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
- OH: T: 11-12, W:9-10, 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 10:10-11:00 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
    - One design competition outside of class time
  - 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
- 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
- All work to be turned in through canvas

Textbook and Materials

- The textbook

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

  will reference 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

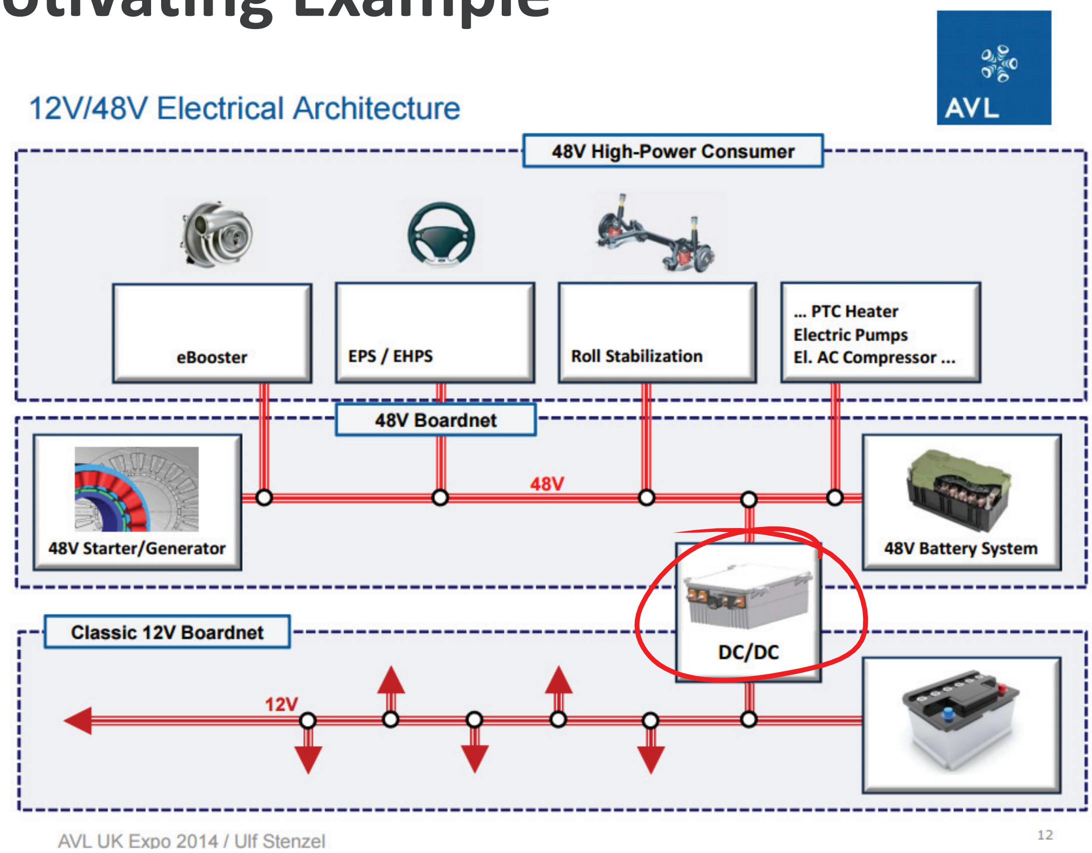
Introduction

- Why high frequency?
  - Power Density
  - Control Bandwidth
- Techniques
  - Devices
  - Control/Modulation
  - Topologies
  - Passives → briefly discuss

