FreeEDA-An Effective Open Source Software for Teaching Engineering Design Course in Electrical Sciences

Sachin Angadi, Anupama Itagi, Sushma V, Kiran R Patil and A B Raju
Department of Electrical and Electronics,
B.V.B College of Engineering and Technology,
HUBLI-580031, KARNATAKA.
sachin@bvb.edu.

***Abstract*—This paper describes the significance of Engineering Design course for allied Electrical Science branches and proposes the use of open source software Free Electronic Design Automation (FreeEDA) tool for effective Teaching-Learning process. The essential requirements of the software identified for teaching the above said course are circuit simulation, Printed Circuit Board (PCB) layout design and 3-D view of the PCB designed. Survey is done by the authors to identify open source software that incorporates the aforementioned requirements. Among different available open source software, FreeEDA has attractive features. Besides basic requirements FreeEDA comes with additional feature of generating system of equations for circuit under consideration and solves them using Scilab. This facility is not available in any commercial simulator. To validate the listed features of FreeEDA a case study of full bridge rectifier is presented.**

I. INTRODUCTION

In present days, engineering education demands engineering graduate to be fluent with set of basic principles necessary to solve real time engineering problems. Hence engineering design is given considerable attention over last few years in design of engineering curricula. Engineering is the application of science for the betterment of mankind. Design is the innovative expression of knowledge. One of the verticals in engineering is to study the laws, fundamental principles, characteristics of materials and so on which can be referred to as engineering science. However when we start utilizing this knowledge of engineering science for betterment of the mankind. We are now being innovative with our knowledge to create new engineering marvels. To put everything in nutshell Engineering design involves the development of a concept and a form to meet a function.

Authors in [1] have discussed the significance of engineering design and also have proposed novel methodology of teaching engineering design for first year students using computer technologies. Authors in [2] have proposed a novel methodology for delivery of engineering design course for undergraduates in MIT using flexible input desirable output controller. Robert LeMaster et al. in [3] have made an attempt to introduce competitive situation in which students must design a real world device. Clive L. Dym et al. discusses with various case studies (Mechanical Sciences) about teaching engineering design to freshmen [4][5]. There is considerable literature available for teaching engineering design for mechanical sciences. However aspects of engineering design for electrical sciences are difficult to find. Also the available methodologies for course delivery of engineering design takes help of proprietary software and hardware platforms which are not suitable for large classrooms.

The importance of Engineering Design for allied Electrical Science branches was realized and hence an effort was put in by a committee in BVBCET to bring in this course for allied Electrical Science branches. The course was designed with the title Engineering Design. It was delivered for the first time in January 2014 for second year engineering students of Electrical sciences in BVBCET, Hubli. Curriculum structure design played an important role in bringing awareness among the students about the application of design process to real world problem. The course essentially discusses the series of steps to be followed to propose a suitable solution to a real time engineering problem. The design of the curriculum structure is out of scope of this paper.

Paper is organized as follows. Section II discusses the engineering design methodology and need for electronic design automation (EDA) platform to teach engineering design for allied Electrical Science branches. Section III introduces various modern engineering tools and their comparison for course delivery. Section IV introduces FreeEDA tool. Section V discusses case study of full bridge rectifier to demonstrate the features of the FreeEDA tool. Section VI concludes the paper.

II. CONCEPTUAL BACKGROUND

The various design steps the students are expected to learn are detailed in the prescriptive design process illustrated in Fig.1. In the block diagram, there are square blocks which represent the process/step, oval blocks which represent input and output of the block respectively. An engineer always starts his design by identifying problem. The very first step is to reshape the problem statement given by the customer based on the resources and skill set available. Redefined problem statement, outputs customer requirements which in turn yield various designs for problem definition. All the possible designs are subjected to conceptualization to call in for one or two best possible designs. These one or two concluding designs are to be tested and evaluated to come up with one ultimate solution to be proposed. The chosen design is then further studied in depth for its feasibility of implementation

leading to deriving design details for implementation. Once the design details are ready, it is communicated using technical reports. Not all the design steps in the process demand usage of modern engineering tools. However it is inevitable to use modern engineering tools for better understanding of few steps involved in design process such as testing/evaluation and detailed design highlighted in the block diagram [4].

