Lecture # 16

ECEN 438/738 Power Electronics

Spring 2025 Semester

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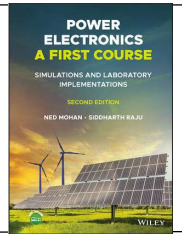
ECEN 438/738 Power Electronics



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

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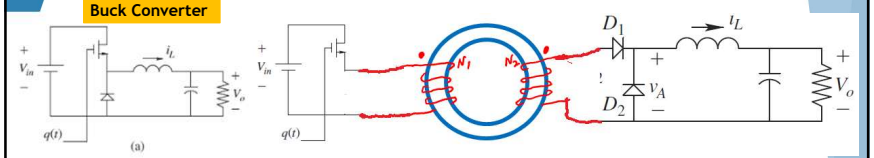
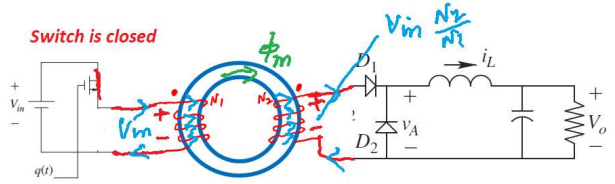
Forward DC-DC Converter - Analysis

Buck Converter





Voltage is induced in the secondary winding, diode D_1 conducts and the current in the output inductor starts to increase and charge the output capacitor similar to a buck converter

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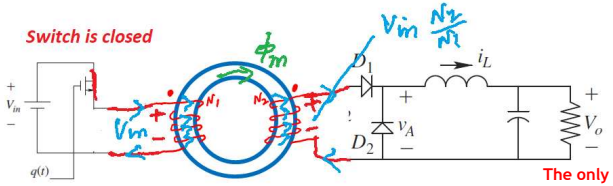
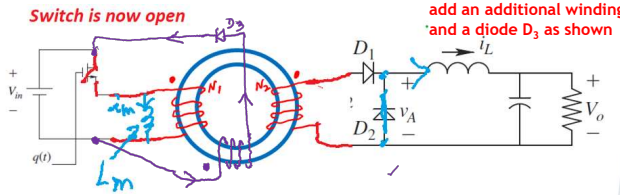
Forward DC-DC Converter - Analysis



The only solution is to add an additional winding and a diode D_3 as shown

Switch is now open

Note: magnetizing current flows through L_m to establish the flux in the core.



Switch open action causes the core flux to collapse, the stored energy in L_m needs a path to flow. Diode D_1 does not allow reverse conduction of current.

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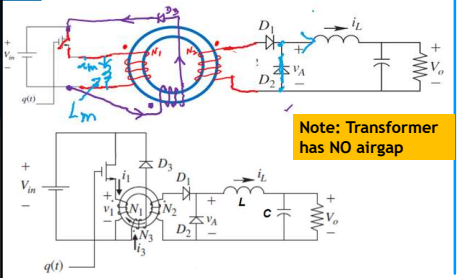
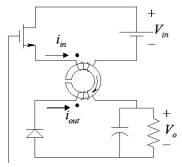
Forward DC-DC Converter



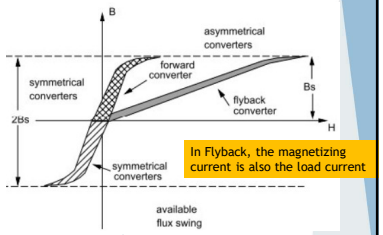
Note: Transformer has NO airgap

- Flyback transformer is actually a coupled inductor that stores all of the energy before sending it into the load, an air gap is required to store this energy and prevent core saturation.
- The air gap has the effect of reducing the overall permeability of the core.
- **Forward converter has a true transformer action and ideally store no energy, thus no air gap is needed.**

Flyback DC-DC Converter



Note: Inductor has an airgap



In Flyback, the magnetizing current is also the load current

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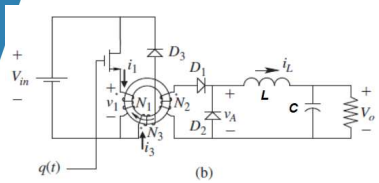
Forward DC-DC Converter - Analysis



All Buck converter design equations are valid on the output side of the converter

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

$$\Delta I_L = \frac{V_o (1-D) T}{L}$$ 2

$$L_{min} = \frac{(1-D) R}{2f}$$ 3

$$C = \frac{(1-D)}{\left(\frac{\Delta V_o}{V_o}\right) * 8 * L * f^2}$$ 6

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Attendance

Spring Break

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Forward DC-DC Converter - Analysis

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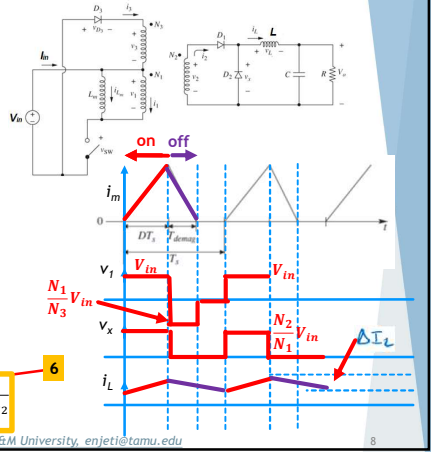

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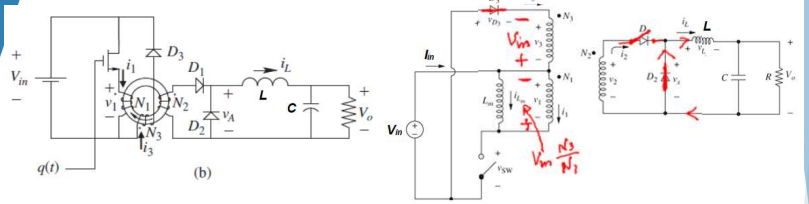
Forward DC-DC Converter - Analysis



Note: when the switch is closed, core flux is established - this can be imagined as magnetizing current to flow through inductor L_m .

