ECEN 4797/5797

Introduction to Power Electronics

Lecture #4

Monday, August 31, 2009

Steady State Converter Analysis:

Conduction Losses & Equivalent Circuit Modeling

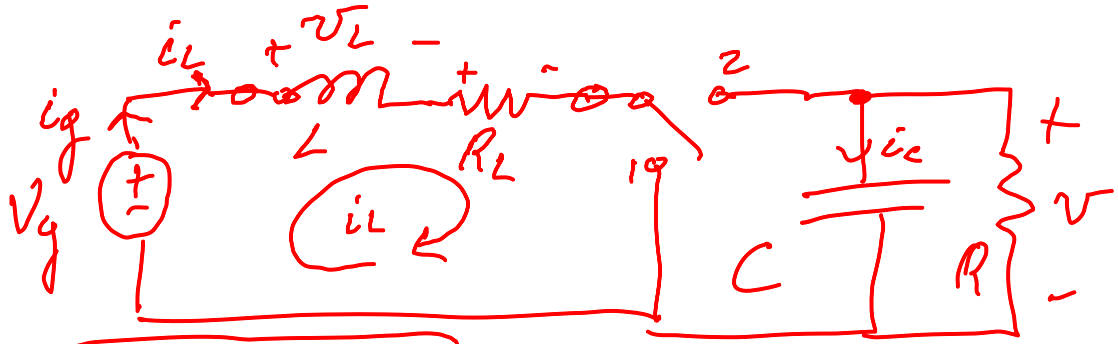
(Chapter 3, 3.1-3.3)

Prof. Regan Zane

Goals Today (& this week)

- Add in conduction losses to averaged steady-state analysis
  - Losses from non-ideal Vg, L's, C's & switches
  - Solve waveforms & output including losses
  - Solve efficiency
- Develop equivalent circuit models
  - Simplify analysis with many converter & loss components
    - Leverage LTI circuit manipulation techniques
  - Gain a more intuitive, design-oriented model

