

# The Power Electronics Program at the University of South Carolina

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# The University of South Carolina

- Founded in 1801
- Main campus in Columbia (capital city)
- 156 facilities on 351 acres
- 350 graduate and undergraduates programs



# The University of South Carolina

- Enrollments:
  - Undergraduate: 16,567
  - Master's: 5,813
  - Doctorate: 1,508
  - First-professional: 1,252



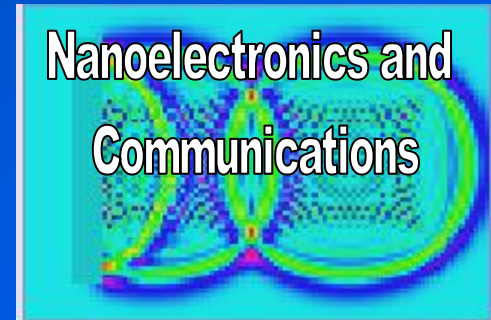
# ELECTRICAL ENGINEERING DEPARTMENT



*Dr. Asif Khan Prof, Chair*  
*Dr. T. Sudarshan Prof.*  
*Dr. G. Simin Assoc. Prof.*  
*Dr. G. Koley, Assist. Prof.*  
*Dr. Jixin Yu, Assist. Prof.*



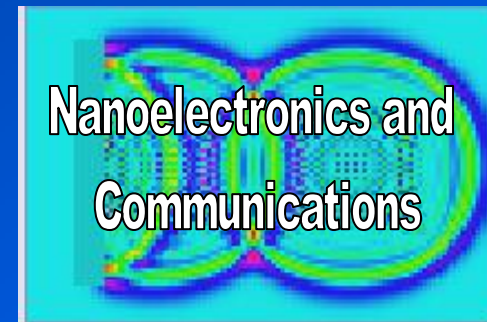
*Dr. R. Dougal Prof, Assoc. Chair*  
*Dr. R. Pettus Prof.*  
*Dr. J. Hudgins Prof.*  
*Dr. A. Monti Assoc. Prof.*  
*Dr. C. Brice Assoc. Prof.*  
*Dr. E. Santi Asst. Prof.*  
*Dr. F. Ponci Asst. Prof.*



*Dr. P. Huray Prof.*  
*Dr. Y. Chen Assoc. Prof.*  
*Dr. J. Seminario Assoc. Prof.*  
*Dr. M. Ali Asst. Prof.*



# ELECTRICAL ENGINEERING DEPARTMENT



## Faculty:

<i>Professors</i>	7
<i>Assoc. Professors</i>	7
<i>Assist. Professors</i>	4
<i>Research staff</i>	29
<i>Instructors</i>	3

## Students:

<i>Undergraduate</i>	130
<i>MS/ME</i>	54
<i>Ph.D.</i>	31

## Degrees:

*B.S. (43)*

*MS/ME (10)*

*Ph.D. (8)*



UNIVERSITY OF SOUTH CAROLINA

# Power Electronics Program at USC

- Faculty: 7
- Number of students:
  - 39 graduates students with assistantship
  - 6 undergraduates with assistantship
- Laboratory:
  - REM Laboratory
  - Power Electronics Laboratory



# Notable Honors

- IEEE Honorable Mention at 2003 Future Energy Challenge
- **Dr. Hudgins** - He co-authored 3 papers that have been chosen first-place winners twice, and second-place once by various technical committees within the IAS. The 1997 top transactions paper published in the *IEEE Transactions on Power Electronics* was one that Dr. Hudgins co-authored. In 1991, he received one of the IEEE Outstanding Student Branch Counselor awards given to the top ten counselors world-wide, and in 2000 was named as an IEEE Third Millennium Medal recipient for “Outstanding Contributions in the area of Power Electronics.”
- “Review of Technologies for Current-Limiting Low-Voltage Circuit Breakers,” *IEEE Transactions on Industry Applications*, Vol. 32, No.5, September/October 1996, pp. 1005-1010, **C. W. Brice**, **R. A. Dougal**, and **J. L. Hudgins**. This paper received the Industrial and Commercial Power Systems Protection Committee Prize Paper Award for 1996



# Faculty Service

- Jerry Hudgins - President of IEEE-IAS
- Dean Patterson – President of IEEE-PELS
- Enrico Santi – Associate Editor of IEEE PELS Transaction, Member of AdCom of PELS
- Antonello Monti – Chair of IEEE-PELS on Modeling, Simulation and Control, Member of AdCom of PELS, Associate Editor of IEEE Transaction on Automation Science and Engineering



# Main research topics

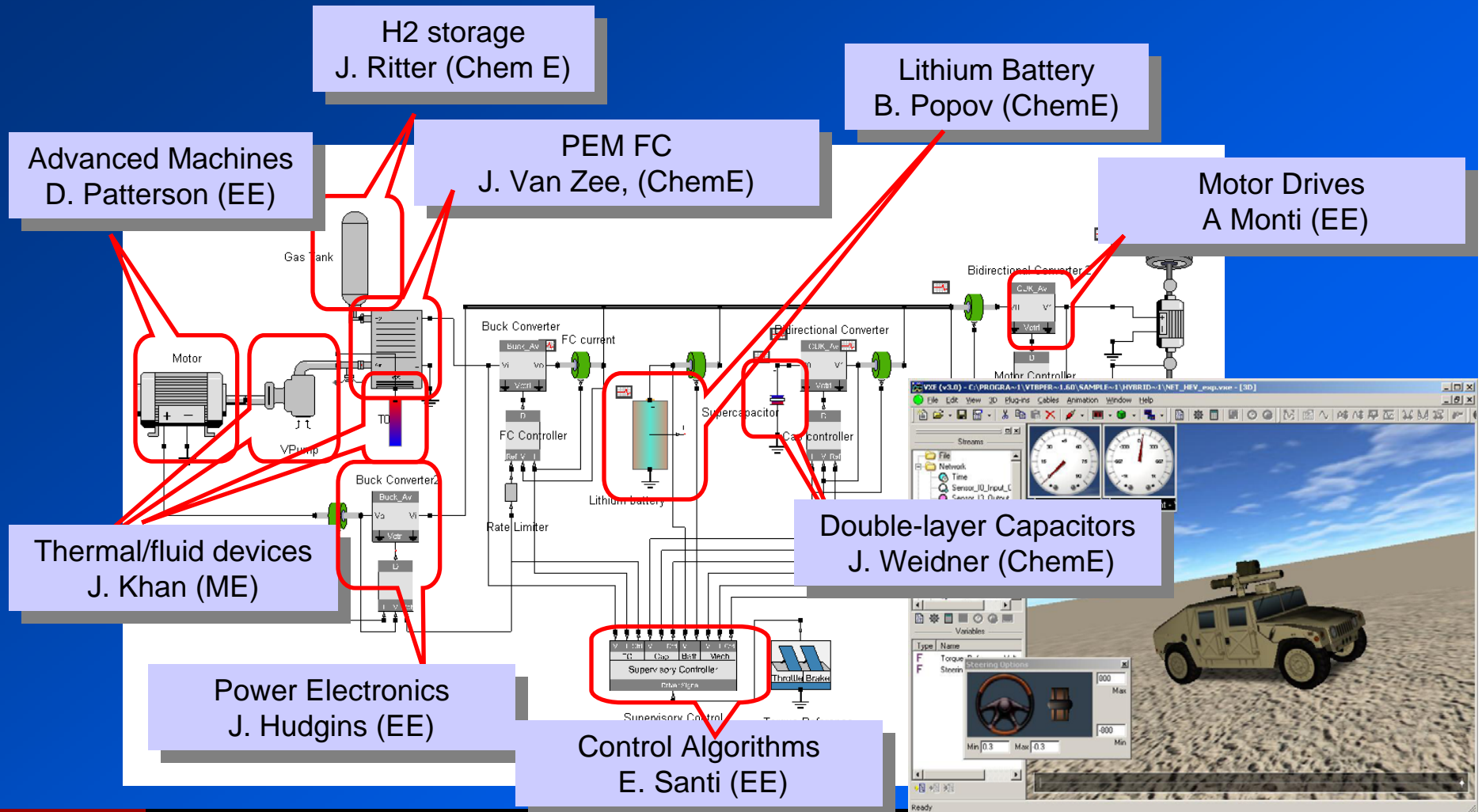
- VTB – Rapid Virtual Prototyping
- Gallium Nitride Converters
- Hybrid Power Sources
- Component modeling
- Advanced Electrical Drives

