ECEN4797/5797
Introduction to Power Electronics

Instructor: Dragan Maksimovic

- Office: OT346, phone: 303-492-4863, fax: 303-492-2758
- E-mail: maksimov@colorado.edu
- Office hours
  - On-campus students have priority:
    - Wednesday 10-10:30am (Mountain)
    - Thursday 9-10:30am (Mountain)
  - Off-campus students (telephone) have priority:
    - Wednesday 9-10am (Mountain)
  - Email questions will be answered within 24 hours (working days)

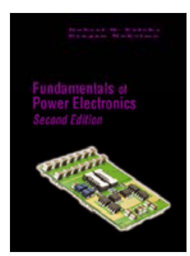
    Please use 5797 in the subject line

ECEN5797 1

ECEN4797/5797
Introduction to Power Electronics

- **Course web site:**
  - **http://ecee.colorado.edu/~ecen5797**
  - Announcements, lecture slides, course materials, assignments, solutions, links to blog, CULearn,…
- **Textbook:**
  - Erickson and Maksimovic, *Fundamentals of Power Electronics*, 2nd edition, Springer 2001
  - Available on-line from CU network at

    http://www.springerlink.com/content/978-0-7923-7270-7
- **On-line course lectures**:
  - Accessible through CAETE



ECEN5797 2

Assignments

- Weekly homeworks (12-13 total), 40% of the grade

  HW1 will be assigned on Friday this week
- Midterm exam (open book/notes, take-home), 20% of the grade
- Final exam (comprehensive, open book/notes, take-home), 40% of the grade
- All assignments, due dates, and solutions posted on the course web site
- Late work will not be accepted except in cases of documented emergencies
- HW and exam scores will be posted during the semester via the CULearn system (linked on the course website)

ECEN5797 3

ECEN4797 versus ECEN5797

- Some homework assignments will include extra problems for ECEN5797 students
- Different exams
- Grading
  - All scores during the semester are taken at face value (no curving)
  - Final score computed according to the published weights (40% HW, 20% midterm exam, 40% final exam)
  - Final grades assigned based on the final score, with grade curving done *separately* for ECEN4797 and ECEN5797 students

ECEN5797 4

Notes for off-campus students: due dates

- Due dates published on the course website are due dates for on-campus students
- One week grace period is allowed to off-campus students: work must be received by the instructor by 5pm Mountain time no more than one week after the on-campus due date

E-mail communication notes:

- I can see only your colorado.edu email address, so please check it for class-wide emails
- In general, please include 5797 in the subject line in your emails to me

Notes for off-campus students: ways to turn in your work

- Electronically, via the CULearn system

  Scan your work using 1-bit black and white, at 150-200 dpi, with all pages in a single relatively small pdf file; if the file doesn't print quickly and correctly on printers available to the instructor and the graders, you will be required to transmit your assignments via other means

  On-campus students can use this method as well

- Mail your work to:

  Prof. Dragan Maksimovic
  Campus Box 425
  ECEE Department
  University of Colorado
  Boulder, CO 80309-0425
  303-492-4863

- Fax your work to: 303-492-2758 (shared ECEE department machine)

  List Prof. Maksimovic/ECEN5797 as the recipient

Keep a copy of your work!

Assignment Policies

Homeworks

- You are encouraged to talk to other students taking the class about homework problems; collaboration is allowed
- You must turn in your own work. Copying someone else's work is not allowed.

Exams

- Take-home, open-book, open notes exams
- Absolutely no collaboration allowed in any form

Any policy violations would lead to severe consequences, starting with an immediate F in the class, for all parties involved

