

Calculating and Visualizing Signal Data with Mathcad for Teaching of Electrical Engineering

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Abstract. A significant group of courses in the study of electrical engineering is oriented to the signal processing. In the teaching of topics from this area, it is very helpful for understanding and appreciating the signal processing approaches to demonstrate calculations and illustrations using a computer-based tool. This paper brings brief information about the mathematical software Mathcad and some experiences from new exercises in the course Signals and Systems based on Mathcad. The main differences between Mathcad and other computer tools are described and a few examples of created worksheets are given.

Keywords

Mathcad properties and features, useful resources, worksheet examples, teaching with Mathcad.

1. Introduction

Nowadays, the main aim of the studying programs for bachelors is to gain the practical skills of graduates whereas theoretical courses including mathematics were reduced. This new situation of reduced space for mathematics brings more problems for teaching and learning of technical science, especially in the field of signal processing based on the engineering mathematics. From this point of view, the computer aided learning based on modern techniques, such as simulation, emulation, and visualization acquires more importance in the education and training. This paper is focused toward teachers, engineering and science students, and others performing electrical calculations. Its purpose is to briefly present Mathcad basic properties and most important features and then show some examples how to apply these features to create calculations with signal data and to visualize the obtained results.

The mathematical software Mathcad differs from the most programming languages in one important respect. Conventional programming systems like C++ or BASIC use text-based languages to create lines of source code, graphical programming systems like LabVIEW create programs in block diagram form, while a Mathcad program is created in formula-based visual format.

2. Why Use Mathcad

The use of Mathcad in the engineering education is very comfortable for the teachers checking and correcting the student's work, and very easy to learn it for the students. Mathcad utilizes standard math notation and no programming is required to use it. To create a worksheet, Mathcad use various interactive toolbars. Main toolbar for calculations is the Math toolbar displayed by default. Each button in this toolbar opens another toolbar of operators or symbols. Many operators, Greek letters, and plots can be inserted by clicking the buttons found on these toolbars. The Math toolbar together with some sub-toolbars are shown in Fig. 1. The equations written on a piece of paper can be entered into Mathcad just as they look on the paper, and just as quickly as on the paper. By combining functional equations, textual comments, graphics, and resulting numerical data in a single worksheet, Mathcad makes it easy to keep track of the complex calculations. Mathcad is available also in German and French versions.

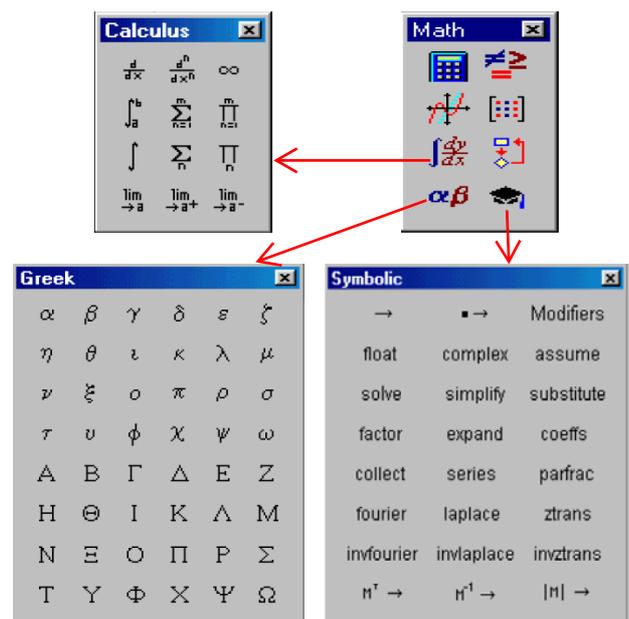


Fig. 1. Various toolbars with buttons used for mathematical calculations in Mathcad.

