

Strengthening Math Skills In The Engineering Sciences Through The Power Of The PC

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Instructors in the engineering sciences at Utah State University find that in teaching their courses, a large proportion of students exhibit weakness in math applications. This lack of strength resulted in some instructors taking a portion of class time to review math, which caused course progress to lag behind schedule. In maintaining course goals, most students fall behind or constantly struggle because they cannot keep up with the pace set by the instructor. Also, many students drop out of individual classes only to repeat them at a later date, or drop out completely from engineering programs.

To help improve student math skills within the electronics engineering classes at Utah State University, a new approach needed to be implemented if students were to succeed and instructors were to keep on course. One approach was to review math principles as they related to coursework to supplement student background. This proved excellent for the student, but too much class time was spent on review and not enough on course objectives.

Computer-assisted instruction was suggested, which then became a popular alternative. A search was begun for software that students could use on their own time and at their own pace. This seemed like a logical and productive answer to integrating math with programming to enhance coursework in electronics classes. This type of aid held promise, and several software programs were investigated. Five are discussed in this paper.

Initially, BASIC was the most available and most widely-used program. After experimenting with this software, results showed there was a slight improvement in scores and student understanding - mostly gained through the process of the students' use of programming skills and using the math within the programming. (Progress checks were made through oral and written exams, and student lecture presentations.) A slight improvement in oral and written tests was observed.

As PASCAL and C programming began to surpass BASIC in popularity, these programs were used. However, with these programs, as well as with BASIC, it took an excessive amount of time to write the programs, and the students vigorously resisted using these programming tools.

PSPICE was then introduced as a teaching aid. It was found that if PSPICE was used early in the students' programming coursework, the students used it more as a crutch, relying too heavily on it to do all their math labor work. In most cases, their math enhancement and resulting coursework scores actually dropped. Using PSPICE midway in their engineering career made negligible difference in their understanding or their scores; and using it later in their program appeared to have no effect.



About this same time, a new software program came out that for our students became an effective panacea for strengthening students in math applications: MathCAD! This program is very user friendly (it can be entered through windows on the monitor in the same way a student would write it down on paper) and its capabilities are a convenient blend of the advantages of each of the aforementioned software programs, as well as adding its own merits. MathCAD requires effort and understanding of math and its applications in electronics engineering, and at the same time, uses the high-speed solution capabilities of the computer.

In some of the classes where MathCAD was used to a significant extent (whereat least half of all the homework problems had to be solved on MathCAD), there was a definite 10 point improvement in class scores, on oral exams, and in class presentations. Gains noticed in class averages that were 70-80% rose to 80-90%. An encouraging bonus was that student interest and positive attitudes in doing engineering problems and working in the labs increased markedly by using MathCAD.

In lab and homework situations, successful keys to a positive learning experience using MathCAD and the PC, are 1) students are required to set up their own format, 2) they formulate their own problems and solve equations within the MathCAD format, and 3) after much repetition in solving engineering problems using MathCAD on the PC, students learn and memorize important equations and learn how to use them for solving various problems. MathCAD also has a unique capability to represent solutions graphically. Students learn these graphing skills through their problem solving. They are required to use the MathCAD program that is available on our University computers. After five or six weeks, however, most students purchase their own personal copy for their home PC's. They often express that they find it very useful for their other classes.

To demonstrate how the PC helps students do homework, labs, memory retention for oral presentations, etc., several MathCAD examples are demonstrated below.

The following problem solving using MathCAD demonstrates how MathCAD-Plus 6.0 can help to more effectively teach math, physics, electronics, electrical, mechanical, and civil engineering. This program combines all phases of math and engineering, and is the vehicle for providing a greater understanding of math and its applications in engineering. Example problem #1 demonstrates how one can use MathCAD to solve a mathematical Fourier Series expansion for a periodic wave. Example problem #2 demonstrates how one can use MathCAD to solve an electronics problem for a band-pass filter.