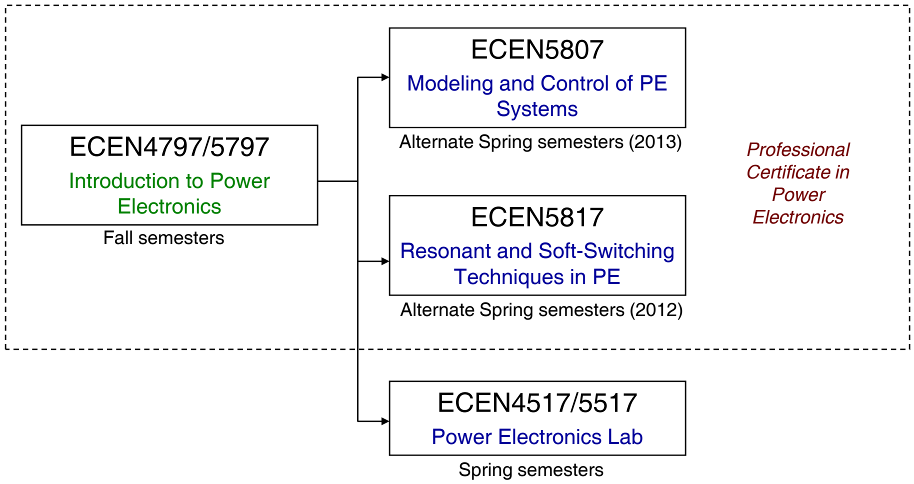
ECEN5797 7

ECEN4797/5797 blog

- Linked on the course website
- You will receive an invitation to contribute to the blog via e-mail

8

Power Electronics Program at CU Boulder

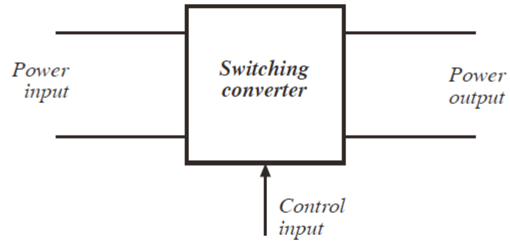


Note: ECEN4797/5797 is the prerequisite for the ECEN4517/5517 lab

Introduction (Chapter 1)

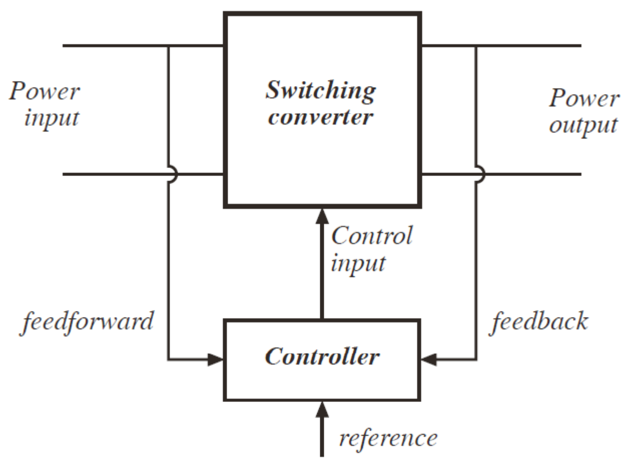
- Introduction to efficient power processing
- Power electronics applications
- Course outline

1.1 Introduction to Power Processing



Dc-dc conversion:	Change and control voltage magnitude
Ac-dc rectification:	Possibly control dc voltage, ac current
Dc-ac inversion:	Produce sinusoid of controllable magnitude and frequency
Ac-ac cycloconversion:	Change and control voltage magnitude and frequency

