

# 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  $D'$ .

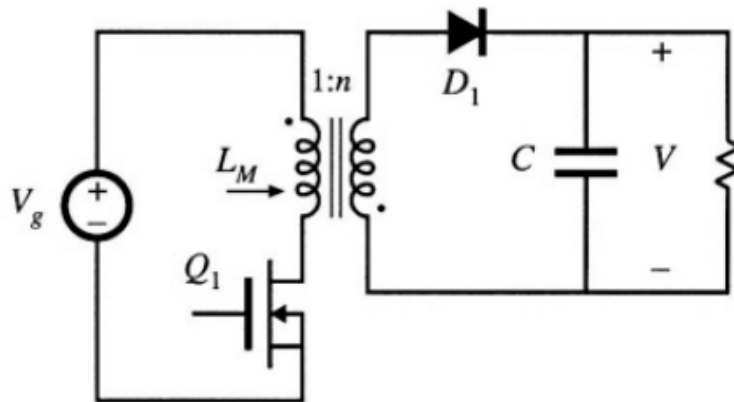


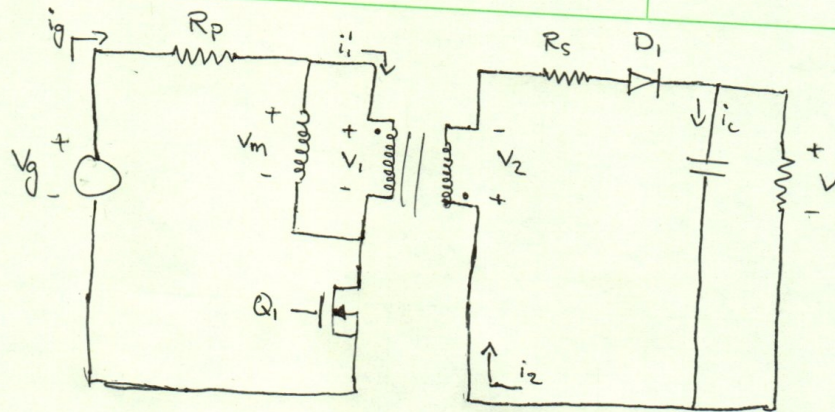
Figure 1: A flyback converter.

