

ECE 481: Power Electronics

Prof. Daniel Costinett

Department of Electrical Engineering and Computer Science
University of Tennessee Knoxville
Fall 2015



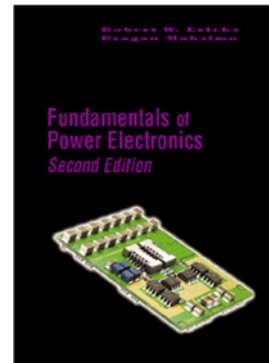
ECE 481: Power Electronics

- Instructor: Prof. Daniel Costinett
 - Office: MK502
 - Telephone: (865) 974-3572
 - Email: dcostine@utk.edu
 - Please use [ECE481] in the subject line for all course-related e-mails.
 - Office Hours: W 1:30-3:00pm, R 9:00-10:00am



Course Materials

- Textbook:
 - Erickson and Maksimovic, *Fundamentals of Power Electronics*, second edition, Kluwer Academic Publishers, ISBN 0-7923-7270-0
 - Available through campus bookstore, online vendors, or online through UT libraries
- Course Website
 - <http://web.eecs.utk.edu/~dcostine/ECE481>
 - Includes lectures slides, handouts, supplemental notes, homework assignments, course announcements



Assignments

- Homework (40%)
 - Due at *beginning* of class on date listed on Lecture Schedule web page (Fridays)
 - No late work accepted except in cases of documented emergencies
 - Collaboration is encouraged on all homework assignments
 - must turn in *your own* work
- Exams
 - 1 Midterm: 25% of grade
 - 1 Final: 35% of grade

ECE 481 vs ECE 599

- Students enrolled in ECE 599 will have additional homework and exam problems
- Grading
 - Separate curving for ECE 481 and ECE 599
 - Extra credit is added to final grade after any curving

Piazza Forum

- New resource for ECE 481 this semester
- Additional method for collaborating on HW



The screenshot displays the Piazza forum interface. On the left, a sidebar lists various questions under categories like 'Planned', 'Unresolved Followup', and 'Resolved'. The main content area shows a detailed view of a question titled 'How do I answer a question?'. This view includes sections for 'the students' answer' and 'the instructors' answer', each with a text box for input and an 'edit' button. The interface also features a 'followup discussions' section at the bottom.

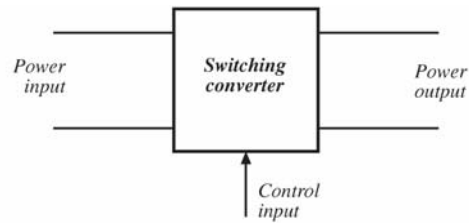
How to Succeed in ECE 481

- Attend all lectures
 - Participate; ask questions or ask for clarification
- Read textbook for clarification
- Complete all homework assignments
 - Work together in-person or using Piazza
 - Review and understand mistakes
 - ~12 assignments for 40% of the grade

Power Electronics Courses at UTK

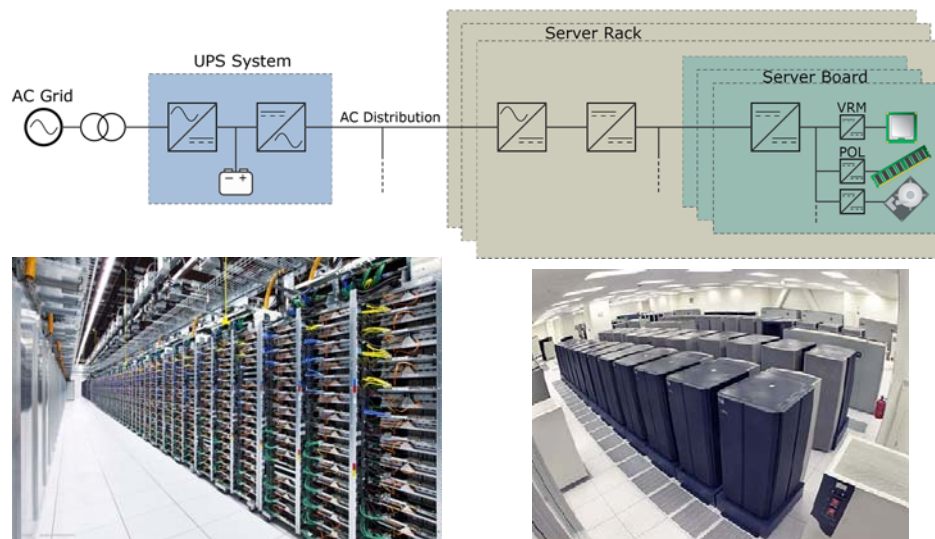
Junior	Senior	Graduate	
ECE 325 Electric Energy System Components	ECE 481 Power Electronics	ECE 523 Power Electronics and Drives	ECE 623 Advanced Power Electronics and Drives
	ECE 482 Power Electronic Circuits	ECE 525 Alternative Energy Sources	ECE 625 Utility Applications of Power Electronics
		ECE 581 High Frequency Power Electronics	ECE 626 Solid State Power Semiconductors

