DISTANCE DELIVERY OF UNDERGRADUATE LABORATORIES

Progress Report

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1. INTRODUCTION

The new Rensselaer program for the Navy personnel at the Kesselring Site in Malta, NY (near Saratoga Springs) has proven to be a resounding success, both academically and financially.   The program was originally established by the former Department of Nuclear Engineering and Engineering Physics in 1993, and was dramatically expanded in the fall of 1997 with the opening of a new site in Malta, NY.   Since last fall, the administration of the program has been assumed by the Office of Continuing and Distance Education, and the academic issues have been coordinated by the School of Engineering.   Since its inception, the program has received the support and cooperation of the Navy Commanding Officer in West Milton and has been very popular among the navy personnel nationwide.   The current enrollment in the program is about 60 students, and may grow to a total of 100 or more in the next few years. However, its future expansion in the present form is limited by the supply of students at West Milton. At the same time, the program constitutes an excellent opportunity to serve as a pilot version of a general distance engineering education program, in particular, for Nuclear Navy personnel nationwide. Since laboratory courses constitute an inherent and required part of undergraduate engineering education, the development of a distance-learning delivery mode for such courses is a major component of the overall action plan aimed at offering BS degrees at a distance. Such courses will make it possible for sailors at remote Navy sites, or anyone else interested in pursuing an ABET accredited Rensselaer degree, to do so from locations other than Troy. Almost all the novel technical and pedagogical solutions developed for the Navy program can be readily applied to any new initiative involving distance learning, situations where scheduling classes becomes a major problem and where an asynchronous mode of course delivery may play a major role.

2. OVERVIEW OF NAVY PROGRAM

Six waves of the Navy students have successfully completed the Summer'99 trimester. Most recently, another wave has started the Fall'99 semester. The motivation and performance of most students have been outstanding, as confirmed not only by the grades but also by the instructors teaching in Malta and representing three academic schools: Engineering, H&SS and Science. Currently, the program includes BS degrees in nuclear engineering and in engineering science, each corresponding to the new 4 x 4 curriculum. Out of the required total of 128 credit hours, graduates of the Nuclear Navy's Power School receive a transfer of up to 30 credit hours toward each degree. It is anticipated that in the near future, a degree in engineering physics may be added to the program, and, later, also degrees in electrical and mechanical engineering. This will attract more students to our program.

One of the major issues associated with offering this new program, especially, its proposed distance-learning version, is concerned with the required laboratory courses. It is important to note that further significant growth of the program will only be possible if we offer it to the nuclear navy personnel at other Navy sites. The proximity of the Kesselring Site will allow for a smooth transition from the current version of the program in Malta into a complete distance-learning facility. Also, issues such as the impact of direct instructor/student and TA/student interaction on teaching quality can be readily assessed by using Malta as a pilot site. This is indeed a very convenient situation, so that after having the program implemented and tested locally, it will be quite straightforward and natural to offer similar programs first to the Navy Site in Charleston, SC, and later to other sites anywhere in the world. The potential future enrollment of high quality students can hardly be overestimated.

3. STUDIO FORMAT OF 'ELECTRONIC INSTRUMENTATION'

The first studio-format laboratory course in engineering, *Electronic Instrumentation* (formerly *Electronics and Instrumentation*), provides a unique opportunity to gain a modern laboratory experience to the Nuclear Navy students and, ultimately, to any interested student unable or unwilling to reside in Troy while obtaining their Rensselaer education. The facility for this course (the Instrumentation Studio in JEC 4107) received its key funding from a 1996 Hewlett-Packard grant entitled `Stimulinc@Distance`, a demonstration of the use of technology-enhanced learning techniques in a highly interactive, hands-on studio environment that is not limited to one on-campus classroom. Unfortunately, we have not been able to make much progress with our intended partner for this enterprise (Calpoly).   Since the Nuclear Navy program needs courses of this type and requires distance education while still being in the neighborhood, we find it a much more productive partner. We get to show that distance laboratory experiences are both academically and economically viable and they get the necessary courses for their degree programs. This course was originally chosen for this endeavor because of its broad appeal. Almost all engineering students take some kind of an instrumentation course, usually offered by their home department. *Electronics and Instrumentation* has typically been taken by the largest group of non-electrical undergrads (Mechanical and Aeronautical Engineering) and, with a few small modifications, can address the needs of other disciplines. Now, for example, the new 4-credit course first offered during the Fall 1999 semester, *Electronic Instrumentation* is a required course taken by taken by Engineering Physics, Nuclear Engineering and Electric Power Engineering students. The equipment needs for this course are also reasonably generic. Thus, any studio ideas built around the resources used here are usually applicable to other courses.

The studio version of *Electronic Instrumentation* is now fully developed. Course materials, which include write-ups for all 10 experiments and 4 projects as well as some standard quizzes, are now in reasonably mature form. New kinds of quizzes have been developed and a standard set of parts and tools has been defined that are now obtained, at reduced cost, from an outside vendor. General information on the course (syllabus, etc.),

all written materials and information on course hardware and software are available starting at http://hibp.ecse.rpi.edu/~connor/ElecInst.html, which also includes documentation on all of the instrumentation and software used in the course. Everything, except for what is provided by personal instructor interaction or direct access to experimental apparatus, is available electronically. These materials and the resources in the classroom are being constantly improved as the course is being taught. For example, OrCAD was recently convinced to donate 25 full commercial licenses for their *Capture* (schematic capture) and *PSpice A/D* (circuit simulation) programs (valued at almost $11,000 each). As a result of this generous gift, all of the experiments, projects, quizzes and homework assignments had to be completely rewritten to work with this new powerful software tool.

