High Frequency Power Electronics

Prof. Daniel Costinett

ECE 581 Lecture 1
August 20, 2014

Course Info

- New course in design an modeling of "high frequency" power electronics
  - Course website: http://web.eecs.utk.edu/courses/fall2014/ece581/
- Goal of course is understanding of motivations and issues with high frequency power electronics; analysis and design techniques; applications
- Prerequisites: undergraduate Circuits sequence, Microelectronics, ECE 481 – Power Electronics, or equivalent

Contact Info

Instructor: Daniel Costinett

- Office: MK502
- OH: T 9-10; W 5-6; By appointment
- E-mail: Daniel.Costinett@utk.edu
- Email questions will be answered within 24 hours (excluding weekends)
- Please use **[ECE 581]** in the subject line

Course Structure

- Course meets MWF 9:00-9:50 am
- Plan to spend ~9 hours per week on course outside of lectures
- Grading:
  - Homework: 40%
    - One per week
    - Assignments due on Fridays unless otherwise noted on course website
  - Midterm: 25%
    - Tentatively scheduled for October 8th
  - Final: 35%

Assignments

- Assignments due *at the start of lecture* on the day indicated on the course schedule
- No late work will be accepted except in cases of documented medical emergences
- Collaboration is encouraged on all assignments except quizzes and exams; Turn in your own work

Textbook and Materials

- The textbook

  R.Erickson, D.Maksimovic, *Fundamentals of Power Electronics*, Springer 2001

  will be used: chapters 19-20 and reference materials from prior chapters. The textbook is available on-line from campus network. Purchase is not required for this course.
- MATLAB/Simulink, LTSpice will be used; All installed in the Tesla Lab
- Lecture slides and notes, additional course materials, homework, due dates , etc. posted on the course website
- Additional information on course website

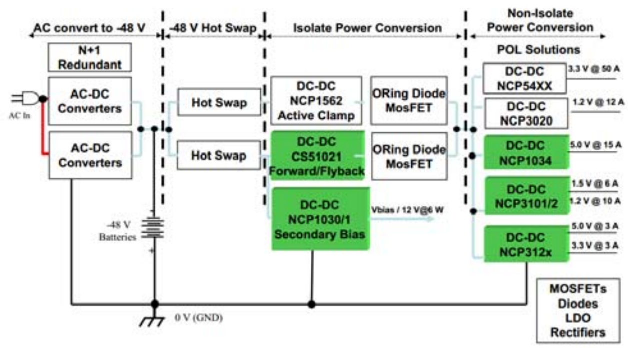
Introduction

- Why high frequency?
  - Power Density
  - Control Bandwidth
- Techniques
  - Devices
  - Control
  - Topologies
  - Passives

8 w Dimmable LED Driver

Voltage Regulation Module

Example Application - Telecom



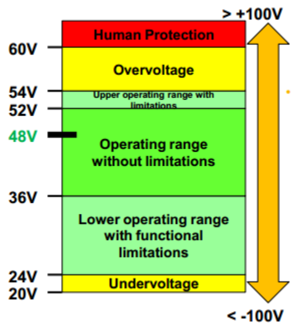
Param	Value
V_g	12 V
V_{out}	48 V
R_{out}	48 Ω
ΔV_{out}	0.1 V

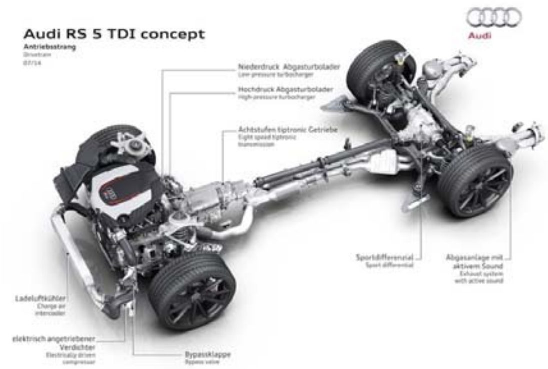
On Semi, "DC-DC Telecom & Networking Solutions", 2008

