

High Frequency Power Electronics

Prof. Daniel Costinett

ECE 581 Lecture 1

August 18, 2025



Course Info

- Course focuses on design and 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 9:10-10:00 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
 - Homework 1 posted, due Aug 29th
 - Midterm: 25%
 - Tentatively scheduled for early-mid October
 - 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/231925>
- No late work will be accepted except in cases of documented medical emergencies
- 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
 - Fall '23 – 48-to-1.2V, 12W
- Specs and details TBD
 - Usually ~October-November
 - Usually in groups of 2

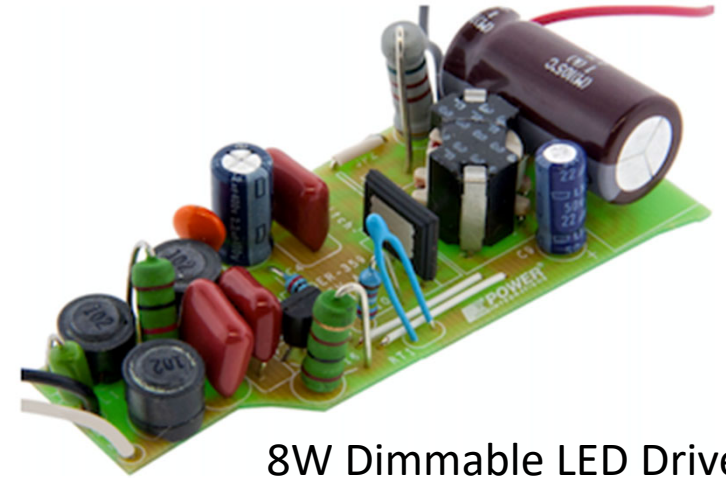
Course Topics

- High Frequency Power Conversion
 - Switching losses and device selection
 - Nonlinear device capacitances
 - Resonance in power electronics
 - Soft switching (ZVS and ZCS)
- Resonant Converters
 - State-plane analysis
 - Resonant converter topologies
 - Sinusoidal analysis
 - AC-modeling and frequency modulation
- Non-resonant soft switching converters
 - State-plane analysis
 - Constant frequency control
 - Resonant switches
 - Modeling and Simulation
 - Discrete time models
- Switched capacitor converters
 - SSL and FSL operation
 - Charge vector modeling
 - Soft-charging operation
- Applications and practical issues of high frequency converters

