High Frequency Power Electronics

Prof. Daniel Costinett

ECE 581 Lecture 1
August 19, 2020

THE UNIVERSITY OF TENNESSEE
KNOXVILLE

Course Info

- Course focuses on design an modeling of “high frequency” power electronics
  - Course website: http://web.eecs.utk.edu/~dcostine/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: MK504
  - Office Hours: TBD
  - 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 10:20-11:10 am
- Plan to spend ~9 hours per week on course outside of lectures
- Grading:
  - Homework/Lab: 40%
    - One homework per week
    - Assignments due on Fridays unless otherwise noted on course website
  - Midterm: 25%
    - Tentatively scheduled for October 29th
  - Final: 35%

Assignments

- Assignments due *at the start of lecture* on the day indicated on the course schedule
- All assignments submitted through canvas
  - https://utk.instructure.com/courses/104569
- No late work will be accepted except in cases of documented medical emergences
- Collaboration is encouraged on all assignments except exams; Turn in your own work
- All work to be turned in through canvas

Textbook and Materials

- The textbook

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

  will cover some of 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 on-campus labs, free, available through apps@UT, or on EECS servers
- Lecture slides and notes, additional course materials, homework, due dates , etc. posted on the course website
- Additional information on course website

Office Hours

- In-person office hours not permitted
- Scheduled office hours are times of maximum availability
- Contact me by e-mail, slack to start a telecon
- Outside of office hours, I will respond within 24 hours to e-mail or slack messages

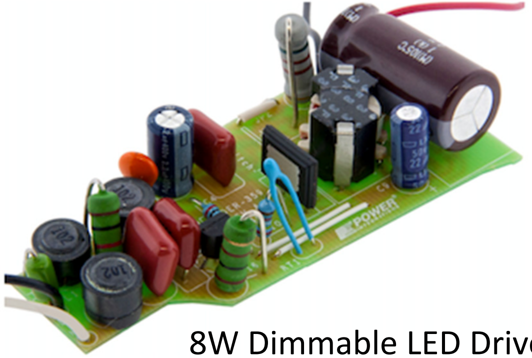
TiNY BOX CHALLENGE

- Design competition to build and test an optimized dc-dc converter
  - Fall ‘16 – 60-to-12V, 60W
  - Fall ‘18 – 48-to-1.2V, 12W
  - Fall ‘20 – 48-to-12V, 36W
- Specs and details TBD
  - Usually ~October-November
  - Usually in groups of 2