2.1 Characteristics of Mathcad

In the past two decades, Mathcad software has developed to the latest academic version Mathcad 15. Today, the most important Mathcad features are as follows:

- User friendly visual format
Mathcad lets bring together live equations, text, and graphs, and work with them visually. Changing any variable or correcting data, Mathcad recalculates all equations and redraws all graphs instantly.
- Application of physical units
Mathcad is able to attach units (also user-specified units) to variables and convert metric measures into English measures.
- Extension packs
Some specialized extension packs, e.g. “Wavelets Pack”, “Signal Processing Pack” or “Image Processing Pack”, provides a powerful design solution for iterative investigative analysis.
- Compatibility with other tools
Mathcad can collaborate with other conventional software tools such as Excel, Word, Visio, AutoCAD, Matlab, C++, etc.
- Export and import of external data
The Data Acquisition Component allows data exchange with recognized measurement devices.

2.2 Useful Resources

In addition to the Help and the Mathcad User’s Guide located in the Mathcad program directory, there is a lot of written documents and illustrative learn worksheets available for Mathcad users. Beginners can start their work, for instance, with the book *Engineering with Mathcad* [1]. It is focused on the application of simple, yet powerful functions, and applying these to building engineering calculations. Many books provide a comprehensive study of all the Mathcad functions. User interested in learning about the very mathematical and complex Mathcad functions can study the four-volume work [2]. An introduction to calculations in the field of statistics, stochastics, and probability can be found in [3]. The series of electronic books *Topics in Mathcad* [4] covers a broad range of specific topics. A part of this series is oriented to the electrical engineering [5] and shows some useful Mathcad techniques for solving common electrical engineering calculations, such as circuit analysis, signal processing or digital filter design. All of the 24 examples include a background section describing the physics or mathematics of an electrical engineering problem and a step-by-step annotated solution using Mathcad. Other e-books can be downloaded from the Electrical Engineering Library accessible through Mathcad distributors. The online user forum Collaboratory combines a computer bulletin board with the convenience of sharing Mathcad worksheets. Its home page is: <http://collab.mathsoft.com>.

3. Teaching Projects in the Course Signals and Systems

In this year, one of the fundamental knowledge courses in the study area *Electronics and Communication* at our Brno University of Technology, namely *Signals and Systems*, was changed in its teaching methods. The traditional exercises in signal calculations were replaced by computer-based exercises using Mathcad. The course includes except these new exercises also exercises focused on laboratory measurements as well as lectures, and is addressed to bachelor students studying in winter semester in their second year of study.

Let’s now give a few examples of created worksheets in practice. Figure 2 shows a piece of worksheet with standard mathematical calculation. Here are numerical expressions using standard math notation, such as power, fraction, integral operator, and summation operator, and symbolic expressions using standard keywords, such as *simplify* and *expand*.

$$\int_{\ln(2)}^{\ln(3)} \sum_{n=1}^{1000} (n \cdot e^{-x^n}) dx = 0.5$$

$$\int_0^{15} \int_0^{30} \frac{y}{\sqrt{(1+x^2+y^2)^3}} dx dy = 2.653$$

$$\int_a^b x \cos(x) dx \rightarrow \cos(b) - \cos(a) - a \cdot \sin(a) + b \cdot \sin(b)$$

$$\frac{\frac{r+s}{s} + \frac{s}{r-s}}{\frac{s}{r-s}} \text{ simplify} \rightarrow \frac{r^2}{s^2}$$

$$(i+j)^3 \text{ expand} \rightarrow i^3 + 3 \cdot i^2 \cdot j + 3 \cdot i \cdot j^2 + j^3$$

Fig. 2. Examples of mathematical calculations (copy from PC screen in Mathcad).

Figure 3 demonstrates synthesis of a periodic signal created by three elements from the Fourier series and then nonlinear signal amplification. By setting and slightly modifying the value of the parameter A2, students can online observe the effect of the nonlinearity power on the output signal in comparison to the input signal. In the case that A2=0, the amplifier becomes linear. Signal changes due to amplifier’s weak quadratic nonlinearity are shown both in time and frequency domain.

