

## Using Virtual Instruments in a Measurements Laboratory

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### I Introduction

Learning instrumentation and how to make measurements is important to all engineering students early in their academic careers. In many cases, knowing how an instrument works, aids in understanding limitations of instruments. Although learning how to use a single instrument is important, learning to use groups of instruments together to make required measurements and analyze the data is equally important. Virtual instruments can be used to teach all of these areas of instrumentation. The Department of Electrical and Computer Engineering at Texas Tech University uses its first project laboratory, offered in the second semester of the sophomore year, to cover measurements, instrumentation and other topics.

### II Project Laboratories

The Department of Electrical and Computer Engineering at Texas Tech University began stand-alone project laboratories in the early 1960s. The project lab structure has continued to evolve over the past 40 years.<sup>1-9</sup> Students take 5, 3-hour credit laboratories not directly associated with any lecture course. Although the laboratories have no directly associated lecture course, they do have pre and co-requisites. In addition, the first 3 labs have general areas of specialization. The objectives of the ECE laboratories, which closely follow some of the ABET suggested “outcomes”<sup>10</sup>, include the ability to:

1. Identify, formulate, and solve practical electrical engineering problems. This includes the planning, specification, design, implementation, and operation of systems, components, and/or processes that meet performance, cost, time, safety, and quality requirements.
2. Communicate effectively through oral presentations and group discussions.
3. Communicate effectively through written reports and other documents.
4. Design and conduct scientific and engineering experiments, and to analyze and interpret the resulting data.
5. Function and communicate effectively within multidisciplinary teams.
6. Interact with other students, faculty and practicing professionals on professional and ethical responsibility issues.

7. Recognize the need for, and develop an ability to engage in, perpetual learning by working both individually and within multidisciplinary teams on projects for which they have no prior experience.
8. Use statistical techniques to represent, analyze, and interpret data.

### III Project Laboratory Structure

In all of the ECE labs, the student will be provided with the following information:

- 1) A basic statement of the project objective.
- 2) The faculty advisor (technical advisor and evaluator)
- 3) The team members

The faculty advisor for the project is the Product Engineering manager and, as such, is the primary technical evaluator for the project. The ECE labs operate in a matrix style of management. The lab instructor, as the Development Engineering manager, is the primary supervisor and project director. The ECE undergraduate labs director and staff (including Teaching Assistants) are the resource and quality control managers. Whenever possible, at least two members of the management team will attend the lab sessions.

To properly manage a project it is necessary to develop a clear and thorough plan and carefully monitor the execution of the plan. In cooperation with the Product Engineering manager (faculty advisor), the Development Engineering manager (lab instructor), and the resource/quality manager (lab director or staff) and within one week after receiving the project, the project team must develop a detailed project plan. Although all projects and project plans are dynamic, it is imperative that a detailed plan be developed initially and continually examined to properly execute the project within time and budget constraints.

For all ECE laboratory projects, activities on a Gantt chart must be broken down into time intervals no longer than one week in duration. Each task must have a specific deliverable (physical evidence) to indicate the task completion. Completion of the project within the given time and budget constraints is critical. Agreement between all parties (students, faculty advisors, lab instructors, and lab director's staff) on acceptable deliverables is required. The project Gantt chart must indicate these weekly deliverables.

Most of the projects in the ECE labs are team projects. Although each team member will be assigned specific actions by the team, *all* team members are equally responsible for successful completion of the project. Team members will be measured for their contribution to the team by their advisor, lab instructor, lab director's staff, and the team itself.

### III Project Requirements

Throughout the semester, each ECE lab student must provide oral progress reports. All oral presentations must be well organized and include visual aids. Each member of the project team is

required to speak during each oral presentation. These presentations must be organized so that each student has approximately the same amount of presentation time. These presentations are mini-design reviews and must contain enough technical information for the other students, the lab instructor, and the lab director's staff to fully understand the direction of the project. The presenter should be prepared to answer *any* questions concerning the project. Although each team member will have specific deliverables, *all* team members are equally responsible for successful completion of the project and *all* team members should be prepared to answer questions on the whole project.

All of the figures in this paper came from student presentations given in fall 2002.

