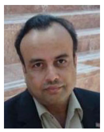
Lecture # 15

ECEN 438/738 Power Electronics

Spring 2025 Semester



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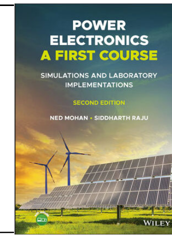
ECEN 438/738 Power Electronics



Power Electronics
A First Course: 2nd Edition

Free Textbook Online Access Link: https://go.oreilly.com/TAMU/library/view/-/9781119818564/?ar

Chapter 7

Magnetic Circuit Concepts

ECEN 438/738 Power Electronics

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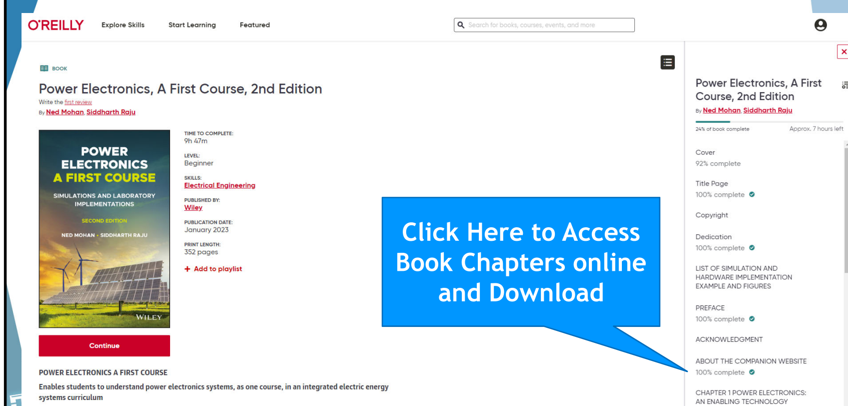
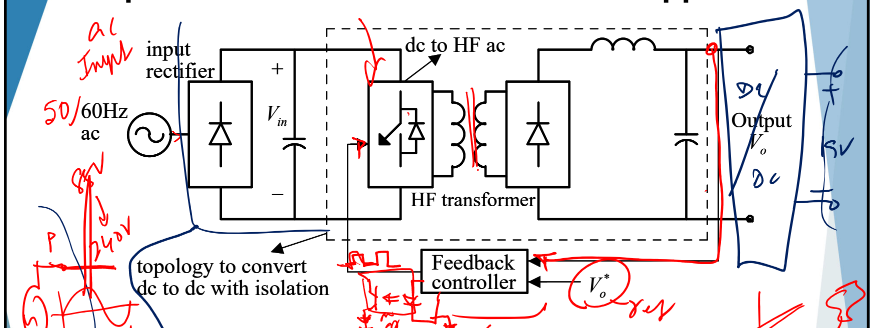


Chapter # 8 Switch-Mode DC Power Supplies



Electrical isolation provides safety & is needed

It is achieved via transformer isolation

Flyback DC-DC Converter

Buck Boost Converter

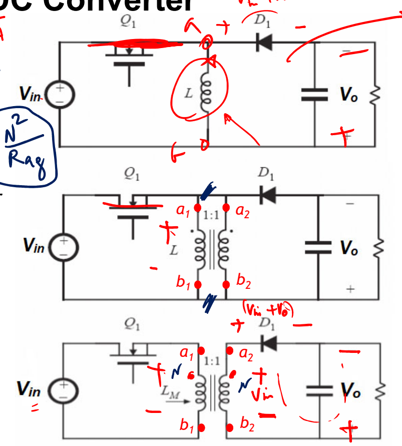
$R_c = \frac{l}{\mu_0 \mu_r A}$

$L = \frac{N^2}{R_c + R_{ag}}$

$R_{ag} = \frac{l_g}{\mu_0 A}$

$L \approx \frac{N^2}{R_{ag}}$

Now construct a inductor with two windings of parallel wires as shown



Buck/Boost

$\frac{V_o}{V_{in}} = \frac{D}{1-D}$

$0 \le D \le 0.5$ – Buck

$0.5 \le D \le 1$ – Boost

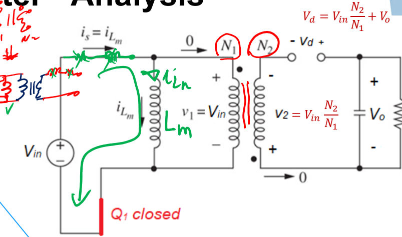
$\frac{V_o}{V_{in}} = \frac{D}{1-D} \, f\left(\frac{N_1}{N_2}\right)$