COURSE INTRODUCTION

Introduction

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



8W Dimmable LED Driver

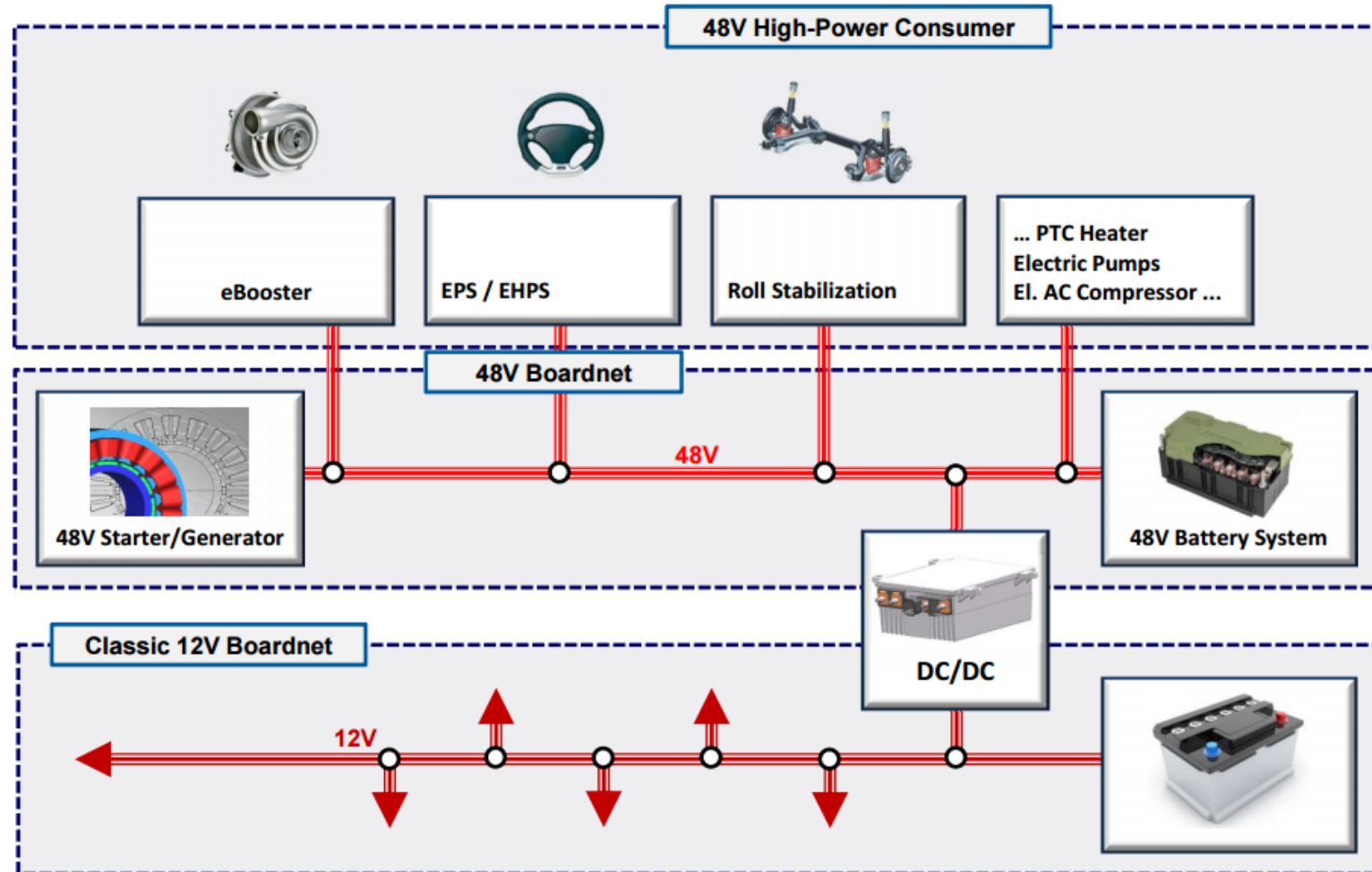