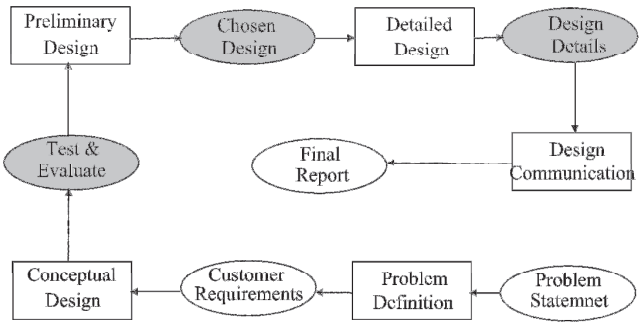

Fig. 1. Block diagram showing different steps in Engineering Design

It was identified that software which facilitates circuit simulation, PCB design and its 3D view is essential for teaching the Engineering Design course for electrical sciences. To meet all the laboratory requirements, proprietary Electronic Design Automation (EDA) tool AUTOTRAX was used for delivering course for the first time. The course delivery details are discussed below in brief. The fundamentals of design methodology were dealt in the classroom. The laboratory sessions for the course were planned suitably to promote the skills required for different steps in engineering design using modern engineering tool. PCB design was chosen as premise to make students understand few important steps of Engineering Design. Laboratory course intended to teach students, the simulation of electronic circuit, deriving its PCB layout and building its 3D model. Course project was introduced to make students understand the design process, bring in team work, raise their confidence and develop effective communication skills. Thus the course is delivered in a versatile manner by addressing students of all learning styles. However the choice of proprietary software for course delivery posed the following limitations:

- No proper study material (manuals and cheat sheet).
- No free license for auto routing tool for PCB design.
- Does not have spice netlist for most of the popular electronic devices like operational amplifier and many more.
- Restricted availability of the software hinders the effective learning of the student.

This paper is an attempt made by authors to show that few intermediate steps in engineering design process demand usage of technical tool. FreeEDA, an open source modern engineering tool can be effectively used to ensure effective Teaching-Learning process.

III. Modern Engineering Tools

The aforementioned prerequisites are satisfied by many proprietary(student version)/open source software independently. However the requirement was single open source software that provides atleast circuit simulation and PCB layout. A survey conducted to find one such software is presented in Table.1

Survey shows that FreeEDA software is suitable for effective Teaching-Learning process of the course.

IV. FreeEDA

FreeEDA is an open source EDA tool for circuit design, simulation, analysis and PCB design. It is an integrated tool built using open software such as KiCad (http://www.kicad-pcb.org), Ngspice (http://ngspice.sourceforge.net/) and scilab (http://www.scilab.org/). It was previously called Oscad. FreeEDA offers similar capabilities and ease of use as any equivalent proprietary software for schematic creation, simulation and PCB design, without having to pay a huge amount of money to procure licenses. Hence it can be an affordable alternative to educational institutions. It was developed by FOSSEE (free and open source software in science and engineering education) group at IIT Bombay. Following are few important features of FreeEDA:

- The software is capable of performing schematic creation, PCB design and circuit simulation (analog, digital and mixed signal)
- The software provides facilities to create new models and components.
- It has capability to explain the circuit by giving symbolic equations and numerical values.
- FreeEDA can be ported on Aakash, the world's lowest cost computing tablet with Linux operating system.
- Spoken tutorials are available to enhance self learning. These spoken tutorials can be downloaded from www. spokentutorials.org
- FOSSEE is involved in Lab migration activity through FreeEDA. This activity aims to migrate labs that use proprietary software to a Free and Open Source Software (FOSS) only.
- Subcircuit and model builder are also available.
- Runs on Linux and a few flavors of Windows (XP and 7, at present).