### Golden Rules

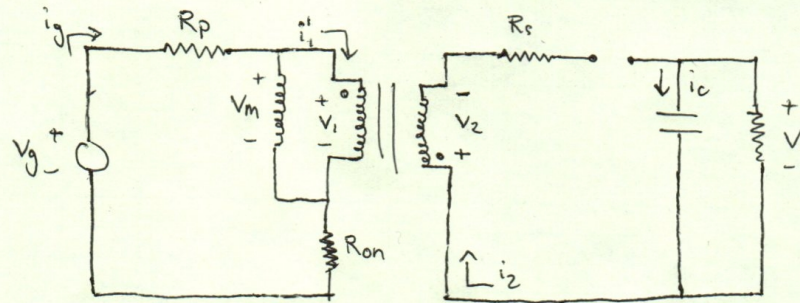
$$\frac{v_1}{n_1} = \frac{v_2}{n_2}$$

$$i'_1 n_1 + i_2 n_2 = 0$$

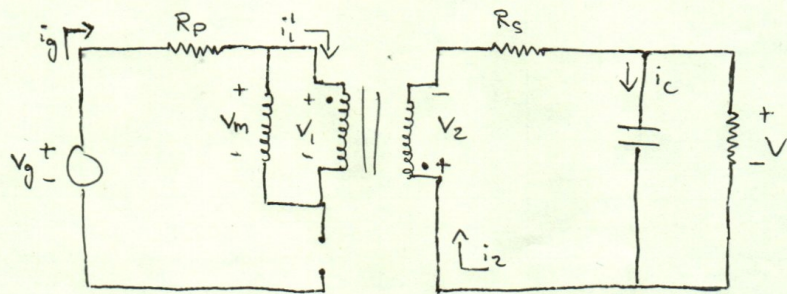




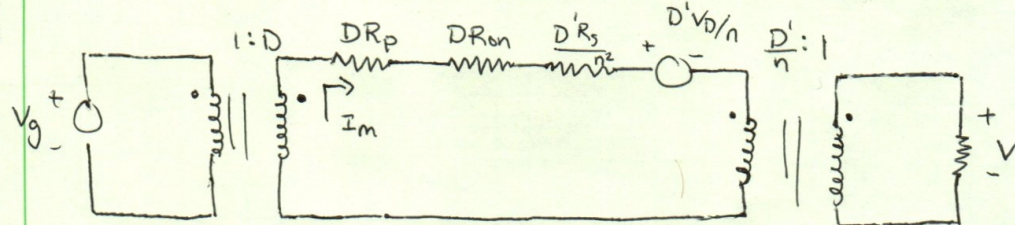
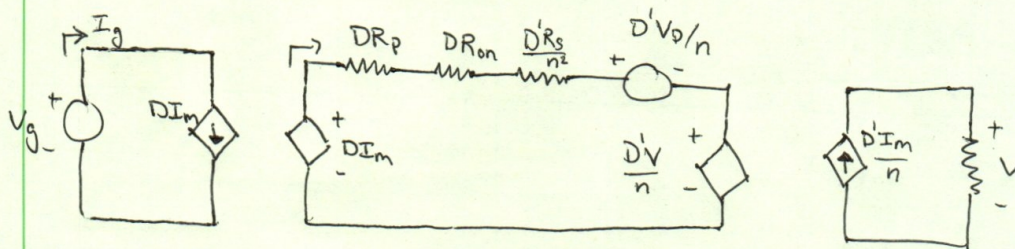
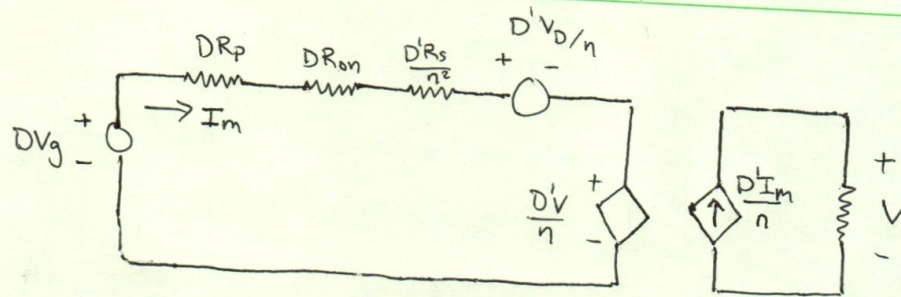
$Q_1$  on,  $D_1$  off



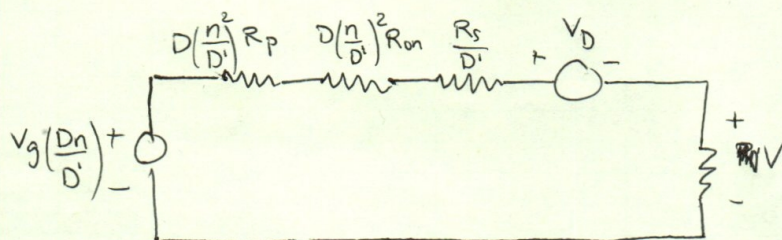
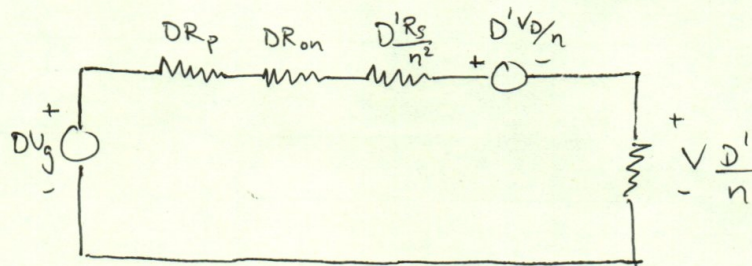
$Q_1$  off,  $D_1$  on







1b.



### Efficiency

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

$$\eta = \frac{VI}{nV_g I \frac{D}{D'}}$$

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

**Switch: [Q1 on, Diode off]**

Charge Balance

$$i_g = i_m$$

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

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Volt Seconds

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

$$i'_1 = i_2 = 0$$

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

$$\begin{aligned} v_1 &= V_g - i_g R_p - i_g R_{on} \\ &= V_g - i_m R_p - i_m R_{on} \end{aligned}$$

Volt Seconds

$$\langle v_M \rangle = \int_0^{T_s} v_M(t) dt$$

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

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

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Charge Balance

$$\langle i_C \rangle = \int_0^{T_s} i_C(t) dt$$

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

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

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$$\langle i_G \rangle = \int_0^{T_s} i_g(t) dt$$

$$\langle i_G \rangle = D \cdot (I_M) + D' \cdot (0)$$

$$\langle i_G \rangle = D I_M$$

**Q1 off, Diode on**

Charge Balance

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

$$i'_1 = -i_m$$

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

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

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Volt Seconds

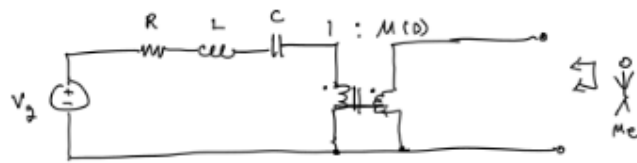
$$v_m = v_1$$

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

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

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

## Notes



Want equiv elements on other side

Result after reflecting elements

