Development of a Senior Elective for EE and EET Majors in the Design of Electronic Instrumentation for Electric Vehicles +

Maher E. Rizkalla, Richard Pfile, Ahmed El-Antably*, and Charles F. Yokomoto
Purdue School of Engineering and Technology at Indianapolis
Indiana University Purdue University at Indianapolis
* Delphi E., Indianapolis, IN

This paper describes innovative ideas for an interdisciplinary EE/EET senior level course. The course integrates different technology that ranges from Power Electronics, Computer Simulation, Data Acquisition, DSP, Neural Networks and Fuzzy Logic, Electromagnetics and Energies, and Microprocessor Control. Normally these topics are covered in details in more than fifteen credit hours, while using "only as needed" philosophy, we can cover what we need from these materials that serve an important application: Electric Vehicles. The paper details the contents of the course, the laboratory components utilizing an actual propulsion system as donated from Delphi E. Inc, a subdivision of GM, and the role of LabView as a data acquisition system. The course was offered in a senior project format and the student satisfaction is reported here. In addition, the course is offered officially in the Spring 1998, and more data will be reported as we progress in the course. The project is funded by FIPSE and this represents the first phase of the project.

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I. Introduction

Recently, with the increase of new topics into electrical engineering and electrical engineering technology, students have to select few courses among many of the EE and EET electives in the senior year. In such courses the technology is studied in depth for most of the semester time. With the credit hour limitation, students are not able to get exposed to many of the technologies used in industries. This course is designed to include much of the theories and technologies, all combined into one real engineering application that serve an automobile sector in the United States. The course is designed to educate engineers and technologists, and prepare them for entering real world where engineers they work together in design teams. The course includes hands-on the design of electronic components of the electric vehicles. The course features the student integration from EE and EET into a design project, and a team of faculty from EE and EET design and teach the course.

II. Innovations

- The new course is a departure from any traditional EE or EET senior electives, and the following summarizes the innovations of this course. The purpose of the innovations is to create a motivational experience covered in the course.

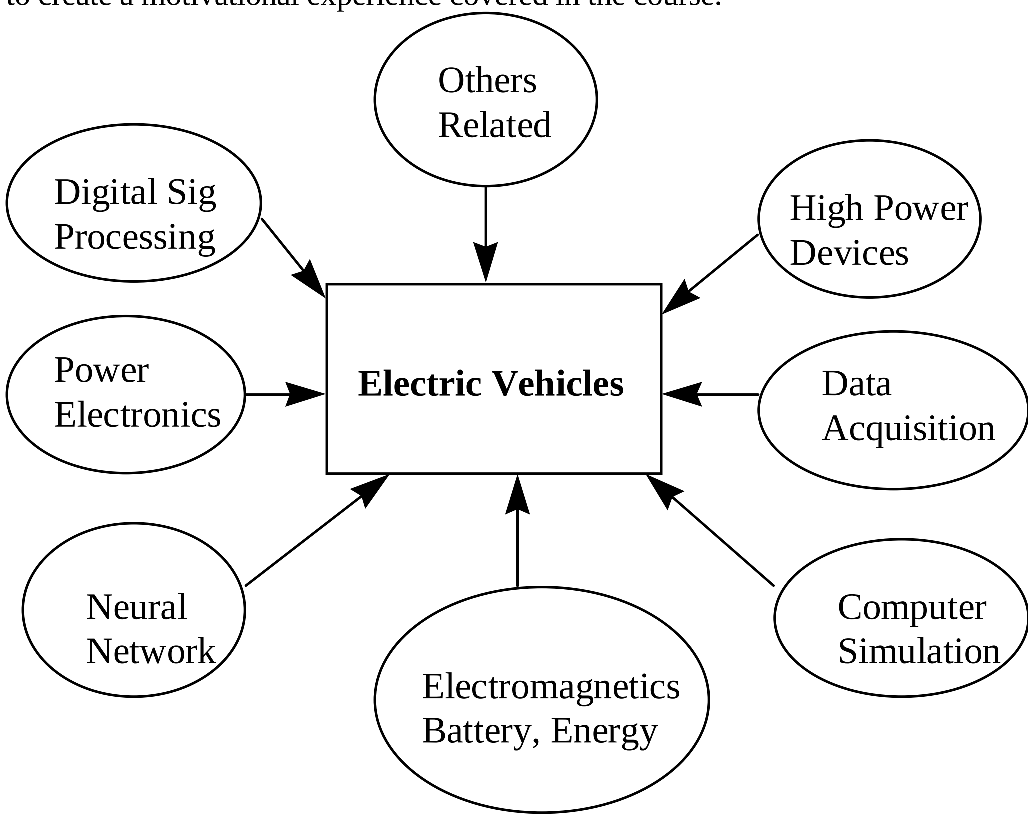

Figure 1: Concept of Integration of Knowledge

- Integration of knowledge [5]. A spectrum of state-of-the-art topics is covered in the course and students are asked to integrate the knowledge gained through design applications. Figure 1 shows the different topics covered in the course.

