Math, Electronics, Tutorials, Testing, Distance Learning and the Web

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Introduction

Many instructors are designing courses of study based on the exciting software simulators for electronics and math that have migrated to the PC in the last decade. In a flurry of development, electronics instructors have designed materials suitable for their classes and math instructors have made a similar effort. The time is ripe for an integration of overall methodology that smoothly weaves all the curriculum threads together. The new technology demands a new way of doing things. It is not enough to simply use the new technology on old problems. Instead, we need to take advantage of the power of the simulators to enrich the learning environment of our students.

Some non-admirers of a too hasty adoption of the 'technical fix' will no doubt be thinking that this vision of enrichment is an admirable goal. However, in attempting to envision how this more demanding course of study could be implemented, these instructors look at the makeup of their current classes, with the ever increasing range of learner abilities and preparedness for the actual grade level and despair. This problem has confronted all of us and has caused a great deal of frustration. Most of our colleagues have made similar observations about the mix of skill sets in the makeup of the class.

The solution, we propose, lies in the direction of a gradual replacement of static print materials, like textbooks, with electronic hypertext documents. It is true that hyperlinks contain text, so learners of the future still need to be able to read at an acceptable level. However, the power of the hyperlink can go a long way in rectifying a major roadblock, i.e., the inhomogeneity of background in the modern day classroom. It is common to ask the members of a class if they have taken some topic that was on the prerequisite list and find that a significant proportion disclaim any previous exposure to that topic. One usually finds that almost every prerequisite has been studied by *someone* in the class, but that it is a different someone depending on the topic at hand.

How can hypertext help? Hypertext can relieve the instructor of the burden of thinking, "What do I do now? How can I fill in the particular gap this student has when I know that it is ineffective to take up class time explaining it to one individual?" Given hypertext study material, the student can jump to a simpler lesson in which the unrecognized concept is defined, explained, drilled and tested. At the other end, students wishing a more challenging lesson can follow a hyperlink to advanced problems and their solution.

The whole idea is one of integration, but integration in a hierarchical way. The tools and the platforms exist. The personal computer that most instructors have has enough hard disk to store

over a million printed pages. That's a lot of textbooks! And the computer can do more than store information. It can speak and play movies, and all of this at the cost of a year's tuition fee at a state college. By connecting to the World Wide Web, course materials can be downloaded for reference during the term. New courses can replace old, and better yet for the curriculum designer, course updates are made much simpler, since the designer is not tied to yearly publishing schedules.

So, with all this potential, what is actually happening? Courses on the Web are blossoming. Many students have personal Web pages, and many of them are publishing tutorials of their own, to the dismay of some instructors, who worry about the possible propagation of the inevitable flaws in the exposition. What is happening can be likened to handing in one's homework in a way that has the potential of letting the whole world see it. We seem to be experiencing, on the cyberspace landscape, a sort of evolutionary explosion of species reminiscent of the burgeoning biological diversity of the Paleozoic era.

Will there be a subsequent mass extinction? Probably, but the biological antecedent had to wait for the late Permian, some 200 million years later. Even taking into account the thousand-fold compression of computer time scales, the eventual winnowing of diversity is a long way off. The particular organism we want to talk about is an integrated math and electronics modular package. The modules incorporate Electronics Workbench [1] for circuit simulation, and Maple [2] for mathematical simulation.   What's more, the curriculum is further organized by the use of a "supervisor package", called Electronics Testbench, that guides the student through the learning process by providing tutorials and practice quizzes. The instructor can concentrate on the creative task of instilling the crucial concepts rather than being a drill master for rote exercises.

Maple has hot key linking built in. Electronics Testbench does not provide for unlimited hypertext, but it does provide hot keys and it provides a mechanism for switching from one program to another. What Electronics Workbench does provide is a test delivery system suitable for drill-and-practice quizzes all the way up to end-of-term exams. It can be used to structure lesson delivery as well. A sample module based on these tools will be discussed.

Preserving the Kinship Between Math and Electronics

Perhaps it really is a curse, but we really do live in interesting times, as the Chinese say. By "interesting times" it is meant that this is a time of great change in our classrooms because of the rapid inroads being made by new technologies, both software and hardware.

