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Computer Laboratory Simulation in Electrical Engineering Technology Analog and Digital Courses*

WALTER W. BUCHANAN
Middle Tennessee State University, Murfreesboro, TN 37132-0019, USA

ALIREZA RAHROOH
Department of Engineering Technology, University of Central Florida, Orlando, FL 32816, USA

Computer software can be used to simulate labs in analog and digital electrical engineering technology courses. For introductory courses, Electronics Workbench has been found to be an effective software package. The authors have used it for a DC circuit class to confirm lab results in basic electrical circuits and to demonstrate the validity of the basic circuit laws. In the introductory analog circuit class, this software is very useful in demonstrating the properties of diodes and transistors. Mirco-Cap IV is a more advanced software package and gives a very good graphical presentation of both AC analysis and transient analysis.

EDUCATIONAL SUMMARY

1. The paper discusses materials for a course in analog and digital electrical engineering technology.
2. Students of the electrical engineering technology departments are taught on this course.
3. The course (year) is intended for freshman and sophomore college students.
4. The course is presented through laboratory demonstration.
5. The material is presented in a regular course.
6. One hour is required for each practical for which the software is used.
7. One hour of student homework or revision is required for each practical.
8. The paper describes the novel use of lab simulation software as a supplement to a normal hardware practical where the computer is not normally used.
9. The standard text recommended for the course, in addition to author's notes is *Troubleshooting with Electronics Workbench*, Don Browning, Interactive Image Technologies Ltd. (ISBN 0-921862-27-X).
10. The material is not covered in the text.

INTRODUCTION

THIS paper shows how computer software can be used to simulate laboratories in analog and digital electrical engineering technology circuit courses. It has been found that students greet this addition to hardware labs with a great deal of enthusiasm as it helps them separate the 'woods from the trees' when they are trying to understand what is going on in the laboratory [1].

For introductory courses, Electronics Workbench [2] has been found to be a very effective software package. It has a very short learning curve and students can be up and running with it in a single session [3]. The authors have used it for their DC circuit class to confirm lab results in basic electrical circuits and to demonstrate the validity of basic circuit laws. In the introductory analog circuit class, this software is very useful in demonstrating the properties of diodes and transistors using the 'Function Generator' and 'Oscilloscope'. Electronics Workbench is also very good in introductory digital classes. The 'Word Generator' and 'Logic Analyzer' make it very easy for students to get the 'big picture' [4].

Micro-Cap IV [5] is a more advanced software package and is a very good alternative to PSpice for AC circuits and network analysis classes. Although it takes longer to master than Electronics Workbench, Micro-Cap IV gives a very good graphical presentation of both AC analysis and transient analysis of an AC circuit [6]. These two packages together can therefore deliver a very effective one–two punch in any instructor's teaching inventory. [7]

DC CIRCUITS

As an example of using Electronics Workbench in a DC circuit lab session, see Fig. 1 where a circuit

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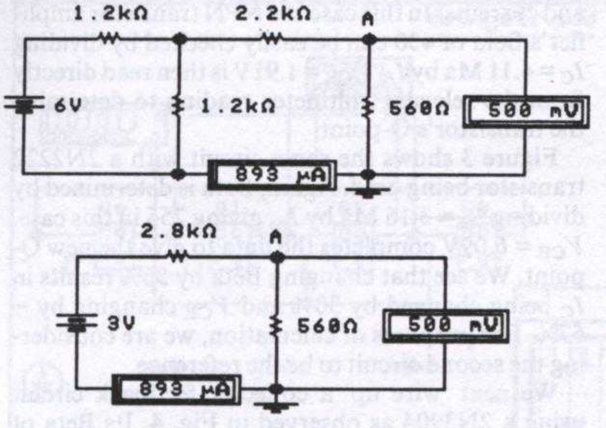

Fig. 1.

and its Thevenin equivalent circuit are shown connected to an identical load. After the students have calculated R_{th} by shorting the source voltage and adding the 2.2K resistor to the 1.2K parallel combination, and using voltage division to get E_{th} from the 1.2K resistors, they are asked to compare the load voltage and current of the original circuit with its Thevenin equivalent. This gives the students a useful reinforcement that theoretical calculations work as expected. They then do the hardware lab session. Many student comments have been received saying that this software addition to the hardware practical really helps them get a good feel as to what is going on.