Voltage Regulation Module

Motivating Example



12V/48V Electrical Architecture

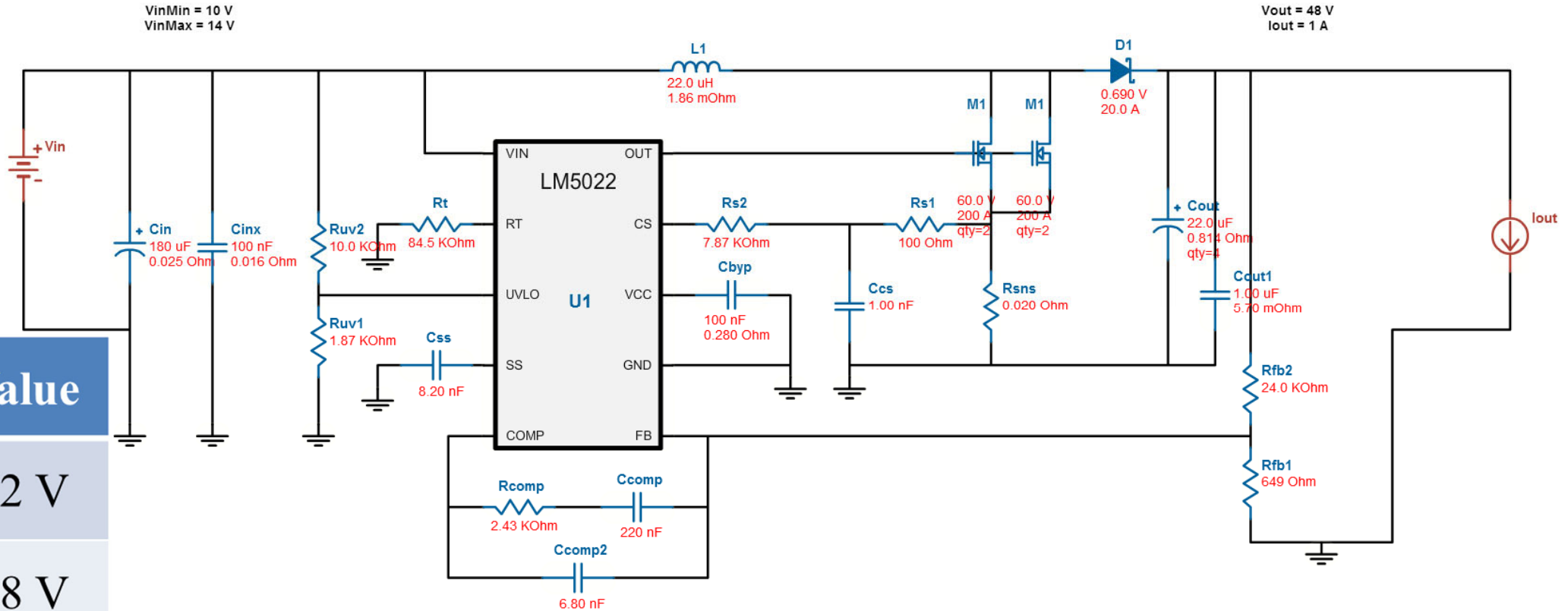


AVL UK Expo 2014 / Ulf Stenzel