Stage 1 was the acquisition of computers by the colleges. This stage is by no means complete, nevertheless, we have all heard how the computer will revolutionize education. Administrators happily point to the hardware, since it is visible, and relish that they have achieved wonders by setting up computer labs. However, is the existence of the computer lab enough?

We have taught in these computer labs for some years now and one of the most perplexing problems can typically be voiced by more than one of our students. "Professor, what is the good

of learning how to do things on the computer when I won't be able to use the computer in the final exam?" These students are looking forward to Stage 2.

Stage 2 arrives when there is an integrated software environment that makes full use of the college's computers. And this software exists today! Curriculum-free products, like Electronics Workbench and Maple, provide a great virtual landscape for exploration. These landscapes are very broad, and they do not limit the student the way print material does, where "what you see is what you get." These products are truly interactive. They attempt, like any good oracle, to answer any and all questions put to them within their area of expertise. They need us, the instructors, to show them the way by providing a "travel guide", just like any good textbook does. Of course, the minute you leave the textbook, you're on your own! With simulators, you still have "willing assistants" to help you with your new problem. What is needed is an infrastructure that solidly inserts computers into the curriculum. We need software resources equivalent to the textbook market, where there are dozens of choices. Many talented instructors have produced texts, giving the rest of us lots of choices to match their work to the level of our classes and to the specific interests of our students. The challenge to those of us who want to provide a well integrated computer curriculum for our students is to craft computerized workbooks that guide, but do not narrowly restrict the students' learning opportunities.

Let us look forward to the day when testing, as well as teaching, benefits from the availability of a computer resource. The more fortunate may already be there. How will this resource be used? One of the authors has been working on a new project that uses Electronics Testbench as both the study guide and the testing device. Since he has built a large number of Electronics Workbench circuits in the past, they are all available to us for use. Also, he taught a math course for the electronics department using Maple, along with Electronics Workbench, so that students could use Maple as a type of "super calculator" to automate the symbolic solution to an electronics problem, then reduce the resulting formula to numbers. [3] The students quickly saw the advantage. Once the problem was correctly set up, the answer was produced without the necessity of repetitive calculations, and the numerical answer is correct to boot.

No matter how intuitive software products become, we have to teach the basic concepts that underlie the discipline. We do not want to have our students become "symbol pushers" any more than we what them to be merely "button pushers." We want them to understand the fundamentals and we want them to be able to apply those fundamental concepts in a variety of complex situations. The place of Electronics Testbench in this scenario is to be the study guide. The whole course is structured in the form of a practice quiz. The beauty of this approach is that it contains all the advantages of standard computer aided instruction (CAI) and eliminates its major disadvantage. Old CAI had a "one track mind." The learning process in Electronics Workbench is guided. A study guide that uses Electronics Testbench presents a guided path through the material, but it does not prevent someone from taking a side trip. It also allows the instructor to put in hints, pictures, or other more elaborate objects along with the topic item. More importantly, it lets the instructor incorporate a live, interactive circuit. Students can perform all the open-ended, what-if types of investigations that they used to do with Electronics Workbench, because Electronics Workbench is available and "live", at the click of a button, through Electronics Testbench. Similarly, assuming Maple is the math package that the school

has, it too can be referenced through Electronics Testbench. Students can be presented with a whole set of activities in which they are the major player, not the passive observer.

After the students have studied the lessons and taken the quizzes, it is time to see what they have learned. As the name implies, Electronics Testbench can be used to deliver the final test interactively, with time constraints if the instructor chooses. And the questions can be multiple choice or essay or both, depending on one's teaching style. Since the instructor controls the questions that Electronics Testbench asks, he or she sets the level of the course. Now that simulators like Electronics Workbench and Maple are available, the students have an open-ended learning environment that can interactively link the mathematics subject to electronics much more closely than previously possible. Could this be the best of both worlds?