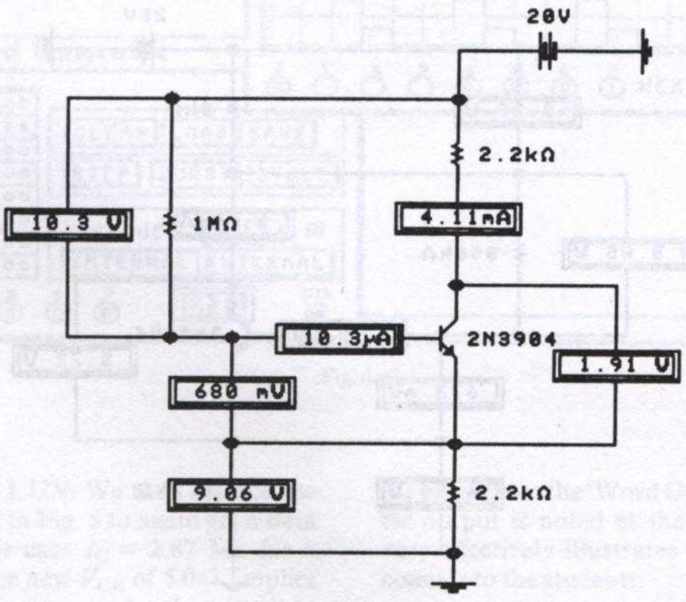

Fig. 2.

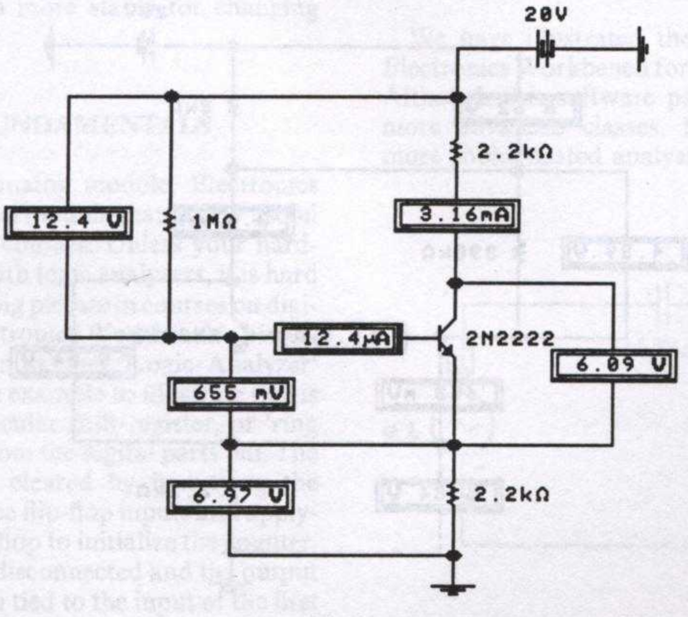

Fig. 3.

ELECTRONIC DEVICE CIRCUITS

Electronics Workbench is also very useful in allowing students to get a better feel of what is going on in electronic device and circuit theory courses. In the following example, it is shown how easy it is to illustrate that a collector feedback bias circuit is more stable than an emitter bias BJT circuit. Figure 2 depicts an emitter bias circuit using a 2N3904 transistor. By using the 'voltmeters' and 'ammeters' in Electronics Workbench's 'parts bin,' the voltages and currents for all necessary calculations can be directly read off of the software's 'workspace.' The program consists of building the circuit using drag-and-drop techniques, and then powering the circuit up to get applicable voltages and currents. In this case the NPN transistor amplifier's Beta of 400 can be easily checked by dividing $I_C = 4.11$ Ma by I_B. $V_{CE} = 1.91$V is then read directly from the relevant voltmeter reading to determine the transistor's Q-point.

