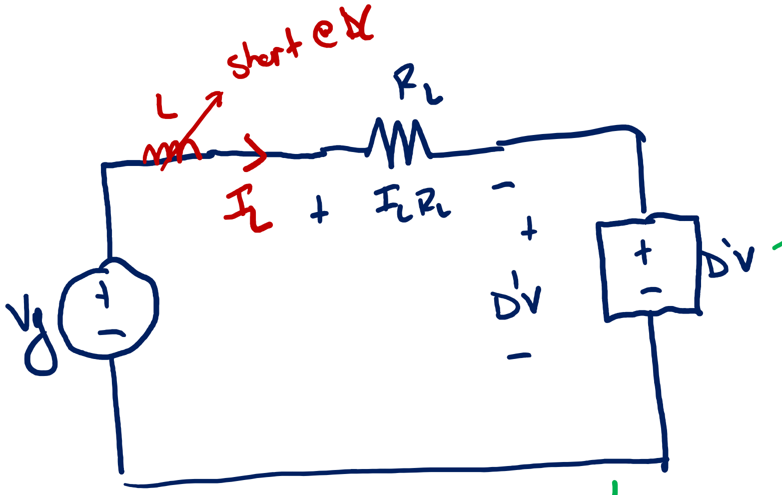
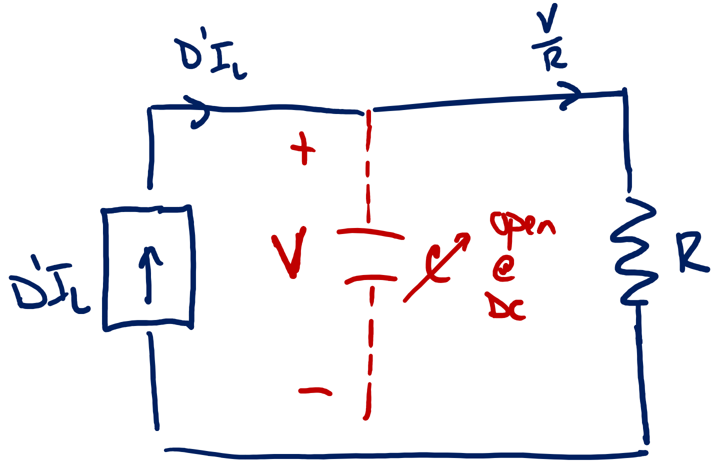
Equivalent Circuit Models

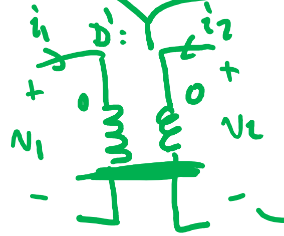
construct an "averaged equivalent circuit" that matches the equations derived by SSA & V-s / C-Q balancing.

