Hybrid and Electric Vehicle
ENGINEERING ACADEMY

May 20 - 24, 2013
SAE Automotive Headquarters
Troy, Michigan, USA

www.sae.org/ACADEMIES

UPON COMPLETION OF THIS ENGINEERING ACADEMY, YOU WILL BE ABLE TO:

- Define and analyze fundamental electrochemistry of battery operation and performance requirements for HEV, PHEV, EREV and full electric vehicle applications
- Estimate the size of a cell to meet a specific requirement
- Create a cradle-to-grave, or cradle-to-use list of materials used in any type of automotive battery
- Compute the temperature response of battery cell and pack assemblies for a simple model
- Describe the functions performed by a Battery Management System (BMS)
- Explain different approaches to estimating state of charge, state of health, power and energy
- Apply the operation of brushless dc and induction motors to HEV and EV vehicles
- Define the torque speed curves for motors and the application to electric and hybrid electric vehicles
- Describe the features of buck, boost, and Transformer converters
- Compare and contrast the various industry standards for hybrid and electric vehicle battery pack applications
- Describe the main hybrid and electric vehicle development considerations and performance requirements for various vehicle system
- Identify how to define key vehicle system requirements and select and size system components that best meet those requirements
Dear Colleague:

Both internal combustion (IC) and hybrid propulsion technologies have gone through continuous evolutionary stages advanced by knowledgeable engineers who translated what was seen as unreachable science into current, practical automotive applications.

In recognition of the need for a comprehensive program to provide the minimum threshold level of education and skills in the technology, SAE International® is offering The Hybrid and Electric Vehicle Engineering Academy led by a team of industry experts and academic professionals. Covering hybrid and electric vehicle engineering concepts, theory and applications relevant to HEV, PHEV, EREV, and BEV, the SAE International® Hybrid and Electric Vehicle Academy provides a comprehensive and immersive training experience, helping new and re-assigned engineers become proficient and productive in a short period of time.

Scheduled May 20 - 24, 2013 at the SAE International® Automotive Headquarters in Troy, Michigan, this engineering academy provides five days of intensive training that includes lectures, demonstrations, and practical sessions designed for the immediate transfer of knowledge - knowledge that you put to work immediately on the job.

Who Should Attend

Individuals who already have a basic understanding of hybrid and/or electric vehicles who are seeking to increase their knowledge and understanding of hybrid vehicle system applications, including mechanical and electrical application engineers, design engineers, project managers, and other individuals who are working with or transitioning to hybrid-electric powertrain development, will find this academy particularly helpful.

View information about this and all engineering academies at www.sae.org/academies. If you have any questions or would like more information about this or any course offering, please contact SAE Customer Service at 1-877-606-7323 or 1-724-776-4970 (outside the US or Canada). We look forward to seeing you at this year’s HEV Engineering Academy.

Dr. Saeed J. Siavoshani
Chief Industry Advisor & Lead Instructor for the SAE Hybrid Curriculum
Adjunct Professor--University of Detroit Mercy

Pawel Lukawski
St. Clair College of Applied Arts & Technology

“An intensive, high-value program put together and delivered by an exceptional group of experts.”

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Pawel Lukawski
St. Clair College of Applied Arts & Technology
Instructors:

Saeed Siavoshani is an adjunct professor at the University of Detroit Mercy where he teaches a comprehensive electric vehicle course. In addition, Dr. Siavoshani is the Chief Industry Advisor for SAE Professional Development Department’s hybrid vehicle technology curriculum. Over the past two decades, he has worked for the Dow Chemical Corporation, General Motors Corporation and Ford Motor Company. During his career, Dr. Siavoshani has worked on composite projects related to offshore oil and gas, infrastructures, and pressure vessels and automotive systems including vehicle powertrain, body, exterior/interior vehicle, and exhaust/induction systems. He has been instrumental in the development of new technology, notably the integrated Front of Dashboard concept and Acoustomize, a unique method of analyzing and offering solutions to automotive noise problems. He has also worked in the area of thermoforming utilizing electro-magnetic field technology. Dr. Siavoshani has helped to build the infrastructure for the electric vehicle battery pack including thermal management as well as reducing the weight of the overall battery. He has been granted several patents and was presented the Forest R. McFarland Award in 2012 for distinction in professional development and education. Dr. Siavoshani has a M.S. in Mechanical Engineering from Wayne State University and a Ph.D. in Mechanical Engineering from Oakland University.