Example Problem #1

FOURIER SERIES EXPANSION OF PERIODIC WAVEFORMS

This example demonstrates how a student can use a MathCAD program to expand any periodic wave into its Fourier Series Expansion. To do this, certain constants such as the period (T), angular frequency (ω), number of elements (N), and number of samples (k), must be defined.

$$\text{Let } T := 1 \quad \omega_0 := \frac{2\pi}{T}$$

$$N := 1..50 \quad k := 1$$

Suppose we wish to expand a narrow pulsed wave having a peak value of 4 Volts. This can be represented by two functions:

$$f_1(t) := 4 \text{ over the first part of the period and}$$

$$f_2(t) := -4 \text{ over the second part of the period.}$$

The Fourier Series Expansion coefficients are given as:

$$A_0 := \frac{2}{T} \left[\int_0^{\frac{T}{5}} f_1(t) dt + \int_{\frac{T}{5}}^T f_2(t) dt \right] \quad (\text{The offset constant})$$

$$A_N := \frac{2}{T} \left[\int_0^{\frac{T}{5}} f_1(t) \cdot \cos(N \cdot \omega_0 t) dt + \int_{\frac{T}{5}}^T f_2(t) \cdot \cos(N \cdot \omega_0 t) dt \right] \quad (\text{The even term coefficients})$$

$$B_N := \frac{2}{T} \left[\int_0^{\frac{T}{5}} f_1(t) \cdot \sin(N \cdot \omega_0 t) dt + \int_{\frac{T}{5}}^T f_2(t) \cdot \sin(N \cdot \omega_0 t) dt \right] \quad (\text{The odd term coefficients})$$

To ensure that no noise terms are generated, we eliminate them by using the following if statement technique.

$$A_N := \text{if} \left(|A_N| \leq 10^{-2}, 0, A_N \right)$$

$$B_N := \text{if} \left(|B_N| \leq 10^{-5}, 0, B_N \right)$$

$$A_0 := \text{if} \left(|A_0| \leq 10^{-2}, 0, A_0 \right)$$



For this example, we wish to expand to 30 terms of the series. Thus, we arbitrarily set $k=30$

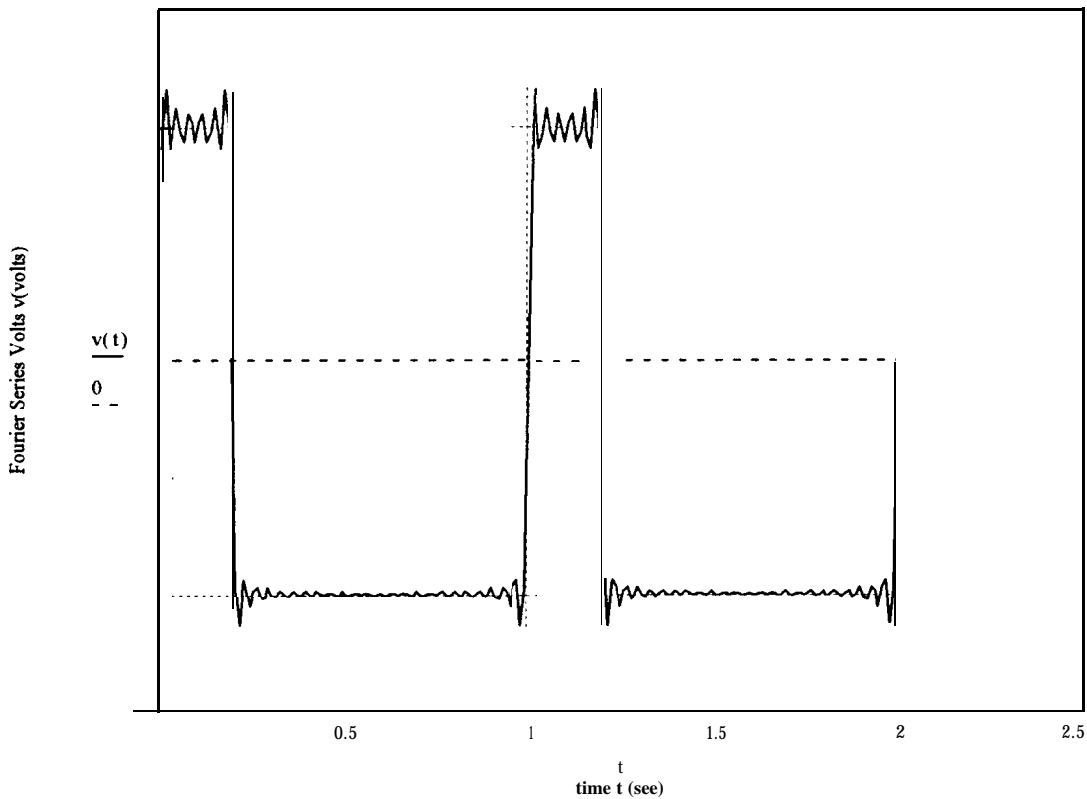
The Fourier Series Expansion is given as:

$$v(t) := \frac{A_0}{2} + \left[\sum_{N=1}^k (A_N \cdot \cos(N \cdot \omega_0 \cdot t) + B_N \cdot \sin(N \cdot \omega_0 \cdot t)) \right]$$