Figure 3 shows the same circuit with a 2N2222 transistor being used. Again, Beta is determined by dividing $I_C = 3.16$ Ma by I_B, giving 255 in this case. $V_{CE} = 6.09$V completes the data to give the new Q-point. We see that changing Beta by 56% results in I_C being changed by 30% and V_{CE} changing by −67%. For purposes of calculation, we are considering the second circuit to be the reference.

We next 'wire up' a collector feedback circuit using a 2N3904 as observed in Fig. 4. Its Beta of 400 can be confirmed by dividing $I_C = 3.13$ Ma by

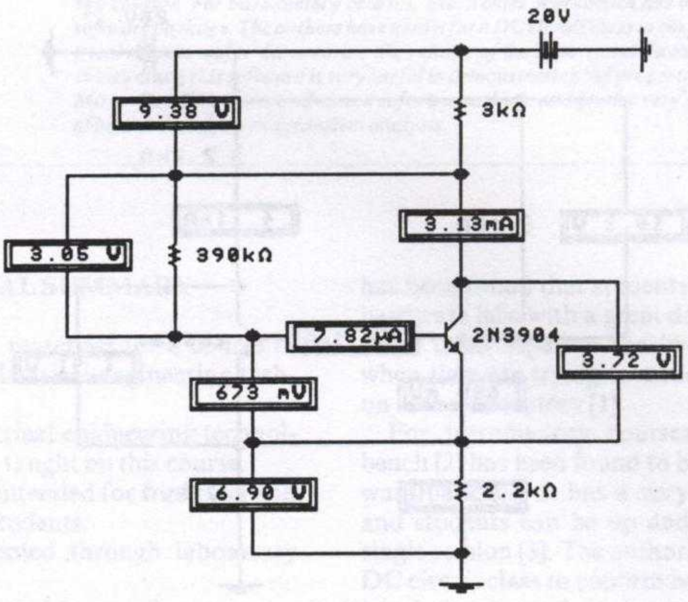

Fig. 4.

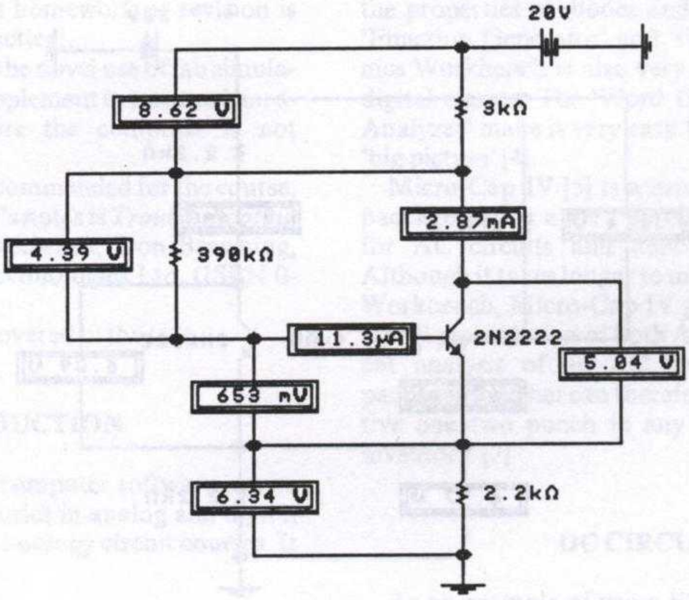

Fig. 5.