Introduction to Power Conversion

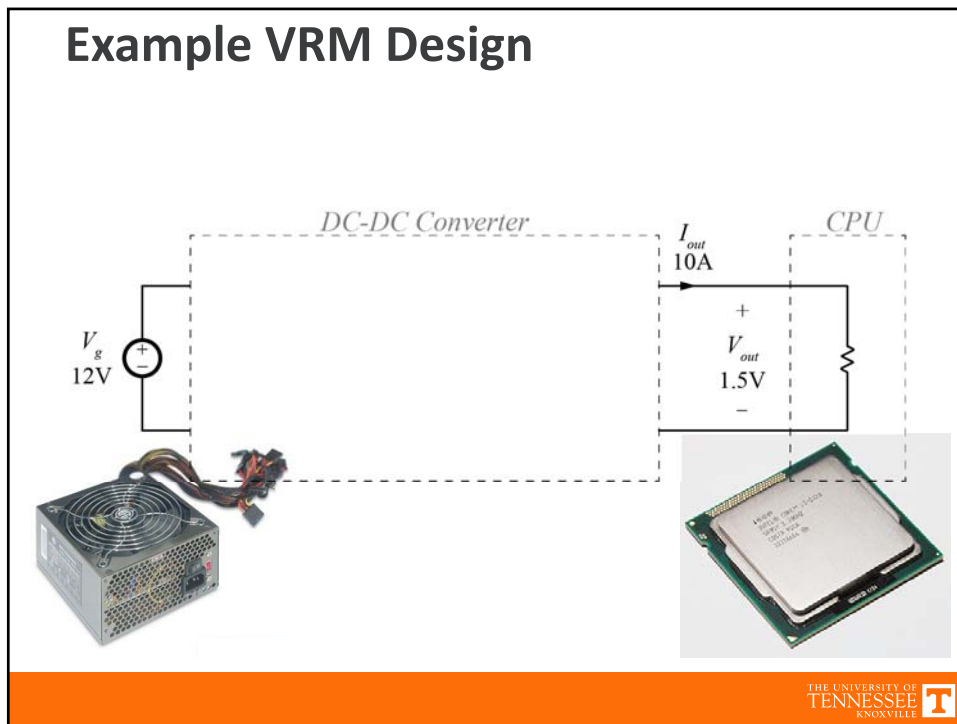


Dc-dc conversion: Change and control voltage magnitude
Ac-dc rectification: Possibly control dc voltage, ac current
Dc-ac inversion: Produce sinusoid of controllable magnitude and frequency
Ac-ac cycloconversion: Change and control voltage magnitude and frequency

