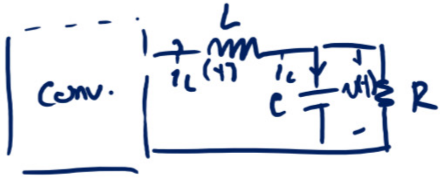
Ripple in Second Order Filters



$\langle i_c \rangle|_{T_s} = I_L - \frac{V}{R} = 0$

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

When SRA trivializes our calculation we need to relax it.

when we approx. $i_L(t) = I_L$

$i_c(t) = 0$ always in steady-state

$\Delta v_c = 0$

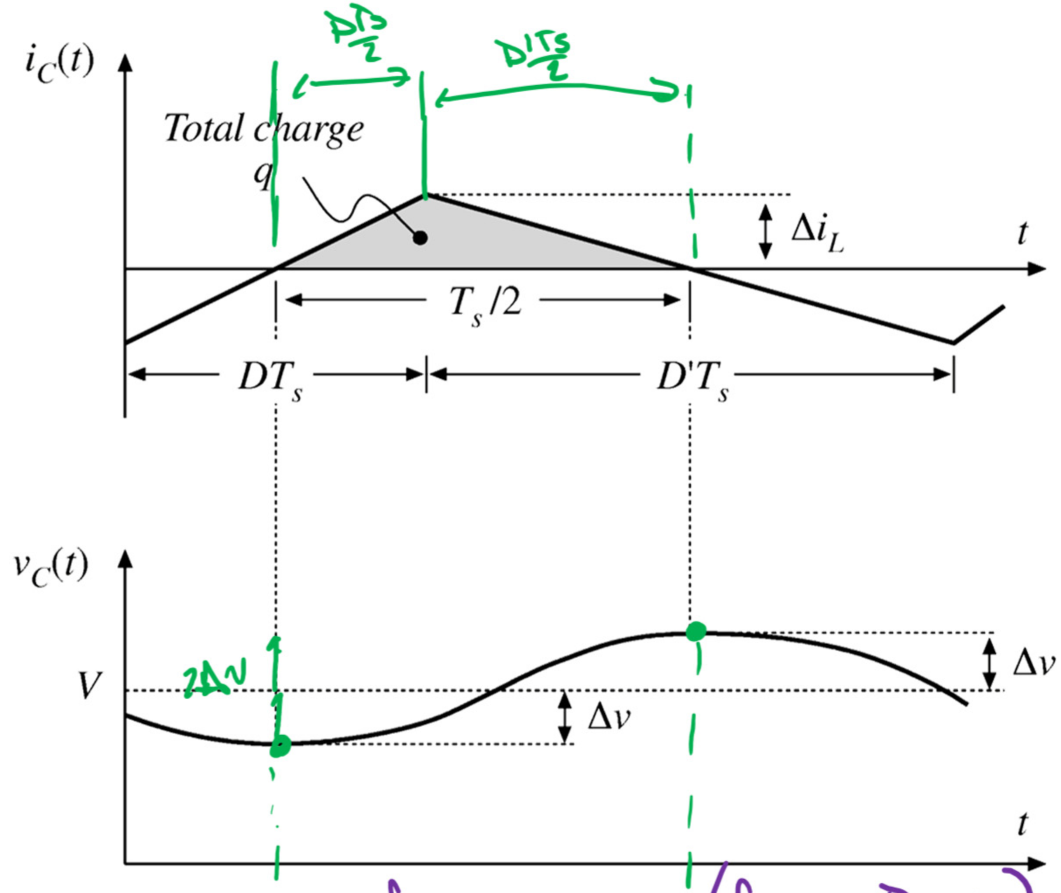
Relax SRA

$i_L(t) = I_L + tri(D, \Delta i_L)$

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

$2\Delta v = \frac{1}{C}\int_{\text{positive portion}} i_c \, dt$

$2\Delta v = \frac{1}{C}\frac{1}{2}\frac{T_s}{2}\Delta i_L \rightarrow \boxed{\Delta v_c = \frac{1}{8C}T_s \Delta i_L}$

