# Enhancing Experiential Learning of Hardware Concepts for the undergraduates of Computer Science and Engineering


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***Abstract*— The focus of Computer Science Engineering graduates is inclined towards software oriented base. To be an efficient programmer there is a need to understand the role of hardware architecture towards the same. It is essential for the students of Computer Science and Engineering to know the basic building blocks of any computing device and how the digital principles can be used to build them. Hence two courses Digital Electronics of 3 credits, which is associated with lab of 1.5 credits and Computer Organization of 5 credits, were introduced at the sophomore level. Activity was introduced with the objective to teach the hardware concepts to the students of Computer science engineering through structured lab. The students were asked to design and implement a component of a computing device using MultiSim simulation tool and build the same using hardware components. The experience of the activity helped the students to understand the real time applications of the SSI and MSI components. The impact of the activity was evaluated and the performance was measured. The paper explains the achievement of the ABET outcomes a, c and k.**



**Keywords—Digital, Computer Organization, ABET, Structured enquiry, course activity**


## I. Introduction

There has been a great breakthrough in the field of digital electronics. With this strong impact of digital technology in our everyday life, a course in digital concepts and design is a standard requirement in Computer Engineering. The students of Information science and engineering have two subjects Digital Electronics (DE) and Computer Organization (CO) at the sophomore level related to electronics and embedded system. The course, Digital Electronics provides an understanding of the basic principles and the application of these principles to the analysis and design of the combinational and sequential logic circuits, which are the basic parts in any computing device.

The course DE is 3 credit course supported by laboratory course of 1.5 credits. The courses DE and DE lab mainly focus on design and implementation of combinational and sequential circuits using SSI and MSI Components. The lab courses are evaluated for 80% in Continuous Internal Evaluation (CIE) and 20% in Semester End Exam (SEE). The CIE for theory includes 20% marks for student activity. In the lab, course term works are weekly evaluated for 60 marks of CIE and 20 marks for the structured enquiry. Similarly, the course, CO describes the organizational features of a computer and the ways basic functional units are connected to form a complete computer system. This course is a 5 credit course which is not supported by a laboratory. This course mainly focuses on the basic functional units of the computer and how these units work together to execute the instructions. The traditional approach to teaching the digital electronics laboratory included eleven weeks of laboratory exercises starting with basic gate circuits and ending with state control counters. The last three laboratories focus on the design of a digital system. The new technique reversed the process by integrating the design into every laboratory and using a design team concept [1]. Active involvement in learning helps the student to develop the skills of self-learning while at the same time contributing to a deeper, longer lasting knowledge of the theoretical material [4]

Earlier the course activities were carried out independently. The drawbacks of this approach were identified as follows.

- The knowledge of real time applications of the SSI and MSI components was lacking.
- The concepts learnt in the CO course was not applied practically.

To overcome the above said drawbacks an integrated course activity was designed, where the concepts from two core courses DE and CO were applied in the DE Lab as part of Structured Enquiry. The DE Laboratory plan is prepared covering the theory syllabus. Also proper co-ordination is maintained between theory and lab so that we ensure the student has understood the concept before he/she enters the lab. In the first week of the semester the students were made aware of the Lab plan and Lesson Plan. In order to inculcate the spirit of learning and to develop own ideas, Structured Enquiry Lab was introduced. Here the students were given scope to come up with innovative ideas which provided an exposure to the students to exhibit the course learnt.

### A. TEACHING AND LEARNING OBJECTIVES

i. **Improving student learning**: the provision of a deeper and more lasting understanding of the theoretical material through learning that is active, not passive; increasing interest, motivation and enjoyment; improving retention of theory through immediate application; development of new learning paths; the development of understanding of the application of a particular theory to a range of situations outside of one's discipline [5].

ii. **Integrate curriculum elements**: link theory more closely to practice; integrate material from different courses (e.g. Digital Electronics and Computer Organization);

This paper presents the method followed to correlate the courses DE and CO to achieve the following said objectives

- Implement the concepts of the course CO
- To understand the practical aspects of SSI and MSI Components.
- Exploring the use of a simulation tool.

In this paper, section II explains the approach of the course activity conducted along with case studies and section III explains the performance measured for the activity.

## II. APPROACH OF THE ACTIVITY

This part of the paper explains the procedure followed during the conduction of the activity. The Fig. 1 explains the process model of the activity which was carried out over span of twelve weeks.

