Michigan Tech Mobile Lab
Delivering Hands-On Education

MichiganTech
10/03/2014
Partnering with Government, Industry, & Nonprofit Organizations to Deliver Hands-On Education Across the Nation

**Uses**
- Hands-on Education: Courses, Short Courses, Seminars
- Outreach: schools, exhibits, conferences, community events
- Product & Technology Demonstrations
- Research partnerships

**Audience**
- College & Pre-College Students
- Engineers
- Corporate Decision Makers
- Governmental Policy Makers
- Defense Personnel
**Classroom, Powertrain Testcells, & Multifunction Laboratory Benches**

- Hands-On Outreach Activities
- Portable Chassis Dyno
- Interactive Microgrid

### Fleet of 20 Test Vehicles
- Saturn Vue MultiMode
- Chevy Malibu BAS
- Hybrid HUMVEE
- Configurable HEV
- Chevy Volt EREV

### Portable Chassis Dyno

### Interactive Microgrid

**Features**
- PHEV & 5kW controllable load
- 80kW generator
- PV array & wind turbine
- Wireless communication
- Interactive GUI

**Education, Demonstration, & Research in Energy Surety**

- Aid in the development of smart microgrids
- Support the transformation of US military installations in safe, reliable power generation
Hands-On Professional Development Courses

• Systems Level, Subsystems, and Broad Engineering Courses

• **Hands-On** Activities Integrated in *Every* Course

• Taught by University *Faculty* Experts

• On-Site at *Your* Location

• **College Credit** Available

• **Custom Courses** Available

• 600 Engineers thus far

“The Mobile Lab training strengthened my knowledge in…[and] is applicable to my every day job function. I *highly recommend* this course”

Blaise DiDonato – Denso
The Product Development Process Through Coursework Using Industry Relevant Tools

- **Fundamental Modeling** (Simulink)
- **Powertrain Subsystems** (VeriStand & INERTIA)
- **Embedded Controls** (NI Powertrain Controls Group)
- **Advanced Modeling** (Cruise & DynaCar)
- **Powertrain HIL Testing** (VeriStand & DynaCar)
- **Systems Validation** (LabVIEW)
- **Vehicle Testing** (LabVIEW)
Example Professional Development Course

Michigan Tech Mobile Lab Short Course:
**Instrumentation & Experimental Methods**

**COURSE DESCRIPTION**
Physical experimentation remains critical throughout the entire product development cycle including advanced research. Conclusions and accuracy of the decisions made from experimental results hinges upon proper installation and setup of transducers and data acquisition systems as well as experimental methods and test plans. Instrumentation and Experimental Methods is a hands-on short course geared toward engineers and technicians involved in planning and conducting experimental studies or installing instrumentation. The course relies on a mix of lecture and hands-on experimentation using state-of-the-art powertrain test cells and data acquisition systems. The course begins with basic principles of electronic data acquisition and transducers including best practices for signal quality and noise reduction. Case studies are conducted on advanced instrumentation systems including emissions analysis equipment and an extensive study of engine combustion analysis systems.

**LEARNING OBJECTIVES**
1. Understand the fundamentals of electronic data acquisition
2. Become familiar with operating principals of several common types of transducers
3. Understand the sources of poor signal quality and noise and subsequent mitigation practices
4. Become familiar with basic experimentation techniques
5. Understand the setup of advanced powertrain instrumentation systems including combustion analysis and emissions analysis
6. Be able to effectively interface with other experimenters

**AUDIENCE**
This course is ideal for engineers and technicians new to experimental studies, or those responsible for setting up and conducting experiments using complex instrumentation systems as well as experienced individuals wishing to increase the depth or breadth of their knowledge. The course is particularly well suited for engineers and technicians working in the powertain fields, although all will benefit.

**PREREQUISITES**
A college degree in a technical or engineering related field.

**TOPICS**
- Instrumentation Plumbing & Wiring
- Basics of Data Acquisition
- Electronic Data Acquisition
- Sampling & Digitization
- Transducers
- Signal Conditioning
- Electrical Noise
- CAN Communications
- Experimentation
- Emissions Analysis
- Combustion Analysis

**HANDS-ON EXPERIMENTS**
Use cutting-edge tools from National Instruments and Wineman Technology among others, and state-of-the-art test cells and vehicles to conduct experiments such as:
- Plumbing & Wiring
- Optimization of a Digitized Signal
- Mitigating Signal Noise
- Development of Analog Filters
- Emissions Analysis
- Development of Digital Filters
- Combustion Analysis
- Transducer Installation & Maintenance
- Encoder Phasing
- Geometry & Setup Considerations

**INSTRUCTOR**
Jeremy Wurm, MS, PE
Mr. Wurm is currently the Director of the Michigan Tech Mobile Lab. He teaches courses in Hybrid Vehicles, Engines, and Instrumentation. His research interests include hybrid vehicle energy management, and IC Engines including efficiency improvements and alternative fuels. Prior to joining Michigan Tech, Wurm held various positions at GM Powertrain where he gained experience in many areas of vehicle development including the development of an engine for a new hybrid vehicle. Wurm has multiple US Patents, and has authored or co-authored numerous journal articles, conference papers, and book chapters.

