Utilizing MATLAB in Undergraduate Electric Circuits Courses

Asad Azemi and Christopher Stook
Department of Electrical Engineering
Penn State University
Great Valley Campus
Malvern, PA 19355-1443

Abstract

The use of MATLAB and its companion toolboxes in teaching graduate and undergraduate control systems and signal analysis courses have been long realized and reported by many educators. More recently, some have started using this package in undergraduate electrical engineering circuits courses. These works concentrate on the numerical capabilities of MATLAB for solving linear equations and its plotting capabilities. This paper describes the use of MATLAB in an undergraduate circuits analysis course focusing on those features of MATLAB that have not been adapted by other educators before. We will present the following topics: (i) generating analytical solutions with the Symbolic Math toolbox, (ii) creating interactive simulations with user interface control, and (iii) the use of MATLAB Compiler and MATLAB C Library to produce stand-alone applications. These topics should also be of interest to those who are developing interactive multimedia courseware products. Examples illustrating these features are included and the codes will be also posted at "http://www.engr.de.psu.edu" site on the World Wide Web. A discussion of how MATLAB helps in reducing the amount of time spent performing computational homework assignments will follow. Finally, the general student reaction to incorporating this software package into circuits analysis course will be reported.

Introduction

The Electrical Engineering Department at the Pennsylvania State University has incorporated computer aided engineering (CAE) packages into its curriculum. The intent of augmenting the curriculum with these packages is to enhance the students' theoretical understanding of the material with hands on analysis and design experience. The benefits of CAE packages in the classroom have been realized by the authors and their co-workers before [1-5]. The benefits of using these packages in a university setting is also confirmed by the number of new undergraduate textbooks, and revisions of previously printed textbooks incorporating new exercises and problems based on these packages, such as [6-14]. This work concentrates on the usage of one of these packages, MATLAB [15], in an undergraduate electrical engineering circuits course. The use of MATLAB in this course is fairly new and most of the effort has been concentrated on using the numerical capabilities of the software to solve linear equations posed in a state space format [17]. In this work we will concentrate on those features of MATLAB that have not been presented by other educators in this field before and could be of interest to those who are working to produce a multimedia package for an undergraduate circuits course.

A summary of the advantages and disadvantages of incorporating these packages into our curriculum are presented below.

General Advantages

The main advantages of using these tools are: the reinforcement of student understanding of theoretical principles by means of enhanced graphical aids and interactive simulations, analysis of more complex systems that can be treated by pencil and paper, and the instructors ability to assign fairly complex design problems that otherwise would have be unrealistic without the help of such software.

Student response concerning the use of these packages is generally favorable. One interesting response received from students is an increased interest in the subject material. It is also worth mentioning that the use of many CAE packages, such as MATLAB, are no longer limited to a a specific filed. Early exposure to these packages will benefit the students. For a more detailed discussion of this topic readers can refer to our previous works [2-4].

General Disadvantages

Three of the disadvantages of using these packages are the maintenance and operation of these packages on an accessible computer system, the extra work required by students (and instructors) to learn how to use CAE packages, and assuring that the packages are included in the baseline curriculum as part of the required course material. A more detailed discussion of this topic can be found in our previous works [2-4].

Using MATLAB in an Electric Circuits Course

Before we start our discussion in regard to the use of MATLAB in a circuits analysis course, it should be mentioned that PSPICE [18] is the most widely used circuit simulation package in electric circuits courses. The benefits of using this package have been long realized and reported by many educators, among them [1-5], and PSPICE has become an integral part of almost all undergraduate circuits books, among them [13-14]. MATLAB aided by the new additional toolboxes, can now be effectively utilized in many areas of electrical engineering. In this work we will focus on some features that can be used, in conjunction with PSPICE, to further enhance electric circuits courses. The role of MATLAB in a circuits course is to help to reduce the amount of time spend in performing routine mathematical calculations. It differs from using a circuit simulation package, such as PSPICE, in that MATLAB requires students to understand circuit analysis techniques before they can fully utilize the package.

Previous works in using MATLAB in a circuit analysis course, such as [16-17], have been focusing on the numerical solutions and simulation capabilities of MATLAB. In this section we will introduce, by way of an example, some functions in the Symbolic Math toolbox that are useful in obtaining analytical solutions to a common circuit analysis problem.

A typical problem in circuit analysis is to obtain the currents of a parallel RLC circuit. MATLAB can be used to obtain analytical solution to such a problem and also plot the results.

