
A "true-interactive" CAL package for the teaching of basic electrical circuit theory

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In electrical engineering, circuit theory is an essential subject normally delivered as lectures, tutorials and practical sessions. The cost to conduct practical sessions however is high due to smaller-size classes, the engagement of laboratory supervisors and the requirements on space, test equipment and consumable components. Although Computer Aided Learning (CAL) and simulator packages that claim to be interactive are used to replace practical experiments, the interaction is normally limited to the keyboard and the monitor. For first year students, a virtual laboratory environment can never replace the experience gained from hands on sessions. The objective of this project is to develop a "true-interactive" CAL package that functions as an electronic tutor, laboratory supervisor and assessor. The package consists of three parts. Part A introduces course topics with examples. Part B guides the student through several practical experiments. Students are expected to assemble and measure the electronic circuits as in a normal laboratory session. A custom-built hardware interface allows the software to monitor the student's progress. Finally, an assessment session will test the student's understanding on the subject. This paper provides the technical description of the development of package and discussions on possible further enhancements.

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1. Introduction

Knowledge on passive electrical components, circuit theories and network analysis is essential for the understanding of electrical engineering. While the subjects have traditionally been delivered as lectures, tutorials and practical sessions, the cost to conduct practical sessions is high due to a smaller class size, and the requirements on space, test equipment and consumable components. Although "virtual laboratory" based on simulators and Computer Aided Learning (CAL) packages are introduced, the interaction between the student and the teaching package is limited to the keyboard and the monitor. For first year students, it is essential for them to gain hands-on experience from practical experiments. The purpose of this project is to develop a "true-interactive" CAL package that functions as an electronic tutor, a laboratory supervisor and an assessor. This project was developed with an aim to extend the functionality of traditional CAL packages by including interactive tutorials in conjunction with hands-on practical experiments. The objectives are:

- To develop an interactive multimedia CAL package that provides:
    a. Lessons on basic electrical engineering and circuit theories including:
        i. Passive components;
        ii. Circuit theorems.
    b. Interactive information and guidance to assist practical experiments.
    c. Measurements on student's experimental set up using appropriate data acquisition system.
    d. A set of short tests on the topics covered.
- To construct a portable test bench that provides:
    a. Component Tests.

b. Flexible circuit verification tests.
c. Measurements on tests performed.

- To deliver a user friendly and conducive learning environment.

2. Development cycle

The development cycle of this project consists of five phases: Initial Requirements Study, Design, Development, Testing and Documentation. The first four phases are proceeded sequentially while documentation is maintained throughout the project. A description of each phase is given in the following sections.

2.1. Initial Requirements Study

The topics to be presented in this package are those of "practical" importance in modern electrical engineering. The subject should include theories and illustrative application examples designed to arouse the interest of student. The topics are divided into two main categories, Passive Components and Fundamental Circuit Theories. Understanding of passive components is essential as these devices form the basic building blocks of all electrical and electronic circuits. The basic passive components covered in the package are: Resistor, Capacitor and Inductor. For each component, the topic is further sub-divided into four sections - an Overview, Characteristics, Types and Tutorial. On fundamental circuit theories, a network is treated as a combination of interconnected electrical components. It comes in all forms, ranging from interconnected power lines carrying thousands of volts, to communication networks carrying a vast amount of information. Ability to analyse and understand the characteristics of a network is therefore fundamental in electrical engineering. The methods covered are: Kirchhoff's laws, Branch Current Method, Node Voltage Method, Superposition Theorem, Thevenin's Theorem and Norton's Theorem. For each of the network analysis method, it is further sub-divided into three sections: Concepts, Illustrations and Tutorials. The arrangement is illustrated in Figure 1.