8 w Dimmable LED Driver

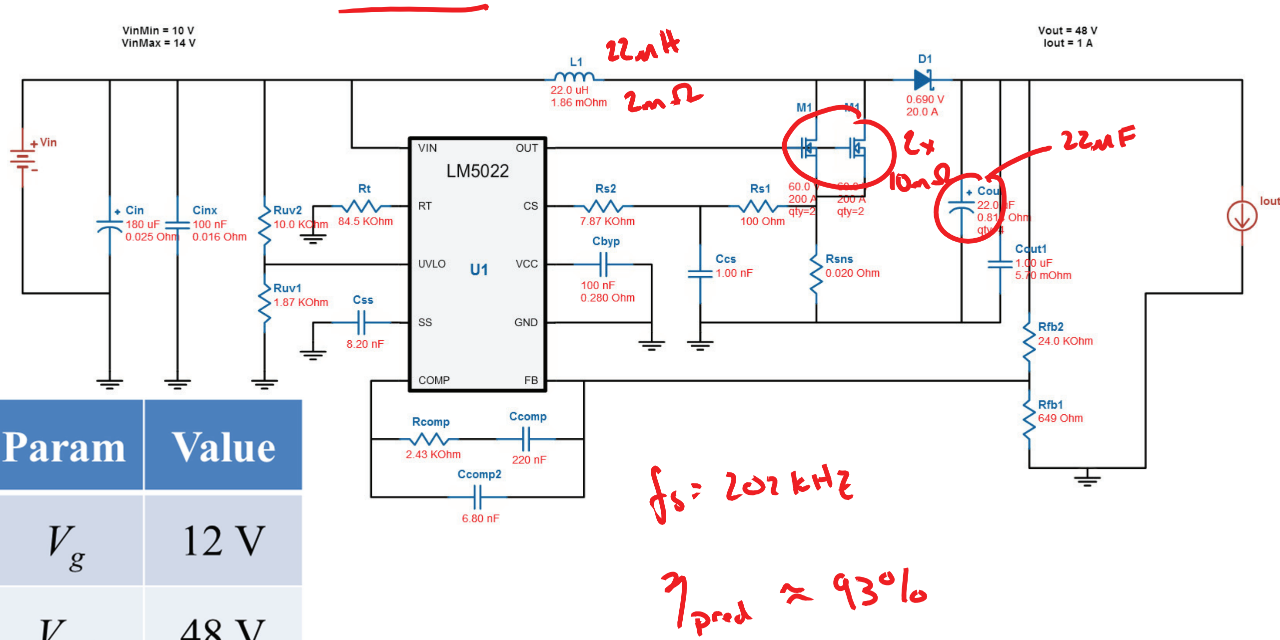
Voltage Regulation Module

Motivating Example



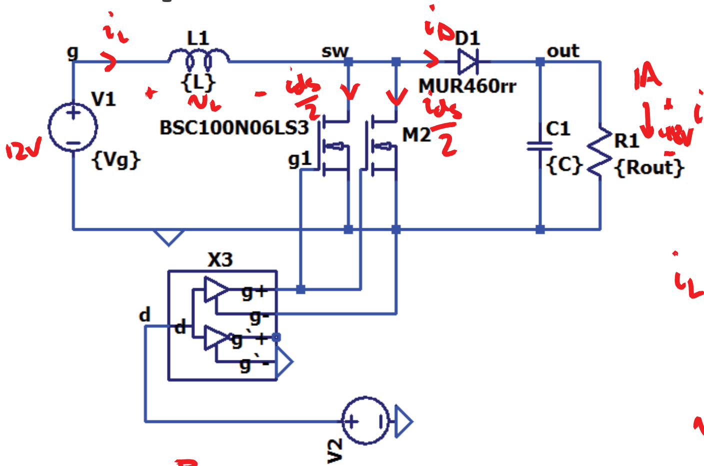
Baseline Design

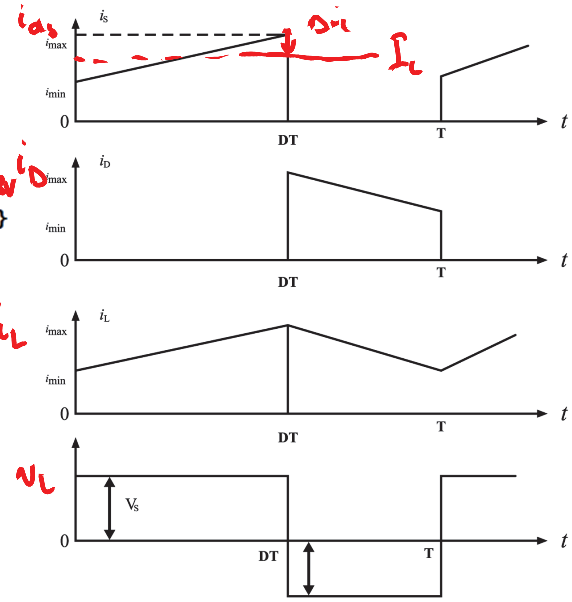
- Use TI WebBench (webench.ti.com) to get a baseline design