## V Project Laboratory I

The first project laboratory has 2 projects. The first project is an instrumentation project and the second project is a microprocessor based robotics project. This paper discusses the first project. The objectives of the first project are: to develop measurement abilities within the project lab framework; to develop understanding of the internal structure of basic instruments, to cover a variety of different instruments, and to cover a variety of different measurement applications. The specific project used during fall 2002 is given below.

### *NI 2002*

*Your group has been chosen to be a test site for a new National Instruments LABVIEW system. LABVIEW allows the creation of virtual instruments on a PC. In this new system, the LABVIEW software is coupled through a Data Acquisition Board (DAQ) to an interface box that contains buffers, power supplies, and a function generator allowing the system to provide for complete testing on many different types of circuits.*

*The objective of this project is to use the system to test a variety of analog, digital, and mixed signal circuits with this new system and compare the results with theoretical values and values obtained using discreet pieces of equipment. A variety of each type of circuit should be used. Characteristics such as frequency response, distortion, stability, and other circuit specific measurements should be made and compared. Example circuits will be provided as a starting point.*

*In addition, the system can be used as a teaching aid for measurements by showing the functionality of a specific instrument in the LABVIEW construction. In line with this, the Virtual Instruments used are to be analyzed and compared to the techniques in stand-alone equipment. Comparisons of accuracy, resolution, frequency response, input impedance, etc. must be made.*

*Specific Instruments:*

1. *Voltmeter - DC, AC; Ohmmeter; Ammeter – DC, AC*
2. *Oscilloscope – Triggering techniques; Dual Trace; etc.*
3. *Spectrum Analyzer*
4. *Special Displays – Frequency Response; X-Y plots*

*Circuits:*

5. *Active filters*
6. *Oscillators*
7. *Tuned Amplifiers*
8. *Power Amplifiers*
9. *Switching Regulators*
10. *Amplitude Modulation and Demodulation*
11. *Phased Lock Loop*
12. *Noise Reduction Circuit*

*Example circuits will be provided.*

## VI Project Details

A virtual instrument is actually a PC that uses plug-in cards and software to create a variety of instruments. Graphical software packages allow the design of the instrument at the block diagram level, which enables the student to see the structure of the instrument without having to actually build it. The characteristics of the instrument can be easily seen and studied at a number of different levels. The virtual instrument can then be compared to actual instruments to show similarities and differences. Instrumentation clusters can also be easily configured on the same system. Since the instrumentation is on a PC, data collection and analysis can be integrated into the same environment.

Figure 1 shows a block diagram of the system used in the lab. It is a National Instruments Electronic Laboratory Virtual Instrument System, or NI ELVIS, plus a Data Acquisition Board, or DAQ. The NI ELVIS uses LabVIEW-based software instruments, a multifunction DAQ device, and a custom-designed benchtop workstation and prototyping board to provide the functionality of a suite of common laboratory instruments<sup>11</sup>. Figure 2 is a picture of NI ELVIS.