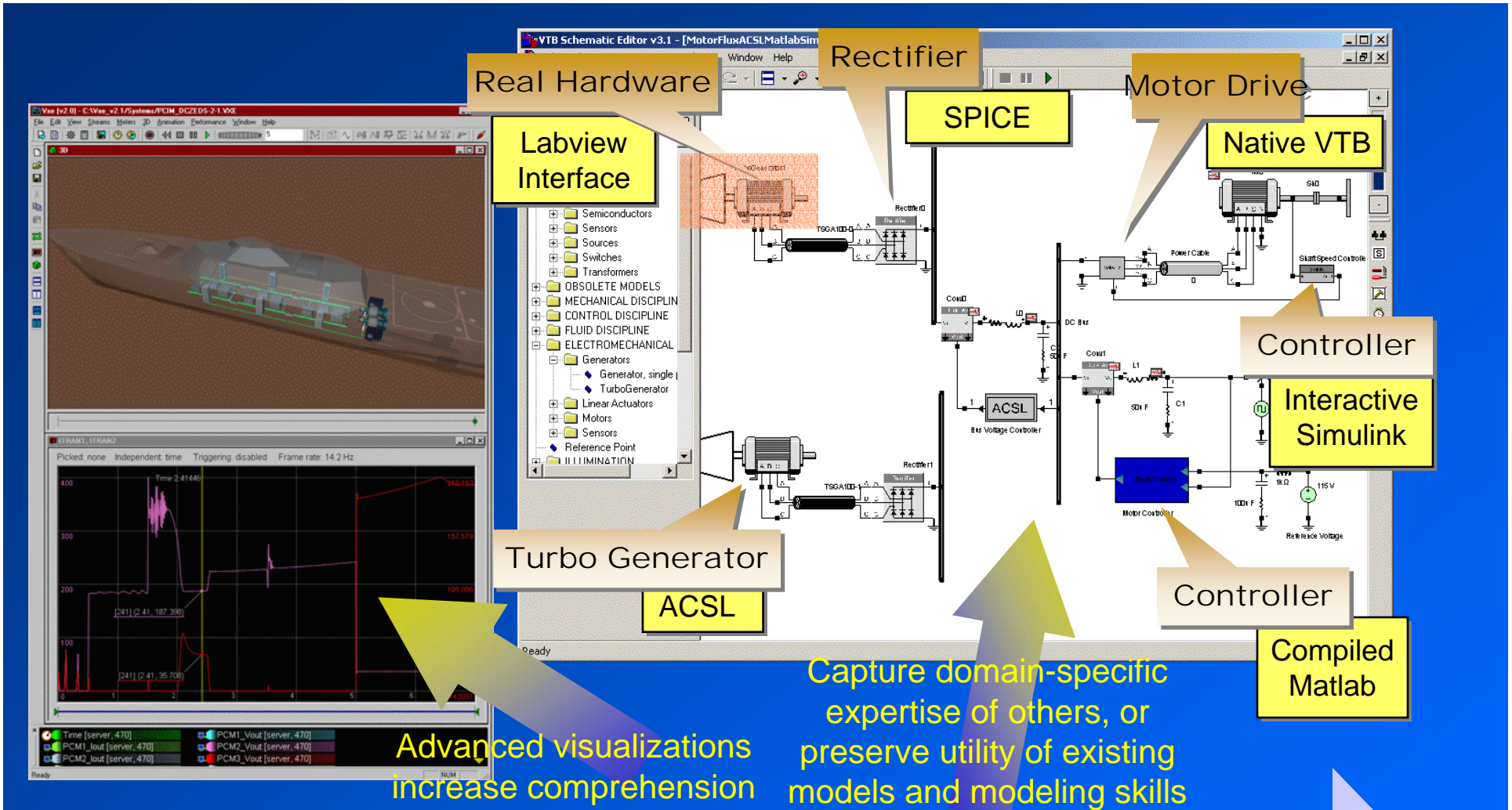


# The Virtual Test Bed



# Design of mobile electric power systems requires an interdisciplinary approach





# Virtual Test Bed

- Provides the environment for integrating the work of interdisciplinary teams
- Provides a “common language” for expression of problems and solutions
- Enables virtual prototyping and tuning of complex dynamic systems.