COURSE INTRODUCTION

Introduction

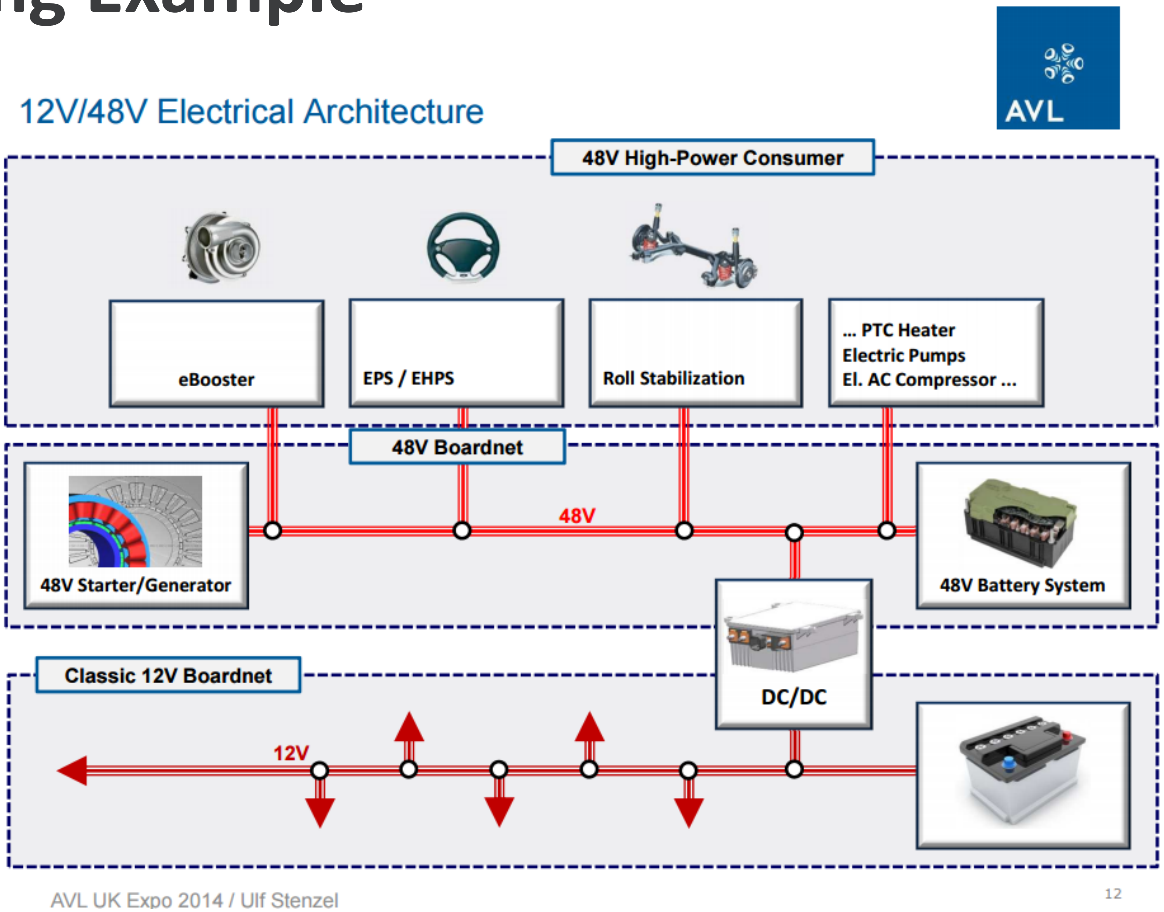
- Why high frequency?
  - Power Density
  - Control Bandwidth
- Techniques
  - Devices
  - Control
  - Topologies
  - Passives