Boost converter w/ Inductor Series Resistance, R_L



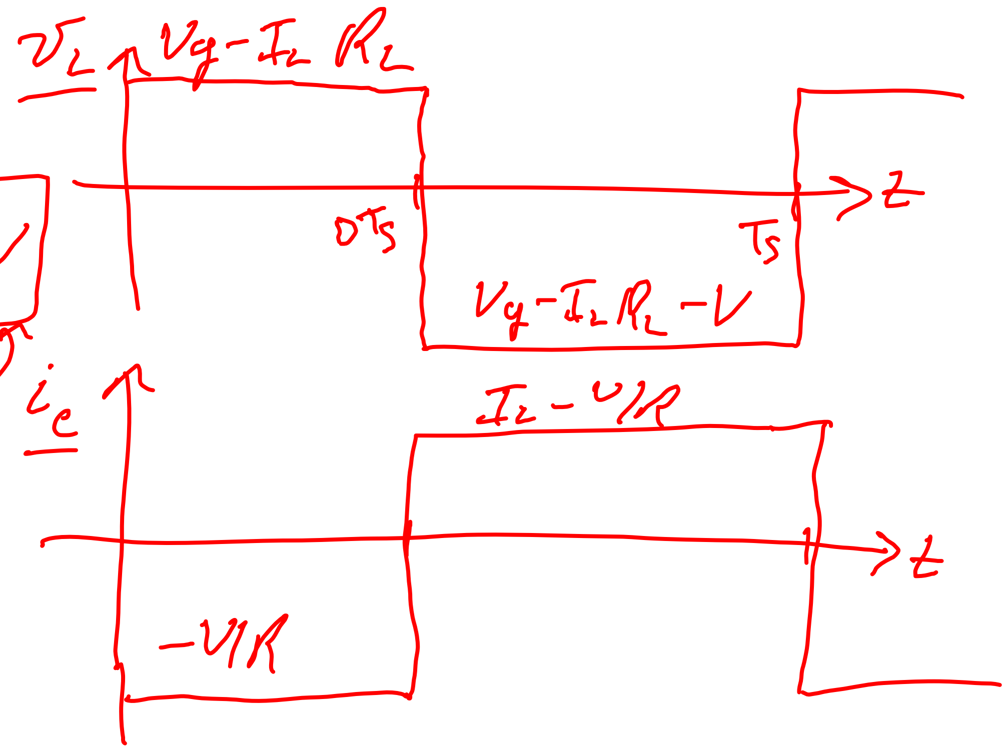
$$v_L = V_g - I_L R_L$$

$$v_L = L\frac{di_L}{dt}$$ ideal

* $\langle v_L \rangle = 0 = V_g - I_L R_L - D'V$

* $\langle i_c \rangle = 0 = D' I_L - V/R$

$\Rightarrow$ $I_L = \dfrac{V}{D'R}$



Boost converter solution

$$\langle v_L \rangle = 0 = V_g - \frac{R_L V}{D' R} - D' V = 0$$

$$\frac{V}{V_g} = M(D)_{\text{losses}} = \frac{1}{D' + \frac{R_L}{D' R}} = \boxed{\frac{1}{D'} \cdot \frac{1}{1 + \frac{R_L}{D'^2 R}}}$$

efficiency: $\eta = \frac{V_o I_o}{V_g I_g} = \frac{V^2}{R \cdot V_g \cdot I_L} = \frac{V^2}{R \cdot V_g} \cdot \frac{D' R}{V} = \frac{V}{V_g} \cdot D'$

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

Solution for output voltage

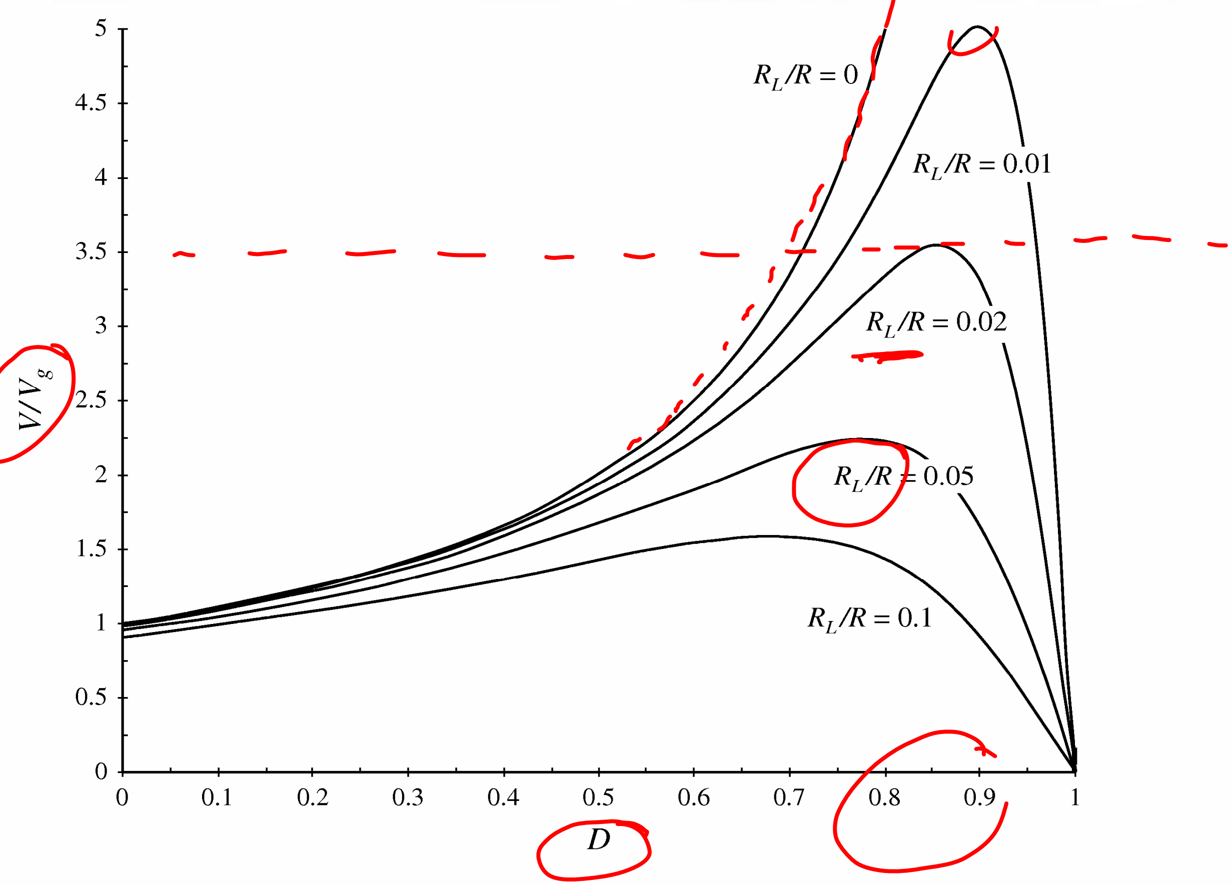
We now have two equations and two unknowns:

$$0 = V_g - I\,R_L - D'V$$

$$0 = D'I - V / R$$

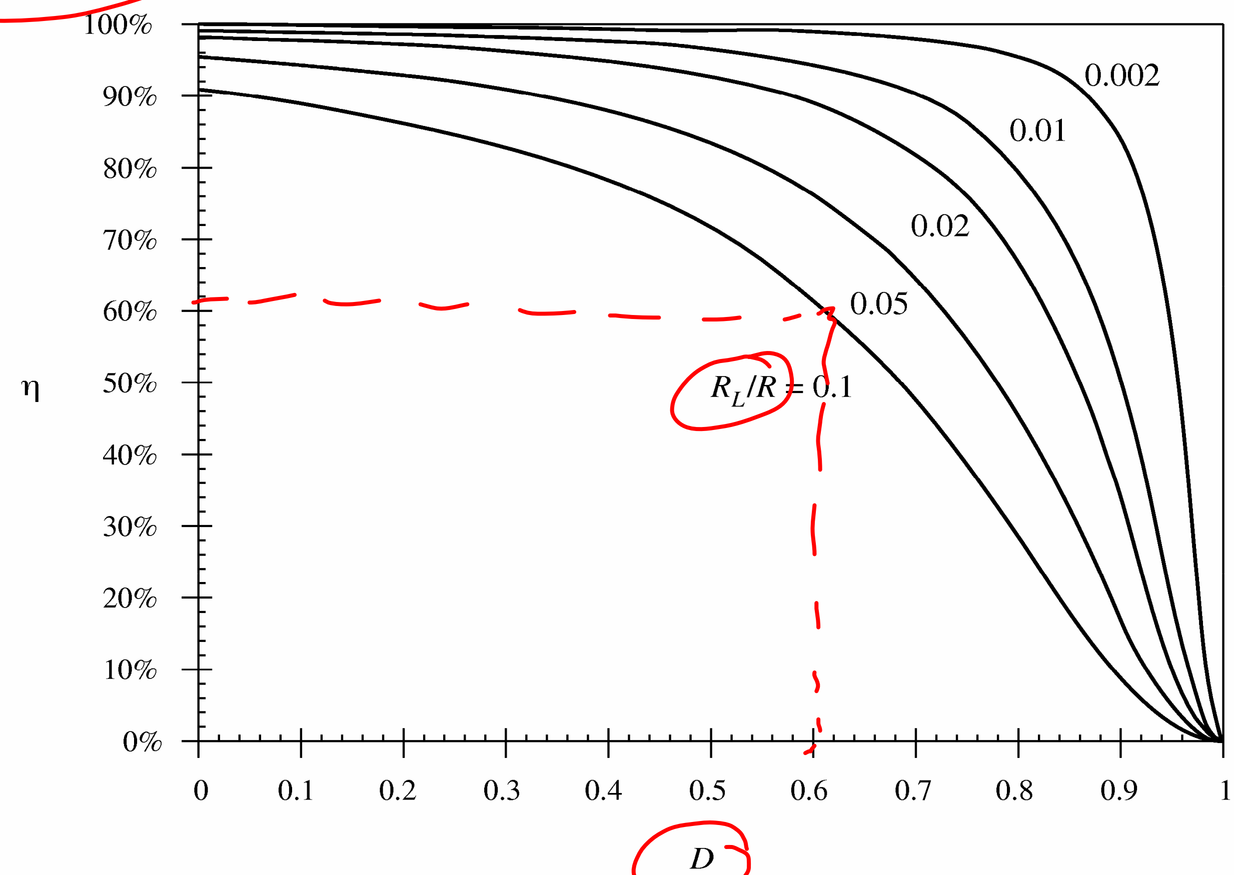
Eliminate I and solve for V:

$$\frac{V}{V_g} = \frac{1}{D'} \frac{1}{(1 + R_L / D'^2 R)}$$



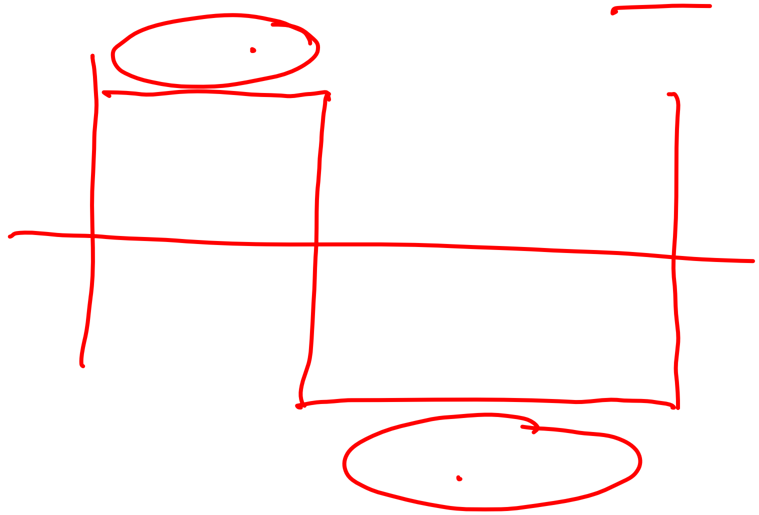
Efficiency, for various values of R_L

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



Equivalent Circuit Modeling

- Same procedure!
- Convert averaged equations to **equivalent circuit models** prior to solving algebra
  - Loop equations, $\langle v_L \rangle = 0$
  - Node equations, $\langle i_c \rangle = 0$