# Gallium-Nitride converters



# Planned Projects

## 1. Power Converters

- Inverter
- H-Bridge

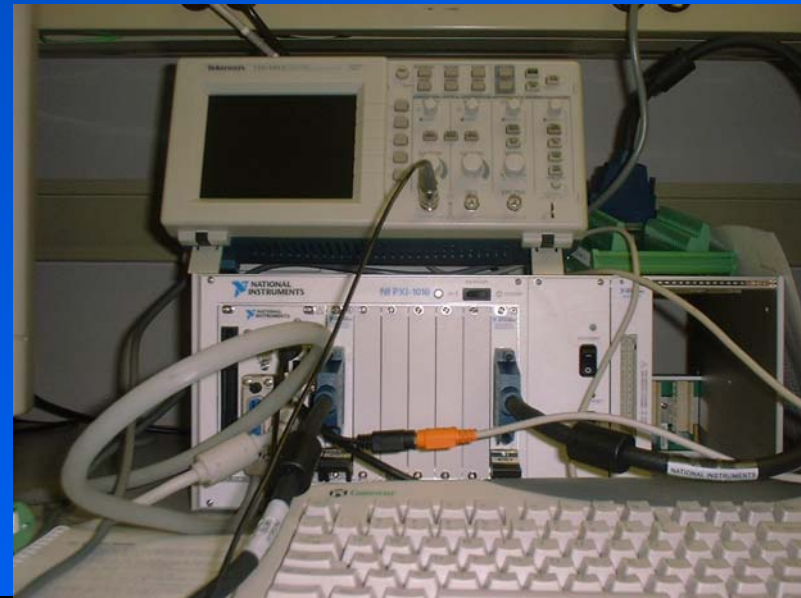
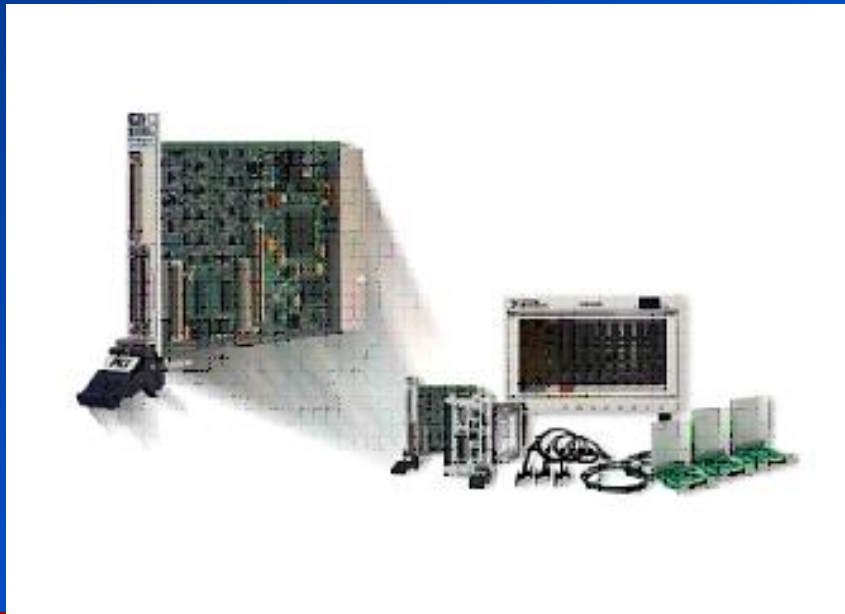
## 2. Class-D power amplifier for audio applications

