

## Automotive Electronics: Enhancing the learning through integrated laboratory

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**Abstract:** Present days' automotive embedded systems have become multifaceted in nature, and their performance has been enabled by introduction of electronics at all levels of design and manufacturing. The purpose of introducing a course on automotive electronics at under graduate level for the electrical sciences stream was to address the needs of embedded and automotive industries and hence providing the necessary knowledge and skills required for those industries.

This paper discusses the process of mixing cognitive and performance learning objectives into one course; which is realized by integrating laboratory with the theory. The laboratory had a focus of building automotive electronics development and test environment for three main domains of automotive which includes power train, comfort/safety and In-vehicle networking. The paper also discusses about the development of in-house experimental trainer modules which demonstrate the entire working of engine management systems.

The laboratory had four different levels of experiments which enabled the students to experience typical automotive embedded system design process. At the same time it is observed that all the levels also address the major three domains of automotive as mentioned earlier. The level one included experiments belonging to automotive sub-systems, demonstration of cut-away modules, level two included model based simulation experiments using MATLAB/SIMULINK & CANalyzer. Level three included experiments on sub module development using sensors, actuators, embedded boards-ARM cortex M3/M4 boards; the last level four was realized through system integration an extended activity which included the integration of sub-modules developed in earlier levels.

The integration of laboratory to the theory course enabled to achieve both technical and professional outcomes of ABET[1]. The outcomes b, c, d, g, i, j, and k were achieved. The paper presents the details of attainment of these outcomes.

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**Key words:** Automotive electronics, integrated laboratory, automotive domains, experiment levels, trainer module, extended activity, ABET outcomes..

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## 1. Introduction

Hands-on experience is very much essential in acquiring physical insight into the embedded systems. Some hardware building experience is very much essential; it is believed that every student should experience the smell of burning plastic of integrated circuit packages. And as a practical matter, most classes do not have the time to let students learn sophisticated hardware platforms with high-performance I/O devices and possibly multiple processors. But at the same time we urge you to avoid the tyranny of hardware building. If you spend too much time building a hardware platform, you will not have enough time to write interesting programs for it. The experience of programming complex embedded systems will teach students quite a bit about hardware as well. There is a requirement for intelligent mix of both hardware and software hands-on for the courses like automotive electronics. The idea of embedding hands-on with the theory is very much essential for application oriented courses like automotive electronics [2].

Automotive electronics is a course which is highly multi disciplinary in nature and which was introduced to all circuit branches as it was highly demanded course of automotive industries. Automotive sector is very huge and new generation vehicles involve around 25-30% of electronics in them. So the automotive sector requires qualified employees in automotive embedded systems. A very large number of students get placed in automotive sector, and these industries mainly seek for competence and skill in automotive embedded systems and model based development.

Automotive electronics course has been introduced since three years in our organization. The course contents were mainly designed with the inputs from collaborating automotive industries like Robert Bosch and KPIT[3]. The course had reached a much matured state with the efforts from faculty and collaborating industries. To provide hands on, the course was supported with the activities like course projects, but it was observed that course project alone cannot provide sufficient hands-on. There was a requirement for a structured approach of providing hands-on to the course. The collaborating industries also expressed the requirement of more practical experience for the course and they came forward to support this activity. So the BVB-Robert Bosch automotive electronics Lab was started at our college.

## Outcome

Integrating the laboratory with theory aims at improving automotive electronics education and emphasizes the training of students' experimental hands-on abilities. It is expected that this can stimulate and promote the education program in students' experimental hands-on experience and produce more skilled automotive electronics engineers.