Rich Byczek is the Technical Lead for Electric Vehicle and Energy Storage at Intertek where he is responsible for the technical development of Intertek’s EV and Battery testing labs across North America, Europe and Asia. Mr. Byczek has significant experience in product validation, EMC testing, and automotive product development. Mr. Byczek has a B.S. in Electrical Engineering from Lawrence Technological University.

Alexandra Cattelan is currently the Chief Engineer of New Energy Systems at AVL. She has extensive experience in hybrid and electric vehicle and powertrain system design, development, validation and production and has been in automotive engineering for 20 years. Prior to her current position, Ms. Cattelan was the Assistant Chief Engineer for the Chevrolet Volt and Vehicle Performance Manager for the Midsize Hybrids at General Motors. Ms. Cattelan holds a B.S. in Industrial Engineering and a M.S. in Mechanical Engineering, both from the University of Toronto, Canada.

Shuvra Das is Professor of Mechanical Engineering and the Associate Dean for Research and Outreach for the College of Engineering and Science at the University of Detroit Mercy. He has published in many conference and professional journals. Dr. Das received his Ph.D. and M.S. degrees in Engineering Mechanics from Iowa State University. He received his B.Tech (Hons.) in Mechanical Engineering from the Indian Institute of Technology in Kharagpur, India.

G. Abbas Nazri is currently the technical director of new technologies at Frontier Applied Sciences and Technologies, LLC. and is also an adjunct professor of Physics and Chemistry at Wayne State University, Oakland University, and University of Windsor, Canada. He is an active organizer of Symposia on advanced batteries and is on the International Science Advisory Board of several Lithium Battery Meetings and Conferences. Dr. Nazri received his Ph.D. in Physical Chemistry from the Center for Electrochemical Sciences, Case Western Reserve University.

Gregory Plett is currently an Associate Professor of Electrical and Computer Engineering at the University of Colorado at Colorado Springs. Dr. Plett has taught courses at several universities including the Universidad Nacional Autónoma de México. His focus is on the modeling and estimation requirements for proper battery management of advanced battery technologies. Dr. Plett received a B.Eng. in Computer Systems-Engineering with high distinction from Carleton University, and a M.S.E.E. and Ph.D. in Electrical Engineering from Stanford University.

Robert Spotnitz leads Battery Design LLC, a company that provides consulting and software for battery developers and users. He founded Battery Design and developed Battery Design Studio® and has led efforts to develop large lithium-ion batteries for hybrid electric vehicles. He has a B.S. in Chemical Engineering from Arizona State University, a M.S. in Computer Science from Johns Hopkins, and a Ph.D. in Chemical Engineering from the University of Wisconsin-Madison.

Tom Stoltz is currently a Senior Engineering Specialist at Eaton Corporation’s Innovation Center and is also an Adjunct Professor of Electrical Engineering at the University of Detroit Mercy. His range of industrial experience includes: manufacturing, product design, and engineering management in automotive powertrain controls, distributed generation, and automated transmissions for heavy trucks. Mr. Stoltz received a B.S. in Electrical Engineering from Michigan State University, a M.S. in Electrical Engineering from the University of Detroit Mercy and is a registered Professional Engineer in the State of Michigan.
**DAY ONE**

