

# ECEN 4797/5797

Introduction to Power Electronics

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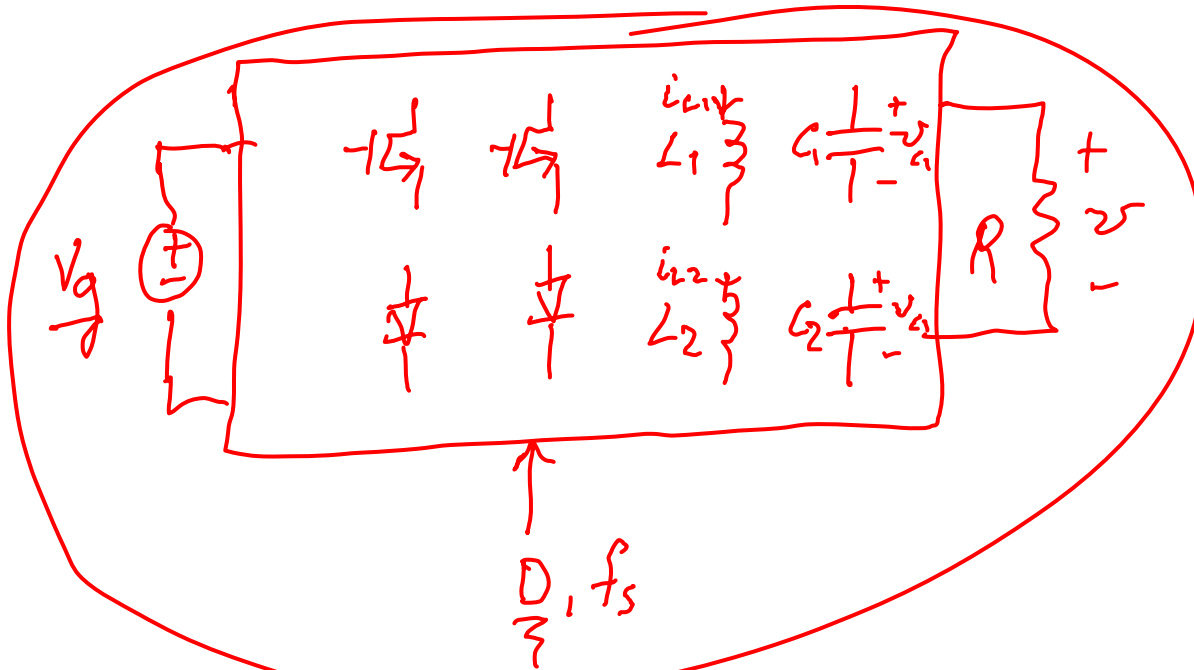
Lecture #3

Friday, August 28, 2009

Steady State Converter Analysis  
(Chapter 2, continued)

Prof. Regan Zane

# Steady-state, equilibrium operation, DC-DC SMPS



States:

$$\underline{i_{L_i}}, \underline{v_{C_i}}$$

Goals:

• solve DC:  $I_{L_i}, V_{C_i}$

• Ripples:  $\underline{\Delta i_{L_i}}, \underline{\Delta v_{C_i}}$

⇒ All signals

• Conversion Ratio:  $M(D)$

• Design / select all  $\underline{L_i}$ 's,  $\underline{C_i}$ 's.

• Select Switches: All comp. stress & ratings.

# Volt-sec & charge balance, ripple magnitudes

Volt-sec Balance:

