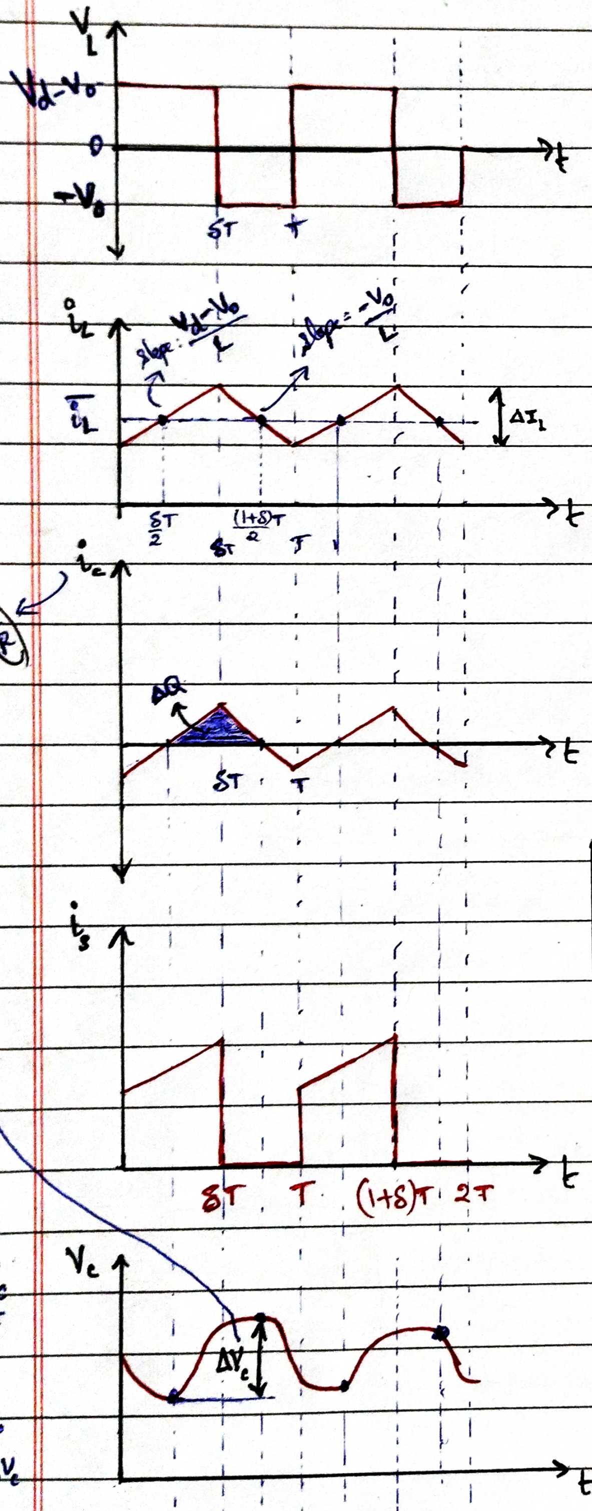
Buck Converter





$\bar{i}_c = 0$, $\bar{i}_L = \frac{V_o}{R}$

$i_c = C\frac{dV_c}{dt}$

$$\int_{\delta T/2}^{(1+\delta)T/2} i_c\,dt = \int_{V_{min}}^{V_{max}} C\,dV_c$$

$$\frac{1}{2}\cdot\frac{T}{2}\cdot\frac{\Delta I_L}{2} = C\Delta V_c$$

In DCM,

@ Steady state:

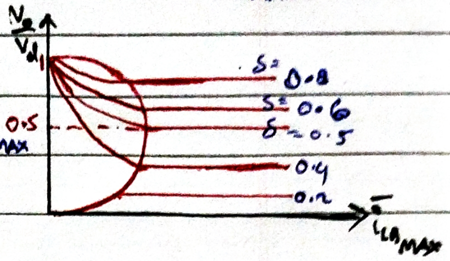
$$I_o = \bar{I}_L \Rightarrow \bar{I}_L = \frac{1}{2}(\delta T + \alpha T) \times \frac{(V_d - V_o)}{L}\delta T \times \frac{1}{T}$$

$\frac{\delta V_d}{\delta + \alpha}$

$$\Rightarrow I_o = \frac{V_d T}{2L}\delta\alpha \Rightarrow \alpha = i_o / 4\bar{i}_{LB_{MAX}}\,\delta$$

$4\bar{i}_{LB_{MAX}}$

$$\therefore \frac{V_o}{V_d} = \frac{\delta^2}{\delta^2 + \frac{i_o}{4\bar{i}_{LB_{MAX}}}}$$



$$\bar{V}_L = 0 \Rightarrow (V_D - V_o)\delta T - V_o(1-\delta)T = 0$$

$$\Rightarrow M_V = \frac{V_o}{V_d} = \delta \in (0,1)$$

DC voltage transfer fn

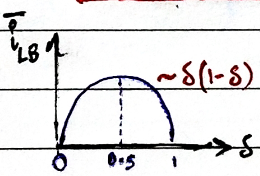
NOTE: If $i_{L_{peak}} = 2\bar{i}_L$, it is edge of CCM.