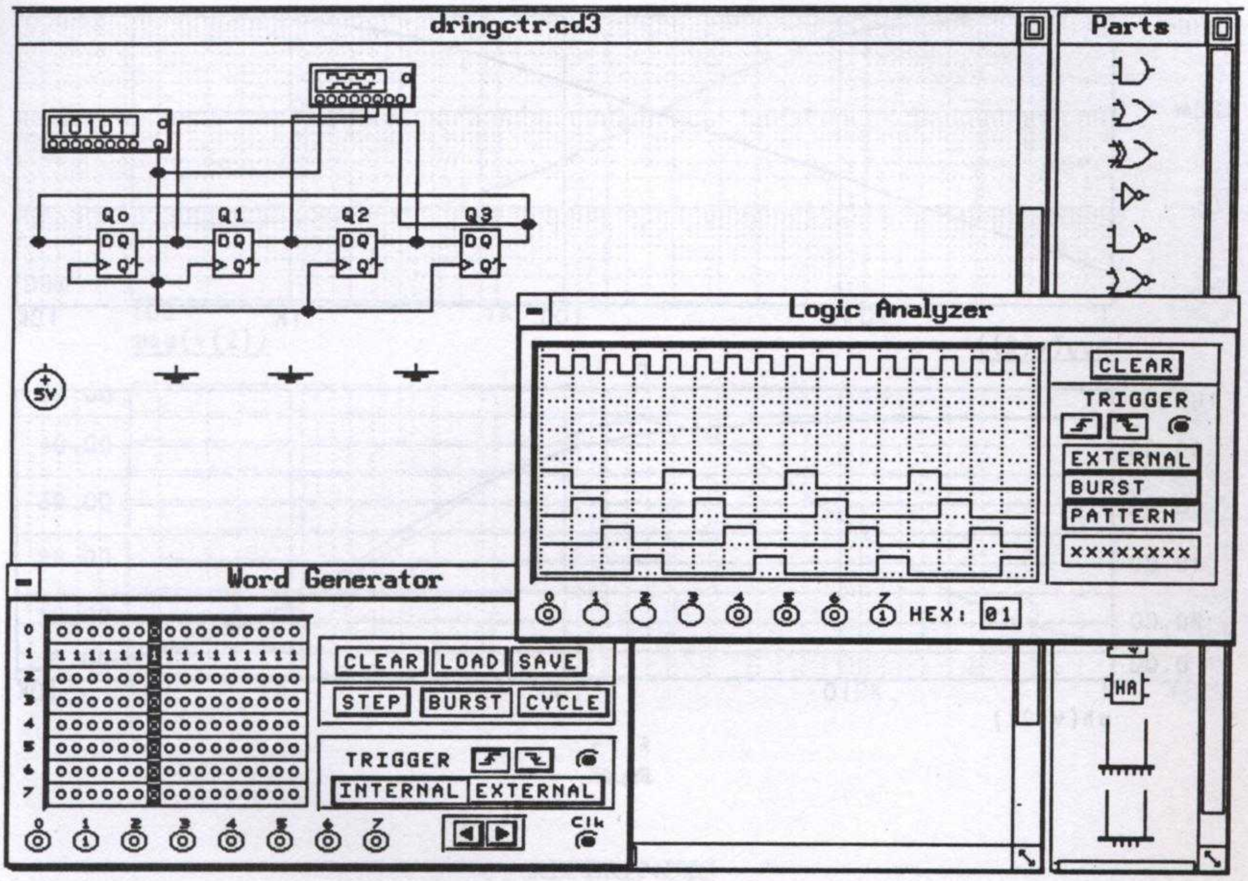

Fig. 6.

I_B. V_{CE} is noted to be 3.72V. We then replace the 2N3904 with a 2N2222 in Fig. 5 to again get a Beta change of 56%. In this case I_C = 2.87 Ma for a change of just 9.1%. The new V_{CE} of 5.04V implies a change of −26% when we consider this circuit to be the reference for calculation purposes. This new Q-point clearly shows the students that the collector feedback circuit is more stable for changing Beta.

