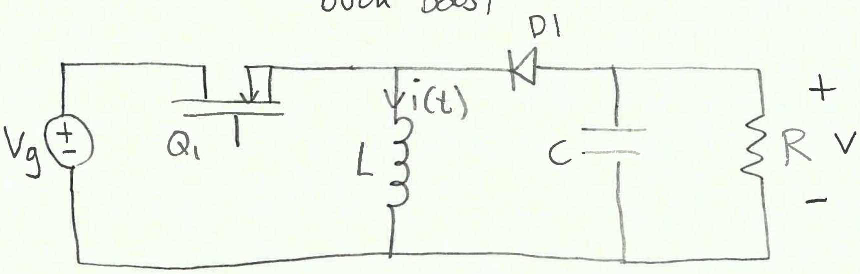
"buck-boost"



(a)

From HW1, the inductor ripple was found

$$\frac{2\Delta i_L}{DT_S} = \frac{V_g}{L}$$

$$\Delta i_L = \frac{V_g}{L}\frac{DT_S}{2}$$

DCM Boundary occurs when inductor current ripple equals the average inductor current

From HW1:

$$\langle i(t) \rangle = \frac{-V}{R}\frac{1}{D'}$$

Therefore DCM boundary occurs when

$$\langle i(t) \rangle = \Delta i_L$$

$$\frac{-V}{R}\frac{1}{D'} = \frac{V_g}{L}\frac{DT_S}{2}$$

Find $R = R_{crit}$

$$-\frac{V}{R_{crit}}\frac{1}{D'} = \frac{V_g}{L}\frac{DT_S}{2}$$

$$R_{crit} = \frac{-V}{D'}\frac{L\,2}{V_g D T_S} \quad (1)$$

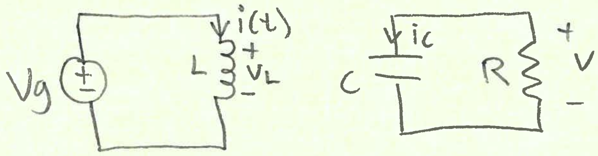
we know $V = \dfrac{-V_g D}{1-D}$ (2)

Solve (1) and (2) for R_{crit} and V where $D' = 1-D$

$$\underline{R_{crit} = \frac{2L}{T_S(1-D)^2}}$$ +3

(b) DCM

Q_1 ON, D_1 off "1"



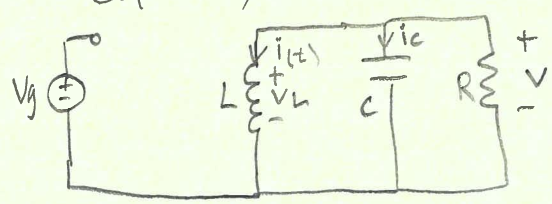
KVL

$V_L(t) = V_g$

KCL

$i_c(t) = \frac{-V(t)}{R}$

Q_1 off, D_1 on "2"



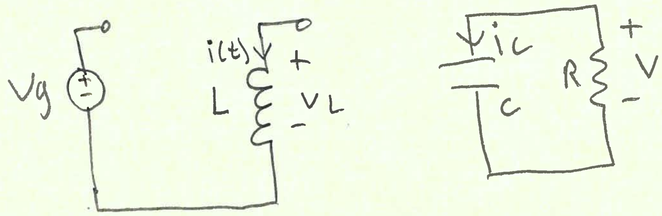
KVL

$V_L(t) = V(t)$

KCL

$i_c(t) = -i(t) - \frac{V(t)}{R}$

Q_1 off, D_1 off "3"



KVL

$V_L(t) = 0$

KCL

$i_c(t) = \frac{-V(t)}{R}$

Small Ripple Approximation

"1"

$V_L(t) = V_g$

$i_c(t) = \frac{-V}{R}$

"2"

$V_L(t) = V$

$i_c(t) = -i(t) - \frac{V}{R}$

"3"

$V_L(t) = 0$

$i_c(t) = \frac{-V}{R}$

(b) cont

Volt-second Balance

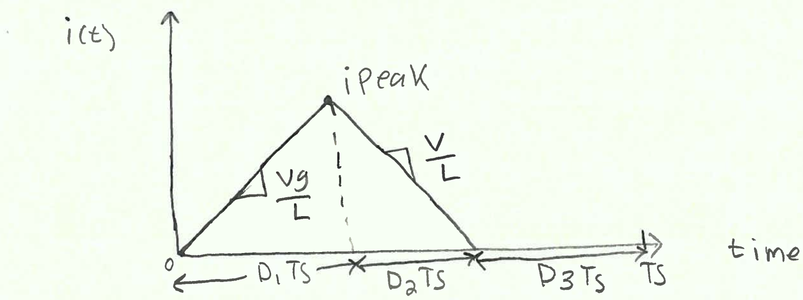
$$\langle v_L(t)\rangle = V_g D_1 + V D_2 + 0 D_3 = 0 \quad (1)$$

capacitor charge Balance

$$\langle i_C(t)\rangle = -\frac{V}{R} D_1 + \left(-i(t) - \frac{V}{R}\right) D_2 + -\frac{V}{R} D_3 = 0$$

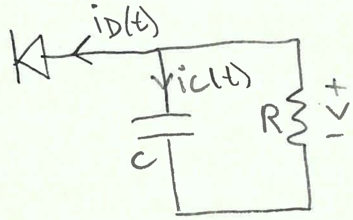
notice not a DC quantity → need another relationship

