Course Introduction

• Hands-on course in design and implementation of power converters
  • http://web.eecs.utk.edu/~dcostine/ECE482

• Course uses electric bicycle platform as framework for the investigation of practical issues in SMPS construction

• Unlike ECE 481, this is not a theory-focused course; expect to spend most of your effort on construction/debugging

• Goal of course is practical experience in designing, building, testing, and debugging power electronics

• System, components, architectures can be modified based on student initiative

• Course is difficult; will require design effort and significant hands-on time outside of class. Expect to experience circuit failures.

• Prerequisites: undergraduate circuits sequence, Microelectronics, ECE 481 – Power Electronics
Course Structure

• Scheduled for two 3-hr lab sessions per week
• Theory is presented as necessary for practical design
• Additional theory may be presented in brief sessions during lab time
• Plan to spend 9-12 hours per week on course; *mostly* lab time
Contact Information

• **Instructor:** Daniel Costinett
  • Office: MK504
  • OH: in-lab, individually scheduled
  • E-mail: Daniel.Costinett@utk.edu
  • Email questions will be answered within 24 hours (excluding weekends)
  • Please use [ECE 482] in the subject line
Textbook and materials

- Portions of the Textbook
  R.Erickson, D.Maksimovic, *Fundamentals of Power Electronics*, Springer 2001 will be used. The textbook is available on-line from campus network
- MATLAB/Simulink, LTSpice, Altium Designer; All installed in MK225 and available on remote servers
- Lecture slides and notes, additional course materials, prelabs, experiments, etc. posted on the course website
- Lab kit is required (purchased from circuits store) in ~1-2 weeks
  - Price: $150-200 per group
  - Additional resistors and capacitors, etc. purchased as needed
  - Need to buy any replacement parts
Grading

**Group**
- Lab Reports
  - 50% of total grade
  - Turn in one per group

**Individual**
- Pre-Lab Assignments
  - 15% of total grade
  - Turn in one per individual

- In-lab Demo and Participation
  - 20% of total grade
  - Questions asked to each group member

- Midterm Exam
  - 15% of total grade
  - Open book/notes, take-home
  - Covers material from experiments

- Labs will be complete in groups of 2-3
  - Choose groups by *this Thursday*
- Late work will not be accepted except in cases of documented emergencies
- Due dates posted on website course schedule
- All assignments turned in via Canvas
Lab Reports

• Report Guidelines document available with Experiment 1
• Grade dominantly based on functionality and completion
  – Make sure to review procedure
    ▪ Include all requested measurements
    ▪ Respond to any questions or prompts
    ▪ Justify all claims with measurements
Design Expo

• No final exam
• Demo operational electric bicycles
• Competition to determine the most efficient and robust system
Lectures

• In past, 5-7x 3-hour lectures
• New trial last semester:
  – Using all recorded lectures
  – Watch prior to the associated lab/prelab
  – Discuss during lab sessions
  – Can add additional lectures if needed
Lab Groups

- Self-assign in Canvas prior to next class
  - People → Groups (tab)
  - Groups of 2-3 (5 students)
  - Do not need to stay in same section 482/582
  - Select one person to obtain key for lab access
    - Should be graduate student, is possible
Key Requests

https://www.eecs.utk.edu/resources/

- Fill out as soon as group selected
- Lab doors remain locked
Use of Lab Time

• Attendance is required during all lectures and scheduled lab time
  – Make use of designated time with Instructor present
  – Informal Q&A and end-of-experiment demonstrations

• Work efficiently but do not work independently
  – Understand all aspects of design

• Outside of normal lab hours, key access will be granted (one per group)
Topics Covered

Course Topics
• Battery Modeling
• Modeling and Characterization of AC Machines
• DC/DC Converter Analysis and Design
• Loss Modeling of Power Electronics
• Basic Magnetics and Transformers
• Debugging and prototyping techniques
• Current-mode Control
• Feedback Loop Design
• Layout of Power Electronics Circuits
• BLDC and PMSM Control Methods
• System-Level Control Design
Electric Bicycle Platform