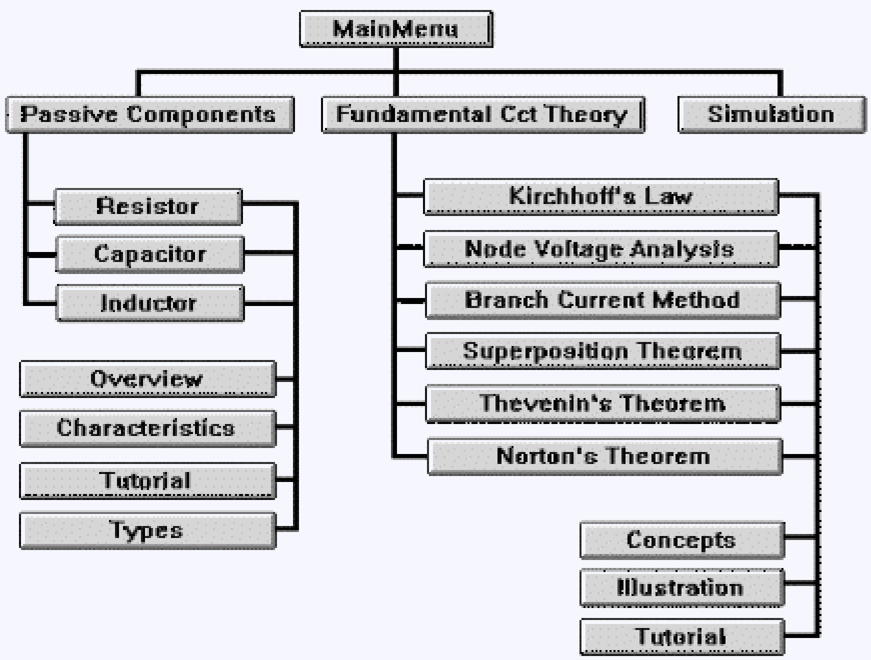

Figure 1: Hierarchical Structure of CAL Package

2.2 Design

The design phase consists of four components:

a. Structure Design - aims to design the overall application structure. This includes tasks such as identifying the various screen topics, gathering screen information, prioritising information, defining the navigation paths between topics and designing the dialogue flow.

b. Content Design - aims to identify and describe elements such as fields and buttons that are incorporated into the software package. Tasks include selecting elements to be used in each screen to convey the appropriate messages, designing screens and functions, creating descriptions of images and graphics, and outlining animation scripts.

c. Design Standards Ð they are necessary to establish a consistent "look and feel" throughout the entire application. Standards include screen layouts, use of color, fonts and point sizes, screen resolution and image format. A list of standards should be documented for reference.

d. Design Walkthrough Ð they are means of validating the system design before continuing with the development activities. Modifications to the design might be required at this stage. Design walkthroughs are done on paper (screen designs) and by building a prototype.

In addition, an interface program is required to send commands and to receive information from the system hardware.

2.3 Development

The development of this project is divided into two main sections. The Software section concentrates on the development of the information presentation and the interface program design. The Hardware section focuses on the system hardware design to support the practical requirements of the package.

For software development, *ToolBook* was selected as the development tool due to its simplicity. ToolBook is an object-oriented software for presentation development operating within the Microsoft Windows environment. It provides graphical drawing tools for creating objects and a full-featured object-oriented programming language called *Openscript*. It offers a way to create Windows applications in a fraction of the time it takes to program in traditional Windows development languages such as C or assembler. It also comes with assorted sample applications and clip art where programmer can use as a source of objects and scripts. This follow figure shows the object hierarchy within a ToolBook application.