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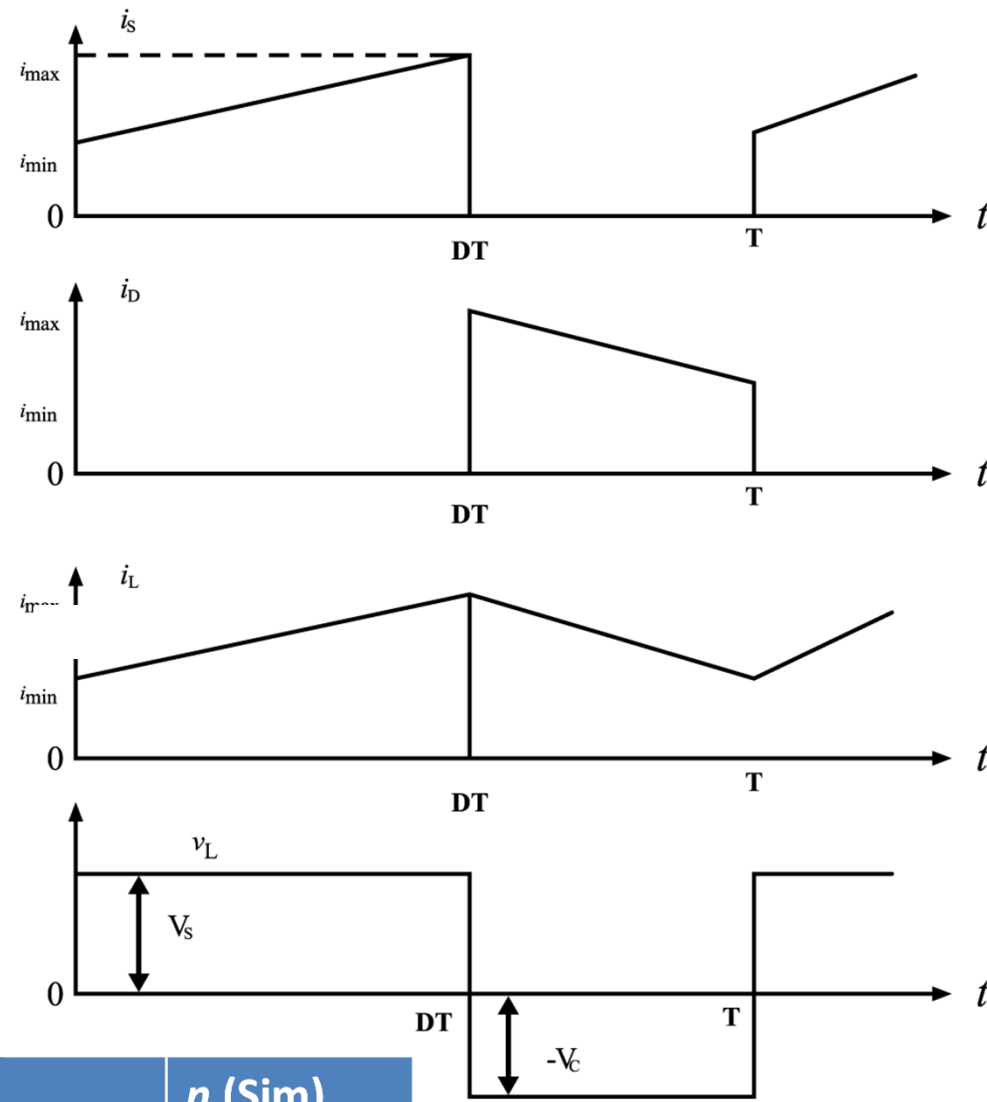
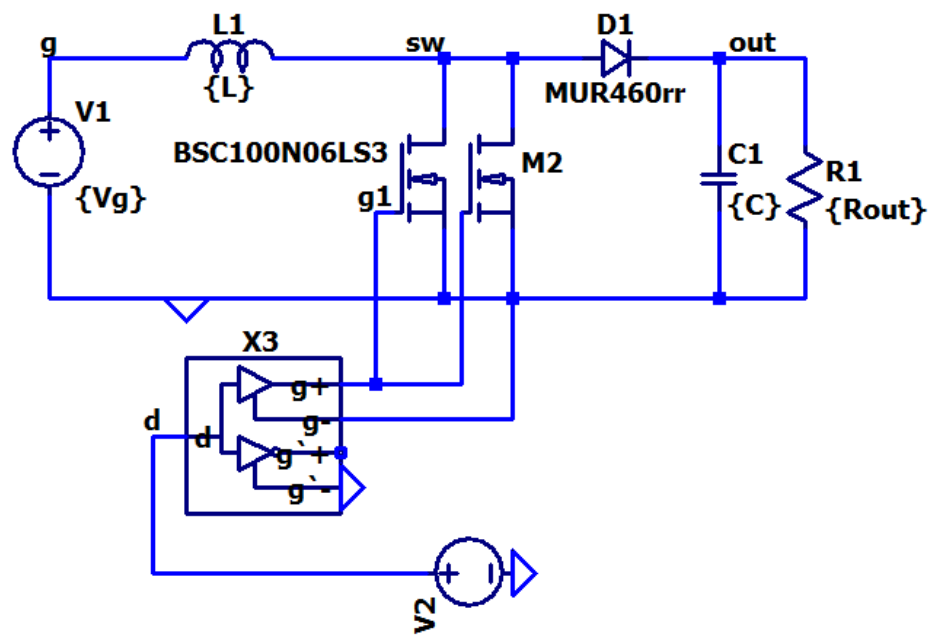
Baseline Design