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

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



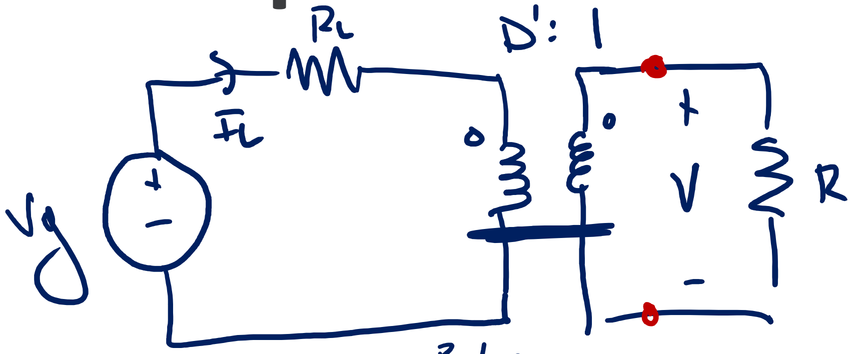


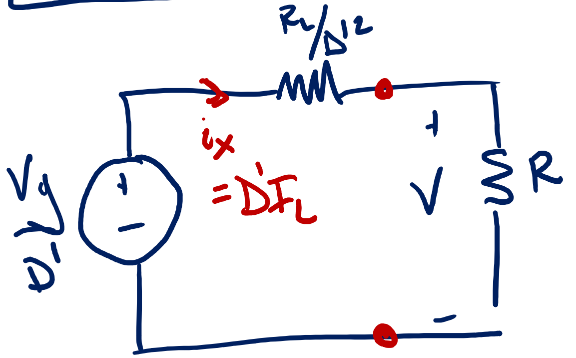


$\frac{N_1}{D'} = \frac{N_2}{1}$, $i_1 D' + i_2(1) = 0$

"DC Transformer" → mathematical-only circuit element

Boost Equivalent Circuit Model



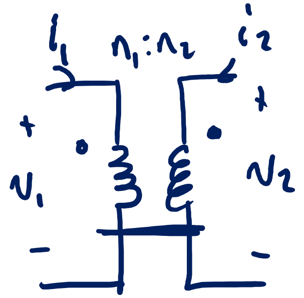


$$V = \frac{V_g}{D'} \frac{R}{R + R_L/D'^2} \rightarrow M = \frac{V}{V_g} = \frac{1}{D'} \frac{R}{R + \frac{R_L}{D'^2}} = \frac{1}{D'}\left(\frac{1}{1 + \frac{R_L}{RD'^2}}\right)$$

M_{ideal} η

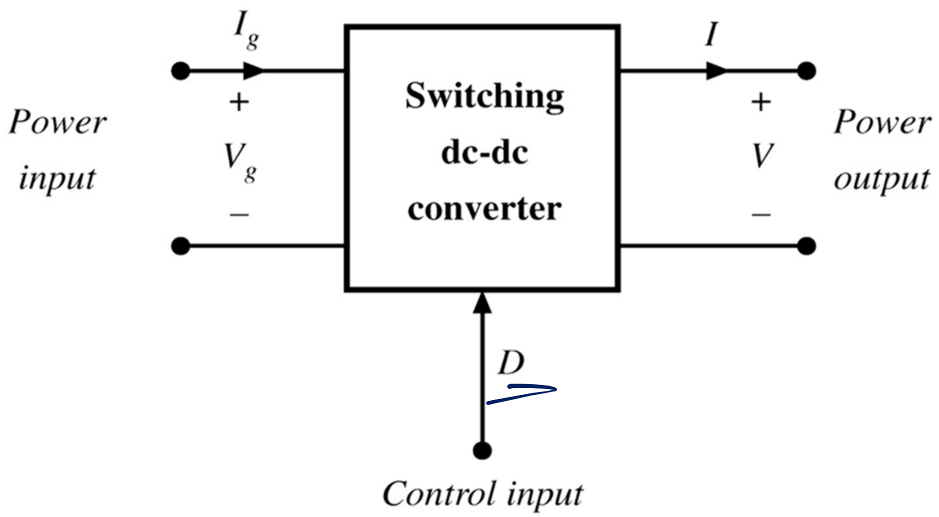
$$\eta = \frac{P_{out}}{P_{in}} = \frac{V i_x}{\frac{V_g}{D'} i_x} = D' \frac{V}{V_g} = \frac{1}{M_{ideal}} M = \eta$$

The DC Transformer Model

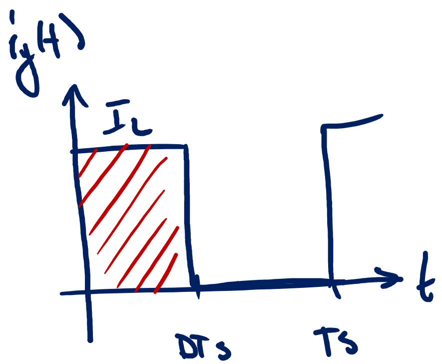


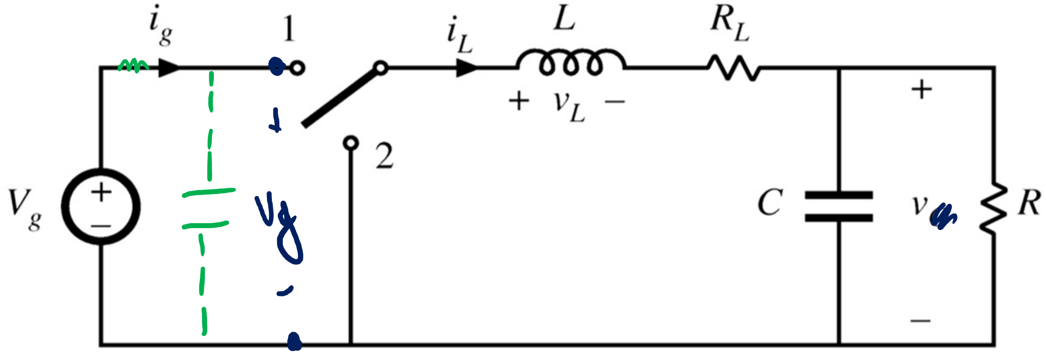
$$\begin{cases} \dfrac{v_1}{n_1} = \dfrac{v_2}{n_2} \\ n_1 i_1 + n_2 i_2 = 0 \end{cases}$$