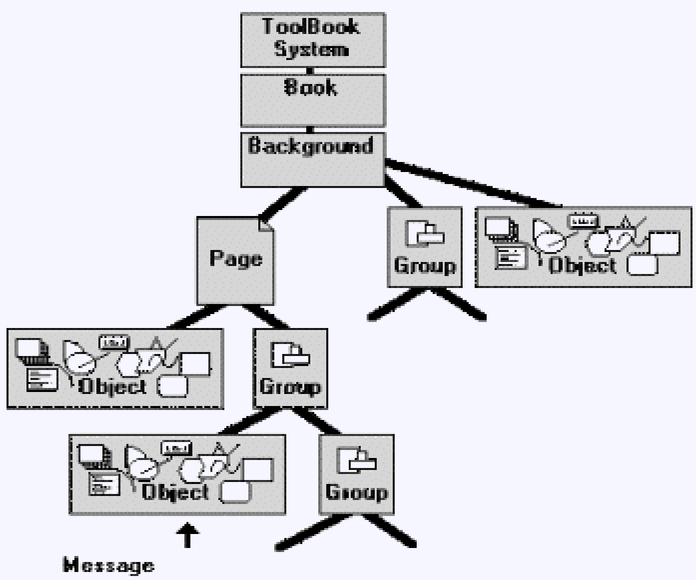

Figure 2: Object hierarchy

To achieve true interactivity, the simulation session guides the user through practical set up and measurements. Values of resistance and voltage from the circuit are obtained via an interface unit between the software and the component or circuit. As ToolBook does not support 'system level' programming, an external programming tool is required. BorlandC++ has been chosen. The information flow between the system software and hardware are illustrated in

Figure 3 below.

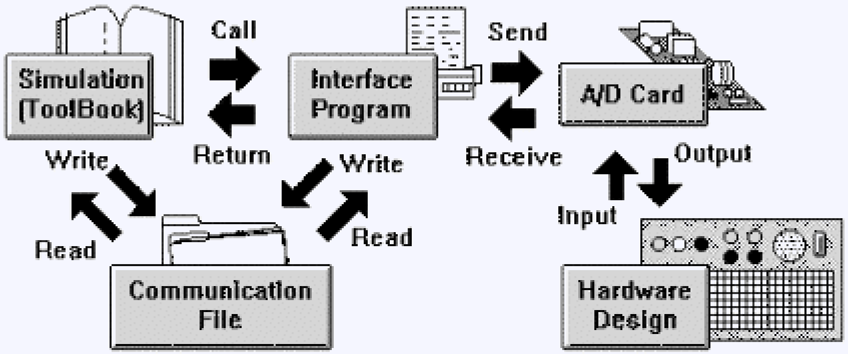

Figure 3: Interface flow design

Basically, there are four main screen designs. Each module has its unique background screen layout to distinguish themselves from the others.

a. **Introduction Screen Design**
   Introduction was designed in a form of a textbook. User can "flip" the pages by clicking the page number indicated at both side of the book. This form of presentation resembles a real book.