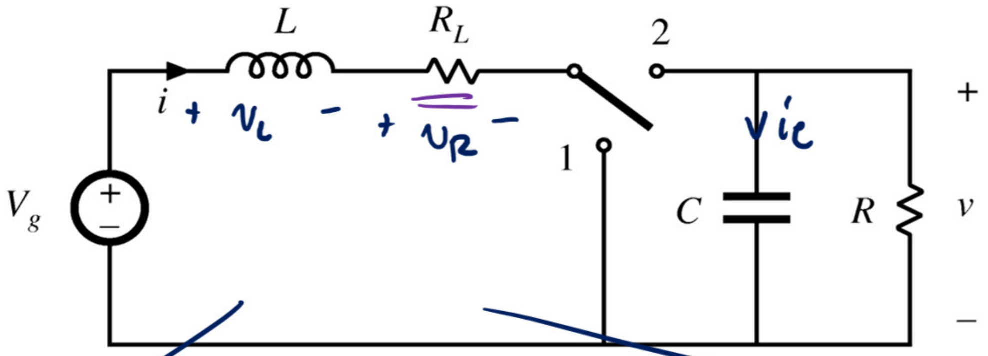


from previous (for Buck)

$\Delta i_L = \frac{V_g}{2L}DD'T_s$

$\Delta v_c = \frac{1}{16LC}T_s^2 DD' V_g$

Nonideal Boost Converter



①

$$v_L(t) = V_g - v_R(t)$$

$$= V_g - i(t) R_L$$

$$= V_g - I_L R_L$$

SRA.

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

②

$$v_L(t) = V_g - I_L R_L - V$$

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

Volt-sec balance $\langle v_L \rangle|_{T_s} = 0 = V_g - I_L R_L - D'V$

Cap-Q balance $\langle i_C \rangle|_{T_s} = 0 = D'I_L - \frac{V}{R}$

Boost Conversion Ratio with Losses

$$0 = V_g - I_L R_L - D'V$$

$$0 = D'I_L - \frac{V}{R} \longrightarrow I_L = \frac{V}{RD'}$$

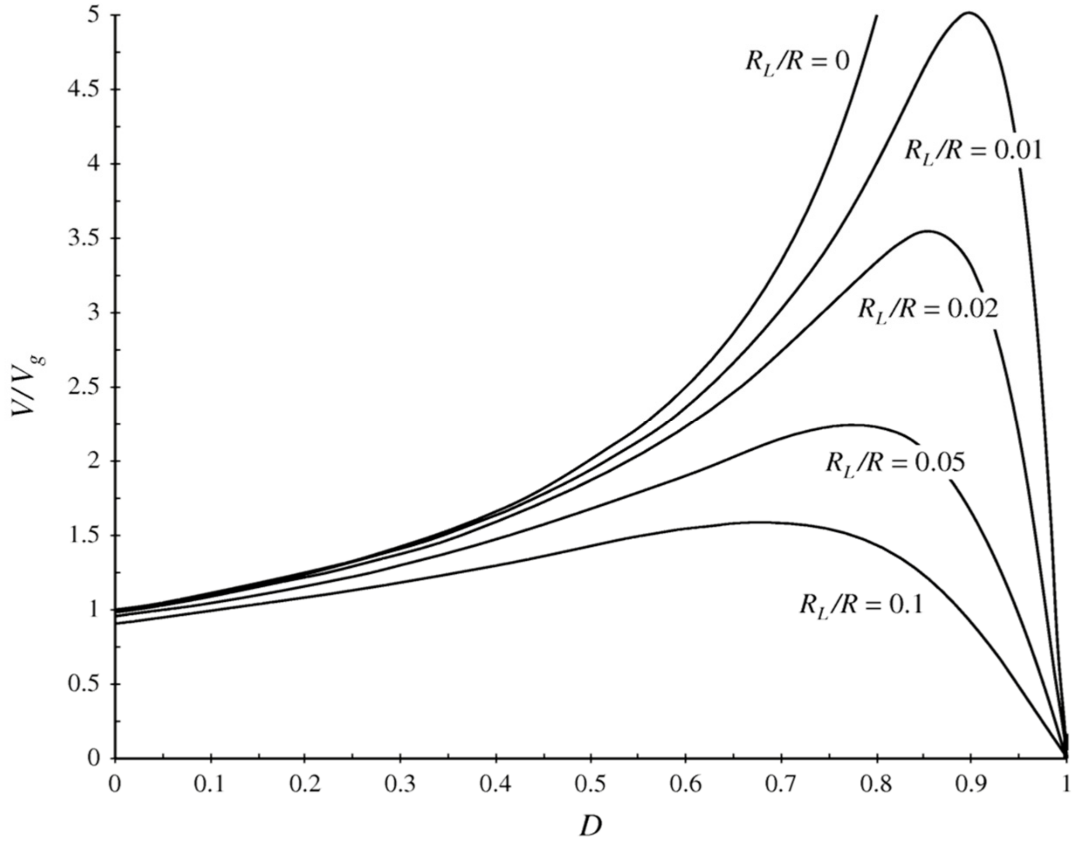
$$0 = V_g - R_L \frac{V}{RD'} - D'V$$

$$V\left(D' + \frac{R_L}{RD'}\right) = V_g \quad , \quad M = \frac{V}{V_g} = \frac{1}{D' + \frac{R_L}{RD'}}$$

let's write this as $M = M_{ideal} \cdot f(R_L, R, D)$

$$M = \underset{\overset{\uparrow}{M_{ideal}}}{\left(\frac{1}{D'}\right)} \underset{\overset{\uparrow}{f(\cdot)}}{\left(\frac{1}{1 + \frac{R_L}{RD'^2}}\right)}$$