8W Dimmable LED Driver

Voltage Regulation Module

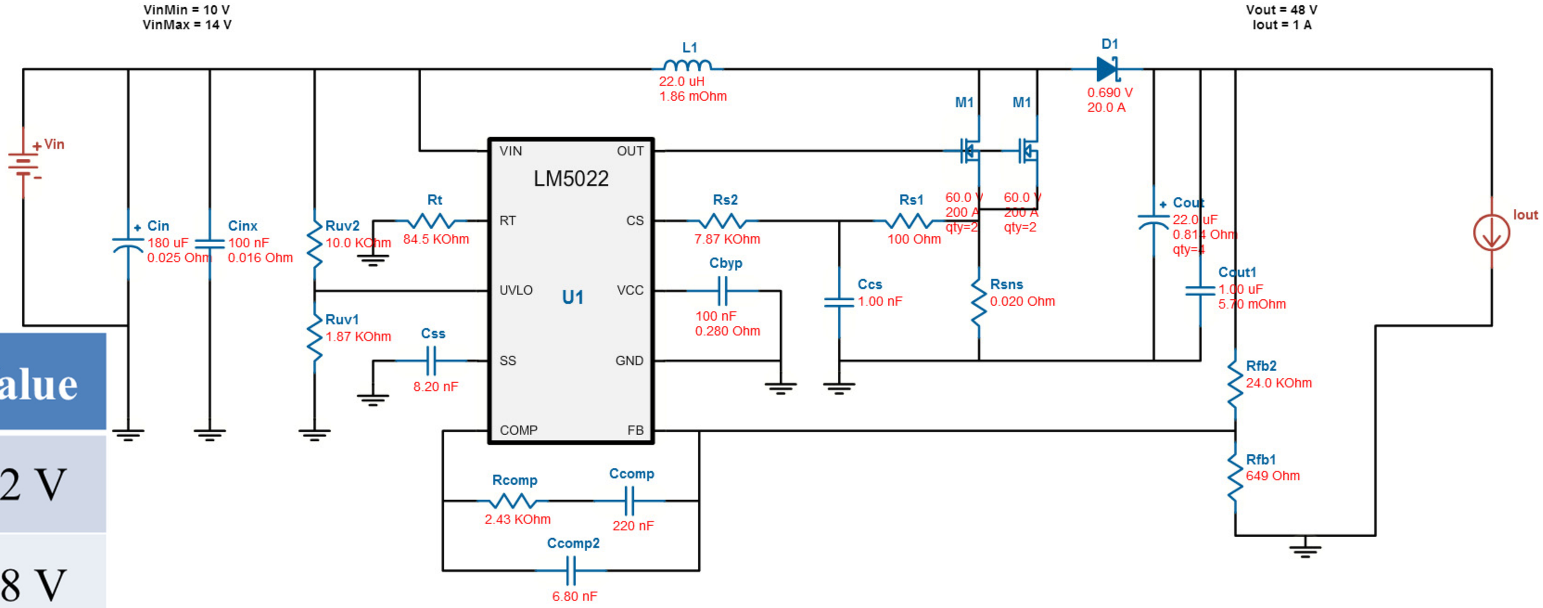
Motivating Example



NXP Semi, “Semiconductors – enablers of future mobility concepts”, 2011
Audi, “Electric biturbo and hybridization”, 2014
AVL, “48V Mild Hybrid Systems”

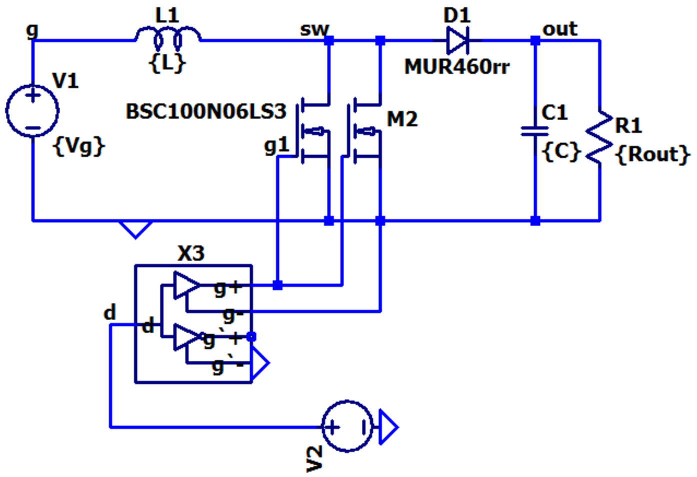
Baseline Design

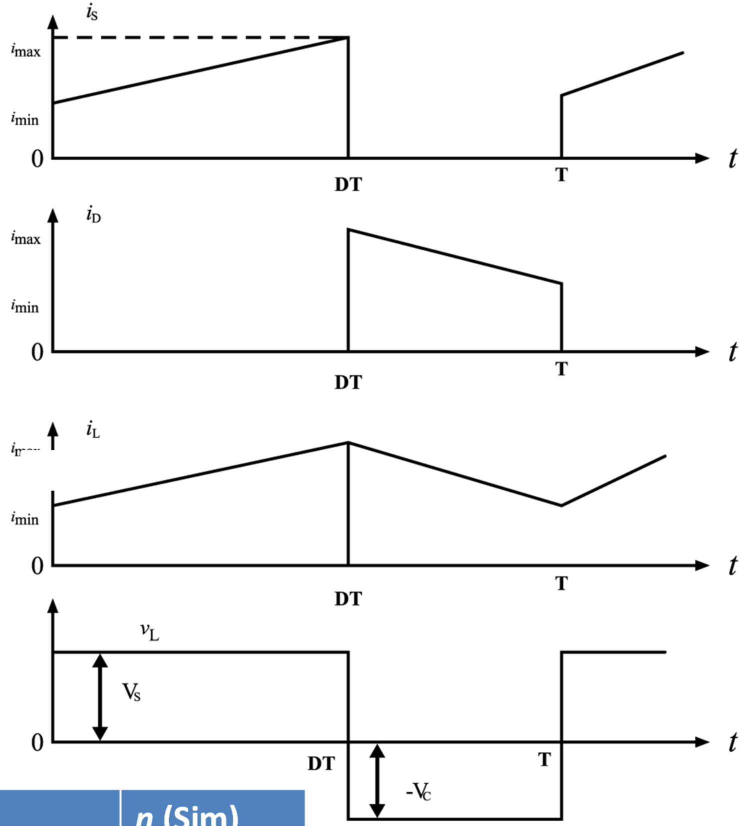
- Use TI WebBench (webench.ti.com) to get a baseline design