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**Example Professional Development Course**

**Michigan Tech Mobile Lab Short Course: Embedded Control Systems**

**COURSE DESCRIPTION**
Through this interactive short course, participants will learn fundamental concepts for the design, implementation, and calibration of embedded control systems. Topics covered include embedded control system architecture, data/address buses, memory, I/O interfaces, A/D and D/A converters, pulse-width modulation (PWM), filters, sensors (pressure, temperature, position, speed, acceleration, & strain gauge), DC motor, servo motor, solenoid, H-bridge, low/high side drivers, sensor scaling and signal conditioning, discrete PID controllers, control algorithm development, serial communication protocols (CAN, SPI, I2C, UART), real-time calibration techniques, and embedded software.

The course will discuss the applications of embedded control systems in the transportation industry, manufacturing automation, communication networks, appliances, and more. Participants will be exposed to the control design for DC motor, valve, battery, engine, and CAN communication.

**LEARNING OBJECTIVES**
1. Understand the concept, system architecture, and components of an embedded control system.
2. Become familiar with commonly used control algorithms in embedded control systems.
3. Understand communication protocols in distributed embedded systems.
4. Learn software design techniques for the implementation of embedded control algorithms.
5. Gain hands-on experience in embedded control systems development.
6. Perform real-time calibration of embedded control systems.

**AUDIENCE**
This course is intended for engineers, managers, and technicians who are involved in the design, development, utilization, and service of embedded control systems. Individuals wanting to gain a basic understanding of embedded control systems may attend the course to learn embedded system architecture, digital controller design, sensors/actuators, embedded software, real-time calibration, and communication protocols.

**PREREQUISITES**
A college degree in a technical or engineering field is recommended.

**TOPICS**
- Embedded System: Components & Architecture
- Sensors: Pressure, Temperature, Position, & Speed
- Actuators: DC Motor, Servo Motor, & Solenoids
- A/D and D/A Converters
- Pulse-Width Modulation
- Drives: Low & High Side Drives, H Bridge
- Discrete PID Controllers
- Communication Protocols: CAN, SPI, I2C, UART, & USB
- Real-Time Calibration Techniques
- Embedded Software & Control Algorithms

**HANDS-ON EXPERIMENTS**
Use cutting-edge tools from National Instruments and Wineman Technology among others, to conduct experiments such as:
- Read Sensor Signals
- Electronic Throttle & Valve Control
- Sensor Scaling & Signal Conditioning
- A/D & D/A Conversion
- Rotational Speed Calculation
- Actuator Driver Experiments
- Digital Controller Design
- Transducer Installation & Maintenance
- Open-Loop & Closed-Loop DC Motor Control
- Engine Fuel Injection Control

**INSTRUCTOR**
Bo Chen, PhD
Dr. Chen is the Dava House Associate Professor of Mechanical Engineering and Electrical Engineering. She has over 20 years of teaching and research experience in mechatronics and embedded control systems. Her research focuses on engine management systems, hybrid electric vehicles, battery control, cyber-physical systems, and automation. She is currently serving as the Chair of the Technical Committee on Mechatronics and Embedded Systems of IEEE Intelligent Transportation Systems Society and the Chair of the Technical Committee on Mechatronic and Embedded Systems and Applications of ASME Design Engineering Division.

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Example Professional Development Course

**Course Description**
Topics covered: In this course include quantization, sampling, aliasing, Fourier transforms, frequency response functions and coherence. Also included is discussion on various types of transducers and signal conditioning. Application areas include noise and vibration, and powertrain operation in various machines including automobiles, snowmobiles, and military vehicles.

The course includes development of concepts in MatLab as well as various commercial implementations. Hands-on exercises are used to reinforce all concepts and to introduce topics such as test setup, types of instrumentation and signal conditioning. National Instruments PXI, Compact DAQ, and Compact FLX equipment is used to acquire data. At the conclusion of this course, participants will have the basic knowledge required to make a broad range of dynamic measurements as well as assess data quality and analyze data.