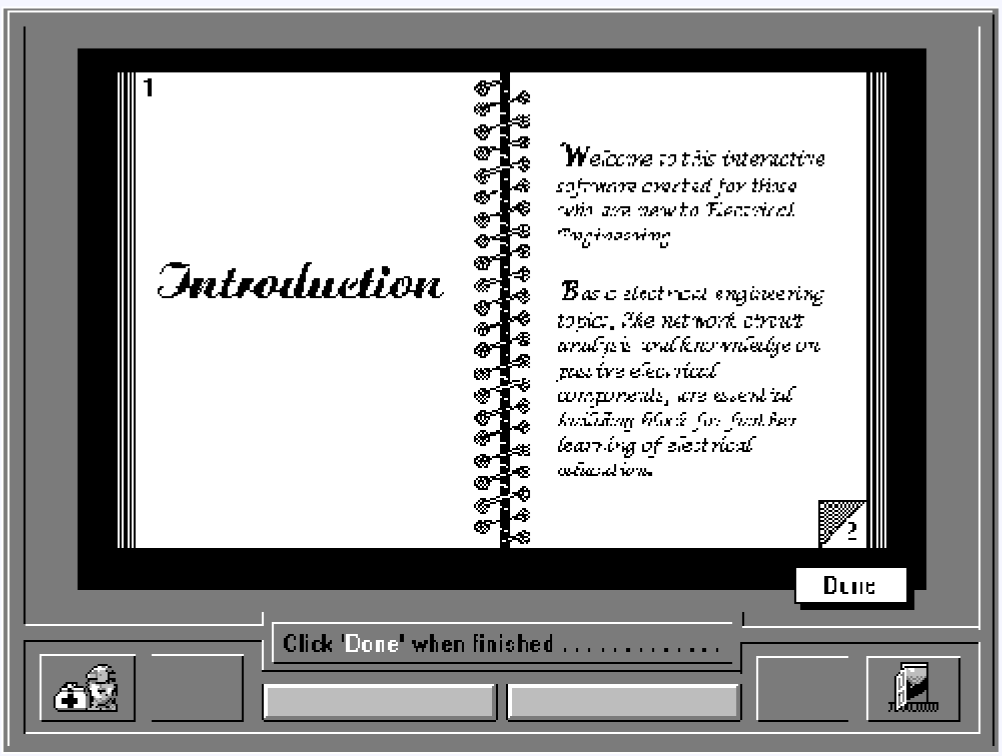

Figure 4: Introduction screen design

b. **Menu Screen Design**
   All menu screen designs are simple and uniform. A 'push down' effect with highlighting of text indicate a particular topics has been selected. An example is shown in Figure 5.

Figure 5: Menu screen design

iii. **Information Screen Design**
Similar to the introduction screen design, a form of the text book presentation can be chosen. The main difference is that only half of the book is used to display text. The other half contains graphical illustrations.

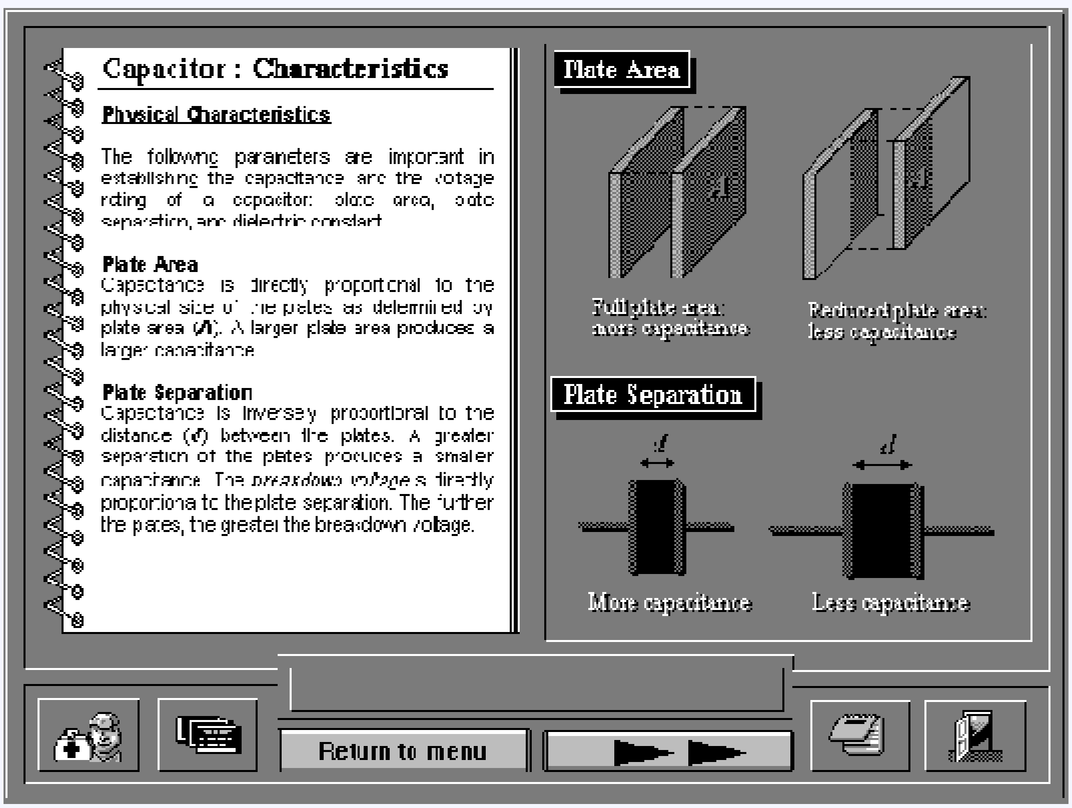

Figure 6: Information screen design

d. **Simulation Screen Design**
The screen design shows the actual layout of the System hardware. This aims to facilitate component identification and circuit testing simulation. During the simulation process, user will be asked to perform specific tasks. Instruction steps will be given and user can follow closely to the screen display, reducing confusion and misunderstanding.