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

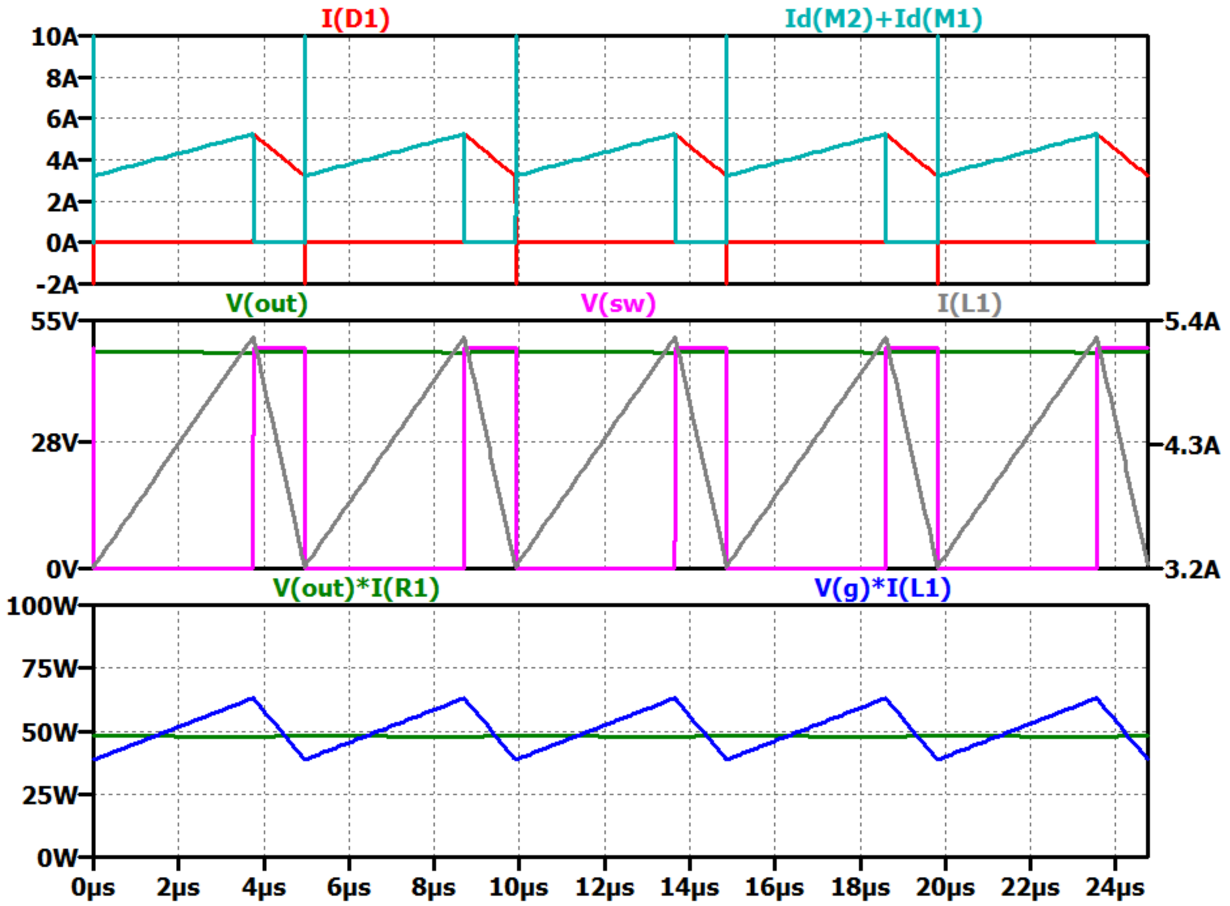
LTSpice Simulation



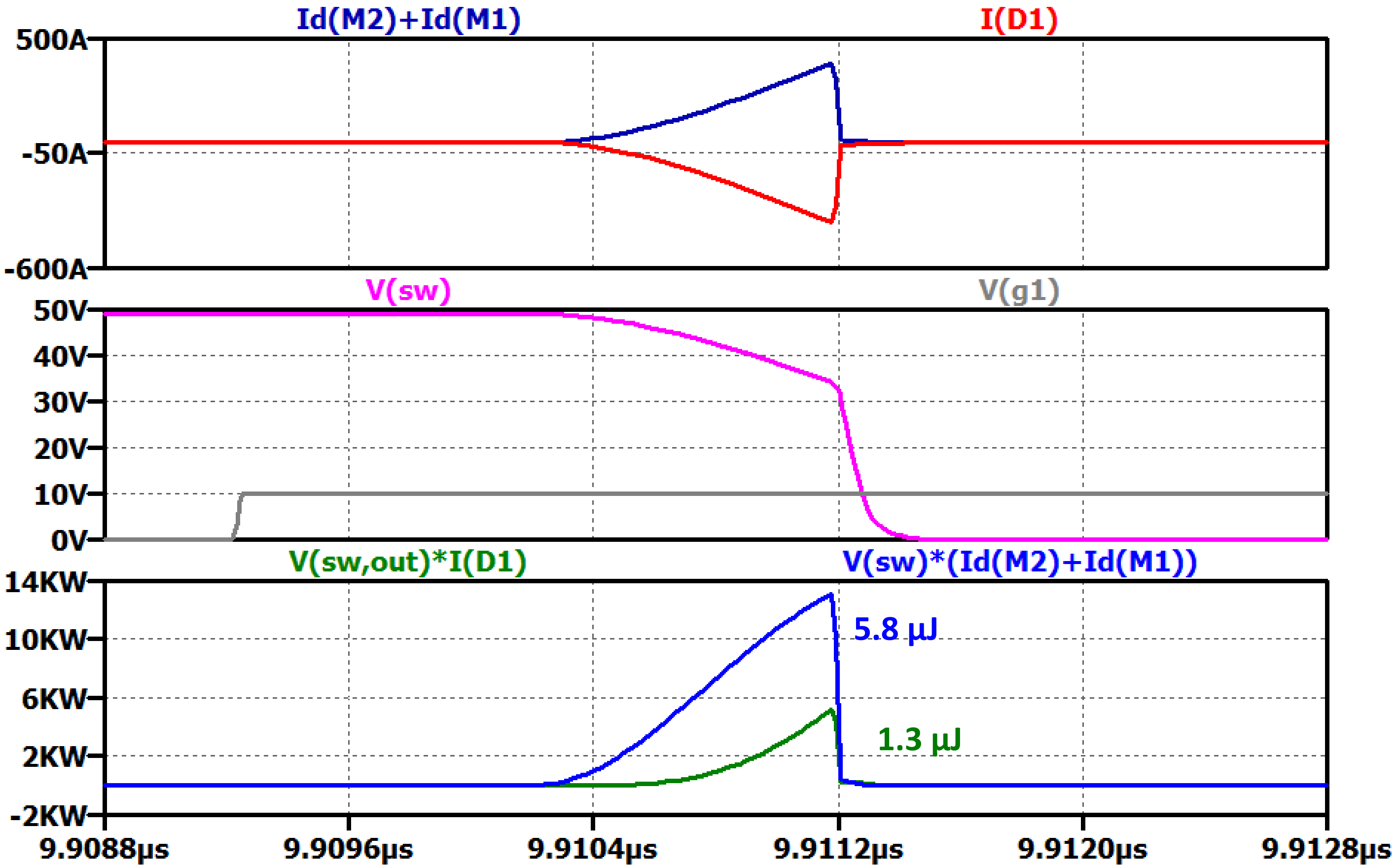


L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%

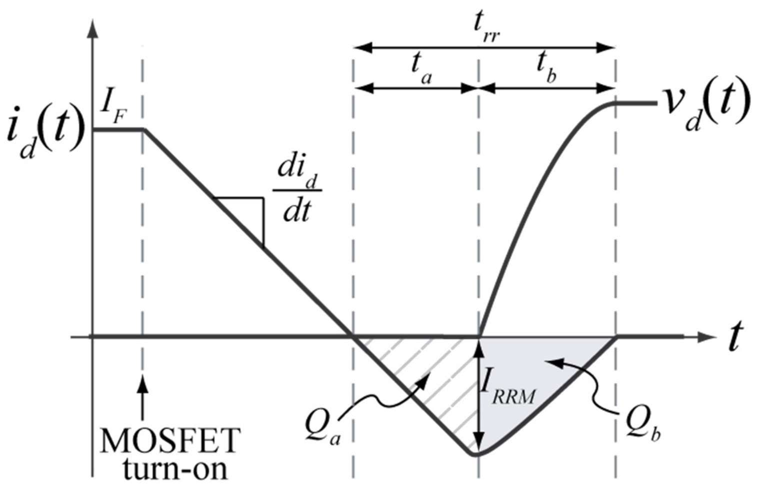