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

LTSpice Simulation



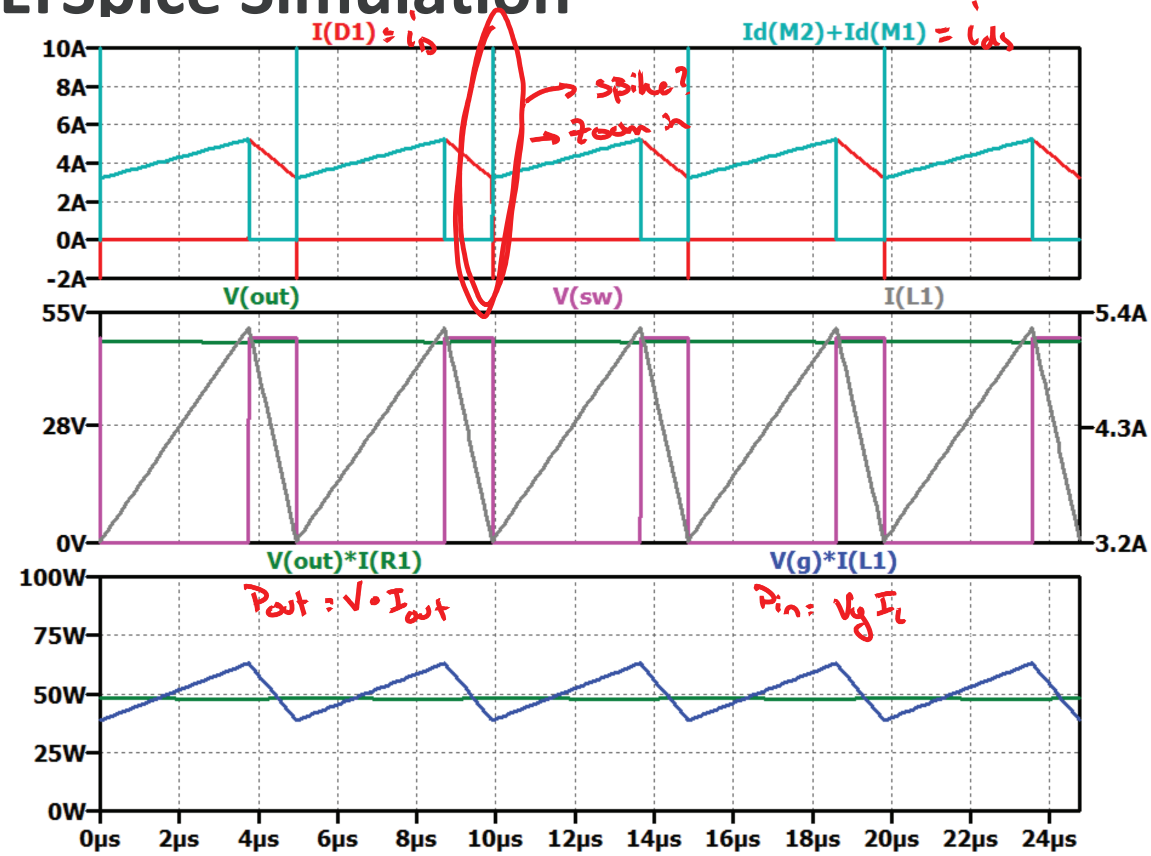


$I_L = \frac{P}{V_g} = 4A$

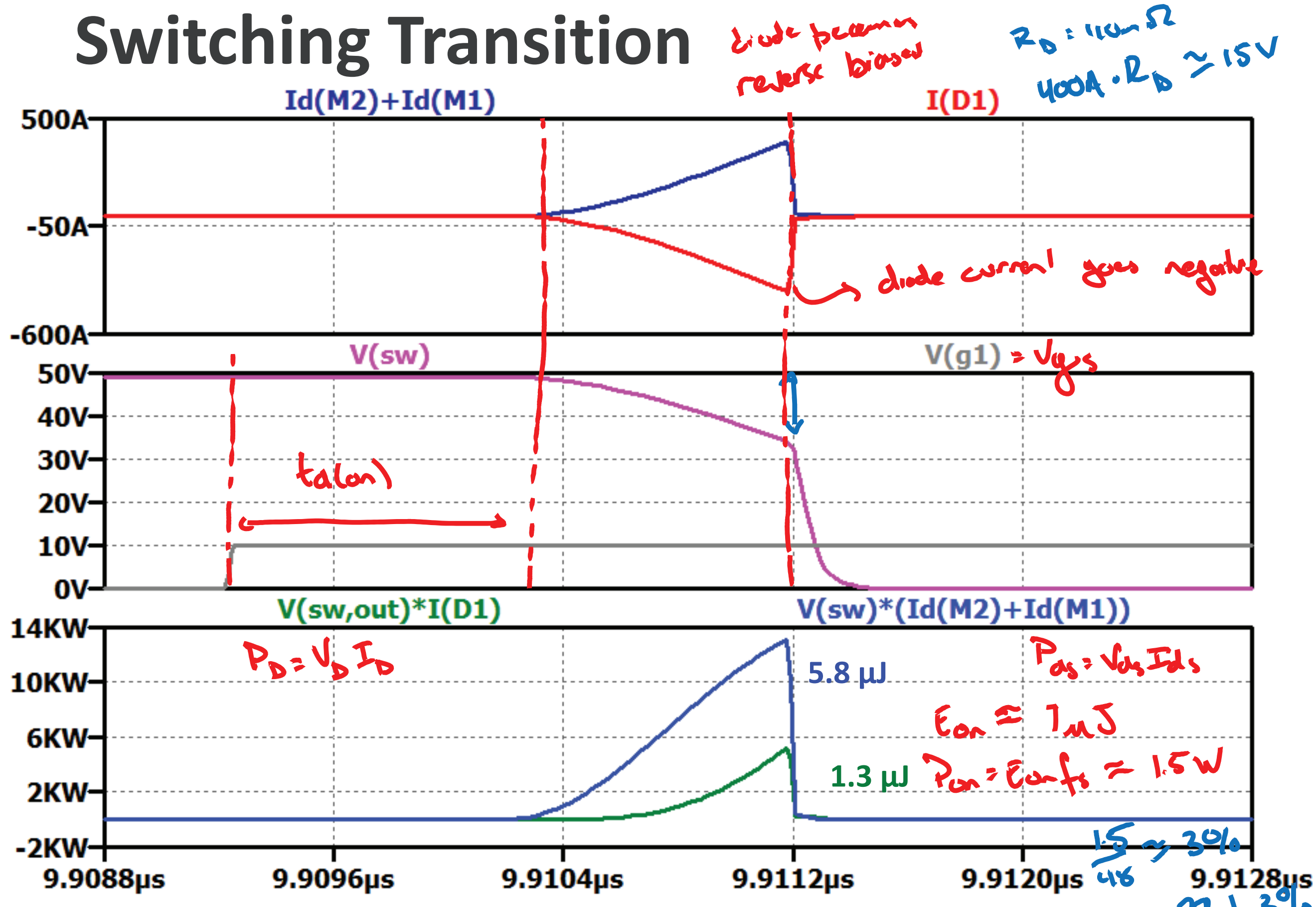
$2\Delta i_L = \frac{V_g}{L} DT_s = 4A$

