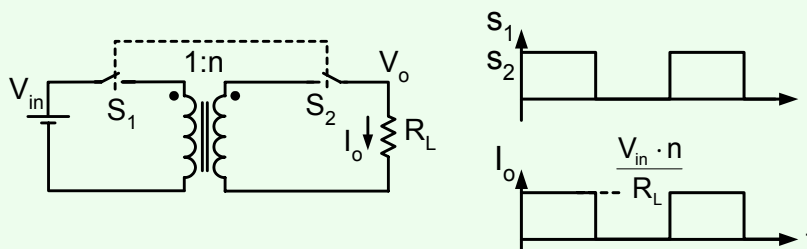


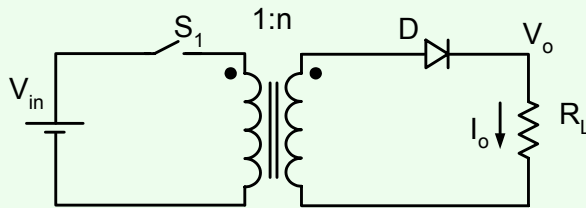
Forward and Flyback (Converters with isolation)

- 4.1 Transfer of DC current via transformer
- 4.2 Forward
 - 4.2.1 Voltage transfer function
 - 4.2.2 Magnetization inductance problem
 - 4.2.3 Transformer reset
 - 4.2.4 Reset of forward
- 4.3 Coupled inductors
- 4.4 Flyback
 - 4.4.1 Voltage transfer function
 - 4.4.2 Flyback with multiple outputs
 - 4.4.3 Characteristics of Flyback

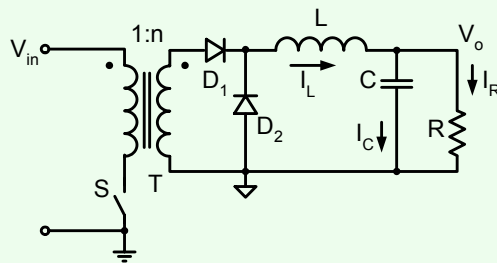
Is transfer of DC current possible?



Replacing S_2 by a Diode



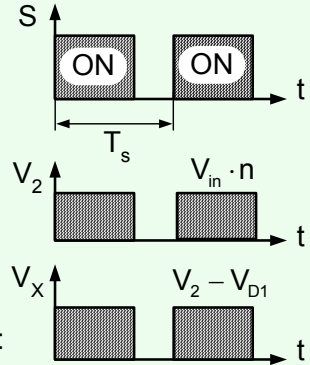
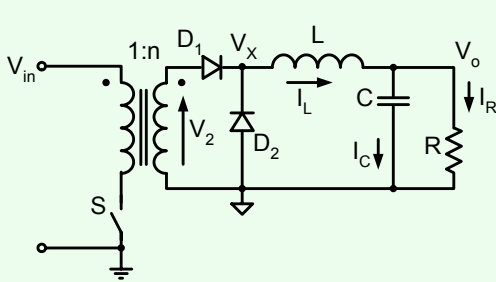
Forward Converter



Forward :

- T is a transformer
- Output section: Buck
- Buck derived

Voltage transfer function



At steady state, over one switching cycle:

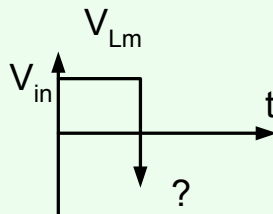
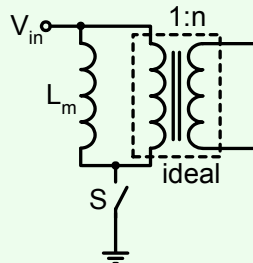
$$\bar{V}_L = 0;$$