Example Server Power Distribution



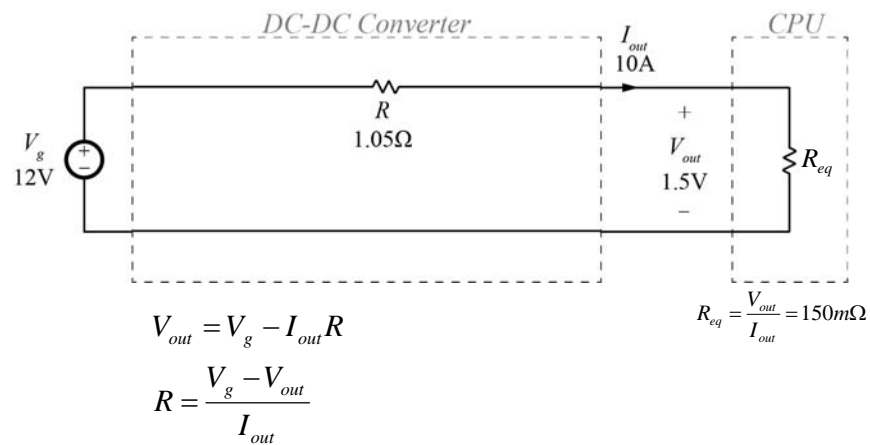
Example VRM Design



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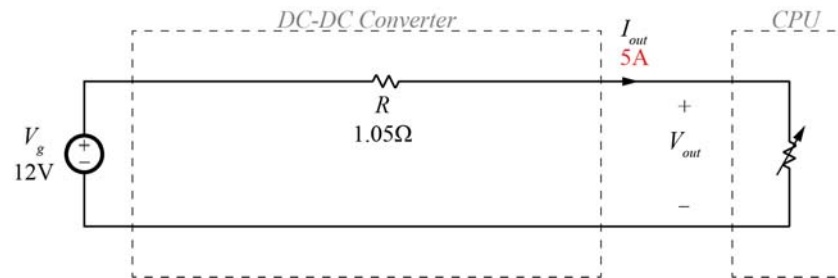
Example VRM Design