**Systems Integration and Analytical Tools**
- Vehicle Development Process Overview
- Requirements Development
- Hybrid Components and Architectures
  - Major components in hybrid powertrain
  - Controls integration
  - Component sizing and integration tradeoffs
  - Hybrid architecture overview
- System Design and Development Considerations
  - Vehicle integration (ex. performance, drivability, NVH)
  - Powertrain integration (ex. energy, power, efficiency, torque, thermal management)
  - HV/LV electrical systems (ex. safety, DC/AC voltage, charging system, efficiency, cables, connectors, fuses)
- Chassis (ex. braking, vehicle dynamics, powertrain to chassis dynamics, ride and handling, steering, fuel system)
- Displays/information (ex. messages, information aids, usage efficiency aids)
- HVAC (ex. HV compressor, HV heater, cabin comfort, efficiency considerations)
- Verification and Validation Considerations
  - Verification and validation test requirements and planning
  - Component test considerations
  - System test considerations
  - Fleet testing

**Safety, Testing, Regulations, and Standards**
- Standards Roadmap for Electric Vehicles
  - SAE; UL; IEC
  - Performance and Safety
  - Applicable Battery Standards
- Battery Transportation & Safety
- Battery Pack: SAE J2464/J2929
- Compare and Contrast the various industry standards
- Vehicle and Charging Standards
  - FMVSS
  - Electric Vehicle Supply Equipment (EVSE) Descriptions
  - Governing Bodies for Regulations
  - Certification Requirements and Options
  - Performance Standards
  - Charging interfaces; SAE J1772 charge protocol
  - USABC/FREEDOMCAR
  - Battery Characterization and life cycle testing
  - Video Demonstrations
  - Mechanical Shock; Short Circuit; Overcharge; Fire Exposure

**DAY TWO**

**Thermal Management for Batteries and Power Electronics**
- Introduction
  - Thermal control in vehicular battery systems: battery performance degradation at low and high temperatures
  - Passive, active, liquid, air thermal control system configurations for HEV and EV applications
- Brief Review of Thermodynamics, Fluid Mechanics, and Heat Transfer
  - First Law of Thermodynamics for open and closed systems; internal energy, enthalpy, and specific heat
  - Second Law of Thermodynamics for closed systems; Tds equations, Gibbs function
  - Fluid mechanics: laminar vs. turbulent flow, internal flow relationships, Navier Stokes equations
- Heat transfer: simple conduction, convection, and radiation relationships; Nusselt number relationships for convective heat transfer; energy equation
- Battery Heat Transfer
  - Introduction to battery modeling: tracking current demand, voltage, and State of Charge as functions of time for given drive cycles
  - Development of thermodynamic relationships for cell heat generation

Curriculum
DAY TWO Continued

- Lumped cell and pack models for transient temperature response to drive cycles
- Model parametric study results
- Thermal Management Systems
- Overall energy balance to determine required flowrates
- Determination of convection and friction coefficients for air and liquid systems in various geometric configurations: flow around cylinders, flow between plates, flow through channels
- Development of a complete thermal system model and parametric study results
- Temperature control and heat transfer using phase change materials
- Thermal Management of Power Electronics

Battery Management Systems
- Block Diagram - Main Functions of a BMS
- Sensing Requirements
  - Cell/module level: cell voltage, cell/module temperature, (humidity, smoke, air/liquid flow)
  - Pack level: current, pre-charge temperature, bus voltage, pack voltage, isolation
- Control Requirements
  - Contactor control, pre-charge circuitry
  - Thermal system control
  - Cell Balancing: Active versus passive, strategies
  - Estimation Requirements
    - Strategies: different approaches and benefits of model-based approach
    - How to create a model via cell tests

- State of Charge estimation; State of Health estimation
- Power estimation
- Energy estimation (range estimation)

Electronics Topologies
- Monolithic versus master/slave versus daisy-chain
- Implications of battery pack topologies: parallel strings versus series modules
- Available chipsets for designing electronics
- Other Requirements: CAN communication, data logging, PH/EV charger control, failure modes/detection, thermal systems control
- Future Directions for Battery Management, Degradation Control

DAY THREE

**Electrochemistry and Battery Materials Design**
- Electrochemical Principles of Energy Storage Systems
- General Overview; Physics and Chemistry of Advanced Lithium Battery Materials
- Advanced Positive and Negative Electrodes
- Advanced Electrolytes and Recent Developments
- Battery Failure Modes, Capacity Fading, and Safety Aspects
- Future Trends and New Concepts in Battery Materials and Design

