EE 452 – Power Electronics Design, Fall 2021

Homework 8

Due Date: Friday December 10th 2021 at 11:59 pm Pacific Time

Instructions. You must scan your completed homework assignment into a pdf file, and upload your file to the Canvas Assignment page by the due date/time above. All pages must be gathered into a single file of moderate size, with the pages in the correct order. Set your phone or scanner for basic black and white scanning. You should obtain a file size of hundreds of kB, rather than tens of MB. I recommend using the "Tiny Scanner" app. Please note that the grader will not be obligated to grade your assignment if the file is unreadable or very large.

Problem 1: The flyback converter shown in Figure 1 operates in the continuous conduction mode. The MOSFET has on-resistance R_{on} and the diode has a constant forward voltage V_D drop The flyback transformer has primary winding resistance R_p and secondary winding resistance R_s.

(a) Derive a complete steady-state equivalent circuit model, which is valid in the continuous conduction mode, and which correctly models the loss elements listed above as well as the converter input and output ports. Sketch your equivalent circuit.

(b) Derive an analytical expression for the converter efficiency in terms of V_g, V_D, R_s, R_p, n, D, and D'.

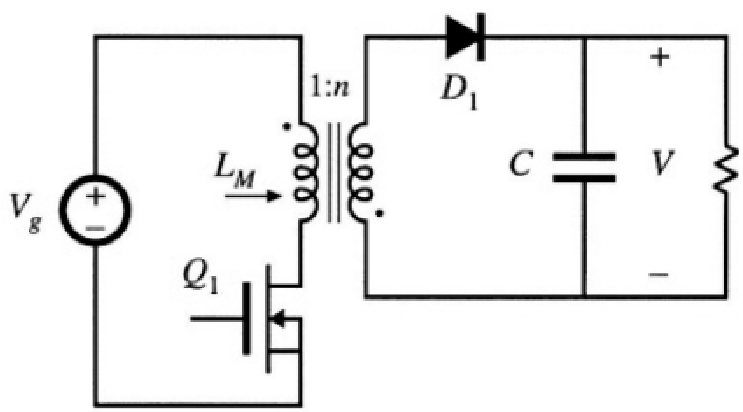
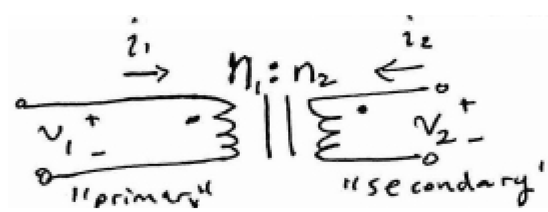


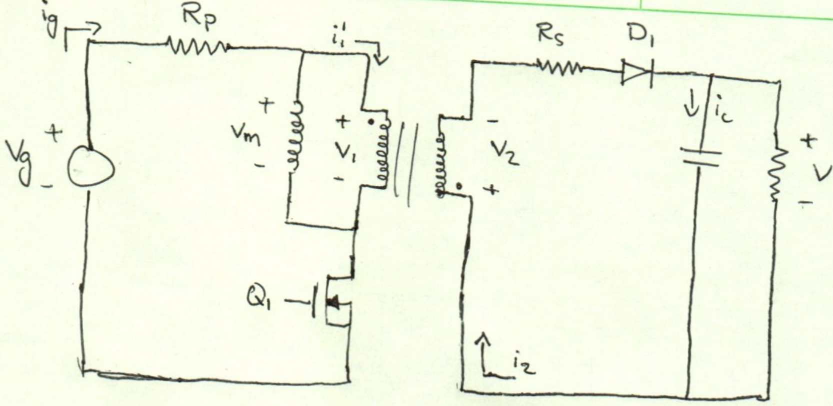
Figure 1: A flyback converter.

