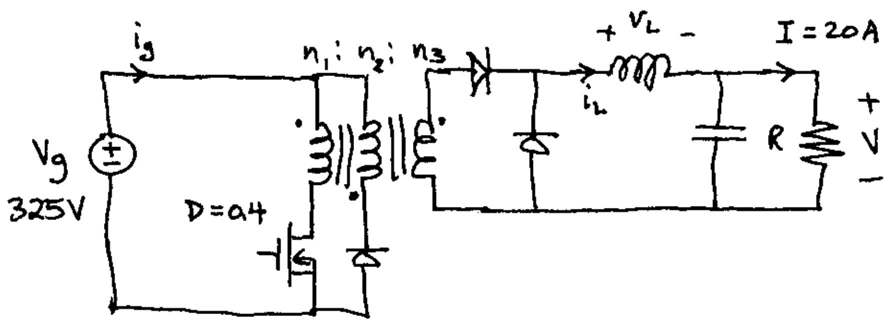
Problem 6.6 — Forward converter with synchronous rectifiers

a) with schottky diodes having $V_F = 0.5V$
MOSFET $R_{on} = 5\Omega$. Assume magnetizing current is negligible



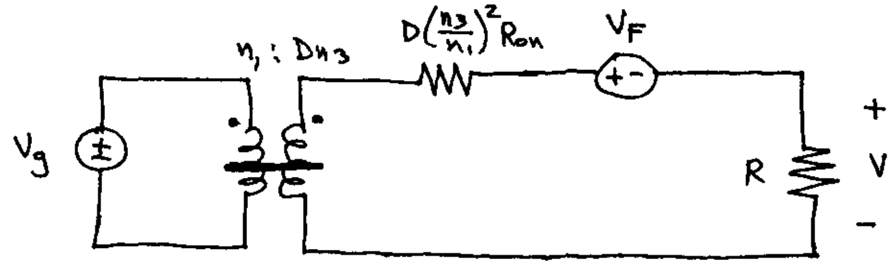
inductor volt-sec balance: $\langle v_L \rangle = 0 = D\left[\frac{n_3}{n_1}\left(V_g - \frac{n_3}{n_1}\langle i_L\rangle R_{on}\right) - V_F - V\right] + D'\left[-V_F - V\right]$

so $0 = D\frac{n_3}{n_1}V_g - D\left(\frac{n_3}{n_1}\right)^2 R_{on} I_L - V_F - V$

average input current: $\langle i_g \rangle = D\frac{n_3}{n_1} I_L$

(note that, even if transformer magnetizing current is modeled, its effect on the average i_g is zero)

Equivalent circuit model



b) Solve model

$$V = \left(\frac{D n_3}{n_1} V_g - V_F\right) \frac{R}{R + D\left(\frac{n_3}{n_1}\right)^2 R_{on}}$$

solve for required turns ratio:

$$\frac{n_3}{n_1} = \frac{D V_g - \sqrt{D^2 V_g^2 - 4VD \frac{R_{on}}{R}(V+V_F)}}{2VD\left(\frac{R_{on}}{R}\right)}$$

Solve for efficiency: $P_{in} = V_g \cdot \frac{D n_3}{n_1} I$

$$P_{out} = VI$$

so $$\eta = \frac{P_{out}}{P_{in}} = \frac{VI}{V_g\left(\frac{D n_3}{n_1}\right) I} = \frac{V}{V_g} \frac{n_1}{D n_3}$$

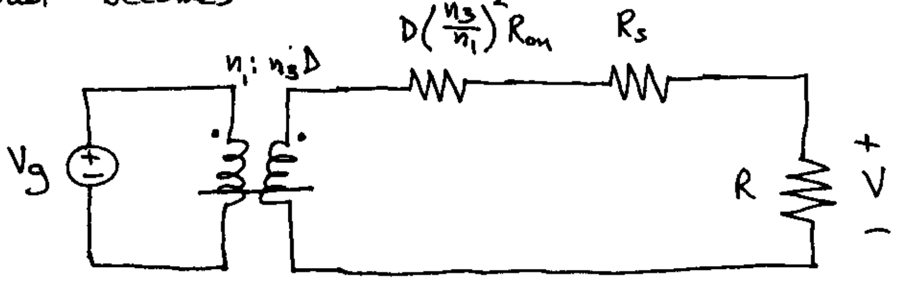
$$= \left(1 - \frac{V_F}{\left(\frac{D n_3}{n_1}\right) V_g}\right) \frac{1}{1 + D\left(\frac{n_3}{n_1}\right)^2 \frac{R_{on}}{R}}$$

<u>calculations</u>

case	$\frac{n_3}{n_1}$	η
(i) $V = 5$	0.0429	89.7%
(ii) $V = 3.3$	0.0295	86.1%
(iii) $V = 1.5$	0.0155	74.6%

c) With synchronous rectifiers

model becomes



with R_s = synchronous rectifier on-resistance = $4\,m\Omega$

solve:

$$V = D\frac{n_3}{n_1} V_g \frac{1}{\left(1 + \frac{R_s}{R} + D\left(\frac{n_3}{n_1}\right)^2 \frac{R_{on}}{R}\right)}$$

$$\eta = \frac{1}{\left(1 + \frac{R_s}{R} + D\left(\frac{n_3}{n_1}\right)^2 \frac{R_{on}}{R}\right)}$$

required turns ratio is

$$\frac{n_3}{n_1} = \frac{1 - \sqrt{1 - 4\left(\frac{V}{V_g}\right)^2 \frac{R_{on}}{DR}\left(1 + \frac{R_s}{R}\right)}}{2\left(\frac{V}{V_g}\right)\left(\frac{R_{on}}{R}\right)}$$

calculations

case	n_3/n_1	η
(i) $V=5$	0.0396	97.2%
(ii) $V=3.3$	0.0262	96.8%
(iii) $V=1.5$	0.0122	94.6%