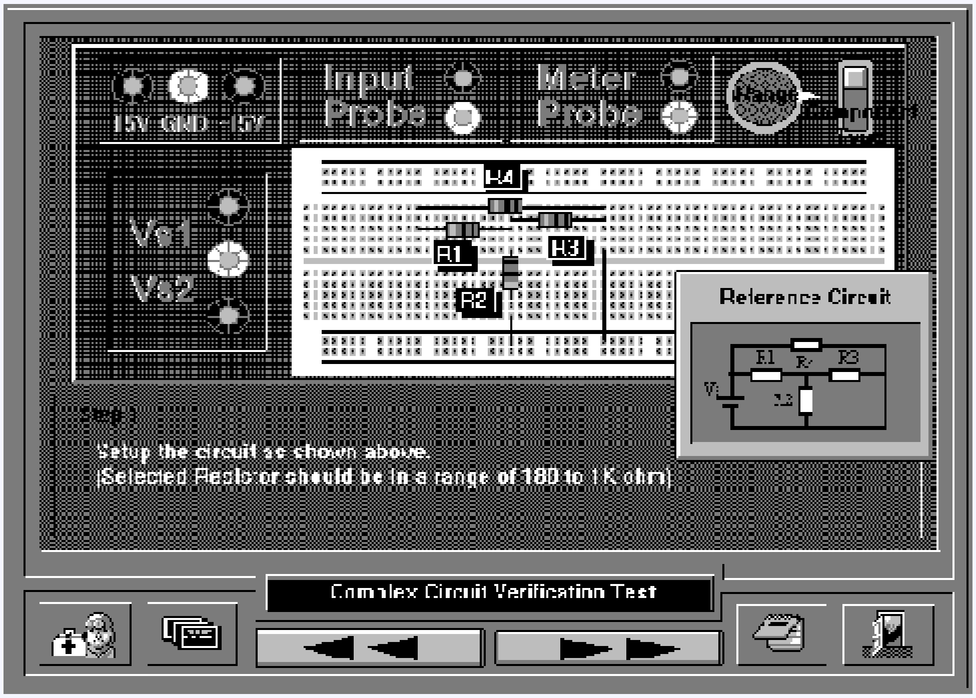

Figure 7: Simulation screen design

The package also provides animation or illustrations consisting of a sequence of related screens. During presentation, these screens overlay on each other. The design and implementation are time consuming but rewarding. Users find the visual effect useful and it helps the user to understand the presented material. As an example, the sequence in Figure 8 illustrates the charging a capacitor.