$$\langle v_{L_i} \rangle_{T_s} = \frac{1}{T_s} \int_{T_s} v_{L_i}(t) dt = 0$$

plot/solve:  $v_{L_i}(t)$

Charge-balance

$$\langle i_{C_i} \rangle_{T_s} = 0$$

plot/solve:  $i_{C_i}(t)$

Ripple mag.  $\Delta i_L, \Delta v_C$

$$v_L = L \frac{di}{dt} \Rightarrow$$

$$\int_{\text{entire pos. } T_s} v_L(t) dt = L \cdot \Delta i_L$$

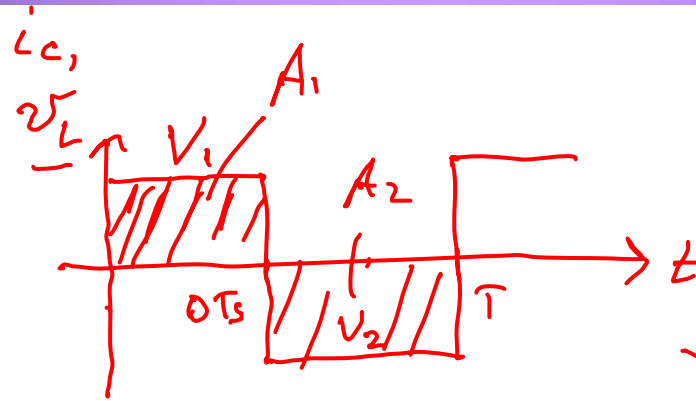
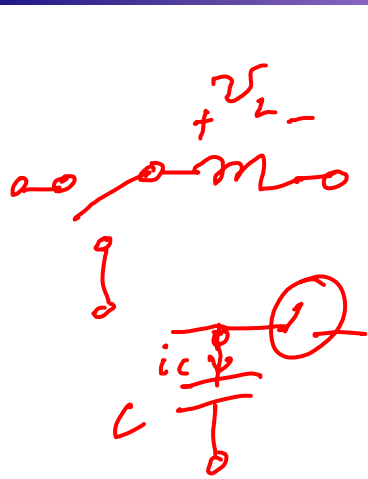
$$\int_{\text{pos. } T_s} i_C(t) dt = C \Delta v_C$$

\* Small-ripple approx:

every:  $i_L = \underline{I_L} + i_{\text{ripple}} \approx \underline{I_L}$

\*  $v_C \approx \underline{V_C}$

# Inductor voltage & capacitor current plots

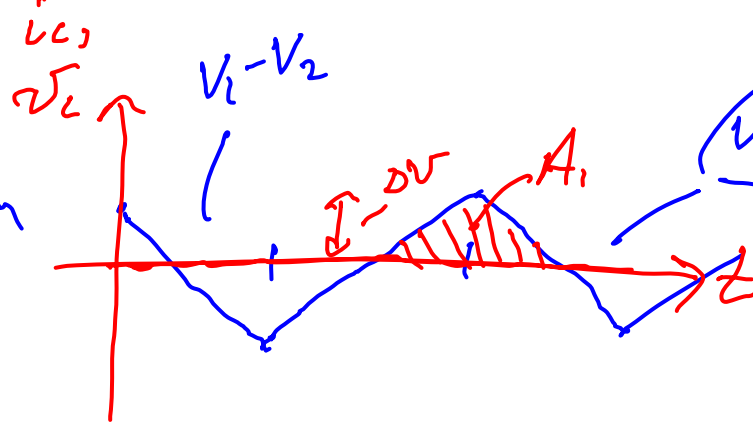
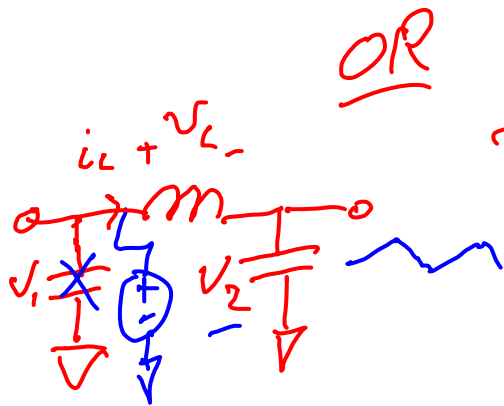


$$DV_1 + D'V_2 = 0 \leftarrow L$$

$$DI_1 + D'I_2 = 0 \leftarrow C$$

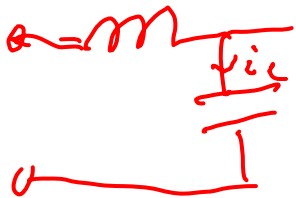
$$\rightarrow A_1 = DT_5 V_1 = L \cdot 2 \Delta i_L$$