**Power Electronics**
- Introduction - Why Power Electronics?
- Overview of Power Density
  - Effects of air vs. liquid cooling
  - Effects of efficiency
- Converter Topologies
  - Buck, boost, transformer
- Inverter Topology
  - 6-pack inverter
  - Space Vector Control

- Sources of Loss in Power Electronics
- Conduction, switching, leakage, and control losses
- Power Semiconductors
  - Insulated Gate Bi-polar Transistor (IGBT)
  - Metal-Oxide-Silicon Field Effect Transistor (MOSFET)
- Emerging technologies: Moore’s law, silicon carbide
DAY FOUR

**Electric Motors**
- Magnetic Circuits
  - The basic concepts of magnetic circuits
  - Governing laws
  - Magnetic material behavior
  - Losses and minimization of losses
- DC Motors
  - Basic concepts of DC motors
  - Governing laws
  - Construction
  - Modeling
  - Control
  - Permanent magnet and separately excited motors

**PM AC Synchronous Motors**
- Construction and generation of magnetic field
- 3-phase behavior
- Torque generation
- Modeling
- Control
- Miscellaneous issues

**High Voltage Battery Charging Methods**
- Basic Battery Reactions
- Overcharge Reactions
- Consequences of Overcharge
- Design Considerations
- Thermal Considerations

**Charging Infrastructure/methods**
- Basic Definitions
- Conductive Charging--Method; Standards
- Inductive Charging
- DC Charging--Definition; Issues: Infrastructure, Thermal, and Life
- Grid Infrastructure
  - Basic infrastructure
  - Grid interactions: bi-directional communication and power flow
- Battery Pack Design

DAY FIVE

**Lithium-Ion Battery Design and Simulation**
- Overview of Battery Design
- Major Cell Components
- Overview of Battery Modeling and Simulation
- Lithium-Ion Cell Design Example

**Lithium-Ion Battery Modeling**

Content is subject to change. Check the website for the complete current topical outline, instructor bios, and to register. www.sae.org/ACADEMIES
“This course demystified battery technology and has helped me to put my finger on the pulse of the ever evolving world of hybrid vehicles.”

Brian Ligeski
Yazaki North America Inc.

**EVENT REGISTRATION FEES:**
SAE Members: Classic—$3,011
   Premium—$2,843
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Non-Members: $3,345

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- Call SAE Customer Service at 1-877-606-7323 (outside the US & Canada) 1+724-776-4970 or
- Email CustomerService@sae.org or
- Visit the web site at www.sae.org/academies, click on the title and then on the Register button
- When registering refer to Promo Code P135172

The fee for this program includes handout materials, continental breakfast, lunch each day, and dinner when evening sessions are conducted. Telephone registrations must be guaranteed with a credit card. Registration for this Engineering Academy is limited to 30 participants.

**ACADEMY LOCATION:**
SAE Automotive Headquarters,
PNC Center, Suite 1600,
755 West Big Beaver Road, Troy,
Michigan 48084, USA; 1-248-273-2455.

**CONTINUING EDUCATION UNITS**
Upon completion of the Academy, students will receive a Certificate of Achievement awarding 3.8 Continuing Education Units. CEUs are a nationally recognized unit of measurement based on one CEU for every ten hours of classroom contact. This Engineering Academy is approved for IACET CEUs.

**HOTEL & TRAVEL INFORMATION**
Visit www.sae.org/academies, click on the Academy title and then Hotel & Travel Information, and select SAE Automotive Headquarters for additional information on travel and lodging options or contact SAE Automotive Headquarters at 1-248-273-2455.

**CANCELLATIONS**
If you cannot attend, you may send a substitute or transfer to a future offering. A full refund is issued if you notify SAE at least 14 days prior to academy start date. If canceled less than 14 days prior, the full fee is charged. For $50, you may process a onetime transfer to a future offering within one year of canceled academy. Canceling may reduce group discounts. To cancel, transfer or send a substitute, call SAE Customer Service (numbers listed above).