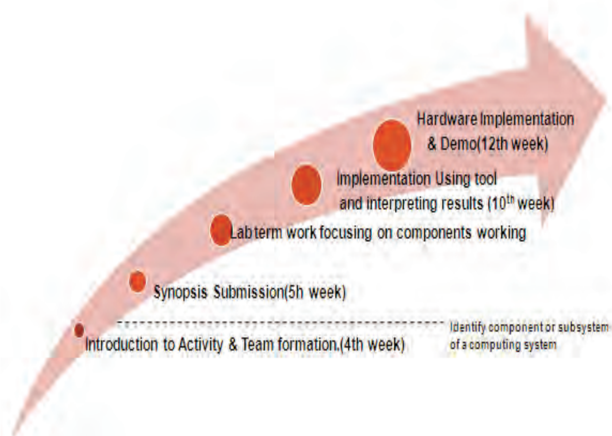


Fig 1: Roadmap of the activity

The activity was evaluated in three reviews in fifth, eighth and twelfth week respectively. During the first week of the semester an introduction to the group activity was given and students were asked to form their teams. The students were asked to design a component of a computing device using the digital components and submit the synopsis containing the components and its design specification in fifth week which was evaluated in review 1. At the same time i.e. during first week to eighth week, students constructed and conducted experiments by designing the digital circuits like multiplexer, decoders, arithmetic circuits and counters using SSI and MSI components. Parallely, in CO the concept of basic processing unit was covered. This helped the students to understand the practical applications of the digital components explore and finalize the problem statement for the activity. Implementation of the project using simulation tool was evaluated as a part of DE theory in the eighth week in review 2. At the same time the evaluation was done for CO. The marks were allotted based on the concepts chosen from CO for the activity. For the DE theory activity, students explored the tool in selecting the components and in observing the behavior of the circuit for different set of inputs.

Some components were not supported by the tool for which the students themselves explored the alternate components that can be replaced, which improved circuit analysis skill of the students. Usage of simulation tool helped them to analyze and optimize the circuit. Phase wise hardware implementation of the activity was carried out in ninth, tenth and eleventh week. The final demonstration was carried out in the twelfth week as part of review 3. In this student teams demonstrated the working of hardware circuits, where the output for multiple combinations of input was checked. Here the problem statements for the activity were chosen such that the concepts of CO course were covered. It also helped the students to understand the instruction execution cycle. By doing this students got the knowledge of both the courses. Some of the problem statements chosen by the student team were as follows:

- Design and implementation of 2-bit ALU.
- Design and implementation of 1-bit stack of 4 words.
- Design and implementation of Bus arbitration.

Two of the case studies are considered as follows.

### *A. Case Study 1: Implementation of De-centralized Bus arbitration using digital electronics.*

The logic circuit replicates the Bus arbitration process used in computers to select a Bus master among the devices which request for it. There are two approaches to Bus Arbitration: Centralized and De-centralized. In centralized arbitration, a single bus arbiter performs the required arbitration. In De-centralized arbitration, all devices participate in the selection of the next Bus master. The device is depicted as a memory element (i.e., D-flip-flop) which uses the Bus to display data stored in it. Here four devices have been taken into consideration. There are also indicators to show which device is active at the moment. The data is fed into flip-flop's using logical inputs. The Fig. 2 shows the simulation model of the Bus Arbitration.

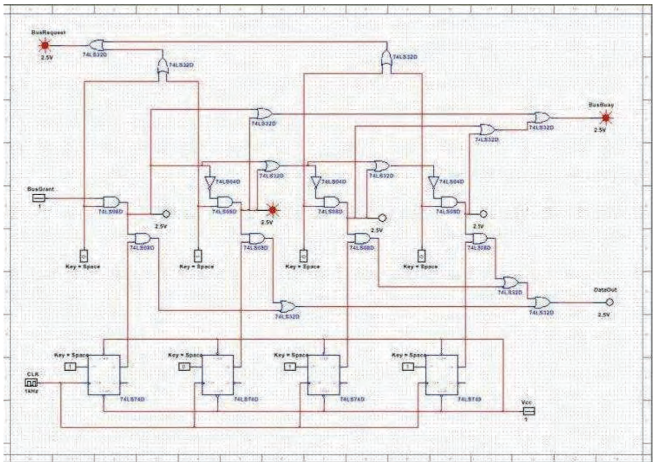


Fig 2: Simulation model of bus arbitration

Devices send a bus request signal in order to gain Bus Mastership .When request signal of any device is set, the Bus Request and Bus Busy signals go high. The Bus Grant signal is given as constant high, when a device gains mastership. It blocks the Bus Grant signal propagation to further devices. To indicate that a device has gained mastership, the data in the flip-flop appears at the output. The devices electrically closer to the grant signal have higher priority than the farther ones. If more than one devices request for the Bus, the one with higher priority gains the mastership of the Bus.