Nonideal Boost Output Voltage



$$M = \frac{1}{D'}\left(\frac{1}{1+\frac{R_L}{RD'^2}}\right)$$

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V^2/R}{V_g I_L} = \frac{V^2/R}{V_g \frac{V}{RD'}} = \frac{V}{V_g \frac{1}{D'}} = \underset{\underset{M}{\uparrow}}{\frac{V}{V_g}}\ \underset{\underset{\frac{1}{M_{ideal}}}{\uparrow}}{D'}$$

$$\eta = M \cdot \frac{1}{M_{ideal}} = \left(M_{ideal}\ f(\cdot)\right)\frac{1}{M_{ideal}}$$

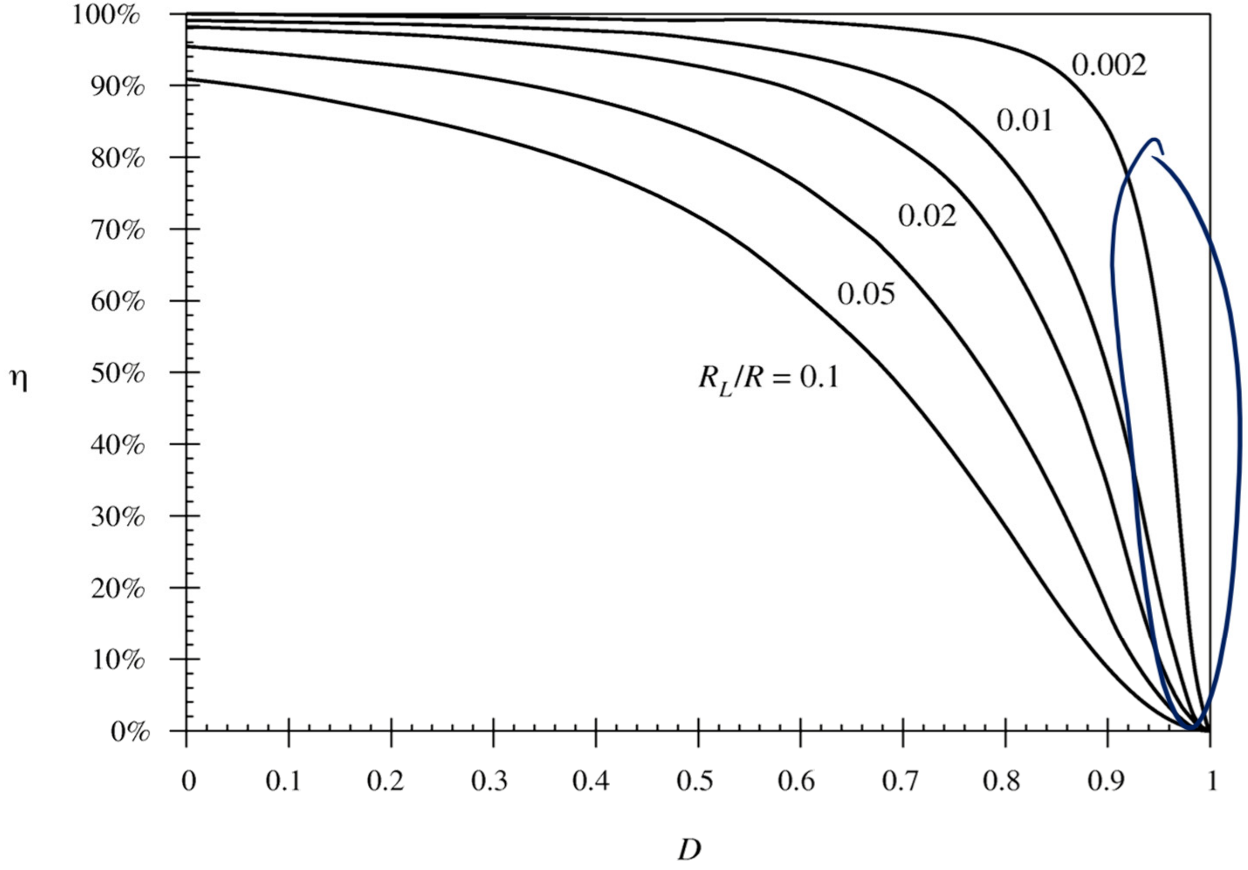
$$\eta = f(\cdot) = \frac{1}{1+\frac{R_L}{RD'^2}}$$

$$\underset{\text{with losses}}{\boxed{M = M_{ideal}\cdot \eta}} \longrightarrow$$