$$S_+ \approx (nV_{in} - V_o) \cdot t_{on};$$

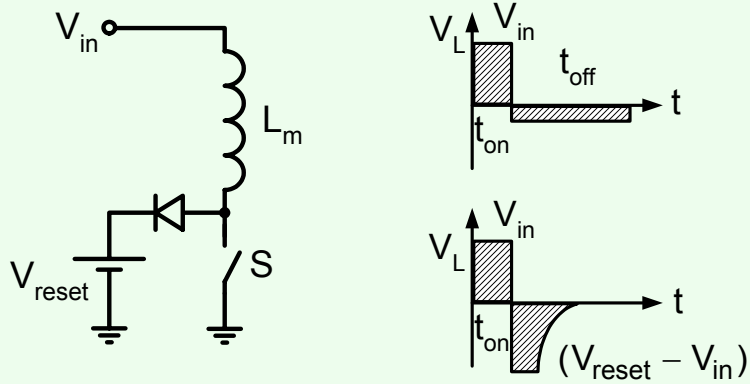
$$S_- \approx (-V_o) \cdot t_{off};$$

$$S_+ + S_- = 0 \Rightarrow \frac{V_o}{V_{in}} = nD_{on}$$

Magnetization Inductance Problem

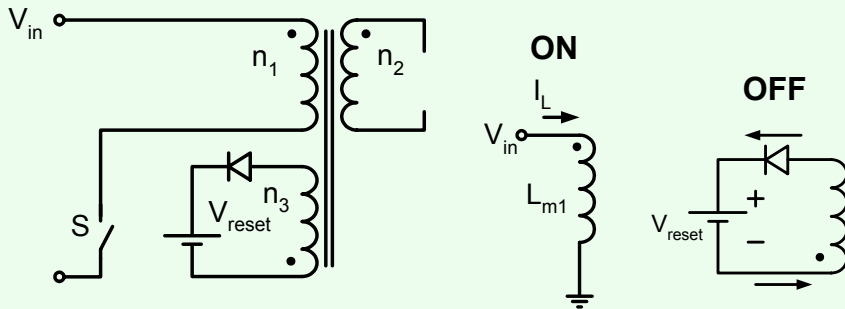


Transformer Reset



$$V_{in}D_{on} = (V_{reset} - V_{in})D_{off}$$

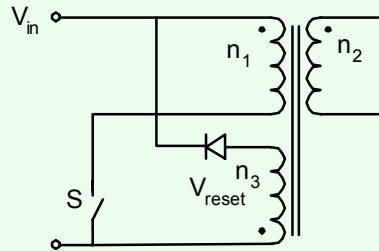
Applying a Reset Winding



Reset Requirements

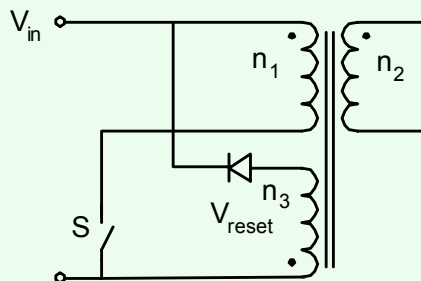
$$D_{off} \frac{V_{reset}}{n_3} \geq \frac{V_{in}}{n_1} D_{on}$$

Applying same source



$$\frac{V_{in}}{n_3} D_{off} > \frac{V_{in}}{n_1} D_{on} \quad \frac{n_3}{n_1} < \frac{D_{on}}{D_{off}}$$

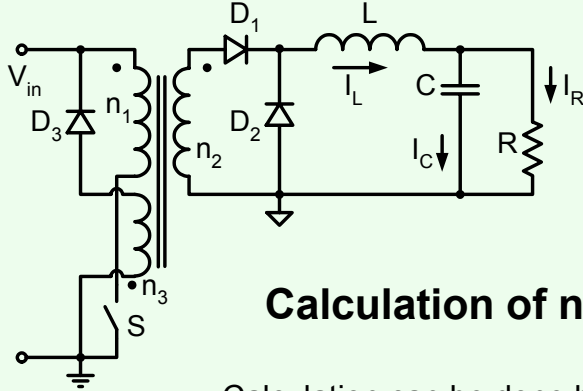
Assignment



Given: $0.1 < D_{on} < 0.7$

What will be the voltage stress on S?

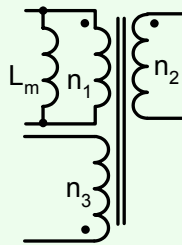
Reset of Forward



Calculation of n₃

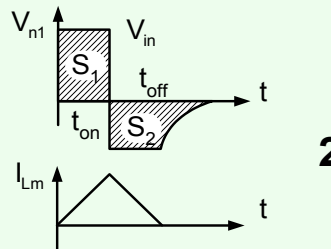
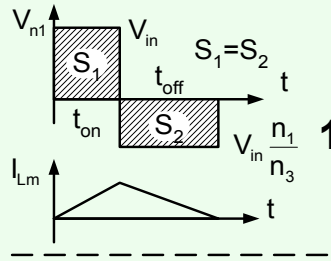
- Calculation can be done by looking at any of the windings n₁, n₂, n₃

Fundamental requirement:

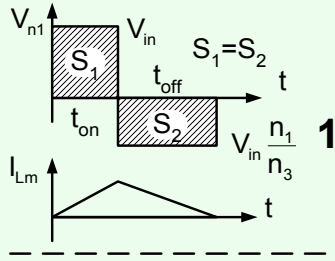


$$\bar{V}_{\text{winding}} = 0$$

- Example: Looking at n₁

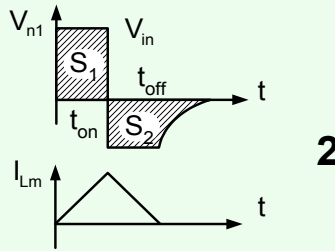


VT



$$V_{in} D_{off} \frac{n_1}{n_3} \geq V_{in} D_{on}$$

$$n_3 \leq n_1 \frac{D_{off}}{D_{on}}$$



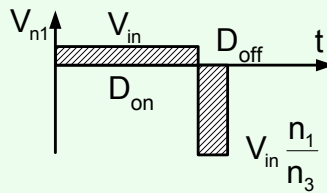
$$n_3 \leq n_1 \frac{D_{off}}{1 - D_{off}}$$

VT

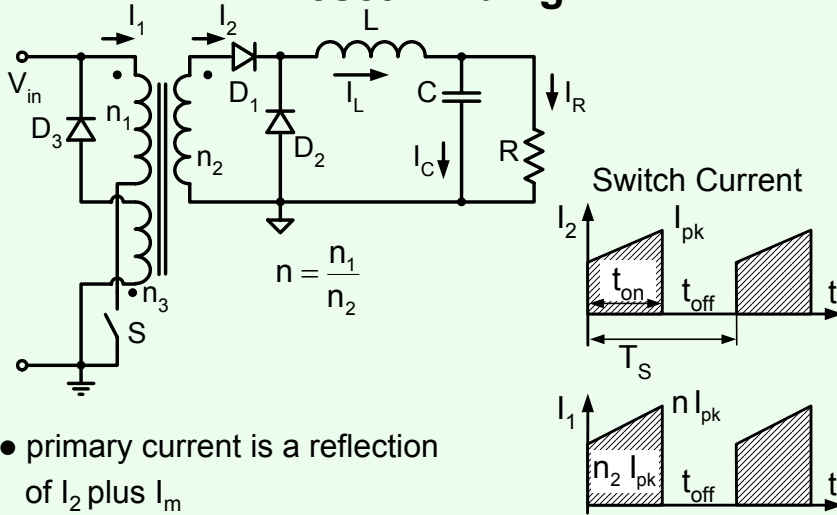
Voltage on switch when "off"

$$V_s = V_{in} + \frac{n_1}{n_3} V_{in}$$

$$V_s = V_{in} \left[1 + \frac{D_{on \max}}{1 - D_{on \max}} \right]$$

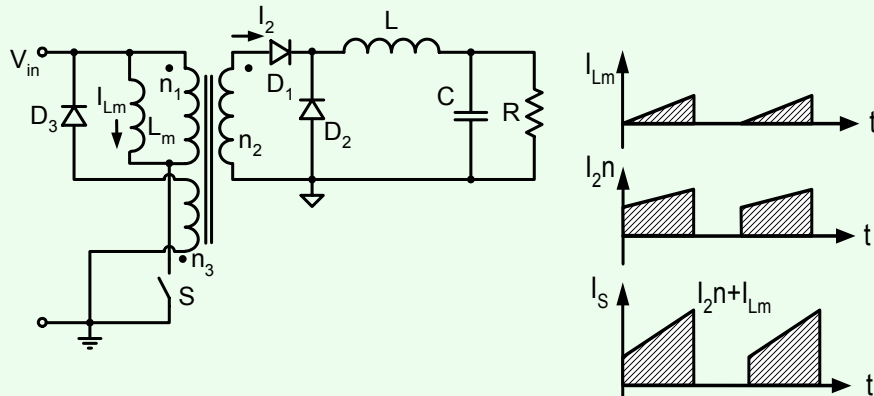


Reset winding



- primary current is a reflection of I_2 plus I_m

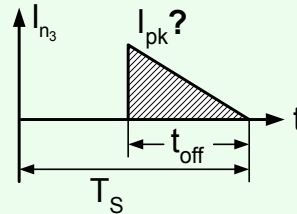
Taking into account L_m



Reset Current

$$\frac{n_1}{n_3} = \frac{D_{on}}{1-D_{on}} \quad V_{reset} = V_{in} \frac{n_1}{n_3} = V_{in} \frac{D_{on}}{1-D_{on}}$$

Question 1: How does I_{n3} look ?