LTSpice Simulation

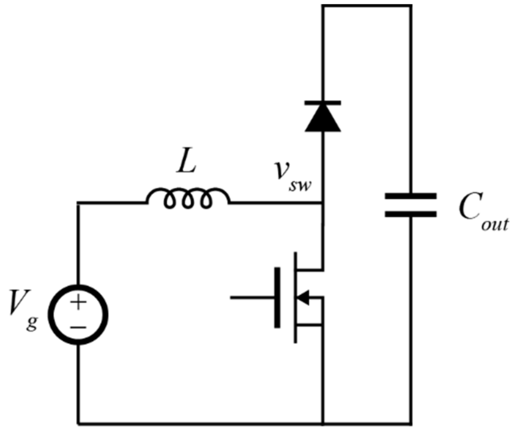


Switching Transition



Diode Reverse Recovery





Datasheet RR Characteristics

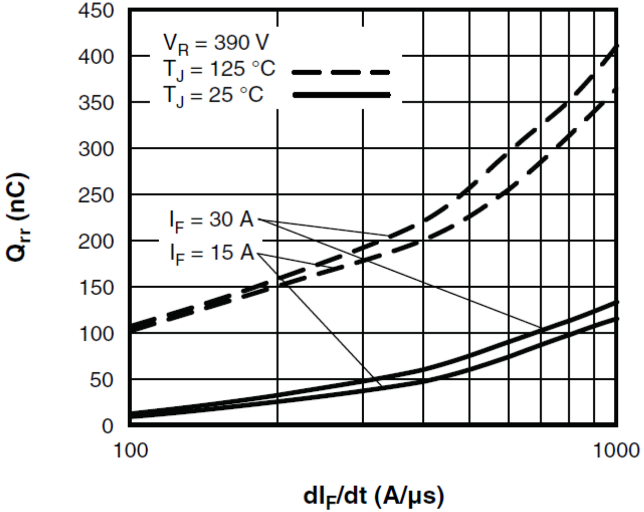


Fig. 10 - Typical Stored Charge vs. dI_F/dt