A Sample Lesson

The following sample uses Electronics Testbench to provide a learning module on operational amplifiers, couched in the form of a practice quiz, and Electronics Workbench 5 for the electronics simulator. The math component is designed as a "replaceable part" that can be serviced by the Texas Instruments line of graphing calculators or the computer algebra packages Maple [4], Theorist, and MathCad. A typical page consists of a question and its live circuit:
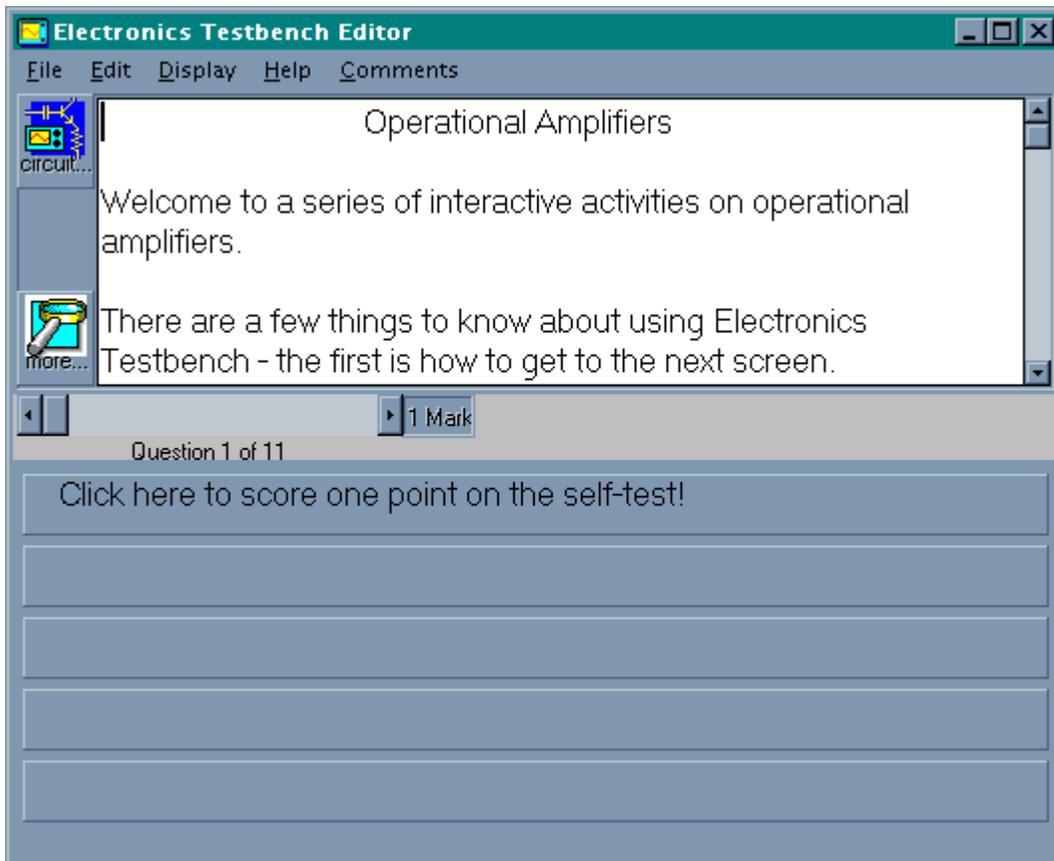

Figure 1 The Electronics Testbench Screen

The screen consists of a question and its associated multiple choice answers. Since this is the opening screen, only one answer is possible, the one saying "Click here …." There is a horizontal scroll bar that allows one to progress through the test, and it also allows one to move quickly back and forth to any question for review.

