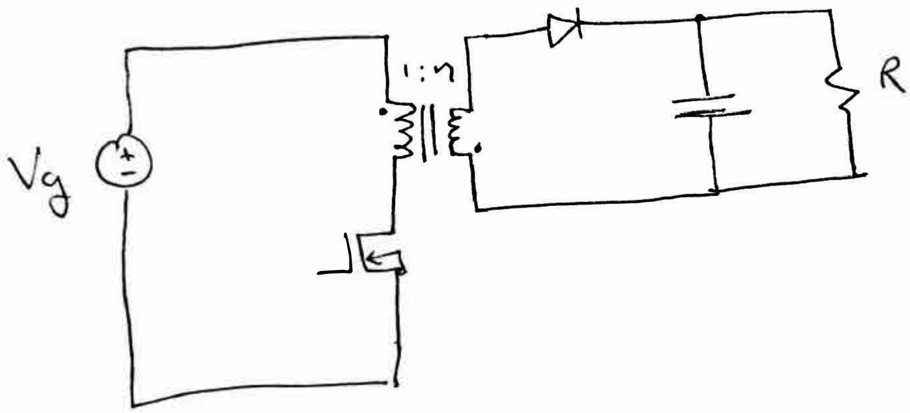
Homework solution

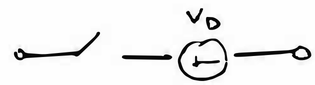
Problem #1

Begin w/ the flyback schematic

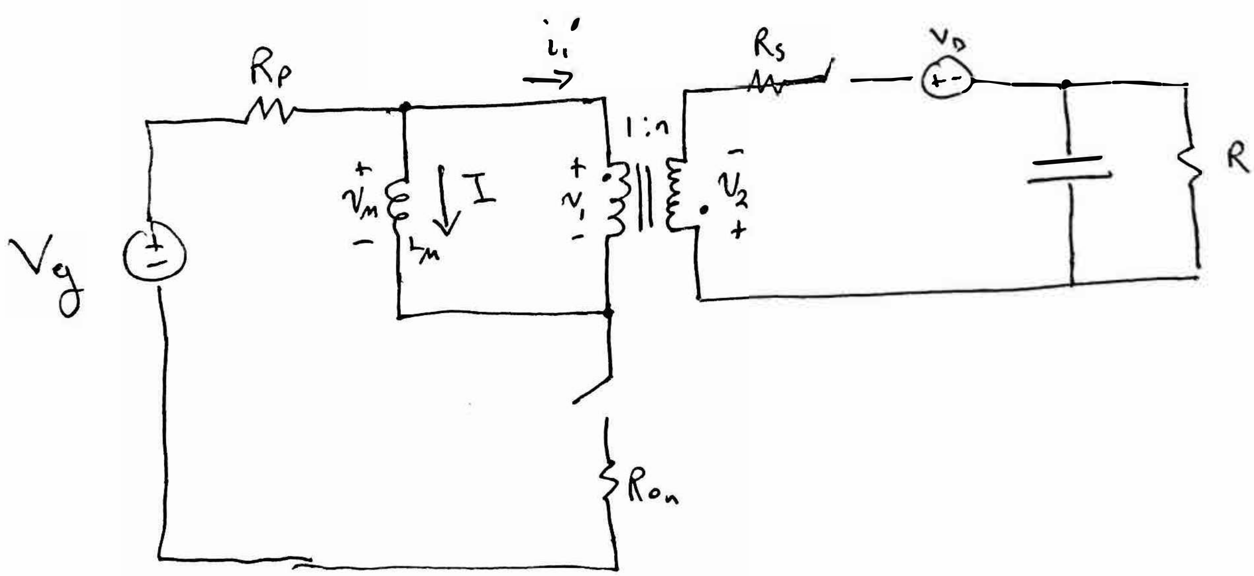


Now redraw with → transformer model w/ R_p & R_s