Two very standard topics in courses on electronics or instrumentation are diodes and ac circuits. We have developed distance lab exercises for both. However, in this report, we will focus on the exercises addressing ac circuit issues. Following the on the webpage listed above, you will find the Experiment 3 writeup on this topic by selecting *Syllabus* and then *Schedule*. The main tasks to be performed by students in this experiment (*and some highlights of what you will find in the writeup)* are as follows:

- Review background materials on physical harmonic oscillators, with special emphasis on the mathematical model of such systems.

    When the beam is bent, it experiences a restoring force like a spring

    $$F = -kx$$

    where k is the spring constant. From Newton's Law

    $$F = ma = m\, dv/dt = m\, d^2x/dt^2$$

    which, when combined with the previous expression, gives us

    $$m\, d^2x/dt^2 + kx = 0$$

    which is the harmonic oscillator equation. In standard form

    $$d^2x/dt^2 + \boldsymbol{w}^2\, x = 0$$

    where $\boldsymbol{w}$ is the frequency of oscillation. Thus, the beam will oscillate at

$$w = (k/m)^{1/2} = 2\textbf{\textit{p}}f$$

The solution to this equation is

$$x = x_o \cos(\textbf{\textit{w}}t + \textbf{\textit{f}}_o)$$

where x_o is the initial deflection of the beam and $\textbf{\textit{f}}_o$ is the initial phase. For simplicity, there is no need to include $\textbf{\textit{f}}_o$. We have also not included any damping in this model. Thus, we get an oscillation that will go on forever, rather than decaying slowly away. Since we have assumed no dissipation (no friction or other damping force), this total energy will be conserved and

$$W = (1/2)\, m\, v^2 + (1/2)\, k\, x^2 = constant$$

To summarize, the pendulum or any harmonic oscillator works by exchanging energy between two different forms – kinetic and potential.

- Perform an experiment to determine the spring constant and equivalent mass of a cantilever beam, as an example of such a system.

  Several known masses are added to the beam and the measured resonant frequency is used to determine these quantities.

- Use these concepts to develop a corresponding picture of electrical oscillators using inductors and capacitors. In particular, develop the current/voltage relationships for inductors and capacitors, using energy conservation laws analogous to kinetic and potential energy expressions for a pendulum or a beam.
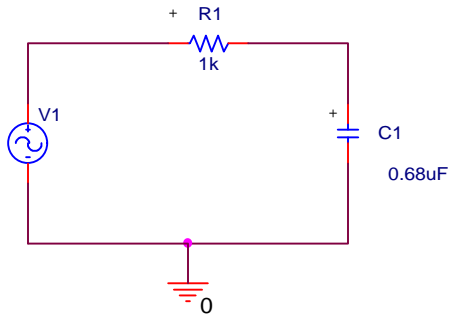
  The total energy of the system must remain constant because there is no dissipative element (no resistor). The total energy is given by

$$W = (1/2)\, C\, V^2 + (1/2)\, L\, I^2 = constant$$

  Since this is a constant, we can take the time derivative of this expression and set it equal to zero, which we can separate into
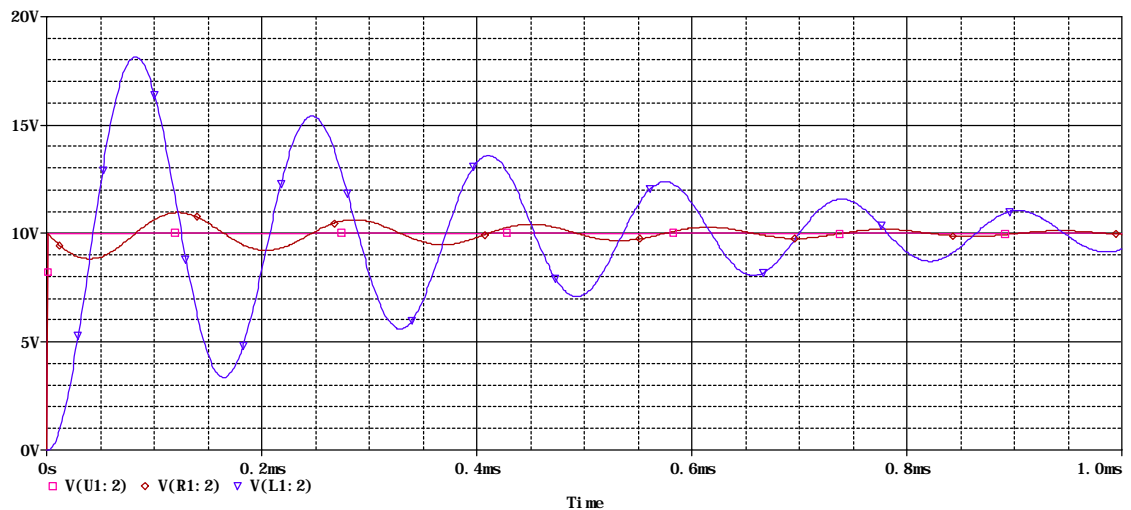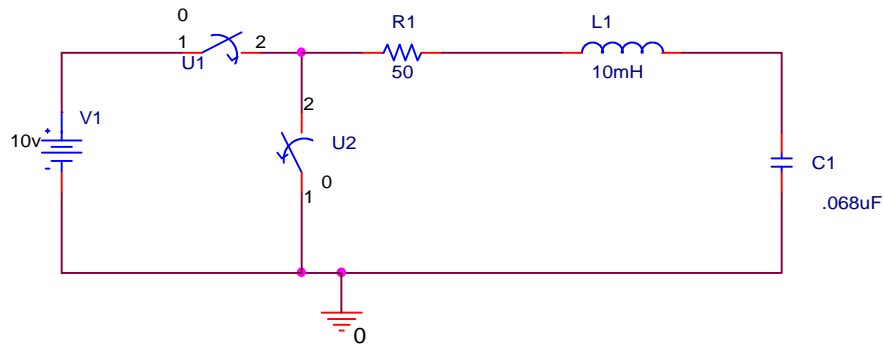
$$L\, dI_L/dt = V_L \text{ and } C\, dV_C/dt = I_C$$

- Using OrCAD PSpice, do a transient analysis of an RC circuit at several representative frequencies. Follow that with an AC sweep analysis with a wide enough range of frequencies to demonstrate the filtering properties of this simple circuit. Perform the latter analysis for both low-pass and high-pass filters.