EV Networks

The (Hybrid) Electrical Vehicle … driving new semiconductor technology

Maximize energy efficiency of the existing conventional electronic system

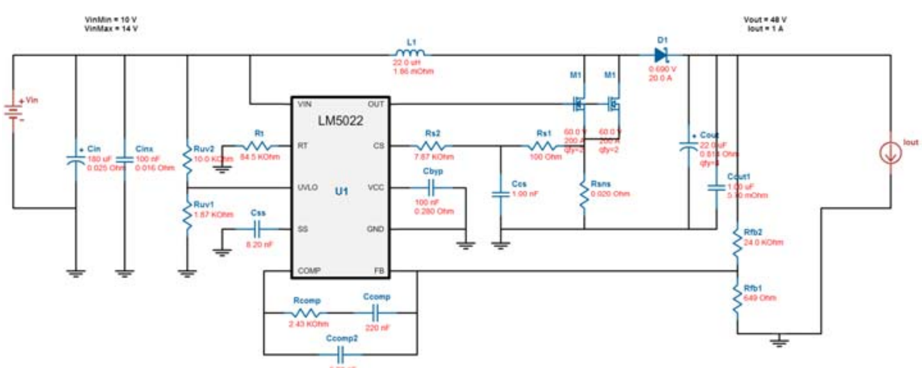




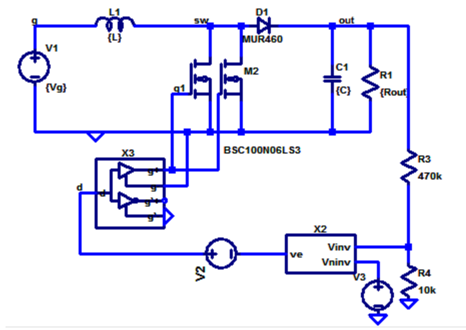
NXP Semi, "Semiconductors – enablers of future mobility concepts", 2011
Audi, "Electric biturbo and hybridization", 2014