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

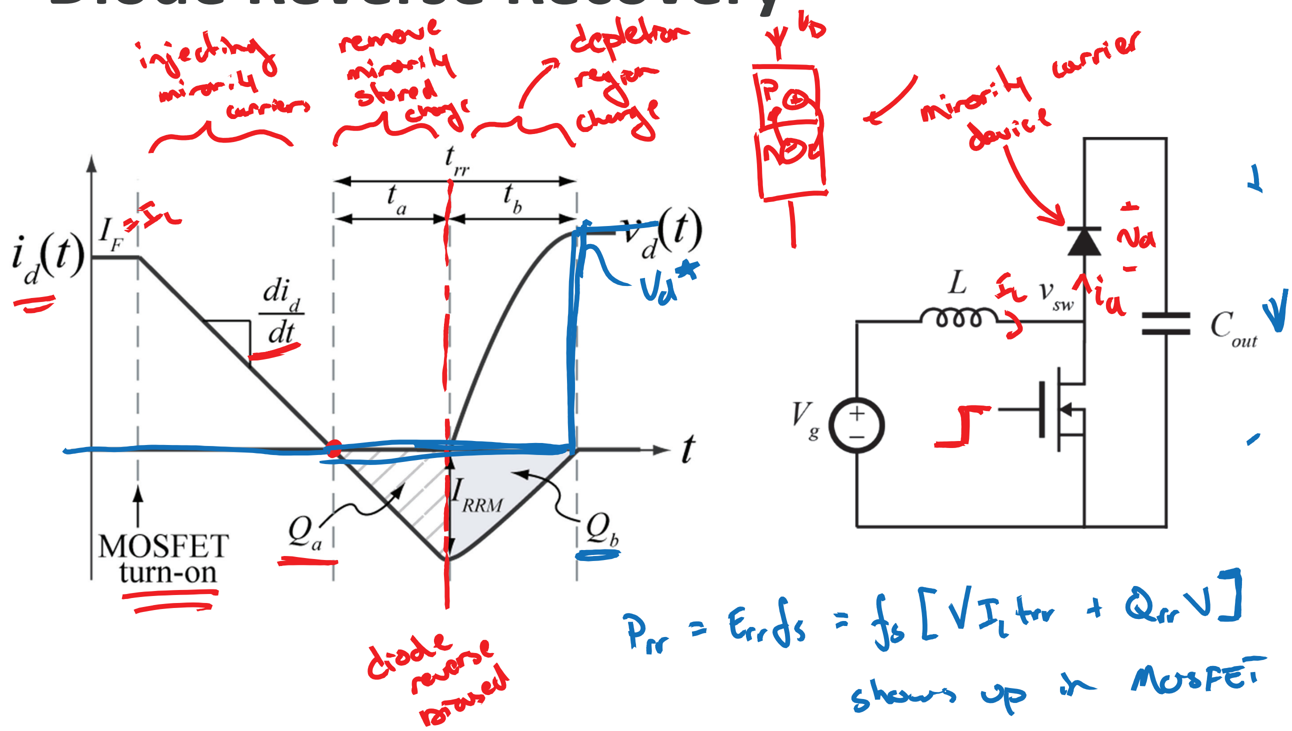
LTSpice Simulation



Switching Transition



Diode Reverse Recovery



$P_{rr} = E_{rr} f_s = f_s [V I_L t_{rr} + Q_{rr} V]$