- Forming a university consortium to actively disseminate the course. Four universities across the country have agreed to join the consortium and teach the course in their campuses.
- The use of WWW to distribute the course materials and to provide a communication link among consortium members.
- To improve motivation, the course design was based on the attached learning principle, where all topics are attached to real-world application.
- Collaborative group techniques will be used to facilitate teamwork, especially between EE and EET students.

III Problems and Solutions

In the setup of the propulsion system, we faced four main problems:

- <u>Students Safety with a High Voltage System</u>

It is the industry regulation that students must have an insurance if they turn on the power switch of the propulsion system directly and take measurements from the high power systems. The School also raised a concern about student safety. This problem was resolved by using a data acquisition system where hardware cards were introduced inside the PC, giving students access to the propulsion system through a PC using LabView 4.1. However, in doing so, a mismatching problem was discovered.

- <u>The mismatch between signals coming out of the propulsion system and the signals required by the data acquisition "LabView." [4]</u>

This problem was resolved by designing and building a signal conditioning circuit as an interface between the high power side and the data acquisition system inside the PC. Much of the signals coming out of the propulsion system are floated and therefore Op Amp circuitries were designed to provide ground terminals to these signals.

- <u>Availability of technical materials</u>.

Because the materials developed by GM are mostly proprietary, we were not allowed to disclose the instrumentation techniques developed by their researchers. We were able to solve this problem by going through reverse engineering. Senior students who participated in the development have gone through trial and error processes using CAD tools to develop equivalent instrumentation circuit to these developed by GM and other companies. For given data, we were able to develop circuits that can be used to reproduce them. The circuits were tested against input-output data for different sources [1-3].

- The Output Signals were not Clear

After the completion of the data acquisition setup and accessing to the high power points inside the engine, the signals were disturbed and noisy. Much of the trials were made to clean them up by using coaxial cables and filter capacitors, but still the output waveforms were not acceptable. This problem has not been solved but will not prevent successful laboratory performance. This problem is being worked on, using digital filters or by using Pulse Width Modulation (PWM) with digital code for minimum harmonics. The rest of the paper details the LabView setup.

IV. Data Acquisition System

The data acquisition software are necessary for the course to provide student safety, and to provide a computer-controlled electric propulsion system including an AC motor and an inverter.

LabView Data Acquisition System

In this system, a variety of signals can be displayed on the computer screen, which is positioned at a remote station away from any high potentials so that shock hazards to students are eliminated.

Data Acquisition for the Battery Charging System

Modern electric vehicles use 3-phase AC motors as the main drive system for the propulsion of the vehicle. A typical system used to propel a modern electric vehicle is shown in figure 2. This includes a 3-phase AC motor and an inverter that sends AC voltage signals to the motor via three separate high voltage AC cables. The 12 V battery system included in this diagram is a standard type of battery that is currently used in conventional automobiles with internal combustion engines. The high voltage battery can be one of a Sodium/Sulfur battery, a Lithium/Iron battery, a Nickel/Iron battery, or a Lead Acid battery. The later is the most popular type of high voltage battery system used in electric vehicles currently. The amount of energy in the high voltage battery system is the primary factor in determining how far the electric vehicle can travel without recharging. As the inverter is operated to supply high voltage on the AC lines to the motor, the power in the high voltage battery is drained. Thus, it is desirable that the inverter convert high voltage DC to high voltage AC as efficiently as possible to enhance the life of the DC battery to increase the range that the electric vehicle can travel before needing to be recharged. The idea proposed to minimize the harmonics will enhance the efficiency of the system, which means getting the same output for less input power drawn from the battery. This will elongate the life time of the high voltage battery. The cooling system of the vehicle includes a cooling of the AC motor and the inverter. It includes cooling conduits routed through the motor and the inverter. A pump is used to circulate the fluid through the coolant conduits and a radiator that removes heat from the coolant circulating through the cooling conduits.

Low Voltage Data Acquisition

The temperature sensors provide temperature signals that allow the components of the cooling system, such as the pump and radiator fan, to be controlled so that the temperature of the inverter and motor can be controlled. Appendix I gives both low and high power signals.