The functional block diagram of FreeEDA is as shown in Fig.2. The block diagram shows that working consists mainly of three parts:

- Schematic Editor.
- Circuit Simulators.
- PCB Layout Editor.

TABLE I. COMPARISON OF OPEN SOURCE SOFTWARE

Software/Features	Schematic	Simulation	PCB editing	OS platform	Open Source	Gerber File	Mathematical Model
Pspice	X	X		Windows			
Ngspice	X	X		Windows/ Linux	X		
Express PCB	X		X	Windows			
KiCAD	X		X	Windows/ Linux	X		
FreeEDA	X	X	X	Windows/ Linux	X	X	X

Any electronic design starts with drawing schematics on paper and the same is entered into computer using schematic editor EEschema. The schematic editor provides the netlist file describing the electrical connections of the schematic in EEschema. After entering the schematic into the schematic editor it is essential to check the integrity of the circuit design. In case of large electronic circuits breadboard testing is impractical. In such situation simulation comes to rescue for electronic engineers. The accuracy of the simulation can be increased by modeling the electronic devices using data available in datasheets. Model builder allows user to define a new model for a device or even edit existing models. The netlist generated by schematic editor cannot be directly used for simulation due to compatibility issues. Netlist converter helps in converting netlist into Ngspice compatible format. Different types of simulation and analysis to be performed on the circuit are provided through Graphical User Interface (GUI) with help of analysis inserter in FreeEDA. To perform component to footprint mapping, CvPCB is used. Once the CvPCB does mapping, the PCB layout of the schematic can obtained by manual routing or auto routing.

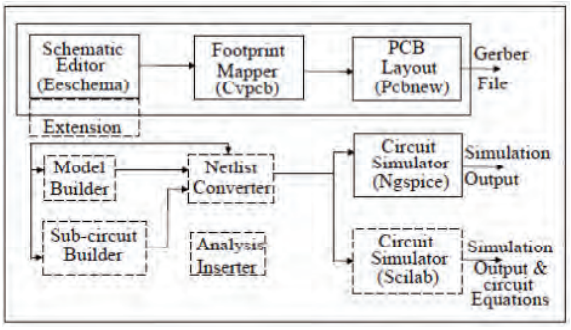

Fig. 2.Functional Block diagram of EDA.

FreeEDA has unique feature of Scilab based circuit simulator. It generates equations from netlist and gets them solved by Scilab, which has many built in state of art numerical methods. This tool is called Scilab based Mini Circuit Simulator (SMCSim) in FreeEDA [6].

V. CASE STUDY

As discussed in previous section FreeEDA comes loaded with many features, exploring which, user can easily perform simulation of electronic circuit, get its PCB layout and also get the 3D view of the PCB designed. For better understanding of the reader, usage of FreeEDA software for performing aforementioned tasks is demonstrated considering the example of full-bridge rectifier. The schematic diagram of full bridge rectifier done in EEschema schematic editor is given in Fig. 3. Schematic is then subjected to annotation and Electrical Rule Check (ERC). The netlist describing electrical connection between circuit components of error free circuit schematic is given below.

```
V1 4 1 sine(O 5 50 O O)
*plotting option vplot l
r1 3 0 10k
d4 0 1 diode
d3 1 3 diode
d2 0 4 diode
d1 4 3 diode
.tran 5e—O3 30e—O3 Oe—OO
.plot v(3)
.plot v(4)—v(l)
.end
```

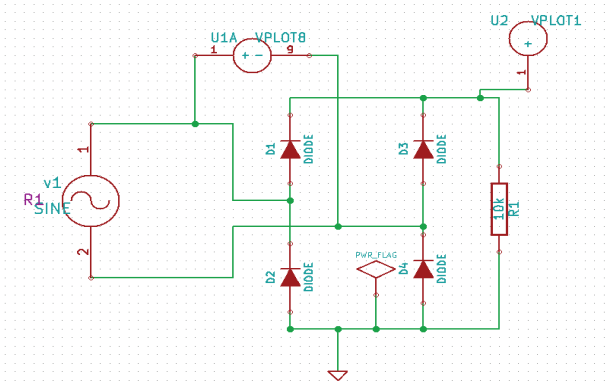

Fig.3. Schematic diagram of full bridge rectifier.