shows up in MOSFET

$Q_{rr} = Q_a + Q_b$

Datasheet RR Characteristics

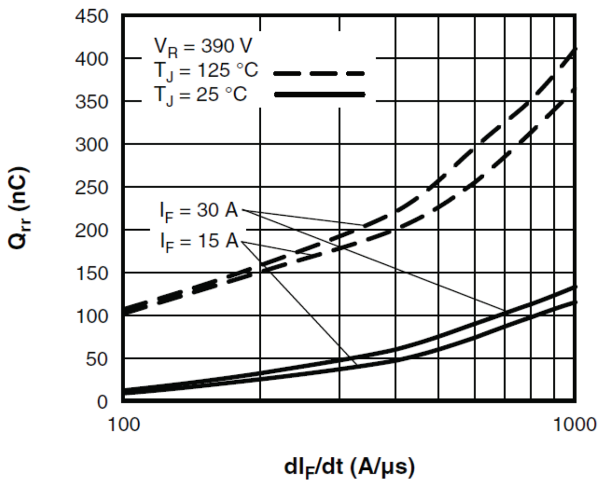


Fig. 10 - Typical Stored Charge vs. dI_F/dt

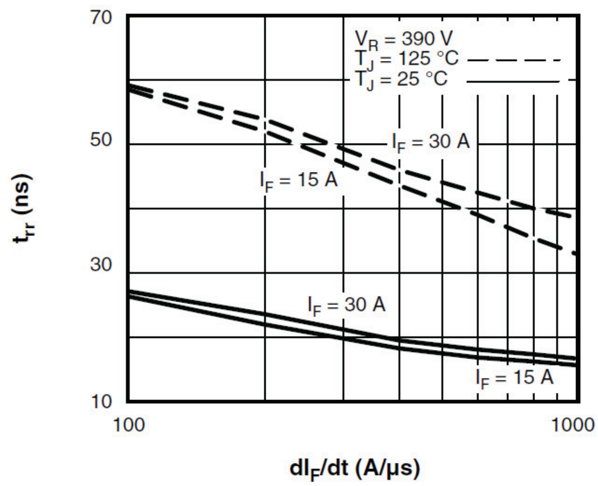


Fig. 9 - Typical Reverse Recovery Time vs. dI_F/dt

$$Q_{rr}, t_{rr} = f(I_F, \frac{di_F}{dt}, T, \ldots)$$

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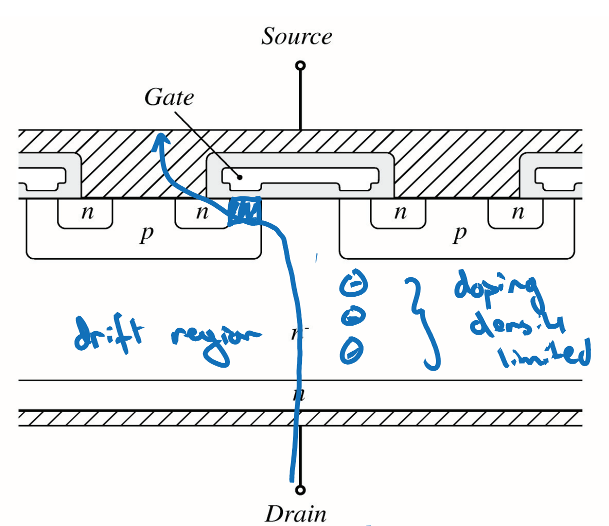
Charge Storage

