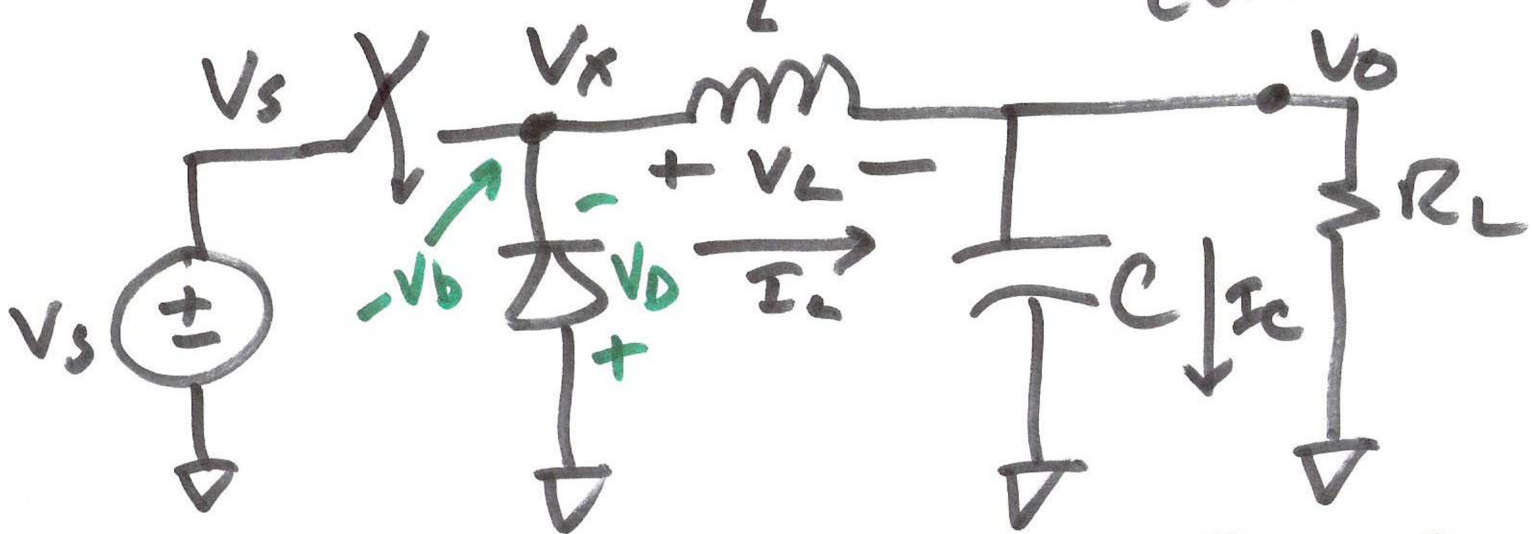
ECE 5/472 Power Electronics

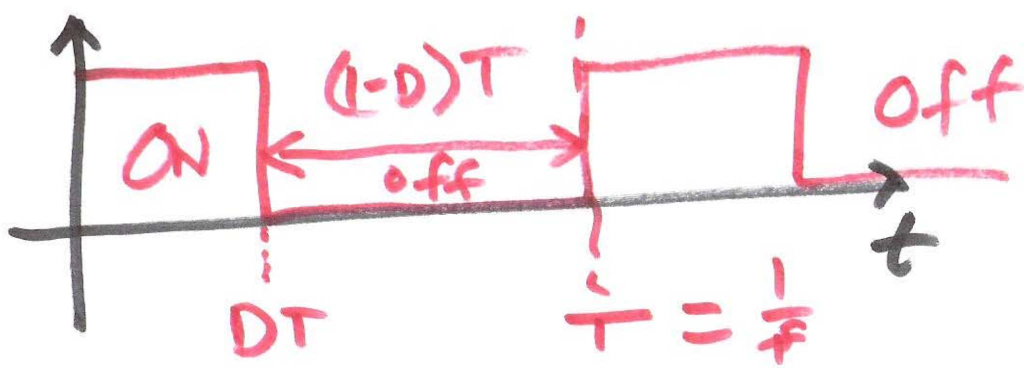
BOISE STATE UNIVERSITY

Lecture 4 Sept. 1, 2011

Design of Buck converters



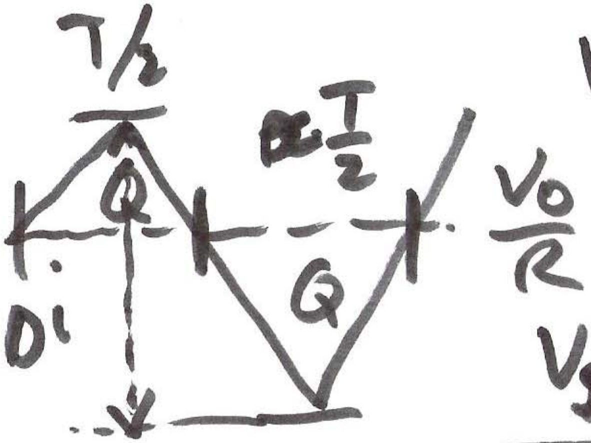
Assume V_O = CONST. SO $I_C = 0$



1)

Switch on $V_x = V_s$, diode is off

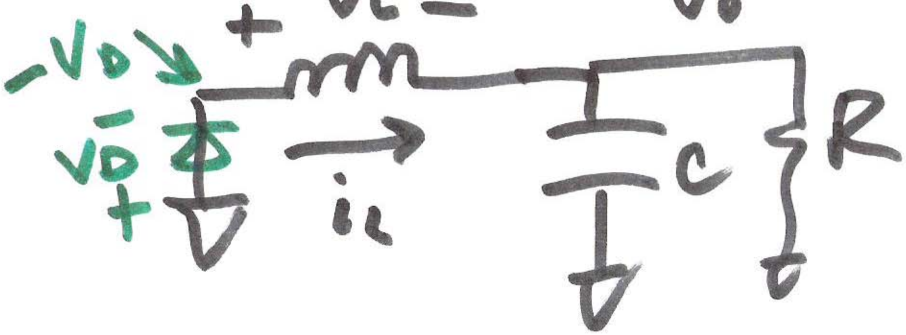
$$I_{AVG} = \frac{V_o}{R_L} \qquad v = L \cdot \frac{di}{dt}$$



$$V_L = L \cdot \frac{di_L}{dt} = \overset{V_s}{\cancel{V_x}} - V_o = L \frac{di_L}{dt}$$