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Variations in Load

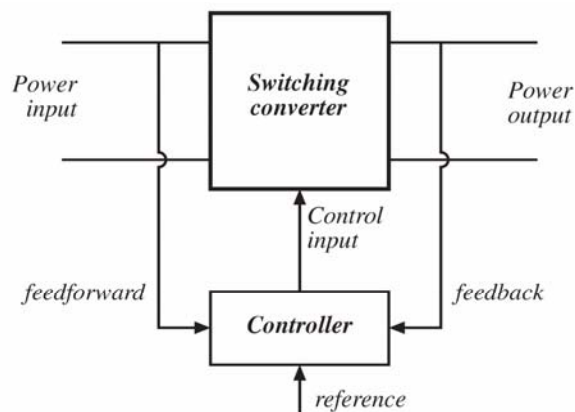


$$V_{out} = V_g - I_{out}R$$

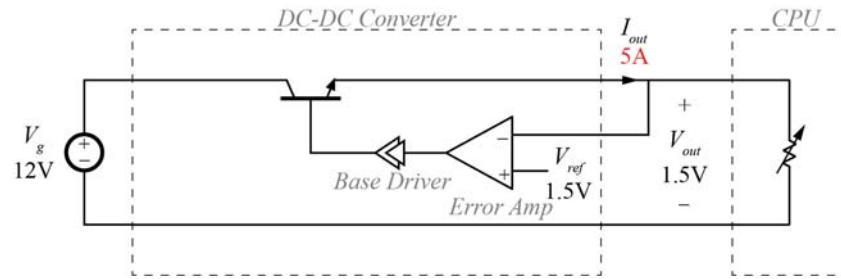
$$V_{out} = 12V - (5A)(1.05\Omega)$$

$$V_{out} = 6.75V$$

Control is Invariably Required



Linear Regulator



$$P_{in} = V_g I_g \approx V_g I_{out}$$

$$P_{in} = (5A)(12V)$$

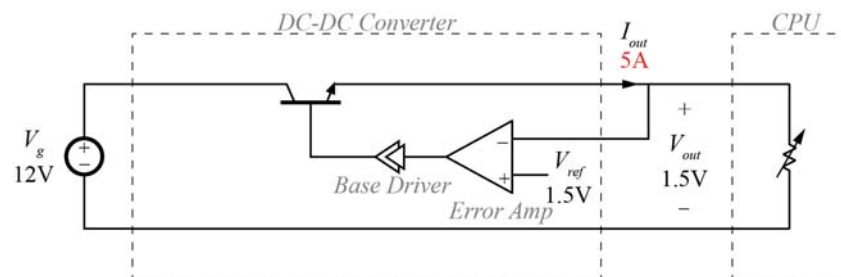
$$P_{in} = 60W$$

$$P_{out} = V_{out} I_{out}$$

$$P_{out} = (5A)(1.5V)$$

$$P_{out} = 7.5W$$

Linear Regulator



$$P_{in} = V_g I_g \approx V_g I_{out}$$

$$P_{in} = (5A)(12V)$$

$$P_{in} = 60W$$

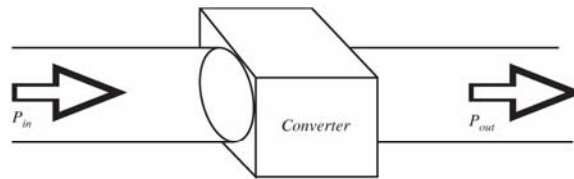
$$P_{out} = V_{out} I_{out}$$

$$P_{out} = (5A)(1.5V)$$

$$P_{out} = 7.5W$$

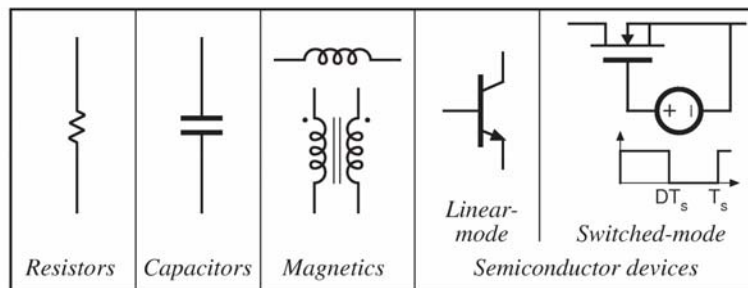
$$\eta = \frac{P_{out}}{P_{in}} = \frac{7.5W}{60W} = 12.5\%$$

A High Efficiency Converter

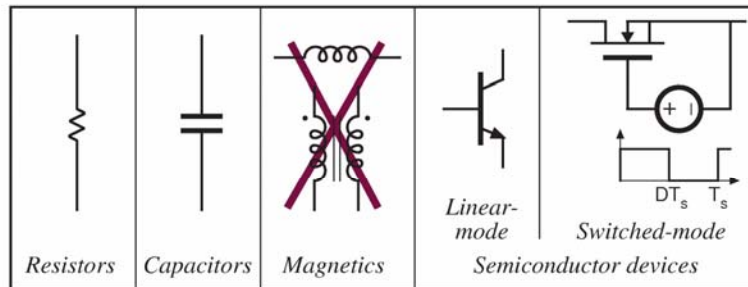


A goal of current converter technology is to construct converters of small size and weight, which process substantial power at high efficiency