Control is invariably required



High efficiency is essential

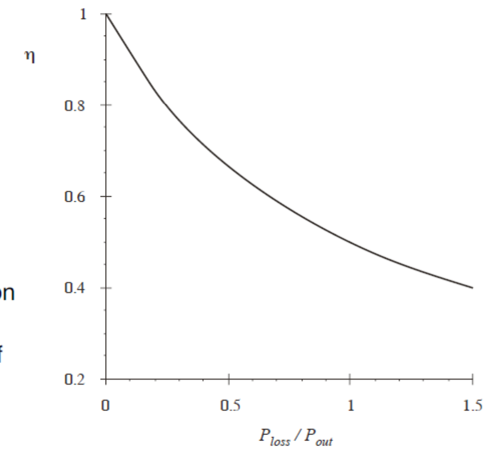
$$\eta = \frac{P_{out}}{P_{in}}$$

$$P_{loss} = P_{in} - P_{out} = P_{out}\left(\frac{1}{\eta} - 1\right)$$

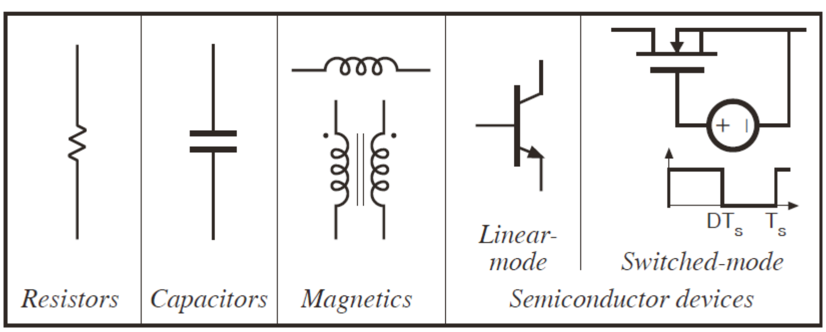
High efficiency leads to low power loss within converter

Small size and reliable operation is then feasible

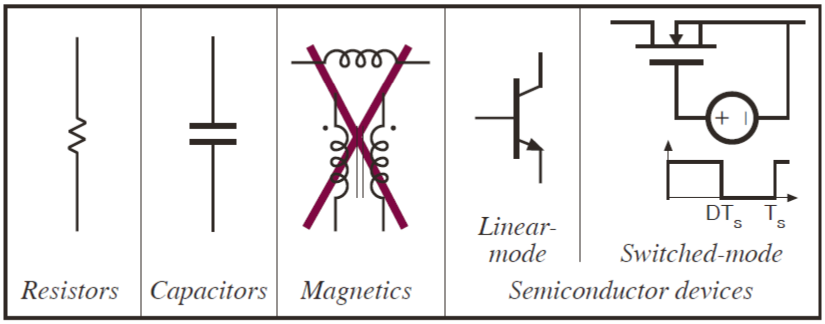
Efficiency is a good measure of converter performance