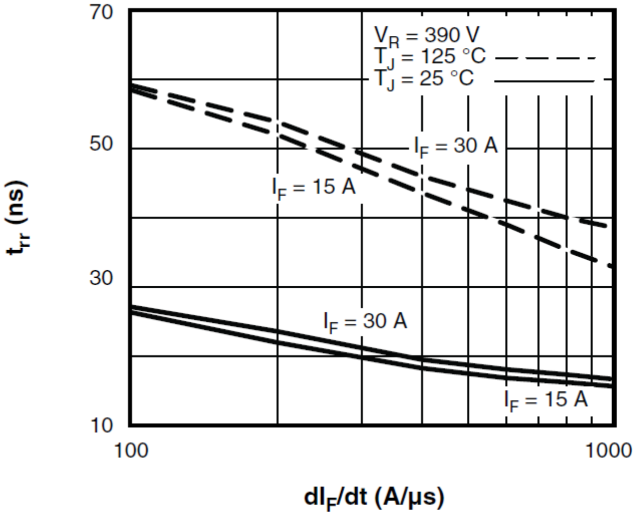
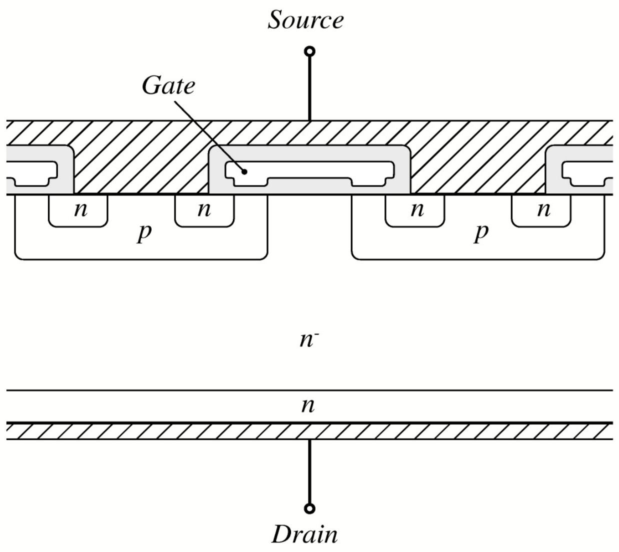
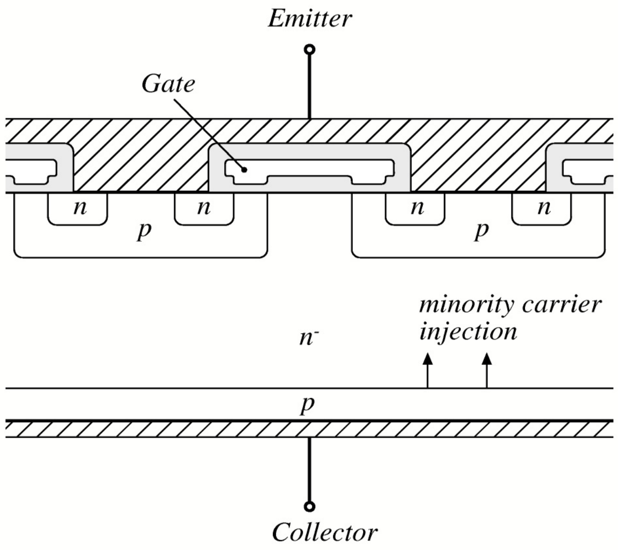


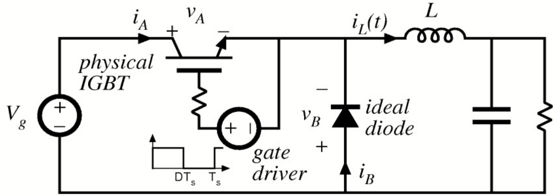
Fig. 9 - Typical Reverse Recovery Time vs. dI_F/dt

Charge Storage