Organization of the paper is as follows section II deals with Structure of the Laboratory, Section III discusses process of developing experimental modules , section IV deals with Outcomes of the laboratory, evaluation methods , their effectiveness and discussion and section VI with Conclusion

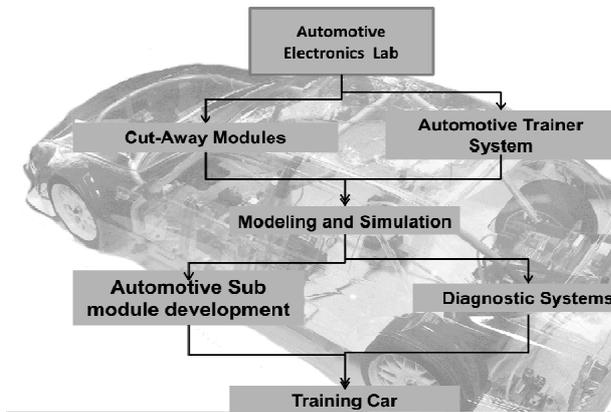
## 2 Laboratory model

In this section the details of laboratory structure and development procedures of in-house trainer models are discussed. The main focus of laboratory was build automotive electronics development and test environment for power train, comfort, safety and In-vehicle networking. With respect to this the laboratory had following learning objectives,

- To enable the basic concepts of the operation of automotive mechanical sub-systems.
- To model, simulate, develop and analyze the electronic systems related to,
  - Engine control
  - Transmissions
  - Safety systems
  - Automotive embedded networking protocols
  - On-board diagnostics systems.

The structure of the lab was decided based on industry inputs. The experiments flow was chosen according to the automotive embedded system design flow. Typically, in automotive industries the carmakers provide the specification of the subsystems to suppliers, who are then in charge of the design and realization of these subsystems, including the software and hardware components. The results are furnished to the carmakers, who in turn integrate them into the car and test them. Based on this design process, the entire laboratory had four levels of

experiments. The structure of the laboratory is shown in figure 1. Again at each level it is observed that all the levels also address the major three domains of automotive as mentioned earlier[4] [5]



**Fig. 1 Automotive electronics Lab structure**

### 2.1 Level-I Demonstration of Cut section modules

At the first level the objective was to demonstrate the students about the construction and working principles of conventional and some very basic automotive systems like engine management system. This was realized by two main categories of experiments one the practical exposure to automotive mechanical systems was provided with the demo lab sessions by automobile department. The course is taught for electrical science stream students who have restricted knowledge about mechanical concepts. As the course deals with the development of embedded systems for mechanical systems it becomes sheer important to make the students understand the mechanical concepts in a short time. The conventional methods of teaching only provide an abstract learning [7]. The demo hands on sessions provided by automobile labs provide them knowledge of real working models of an automobile. Students very easily understand the working principles in a very short time. The lab sessions included the hands on sessions on basic automotive mechanical systems consisting of different types of engines (gasoline, diesel), transmission systems, braking systems, steering systems and suspension systems. The labs provide the demos and hands on experiences using cut-sections of all these models. The snapshot of one such model is given here in figure. 1.



**Fig 2. Cut section models**

The other categories of experiments in level 1 were the demonstration of working of engine management system using in-house developed trainer models. The process of development of in-house trainer model is discussed later in the paper. Engine management system is a very a major sub system of automotive. The model had anoption for varying two major parameters of EMS, the injection control and ignition control. The theoretical concepts learnt can be visualized by the trainer model. Below figure 3 is the snapshot of EMS model.



**Fig. 3 EMS trainer model.**

### 2.2 Level-II Model Based Simulation

The next level two is model based simulation experiments using MATLAB/SIMULINK. Model based development is the process towards which all the embedded and automotive industries are moving. To enable our students to gain experience on this we

introduced model based development during second level of the laboratory. For developing automotive applications it is found that simulation to be a vital tool in the timely and cost-effective development of advanced control systems. As a design tool, Simulink has become the standard for excellence through its flexible and accurate modeling and simulation capabilities. As a result of its open architecture, Simulink allows engineers to create custom block libraries so they can leverage each other's work. By sharing a common set of tools and libraries, engineers can work together effectively within individual work groups and throughout the entire engineering department. In addition to the efficiencies achieved by Simulink, the design process can also benefit from Stateflow, an interactive design tool that enables the modeling and simulation of complex reactive systems. Tightly integrated with Simulink, Stateflow allows engineers to design embedded control systems by giving them an efficient graphical technique to incorporate complex control and supervisory logic within their Simulink models.