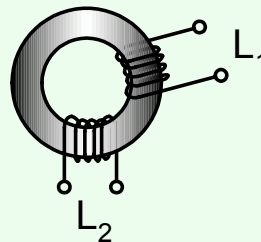
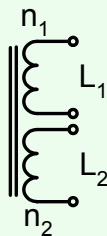


Question 2: If $D_{max}=0.3$

2.1 Calculate n_1/n_3

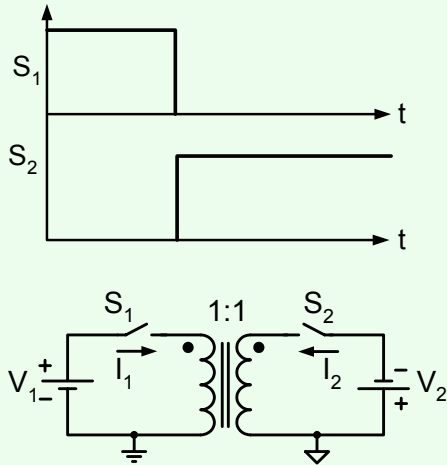
2.2 Find maximum voltage on switch

Coupled inductor



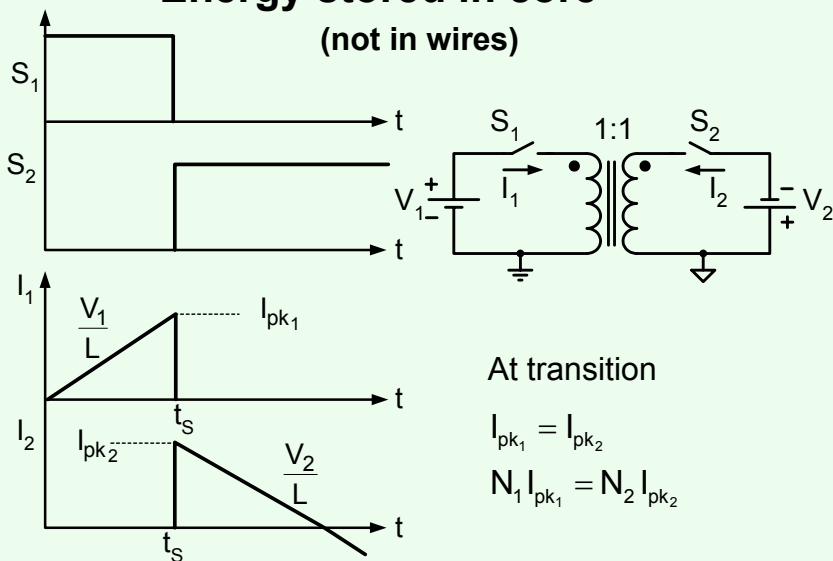
$$\frac{L_1}{L_2} = \left(\frac{n_1}{n_2} \right)^2$$

Current in a Winding CAN be Interrupted !

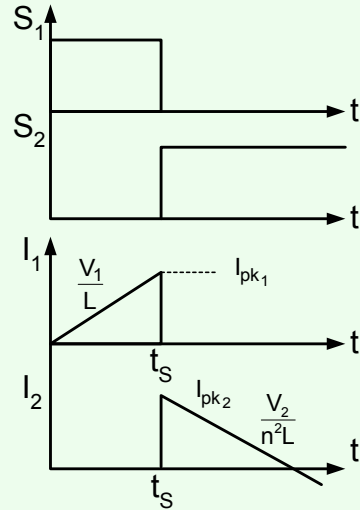
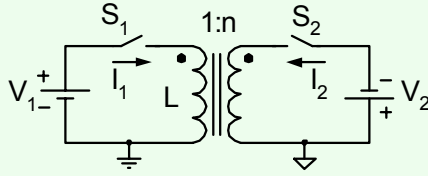


Energy stored in core

(not in wires)