Devices Available to the Circuit Designer

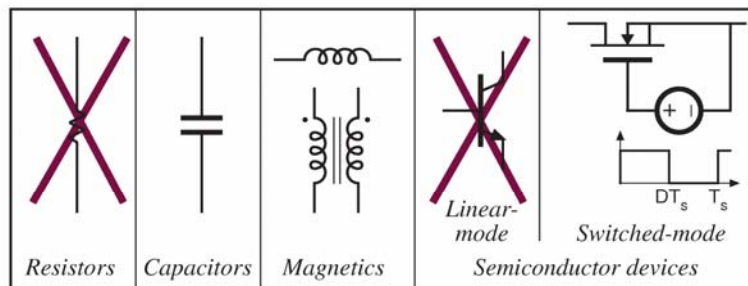


Devices Available to the Circuit Designer



Signal processing: avoid magnetics

Devices Available to the Circuit Designer



Power processing: avoid lossy elements

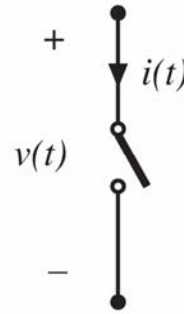
Power Loss in an Ideal Switch

Switch closed: $v(t) = 0$

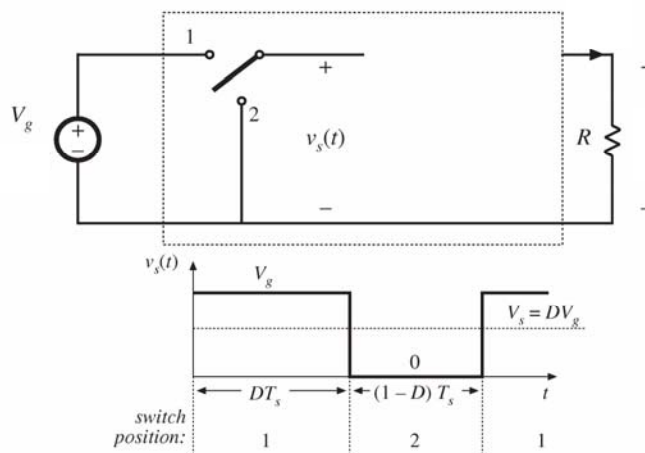
Switch open: $i(t) = 0$

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

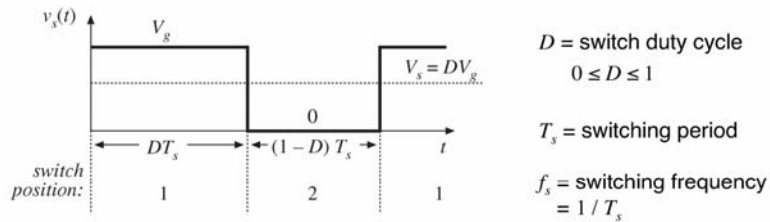
Ideal switch consumes zero power



Use of SPDT Switch



Controlling Duty Cycle

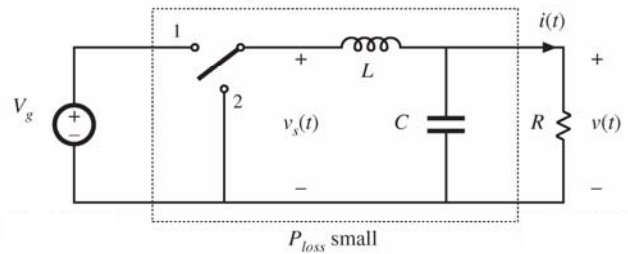


DC component of $v_s(t)$ = average value:

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

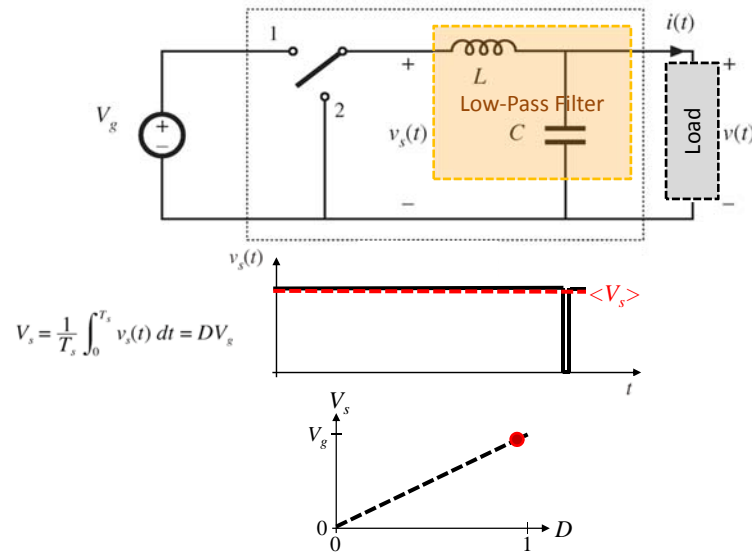
Addition of Low Pass Filter

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"