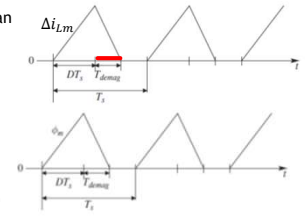
When the switch is open the magnetizing current in L_m finds a path via diode D_3 and winding N_3 and the stored energy in L_m is returned to input battery (source).

$Switch\ is\ on, we\ have\ \ L_m \frac{\Delta i_{Lm}}{DT} = V_{in};$

$Switch\ is\ off, we\ have\ \ L_m \frac{\Delta i_{Lm}}{T_{demag}} = V_{in} \frac{N_1}{N_3}$

Equating Δi_{Lm} We have

$T_{demag} = DT(\frac{N_3}{N_1})$



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Forward DC-DC Converter - Analysis

$Note:\ T_{demag} = DT(\frac{N_3}{N_1})$

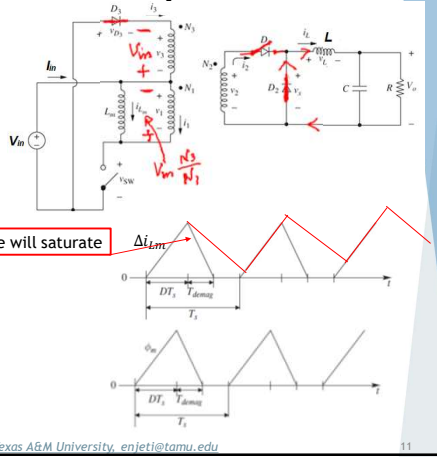
$Also:\ DT + T_{demag} < T$

$i.e.\ DT + DT(\frac{N_3}{N_1}) < T$

$or\ \ D(1 + \frac{N_3}{N_1}) < 1$

$if\ \frac{N_3}{N_1} = 1; we\ have\ D < 0.5$

$if\ D > 0.5$ - core will saturate



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Forward DC-DC Converter - Analysis

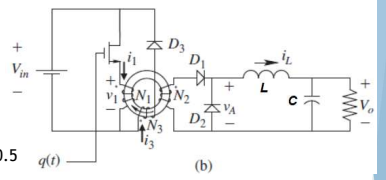
Design a Forward converter for the following specifications:

V_{in} = 170V

V_o = 5V ; Output power P_o = 25W

f = 300kHz

The output voltage ripple must not exceed 2%, choose transformer turns ratios, duty ratio D



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

Substituting V_{in}, V_o and choosing D < 0.5 i.e. say D = 0.35, we have

$\frac{N_1}{N_2} = 11.9\ ; say = 12$

Now recalculate D = 0.353

$\Delta I_L = \frac{V_o (1-D) T}{L}$ — 2

$Assume\ \Delta I_L = 40\%\ of\ I_o = 0.4 * 5 = 2A$

$From\ (2) we\ have\ L = 5.39\ uH$

$C = \frac{(1-D)}{\left(\frac{\Delta V_o}{V_o}\right) * 8 * L * f^2}$ — 6

$C = 8.3\ uF$

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Forward DC-DC Converter - Analysis

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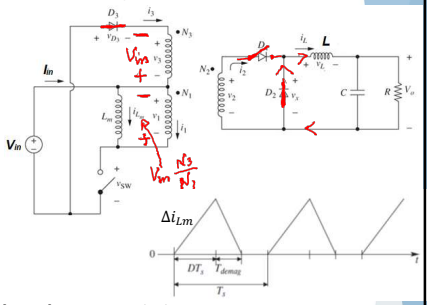

Find the switch and diode ratings

$Since\ V_{in} * I_{in} = V_o * I_o = P_o\ \ ;\ I_{in} = 0.147\ A$

$Also,\ \ \ V_o * I_o = 25\ W\ \ ;\ I_o = 5\ A$

$For\ diode\ D_1;\ \ I_{D1} = D * I_o = 0.353 * 5 = 1.765\ A$

$Voltage\ rating\ of\ diode\ D_1 is = \frac{N_2}{N_3} V_{in}; since\ N_3 = N_1; we\ have\ the\ rating\ as\ 14.17\ V$

$For\ diode\ D_2;\ \ I_{D2} = (1-D) * I_o = (1-0.353) * 5 = 3.235\ A$

$Current\ rating\ of\ diode\ D_3\ is = \frac{1}{2} * \frac{T_{demag} * \Delta i_{Lm}}{T}$

$= \frac{1}{2} * D * \Delta i_{Lm}$

$Voltage\ rating\ of\ diode\ D_3 is = 2 * V_{in}\ since\ N_3 = N_1$

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Thank you!!