DIGITAL FUNDAMENTALS

In addition to its analog module, Electronics Workbench has a digital module that is very useful for digital electronics courses. Unless your hardware lab is equipped with logic analyzers, it is hard for students to get the big picture in courses on digital fundamentals. Electronics Workbench's binary number 'Word Generator' and 'Logic Analyzer' solve this problem. An example to illustrate this is shown in Fig. 6. A circular shift-register, or 'ring counter,' is wired up from the digital parts bin. The D flip-flops are then cleared by first tying the grounds to the last three flip-flop inputs and applying 5 V to the first flip-flop to initialize the counter. These inputs are then disconnected and the output of the last D flip-flop is tied to the input of the first flip-flop to form the circular shift register. Using the clock from the 'Word Generator', the ring counter output is noted at the 'Logic Analyzer'. This very effectively illustrates the operation of a ring counter to the students.

NETWORK ANALYSIS

We have illustrated the effectiveness of using Electronics Workbench for the above three classes. Although this software package can be used for more advanced classes, Micro-Cap IV can do more sophisticated analysis. The trade-off is that

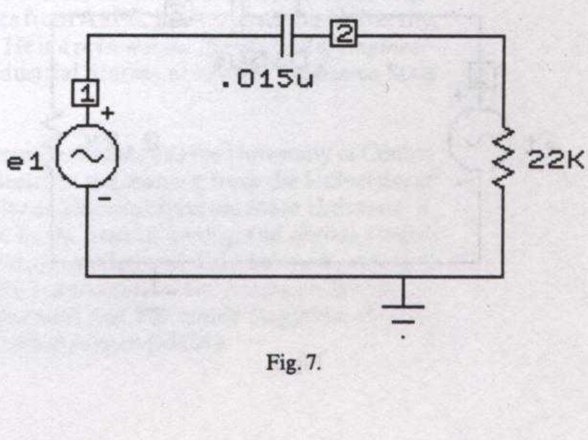

Fig. 7.