**Learning Objectives**
1. Gain proficiency in making high quality measurements
2. Understand the fundamentals of digital data acquisition systems
3. Become familiar with dynamic transducers and their calibration
4. Understand the fundamentals of Digital Signal Processing
5. Understand common signal processing techniques including Fast Fourier Transforms, Frequency Response Functions, and Coherence

**Hands-On Experiments**
Use cutting-edge tools from National Instruments and Wineman Technology among others, and state-of-the-art test cells and vehicles to conduct experiments such as:
- Sampling, Quantization, Aliasing, & Leakage of Dynamic Signals
- Development of Frequency Response Functions and Coherence
- Measurement & Analysis of Engine Combustion Knock
- Measurement & Analysis of Vehicle Systems including Tire Noise, Cabin Noise, & Seat Track Vibration

**Instructor**
Jason Blough, PhD
Dr. Jason Blough is a faculty member at Michigan Technological University. At Michigan Tech, Dr. Blough has fund programs in military vehicle NVH design, locomotive vibrations and dynamics, engine systems, transmission systems, consumer appliances, and various other projects. Prior to joining Michigan Tech, Dr. Blough worked at GM in their Noise and Vibration Center focusing on quieting engines and automatic transmissions. Dr. Blough also has experience as an independent consultant on a broad range of projects. Dr. Blough serves on the SAE Snowmobile Committee to improve noise and vibration testing standards.

**Prerequisites**
A college degree in a technical or engineering field is recommended.
Example Professional Development Course

Michigan Tech Mobile Lab Short Course:
Advanced Digital Signal Processing

This advanced short course is intended for engineers and technicians wishing to conduct complex data analysis including rotational machinery, order tracking, wavelet analysis, and other techniques.

COURSE DESCRIPTION
This hands-on short course delves into advanced topics and applications in digital signal processing. Topics covered in this course include advanced digital filtering, rotating equipment analysis, order tracking, advanced frequency domain measurements and analysis, and joint time-frequency domain analysis techniques. Application areas include noise and vibration and powertrain operation on various machines including automobiles, snowmobiles, and military vehicles.

This course includes development of concepts in Matlab as well as various commercial implementations. Hands-on exercises are used to reinforce all concepts and to introduce topics such as test setup, types of instrumentation and signal conditioning. National Instruments PXI, Compact DAQ, and Compact FIO equipment is used to acquire data.

LEARNING OBJECTIVES
1. Gain proficiency in advanced Digital Signal Processing techniques
2. Understand the intricacies of rotating equipment analysis
3. Apply advanced Digital Signal Processing Techniques including complex digital filtering, order tracking, advanced frequency domain analysis, and joint time-frequency domain analysis

AUDIENCE
This hands-on short course is well suited for test and analysis engineers and technicians who wish to increase the speed, accuracy, and value of their experimental measurements through the application of advanced digital signal processing techniques. While a strong math background is not required, a sound understanding of engineering math will make some concepts easier to understand and is recommended.

PREREQUISITES
A college degree in a technical or engineering field is recommended.

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TOPICS
- Overview of Data Acquisition Fundamentals
- Advanced Digital Filtering
- Rotating Equipment Analysis
- Order Tracking
- Joint Time / Frequency Analysis
- Wavelet analysis

HANDS-ON EXPERIMENTS
Use cutting-edge tools from National Instruments and Wiseman Technology among others, and state-of-the-art test cells and vehicles to conduct experiments such as:
- Development & Application of Advanced Digital Filters
- Order Tracking on a Hybrid Electric Powertrain System
- Torsional Vibration Analysis of a Power Transmission System
- Joint Time / Frequency Analysis of Engine Combustion Knock
- Measurement & Analysis of Vehicle Systems including Tire Noise, Cabin Noise, and Seat Track Vibration

INSTRUCTOR
Jason Blough, PhD
Dr. Jason Blough is a faculty member at Michigan Technological University. At Michigan Tech, Dr. Blough has had funded programs in military vehicle NVH design, locomotive vibrations and dynamics, engine systems, transmissions systems, consumer appliances, and various other projects. Prior to joining Michigan Tech, Dr. Blough worked at GM in their Noise and Vibration Center focusing on quieter engines and automatic transmissions. Dr. Blough also has experience as an independent consultant on a broad range of projects. Dr. Blough serves on the SAE Snowmobile Committee to improve noise and vibration testing standards.

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Example Professional Development Course

**Experimental Studies in Hybrid Vehicles**

**COURSE DESCRIPTION**
Vehicle powetrain hybridization is a critical step on the pathway to sustainable transportation. Hybrid powetrain systems are able to realize improvements in efficiency through strategic energy management principles. Although effective, these systems bring a significant degree of complexity to the vehicle development process, and engineers must be familiar with the operation of systems outside their core area of expertise.