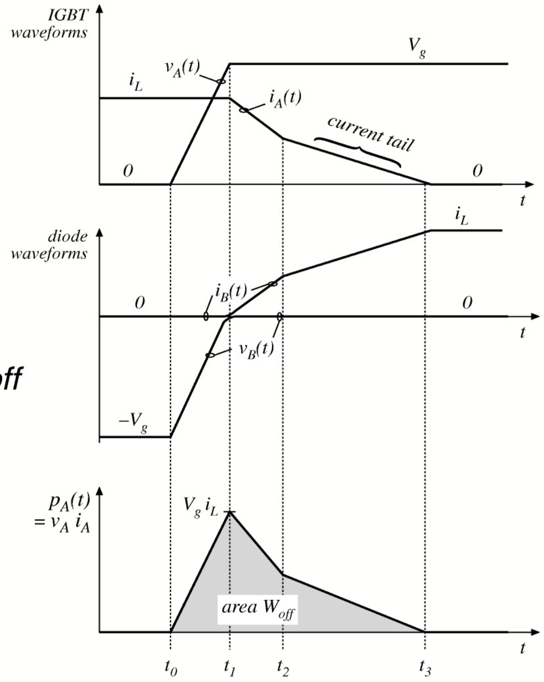


IGBT Current Tailing



Example: buck converter with IGBT

transistor turn-off transition



$$P_{sw} = \frac{1}{T_s} \int_{\substack{\text{switching}\\\text{transitions}}} p_A(t)\, dt = (W_{on} + W_{off})\, f_s$$