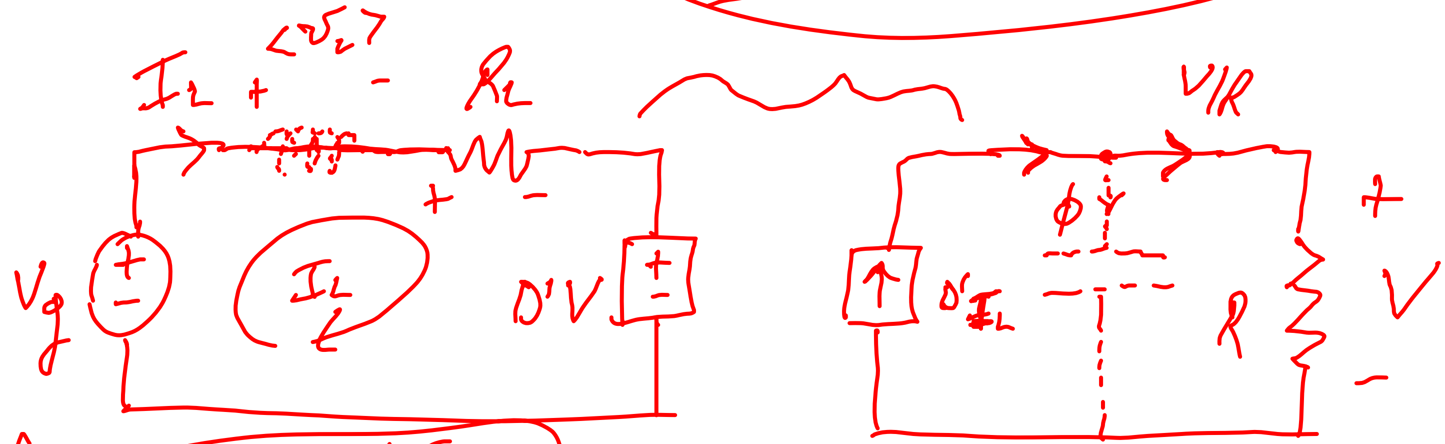


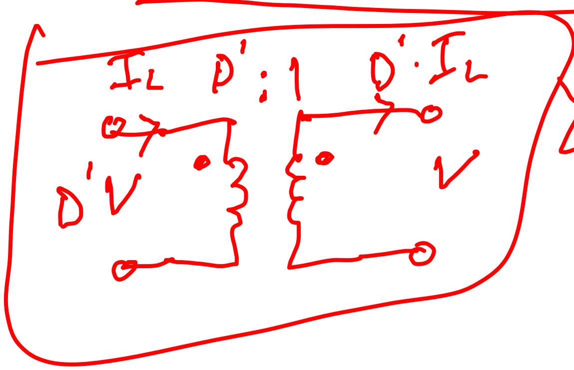
Boost Equiv. Circuit Model

$$\langle v_L \rangle = 0 = V_g - I_L R_L - D'V$$

$$\langle i_C \rangle = 0 = D'I_L - V / R$$

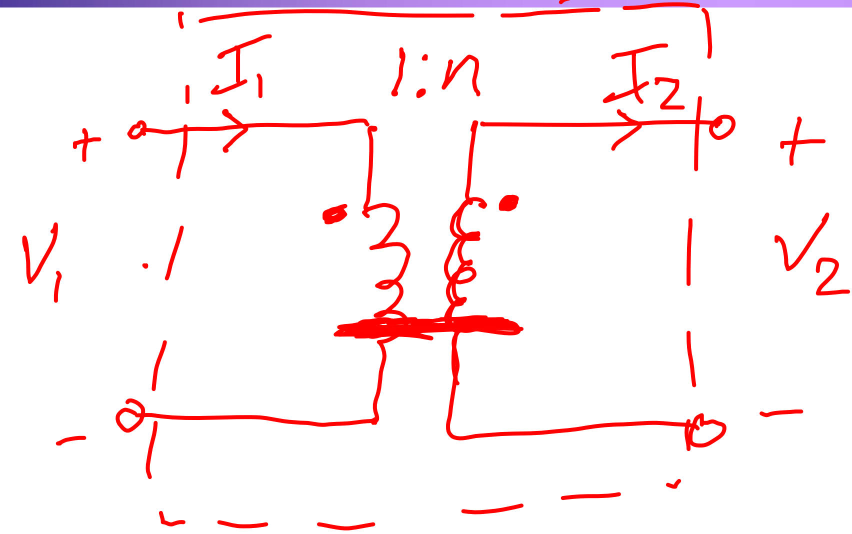
ideal transformer





Dependent Sources (?)