General result for averaged converters including conduction losses

Boost Converter Efficiency

$$\eta = \frac{1}{1 + \frac{R_L}{D'^2 R}}$$



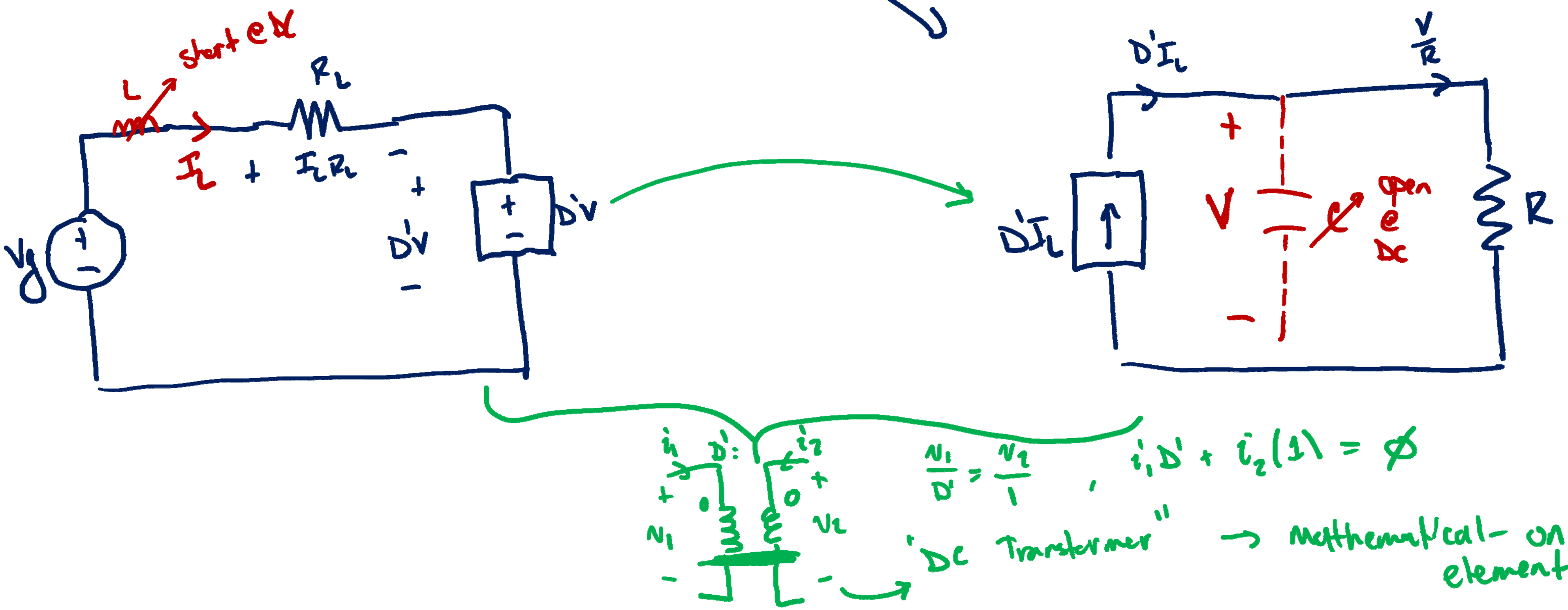
Fundamentals of Power Electronics 19 *Chapter 3: Steady-state equivalent circuit modeling, ...*

Equivalent Circuit Models

construct an "averaged equivalent circuit" that matches the equations derived by SRA & V-s / C-Q balancing.

$$\langle v_L\rangle|_{T_s} = 0 = V_g - I_L R_1 - D'V \rightarrow \text{KVL equation}$$

$$\langle i_C\rangle|_{T_s} = 0 = D'I_L - \frac{V}{R} \rightarrow \text{KCL equation}$$



$\frac{N_1}{D'} = \frac{N_2}{1}$, $i_1 D' + i_2(1) = 0$

"DC Transformer" → mathematical-only circuit element

Boost Equivalent Circuit Model