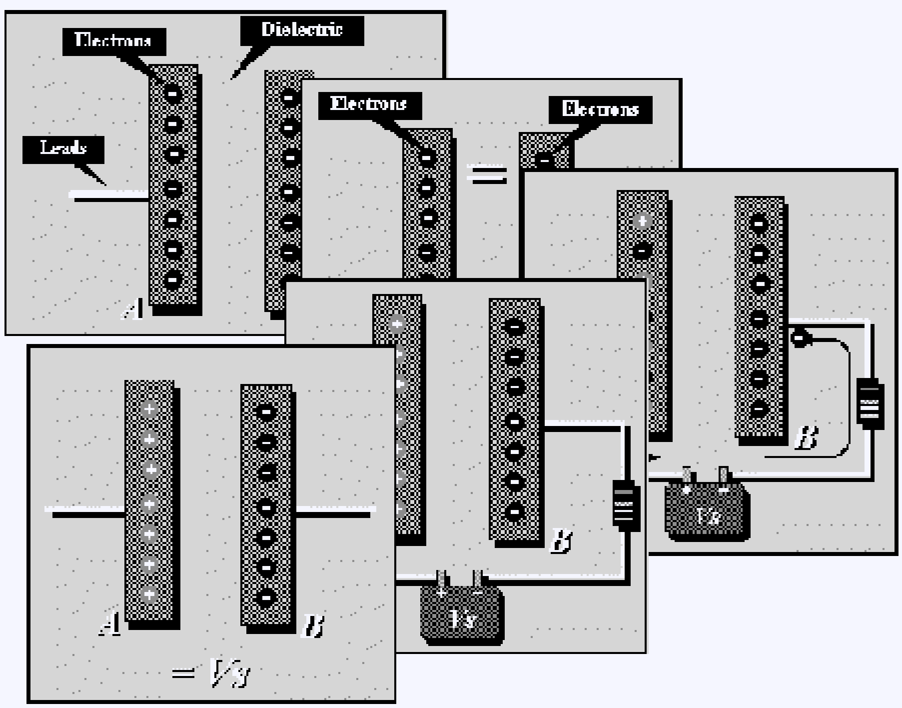

Figure 8: Illustration of the charging of a capacitor

2.4 Testing

Unlike other programming languages, the testing and debugging processes are comparatively simple. In this project, the main point was to ensure the control and display flows are smooth and correct. Testing can be carried out once the page design is completed. If there is no animation involved, testing is simply a check on the flow, whether the program branches to the correct page or opens the right book in accordance to the user's selection. Testing of animation is carried out after the whole process has been completed. Most of the time, the process has to be experimented and tried several times before it can be finalised. When an error occurs, Top-down approach is used to test the animation stage by stage.

The initial testing of the interface program is to verify the selected input channels and the output ports. The final interface program is tested together with the system hardware. The interface program reads in the binary data from the system hardware through an Analog-to-Digital converter card. The data is then converted into its corresponding value and is written into a communication file. Verification is carried out by checking the values in the file against the calculated values. During simulation process, user applies voltage source to the system hardware, as well as obtaining measurements from the circuits or passive components. Testing is carried out by connecting a known resistor to the system hardware and then obtains the voltage level from the communication file. Due to tolerance of the resistors and the resolution of the A/D card conversion, the resultant resistance computed may not match the resistor value exactly. As long as the tolerance does not exceed 12% of the actual resistance, it is considered to be correct. Final testing covers the entire system in order to provide a feel of the overall presentation. The purpose of this test is to finetune any minor presentation layouts such as a change of colour or typographical errors in the information.

3. System Hardware

The hardware design consists of three passive components measuring meters, a data acquisition card and a test bench. The three measuring instruments are an ohmmeter, a capacitance meter and an inductance meter. They are meant for the user to verify the readings of the passive components. The test bench, which is a "bread-board", provides an area for the users to test the passive components and to set up or to verify basic electrical circuits. The data acquisition card serves two main functions, analog-to-digital and digital-to-analog conversions. For analog-to-digital conversion, it reads in the outputs from the meters/test circuits and converts it to digital data for further processing. For digital-to-analog conversion, the card reads in the input data entered from the keyboard and performs the corresponding conversion prior to generating the output voltage. The following diagram illustrates the various input and output connections of the integrated RLC meter.