$$A_1 = C \cdot 2 \Delta v_C$$

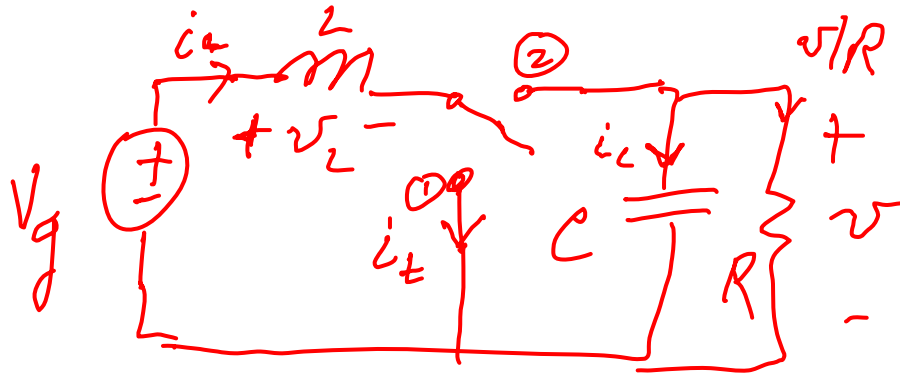


$$V_1 = V_2$$

$$\rightarrow A_1 = L \cdot 2 \Delta i_L$$



# Boost Example



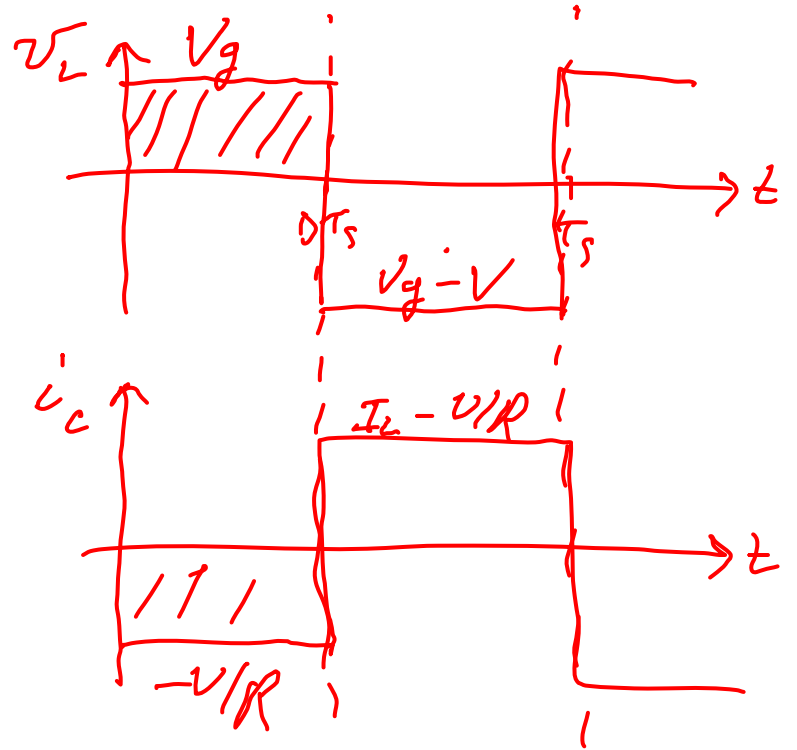
$i_L \approx I_L, v \approx \underline{V}$

$v_L: D V_g + D'(V_g - V) = V_g - D'V = 0$

$$\Rightarrow \frac{V}{V_g} = \frac{m(D)}{D'} = \frac{1}{D'} = \frac{1}{1-D}$$

$i_C: -\frac{DV}{R} + D'(I_L - V/R) = D'I_L - \frac{V}{R} = 0 =$

$$\Rightarrow \underline{I_L} = \frac{1}{D'} \cdot \frac{V}{R} = \frac{1}{D'^2} \cdot \frac{V_g}{R}$$



$$DT_s V_g = L \cdot 2 \omega i_L$$

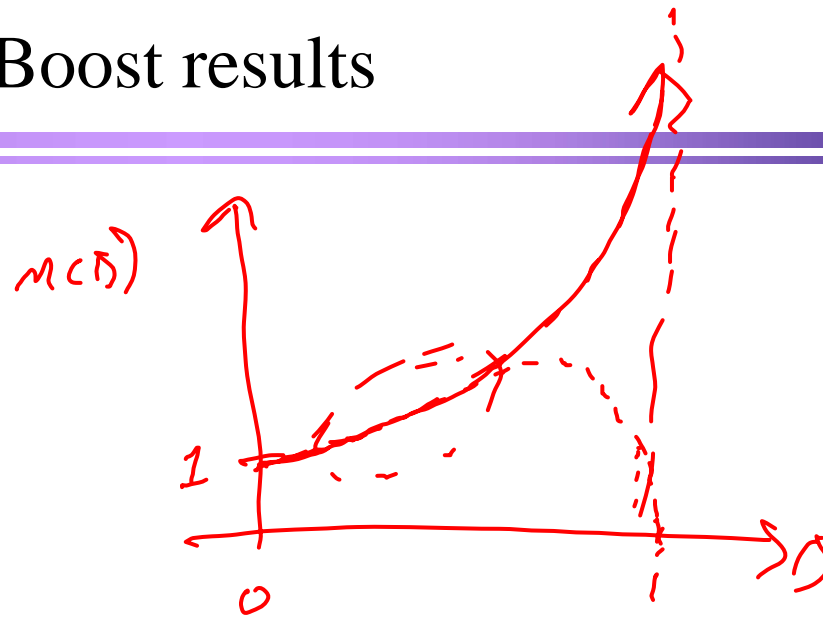
$$-\frac{V}{R} DT_s = -C \cdot 2 \omega V$$