$$\frac{V_s - V_o}{L} = \frac{\Delta i_L}{DT}, \quad \boxed{\Delta i_{LU} = DT \cdot \frac{(V_s - V_o)}{L}}$$

Switch off



$$\frac{\overset{-V_D}{\cancel{0}} - V_o}{L} = \frac{\Delta i_L}{(1-D)T}$$

$$\boxed{\Delta i_{LD} = (D-1)T \frac{(V_o + V_D)}{L}}$$

2)

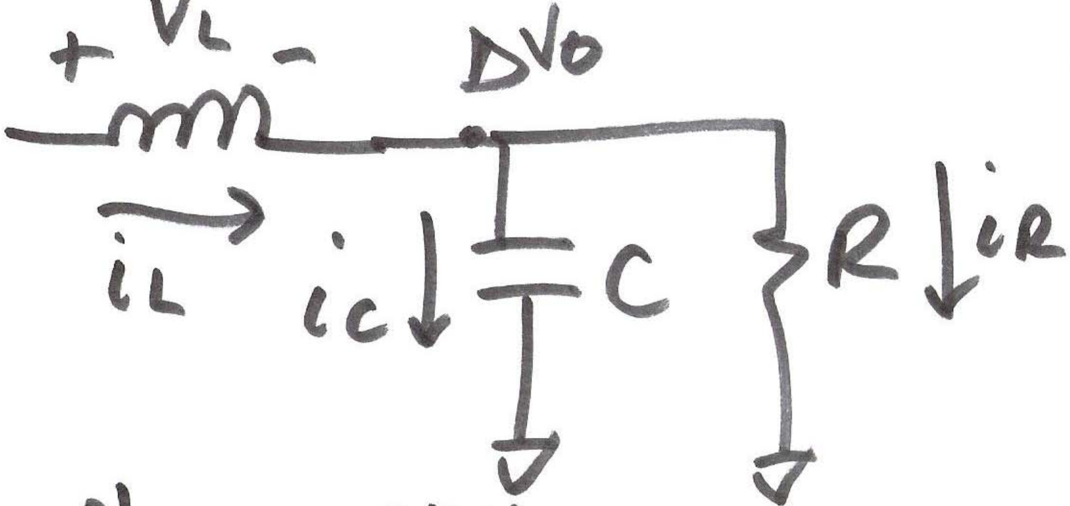
$$DT\underline{(V_s - V_o)} = -(D-1)T \cdot \underline{V_o}$$

$$DTV_s - \cancel{DTV_o} = -\cancel{DTV_o} + TV_o$$

$$\boxed{D \cdot V_s = V_o}$$

3)