This introductory short course treats the vehicle as a series of energy conversion processes. The course will rely on a mix of lectures, hands-on experimentation using production and one-half scale configurable Hybrid Vehicles and a complete powetrain test cell. Participants will learn the basic operating principals governing all major hybrid vehicle subsystems before using commercial vehicle modeling software and operational hardware to optimize the performance of a configurable hybrid electric vehicle.

**LEARNING OBJECTIVES**
1. Understand the energy conversion processes and energy flow through a hybrid electric vehicle
2. Understand the basic operating principals of hybrid electric Vehicles and their subcomponents, especially their impact on the energy conversion process
3. Be able to interface with engineers across various disciplines on a hybrid vehicle development team
4. Understand typical experimental techniques and apparatus used in vehicle development
5. Become familiar with vehicle simulation and correlation to experimental data

**AUDIENCE**
This short course is intended for engineers new to the hybrid vehicle field, those wishing to enter the hybrid vehicle field, or experienced hybrid vehicle engineers wishing to learn more about other areas of the hybrid vehicle outside their area of expertise. The course is also appropriate for managers and technicians wishing to expand their knowledge of hybrid vehicles.

**PREREQUISITES**
An engineering degree, or a working knowledge of thermodynamics, a basic understanding of electronic data acquisition, and the ability to solve closed-form equations.

**TOPICS**
- HEV safety & architecture
- Drive cycles & experimental techniques
- Fuel economy & emissions regulations
- Aerodynamics & rolling resistance
- Batteries
- Engines
- Electric machines & power electronics
- Embedded controls
- Systems integration
- Vehicle modeling

**HANDS-ON EXPERIMENTS**
Use cutting-edge tools from National Instruments, Wierzban Technology, and others to conduct hands-on experiments:
- Disable a high-voltage electrical system
- Identify and become familiar with components
- Determine in situ fuel economy
- Determine the effects of aerodynamics & rolling resistance through vehicle coast-down testing
- Characterize the performance of a battery pack
- Characterize the efficiency & output of an engine
- Characterize the efficiency & output of an electric machine
- Send & receive messages on a CAN bus
- Vehicle simulation
- Optimize a configurable hybrid vehicle

**INSTRUCTOR**
Jeremy Worr, PE
As Director of the Michigan Tech Mobile Lab, Worr teaches curriculum courses in the area of hybrid vehicles, engines, and powetrain instrumentation. His research interests include hybrid vehicle energy management, and ICE engines including efficiency improvements and alternative fuels.

Prior to joining Michigan Tech, Worr held various positions at GM Powertrain where he gained experience in many areas of vehicle development including an engine for a new hybrid vehicle. Worr has multiple US patents, and has authored or coauthored numerous journal articles, conference papers, and book chapters.

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Example Outreach: Why Hybrid Vehicles?

**Hands-On STEM Outreach**
Short Duration – High Impact Experiences in Sustainable Transportation

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Apply the Concepts:
- Design for Energy Surety with a controllable renewable microgrid
- HIL testing with a Real Powertrain
- "Seat of the Pants" feel with a Configurable HEV

How it Works:
- Electric Machines
- Engines
- Batteries

Apply the Concepts:
- "feel" the energy flow
- HEV Gaming - A virtual garage and drive route
- Production HEV’s in the “real world”

Design for Energy Surety with a controllable renewable microgrid

Short Duration – High Impact Experiences in Sustainable Transportation
Example Utilization

**Outreach**
- Trade shows
- Conferences
- Exhibitions
- Fairs
- Parades
- K-12 Schools
- Technology Awareness
- Community Events

**Education**
- Graduate Courses
- Undergraduate Courses
- Short Courses
  - Basic through Advanced
  - Specialty courses
  - Training courses
  - Custom content or co-taught
  - Delivered at a customers site
- Audience
  - Students
  - Practicing engineers
  - Corporate executives
  - Governmental policy makers
  - Military Commanders
  - Automotive enthusiasts
Mobile Laboratory:
A Unique Venue for Education, Outreach, and Research Toward Sustainable Transportation and Energy Surety

Michigan Tech
Create the Future

MOBILE LAB PARTNERS:

U.S. Department of Energy

GM

National Instruments

Kohler

AVL

Magna

PCB Piezotronics

MiSA Michigan Skills Alliance

WTI

Wineman Technology Incorporated

Detroit Diesel

Demand Performance

TAPpec

Woodward
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