## 3. Physics based modeling and simulation of GaN/AlGaN HFET

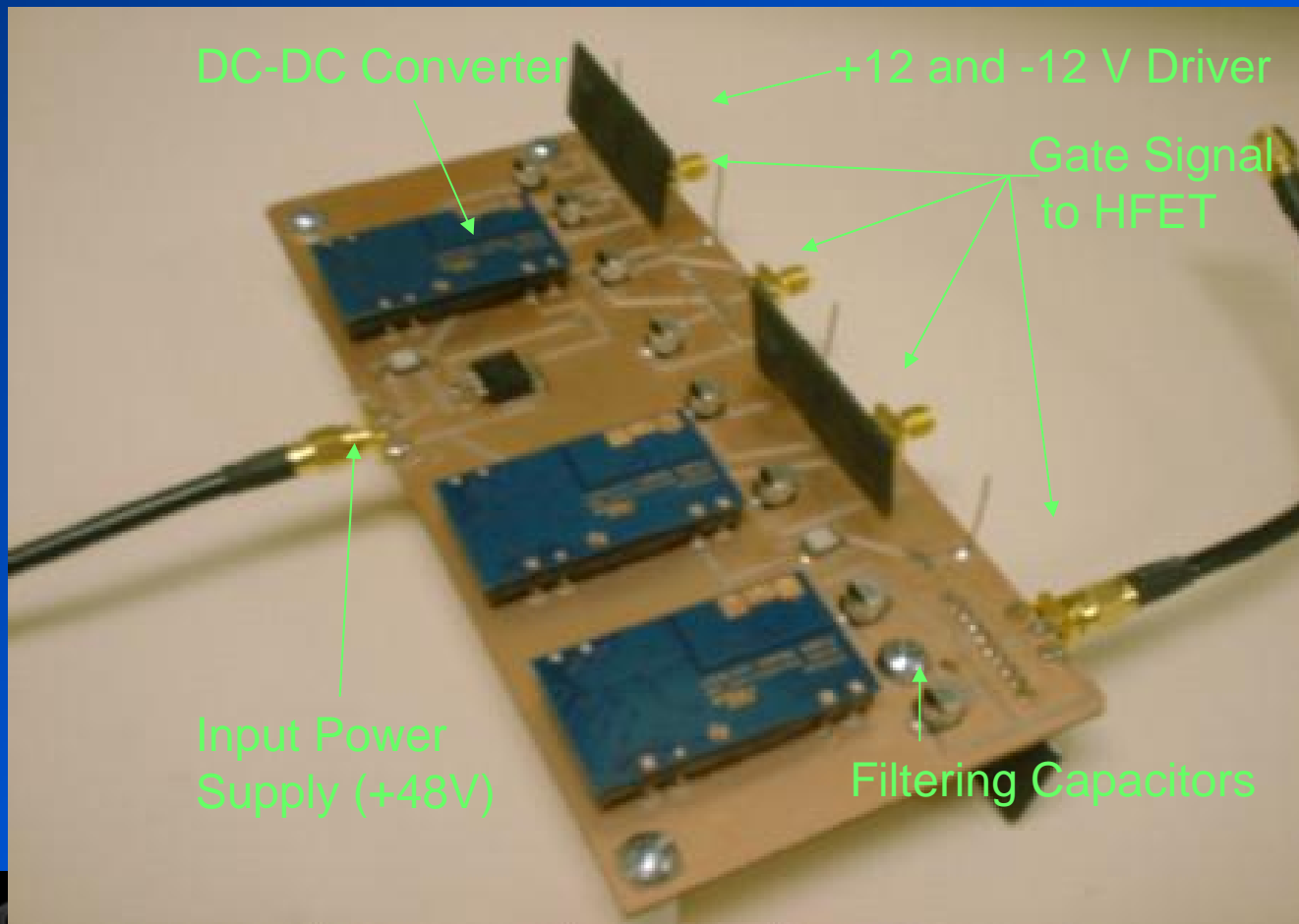


# Controller Hardware

- National Instruments PXI – FPGA Module



# GaN/AlGaN Driver



# Research Labs 10,000 sq. ft. Clean Room Space



# Hybrid Portable Power Sources



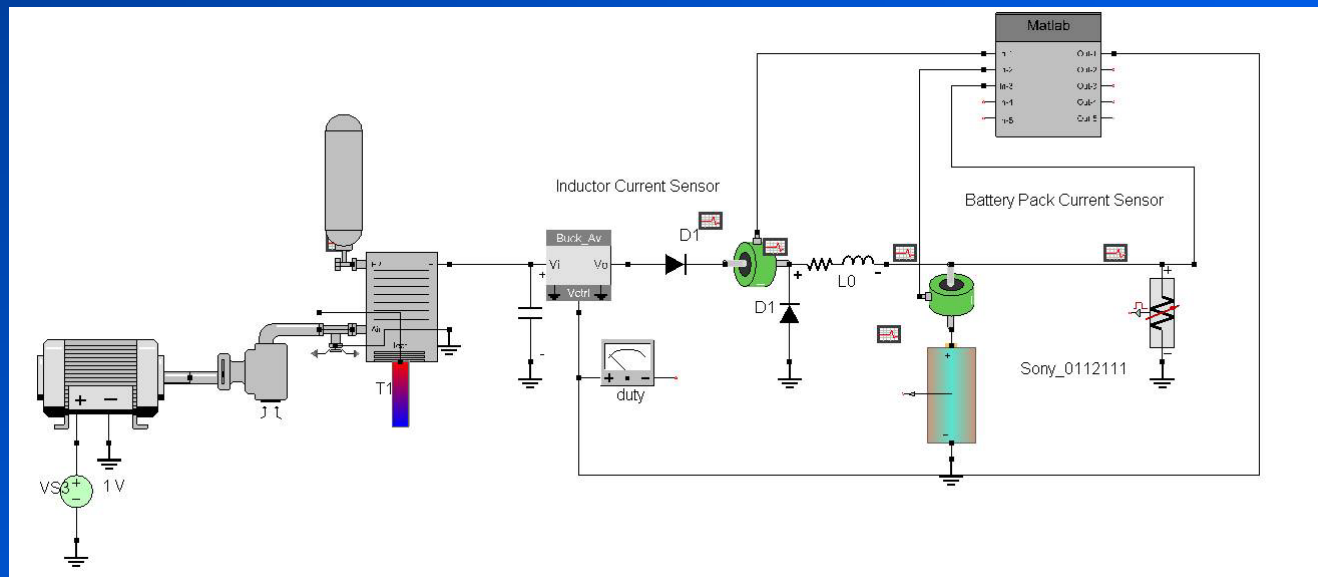
# Objectives

- Develop capabilities to select, design, or specify optimal, mission-specific, power sources for
  - Man portable sources for “soldier system” customers such as Marine Corps, Special Forces, etc.
  - Air and space vehicle power systems for customers such as National Reconnaissance Office

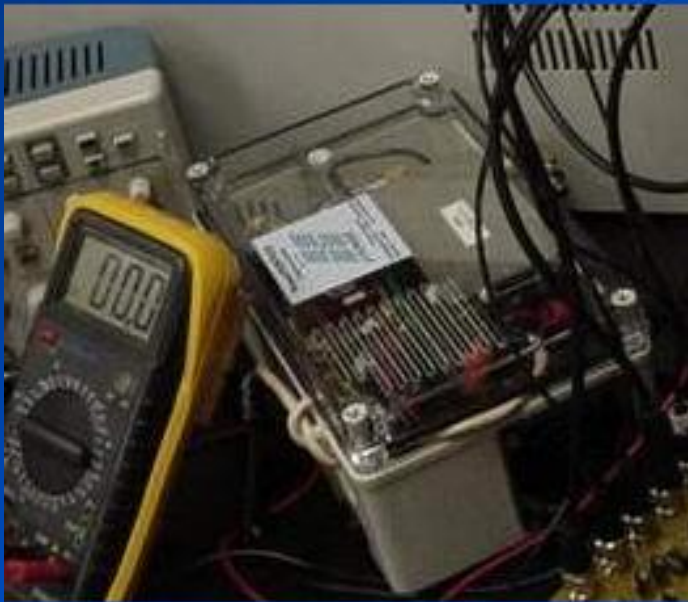


# Active fuel cell-battery hybrid power sources

- Power converter control requirements
  - Optimize current sharing between battery and fuel cell while meeting all load requirements
  - Enforce appropriate battery current limits (charge/discharge)
  - Appropriately manage fuel cell operating conditions