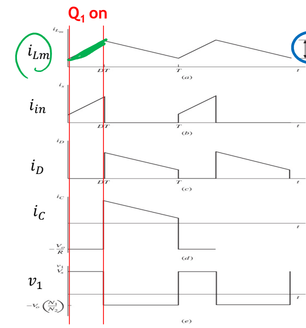
Flyback DC-DC Converter - Analysis

Switch Q_1 is Closed for DT

$\frac{V_1}{V_2} = \frac{N_1}{N_2} \Rightarrow V_2 = V_1 \cdot \frac{N_2}{N_1}$

$V_d = V_{in}\frac{N_2}{N_1} + V_o$





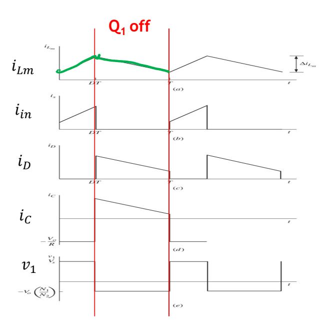
$$v_1 = V_{in} = L_m \frac{di_{Lm}}{dt}$$

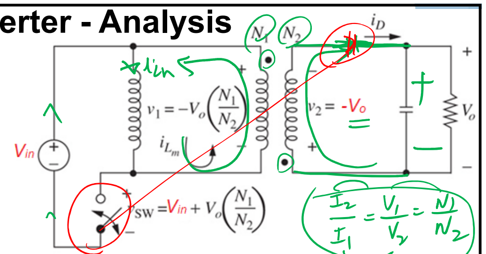
$$\frac{di_{Lm}}{dt} = \frac{\Delta i_{Lm}}{DT} = \frac{V_{in}}{L_m} \qquad L_m = \frac{V_{in} * DT}{\Delta i_{Lm}}$$

Diode voltage rating is: $V_d = V_{in}\frac{N_2}{N_1} + V_o$

Flyback DC-DC Converter - Analysis

Switch Q_1 is Open for (1-D)T





$\frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{N_1}{N_2}$

Volt-sec balance across the inductor L_m we have

$$V_{in} * DT + \left(-V_o\left(\frac{N_1}{N_2}\right)\right) * (1-D)T = 0$$

$$\frac{V_o}{V_{in}} = \left(\frac{D}{1-D}\right) * \frac{N_2}{N_1}$$

Voltage rating of the switch is: $V_{sw} = V_{in} + V_o\frac{N_1}{N_2}$

Power Integration Com Switch

Flyback DC-DC Converter – Analysis - Summary

$T = \frac{1}{f}$

$$\frac{V_o}{V_{in}} = \left(\frac{D}{1-D}\right) * \frac{N_2}{N_1}$$

$$L_m = \frac{V_{in} * D}{\Delta i_{Lm} * f}$$

$$C = \frac{D}{R * f * \left(\frac{\Delta V_o}{V_o}\right)}$$

Capacitor equation is same as buck-boost

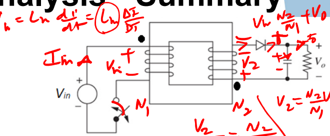
$$V_{in} * I_{in} = V_o * I_o$$

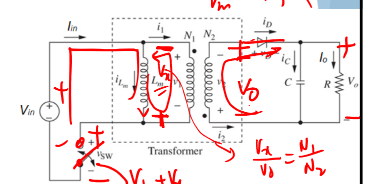
$$I_{in} = \frac{V_o}{V_{in}} I_o = \frac{D}{1-D} * \frac{N_2}{N_1} I_o$$

$$I_{Diode} = I_o = \frac{V_o}{R}$$

Voltage rating of the switch is: $V_{sw} = V_{in} + V_o\frac{N_1}{N_2}$

Diode voltage rating is: $V_d = V_{in}\frac{N_2}{N_1} + V_o$



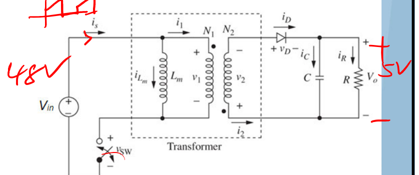


V_{in}	V_o	D	$\frac{N_2}{N_1}$	V_{sw}	V_d
50 V	400 V	0.5	8	100 V	800 V
50 V	400V	0.8	2	250 V	500 V

Flyback DC-DC Converter - Analysis

A flyback converter is to be designed for the following specifications:
V_{in} = 48V ; V_o = 5V ; P_o = 30W ; f = 150kHz. It is desired that 0.3 < D < 0.5
Assume all losses are negligible

a) Find a suitable turns ratio N_1/N_2
b) Find the duty cycle D
c) Voltage & current ratings of the switch and diode
d) Output filter capacitor value for a 2% voltage ripple



$$\frac{V_o}{V_{in}} = \frac{D}{1-D} * \frac{N_2}{N_1}$$

$$V_d = V_{in}\frac{N_2}{N_1} + V_o$$

$$V_{sw} = V_{in} + V_o\frac{N_1}{N_2}$$

If $D = 0.5$ we have

$$\frac{N_1}{N_2} = 9.6$$

Note: the turns ratio needs to be an integer

Choose: $\frac{N_1}{N_2} = 9$

$\frac{N_1}{N_2}$	D	V_{sw}	V_d
9	0.484	93 V	10.33 V
6	0.384	78 V	13 V
5	0.342	73 V	14.6 V
4	0.294	68 V	17 V