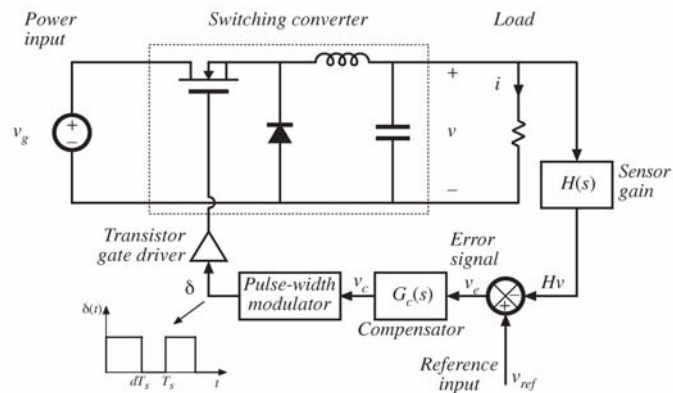
Duty Cycle Control



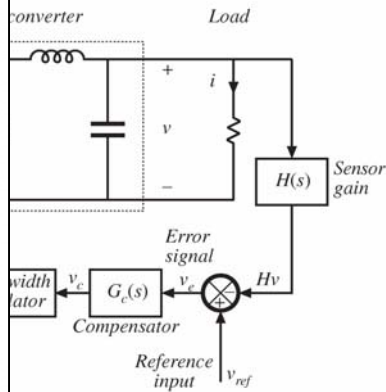
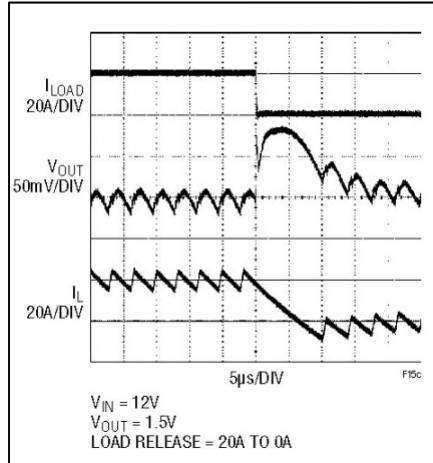
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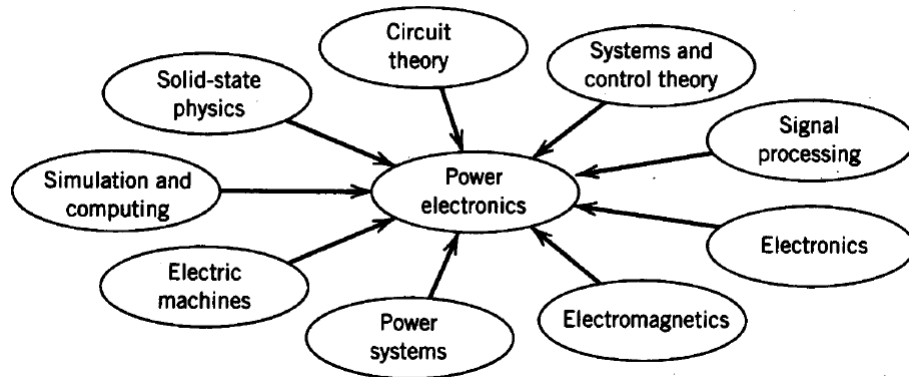
Control System for Voltage Regulation

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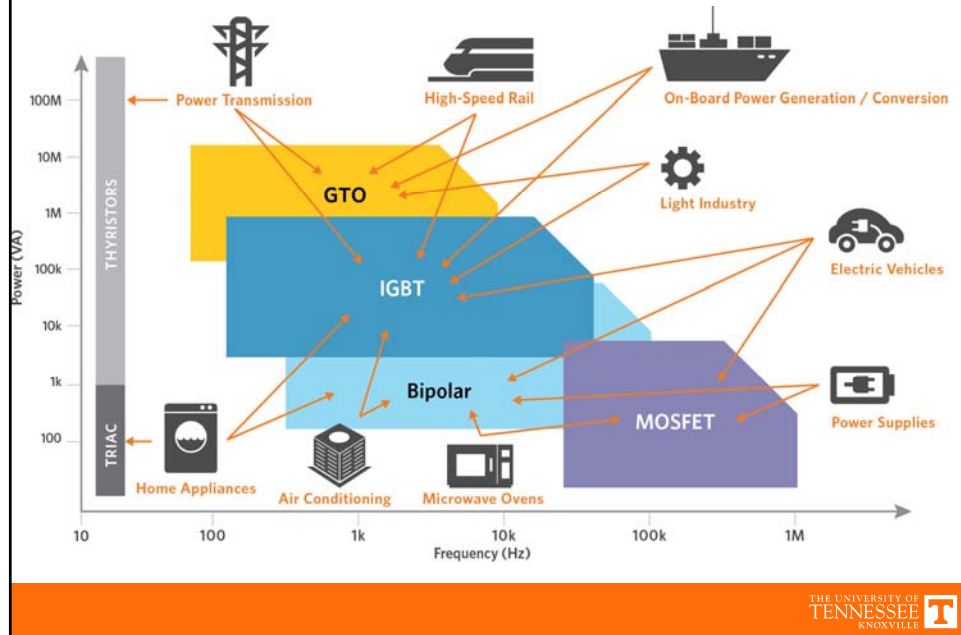
Dynamic Performance