We choose the time limits to include at least two periods of the function:

$$t := 0, 0.01 \dots 2 \cdot T$$

The graph of this expansion follows:



PULSE (PERIOD = T, WIDTH = T/S)

Note: By a simple change of constants, the shape of the pulse can be modified and its graph can be immediately observed. The effect of different sample sizes (k) will also show how band limiting can modify the signal. This method presents a powerful tool for analyzing the effects of various limits places on a system by its transfer characteristic.

Example Problem #2

PASSIVE BAND - PASS FILTER DESIGN

This example demonstrates how a student can use a MathCAD program to design a passive band-pass filter using several passive components (resistors, inductors, and capacitors). Certain constants such as frequency (**f**), inductance (L), capacitance (C), and resistance (R), must first be defined.

$$\text{Let } f := 10^3, 10^4 + 10^3 .. 10^7$$

$$\omega(f) := 2 \cdot \pi \cdot f$$

$$L := 3 \cdot 10^{-3}$$

$$C := 0.001 \cdot 10^{-6}$$

$$R = 22 \cdot 10^3$$

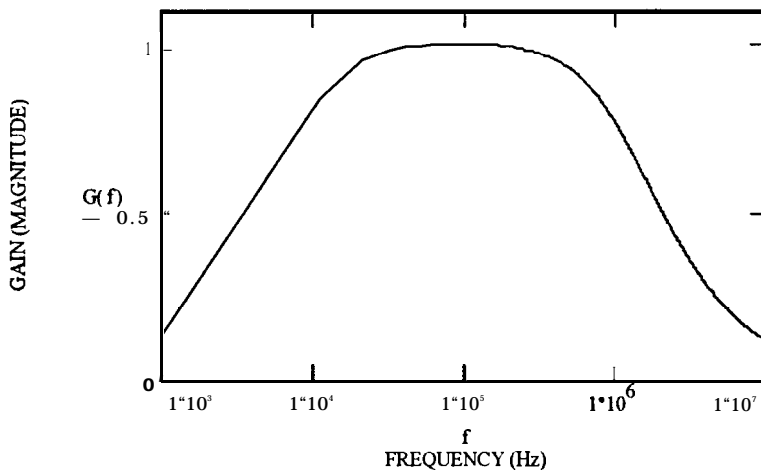
The gain of the filter is given by:

$$G(f) := \left| \frac{R}{\sqrt{R^2 + \left(\omega(f) \cdot L - \frac{1}{\omega(f) \cdot C} \right)^2}} \right|$$

The center frequency of the band-pass filter is defined by the equation:

$$f_{\text{ctr}} = \frac{1}{2 \cdot \pi \cdot \sqrt{L \cdot C}} \quad \text{or} \quad f_{\text{ctr}} = 9.189 \cdot 10^4 \text{ Hz}$$

If we plot the gain as a function of frequency, we get:



PASSIVE BAND-PASS FILTER



Note: By changing different values of R, L, or C, the student can simultaneously observe the changes in the location of the center frequency of the filter. This provides the student with immediate feedback on his/her design.

CONCLUSION

By integrating MathCAD software into the problem - solving portion of our electronics, physics, and math programs at Utah State University, we observed that most students improved significantly in their understanding of the course material. Test scores increased in many cases by as much as 10 points on a 100 point scale. Some showed as much as a 20 point improvement over previous programs not using MathCAD.

BIOGRAPHY

CHARLES E. TINNEY, an assistant professor in the Industrial Technology & Education Department of Utah State University, received his BS and MS in electrical engineering at Brigham Young University. A PhD was received in biomedical engineering at the University of Utah, and a BS in physics from Utah State University. Current interests include publishing electronics, physics, and math textbooks and research of IR scanning devices.