$$\frac{v_2}{v_1} = \frac{n_2}{n_1} \longleftrightarrow M(D)$$



Buck Converter: Input Port Model





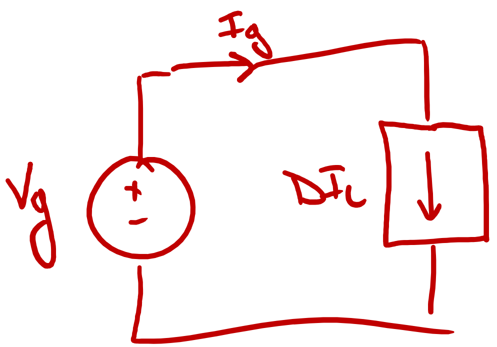
when pulsating waveform applied to a source, need to average the source for an additional equation

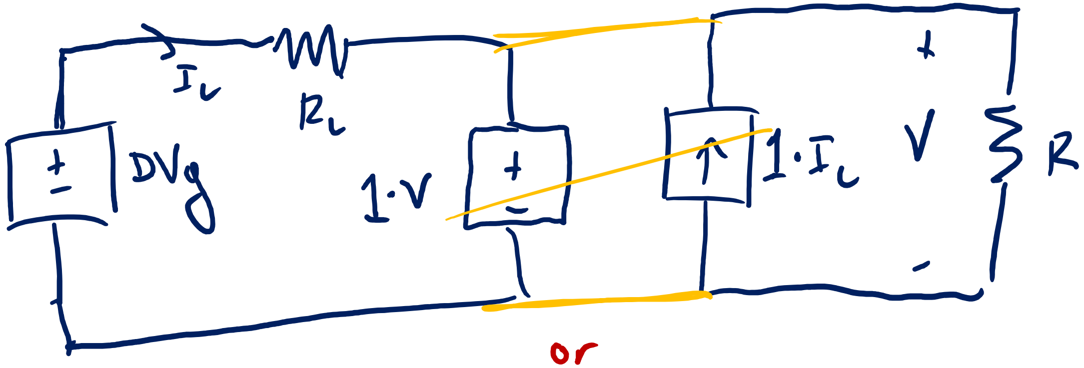
$$I_g = \frac{1}{T_s}\int_0^{T_s} i_g(t)\,dt$$

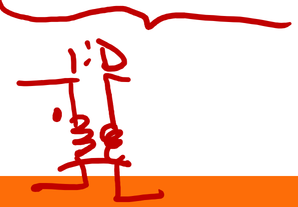
$$\boxed{I_g = DI_L}$$

$$\langle v_L \rangle_{T_s} = 0 = DV_g - I_L R_L - V$$

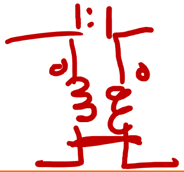
$$\langle i_C \rangle_{T_s} = 0 = I_L - \frac{V}{R}$$

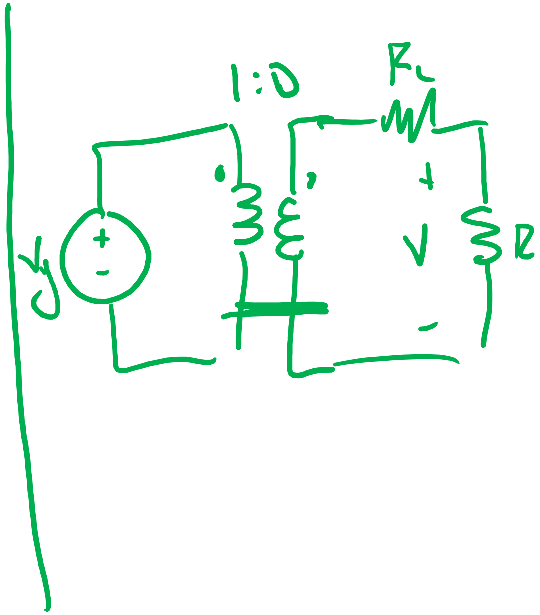






or





Semiconductor Conduction Loss Models