Consider the inductor current



$$i_{peak} = \frac{V_g}{L} D_1 T_S \quad (2)$$

Consider diode current



$$-i_D(t) = -i_C(t) + \frac{V(t)}{R}$$

or

$$i_C(t) = -i_D(t) - \frac{V(t)}{R}$$

by S.R.A. $\approx V$

"capacitor charge balance"

$$\langle i_C(t)\rangle = \frac{1}{T_S}\int_{T_S}\left(-i_D(t) - \frac{V(t)}{R}\right)dt$$

$$\langle i_C(t)\rangle = \frac{1}{T_S}\int_{T_S} -i_D(t) - \frac{1}{T_S}\int_{T_S}\frac{V}{R}dt$$

$$\langle i_C(t)\rangle = -\langle i_D(t)\rangle_{T_S} - \frac{1}{\cancel{T_S}}\frac{V}{R}\cancel{T_S} = 0$$

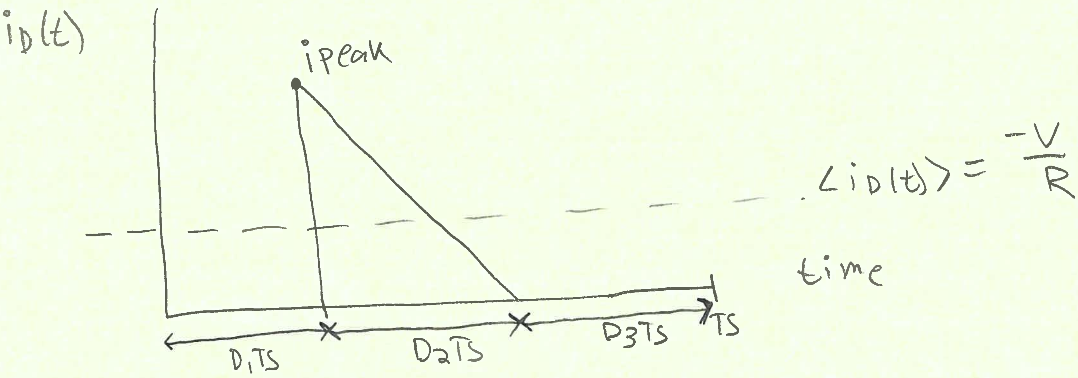
$$\langle i_D(t)\rangle = -\frac{V}{R}$$

(b) cont

We showed the dc component of the diode current

$$\langle i_D(t) \rangle = \frac{-V}{R}$$

so we need to sketch the diode current



$$\langle i_D(t) \rangle = \left(\frac{1}{2} \, i_{peak} D_2 \cancel{T_S}\right) \frac{1}{\cancel{T_S}}$$

$$\frac{1}{2} \, i_{peak} D_2 = \frac{-V}{R} \quad (3)$$

recall

$$V_g D_1 + V D_2 = 0 \quad (1)$$

$$i_{peak} = \frac{V_g}{L} D_1 T_S \quad (2)$$

Three equations + Three unknowns

- Solve for i_{peak}, D_2, and V

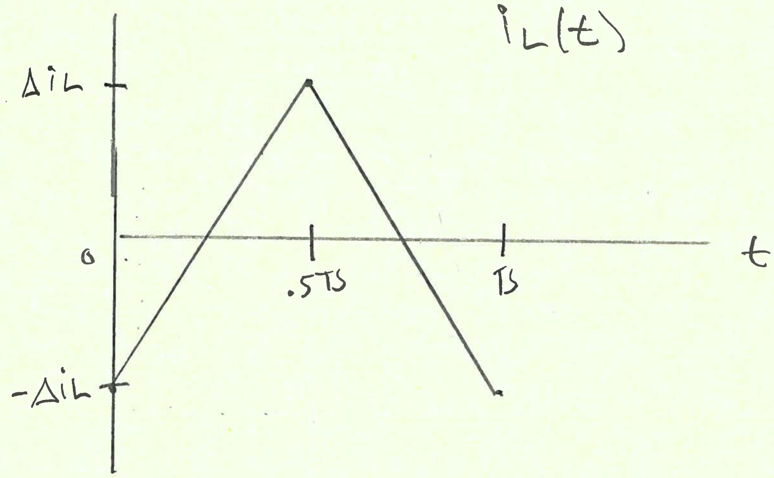
$$D_2 = \sqrt{\frac{2L}{R T_S}}$$ +2.5

$$V = -V_g D_1 \sqrt{\frac{R T_S}{2L}}$$ +2.5

c) When R goes to infinity, the output voltage tends to - infinity. A voltage regulator is required to drive the duty cycle to zero to prevent damage. +0.5

a) <u>No</u>. Synchronous rectification allows inductor current to flow in both directions. The Mosfet allows bidirectional current flow. Since inductor current can go negative, the converter always operates in <u>CCM</u>.

b)



+1.5

$$\Delta i_L = \frac{V_g - V}{2L} D T_S$$

$$D = 0.5$$

$$\Delta i_L = \frac{(V_g - V)}{4L} T_S = \frac{V_g - DV_g}{4L} T_S$$

$$\Delta i_L = \frac{V_g - .5V_g}{4L} T_S$$

$$\Delta i_L = \frac{V_g}{8L} T_S$$