Baseline Design

- Use TI WebBench (webench.ti.com) to get a baseline design

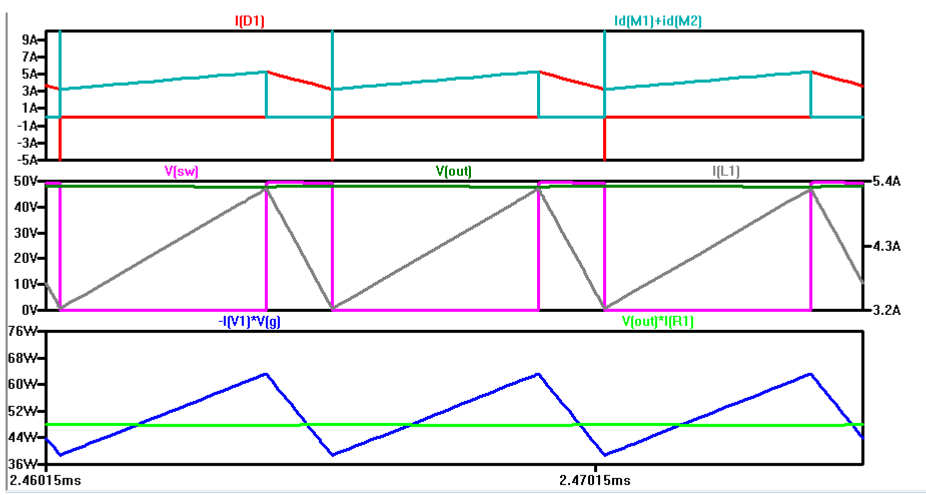


LTSpice Simulation

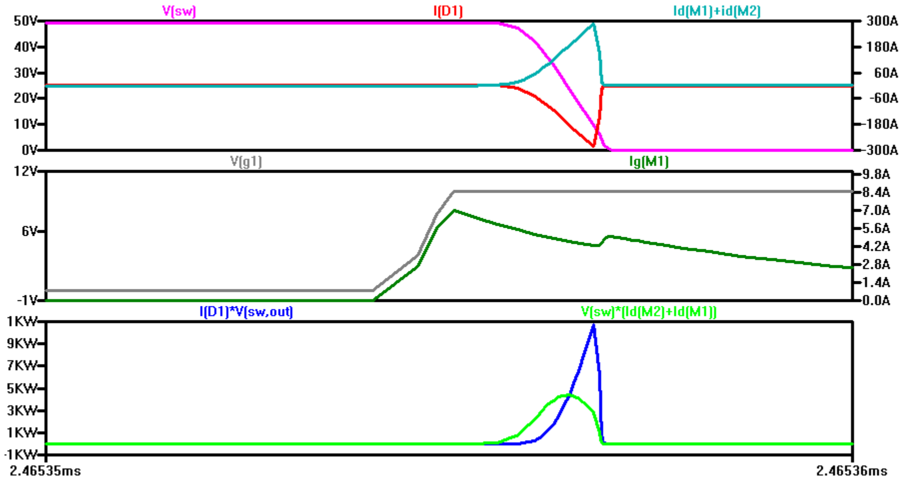


L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%

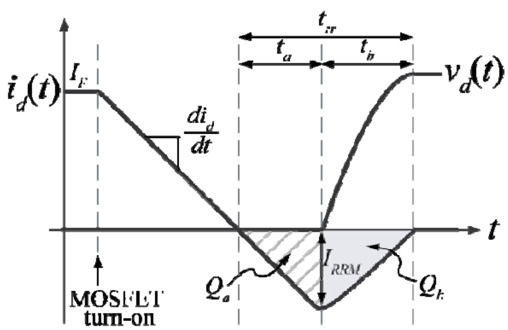
LTSpice Simulation



Switching Transition



Diode Reverse Recovery



Datasheet RR Characteristics

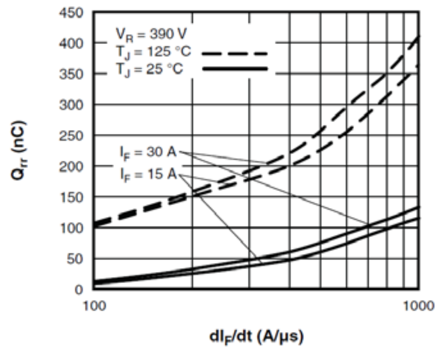


Fig. 10 - Typical Stored Charge vs. dI_F/dt

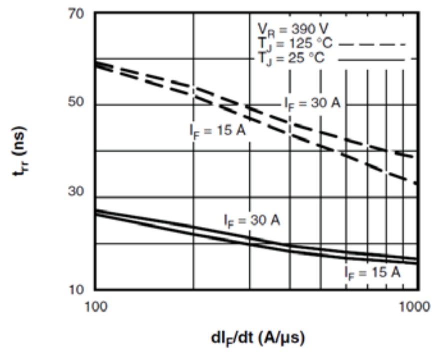
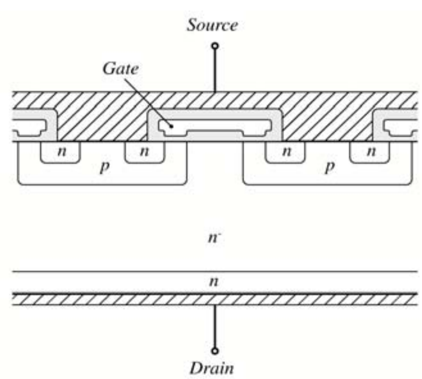
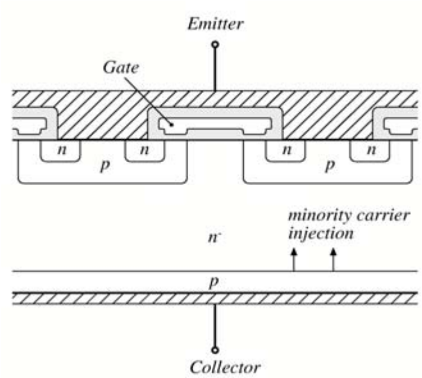