# Boost results

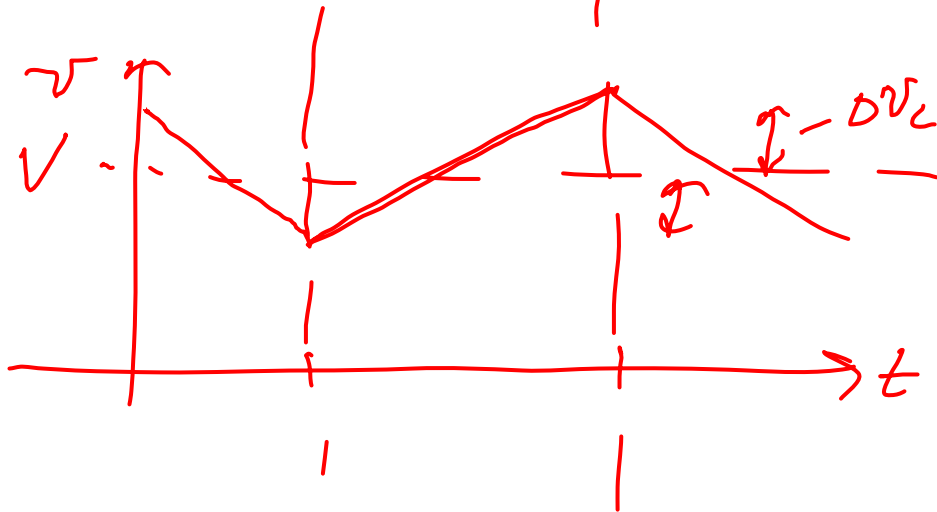
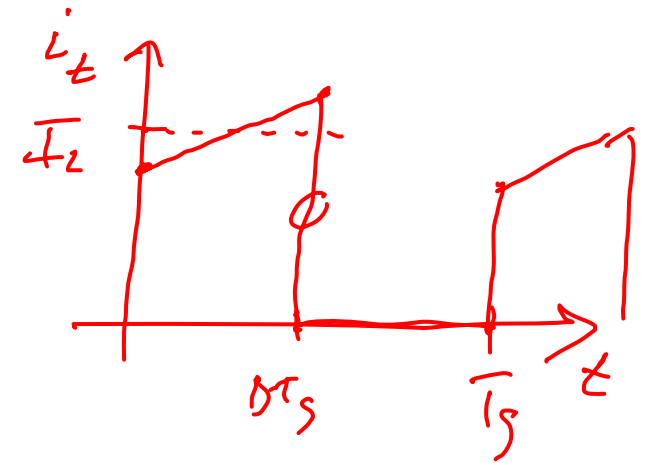
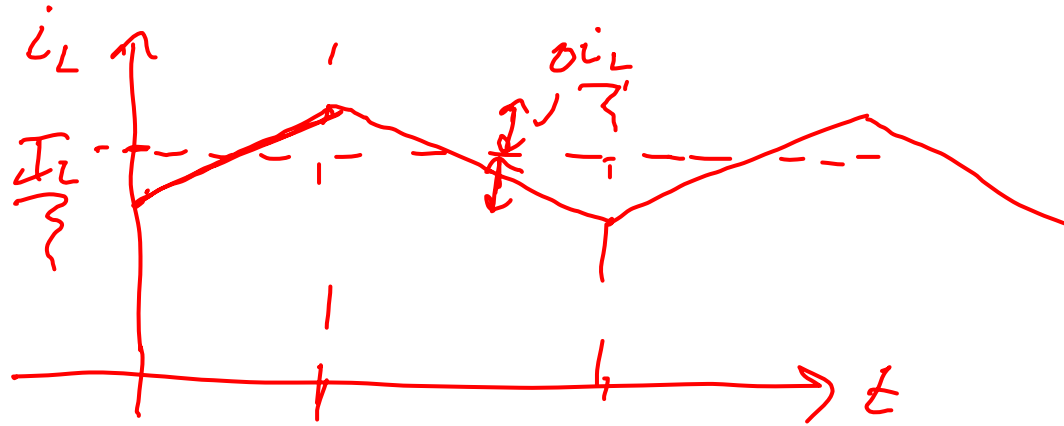
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$$M(D) = \frac{1}{1-D}$$