Devices available to the circuit designer

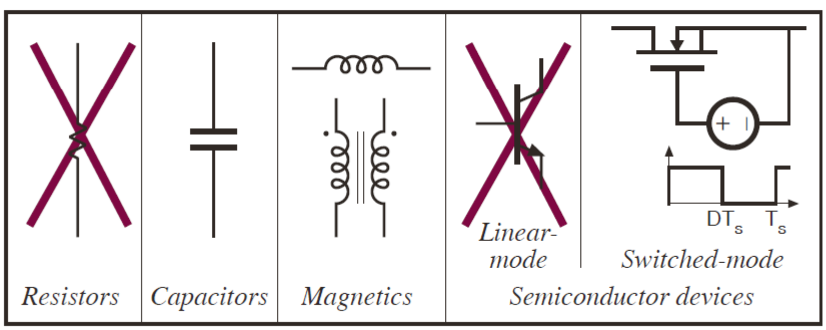


Devices available to the circuit designer



Signal processing: avoid magnetics

Devices available to the circuit designer



Power processing: avoid lossy elements

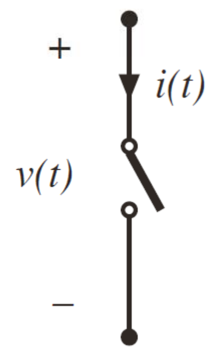
Power loss in an ideal switch

Switch closed: $v(t) = 0$

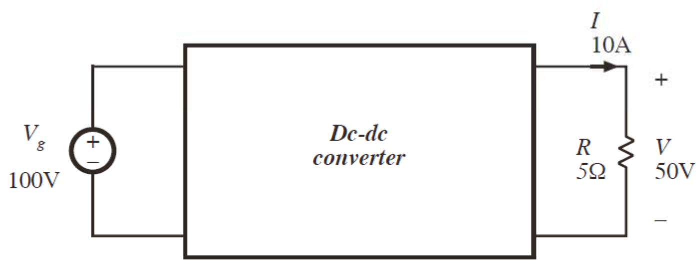
Switch open: $i(t) = 0$

In either event: $p(t) = v(t)\ i(t) = 0$

Ideal switch consumes zero power



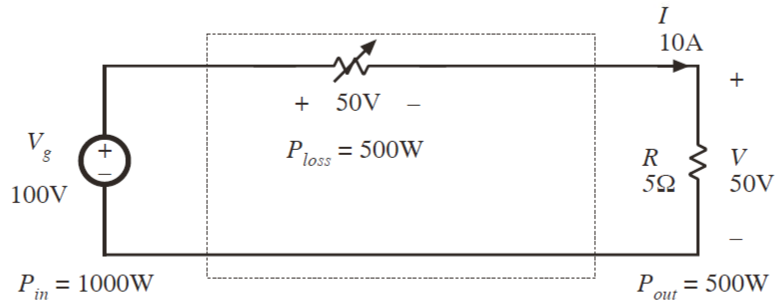
A simple dc-dc converter example



Input source: 100V
Output load: 50V, 10A, 500W
How can this converter be realized?

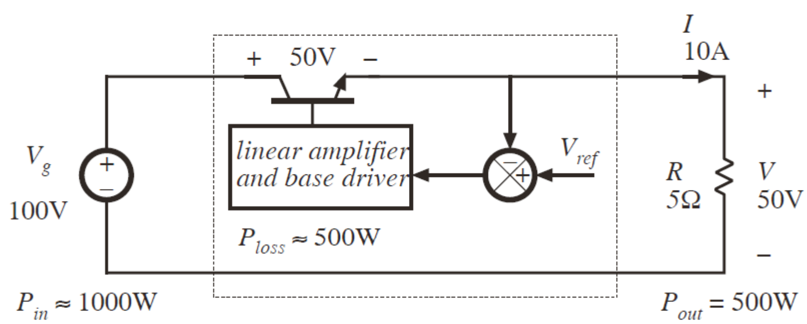
Dissipative realization

Resistive voltage divider

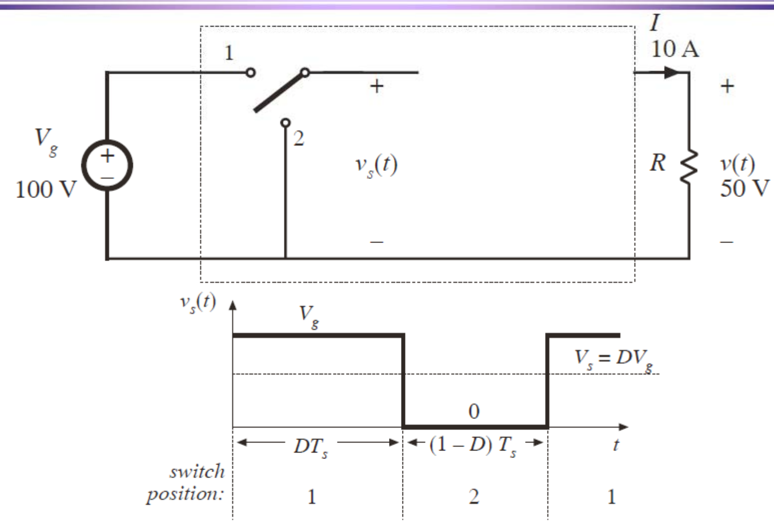


Dissipative realization

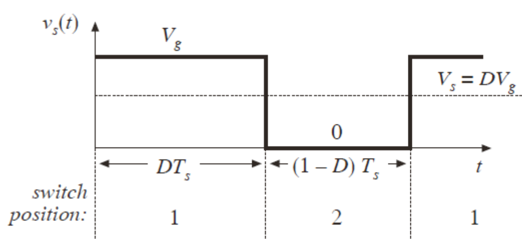
Series pass regulator: transistor operates in active region