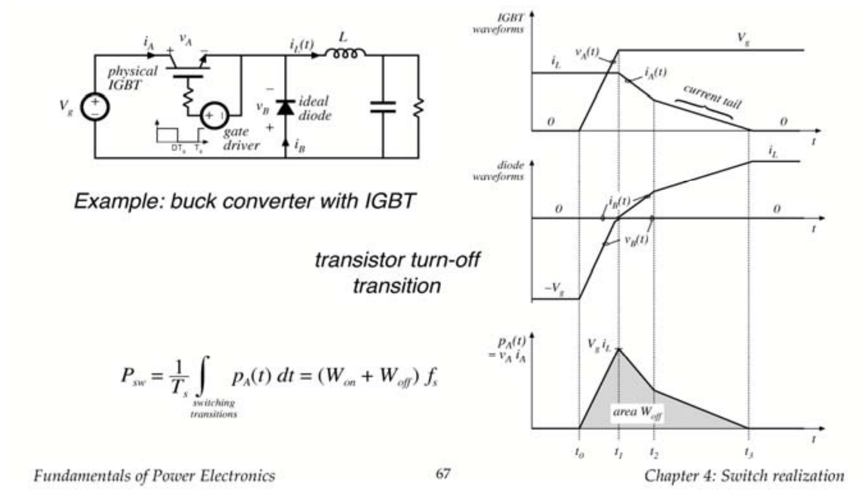
Fig. 9 - Typical Reverse Recovery Time vs. dI_F/dt