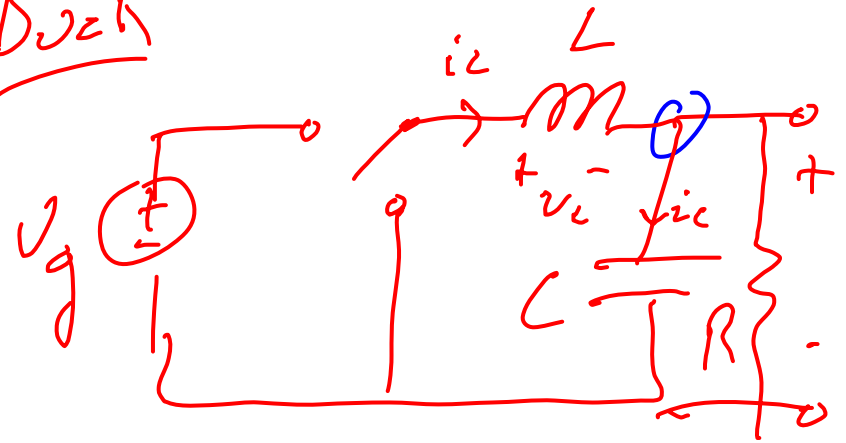
$$I_2 = \frac{V_g}{R} \cdot \frac{1}{(1-D)^2}$$



# Boost results



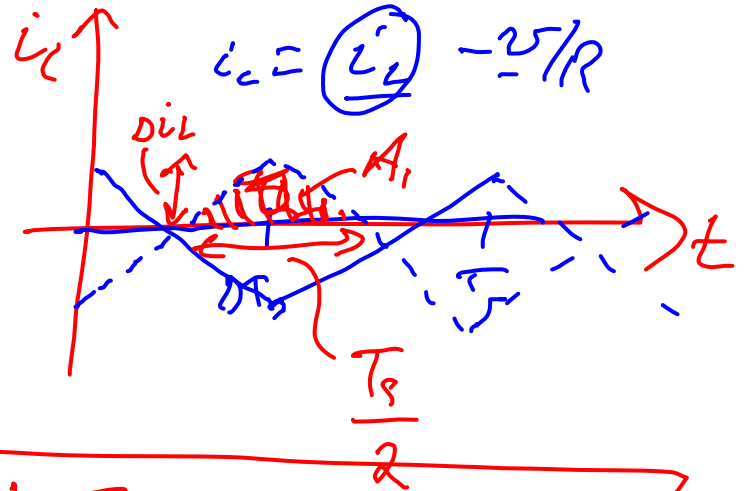
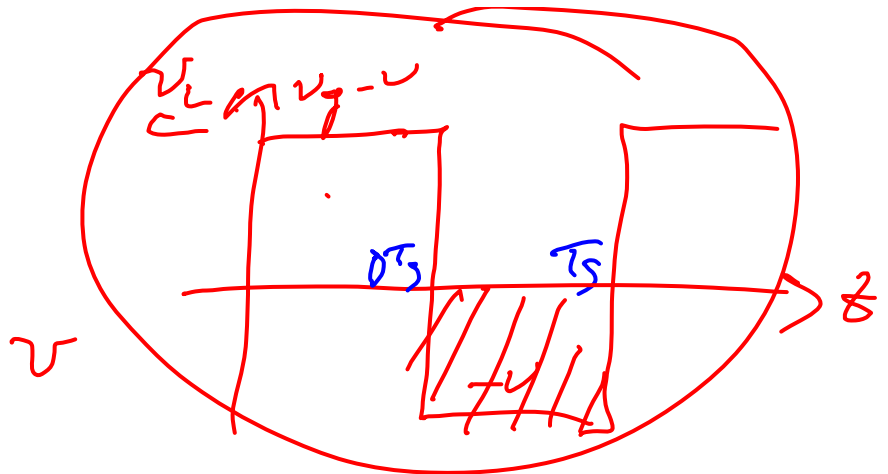
Buck



- $i_L \approx I_L$
- $v \approx V$

$$I_L = \frac{V}{R}$$

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



$$A_1 = \frac{1}{2} \cdot \frac{T_S}{2} \cdot \Delta i_L = \underline{\underline{C \cdot 2 \Delta v_c}}$$

$$+V D' T_S = L \cdot 2 \Delta i_L$$