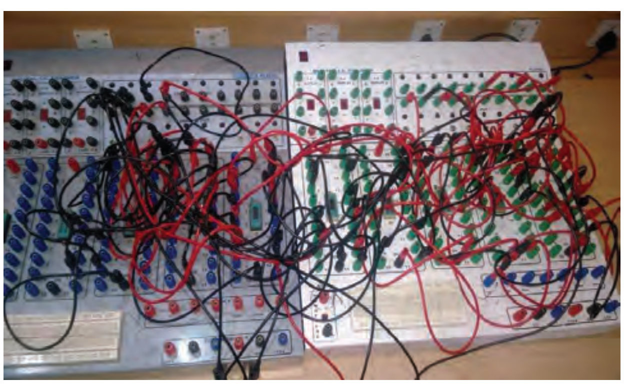

Fig 3: Logic Diagram of Bus Arbitration

The Fig. 3 shows the logic diagram for the bus arbitration. The inputs for the system are Bus request signals and Data input to flip-flop and the outputs are Bus Busy Indication, Bus Request Indication, Data output and Device status.

*B. Case Study I1: Implementation of Stack using digital electronics.*

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The DIGISTACK shows whether the elements pushed inside the stack is either of 0 or 1, status of the flip-flop (whether s filled or empty) and whether the complete stack is in full or empty condition. This is obtained by using shifting operation. D flip flops are used to store the data on which push and pop operations are implemented. Push operation is to store the data element in the flip flop and pop operation is to delete the data element from the flip flop. And to indicate the status of the flip flop whether it is full or empty the other set of flip flop and multiplexers are used. And the element is present or no in each flip flop is also indicated. The Fig 4 shows the simulation model for the DIGISTACK.

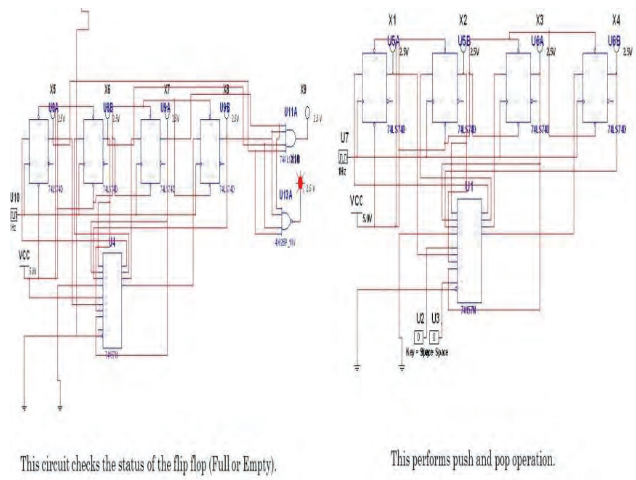


Fig 4: Simulation model of DIGISTACK

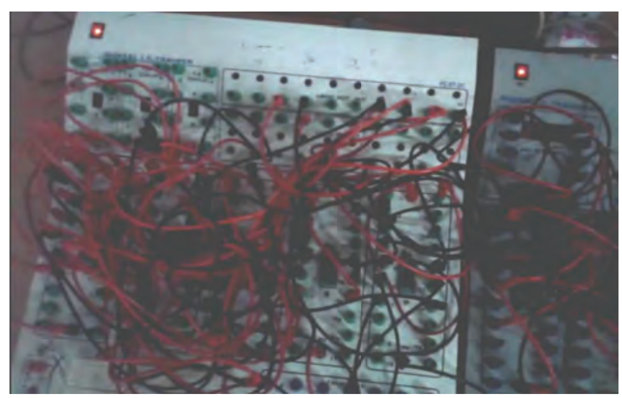

Fig. 5: Logic diagram of DIGISTACK

The Fig. 5 shows the logic diagram of the stack. The input for system are PUSH and POP instructions for the data stored in the 1-bit register. The register consisted of 4 words.

## III. PERFORMANCE MEASUREMENT

The Impact of conducting this activity was assessed by comparing the outcomes attained in activity during the year 2013.
The Fig. 6 shows the comparison of the outcome attainment of the activities conducted during the respective years. The outcomes are mapped to the ABET criteria [2][3]. The Table I gives the mapping of PO's to the PI's.