Use of a SPDT switch



The switch changes the dc voltage level



D = switch duty cycle
$0 \le D \le 1$

T_s = switching period

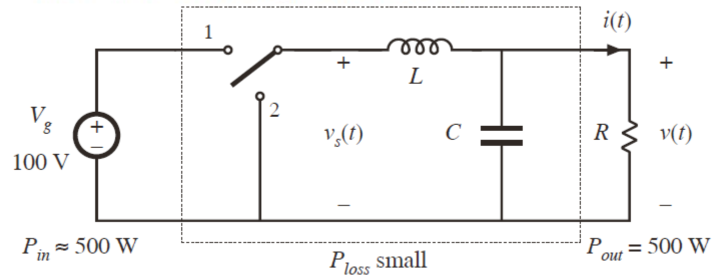
f_s = switching frequency
$= 1 / T_s$

DC component of $v_s(t)$ = average value:

$$V_s = \frac{1}{T_s}\int_0^{T_s} v_s(t)\, dt = DV_g$$

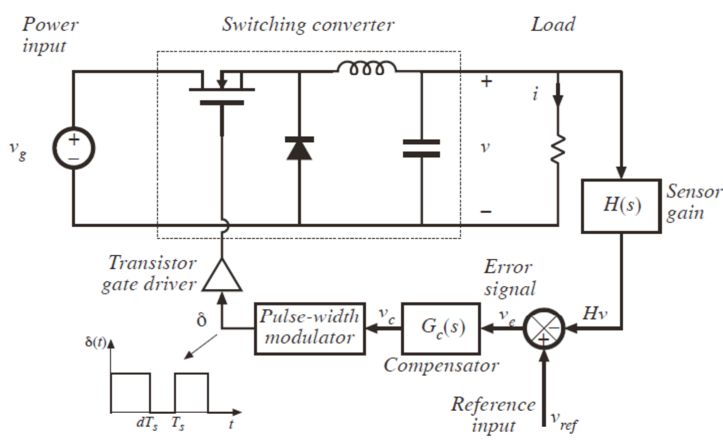
Addition of low pass filter

Addition of (ideally lossless) L-C low-pass filter, for removal of switching harmonics:

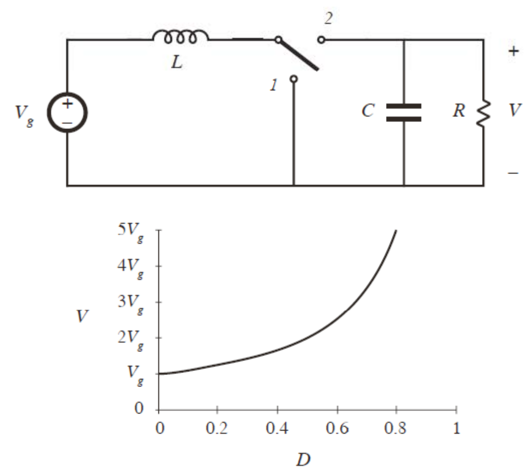


- Choose filter cutoff frequency f_0 much smaller than switching frequency f_s
- This circuit is known as the "buck converter"

Addition of control system for regulation of output voltage



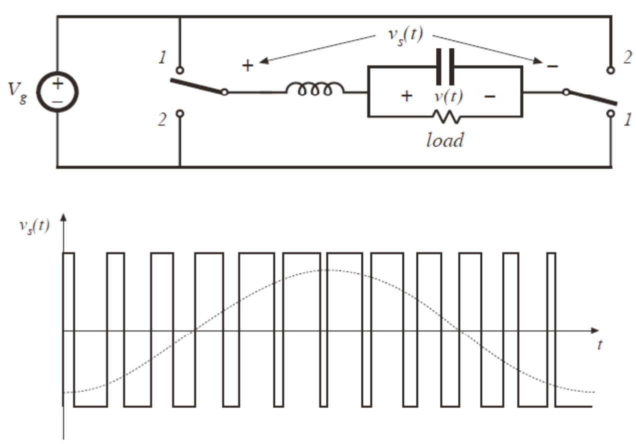
The boost converter



Fundamentals of Power Electronics 18 *Chapter 1: Introduction*

ECEN5797 25

A single-phase inverter



"H-bridge"