For the low-pass filter shown, the calculated frequency response is shown in the following plot.

- On a protoboard, set up both types of filters and do an experiment similar to the transient analysis done above. Then, using the HPVEE program *bode*, do an AC sweep over the same range of frequencies as the PSpice analysis.

- Perform a PSpice transient analysis of a series RLC circuit – the electrical equivalent of the cantilever beam, as can be seen in the following plot.

- There is one more experiment to be done – finding the internal impedance of a standard battery – that does not relate to this general topic, but is necessary for a the next scheduled project.

4. STATIONARY FORMAT OF 'NUCLEAR ENGINEERING AND ENGINEERING PHYSICS LABORATORY'

ENVE-4860 *NUCLEAR ENGINEERING AND ENGINEERING PHYSICS LABORATORY* is the major laboratory course which all undergraduate students majoring in either Nuclear Engineering or Engineering Physics are required to take in their senior year. The course included the following experiments:

1. Determining Distance with an Uncalibrated Measuring Device.

2. Digital Multimeter and Oscilloscope.

3. Frequency Analysis of Signals.

4. The Michelson Interferometer.

5. Thermistor Calibration and Transient Response Time.

6. Alpha Decay and Spectroscopy.

7. Determination of Bubble Characteristics by Laser methods.

8. Laser Doppler Velocimetry.

9. Fluid Flow in Circulating Loop.

As the above list indicates, the course combines experiments dealing with electronic instrumentation used in nuclear physics and engineering, optics, laser applications, nuclear radiation, and applied fluid mechanics.

For the purpose of this project, experiment #5 'Thermistor Calibration and Transient Response Time has been selected.   This experiment includes the use of electronic equipment, an actual physical detector (thermistor), reference temperature devices and computer software.   A description of the major elements of this experiment is given next.

THERMISTOR CALIBRATION AND TRANSIENT RESPONSE TIME

Objective:

Calibrated a thermistor and determine its transient response time under a variety of environmental conditions

Principle of Thermistor:

Stienhart-Hart relation relating temperature and resistance is given by

$$\frac{1}{T} = A + B \ln R + C(\ln R)^3 \tag{1}$$

where A,B,C are to be determined from the experiment

The response time and the expected temperature profile:

$$MC\frac{dT}{dt} = -hA(T - T_\infty) \tag{2}$$

Using the lumped capacitance model, the transient energy equation with convection can be written as

$$\frac{d\boldsymbol{q}}{dt'} + \boldsymbol{q} = 0 \tag{3}$$

The above equation can be rewritten in dimensionless form as

$$\boldsymbol{q}(t') = Exp(-\frac{t'}{\boldsymbol{t}}) \tag{4}$$

The temperature profile obtained from solving the above equation is of the form

$$T(t) = T_i - (T_i - T_\infty)[1 - Exp(-\frac{hA}{MC}t)] \tag{5}$$

Procedure:

A thermistor having a nominal resistance of 5 kΩ, and a virtual interface developed for use on computer is provided.

1. Using Equation (1) and the resistances indicated by the digital multi meter (DMM) at the ice point of water (well stirred), the boiling point of water, and the ambient value, calibrate the thermistor.

2. Get the thermistor reading for an arbitrary temperature. Based on the resistance shown on the DMM, and using your calibration, estimate the temperature. Compare against the temperature shown on the LabVIEW screen.

3. Use Equation (4) to determine the transient response time when moving from air to boiling water or ice assuming $\tau = 6$.

5. PEDAGOGICAL AND TECHNOLOGICAL ISSUES IN DISTANCE DELIVERY OF LAB COURSES

Several technical and pedagogical issues must be addressed in the development of sound distance-learning concepts for laboratory courses.

In terms of the delivery modes, several options have been considered, including the following:

1. Synchronous using on-site hardware
2. Asynchronous using on-site hardware
3. Remotely-controlled experiments using pre-set hardware on campus
4. Virtual experiments
5. Providing a set of equivalent instruments at much lower cost using a simple I/O board

The major characteristics of the individual models, and the rationale behind using them, are discussed below.

Synchronous and Asynchronous using on-site hardware: In modes 1 and 2 the students will be performing experiments in Malta using the equipment installed in a dedicated classroom there. Specifically, three sets will be installed, each operated by a team of four students. In this way, a group of twelve students will be working in the lab simultaneously. Each experimental set will include a computer equipped with software allowing for two-way communications with the studio-type classroom on campus. It is anticipated that the link between the Malta site and the campus will be based on using Proshare and the Internet, so that is the configuration we have studied. We were also able to obtain two computers with this capability from computer services.