Golden Rules

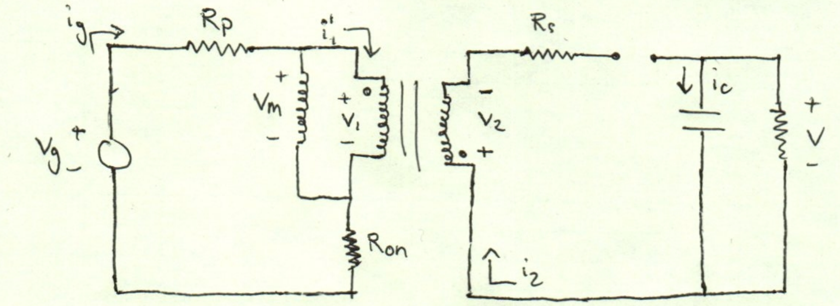
$$\frac{v_1}{n_1} = \frac{v_2}{n_2}$$

$$i_1' n_1 + i_2 n_2 = 0$$

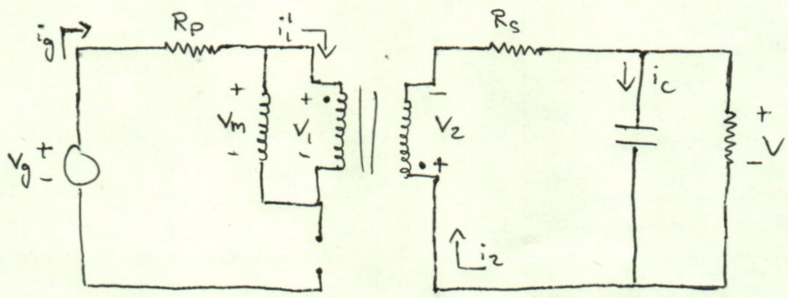


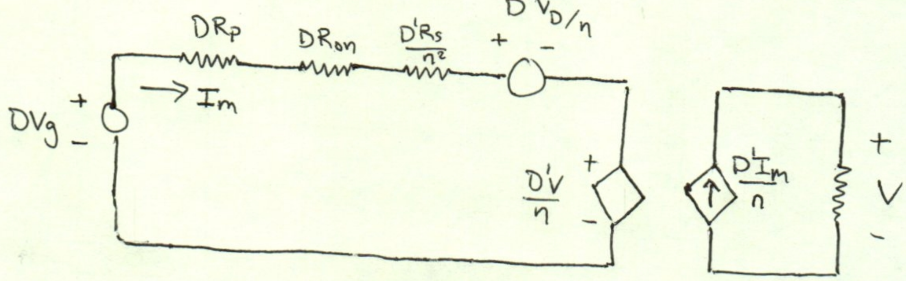


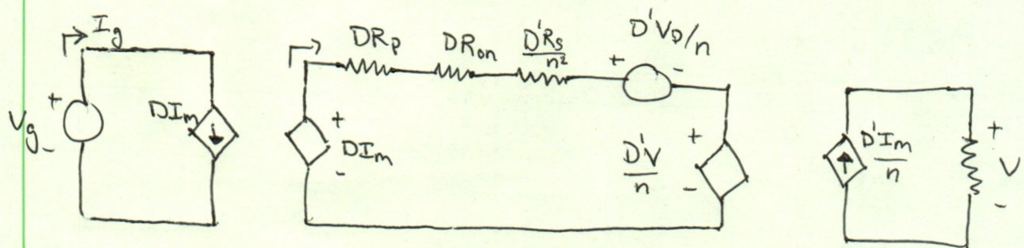
Q_1 on, D_1 off



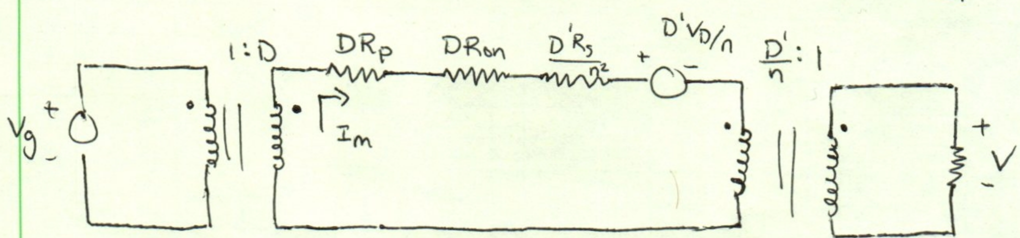
Q_1 off, D_1 on



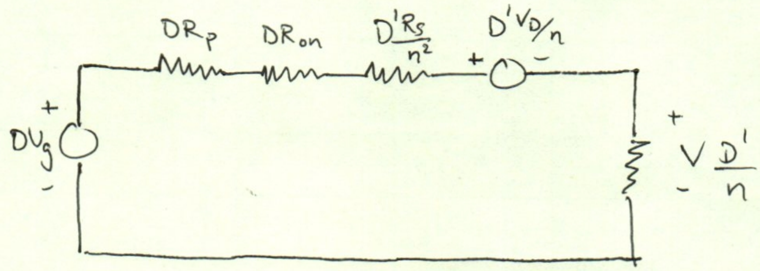




1a



1b.