Modulate switch duty cycles to obtain sinusoidal low-frequency component

Fundamentals of Power Electronics 19 *Chapter 1: Introduction*

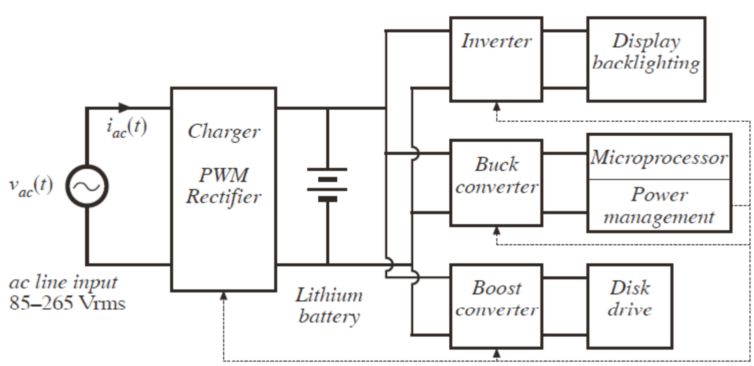
ECEN5797 26

Applications of Power Electronics
from micro-watts to mega-watts

- Battery-operated electronics - less than 1 W
- Energy-efficient lighting - tens of watts
- Power supplies in computers, office, telecom, medical electronics - tens, hundreds or thousands of watts)
- Variable-speed motor drives (e.g. industrial applications, or electric-drive vehicles) – kW to MW
- Solar power systems – kW to MW
- Wind turbine drive trains – hundreds of kW to MW
- Utility-scale rectifiers and inverters, dc transmission systems – hundreds of MW to GW