The figure 4 shows the image of Simulink models.

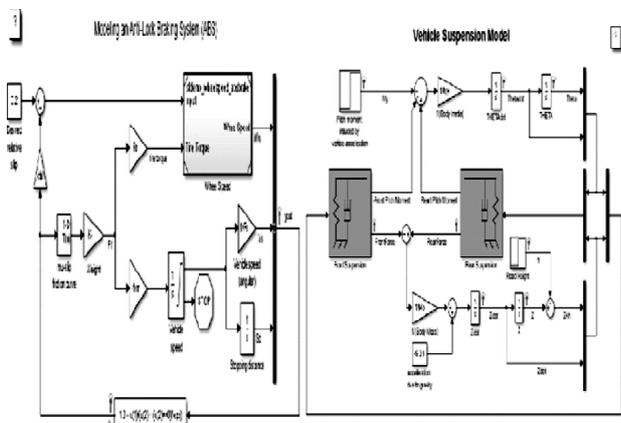


Fig 4 Simulink Models

### 2.3 Level-III Sub Module Development

The third level included the embedded Experiments which had sub module development using sensors, actuators, embedded boards-ARM cortex M4. This level mainly included the experiments belonging to embedded system development. The experiments were involving both hardware and software development for automotive ECU[8]. Students used ARM cortex M3 and M4 as hardware. The software was written using both

embedded C and MATLAB. This level exposed the students both scripting and model development. Fast prototyping or model based development is the new trend in industry. The students wrote a MATLAB/SIMULINK code and ported the application to hardware. Few examples of this level are realization of Engine functions, safety systems like Seat belt warning system, vehicle Speed control, for communication related applications CAN bus implementation. Figure 5 shows the images of sub modules

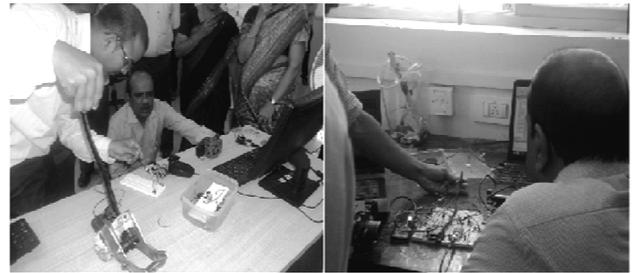


Fig. 5 Sub modules

### 2.4 Level-IV Integration and Testing

The fourth level included integration of multiple functions related to specific system. During this level students integrated the sub modules developed at the earlier stages. The challenges of integrating sub modules, testing and verifying the modules after integration were experienced by the students. Figure 6 shows the images of integrated modules.



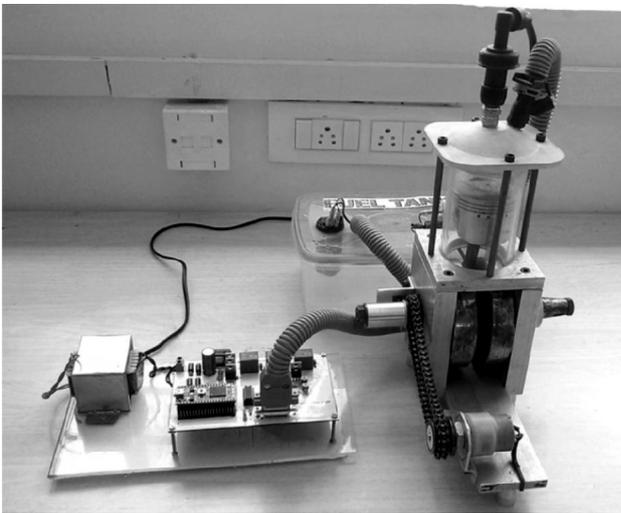
Fig 6 Integrated modules

## 3. Development of Experimental Modules

Indeed we were in need of trainer modules to enhance the learning of the students through practical means but demo modules were not sufficient as these modules were not fit for any experimentation by the students. Then the search for Trainer modules began in the area of EMS, Safety, communication and infotainment.