# Physical implementation



H power 35 W pem fuel cell

+

4-cell lithium ion battery

Power controller

=

100 W power source

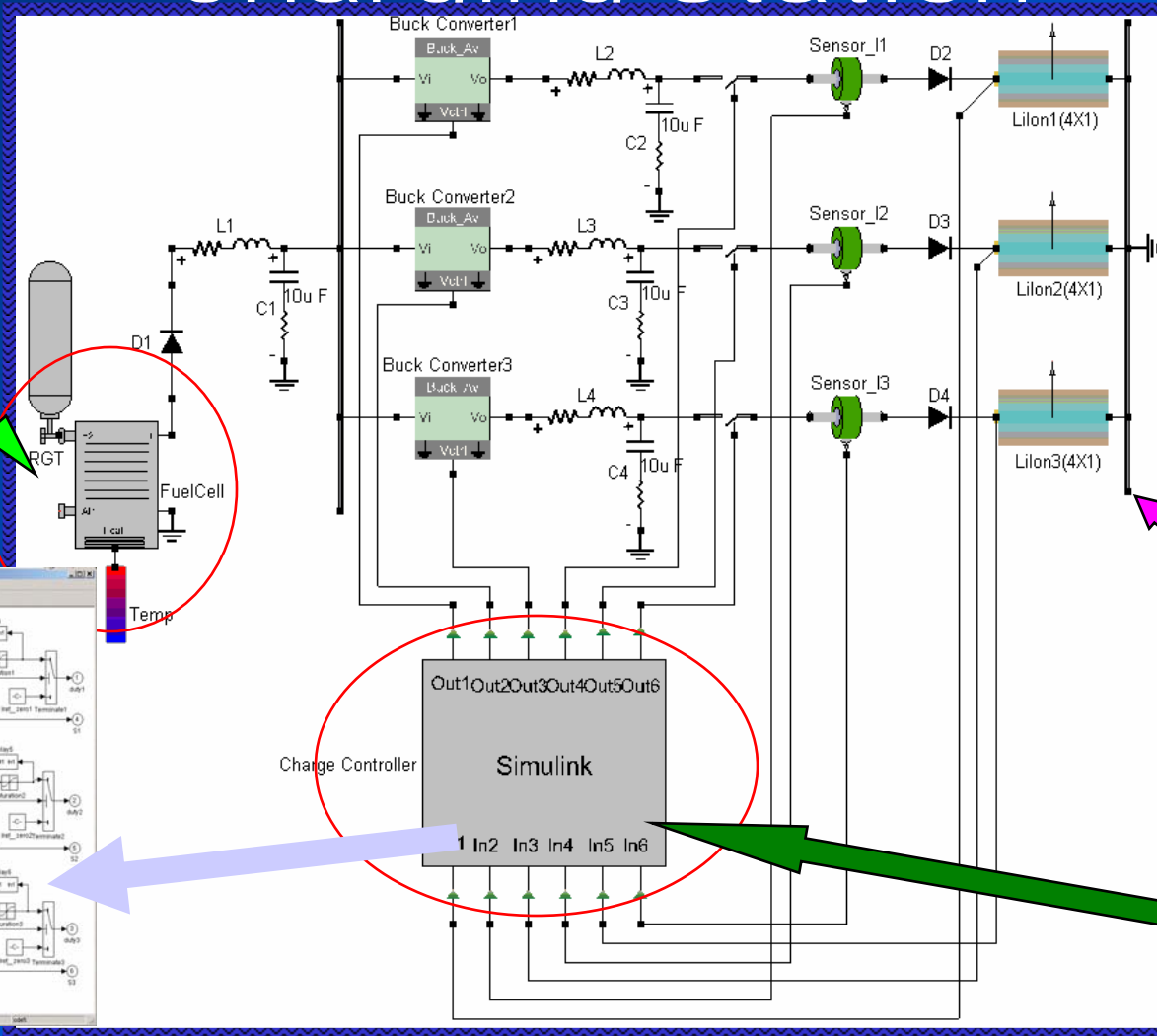
Exact same package

Weight increase ~ 10%



# Fuel Cell Powered Battery Charging Station

25-cell PEM fuel cell stack



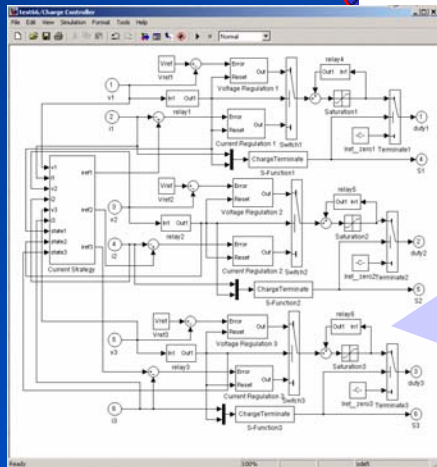
SOC=0.6

SOC=0.5

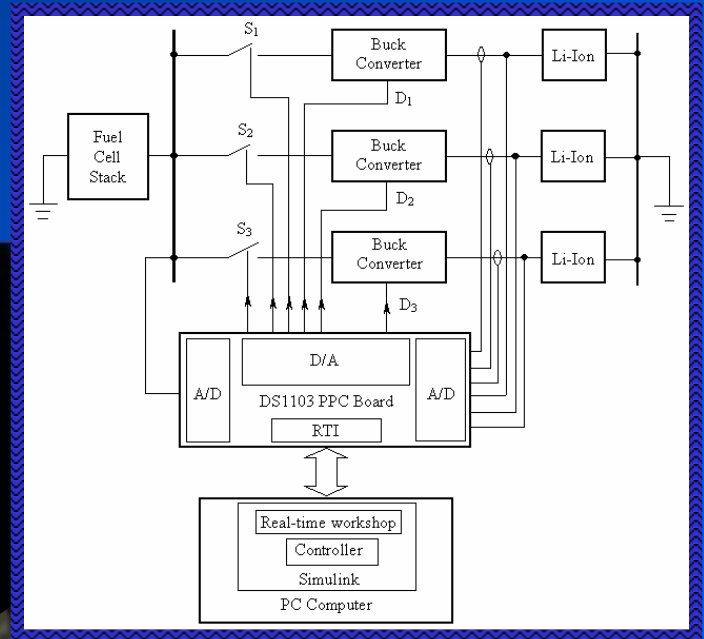
SOC=0.4

4 Li-Ion cells  
1500mAh

Charge  
Controller



# Hardware Prototype



DSpace board and Interface

Li-Ion Battery Pack

H-Power DS35 Fuel Cell Stack

Power Converter



# Power Components Modeling and Characterization

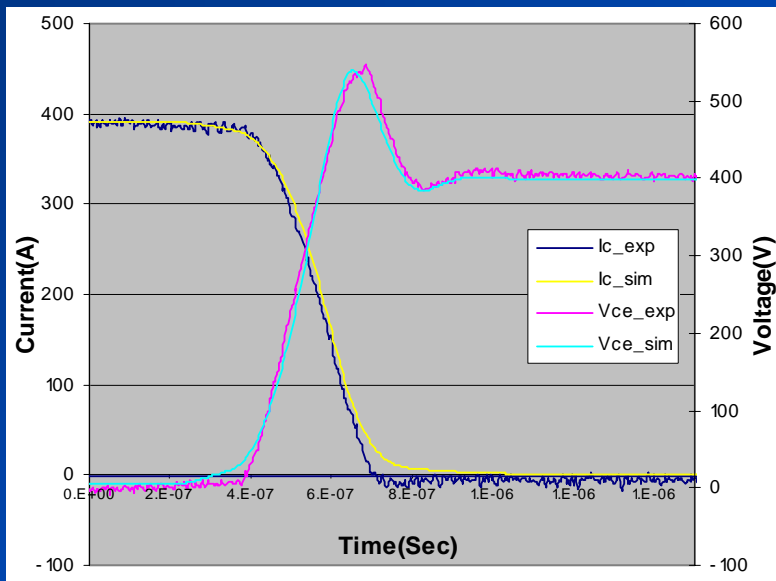


# Research Areas

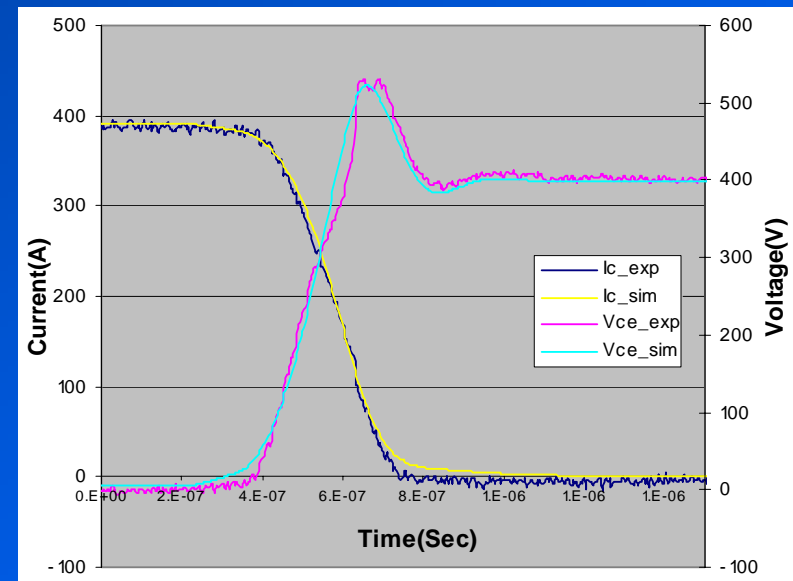
- Device characterization, physics-based modeling, and simulation
- Characterization of advanced non-silicon semiconductor devices (GaN and SiC)
- Cryogenic study of power semiconductor components (Germanium)