Using analysis inserter GUI, analysis command is generated to perform transient analysis. The Netlist Converter tool is used to enter the details of sources used in the circuit. The netlist created in the schematic editor is converted to Ngspice format and analysis commands are appended to it by Netlist Converter tool [6]. The input and output voltage waveforms of full bridge rectifier circuit are shown in Fig.4 and Fig. 5

PCB design is an important step in electronic system design. Every component of the circuit needs to be placed and connections routed to minimize delay and area. PCB design

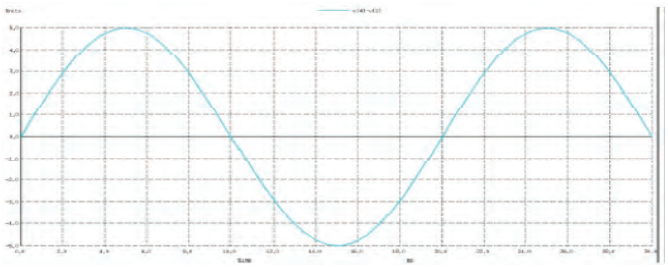

Fig. 4. Input of full bridge rectifier

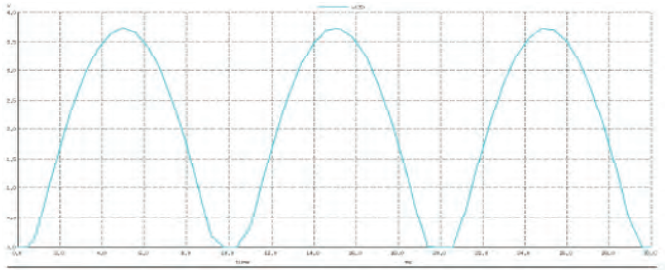

Fig. 5. Output of full bridge rectifier

involves associating footprints to all components, placing them appropriately to minimize wire length and area, connecting the footprints using tracks/vias and finally extracting the required files needed for printing the PCB [6]. The PCB layout and its 3D view is given in Fig.6 and Fig.7.

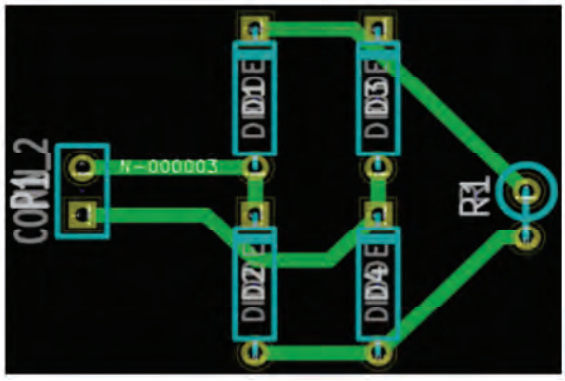

Fig. 6. PCB layout of Full bridge rectifier.

Electronic circuit simulation uses mathematical models to replicate the behaviour of an electronic circuit. Unfortunately, no simulator gives the system of equations it solves, in order to understand the simulation. In FreeEDA there is an option to simulate the circuit using SMCSim (Scilab Based Mini Circuit Simulator). An important feature of SMCSim is that it gives system of equations for the circuit under test. SMCSim works in three modes: normal, symbolic and numerical. In normal mode, SMCSim solves the circuit and gives the final output. In symbolic mode, it gives symbolic equations along with results. In numerical mode, it gives symbolic equations, intermediate numerical values of the components and elements in system matrices and the final output. Scilab modeling equations and the result of full bridge rectifier is shown in Fig.8 and Fig.9 respectively.