TABLE I. MAPPING OF PO'S AND PI'S

| Courses | Program Outcomes | Performance indicator |
|---|---|---|
| Digital Electronics theory activity | **a** : An ability to apply knowledge of mathematics, computer science and engineering | **a3A** :Apply the knowledge of System Engineering |
| | **k**: An ability to use the techniques ,skills and tools necessary for computer engineering practice. | **k1A** : An ability to use techniques, skills and tools necessary for computer engineering practise |
| Digital Electronics lab structured enquiry | **a** : An ability to apply knowledge of mathematics, computer science and engineering | **a3A** :Apply the knowledge of System Engineering |
| | c: An ability to design a computer based system, component or process to meet the desired needs within realistic constraints. | **c3A**: Ability to develop an algorithm. Functional module. **c3B**: Ability to implement the modules. |
| Computer Organizatio n Theory | **a** : An ability to apply knowledge of mathematics, computer science and engineering | **a3A** :Apply the knowledge of System Engineering |

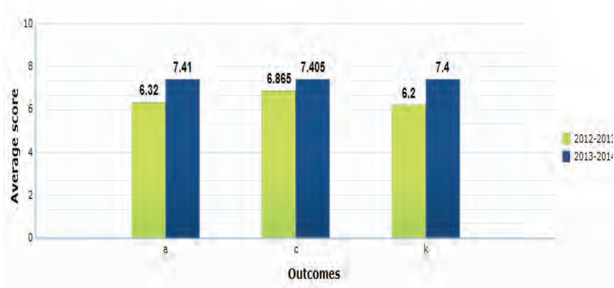


Fig 6: Comparison of outcome attainment

In Fig 6 x-axis shows the ABET outcome and Y-axis shows the average marks scored by the students. The analysis shows that there is an improvement in outcome a, c and k. Through the integrated course activity following outcomes were achieved

- Fundamental concepts were clear to the students, which addressed program outcome 'a'(apply the knowledge of system engineering-a3A)
- Since the basic concepts were clear, students could design and implement the given activity. This helped to strengthen outcome 'c'(ability to develop a algorithm/functional module-c3A;ability to implement modules-c3B)
- Usage of simulation tool helped the students to analyze and optimize the circuit. Through this outcome 'k' could be achieved. ( Ability to use CASE tools for modeling and simulation- k1A)

Student satisfaction about the course activity was measured by taking the feedback for the questionnaires shown in Table II.

TABLE II. FEEDBACK QUESTIONAIRIES

| Sl.No | Questions | Answers |
|---|---|---|
| 1. | Integrated learning made the concepts of two courses clear. | SA A N D SD |
| 2. | Applying the knowledge of digital electronics to design computer subsystem was a challenge and interesting. | SA A N D SD |
| 3. | Simulation of the design using Multisim tool was of a great help to understand the working of the circuit. | SA A N D SD |
| 4. | Identifying the different designs for the problems and discussing with the staff helps in finalizing the design | SA A N D SD |

**SA**: Strongly Agree, **A**: Agree, **N**: Neither Agree Nor Dis-Agree, **D**: Dis-Agree, **SD**: Strongly DisAgree

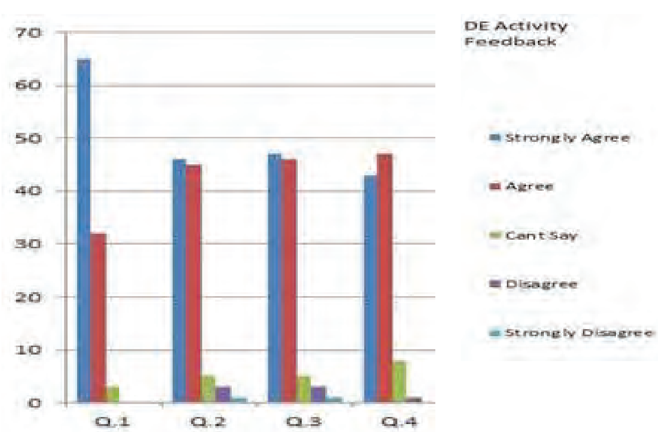


Fig. 7: Feedback Assessment

The feedback given by the students as shown in Fig. 7, shows that most of the students agreed that integrated learning improved their understanding of the basic concepts due to which they were able to build the component using the tool and hardware in a better way.

## CONCLUSION

Integrated learning of Computer Organization and Digital Electronics helped the students in understanding the concepts of both the courses. This integrated approach enhanced student's designing skills, circuit analysis skills and tool utilization. This also helped the students to apply the knowledge of the digital electronics in real time applications.

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