# Examples of PT-IGBT Simulations



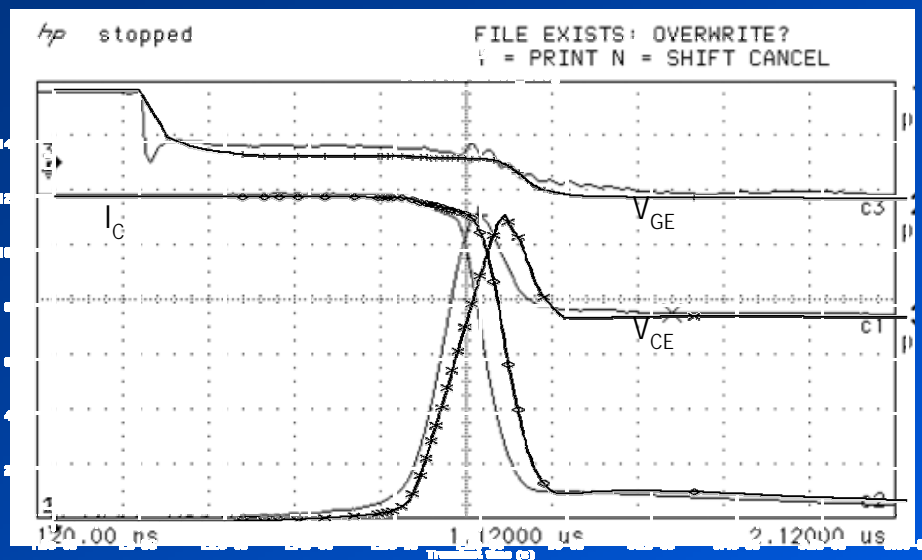
PT-IGBT at room temperature. Comparison between the experimental result (dark blue-current & pink-voltage) and simulation (yellow-current & light blue-voltage) during turn-off.



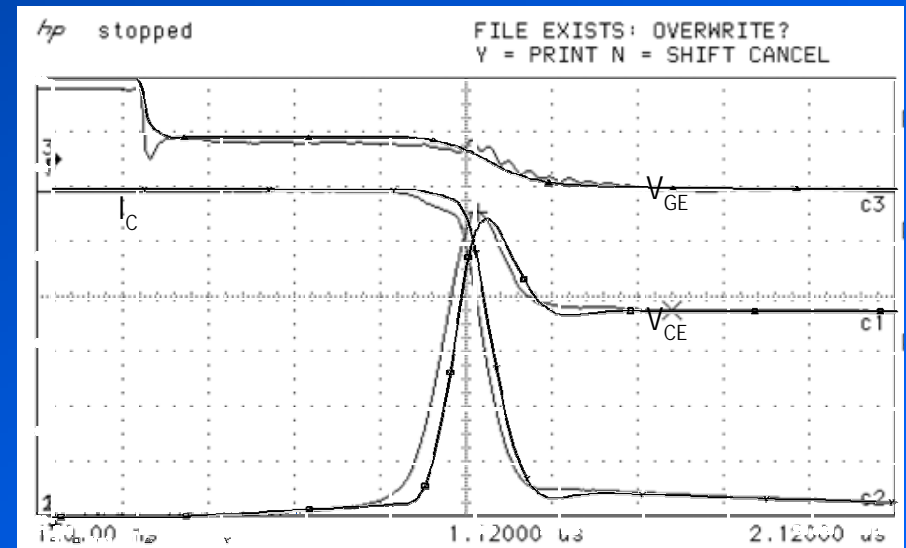
PT-IGBT at 100 °C. Comparison between the experimental result (dark blue-current & pink-voltage) and simulation (yellow-current & light blue-voltage) during turn-off.