Charge Storage

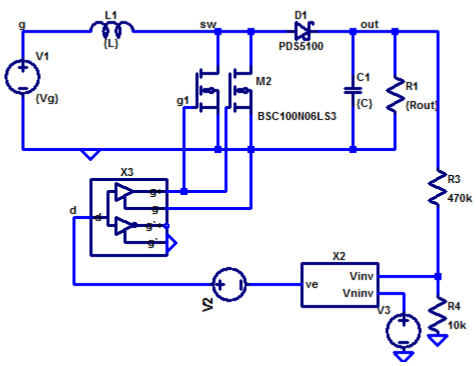




IGBT Current Tailing

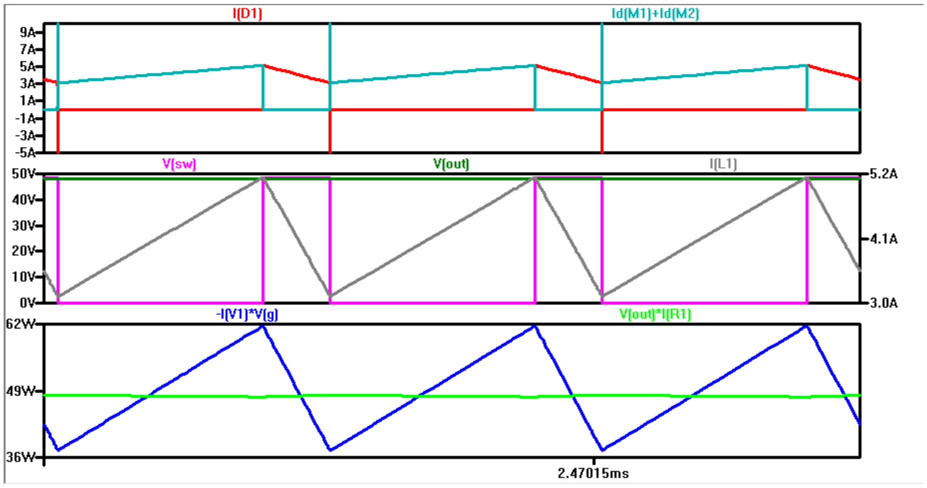


Schottky Diode

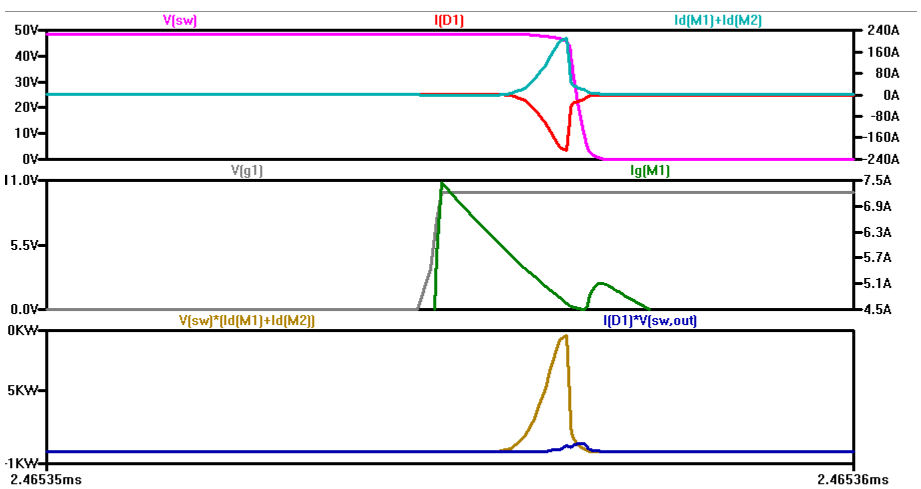


L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%
22uH	22uF	202k	Si Schottky	96.9%