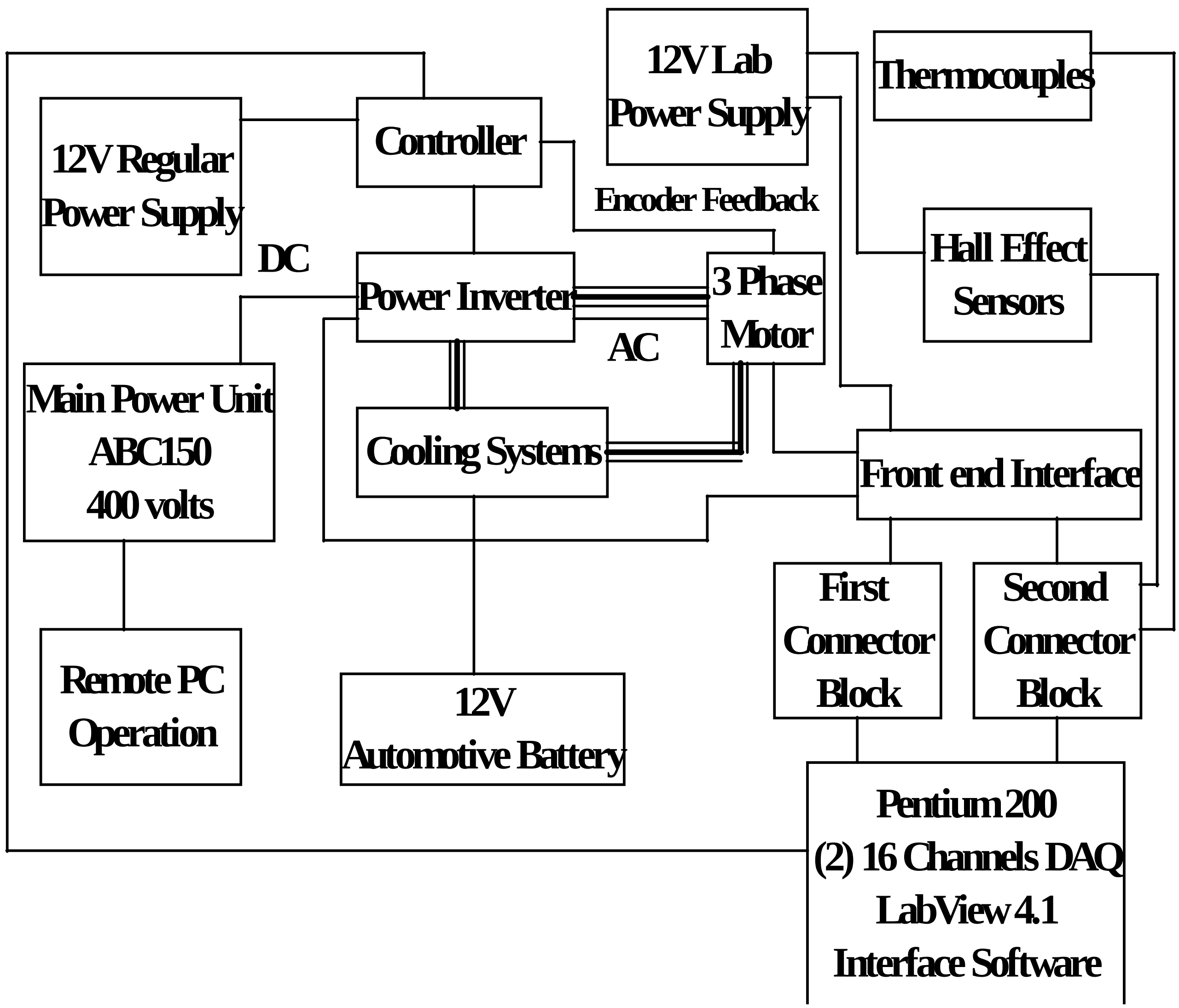

Figure 2: Conventional Motor/Inverter System with Data Acquisition

V. Student Assessment

For each statement, SA=strongly agree, A=agree, N=neutral, D=disagree, and SD=strongly disagree. The following results are presented on a numerical scale with 5 = strongly agree. Since the students surveyed were independent study students, only four students were included in the study.