$V_L = L\frac{di_L}{dt}$

$$\therefore \bar{i}_{L(lim)} = i_{L_{peak}}/2$$

$$\Rightarrow \bar{i}_{LB} = \frac{1}{2}\cdot\frac{(V_d - V_o)}{L}\cdot\delta T \quad \text{where } V_d = V_o/\delta$$

$$\boxed{\bar{i}_{L_B} = \frac{V_d T}{2L}\cdot\delta(1-\delta)} \qquad \boxed{\bar{i}_{LB_{MAX}} = \frac{V_d T}{8L}}$$

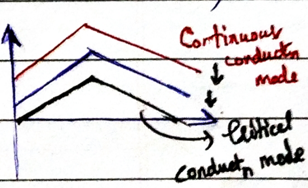


$$\boxed{\frac{\Delta V_o}{V_o} = \frac{T^2(1-\delta)}{8LC}}$$

Upon reducing load... (ie: $R_L\uparrow \Rightarrow I_o\downarrow \Rightarrow \bar{I}_L\downarrow$)

But $\because$ I_L does NOT change quickly

$V_o = R_L^{\uparrow} \times I_o$ (const) $\uparrow$



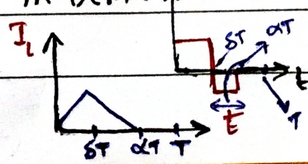
$\therefore (V_d - V_o) \rightarrow$ less rising slope $\quad -V_o \rightarrow$ more falling slope $\quad$ then eventually, $\bar{I}_L\downarrow$

$$\therefore \boxed{V_{o_{DCM}} > V_{o_{CCM}}}$$

NOTE: @ Steady state, $\bar{I}_L = I_o$ FOR CCM

$$\Rightarrow \frac{\Delta i_L}{2} = \frac{V_o}{R} \Rightarrow \frac{1}{2}\frac{(V_d - V_o)}{L}\cdot\delta T = \frac{V_o}{R}$$

In DCM:

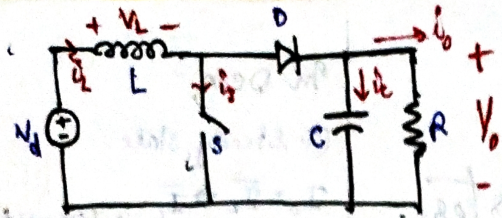


$$\bar{V}_L = 0 \Rightarrow (V_d - V_o)\delta T = V_o(\alpha - \delta)T$$

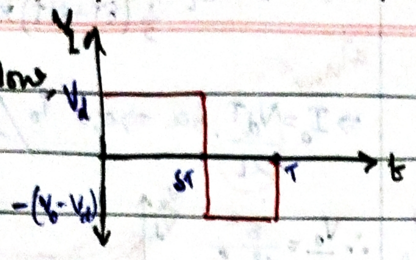
$$\Rightarrow \frac{V_o}{V_d} = \delta/\alpha + \delta$$

$$\Rightarrow V_o > \delta V_d.$$

Boost Converter



Now,

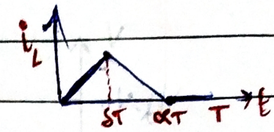


$\overline{V_L} = 0 \Rightarrow V_d \delta T + (V_d - V_o)(1-\delta)T = 0$

$\therefore V_o/V_d = \frac{1}{1-\delta} \Rightarrow V_o \geq V_d$.

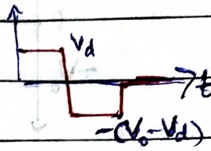
* @ Steady state, voltage across C should NOT change $\Rightarrow \overline{i_C} = 0 \Rightarrow \overline{i_L} = i_o$.

$\therefore$ again $I_o = \frac{V_d T \delta(1-\delta)}{2L} \Rightarrow I_{oB}\big|_{MAX} = \frac{V_d T}{8L}$

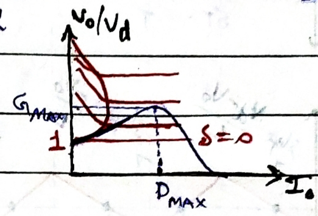


If $\overline{i_L}$ falls below threshold (in DCM):

$V_d \delta T + (V_d - V_o)\alpha T = 0 \Rightarrow \frac{V_o}{V_d} = \frac{\delta + \alpha}{\alpha}$



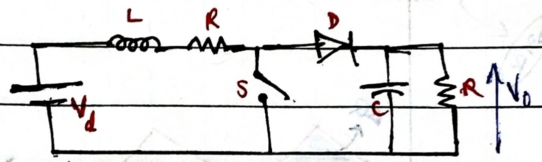
where α is again equal to $\boxed{\frac{i_o}{4 I_{oB_{MAX}}\,\delta}}$



Ripple: $\underbrace{\Delta Q}_{I_o \delta T} = C\Delta V \Rightarrow \frac{\Delta V}{V_o} = \frac{\delta T}{RC} \Rightarrow \frac{\Delta V}{V_o} = \frac{\delta}{\tau f_s}$.

$I_o \to V_o/R$

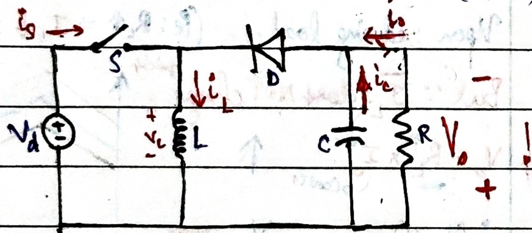
Upon considering inductor resistance:



$(V_d - i_L r)\delta T + (V_d - V_o - i_L r)(1-\delta)T = 0$

$\boxed{\delta_{MAX} = 1 - \sqrt{\frac{r}{R}}}$ $\boxed{G_{MAX} = \frac{1}{2}\sqrt{\frac{R}{r}}}$

Buck-Boost Converter



$(\overline{V_L} = 0)$

$V_d \delta T - V_o(1-\delta)T = 0 \Rightarrow V_o/V_d = \frac{\delta}{1-\delta}$.

! Almost all the others remains same.

* Buck-Boost converter inverts the polarity of the output wrt same ⊥ as the i/p.

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22B3936