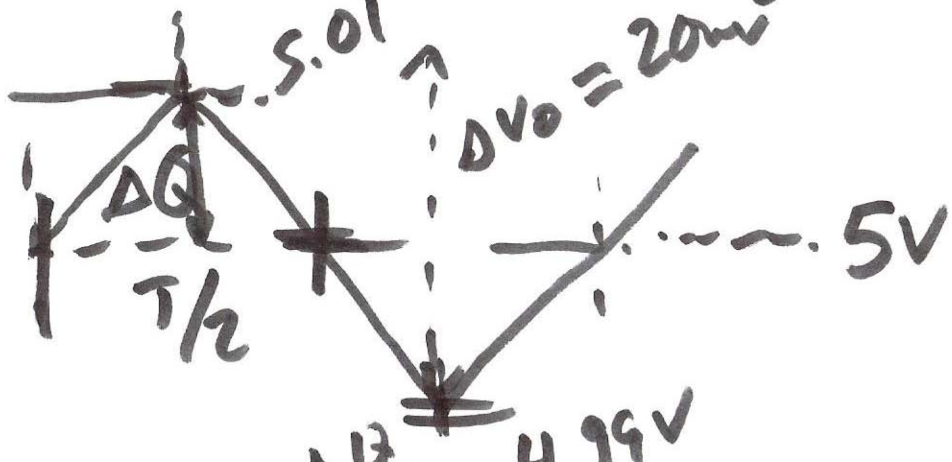
OUTPUT Voltage Ripple



$$i_L = i_C + i_R$$

$$i_C = C \cdot \frac{\Delta V_o}{T/2}$$

$$i_R = \frac{\Delta V_o}{R}$$



$$CV = Q$$

$$C \cdot \Delta V_o = \Delta Q$$

$$\Delta V_o = \frac{\Delta Q}{C}$$

$$\Delta i_c = \frac{\Delta Q}{T/2}$$

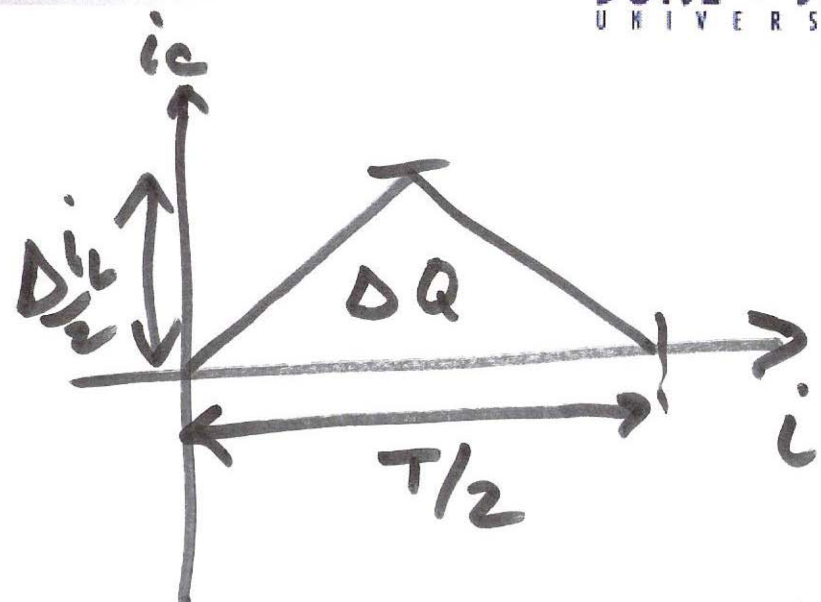
$$\Delta Q = \frac{1}{2}\left(\frac{T}{2}\right)\left(\frac{\Delta i_L}{2}\right) = \frac{T \cdot \Delta i_L}{8}$$

$$\Delta V_o = \Delta i_C \cdot C \cdot \frac{T}{2} = \Delta Q \cdot C = T \cdot \frac{\Delta i_L}{8C}$$