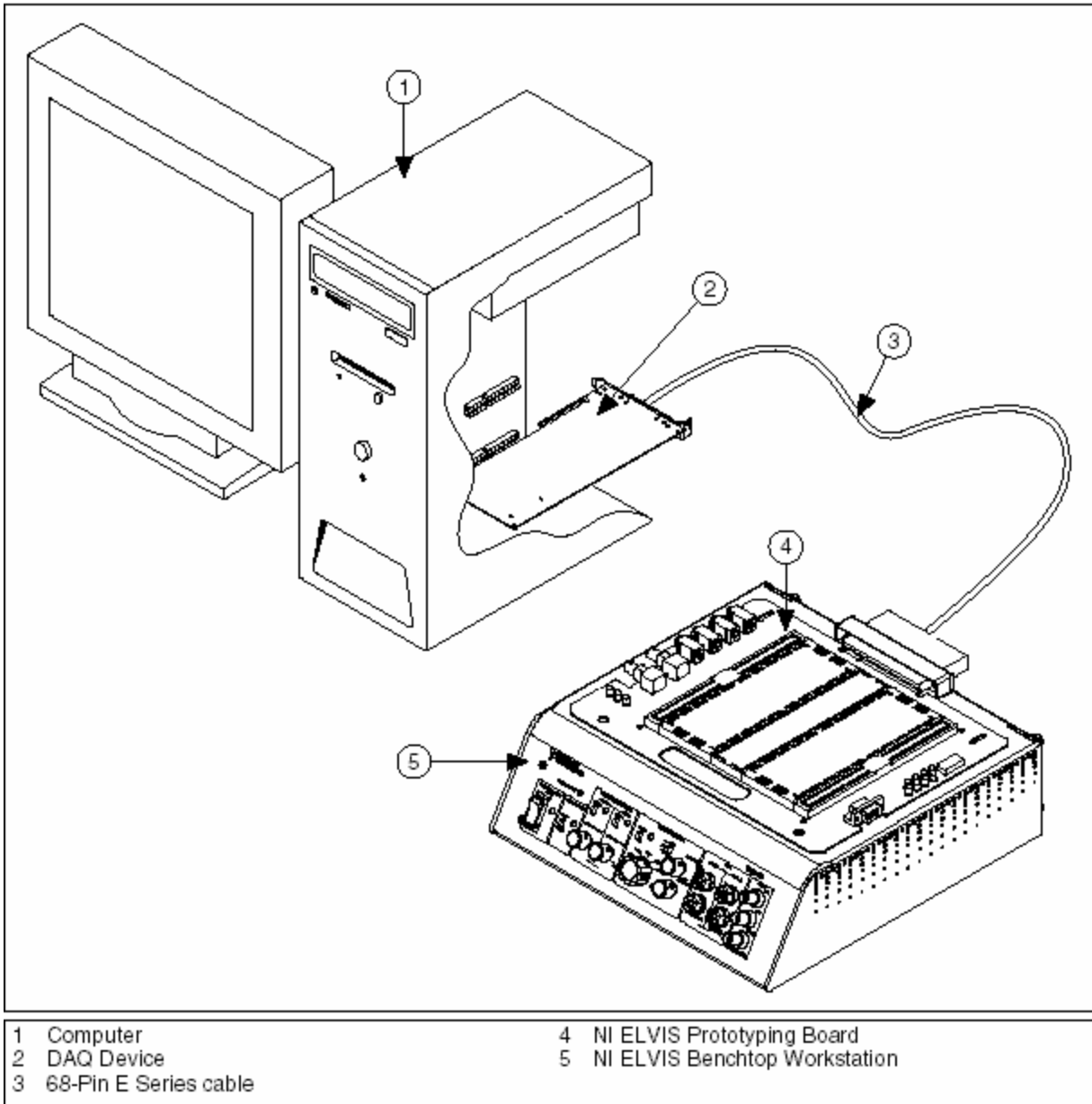


Figure 1. Block Diagram of NI ELVIS<sup>11</sup>

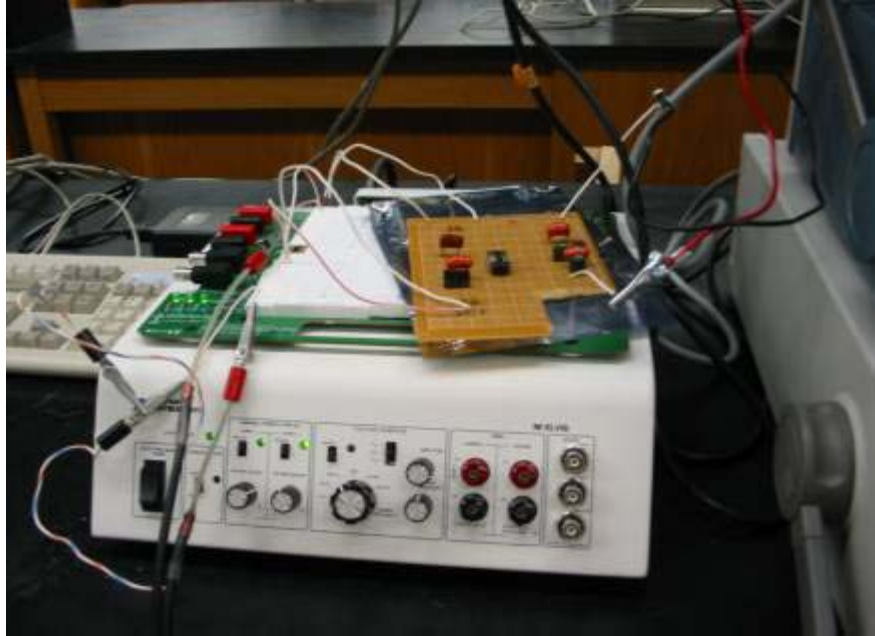


Figure 2. NI ELVIS

The Laboratory Instruments built into the ELVIS system include a positive and negative, variable up to 12 volt, DC power supply as shown in Figure 3.