→ MOSFET lossy model 

→ Diode lossy model 

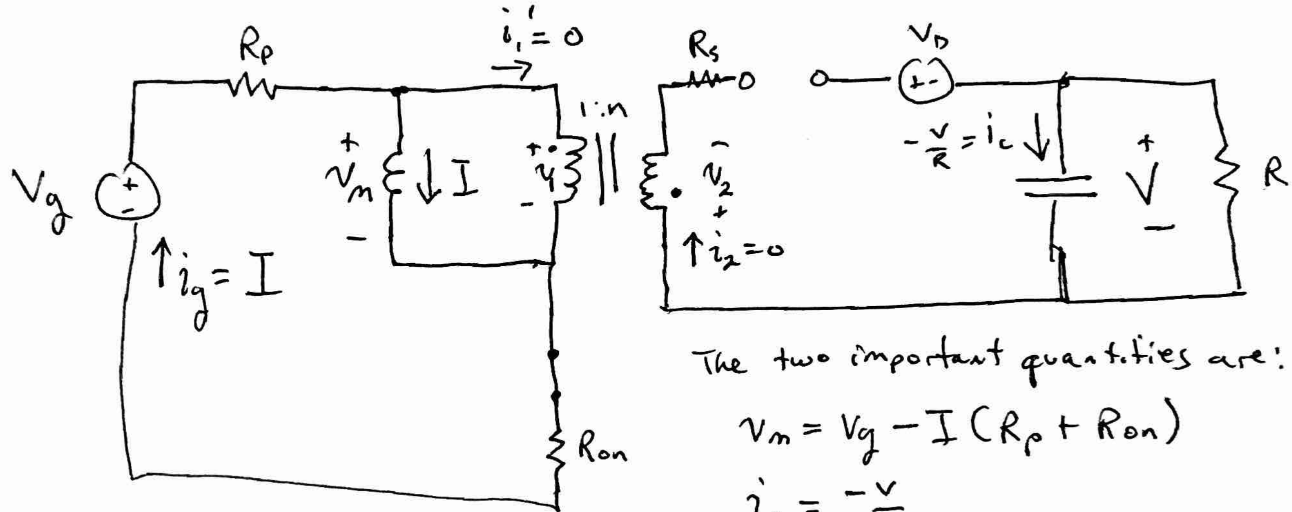
we get



(a) Derive the equiv s.s. ckt:

- Following my notes/guidelines we obtain the following circuits for both configurations

— Configuration ① duration DT_s:

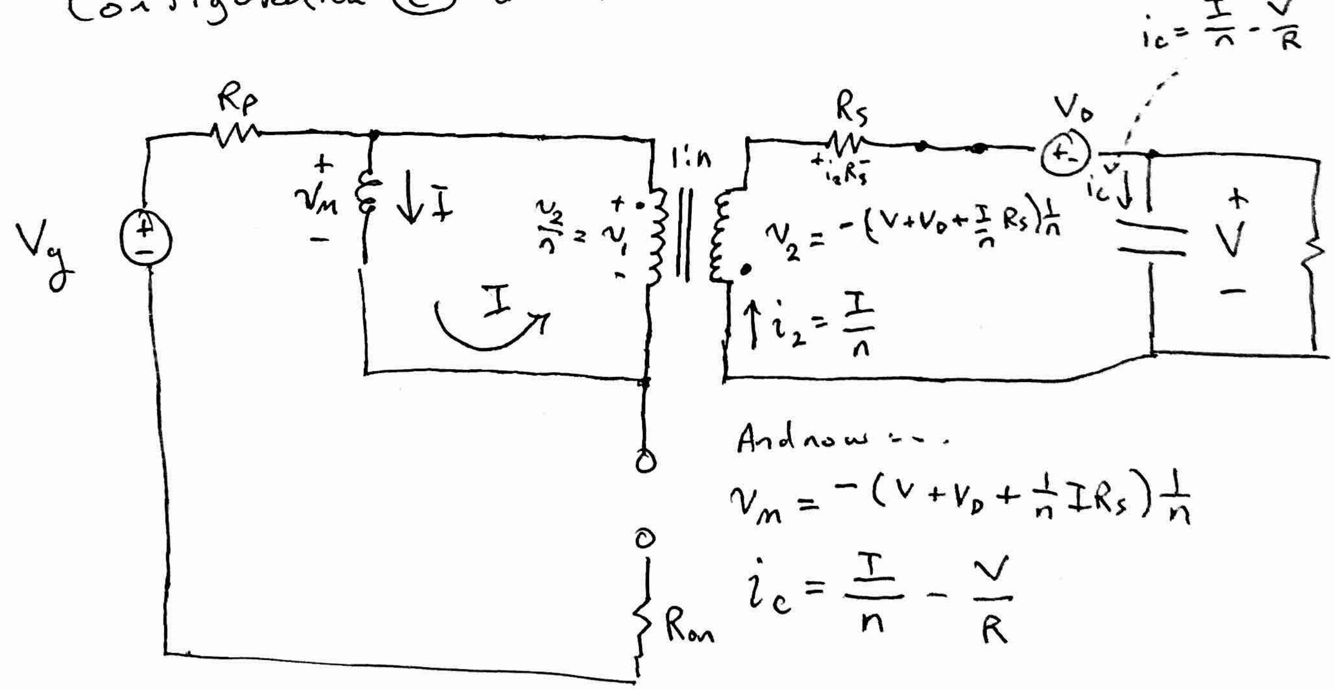


The two important quantities are:

$$v_m = V_g - I(R_p + R_{on})$$

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

— Configuration ② duration $D'T_s = (1-D)T_s$:



And now ...

$$v_m = -\left(V + V_D + \frac{1}{n} I R_s\right)\frac{1}{n}$$

$$i_c = \frac{I}{n} - \frac{V}{R}$$

- Now apply the balance equations:

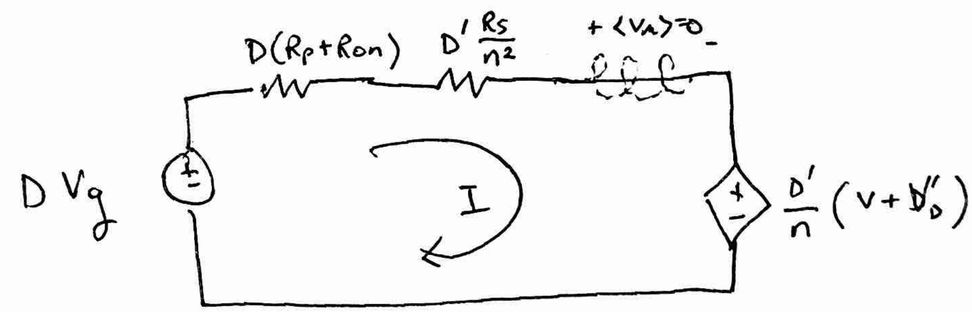
$$\langle v_L \rangle = 0 = D\left(V_g - I\left(R_p + R_{on}\right)\right) - D'\left(V + V_D + \frac{1}{n} I R_s\right)\frac{1}{n} = 0 \qquad (1)$$

and

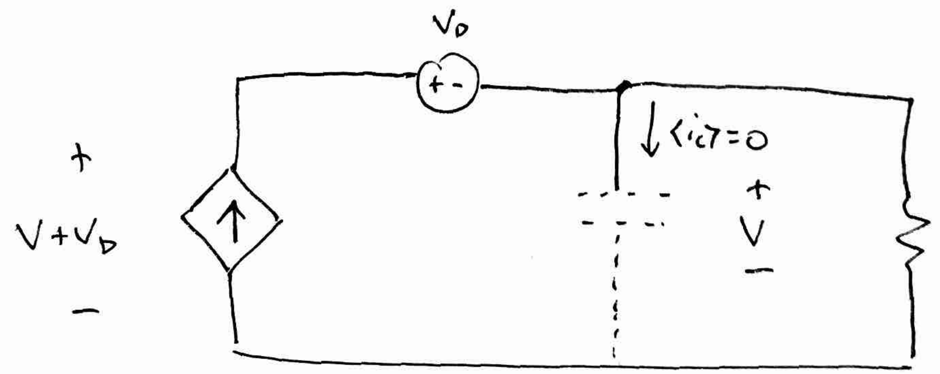
$$\langle i_c \rangle = 0 = D\left(\frac{-V}{R}\right) + D'\left(\frac{I}{n} - \frac{V}{R}\right)$$