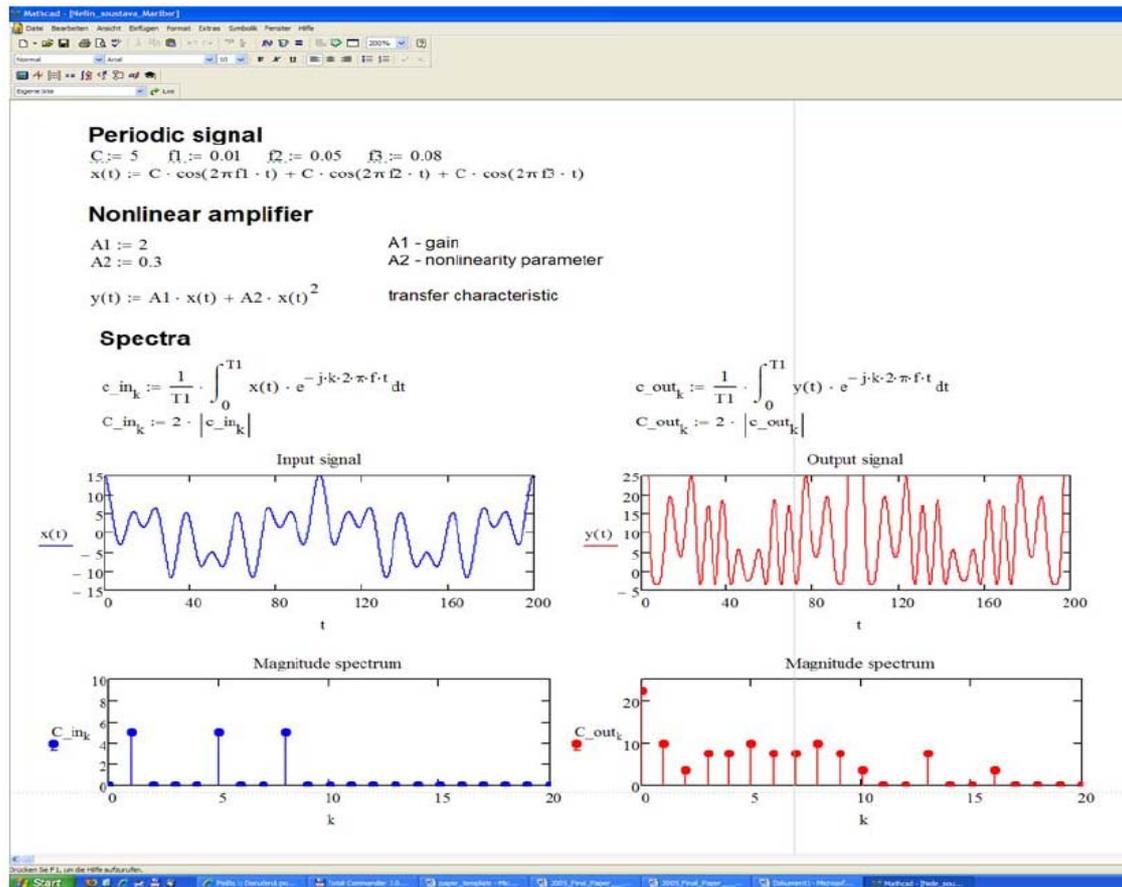


Fig. 3. Effect of a nonlinear amplifier on the signal waveform and its spectrum.

4. Conclusion

The teaching experience with Mathcad is very positive. Teachers can quickly search for errors in a student's worksheet directly on the PC screen and correct them during the exercise. Using Mathcad, students are able to process signal data without learning complicated programming. This is an important advantage especially in the distance learning because external students have mostly very different programming skill. Student response to both the software used and the new exercises has been very favourable. Students appreciate the ease with which they can begin to actually do something with what they are learning in the classroom. On the other hand, the use of a computing tool should not be considered as universal remedy for enhancement of theoretical student's knowledge gained in any course. In my opinion, good students can learn to solve more complex technical problems using mathematical software. Bad students learn to use the software only.

In general, practicing electrical engineers use only a small percentage of the Mathcad functions. It takes a considerable amount of time to sort through all the functions and determine which ones are going to be useful

to the specific needs. In the future, it will be necessary to create a concise Mathcad guide in Czech perfectly tuned with the topics of electrical engineering taught at our University.

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