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



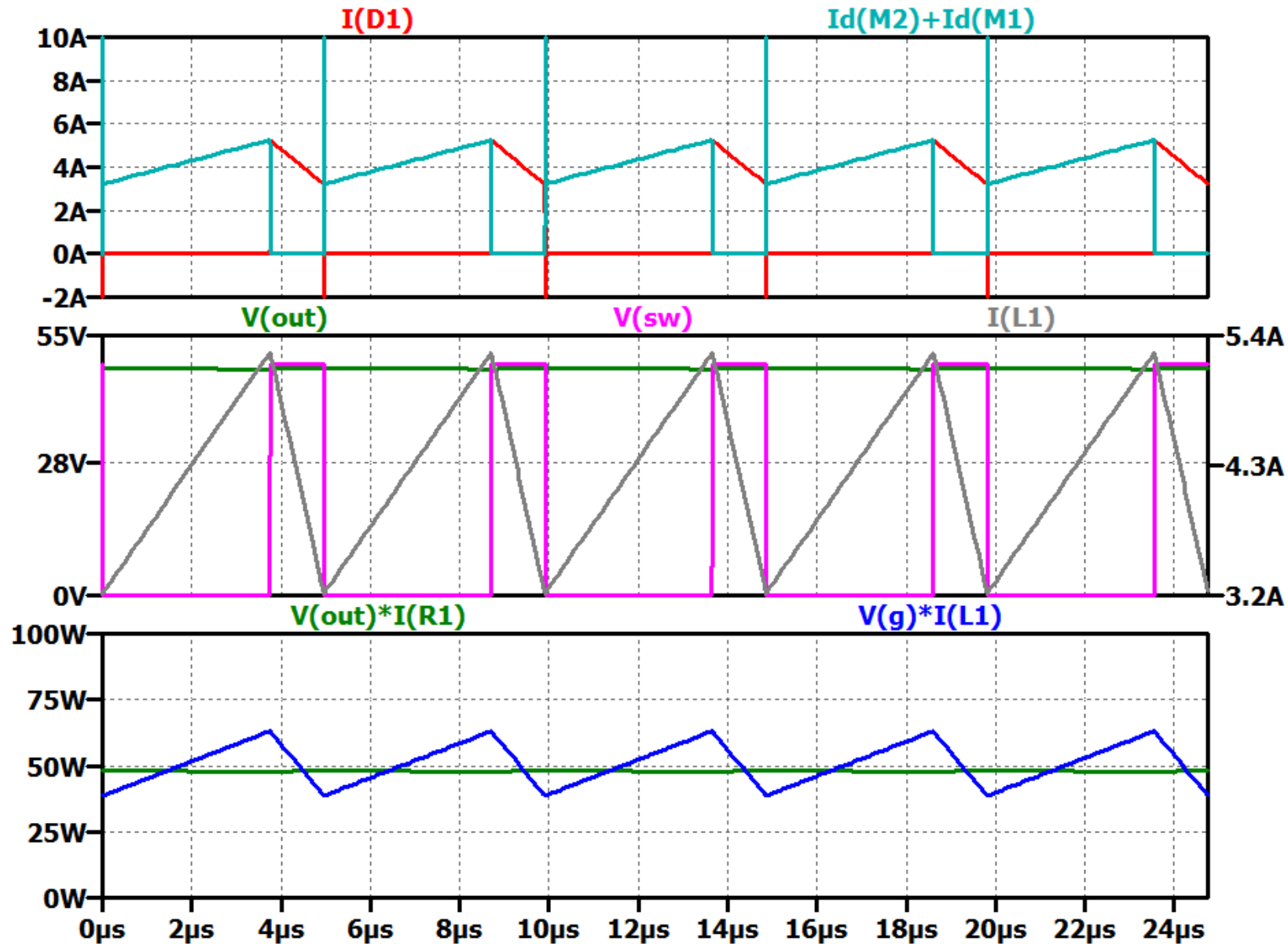
Param	Value
V_g	12 V
V_{out}	48 V
R_{out}	48 Ω
ΔV_{out}	0.1 V