The quiz questions are "live." Notice the two buttons, respectively called "circuit …" and "more …" The *circuit* button switches the context to the Electronics Workbench window and causes a circuit specific to the current question to be loaded. The circuit file for the introductory page is this:
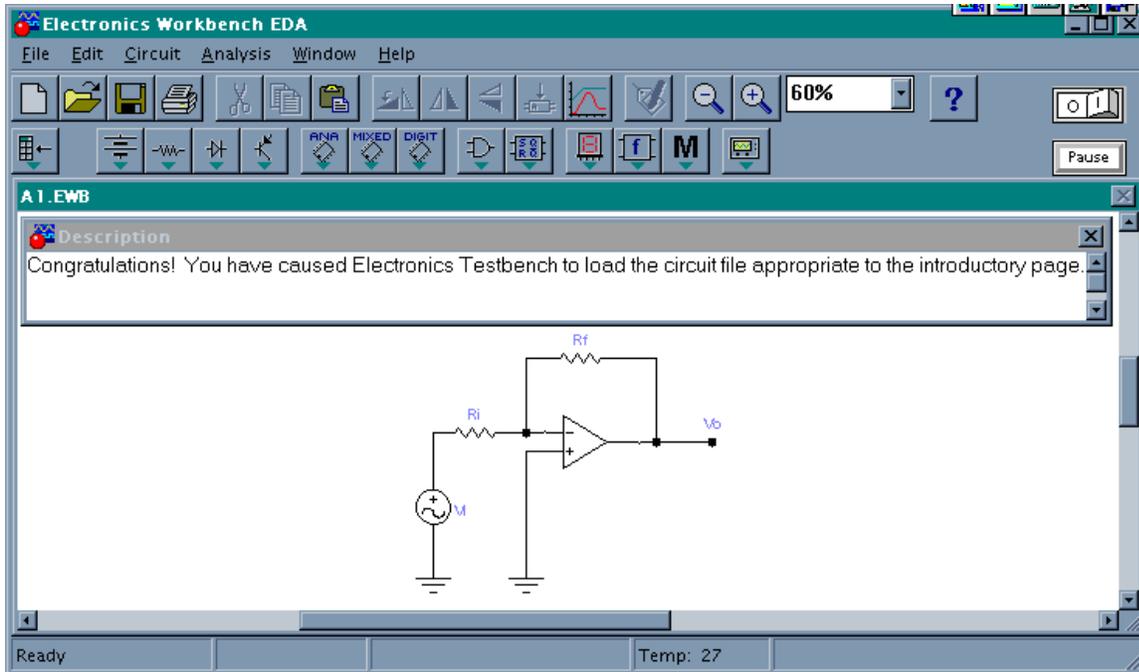

Figure 2 An Electronics Workbench circuit file that is loaded by clicking on the *circuit ...* button in Electronics Testbench

The context switching is accomplished by a taskbar, appropriately called the *switcher*. It looks like this:
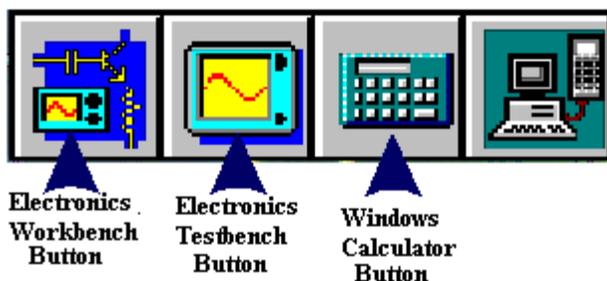

Figure 3 The Switcher's taskbar

Like the Microsoft Office Manager taskbar, the Switcher causes the selected application's window to be in the foreground if the application is currently active or it launches it with its window in the foreground. The distinction between the Switcher and the '*circuit ...*' button is that the '*circuit …*' button causes the application to load a specific file as well as bringing its window to the foreground.