Choose N1/N2 = 5

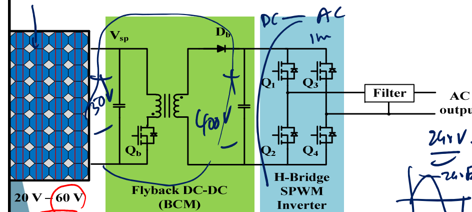
$C = 136.8\ uF$

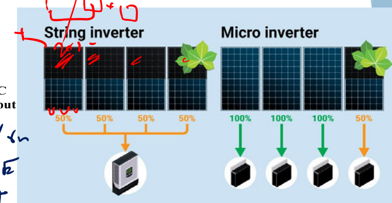
Flyback DC-DC Converter - Analysis

A flyback converter is to be designed for a solar pv system:
V_{in} = 50V ; V_o = 400V ; P_o = 300W ; f = 200kHz.
Assume all losses are negligible. If the converter is operating at the boundary of continuous and discontinuous conduction find the required L_m

a) Find a suitable turns ratio N_2/N_1
b) Find a suitable duty cycle D and discuss your choice based on the switch and diode voltage ratings
c) If the converter is operating at the boundary of continuous and discontinuous conduction find the required L_m
d) Voltage & current ratings of the switch and diode
e) Output filter capacitor value for a 2% voltage ripple

http://enphase.com

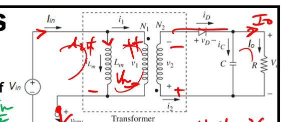




Flyback DC-DC Converter - Analysis

A flyback converter is to be designed for a solar pv system:
V_{in} = 50V ; V_o = 400V ; P_o = 300W ; f = 200kHz.
Assume all losses are negligible. If the converter is operating at the boundary of continuous and discontinuous conduction find the required L_m

a) Find a suitable turns ratio N_2/N_1 ← depends on D ⇒ 0.8
b) Find a suitable duty cycle D and discuss your choice based on the switch and diode voltage ratings
c) If the converter is operating at the boundary of continuous and discontinuous conduction find the required L_m
d) Voltage & current ratings of the switch and diode
e) Output filter capacitor value for a 2% voltage ripple



$V_{sw} = V_1 +$ $\quad V_D = \frac{N_2}{N_1}V_{in} + V_o$

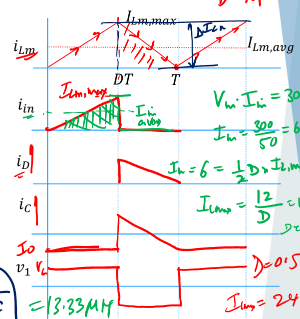
$$\frac{V_o}{V_{in}} = \frac{D}{1-D} * \frac{N_2}{N_1} \qquad \frac{N_2}{N_1} = \frac{V_o}{V_{in}} * \frac{1-D}{D}$$

$V_{in} = L_m \cdot \frac{di_m}{dt}$

$V_{in} = L_m \cdot \frac{\Delta I_{Lm}}{DT}$

$L_m = \frac{V_{in} DT}{\Delta I_{Lm}}$

$\boxed{L_m = \frac{V_{in} \cdot D}{I_{Lm,max} \cdot f}}$ $= 13.33\mu H$



$V_{in} \cdot I_{in} = 300$

$I_{in} = \frac{300}{50} = 6\ A$

$I_{in} = 6 = \frac{1}{2} D \cdot I_{Lm,max}$

$I_{Lm} = \frac{12}{D} = 15$

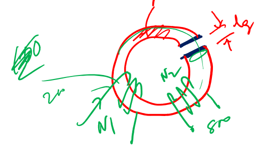
D = 0.5

$I_{Lm} = 24$

V_{in}	V_o	D	$\frac{N_2}{N_1}$	V_{sw}	V_d
50	400	0.5	8	100 V	800 V
50	400	0.8	2	250	500 V

$L_m = 13.33\mu H$

μr Very high

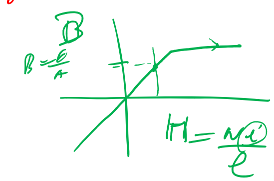


$N_1 \quad N_2$

2 8

$L_m = \frac{N_1^2}{R_{eq}}$

$R_{eq} = \frac{l_g}{\mu_0 \cdot A}$



$B = \frac{\phi}{A}$

$H = \frac{Ni}{l}$