In mode 1, classes in Malta will be scheduled at the same time as similar studio classes on campus. In mode 2, the off-campus student will be working in a mode much like our on-campus students in open shop. The former arrangement is more challenging to manage, since the instructor, with the help of TA(s), will be interacting with both the on-campus and off-campus groups simultaneously. Much of our time in studio is spent in an open shop like environment in which the staff wander from station-to-station helping students with problems and prodding them with questions. We could easily handle some

off campus questions during this time period, so this time could be used to supplement available open-shop time. We can broadcast our mini-lectures to Malta or we can just provide additional reading materials to the students there. If we broadcast the mini-lectures (mode 1), the distinctions between using class time or open shop time will be the greatest. However, our preference is to stick to a model that does not require the availability of an instructor to deliver a lab course such as this, mainly because the Malta students are not on a schedule that is anything like our on-campus students.

The difference between mode-1 and mode-2 is that the latter will allow the students in Malta to perform experiments at their own time. The only constraint will be that in order to get assistance, the experimental sessions should overlap somewhat with the open shop or class hours on campus. It is anticipated that the open shop will continue to be held for several hours almost every day in order to accommodate the needs of the on-campus students. During the present semester, for example, there is a total of 18 class hours and 12 open shop hours each week.

Remotely-controlled experiments using pre-set hardware on campus: Mode 3 will serve two major purposes. First, it will allow the remote site students to understand the principles of each experiment using a pre-installed setup. These setups will be functionally identical to what the student is to build, but will not use any temporary hardware such as protoboards. They should be reliable and easy to run. In effect, these more permanently constructed experiments can play the role of posted answers to class questions, with the added benefit that it is still necessary for the student to know how to run them. Secondly, it will serve as a backup in the case of any technical problems with the equipment in Malta. Each instrument in need of repair means that a third of the students will not be able to work. It is possible for students with no equipment to split up and join other groups, but a key part of the studio model is learning to work well in groups.

Virtual experiments: Mode 4 will play a role similar to mode 3 and will be used to test the future distance delivery of lab courses to sites far away from the Troy campus (for example, in Charleston, S.C.). It is common, for example, for managers in industry to give permission for someone to take a course just as the semester is beginning. If a student has to wait for the delivery and installation of a set of instruments and some

computers before they can take a course, it might never happen. Also, someone might be given the task of taking a course as a guinea pig to see if it makes sense for others in an organization to do so. Again, it would make no sense for this to hinge on ordering a lot of expensive equipment, when just having a computer available will do.

Providing a set of equivalent instruments at much lower cost using a simple I/O board: Finally, modes 1-3 are based on the use of excellent, standard Hewlett-Packard instruments and software like LabView and HPVEE. This kind of apparatus offers the best possible experience for the student because of its outstanding capabilities and the very high likelihood that our students will see essentially the same kind of instruments on the job. Also, this combination of software and hardware makes it possible to readily implement almost any kind of laboratory experience without having to invent a lot of new devices or write a lot of code. However, most of the same educational value can be found with much cheaper equipment such as the boards available from the South African company, *Eagle Technology* (see http://www.eagle.co.za/main.html). By limiting the educational activities to the audio frequency range (0 - 18kHz), one can provide a digital 'scope, function generator, power supplies, etc. that can do most of what is in this course, all based on a cheap I/O board instead of a set of instruments worth several thousand dollars. This fifth mode is a very labor-intensive option requiring a lot more initial investment but one that could make it possible for almost anyone to take a distance lab course as long as they own a computer. This is presently a long shot since it is very difficult to estimate the kind of work it would take to make this a reality. However, Don Millard bought such a board and got it to do some very useful things for this course with a reasonably small amount of *Director* programming. One of us (Ken Connor) is working on an NSF funded project to investigate this option along with some other web-based instructional methodology. In addition, we presently have a visitor from Hong Kong (Prof. Robin Bradbeer), now teaching a section of Electronic Instrumentation, who has done quite a bit of work of this type with an *Eagle Technology* board. We have not pursued this kind of activity in our present SI funded project, but rather have left it to others.

6. DISTANCE DELIVERY MODES CONSIDERED IN THIS PROJECT

Both the instrumentation course and the NEEP lab, utilize software like *LabView, HPVEE,* or *HP-Benchlink* to control experiments and collect data. By extending the use of such software to all aspects of each experiment and standardizing the experimental apparatus, it becomes possible to run the experiments remotely. If the remote operation is to be done over the web, it is necessary to add one more piece of software, something like *PCanywhere* to access the routines local to the apparatus over the web. We have successfully added the experimental control using *HPVEE* and tested the remote web access. A set of instruments like the one in the studio classroom has been acquired for the remote site and used to develop selected experiments in a distance delivery mode. These instruments have been set up with the necessary computer control, so that the technological feasibility of the proposed approach can be demonstrated. The proposed delivery mode does not include any video connections so it can be used in a fully asynchronous mode. This makes it possible for experiments to be run remotely so that students elsewhere can participate or an on-campus instructor can help out an off-campus student using only email and audio connections for communication. This will permit the Navy students to take a lab course using one of two options:

(a) they have a complete set of apparatus on site and only need assistance and directions from the instructor, and,

(b) they are supposed to connect to the campus lab and perform experiments by either using a setup prepared in advance or by running virtual experiments.

The implementation of this approach will also require more extensive notes than are now in use in the on-campus course, since there is no instructor at the distant site.

While the primary goal of this work has been to develop a practical method for providing a laboratory experience for the Navy students, we have invested equal thought in developing ideas for increasing the quality of this experience while also addressing costs. It is our hope that the distant student's experience will be as rich as that of their on-

campus peers, while not requiring large investments in staffing and equipment that the most simplistic distance delivery systems feasible.