- Battery
- Power Conversion and Control
- Electric Motor
Electrical Build Space
System Structure

Battery

BMS

Boost DC-DC Converter

PWM Controller

3-φ PWM Controller

3-φ Inverter / Driver

Motor

Filtering and Control

Throttle

$D$, $V_{out}$

$g_{1-6}$, $I_{abc}$

$\theta_{abc}$

$V_{ref}$

$f_{ref}$
Experiment 1

- Identification and characterization of motor
- Modeling of motor using simulink
- Derivation of model parameters from experimental data
Experiment 2

- Microcontroller programming
- Basic motor modulation
Experiment 3

- Open-loop operation of Boost converter
- Inductor design
- Converter construction and efficiency analysis
- Bidirectional operation using voltage source / resistive load
Experiment 4

- Closed loop operation of boost converter
- Feedback loop design and stability analysis
- Analog control of PWM converters
Experiment 5

- Circuit layout and PCB design
- Device selection and implementation according to loss analysis
- Basic control of BLDC motors
Experiment 6

- System-level control techniques
Experiment 7

- System improvements
Example System Implementation

Experiment 3

Experiment 1

Experiment 4

Experiment 2

Experiment 5 & 7

Experiment 6
Electric Bicycle Safety and Law

• Traffic Law:
  • Electric motor with power output not more than 1000 W
  • Not capable of propelling or assisting at greater than 20 mph
• No helmet laws for riders over age 16; you may request one at any time
• Read Tennessee bicycle safety laws on website
General Safety

- Lab will work with high voltages (Up to ~75 V)
- Will use various machinery with high power moving parts
- High temperatures for soldering
- Use caution at all times
- You may not work with electrical power alone in the lab
- No food or drink allowed in the lab
Safety training Requirements

• Login to canvas at https://utk.instructure.com/courses/29416/modules
• Complete training modules
  - General Lab Safety
  - Hazardous Waste
  - Hazard Communication Training and GHS Updates
  - Fire Extinguisher Training
  - Fire Safety in Laboratories
  - Chemical Fume Hood Safety Training
  - Compressed Gas Cylinder Training
  - Laboratory Safety for Undergraduates and Minors (required only if UG or minor)
  - Personal Protective Equipment
  - Electrical Safety, Orientation Level
  - Lead Awareness Training
• Once all training is completed print your “Completed” Transcript and turn it in to Dr. Costinett by e-mail
• Must complete with passing scores before Thursday 1/18
Lab 1
Model D: Diffusion (one-state) [Plett 2004]
3-Phase, P-Pole PMSM

\[ P = 4 \text{ example} \]

Electrical and mechanical angle

\[ \theta_r = \frac{P}{2} \theta_{rm} \]

Electrical and mechanical speed

\[ \omega_r = \frac{P}{2} \omega_{rm} \]

Max torque per amp

\[ T_m \leq \lambda_m \frac{P}{2} \frac{3}{2} I \]
Battery Modeling in Experiment 1

• Batteries have Battery Management System (BMS)
  − Limit over-current, over-discharge
  − **Do not** connect directly to battery cell
• Never leave charging or discharging batteries unattended
• Not entirely analytical and solution may not be unique
  − Guess and check is fine, where appropriate
  − Not all parameters need to be included
• Insert batteries into BMS in correct polarity
  • Use voltmeter to be sure
  • BMS will cut off with sustained, large current (>~2A)
• After BMS cutoff, connect leads to charger to reset BMS
Motor Modeling in Experiment 1

- Should not apply any voltage to the motor windings or hall outputs
  - Solely measure induced voltage
  - Can power up hall sensors as detailed in lab
- Be careful not to short any wires while spinning the motor
Homework

• Watch experiment 1 recorded lectures
  – With required background ~30 min
• Complete Safety Training
• Select lab groups of 2-3
  – Submit key request (one per group)