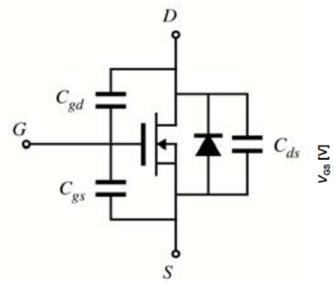
Simulation Waveforms

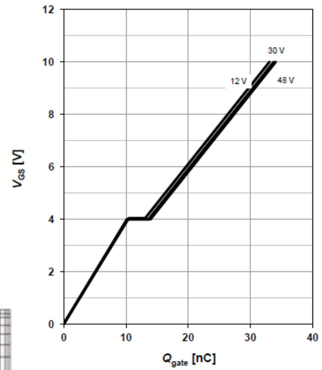


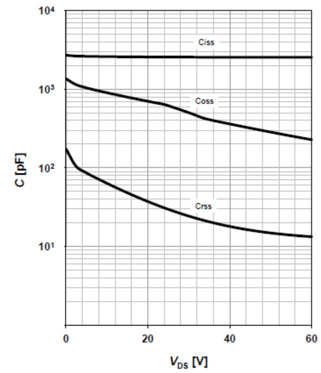
Switching Transition

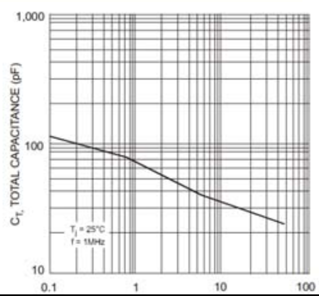


MOSFET Stored Charge

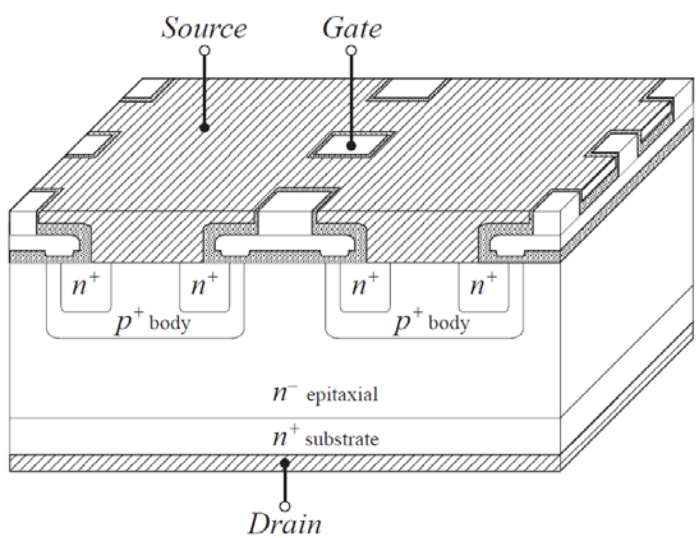




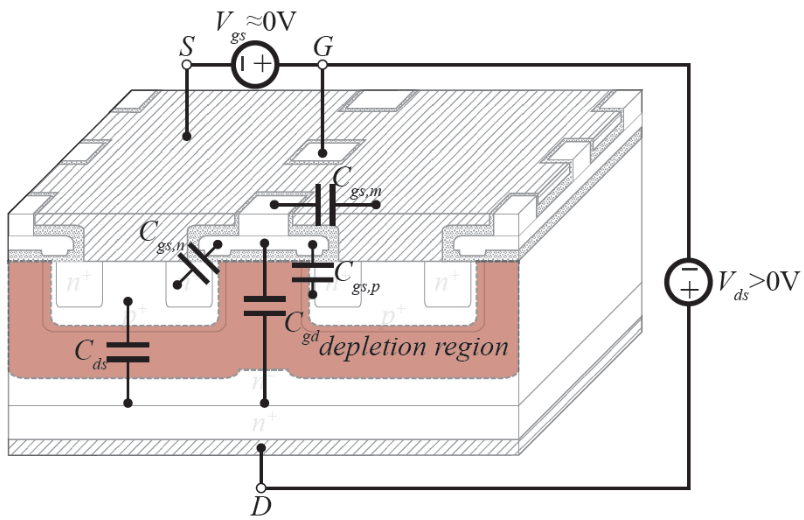




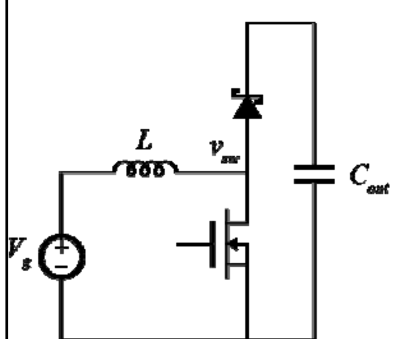
MOSFET Cross Section

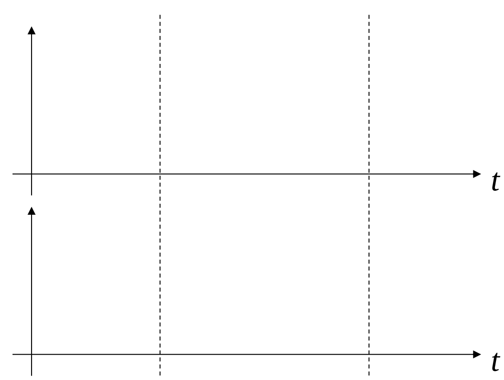


MOSFET Depletion capacitance

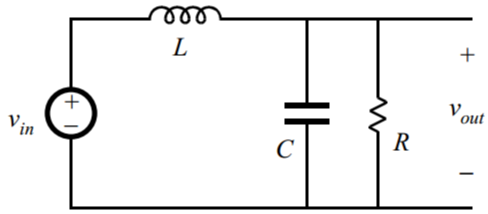


Device Capacitances





Resonant Circuits



Resonant Circuit Analysis