Coupled windings



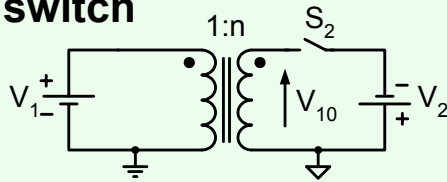
Problem: Leakage inductance
(will be discussed later)

$$I_{pk1} \cdot 1 = I_{pk2} \cdot n$$

$$I_{pk1} = \frac{I_{pk2}}{n}$$

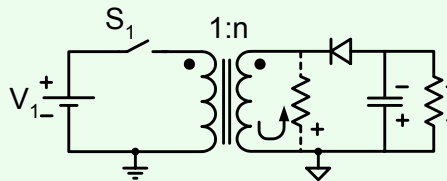
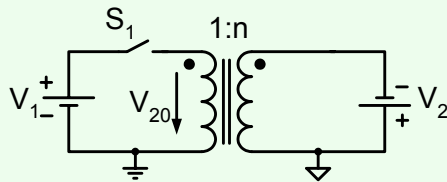
Diode replace a switch

$$V_{10} = n \cdot V_1$$

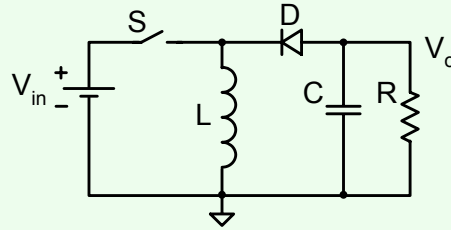


$$V_{20} = \frac{1}{n} V_2$$

(negative voltage)



Buck Boost

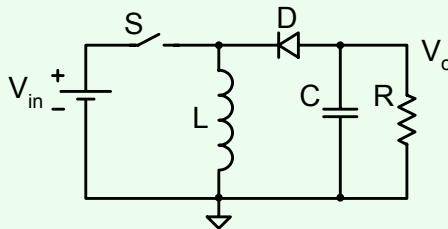


Polarity Reversal

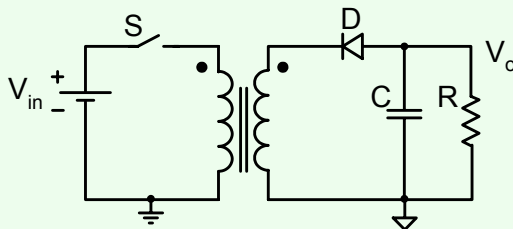
$$V_{in}D_{on} + V_oD_{off} = 0$$

$$\frac{V_o}{V_{in}} = -\frac{D_{on}}{D_{off}}$$

Flyback

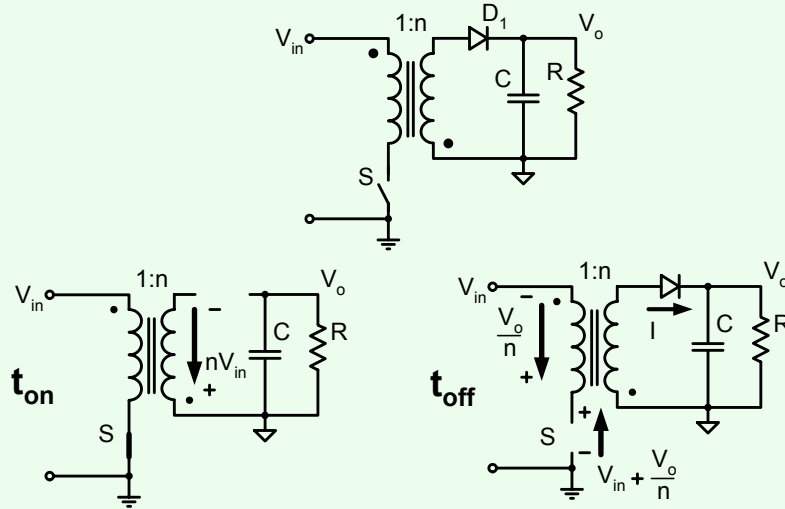


Buck Boost



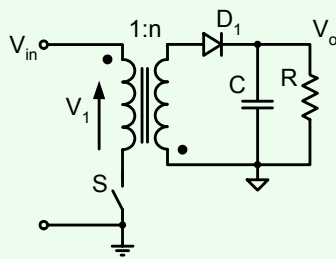
Isolated Back-Boost
Flyback

Flyback converter

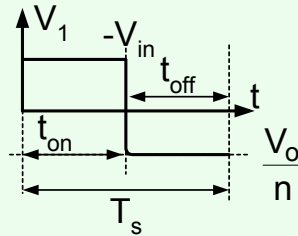


Voltage transfer function

The average voltage method



Voltage across primary

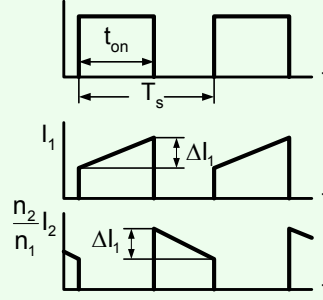
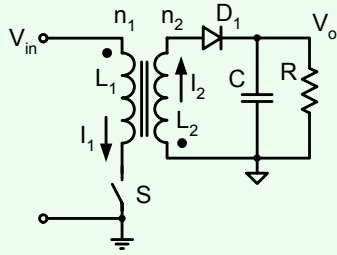