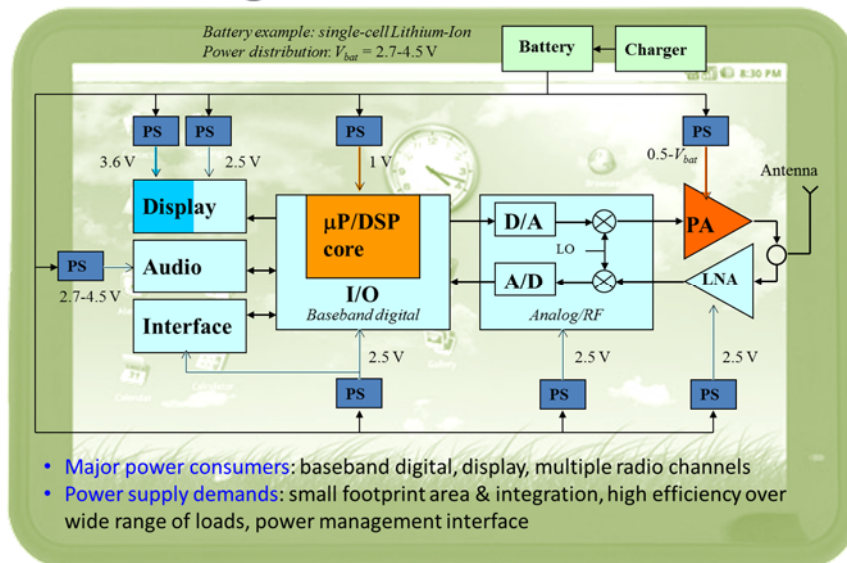
Power Electronics Overview



Some Power Electronics Applications

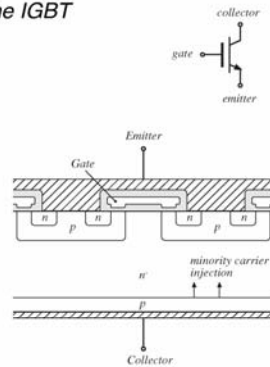


Power management in mobile electronics



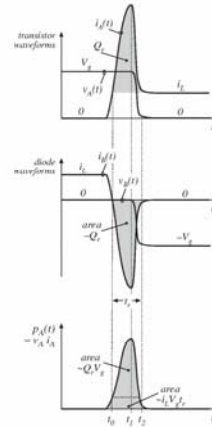
Switch Realization: Semiconductor Devices

The IGBT



Fundamentals of Power Electronics

Switching loss



Chapter 1: Introduction

Part II: Converter Dynamics and Control

7. Ac modeling
8. Converter transfer functions
9. Controller design
10. Input filter design
11. Ac and dc equivalent circuit modeling of the discontinuous conduction mode
12. Current-programmed control

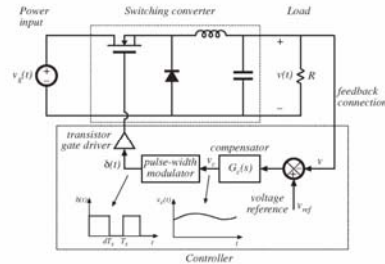
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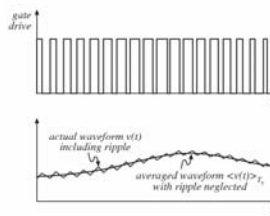
Chapter 1: Introduction

Part II: Converter Dynamics and Control

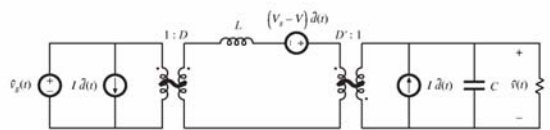
Closed-loop converter system



Averaging the waveforms



Small-signal averaged equivalent circuit



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Chapter 1: Introduction

Part III: Magnetics

13. Basic magnetics theory
14. Inductor design
15. Transformer design

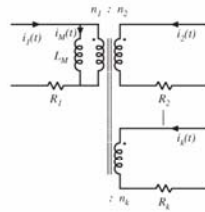
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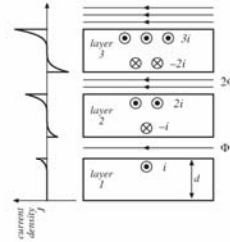
Chapter 1: Introduction

Part III: Magnetics

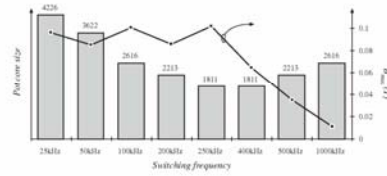
transformer design



the proximity effect



transformer size vs. switching frequency



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Chapter 1: Introduction