Item	Results out of 5
In the project course, I learned technical contents that were not covered in any other EE courses.	**4.75**
I enjoyed using computer simulation software to model electric vehicle components.	**4.62**
I enjoyed using LabView to develop data acquisition system.	**4.75**
I enjoyed the hands-on aspects of this course.	**4.375**
Courses like this one motivate me to put more efforts into my studies.	**4.625**
I enjoyed learning about the operation of the different components of the vehicle.	**4.75**
If I were looking for more technical electives, I would like to continue taking more credits in this area.	**4.625**
I am interested in working on a senior design project in this area.	**4.875**
I enjoyed doing outside reading and research to learn more about the different component systems in the electric vehicle.	**4.25**
I enjoy learning on my own with guidance from the instructor.	**4.875**
This course required me to integrate knowledge from other courses that I have taken.	**4.875**
I would like to find a job in this area.	**4.375**
The materials covered in this course have given me a better view of how my engineering education is preparing me for work in industry.	**4.5**
Overall, taking this course was an enjoyable experience.	**4.75**

Even though the students in the survey were motivated by self selection, we are pleased with the initial response. We will survey the first offering of the course in Spring 98 semester.

VI. Conclusion

The interdisciplinary team of faculty from the two sponsoring departments on the IUPUI campus and from the Ohio State University have developed sufficient materials for the course to be offered during the Spring 1998 semester. Assessment of student satisfaction for those who took the course in summer 1997 pilot self study course demonstrates the potential of the course. On a scale 5.0=highly satisfied to 1= highly dissatisfied, the satisfaction data shows that the students were highly satisfied with using computer simulation (4.75/5.00), LabView (4.75/5.00), and hands-on experiences (4.38/5.00); were motivated to put more efforts into studies (4.65/5.00); would be interested in taking more courses (4.63/5.00); doing a senior project in this area (4.88/5.00), the finding a job in this area (4.38/5.00); enjoyed outside reading and research (4.25/5.00); and overall enjoyed the experience (4.75/5.00).

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<u>Appendix I: Low and high power signals displayed by the data acquisition</u>

Acquired Signals	Source of Signal	Type of Signal
1. Encoder Phase I	Motor Encoder	Square Wave
2. Encoder Phase 2	Motor Encoder	Square Wave
3. PWM Triangle	Inverter	Triangle Wave
4. PWM Phase A Sine	Inverter	Sine Wave
5. PWM Phase B Sine	Inverter	Sine Wave
6. PWM Phase C Sine	Inverter	Sine Wave
7. PWM Phase A Square	Inverter	Square Wave
8. PWM Phase B Square	Inverter	Square Wave
9. PWM Phase C Square	Inverter	Square Wave

10. Gate A1 Timing	Inverter	Square Wave
11. Gate A2 Timing	Inverter	Square Wave
12. Gate B1 Timing	Inverter	Square Wave
13. Gate B2 Timing	Inverter	Square Wave
14. Gate C1 Timing	Inverter	Square Wave
15. Gate C2 Timing	Inverter	Square Wave
16. DC Voltage (scaled)	Inverter	Constant
17. DC Voltage (scaled)	Inverter	Constant
18. Phase A AC Current	Hall Effect Sensor	Sine Wave
19. Phase B AC Current	Hall Effect Sensor	Sine Wave
20. Phase C AC Current	Hall Effect Sensor	Sine Wave
21. IGBT Temperature	Thermocouple	Constant
22. Motor Temperature	Thermocouple	Constant
23. Coolant Temperature	Thermocouple	Constant

Biographies:

MAHER E. RIZKALLA holds the rank of Professor of Electrical Engineering at IUPUI. He received his Ph.D. from Case Western Reserve University in Electrical Engineering in 1985. His current research interests include VLSI design as applied to DSP, electromagnetics, solid state electronics, and applied engineering education. He is the recipient of two FIPSE grants and NSF ILI grant, and many other industrial grants. He received the Outstanding Teaching Award from the Department of Electrical Engineering at IUPUI in 1987 and 1993, the Teaching Excellence Recognition Award at IUPUI in 1996, and the Professor of The Year at Purdue University Calumet in 1986. He is a registered professional engineer in the State of Indiana.

CHARLES F. YOKOMOTO hold the rank of Professor of Electrical Engineering at IUPUI. He received the BSEE, MSEE, and PhD degrees from Purdue University. His current research interests are in the area of assessment of learning outcomes, coaching, learning styles, problem solving, and personal heuristics. He has been using the Myers-Briggs Type Indicator (MBTI) in research and classroom applications. In the field of electrical engineering, his research interests are in the area of computer-aided network design, optimization, and design centering.

RICHARD PFILE holds the rank of Associate Professor of Electrical Engineering Technology at IUPUI. His research interests include Microprocessor Applications. He teaches courses in micro-controllers and electric vehicle technologies.

AHMED EL-ANTABLY is a Research Scientist at Delphi Energy Inc, a sub-division of GM, Indianapolis, IN. His research interests include power systems, power electronics, and electric and hybrid vehicles.