Some of the advantages of the present approach include:

- Remote operation of experiments using a simple computer interface such as *PCanywhere*
- Virtual experiments that look and feel like real experiments so that we have a backup in case of equipment failure or to provide a type of experimental activity at sites without equipment
- Video display of on-campus experiments so the student and instructor can be looking at the same apparatus as they address the student's questions
- A set of on-campus experiments selectable by off-campus students who do not have access to an equipment set
- Video connections so that we can see the experiment the student is working on and, thus, provide more help

In addition, evolution of the present approach will offer additional advantages.

- A replacement for the HP instruments using an *Eagle Technology* board (This board can be used to create function generators, digital scopes, etc with very limited bandwidth and low hardware cost)
In addition, evolution of the present approach will offer additional advantages.

The standard experiment station for this course consists of two computers (one for each pair of students), a 60 MHz Oscilloscope, two triple-output DC power supplies, a digital multimeter, a 15 MHz function generator, and a 225 MHz universal counter. We have found that the counter is not necessary for our purposes, since the multimeter also has a counting function.   Software packages on the computers include Netscape, Matlab, Maple, OrCAD Capture and PSpice, Excel, HP Benchlink Suite, HPVEE, XWin32, and EZFlux.

7. DISTANCE LEARNING MODE OF A TYPICAL EXPERIMENT IN THE 'ELECTRONIC INSTRUMENTATION' COURSE

Experiment 3, *Bode Plot of RC Low Pass Filter*, described in Section 3 of this report, contains many tasks.   Like most of the other experiments, most of the tasks in Experiment 3 involve either PSpice simulation of experiments (which run basically like virtual experiments) and simple experiments requiring a small number of components to be installed on a protoboard. The simulations can be either run using the computer equipment installed at the remote site (currently, in Malta), or by connecting to the campus network using Roadrunner.   For the experiments requiring hardware, most are not difficult to do, especially since the simulation is generally done first. However, should the student have problems, it is anticipated that they will first try to run remotely the identical experiment located in the campus lab in Troy. The most difficult of the tasks in Experiment 3 is the generation of the Bode Plot. That is why we have chosen this task to test out the distance laboratory concept.

Objective:

Develop an understanding of Bode Plots for simple circuits as part of an introductory experiment on AC circuits.
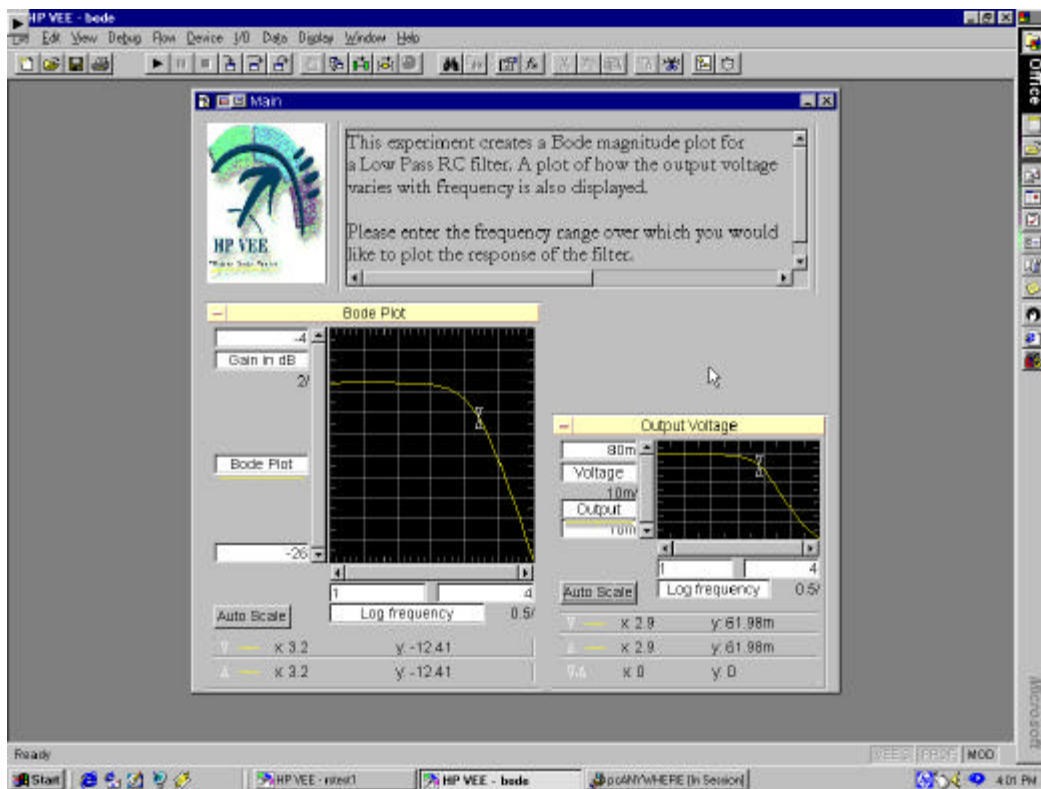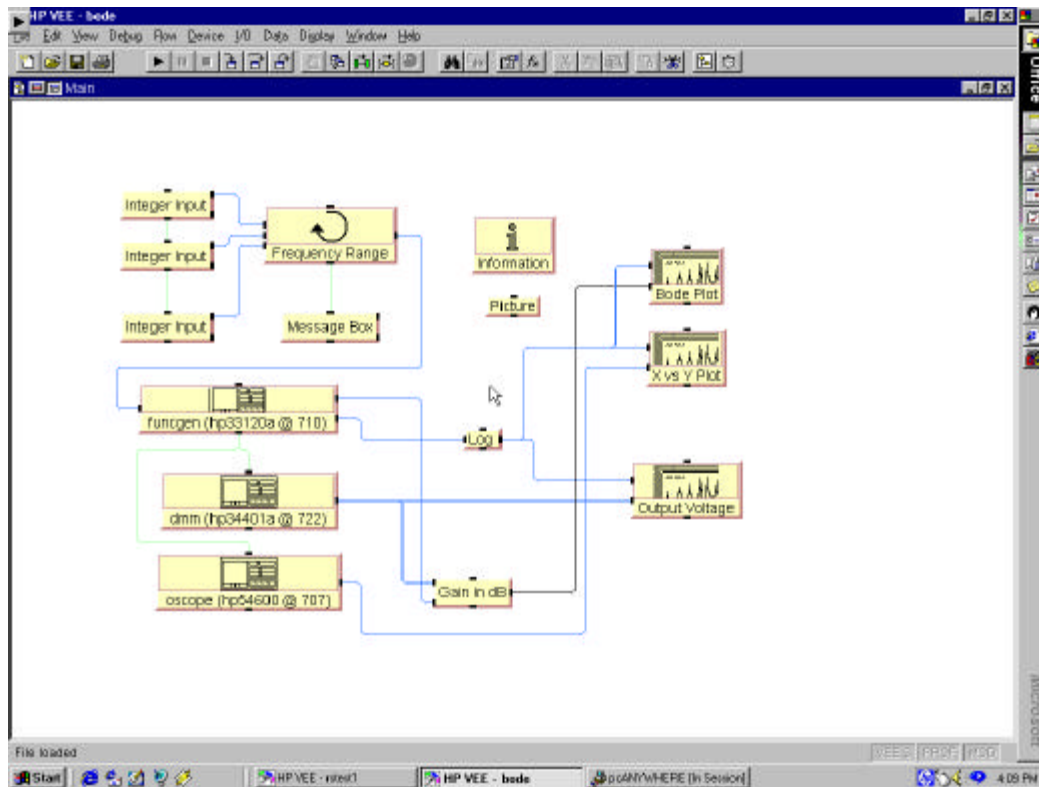
Principle:

Use a function generator to input a sinusoidal voltage with a broad frequency range to an RC low-pass filter. This method is usually difficult to do manually since both the input and output voltages change as the frequency is swept.

Procedure:

1. Select a resistor and a capacitor for the RC filter

2. Calculate the corner frequency to determine the frequency range in which to test the circuit

3. The function generator and multimeter are connected as shown in the HP VEE layout. Select the frequency range and resolution and run the HPVEE program

The program layout for the HPVEE program, and the resultant plot and the corresponding data stored in an Excel file, are shown below.

8. DISTANCE LEARNING MODE OF A TYPICAL EXPERIMENT IN 'NUCLEAR ENGINEERING AND ENGINEERING PHYSICS LABORATORY' COURSE

The experiment selected for conversion into distance delivery mode, *Thermistor Calibration and Transient Response Time*, is described in Section 4. The experimental procedure is summarized below.

Objective:

Calibrate a thermistor and get its transient response time using HPVEE program.
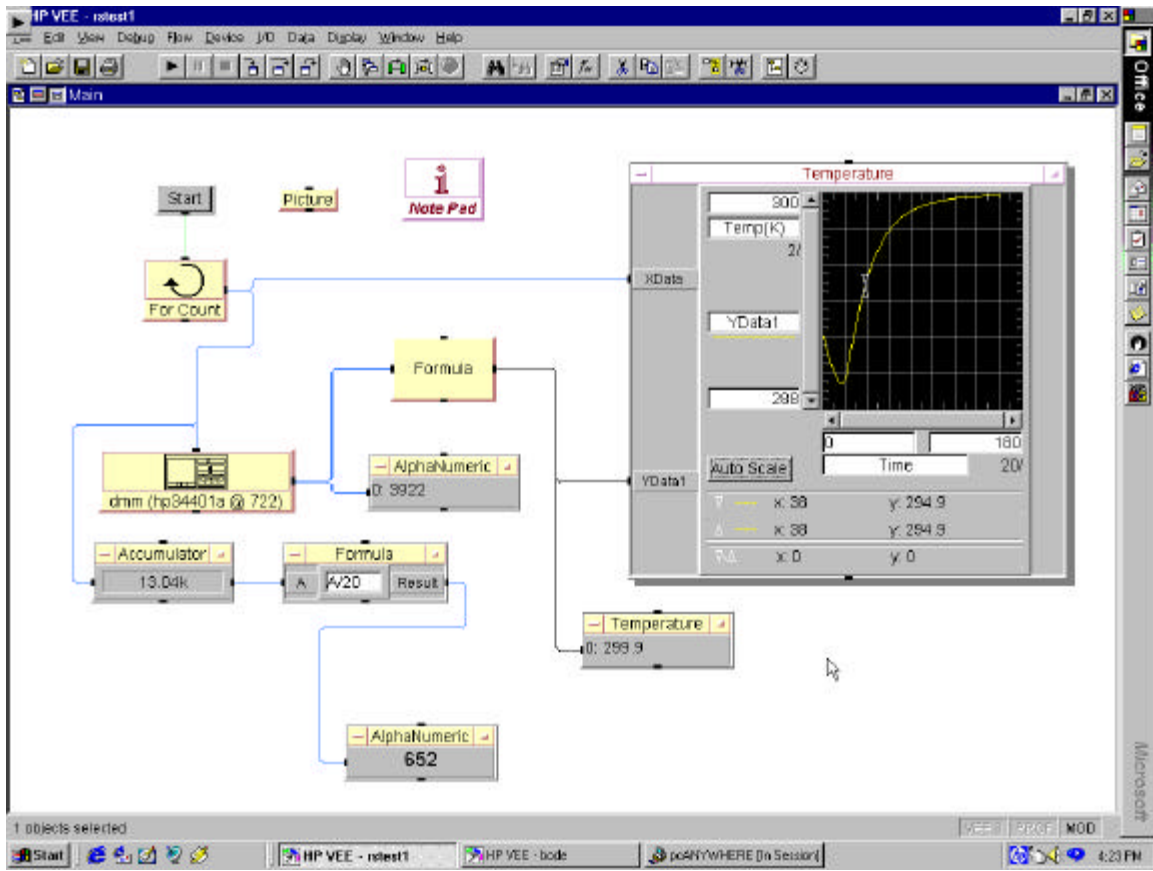
Principle of Thermistor:

- Resistance-dependent temperature is given by Stienhart-Hart relation
- Response time predicted using a transient energy equation

Procedure:

1. Using a digital multimeter (DMM) measure thermistor resistances at melting point and boiling point of water, and at ambient temperature

2. Measure an arbitrary temperature and compare against the temperature displayed by HPVEE

3. Determine transient response time when moving thermistor from ambient air to boiling water

The program layout for the HPVEE program and thermistor transient response are shown next in block diagram form.

Detailed instruction regarding the remote operation of experiment using the *PCanywhere* computer interface is outlined below.

Instructions to the remote user

1. Start the PC Anywhere Express Client and connect to the host PC by specifying its IP address. You now have complete access to the host PC from the remote location.
2. Now start up the Video Conference Manager program and dial up to the host to establish a video conferencing link. At this point, you should be able to see host PC and the experimental setup of the lab at the host location.
3. Execute the HPVEE program on the host PC by following the step-by-step instructions and get the results.

4. Exchange views and/or data with the instructor or TA (if any) at the host location. You may also clarify doubts that you have by interacting with the instructor.
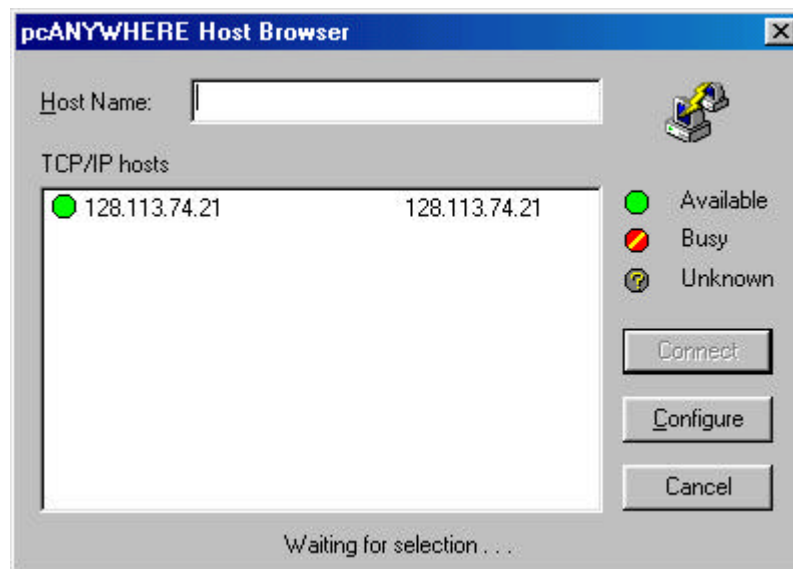
Instructions to setup PCanywhere

To setup the host PC:

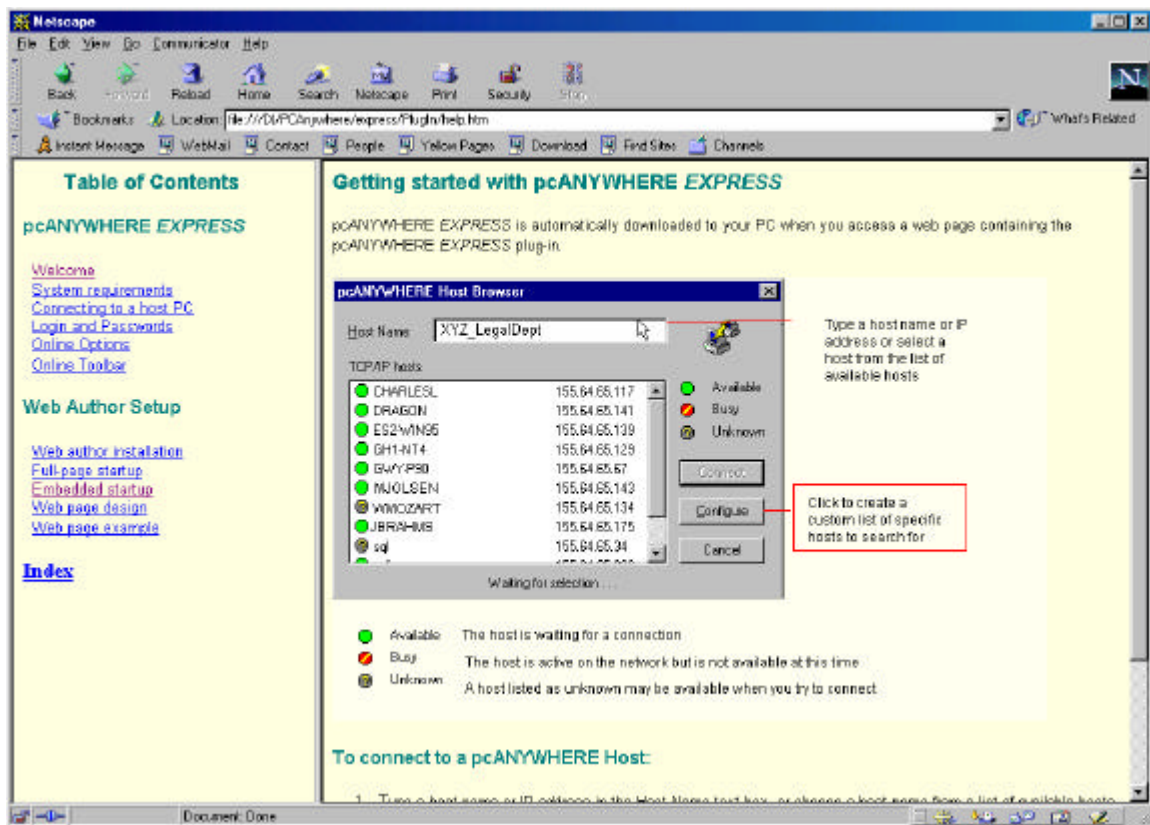1. Hit start.
2. Programs.
3. PCanywhere 32.
4. PCanywhere.