Ideal DC Transformer



$$V_2 = n V_1$$

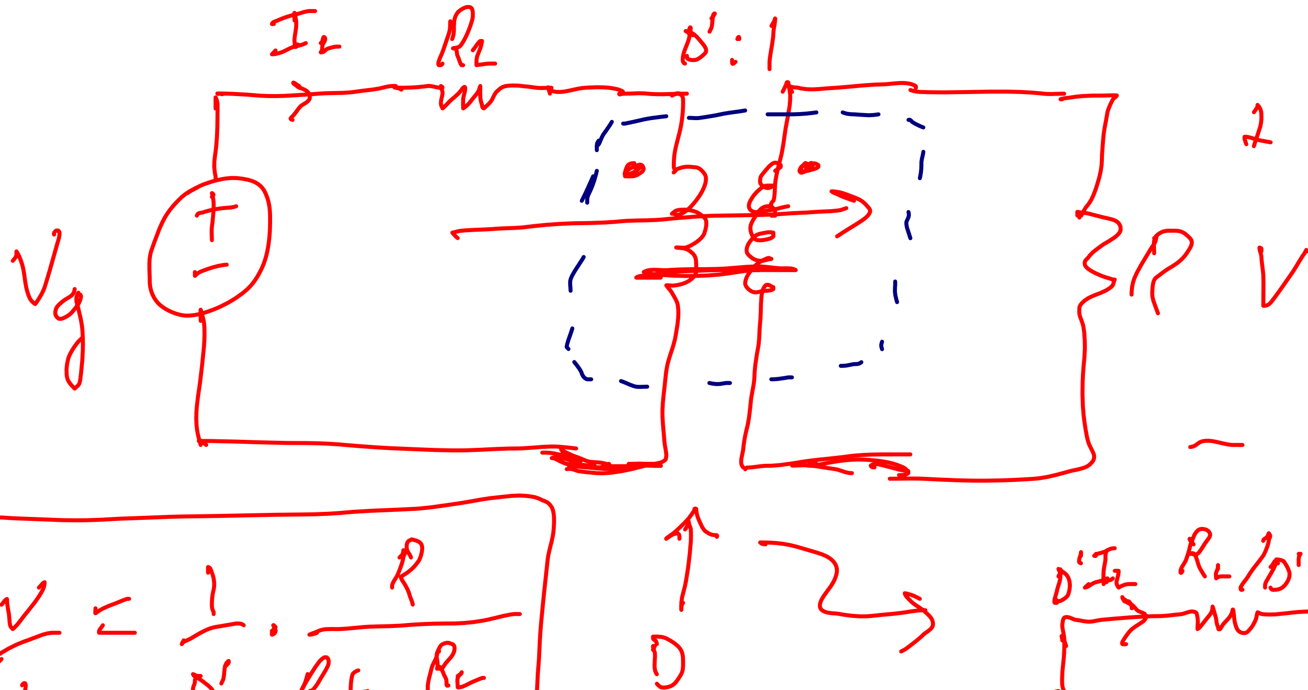
$$I_1 = n I_2$$

$$P_{in} = V_1 \cdot I_1 =$$

$$P_{out} = V_2 I_2 = n V_1 \cdot \frac{I_1}{n} = V_1 I_1$$

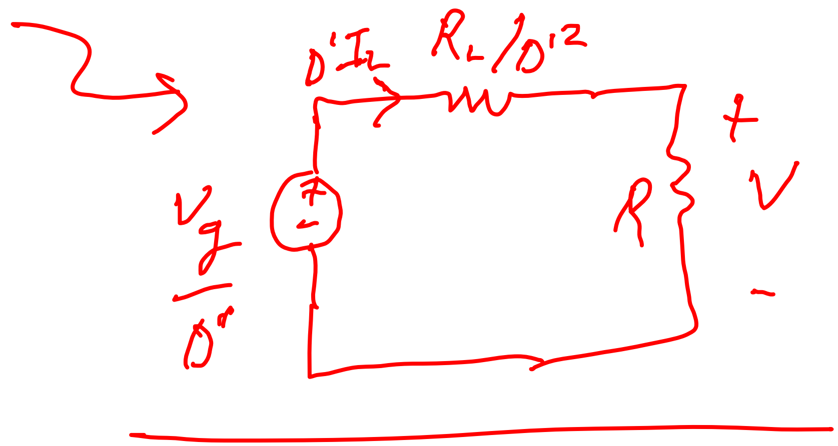