ECEN5797 27

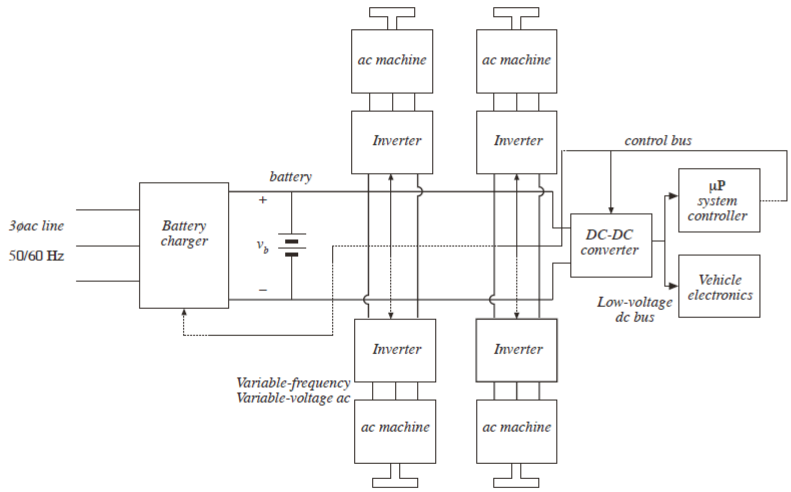
A laptop computer power supply system



Fundamentals of Power Electronics 21 Chapter 1: Introduction

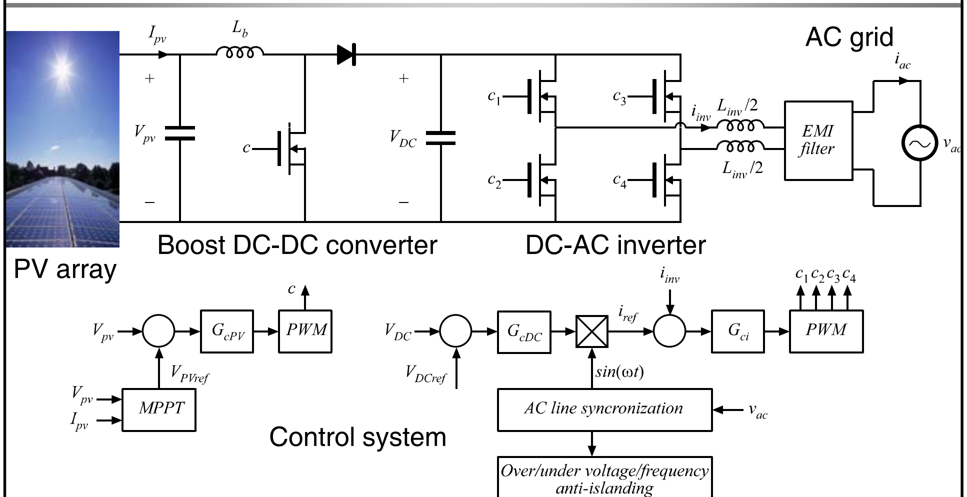
ECEN5797 28

An electric vehicle power and drive system



Fundamentals of Power Electronics 23 *Chapter 1: Introduction*

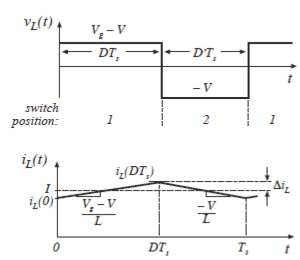
Solar Power System



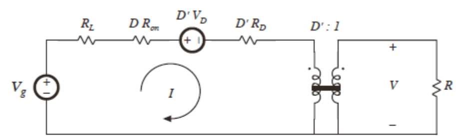
Course outline: 1. Converters in equilibrium

Textbook Chapters 2-6

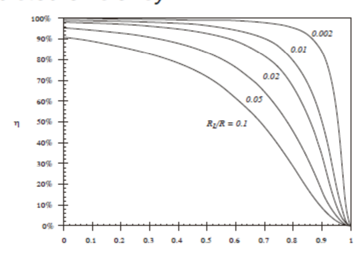
Inductor waveforms



Averaged equivalent circuit



Predicted efficiency



Discontinuous conduction mode

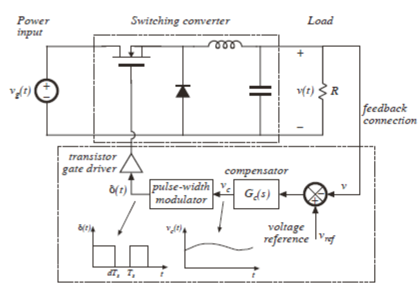
Transformer isolation

ECEN5797 31

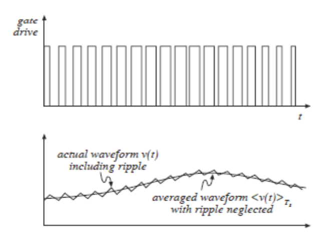
2. Converter dynamics and control

Textbook Chapters 7-9

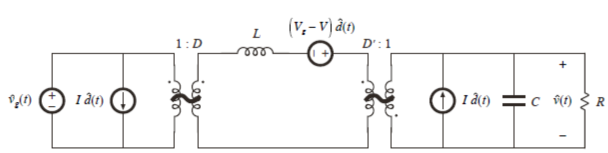
Closed-loop converter system



Averaging the waveforms



Small-signal averaged equivalent circuit

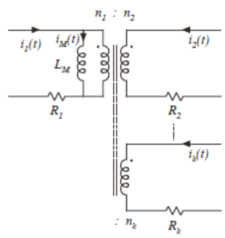


ECEN5797 32

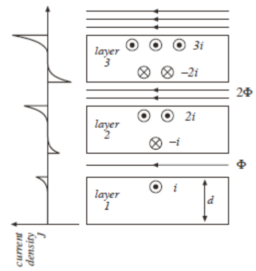
3. Magnetics

Textbook Chapters 13-15

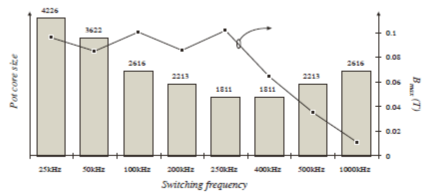
transformer design



the proximity effect



transformer size vs. switching frequency



ECEN5797 33