Then

- Hit the "Be a Host PC" button (next to quick start).
- Double click "NETWORK". A window should now open up that says "PC anywhere waiting..."
- TCP/IP Host service: [IP address of the computer] .

pcANYWHERE Host Browser

Host Name: |

TCP/IP hosts

○ 128.113.74.21   128.113.74.21

○ Available
◐ Busy
⊙ Unknown

Connect

Configure

Cancel

Waiting for selection . . . .

A box "Waiting for connection..." will appear.

- The host PC is now all set to be operated from a remote location.
- When "PCanywhere EXPRESS" appears, enter the IP address of the host PC in the window where it says "Host name:" and then hit the "connect" button.

A typical computer image is shown next.

Since the video conferencing option is also being considered for the remote site, the students will be provided with the following instructions

Step by step instructions to setup video-conferencing:

Setting up the PC for conference

This is the procedure to set up both the host and remote PCs.

- Click on the icon-conference manager
- Turn on the camera by sliding the front window open

- Welcome to....will appear and hit "continue ". Now an image in the local window will appear.

To make a call:

In the conference manager window:

- hit "call" and key in the IP address of the computer you wish to call and press enter key

   (or)

- hit 'dial list' and select an IP address from there

Note: To add a new address in the dial list, hit 'dial list' and then select "edit dial list"

1.Fill up the field as required

2.Add>>

3.Save

4.Close the window

Once the connection is established, an image in the remote window will appear.

To use the white board:

In the conference manager window, hit "share"

To chat:

In the conference manager window, hit "tools" then click on "chat"

File Transfer:

The transferred file is saved in Program Files\net meetingNT\Received Files (in the receiving computer)

To disconnect:

- Hit "HANGUP"

To adjust image settings for the video window:

1.In the video window, hit the button right next to "Mute" with the blue rectangle on it.

2.Scroll down to "image controls"

3.Adjust the image

4.Save

5.Close

To take a snap shot:

- One can take a snap shot of either the image window or even the remote window
- Just click on the camera icon below the respective window (local/remote) and the picture will be available on the clipboard(after hitting the snap and close)

To access the clipboard:

1.Click on the start key

2.Point to programs

3.Accessories

4.Clipboard viewer

Note: Click on the "?" below the clock in the conference manager for more online help

9. FUTUFRE WORK

In the work performed so far we have been successful in establishing the proof of concept for remote delivery of selected experiments in two lab courses.   Currently, we intend to take advantage of the recent installation of Roadrunner at the Malta site to test the various teaching modes discussed in this report using the real lab environment.   Also, additional work is needed in order to prepare new lab instructions and other necessary materials for Malta students using WebCT.

Since the present project consititutes only a starting point in the development of distance-learning laboratories for undergraduate programs, more work will clearly be needed in order to convert complete laboratory courses such as Electronic Instrumentaiton and Nuclear Engineering and Engineering Physics Laboratory into distance-delivery modes.   It is anticipated that external funding can be obtained for the continuation of the present work from various sources, including both the federal government, New Yok State agencies, and industry.

Specifically, we are planning to submit proposals to one or more of the following institutions:

- NSF, where significant funding has been designated for the development of novel teaching techniques and where funding has already been obtained for related activities,
- DOE, where there is significant interest in the development and expansion of remotely controlled experiments, especially for reasearch purposes,
- US Navy, where the proposed technology may be useful for a variety of professional education and training programs,

Hewlett Packard and other high tech hardware companies, to get asistance in acquiring the necessary instrumentation for the new distance lab courses to be developed.

10. STRATEGIC BENEFITS

The proposed distance-learning laboratories, while focused on the Navy students in Malta will actually serve a much broader population of RPI students.   The enrollment in Malta may significantly increase if the Navy students do not have to commute to the Troy campus to perform each and every experiment required by their curriculum.

The inclusion of a remote site in Charleston (which will only be possible if we are capable of offering complete BS engineering program(s) in engineering, including the laboratory courses discussed in this proposal) will likely double or even triple the enrollment in Malta. St the same time, with the introduction of distance learning capabilities the cost of program delivery will be significantly reduced.

Last, but not least, the new lab courses may be offered to other RPI students who, for various reasons, cannot come to Troy to perform the work.

Some of the major strategic benefits associated with future introduction of complete distance-learning undergraduate programs are:

- Improved national visibility and reputation of RPI

- Increased enrollment of high quality students

- Pioneering work in delivering distance-education undergraduate programs

- The already-proven success guarantees a quick return on investment

- Big step toward making Rensselaer 'Global University'

- Clear ways for future expansion to working professionals and other nontraditional groups of students (i.e., merchant marines, off-shore oil rig workers, etc.)

- Lower cost per student (after a course has been prepared, it can be delivered many times, with only small updates, to a large number of students)