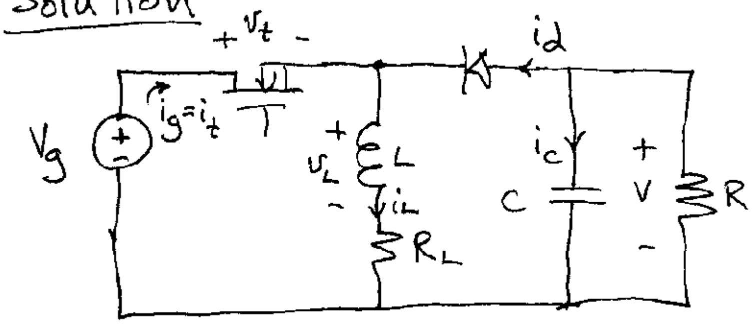
Additional Problems on Switching Loss

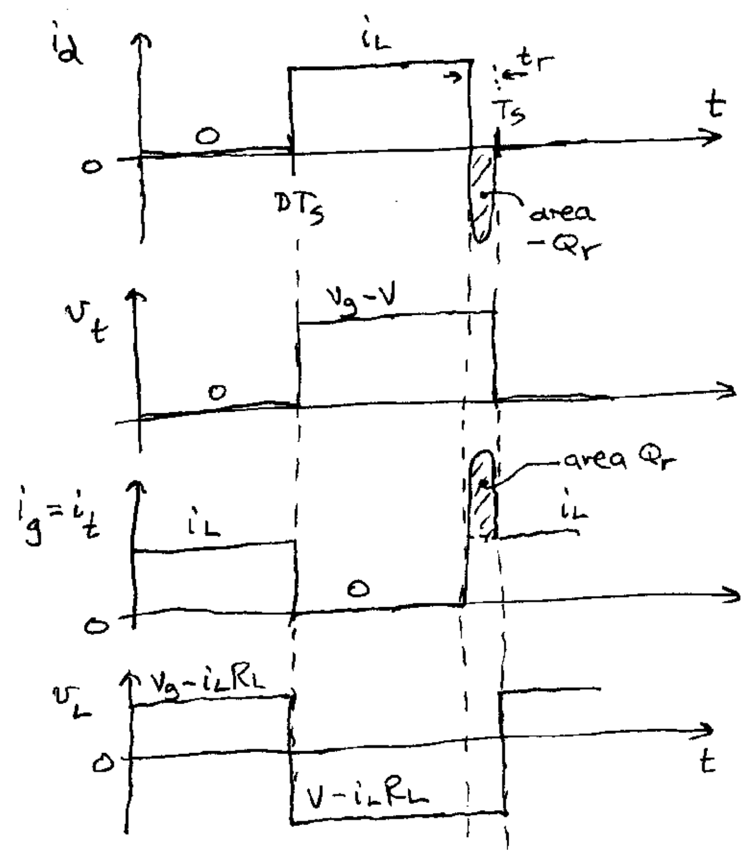
Introduction to Power Electronics
Fall 2004

1 A certain buck-boost converter is implemented with a MOSFET and a p–n diode. The MOSFET can be modeled as ideal, but the diode exhibits a substantial reverse-recovery process, with reverse recovery time t_r and recovered charge Q_r. In addition, the inductor has winding resistance R_L.

Derive an equivalent circuit that models the dc components of the converter waveforms and that accounts for the loss elements described above.

Solution





Small ripple approximation:

$i_L(t) \approx I_L$

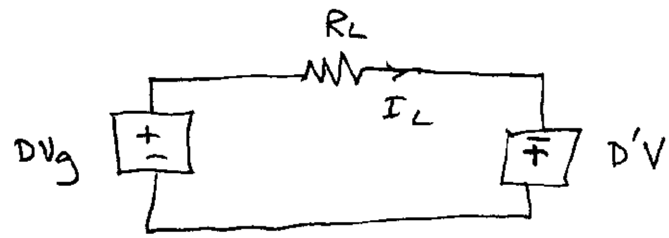
$v(t) \approx V$

Volt-second balance

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

with $D' = 1 - D$

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



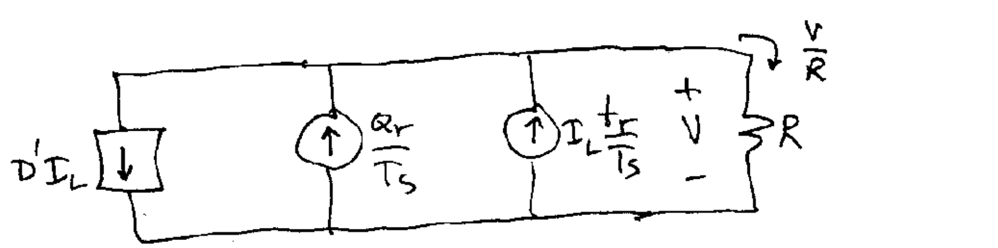
charge balance

$$i_c + i_d + \frac{v}{R} = 0 \quad \text{with} \quad \langle i_c \rangle = 0$$

so $$\langle i_c \rangle = -\langle i_d \rangle - \frac{V}{R} = 0$$

and $$\langle i_d \rangle = \left[-Q_r + I_L \cdot (D' T_s - t_r) \right] \frac{1}{T_s}$$

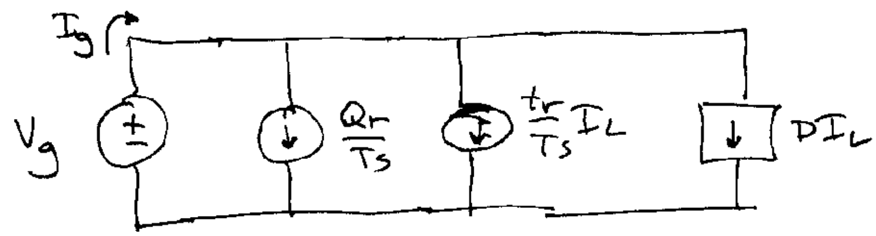
so $$\langle i_c \rangle = 0 = \frac{Q_r}{T_s} - D' I_L + I_L \frac{t_r}{T_s} - \frac{V}{R}$$



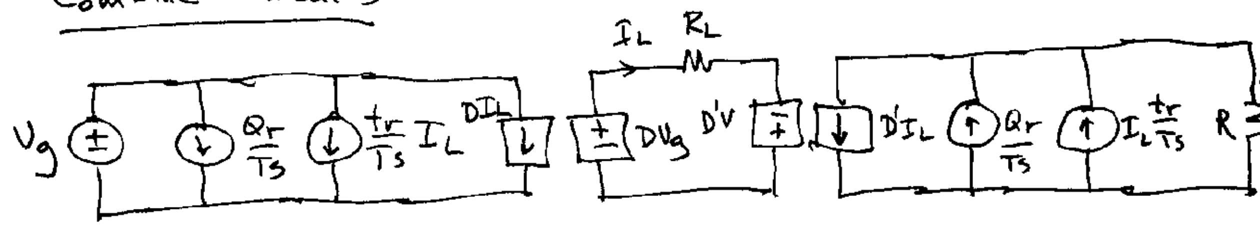
average input current

$$I_g = \langle i_g \rangle = \langle i_t \rangle = \frac{1}{T_s}\left[I_L D T_s + Q_r + t_r I_L \right]$$

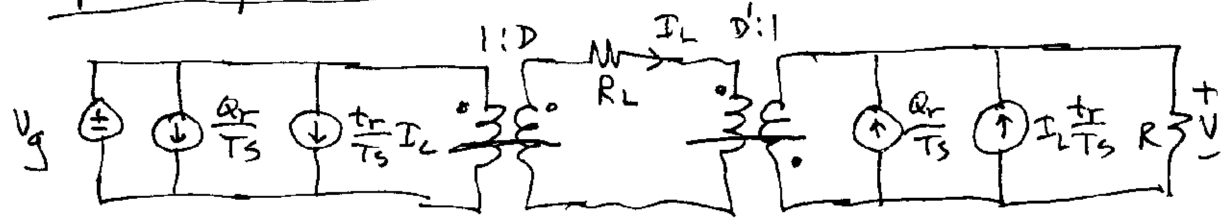
$$= D I_L + \frac{Q_r}{T_s} + \frac{t_r}{T_s} I_L$$



Combine circuits



Replace dependent sources with transformers



Note that V is negative