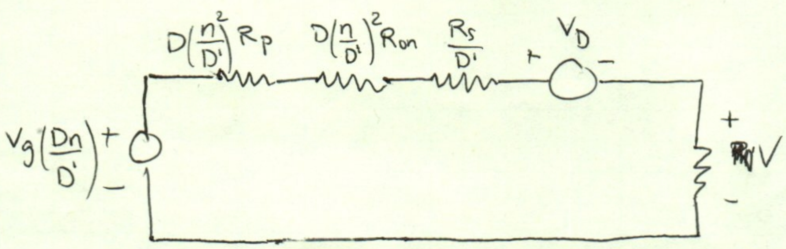


Efficiency

$$\eta = \frac{P_{out}}{P_{in}}$$

$$\eta = \frac{V\,I}{nV_g I \frac{D}{D'}}$$

$$= \frac{V}{nV_g \frac{D}{D'}}$$



Switch: [Q1 on, Diode off]

Charge Balance

$$i_g = i_m$$

$$i_C = \frac{-V}{R}$$

Volt Seconds

$$\text{Diode off:} \quad i_2 = 0$$

$$i_1' = i_2 = 0$$

$$v_m = v_1 = \frac{v_2}{n}$$

$$v_1 = V_g - i_g R_p - i_g R_{on}$$

$$= V_g - i_m R_p - i_m R_{on}$$

Q1 off, Diode on

Charge Balance

$$\text{Q1 off:} \quad i_g = 0$$

$$i_1' = -i_m$$

$$i_2 = -\frac{i_1}{n_1 n_2} = \frac{i_m}{n}$$

$$i_c = i_2 - \frac{V}{R} = \frac{i_m}{n} - \frac{V}{R}$$

Volt Seconds

$$v_m = v_1$$

$$v_1 = \frac{v_2}{n}$$

$$v_2 = -(V + V_D + i_2 R_s)$$

$$= -(V + V_D + R_s \frac{i_m}{n})$$

Volt Seconds

$$< v_M > = \int_o^{T_S} v_M(t)dt$$

$$0 = D \cdot (V_g - I_M R_p - I_M R_{on}) + D' \cdot \left(-\frac{1}{n}(V + V_D + R_s \frac{I_M}{n})\right)$$

$$0 = DV_g - DI_M(R_p + R_{on}) - D' \frac{V}{n} - D' \frac{V_D}{n} - D' \frac{I_M R_s}{n^2}$$

Charge Balance

$$< i_C > = \int_o^{T_S} i_C(t)dt$$

$$0 = D \cdot (-\frac{V}{R}) + D' \cdot (\frac{I_M}{n} - \frac{V}{R})$$

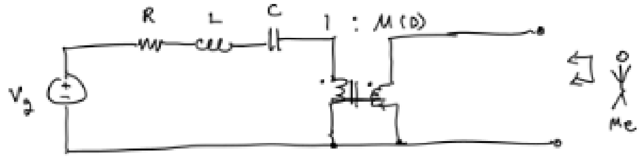
$$0 = -\frac{V}{R} + D' \frac{I_M}{n}$$

$$< i_G > = \int_o^{T_S} i_g(t)dt$$

$$< i_G > = D \cdot (I_M) + D' \cdot (0)$$

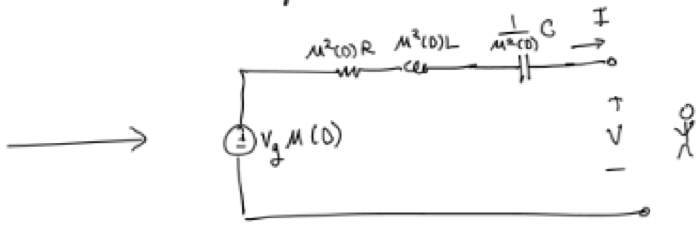
$$< i_G > = DI_M$$

Notes

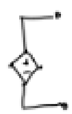


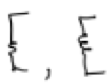
Want equiv elements on other my side

Result after reflecting elements



easier to analyze

 $\longrightarrow$ scale by $M(D)$

 $\longrightarrow$ scale by $M^2(D)$

 $\longrightarrow$ scale by $\frac{1}{M^2(D)}$