MATLAB Tutorial for Engineering Electromagnetics… and Beyond

by

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Introduction

This tutorial provides a brief introduction to the basics of using MATLAB, the MathWorks' Corporation's mathematical computation package. It was written to accompany *Fundamentals of Electromagnetics with MATLAB, Second Edition* by Lonngren, Savov, and Jost for students coming to the first engineering electromagnetics course with no or little prior exposure to MATLAB. Students who have purchased the text and registered their books are receiving the Tutorial as a free supplement on the Student CD or accessible from the book's website upon User log-in. Those who have purchased a previous version of the text or are using another book can purchase an "Upgrade CD" from SciTech that contains the MATLAB Tutorial or access it, along with other helpful files, from the dedicated Lonngren et al website www.scitechpub.com/lonngren2e.htm. Any other use of this copyrighted material should be discussed and approved with permission by SciTech Publishing by calling 919-847-2434.

MATLAB in Today's ECE Curriculum

MATLAB is a high-level programming language, as well as an interactive environment for technical computing. MATLAB allows you to perform computationally intense tasks with minimum development time due to its many built-in functions and capabilities. MATLAB also offers extensive visualization capabilities with easy-to-use routines for plotting data in a multitude of formats. To extend MATLAB beyond it core capabilities, there are a large number of add-on products, called toolboxes, that provide additional capability for electrical and computer engineers (ECE) in such areas as image processing, signal processing and communications, mathematics and optimization statistics and data analysis, control system analysis and design, and many other specialty areas. Rare is the ECE curriculum today that does

not make use of MATLAB at some point. Many instructors believe the time has come for its early introduction and application in the junior year's electromagnetics course, perhaps even earlier in a sophomore preparatory course. In either case, we believe this Tutorial will be quite helpful to electrical and computer engineering students.

The authors of this tutorial - Jost an electrical engineer and Padgett an aerospace engineer with teaching electromagnetics to mechanical engineers - believe that undergraduate use of computational tools like MATLAB can greatly improve the understanding of challenging concepts that engineering students are exposed to in their beginning courses. Ideally, one could take an introductory course in basic programming and engineering problem-solving based on using MATLAB, and there are many texts available for such a course. However, engineering students have been exposed to these concepts in a course on C / C++ programming and in their other beginning engineering courses, leaving no time for a detailed introduction to a tool like MATLAB. Therefore, the authors decided to put together a "bootstrapping" tutorial on MATLAB operations and applications specifically for those ECE students who need a quick but thorough exposure to the language.

This set of tutorial lessons makes use of examples and files taken from an innovative electromagnetics textbook, but there is a broader perspective and application to electrical and computer engineering generally. It is our hope that through this tutorial a burden is lifted from instructors and a pathway is shown to students so that MATLAB can permeate the entire ECE curriculum quickly, painlessly, and fruitfully.

The Rationale for Another MATLAB Tutorial

Given that there are a multitude of basic books and tutorials on MATLAB already, including some on The MathWorks website, the obvious question is, "Why another tutorial?" Upon review, the authors found that most of them fell into two categories that didn't meet the authors' needs. On the one hand, many existing tutorials are very short documents with only a few examples of simple commands or a simple plotting example. These tutorials don't begin to cover the richness of capabilities that MATLAB offers and thus short- changes the ECE engineer who wants to solve a more sophisticated problem or create a fairly detailed simulation. On the

other extreme of the spectrum are entire texts which purport to cover MATLAB for a general engineering audience. However, upon examining these texts closely, most of them are written with an emphasis on civil or mechanical engineering and have few or no examples that are useful for an ECE engineer.

What we have tried to do with this tutorial is to cover most of the basic operations of MATLAB, as well as some of the more advanced capabilities that would be useful for any engineering student: electrical, mechanical, civil, etc. At the same time, we wanted to provide examples that were detailed enough that they would provide a good template for more interesting and advanced problems with an electrical and computer (ECE) engineering flavor. Finally, we are trying to provide a series of lessons that are self-contained enough that the reader can easily read each lesson in two hours or less and get a good feel for the lesson topic and some of its applications. Because the core of MATLAB consists of over three hundred built-in functions and well over one thousand more M-file based functions, it is impossible to cover every capability of MATLAB in detail. However, we believe that after you have worked through the lessons in this tutorial, you will have a very good grasp of many of the operations you can perform in MATLAB.

Organization of the Tutorial Lessons

This tutorial organizes the lessons into three parts. *Part One* consists solely of an extensive "Lesson 0," a broad overview of MATLAB to get you started. After this lesson you should have a good idea of how to begin using MATLAB, as well as having the tools necessary to explore other information about MATLAB on your own. In fact, this lesson should provide sufficient background for many users to accomplish a few simple tasks that their instructors may require of them, such as running pre-programmed MATLAB routines and making simple modifications to them.

Part Two, consisting of lessons1-7, comprises the bulk of the tutorial and covers the core functions and capabilities of MATLAB with example M-files provided. The lessons contained in the *Part Two* revisit some of the concepts in "Lesson 0" in much more detail and will provide the background to

- work with real and complex numbers, scalars, vectors and matrices

- write your own programs using MATLAB's programming constructs
- output results in many of the available plotting and visualization formats
- use the many advanced mathematical functions that are built into MATLAB.

After going through these lessons, you should be able to carry out most assignments that your instructor might give you that would require MATLAB's programming capability.

Part Three, consisting of the remaining lessons, covers the more advanced topics and applications of MATLAB as a capstone to what has gone before. If this were golf, we'd say we are finally getting off the driving range and putting green in order to put our developed skill set to the test on a real golf course with its varied holes and conditions. There are lessons on solving many types of equations that arise in engineering, more advanced options for input and output of data from MATLAB, and an introduction to using the Graphical User Interface (GUI) capability of MATLAB. After covering these lessons, you should be able to create some fairly sophisticated programs and simulations.

Tutorial Lesson Elements

Each lesson consists of three types of files:

- The Lesson itself in your choice of Word of PDF format. Exposition and screen shots from the MATLAB program are integrated together
- PowerPoint slides of screen shots - whether an individual user wishes to zoom in and see the screen shots more clearly or an instructor wishes to show the evolving screens in a classroom setting, the PowerPoint versions of the screen shots shown within the lesson are a useful option
- The M-Files also supplied are MATLAB code that can be used in MATLAB and easily altered to produce variations. Most of these M-files are drawn from the many Examples and Figures used in the textbook *Fundamentals of Electromagnetics with MATLAB 2nd Edition* by Lonngren et al and supplied to its users.

Summary and Request for Feedback

Although you may not become an expert in the use of MATLAB, by the time you have finished reading through these lessons and the examples and exercises associated with them, you

will be able to solve many more problems, with a significantly higher degree of difficulty, much more quickly than you could before. In turn, you will find your knowledge and understanding of engineering enhanced by being able to numerically experiment with the problems assigned to you, whether in the classroom or later in the workplace. Employers in today's industry value quite highly graduates who come to them with MATLAB skills.

The authors actively seek your feedback concerning the usefulness and clarity of this tutorial in your learning (or teaching) of MATLAB. In fact, with more time and user feedback, there's every reason to believe that additional lessons or subsections on complex problems and simulations can be continually added to on SciTech's website and future editions. We request that you contact us concerning any errors or areas that are unclear so that the tutorial lessons may be corrected and upgraded in the promptly. Send your comments or corrections to matlabtutorial@scitechpub.com (which will reach both authors and the publisher simultaneously) or directly to Dr. Randy Jost at r.jost@ieee.org.