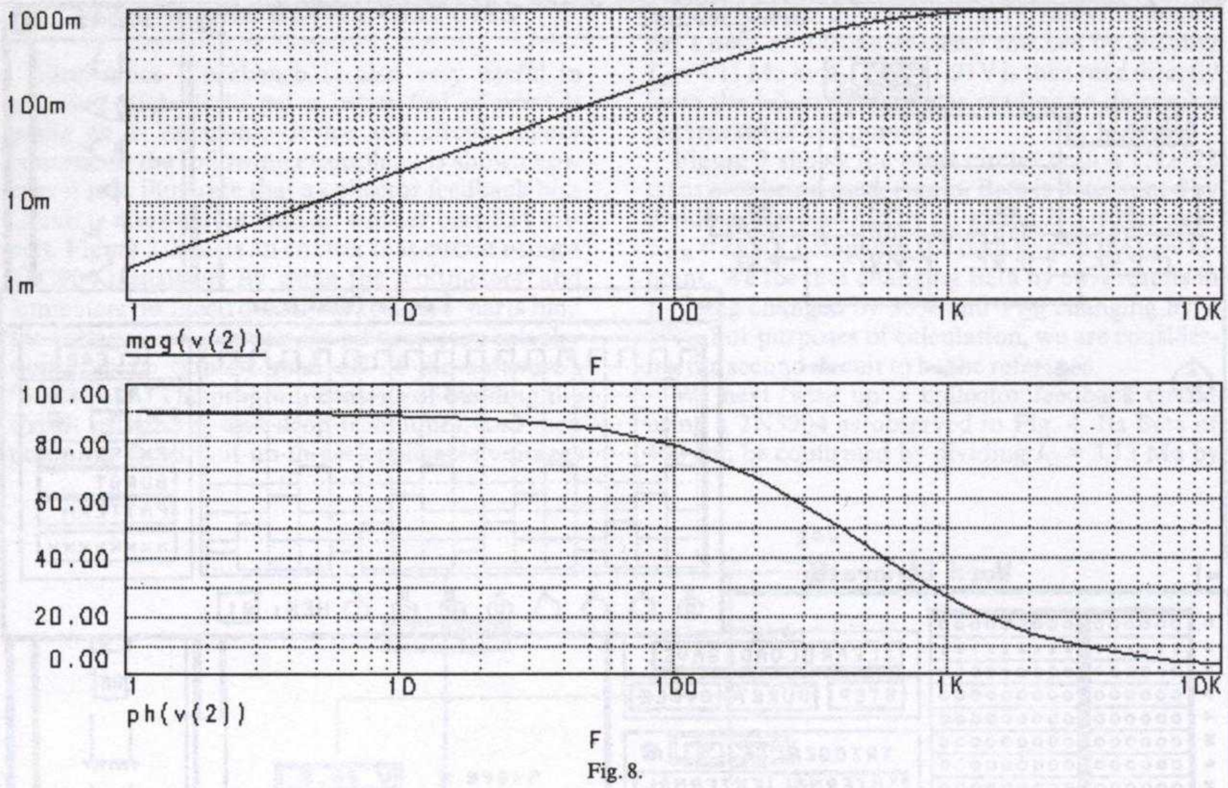

Fig. 8.

Micro-Cap takes longer to learn. Its use will be illustrated in the following example. Figure 7 illustrates a high-pass filter that has been drawn using Micro-Cap. As with Electronics Workbench, this sets the program which is used to run the analysis. After appropriate limits are set, the resulting output is shown in Fig. 8. As expected, the phase shift goes from 90 to 0. These results are obvious from the transfer function of $jwRC/(1 + jwRC)$. As frequency increases, the magnitude goes to unity and the phase shift goes to zero.

The above procedure is now repeated using the circuit in Fig. 9. Here a resistor is placed in parallel with the capacitor. Calling this resistor R_2, and the output resistor R_1, The parallel combination of R_2 and $X_C = 1/jwC$, gives $R_2/(jwR_2C + 1)$. Now using voltage division, the transfer function of the circuit is easily calculated to be:

$$(R_1 + jwR_1R_2C)/(R_1 + R_2 + jwR_1R_2C)$$

Plotting the magnitude and phase of this transfer function would be very tedious. However, by observing Fig. 10, the results are easily understood. When frequency is zero, the initial magnitude is $R_1/(R_1 + R_2)$ as would be expected from voltage division, and as frequency increases, the resulting ratio goes to unity. Using the same logic for phase shift, it can be seen that phase shift will start and end at a low value and never increase above 45.

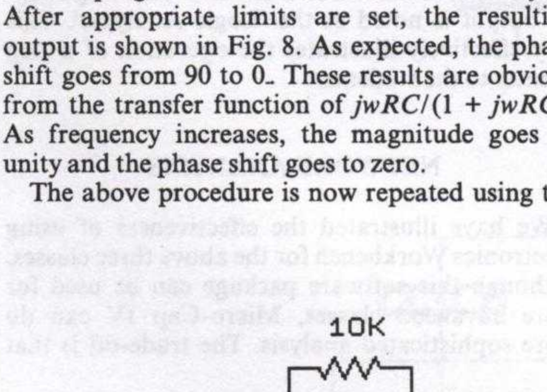

Fig. 9.

SUMMARY

The above examples illustrate how using a laboratory simulation package greatly aids students in seeing what is going on in an electrical circuit. Although hardware laboratory practicals should never be replaced with software, they can greatly assist the student in getting the 'big picture' as to what is going on in the laboratory. As such, they are a valuable addition to an instructor's teaching inventory.