$$V_{in} \cdot t_{on} = \frac{V_o}{n} \cdot t_{off}$$

$$V_{in} \cdot D_{on} = \frac{V_o}{n} \cdot D_{off}$$

$$\frac{V_o}{V_{in}} = n \frac{D_{on}}{D_{off}}$$

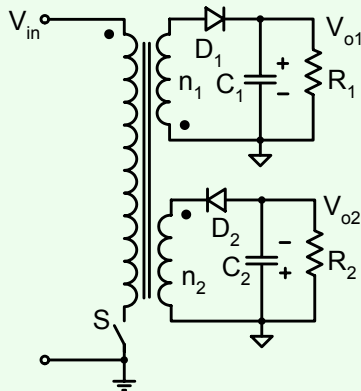
Voltage transfer function The ΔI method



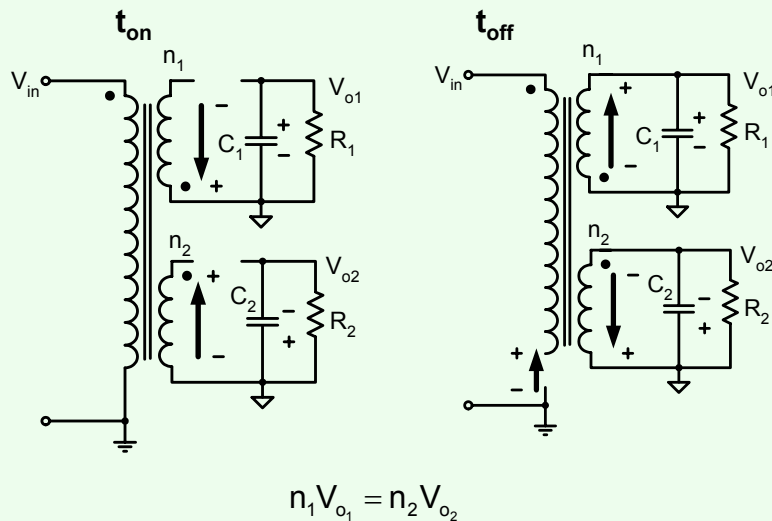
$$n_1 \Delta I_1 = n_2 \Delta I_2 \quad n_1 \frac{V_{in}}{L_1} t_{on} = n_2 \frac{V_o}{L_2} t_{off};$$

$$\frac{n_2 L_1 V_o}{n_1 L_2 V_{in}} = \frac{t_{on}}{t_{off}} = \frac{D_{on}}{D_{off}} \quad \frac{n_2 \left(\frac{n_1}{n_2}\right)^2 V_o}{n_1 \left(\frac{n_2}{n_1}\right) V_{in}} = \frac{D_{on}}{D_{off}} \quad \frac{V_o}{V_{in}} = \frac{n_2 D_{on}}{n_1 D_{off}}$$

Flyback with multiple outputs



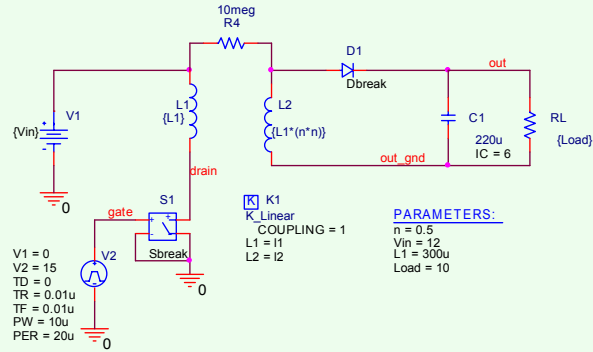
Flyback



Characteristics of Flyback

- Isolation
- Step-up or Step-down
- Discontinuous current at input and output (Buck-Boost Derived)
- Multiple outputs (economical)

Exercise



- Find by simulation L_{lk} and L_m of the magnetic body if $k=.9$
- Calculate A_p of magnetic element