The *dsolve()* function solves simultaneous differential equations. It can be used to obtain the analytical solution to the stated problem. The same problem can also be solved in frequency domain by using *laplace()* and *invlaplace()* functions which calculate Laplace and inverse Laplace transform of a function, respectively. Our experience shows that the answer obtained from the frequency domain transformation is usually more compact and easier to understand. It should be mentioned that the use of Symbolic Math toolbox may not always be appropriate. In some cases the complexity of the answer obscures the insight that expected from an analytical solution. Due to the page limitation, the example utilizing these function is not included in the paper but it can be found at the indicated web site.

Interactive Simulations with MATLAB

MATLAB is also capable of producing interactive simulations. This can enhance the quality of presentation with graphical simulations. With the help of interactive simulations instructors can effectively illustrate the change in system response due to parameter variations. This helps students gain a better understanding of the subject. Moreover, since there is no need for students to do any programming, this will allow students with limited or no knowledge of MATLAB programming to access features of MATLAB with little investments of time. This feature is essential in an interactive courseware development.

Interactive simulations are produced with the help of graphical user interface (GUI) functions. The GUI is made up of graphical objects, such as menus, buttons, lists, and fields. These objects have meanings; when a user "chooses" an object there is an expectation that a certain kind of action will take place. In MATLAB the GUI is implemented using user interface (UI) controls.

To illustrate these features, we have put together a program which will plot the voltage, stored energy, and dissipated power for a parallel RLC circuit. Moreover, it displays the damping status of the circuit as well as the values and plot of the roots of the characteristic equation. The component values and the initial conditions for the capacitor and inductor can be changed with the help of the slider bars. Results can be obtained by pressing the "recalculate" button. Figure 1 illustrates the user interface controls for this problem. The actual code can be obtained at the given web site and CD-ROM version of the proceedings.

Using MATLAB to Produce Stand-Alone Applications

There are two new additions to the MATLAB family that can be used to produce stand-alone applications, namely MATLAB compiler and MATLAB C library. The MATLAB compiler produces MEX-files that are binary format and run faster than the M-files. In order to create stand-alone applications one needs to use the compiler to create a MEX-file and then link the MEX-file with appropriate MATLAB Math and ANSI C libraries. The result will be an executable file which does not require the presence of MATLAB to run. This new feature is useful for those who are producing multimedia courseware packages and would like to incorporate MATLAB examples in their package without requiring the user to have MATLAB software. We were able to produce stand-alone examples utilizing MATLAB in the way that has been described. But, due to the restrictions on the MATLAB compiler, such as its inability to handle interactive input functions and plot routines, its usage in circuit analysis or similar courses is limited.

Conclusion

In this paper, we have presented the use of MATLAB software packages in undergraduate circuit analysis courses, at Penn State University. Several of the advantages provided by computer simulation packages, such as MATLAB, have been mentioned. The general student reaction to the use of MATLAB has been positive. Since students coming to this class have little or no prior exposure to the CAE packages, some lecturing and hands-on training are appropriate. MATLAB is capable of providing complex analytical solutions. Using user interface controls one can produce user friendly simulations. These features can be utilized very effectively in a courseware package. Using the new MATLAB compiler one can also produce stand-alone applications, but this feature has limitations due to the restrictions on the compiler.

Links:

- MATLAB simulated file RLC.M
- MATLAB simulated file RLC_GUI.M
- MATLAB simulated file RLCDEQ.M
- MATLAB simulated file SYMRLC.M

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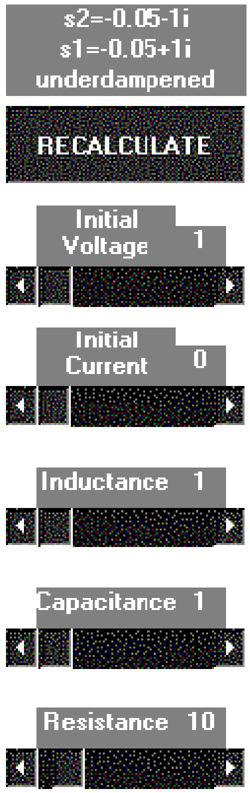
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s1=-0.05+1i
underdampened
RECALCULATE
Initial Voltage 1
Initial Current 0
Inductance 1
Capacitance 1
Resistance 10

Figure 1.