$$\eta = 1$$

Boost Equiv. Circuit w/ DC Transformer

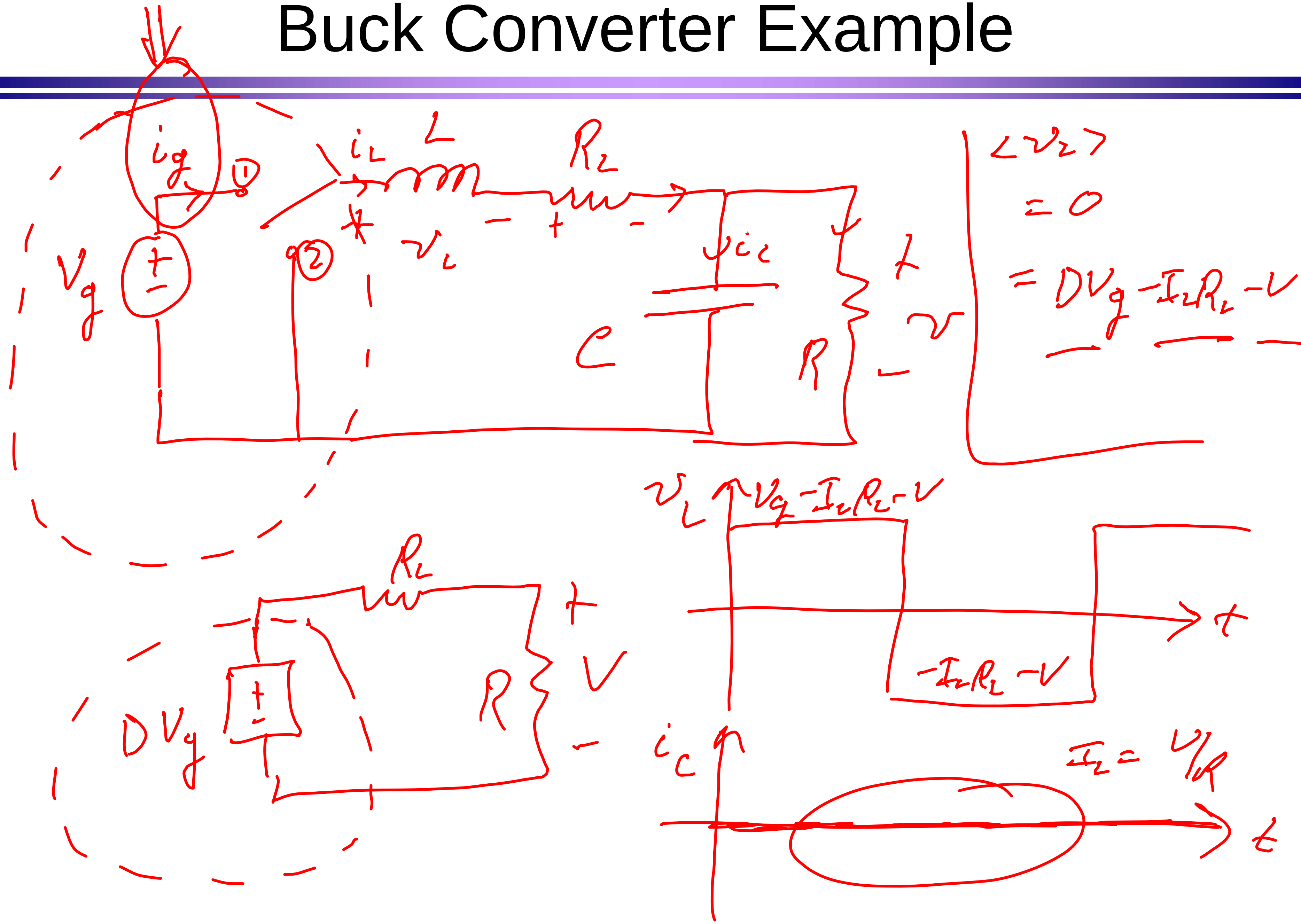


$$\frac{V}{V_g} = \frac{1}{D'} \cdot \frac{R}{R + \frac{R_L}{D'^2}}$$

$n =$



Buck Converter Example



Input Port Modeling