Figure 3. Front Panel for DC Power Supply<sup>11</sup>

A virtual Function Generator, shown in Figure 4, provides a choice of waveforms (sine, square, or triangle) with amplitude and frequency variability. The Generator also has DC offset, frequency sweep, and modulation capabilities.

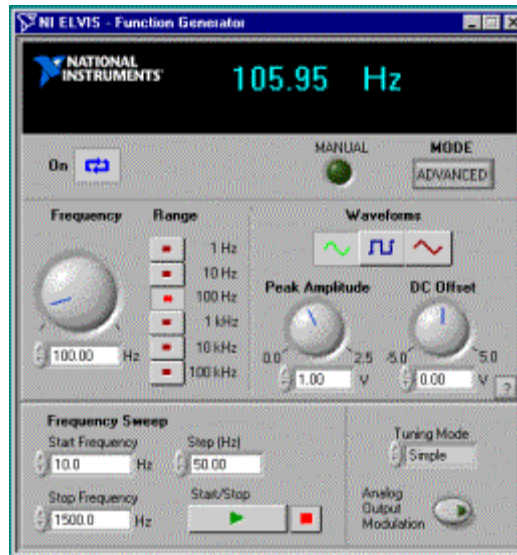


Figure 4. Front Panel for Function Generator<sup>11</sup>

A virtual Digital Multimeter (DMM) is shown in Figure 5. This instrument can measure AC and DC voltages, resistance, and capacitance. It can also perform continuity checks and test diodes.

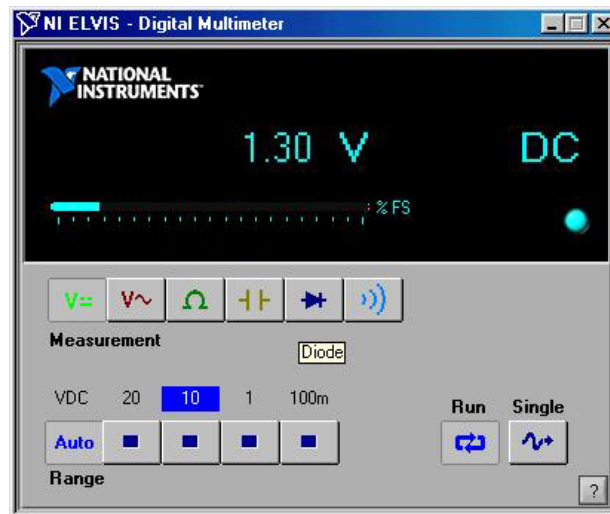


Figure 5. Front Panel for Digital Multimeter<sup>11</sup>

The control panel of the NI ELVIS built-in virtual 2 Channel Oscilloscope is shown in Figure 6. The scale and position for each channel is adjustable as is the timebase. The trigger source and mode can also be set. All of the functions are similar to a standard laboratory oscilloscope.