$$= -\frac{V}{R} + D'\frac{I}{n} = 0 \qquad (2)$$

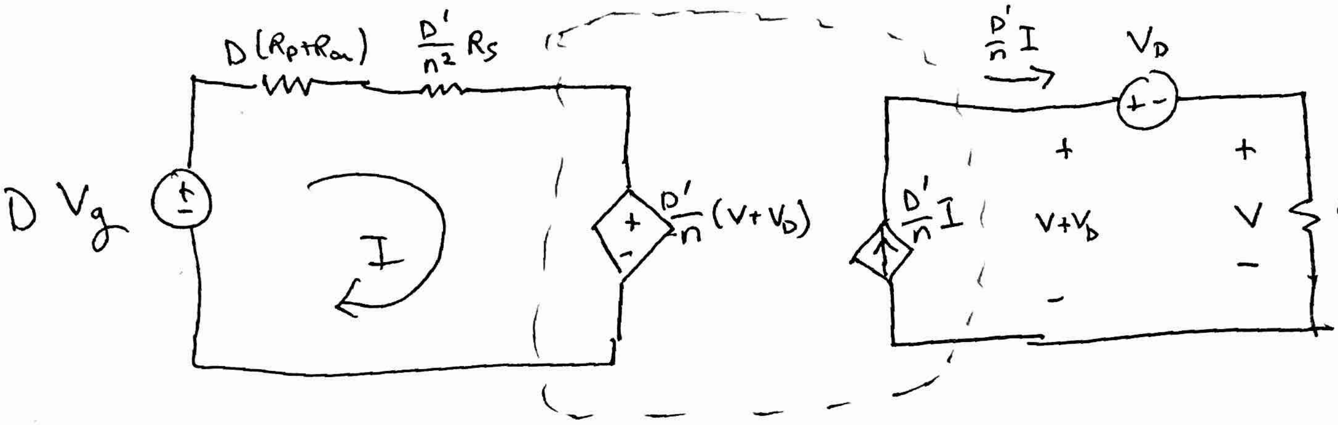
- (1) looks like a KVL loop equation for $\langle v_L \rangle = 0$



- (2) looks like a KCL equation for $\langle i_c \rangle = 0$



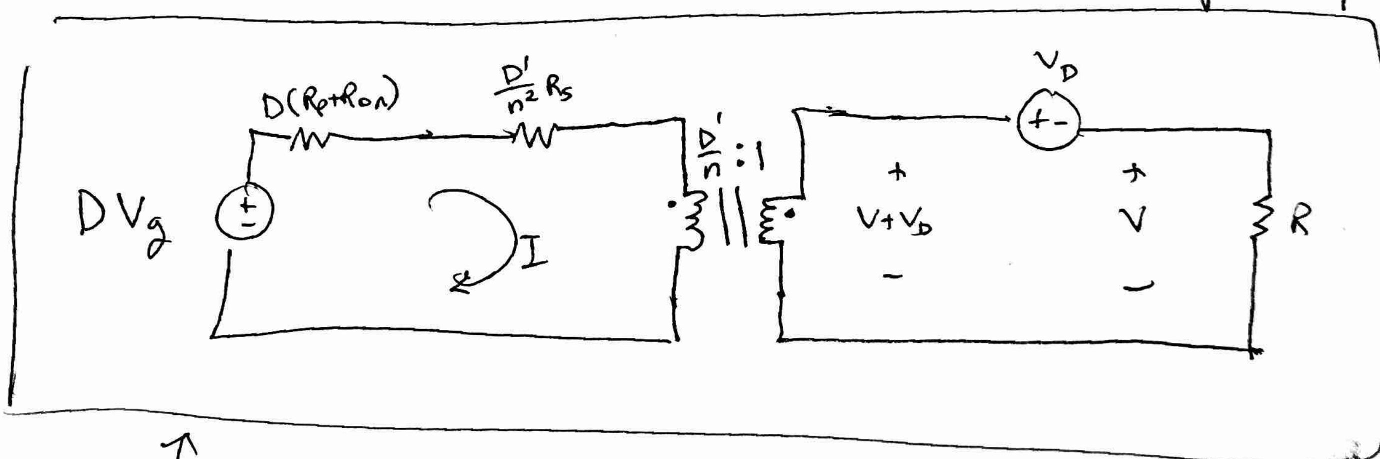
Now combine to get:



⇓

redraw as equiv ideal xfmr

1a



Equiv ckt model in S.S.

b) Compute efficiency η in terms of $V_g, R_{on}, R_p, R_s, V_D, D, D'$.

- Revisit (1)-(2) balance equations. Follow same procedure from past HW assignments → compute/solve for I first
  → Eliminate I & V from equations
  → look @ P_{in} & P_{out}, take ratio, and do algebra.

- Calculate I from (2)

$$I = \frac{nV}{D'R} \qquad (3)$$

- Substitute (3) → (1) & solve for V since we need to eliminate it.

$$0 = D\left(V_g - \frac{nV}{D'R}(R_p+R_{on})\right) - \frac{D'}{n}\left(V + V_D + \frac{R_s}{\cancel{n}}\left(\overbrace{\frac{\cancel{n}V}{D'R}}^{I}\right)\right)$$

$$= DV_g - V\frac{nD}{D'R}(R_p+R_{on}) - \frac{D'}{n}V - \frac{D'}{n}V_D - VR_s\frac{\cancel{D'}}{\cancel{D'}nR}$$

* collect terms

$$= DV_g - V\left(\frac{nD}{D'R}(R_p+R_{on}) + \frac{D'}{n} + \frac{R_s}{nR}\right) - \frac{D'}{n}V_D = 0 \qquad (4)$$

$$\rightarrow V = \frac{DV_g - \frac{D'}{n}V_D}{\frac{nD}{D'R}(R_p+R_{on}) + \frac{D'}{n} + \frac{R_s}{nR}} \qquad (5)$$

- Now look @ P_{in} & P_{out} avg values
  * look @ equiv ckt from pt (a) to see more clearly

$$P_{in} = \underbrace{I}_{\text{input } i}\underbrace{DV_g}_{\text{input } v} = \underbrace{\frac{nV}{D'R}}_{I} DV_g = \frac{nDVV_g}{D'R}$$

and

$$P_{out} = \frac{V^2}{R}$$

and

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V^{\cancel{2}}}{\cancel{R}}\frac{D'\cancel{R}}{nD\cancel{V}V_g} = \frac{V D'}{V_g n D}$$

* plug in (5) for V

$$\boxed{\frac{D'}{V_g n D}\,\frac{DV_g - \frac{D'}{n}V_D}{\frac{nD}{D'R}(R_p + R_{on}) + \frac{D'}{n} + \frac{R_s}{nR}} = \eta}$$

This is the solution. with some work, we can probably put it into a more clean/ elegant form

* sanity check

$$\lim_{R_s, R_p, R_{on}, V_D \to 0} \eta = \frac{D'}{V_g n D}\,\frac{DV_g - 0}{\cancel{\frac{nD}{D'R}(0)} + \frac{D'}{n} + 0}$$

$$= \frac{\cancel{D'}}{\cancel{V_g}\cancel{n}\cancel{D}}\,\frac{\cancel{D}\cancel{V_g}\cancel{n}}{\cancel{D'}} = 1 \;!$$

If all lossy elements dissapear $\eta \to 1$!