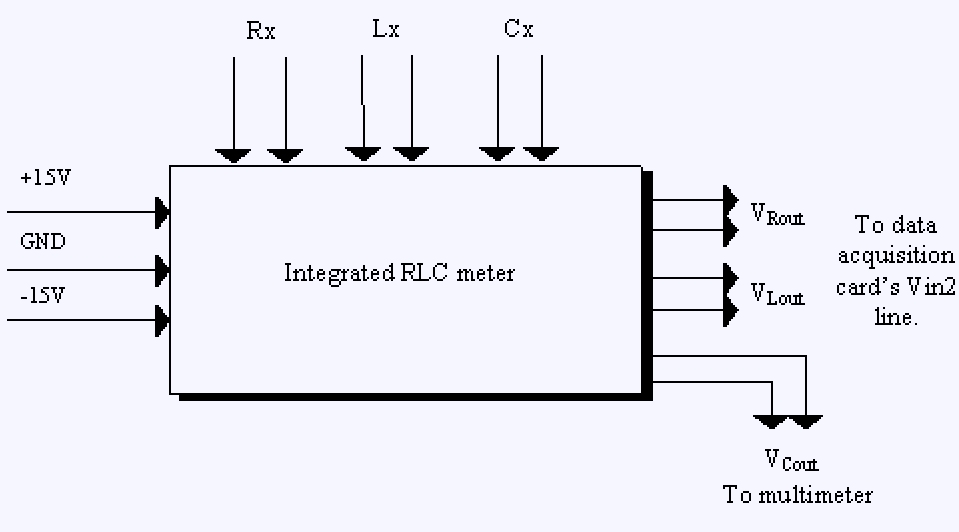

Figure 9: Input and output connections of the RLC meter

The final selection on the software menu is the Simulation session. The simulation session incorporates interactive tutorials that encourage the users to participate in the practical experimentations. This session permits the users to apply knowledge that they have acquired in the earlier sessions and to strengthen their understandings of the basic concepts. In order to achieve these objectives, the Human factors and Hardware considerations are taken into account during the design of this interactive tutorial session.

3.1 Human factors

Research has shown that human has three processes of understanding, theoretical, intuitive, and procedural understanding. The understanding process is speeded up if the overall concept is simplified (Nishida, 1992). The development of the interactive tutorial was therefore based on this concept. The interactive tutorials are structured in such a way that they are relatively simple and flexible. Other keys to solve engineering problems are visualisation and planning (Haertel, 1993). The tutorials on the circuit theorems are carefully structured so that they do not impede the visualisation process of the users. Another major consideration on the design of the tutorial questions is the degree of difficulty and the setup time. Long setup time and complicated connections distract and cause the user's interest to wane (Willis, 1987). To sustain the student's interest, the circuits provided should be fairly sophisticated and challenging but they should be completed by the student in a reasonable time frame.

3.2 Hardware considerations

The interaction with the right mix of hardware experimentation and software simulation allows users to gain new insights and to make their own discoveries (Brown, 1992). The tutorials in the simulation session should be designed in such a way that there are more than one way of obtaining the final results. Users can either follow the step-by-step guidance provided or explore further alternative solutions by making changes on the test bench. An ideal situation would be by providing the students with a fully equipped laboratory set-up so that after the tutorials have been completed, then they may proceed to the proper equipment. However, this implies financial commitment and incurs further costs.

4. Conclusion

In this paper, the development of a "true interactive" CAL package for the teaching of basic electrical engineering and circuit theories is reported. The main feature is the ability of the system to provide hands-on practical experimentations. This project covers the important fundamental ideas applied to the teaching of basic subjects and concepts in electrical engineering. As the package is aimed at units in the first year level, efforts are made to ensure ample guidance is provided. Although the fundamental goals of the project have been achieved, there are areas that the package needs improvements. If the CAL package is to be effective in teaching and learning and intended to be used for a longer time, upgradeability and diversity must be built into both the software and hardware designs. The concept of this project may also be extended to other units that include practical components.

5. References

Brown, J. R. (1992). The Multi-faceted Blackboard: Computer Graphics in Higher Education. *Computer Graphics and Education '91 Conference*. Springer-Verlag.

Haertel, H. (1992). Visualisation of Concepts in Physics. *Computer Graphics and Education '91 Conference*. Springer-Verlag.

Nishida, S. (1992). Hyper-Simulator Based Learning Environment to Enhance Human Understanding. *Computer Graphics and Education '91 Conference*. Springer-Verlag.

Willis, J. and Hovey, L. (1987). *Computer Simulations: A Source Book to Learning in an Electronic Environment*. Garland Publishing.

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Times. Proceedings of the 7th Annual Teaching Learning Forum, The University of Western Australia, February 1998. Perth: UWA. http://lsn.curtin.edu.au/tlf/tlf1998/fung.html

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