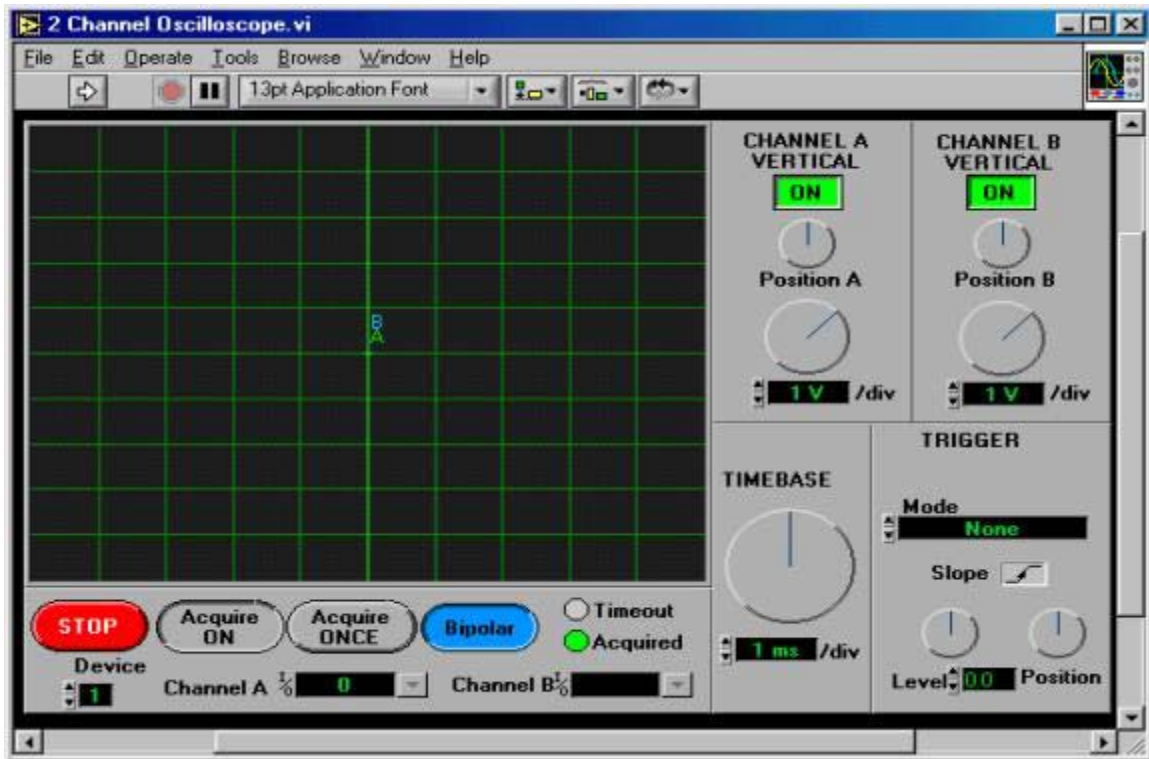


Figure 6. Front Panel for 2 Channel Oscilloscope<sup>11</sup>

One of the major advantages of a virtual instrument is the ability to see inside the instrument and to understand how it works. The functional diagram of each of the instruments is available in the form of a graphical programming language. The program for the 2 channel oscilloscope is shown in Figure 7. It is beyond the scope of this paper to discuss the details of the graphical program. The point is that the internal structure of the instrument is readily available. This is analogous to examining the block diagram of a standard laboratory oscilloscope in a technical manual. As with many block diagrams, there are numerous other blocks that can be examined in more detail, down to the circuit schematic level for a standard instrument. The process can be carried out with virtual instruments by examining the sub-virtual instruments (Sub-VIs). This allows the students to fully understand the operation of the instrument along with what it can and cannot do. By comparing these virtual instruments with more classical hard instruments in both their structure and capabilities the students are able to have a better understanding of instrumentation and measurement capability.