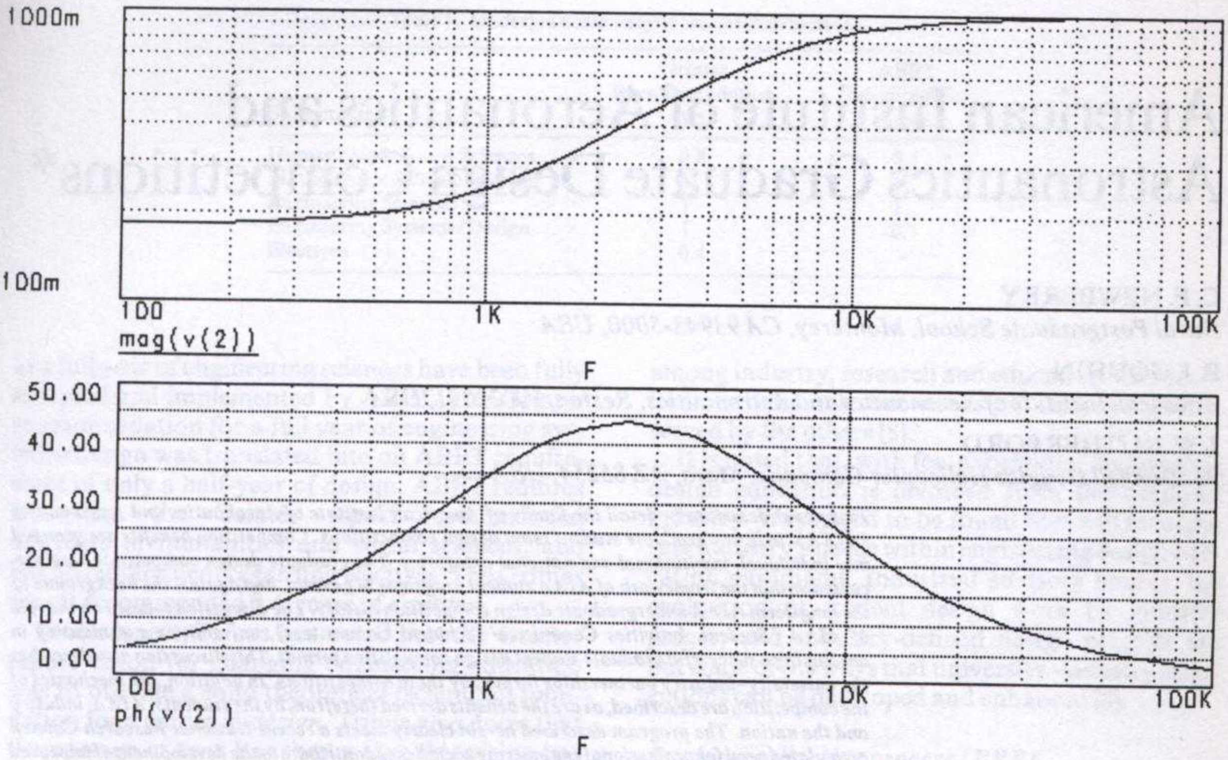

Fig. 10.

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Walter Buchanan served as Deputy Coordinator for Electrical Engineering Technology Associate Degree Programs at the University of Central Florida (UCF). He received his engineering degrees from Purdue University and his Ph.D. and JD from Indiana University. He is a Professional Engineer and is chair of the National Society of Professional Engineer's Continuing Professional Development Committee. He has written 35 papers for American Society for Engineering Education (ASEE) and Institute of Electrical and Electronic Engineers (IEEE) publications and has received grants from ASEE, Purdue, Indiana University, and UCF for his teaching and research activities. He is a reviewer for the *Journal of Engineering Technology*. He is currently chairman of Industrial Studies at Middle Tennessee State University.

Alireza Rahrooh is assistant professor of engineering technology at the University of Central Florida. He received his BS, MS and Ph.D. in electrical engineering from the University of Akron. Dr Rahrooh was previously on the faculty at The Pennsylvania State University at Harrisburg. He has had many papers published in the area of analog and digital control theory, system simulation, electronic instrumentation, analog and digital circuits, robotics, digital signal processing and electromagnetics. He is a member of the American Society for Engineering Education (ASEE), Institute of Electrical and Electronic Engineers (IEEE), and the International Society for Computers and Applications (ISCA).