There is more functionality in the '*more…*' button when a package like Maple is linked to a quiz question. Consider question *q*12 in the operational amplifier module, that asks about a plot of the closed loop gain as a function of a variable open loop gain *A*.
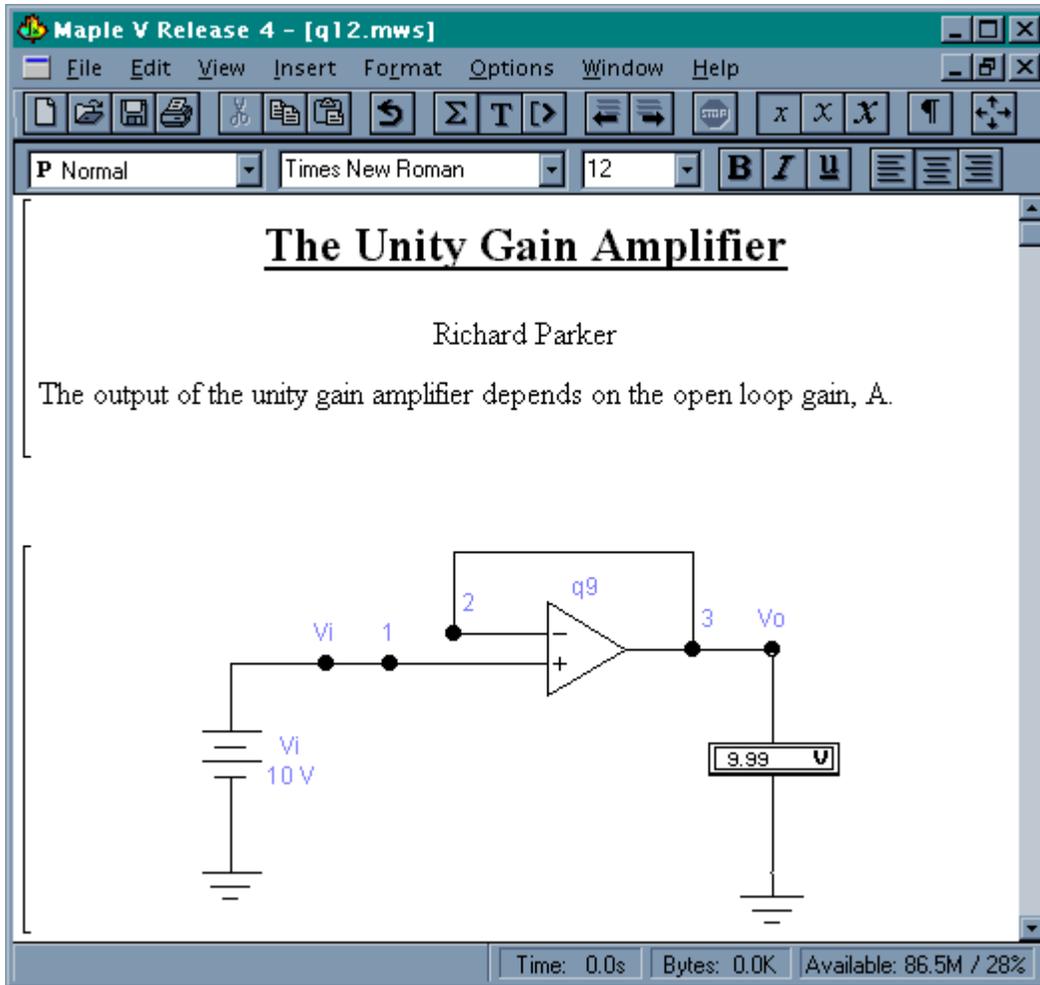
Figure 4 A Maple worksheet

The rest of the worksheet is all contained within collapsible sections. This presents an uncluttered screen containing only major headings. The student opens these headings by clicking on the plus sign to the left of the section heading. In a very detailed worksheet, the next level might be a group of subsections, each containing interactive lesson material. By opening one section at a time, the student has less chance of getting lost.
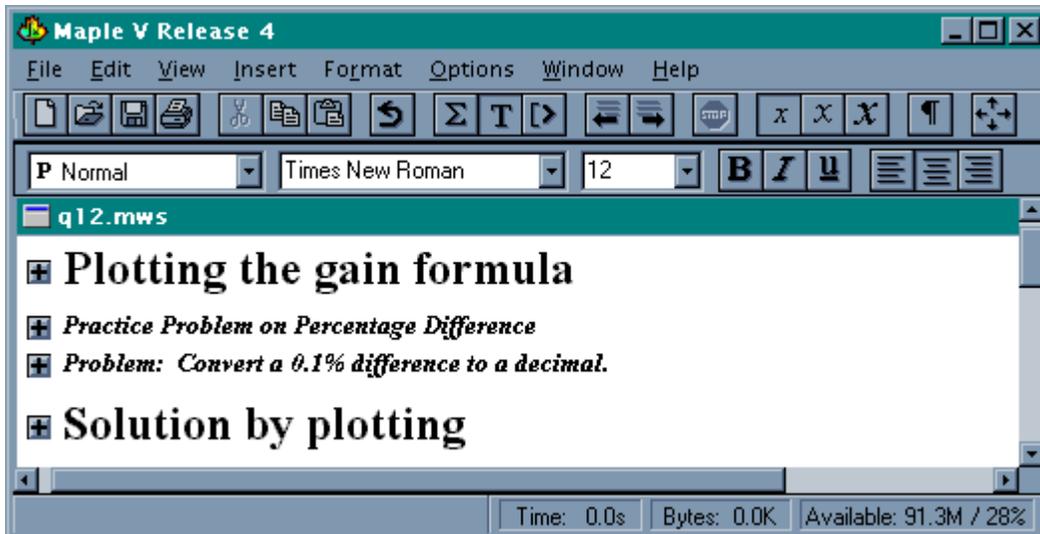
Figure 5 The Maple worksheet is in collapsible sections
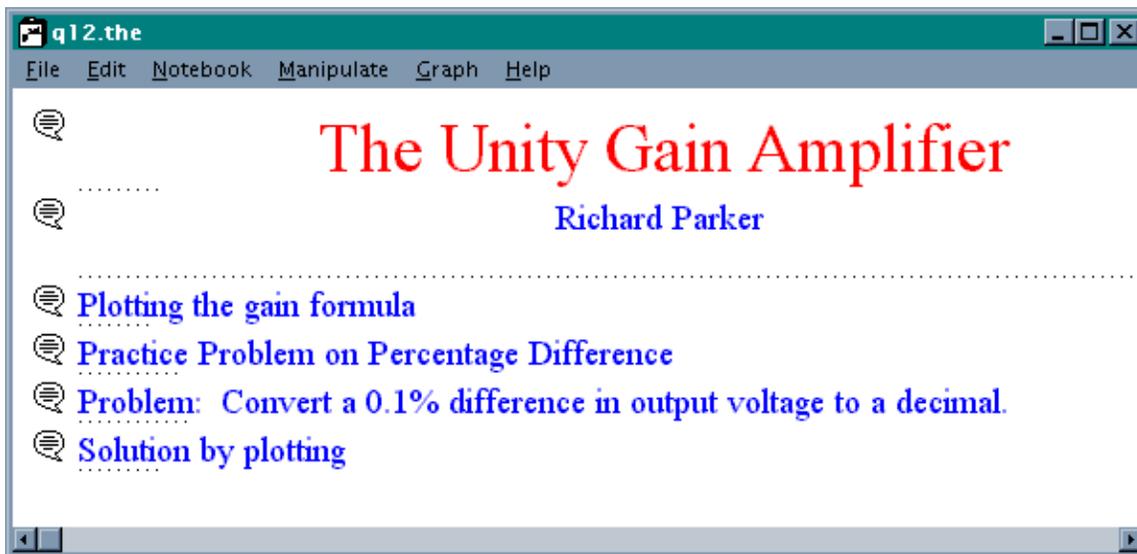
Figure 6 The Theorist notebook is also in collapsible sections