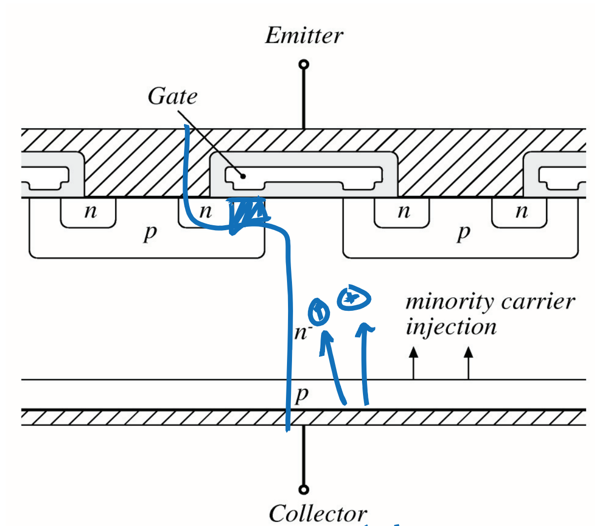
MOSFET

majority carrier

IGBT

minority carrier





+ Low stored charge
= R_{on} limited by doping

+ conductivity modulation (low R @ high currents)
- Removing minority charge @ shutoff

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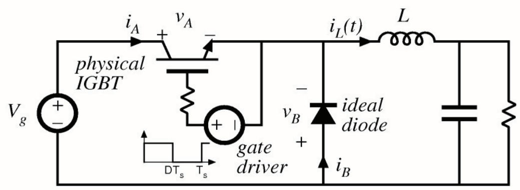
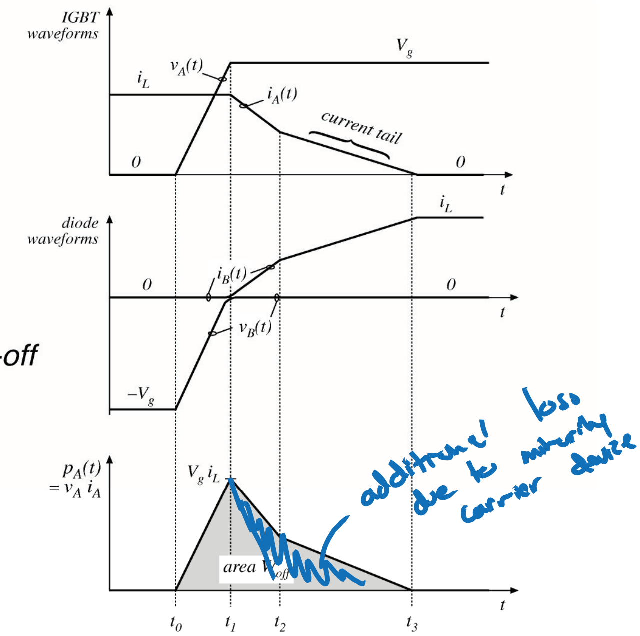
IGBT Current Tailing



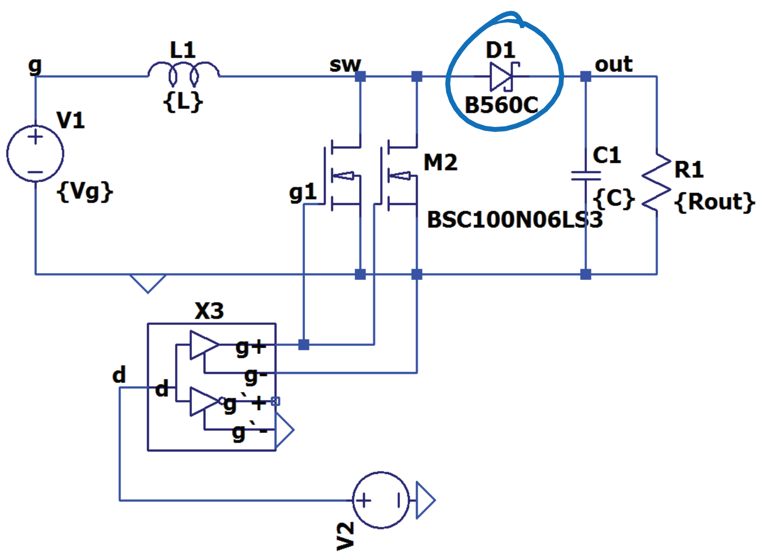
Example: buck converter with IGBT

transistor turn-off transition



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

Schottky Diode



L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%
22uH	22uF	202k	Si Schottky	95.8%

only 2% increase!