The Trainer modules available in India were good but after detailed analysis showed that, these modules are very close to demo modules and were not up-to the mark. Some trainer modules from outside India were good enough but the cost was huge and more importantly there was limitation in their programmability of these modules. So this led to the in-house development of the trainer modules and which also did bring down the cost and more importantly enhance the competency of the faculties.

This initiative made us proud because this also falls in line with our nation and our college vision that is “Make in India and Made in India” latter “Make in Hubballi” and “Made in Hubballi”. Figure 6 shows the snapshot of such module.



**Fig. 6 Fuel injection/ Ignition system model**

Many industries and university experts visited automotive electronics lab expressed their view that, this is the best way to enhance the learning of the students through the trainer module that are developed in BVB campus, enquired if these modules can be procured from BVB. Many modules are being developed one such module is EMS, named as Hardware in loop for Engine management system.

This module “Hardware in loop Engine Management System” is the model which replicates the real time engine management system. The main need of the model is, in real time to analyze the working principle of engine system is very difficult and complex so by this model it is easy to analyze and understand working principle of the engine. To demonstrate engine in the lab or classes etc., it is difficult to show the real engine and it is not easy to

use, no safety to learn so there is requirement of the product which will do the same work and exact replica of the real time engine therefore it will give the good environment to learn.

The sensors used in Hardware-in-loop for Engine Management System.

1. Metal sensor [SM18]
2. IR sensor [MOC 7811]
3. Temperature Sensor [LM35]
4. Pressure sensor
5. Level Sensor

The circuit operates on 12v DC Regulated power supply. Metal sensor detect the position of Crankshaft at TDC in order to ignite the spark using Ignition coil and Spark plug. IR sensor detects Speed of Engine RPM & the position of Crankshaft at BDC in order to Inject using Fuel injector. Temperature sensor detects the temperature of the Engine. Pressure sensor detects the Air Pressure. Level sensor indicates the fuel level in the tank.

The next step was to program a graphic user interface (GUI) for deployment with a personal computer. With the GUI, user has the option of see how an interface is built. More commonly, even without knowledge of programming they can simply use it to experiment with the basic interfacing and control operations, e.g., in a freshman class hands-on experiment, by modifying controller parameters from the GUI. Since the system counts with a USB for programming this same port was used for the computer serial interface.

The first GUI was written in Visual Basic. The first part of the project was to make a connection between the serial interface and the embedded controller and build some very basic instructions that the controller will read and interpret then control action is done.

#### 4. Outcomes and Effectiveness

Integration of laboratory with the theory helped the students to attain both technical and professional competencies. The major technical competencies achieved were,

- Embedded system design flow
- Modular software development

- Handling multiple files during software development
- ECU design
- Integration of modules
- Optimization techniques
- Model based design techniques
- Porting of applications to different platforms

The major professional competencies achieved through the activity are,

- Ability to work with larger team
- Industry experience
- Deadline management
- Project Management
- Communication skills
- Working with Multi-disciplinary teams
- Present trends in industries
- Working with tools

The activity also helped to achieve both technical and professional outcomes of ABET. The outcomes b, c, d, g, i, j, and k were achieved[6].

## 5. Conclusion

The details of the integrating laboratory with the theory are discussed. The laboratory design enabling the students to experience the embedded systems design flow is discussed. The process of developing in-house trainer model is elaborated. The introduction of laboratory provided the desired competency and skill development for automotive engineers.

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