In Theorist's terminology, an application file is called a *notebook*. Sections are introduced by text balloons. Those that show dotted lines underneath the balloon indicate the presence of a subsection. Double clicking on the balloon to the left of the heading called *Solution by plotting* expands this section. The graph in Figure 7 appears, along with explanatory text. The graphs in MathCad and Maple look slightly different, but they convey the same information. All are interactive, so students can take measurements at various points along the graph. In all cases, it is easy to modify the graph ranges.
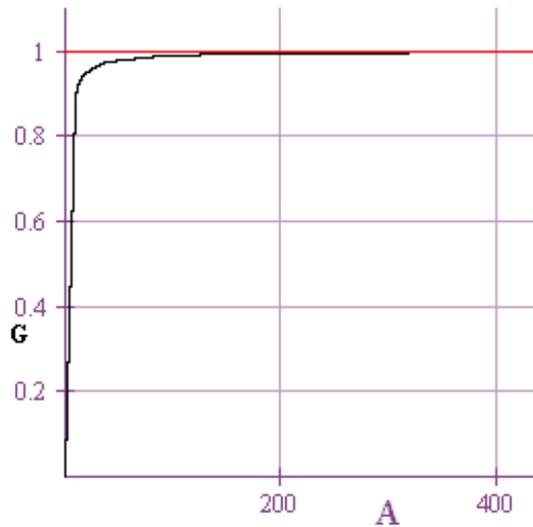
Figure 7 The operational amplifier gain curve, according to Theorist