# Model Validation



Atlas finite element simulation

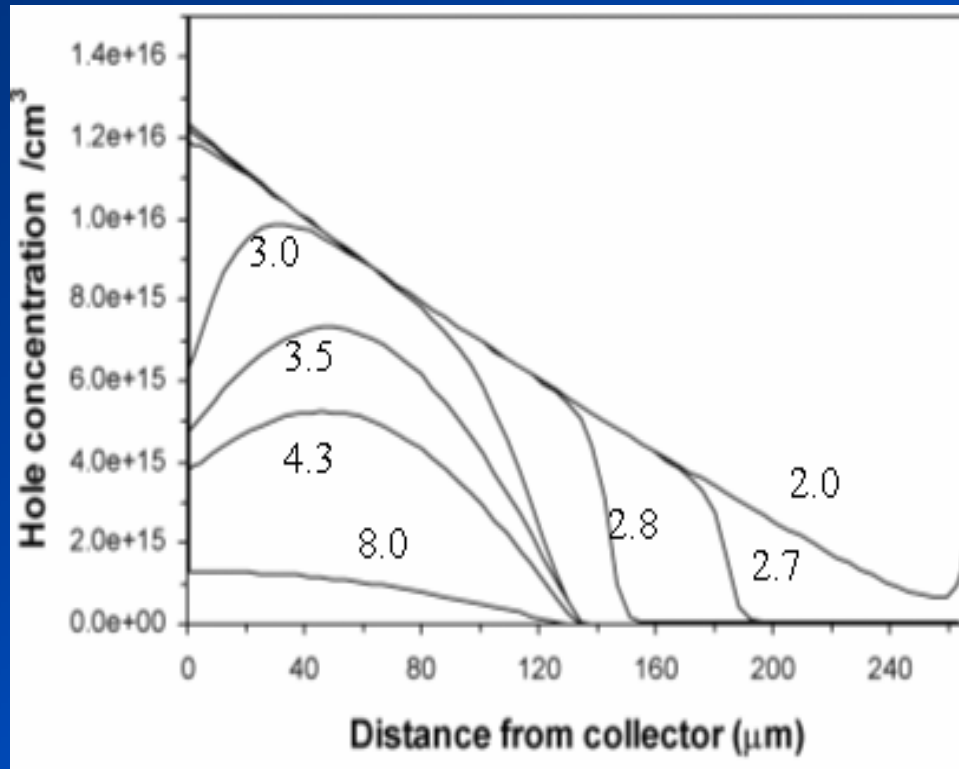


Circuit simulator model

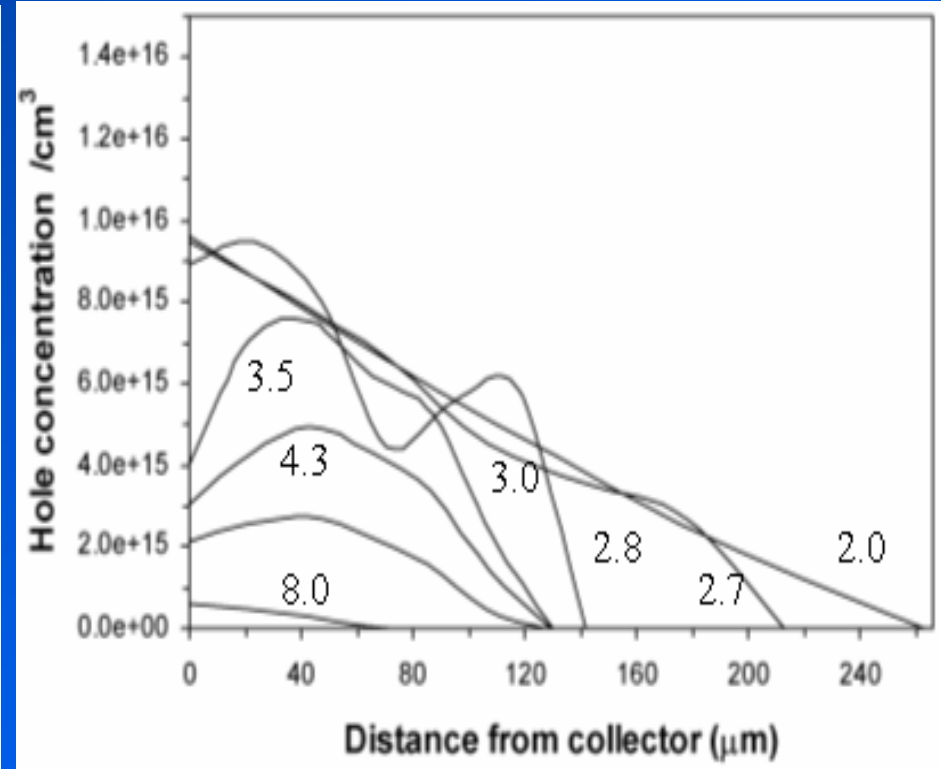


# Validation of Fourier-Based-Solution Approach

--Charge profiles during inductive turn off



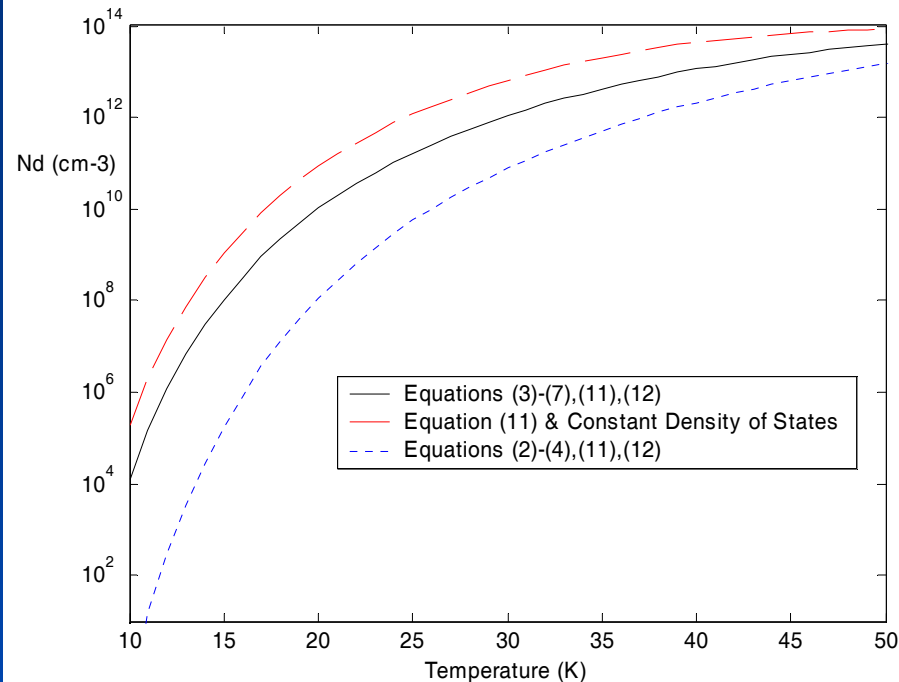
ATLAS finite element simulation



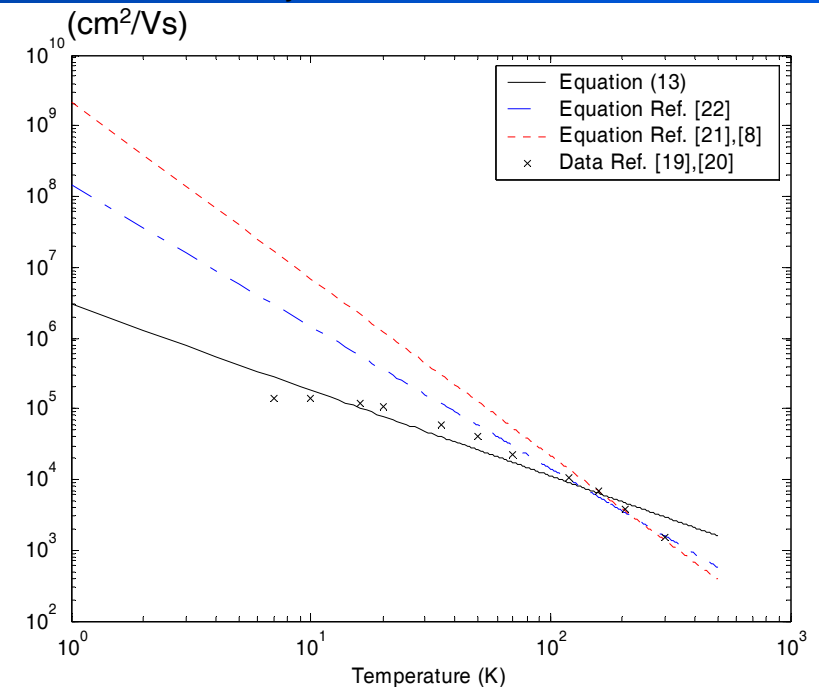
Circuit simulator model



# Cryogenic Operation



## Electron Mobility



Ionized donor concentration as a function of temperature. The background doping density is assumed to be 10<sup>14</sup> cm<sup>-3</sup> and phosphorous as the dopant species.

Electron mobility as a function of temperature for  $T < 300$  K.