LTSpice Simulation

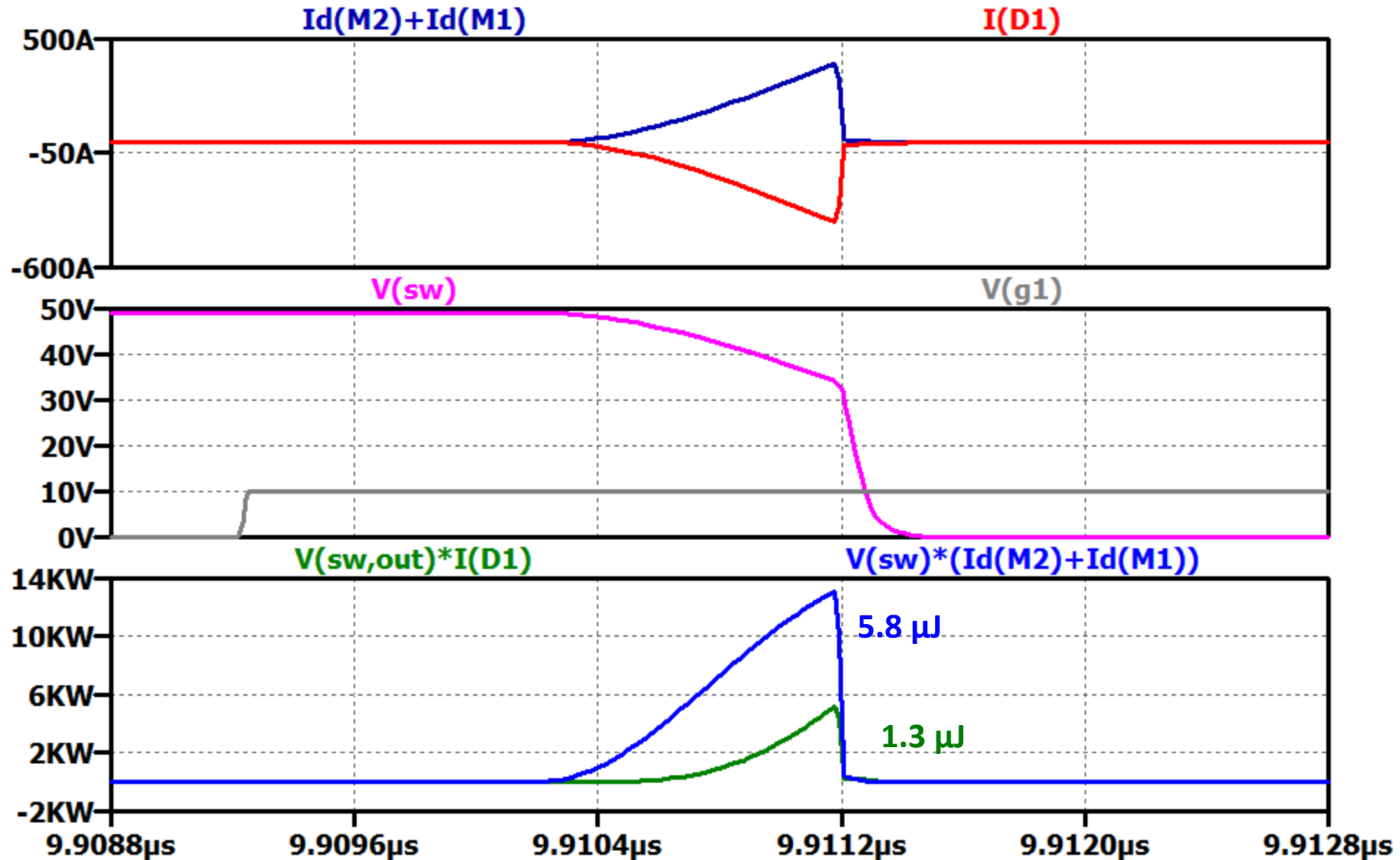


L	C_{out}	f_s	Diode	η (Sim)
22uH	22uF	202k	Si (FR)	93.9%

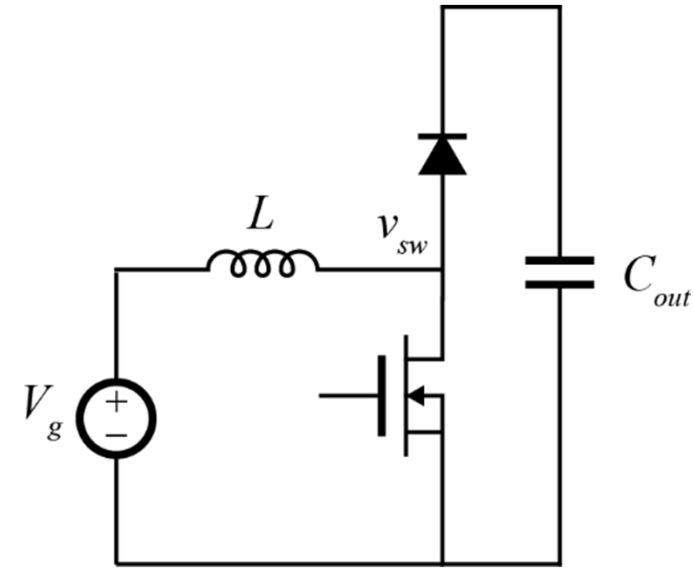
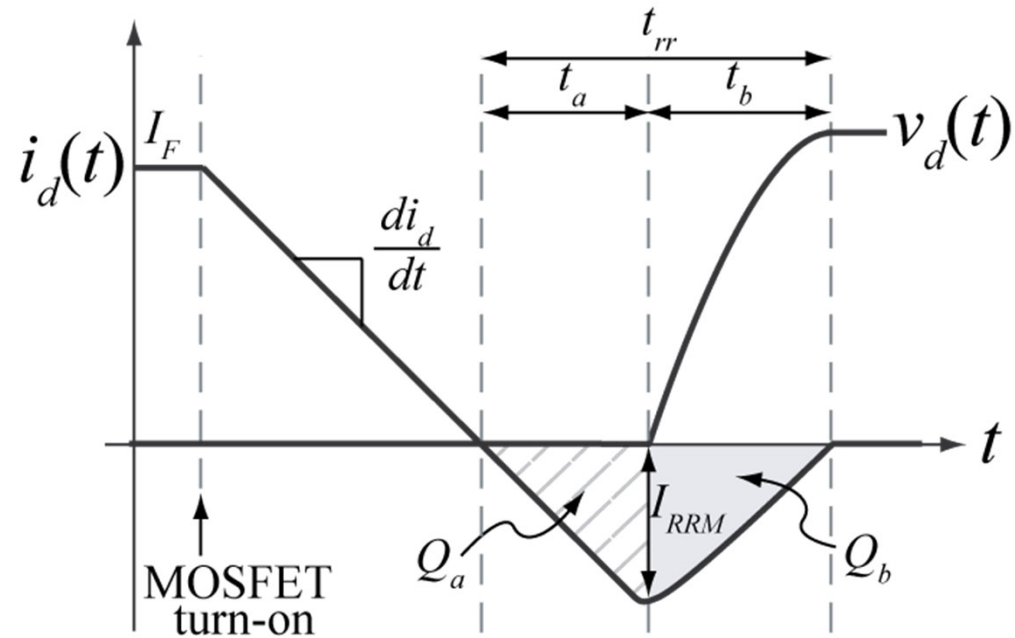
LTSpice Simulation