MathCad is similar to the CAS (computer algebra systems) previously discussed. A sample screen is shown in Figure 8.
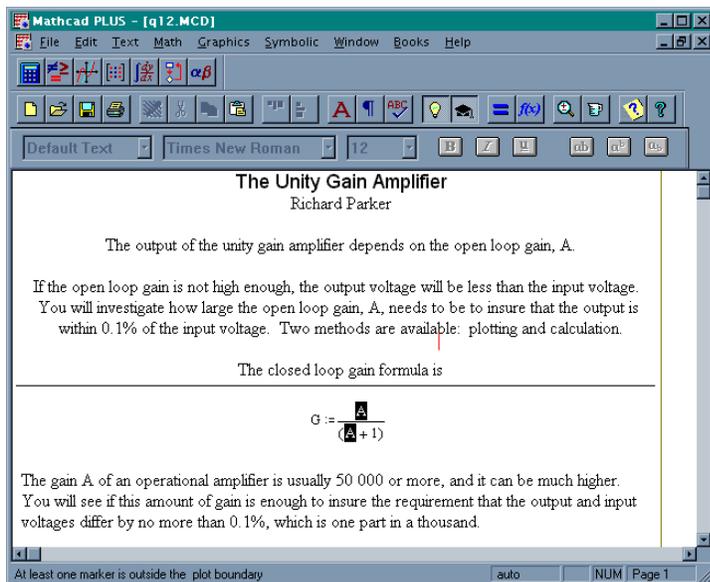
Figure 8 The MathCad worksheet

Finally, calculators may be used in place of computer algebra packages as long as they can be connected to a computer to download stored programs. Figure 9 shows the Texas Instruments Graph Link screen. The same plot as that in Figure 7 is produced on the TI-85 by downloading the graphing commands in the file called *opamp*. Clicking on the *Send* button with the TI-85

connected via a comm port loads the program in the calculator. The calculator permits a wide range of interactive activities, including the determination of the intersection point of two curves.
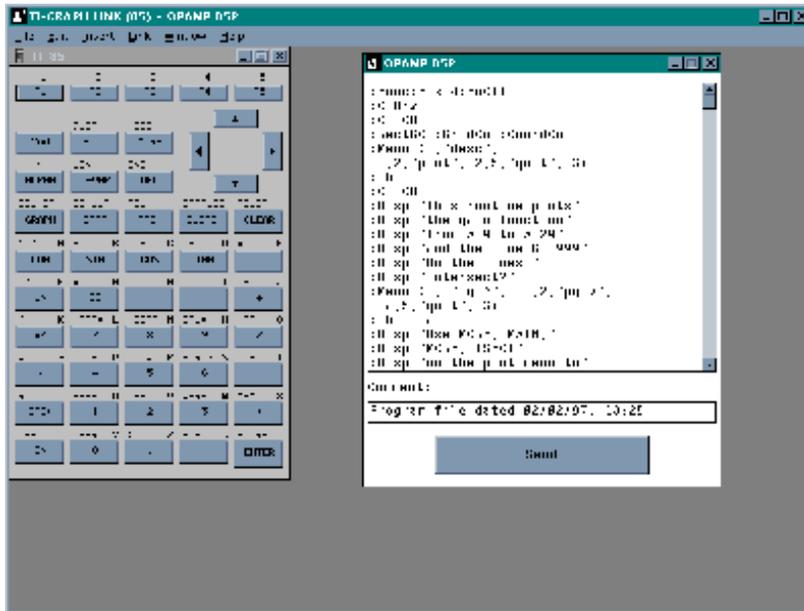
Figure 9 The Texas Instruments Graph Link screen, showing a portion of the *opamp* program

Implications for Distance Learning

A learning module incorporating Electronics Testbench, Electronics Workbench, and a math package can be distributed over the World Wide Web easily because the lesson files are quite compact. The learner already has Electronics Testbench, Electronics Workbench, and the math application loaded on his or her computer.[1] The lesson contains mainly text and commands for Electronics Workbench and the math package, so the overall size is only a few kilobytes. The commands are expanded by the application programs into graphs and circuit diagrams so there is no need for bitmaps for these visuals.

Of course, it is even easier to put the lessons on a college's network so that they become accessible in a learning center and in the computer labs. Students can grade themselves on the practice quizzes and they can e-mail the evaluation tests (where they do not get feedback on which answer is correct) to their instructor. The multiple choice part of the test can be graded by the computer, freeing the instructor for grading the essay questions only.

There is so much potential in constructing lessons in electronic form with a heavy interactive component that fosters experimentation. As these resources become more available, learners will have a real choice to match their learning needs to existing hierarchically constructed curriculum materials.

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[1]Electronics Testbench and TI Graph Link™ is free for the student, and low cost student versions of Electronics Workbench® and most math packages exist.

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4.   Olive, S. & Parker, R. (1992). A Canadian College Introduces Maple to Engineering Technology Classes, The Maple Roots Report, 2(1): Seneca College

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