# Advanced Electrical Drives

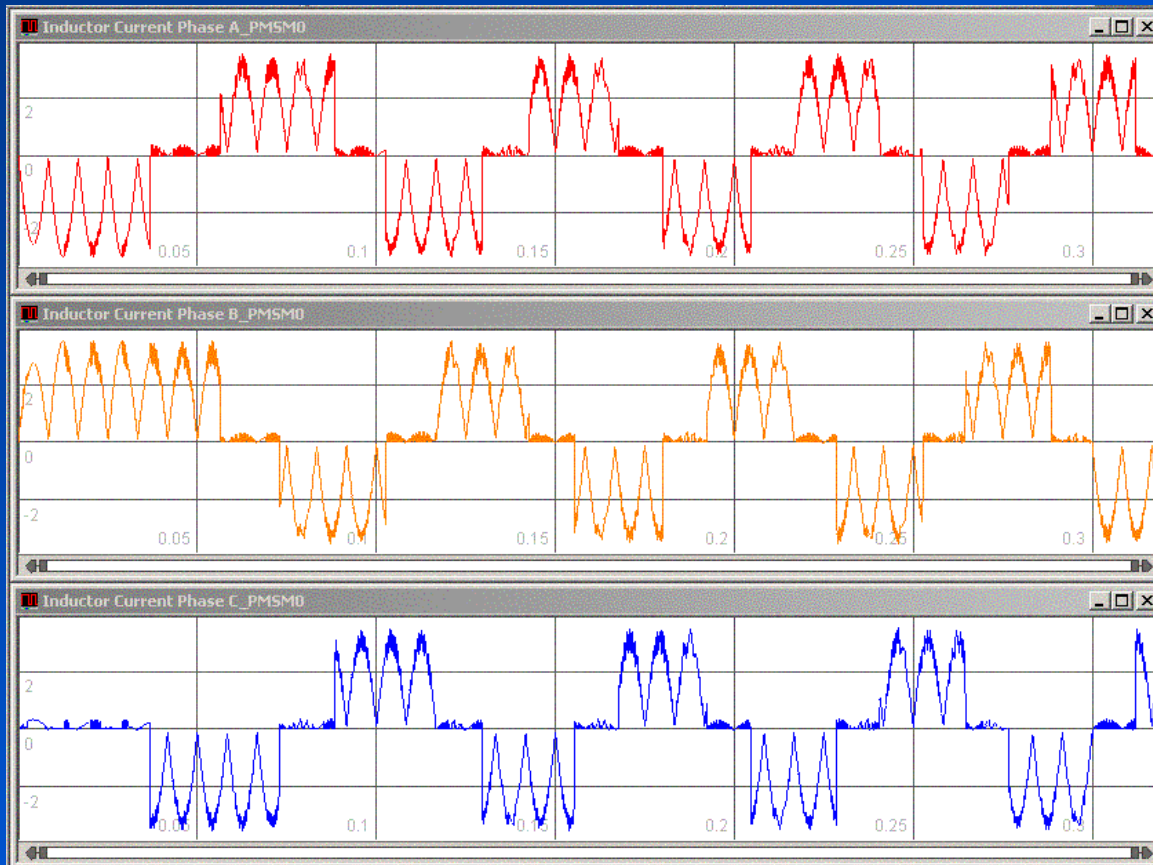


# Research topics

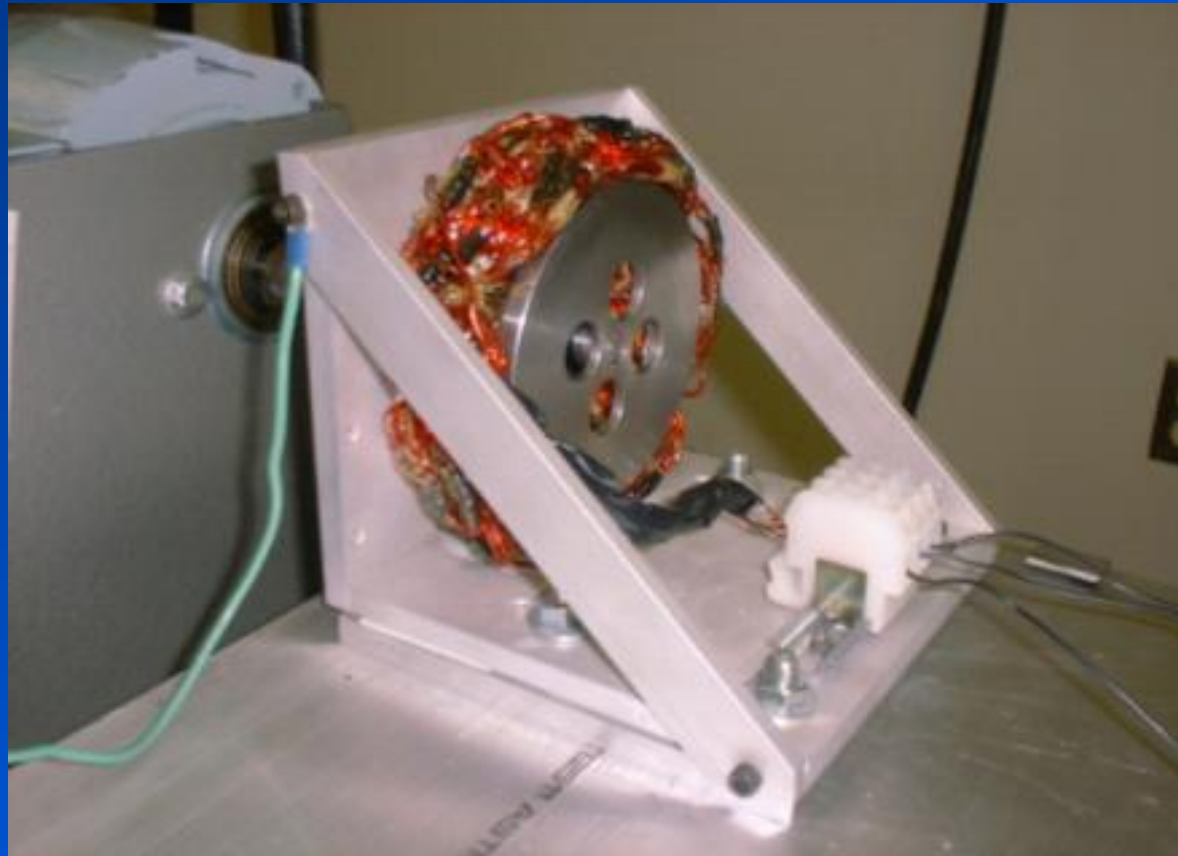
- Design of advanced drive for home appliances
- Design of a modular linear motor with sensorless modular control
- Design of advanced permanent magnet motors



# Simulation results



# Hardware prototype



# Contact Point

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