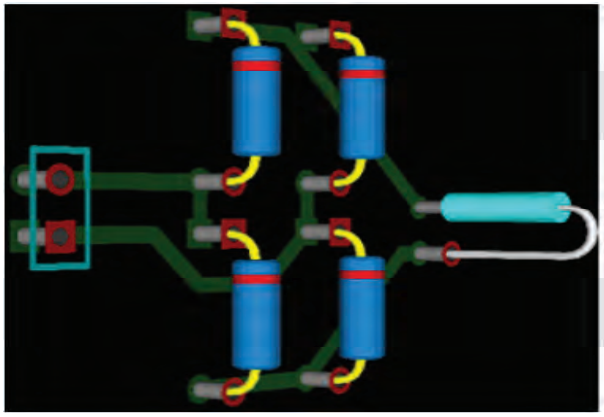

Fig.7 PCB Layout of Full bridge rectifier.

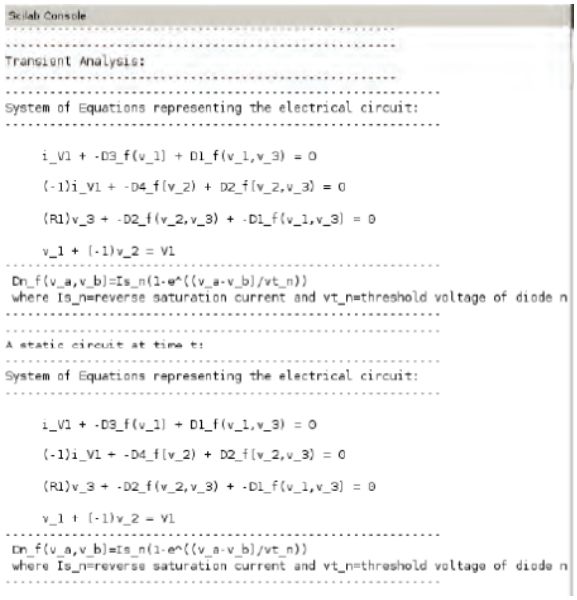

Fig.8 Equation generated by Scilab for full bridge rectifier.

Bill of Materials generated by FreeEDA is given below.

```
#Cmp (order =Reference)
D1 DIODE
D2 DIODE
D3 DIODE
D4 DIODE
R1 10K
U1 VPLOT8
U2 VPLOT1
v1 SINE
#End Cmp
#Cmp (order = value) 10k R1
DIODE D1
DIODE D2
DIODE D3
DIODE D4
SINE v1
VPLOT1 U2
VPLOT8 U1
#End Cmp
#End Cmp
```

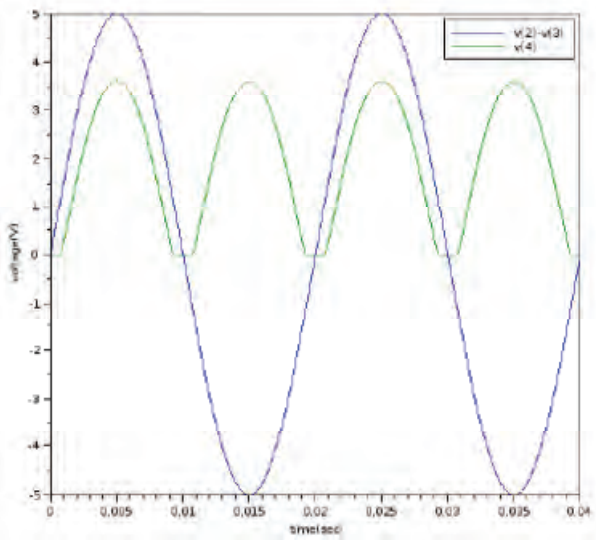

Fig.9.Scilab simulation output of full bridge rectifier.

VI. Conclusion

In this paper authors have proposed the usage of FreeEDA to teach Engineering Design course. As per the survey done, FreeEDA is open source software which supports circuit simulation, PCB design, 3-D view of PCB and mathematical modeling of circuits. This tool can even be used for better understanding of various courses in allied Electrical Science branches. Case study discussed validates the features of FreeEDA.

Acknowledgement

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