Switching Transition



Diode Reverse Recovery



Datasheet RR Characteristics

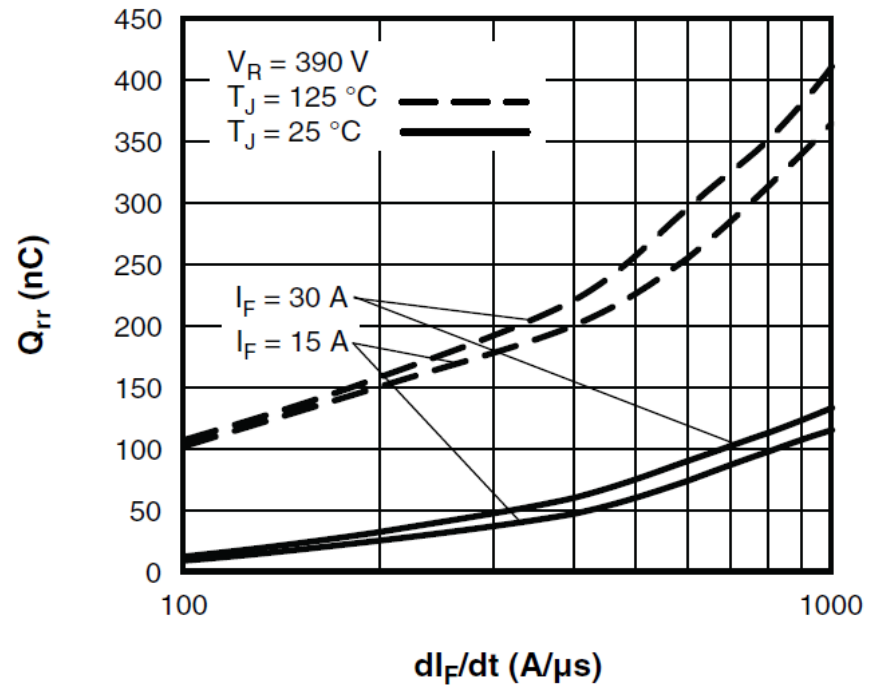


Fig. 10 - Typical Stored Charge vs. di_F/dt

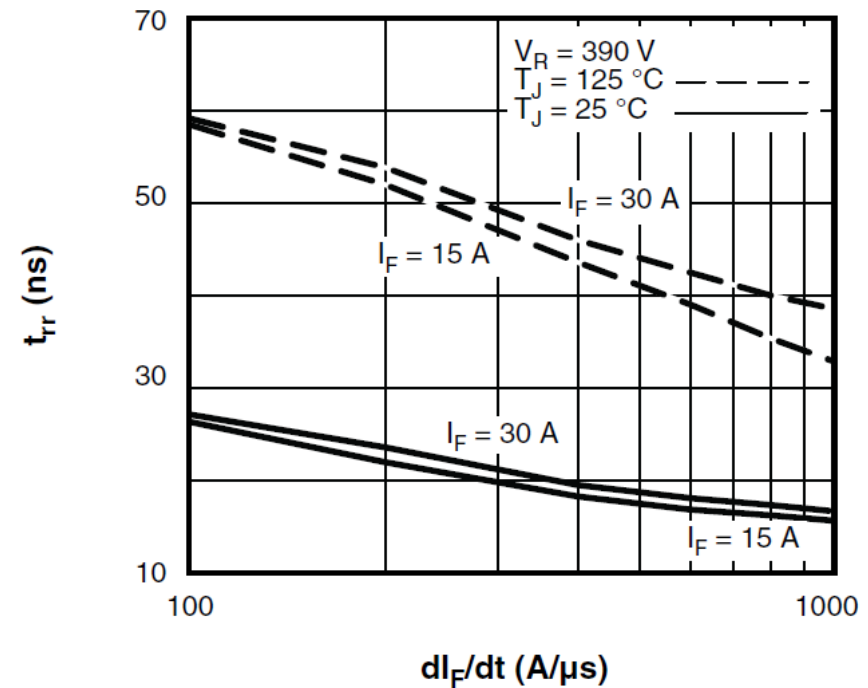
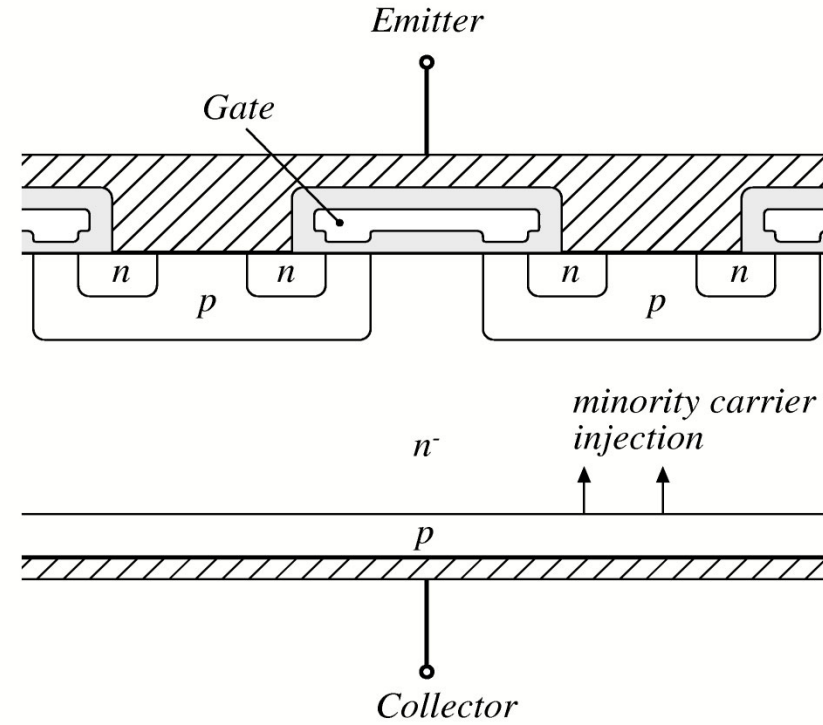
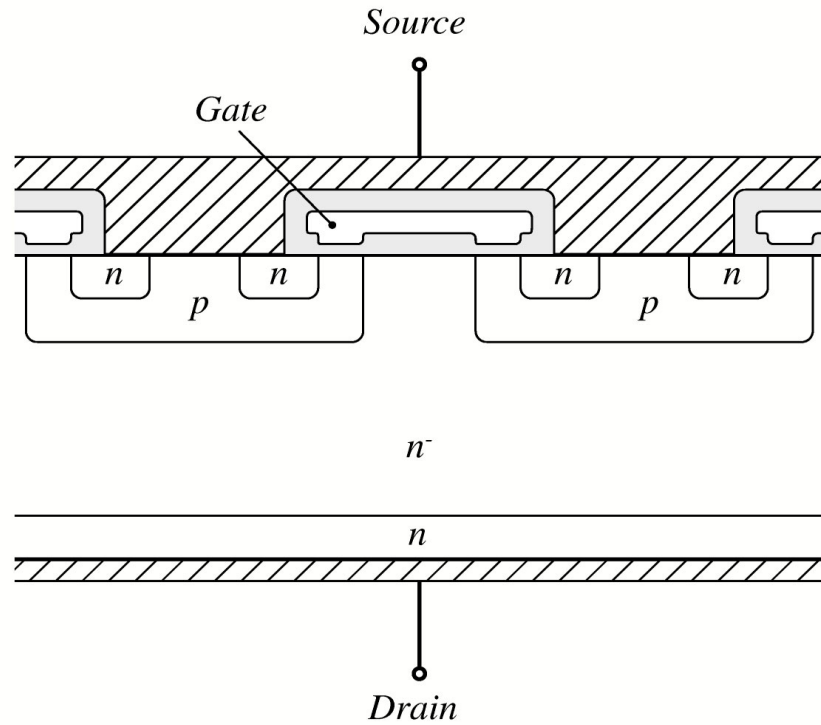
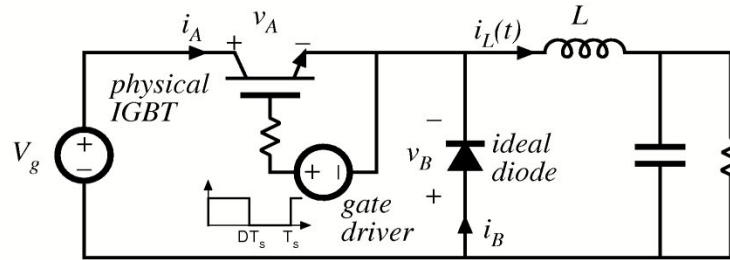


Fig. 9 - Typical Reverse Recovery Time vs. di_F/dt

Charge Storage



IGBT Current Tailing



Example: buck converter with IGBT

transistor turn-off
transition

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