4)

$$\Delta V_c = \Delta V_0$$

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



$$CV = Q$$

$$C \cdot \Delta V_c = \Delta Q$$

$$\Delta V_0 = \frac{\Delta Q}{C} \qquad \Delta Q = \frac{1}{2}\left(\frac{T}{2}\right)\left(\frac{\Delta i_L}{2}\right)$$

$$= \frac{T \cdot \Delta i_L}{8}$$

$$\Delta V_0 = \frac{T \cdot \Delta i_L}{8C}$$

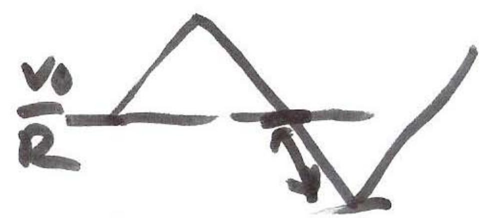
$$T = \frac{1}{f} \qquad = \frac{T}{8C} \cdot \frac{DT(V_s - V_0)}{L} = \boxed{\frac{(1-D)V_0}{8CLf^2}}$$

5)

$$V_S = 24V \qquad V_O = 5V$$

$$f = 1\,MHz \qquad I_{MIN} = 1A$$

$$L_{MIN} = \frac{(D-1)T \cdot V_O}{\frac{V_O}{R} - \frac{\Delta i_L}{2}}$$



$$- - - - - - - - - I_{DC} = \frac{V_O}{R}$$

$$\frac{V_O}{R} - (D-1)\frac{1}{f L_{MIN}} \cdot V_O = 0$$

$$L_{min} = \frac{(D-1)R}{f\,2}$$

$$0 = \frac{1}{R} + \frac{(1-D)}{f L_{min}}$$

6)

$V_s = 24 \qquad V_o = 5$

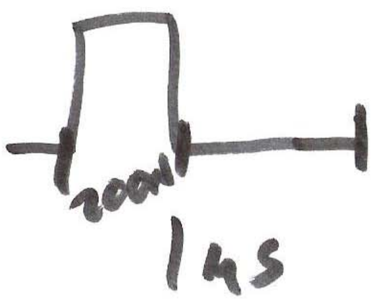
$f = 10^6\,\text{Hz} \qquad I_{min} = 1\,\text{A}$

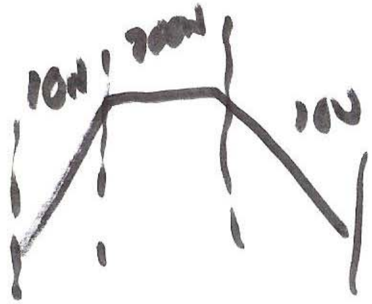
$\underline{\underline{R = 5\,\Omega}}$

$.01 = \dfrac{\Delta V_o}{V_o} \qquad D = \dfrac{5}{24} = 0.2$

$.01 = \dfrac{1-.2}{8 \cdot 24 \cdot C \cdot 10^{12}} \qquad L_{min} = \dfrac{(0.2+1)\cdot \cancel{R}^{\,5}}{\cancel{f}_{\,10^6} \cdot 2} = \dfrac{4}{2 \cdot 10^6}$

$= \underline{\underline{2\,\mu H}}$





$C_{min} = \dfrac{.8 \cdot 100}{16 \cdot 10^{-6} \cdot 10^{12}} = 5.0 \cdot 10^{-6}$

$= \underline{\underline{5.0\,nF}}$

7)

$$\frac{DT(V_S - V_O)}{L} = \frac{(1-D)T(V_O + V_D)}{L}$$

$$DV_S - DV_O = V_O + V_D - DV_O - DV_D$$

$$DV_S + DV_D - V_D = V_O$$

$$V_O = DV_S - V_D(1-D)$$

$$= \underbrace{0.2 \cdot 24}_{4.8} - \underbrace{0.7(.8)}_{.56}$$

$$V_O = 4.24V$$

8)