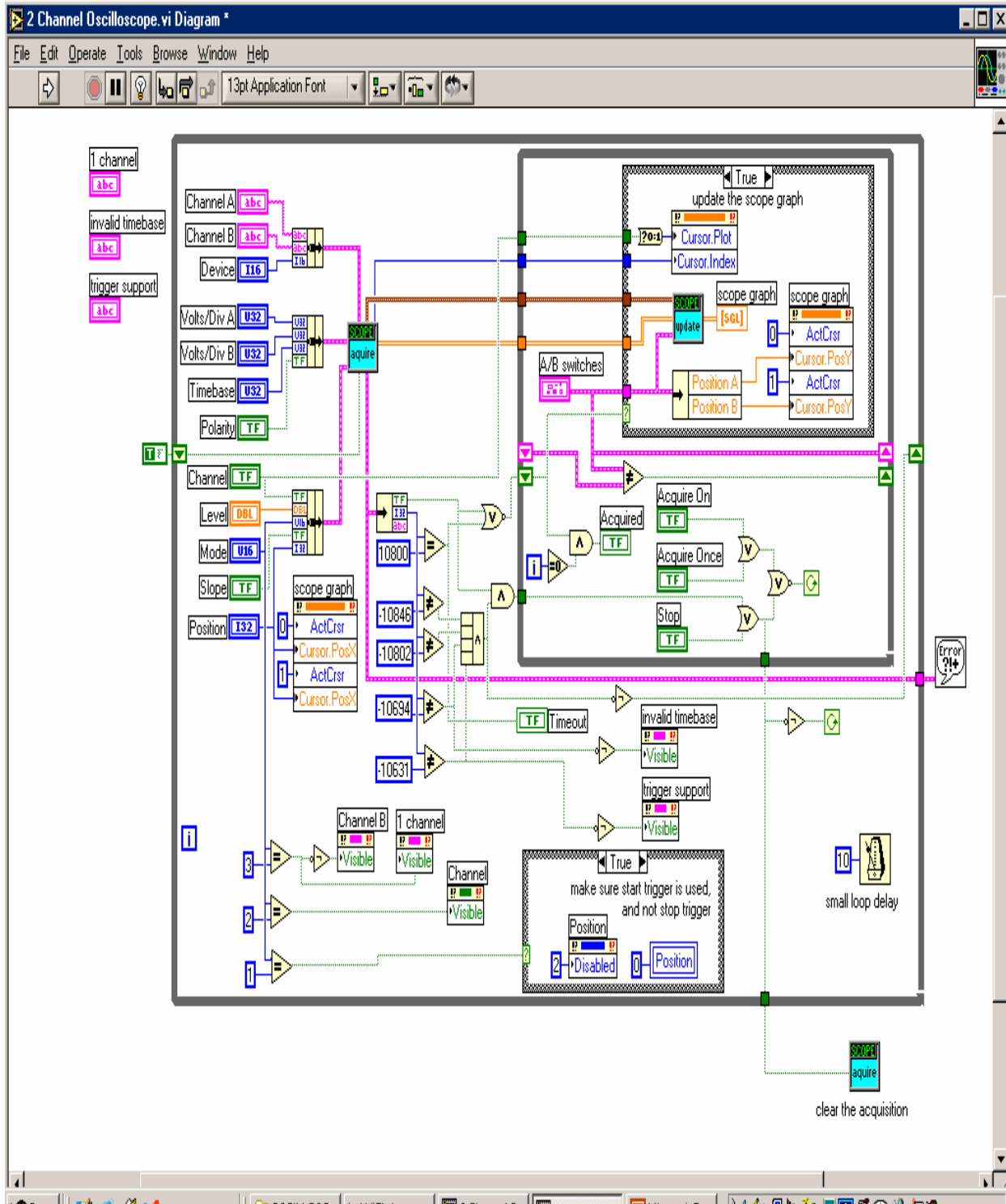


Figure 7. Program for 2 Channel Oscilloscope<sup>12</sup>

Another advantage of the Virtual Instrument is that the data is already available within the PC. This allows for additional data manipulation and analysis with ease. Figure 8, for example, shows a sample log file from the 2 channel oscilloscope. The sample time and value of each channel at that time are recorded for further analysis, if desired.

```

Q0.txt - Notepad
File Edit Format Help
waveform, [0], [1],
t0, 9/22/02 17:29:24.380743, 9/22/02 17:29:24.380743,
delta t, 2.000000E-6, 2.000000E-6,

time[0], Y[0], time[1], Y[1]
9/22/02 17:29:24.380743, 4.052734E+0, 9/22/02 17:29:24.380743, 2.539062E-1
9/22/02 17:29:24.380745, 3.842773E+0, 9/22/02 17:29:24.380745, 2.539062E-1
9/22/02 17:29:24.380747, 3.789062E+0, 9/22/02 17:29:24.380747, 2.539062E-1
9/22/02 17:29:24.380749, 3.808594E+0, 9/22/02 17:29:24.380749, 2.587891E-1
9/22/02 17:29:24.380751, 3.798828E+0, 9/22/02 17:29:24.380751, 2.539062E-1
9/22/02 17:29:24.380753, 3.798828E+0, 9/22/02 17:29:24.380753, 2.587891E-1
9/22/02 17:29:24.380754, 3.808594E+0, 9/22/02 17:29:24.380754, 2.539062E-1
9/22/02 17:29:24.380756, 3.798828E+0, 9/22/02 17:29:24.380756, 2.539062E-1

Q1.txt - Notepad
File Edit Format Help
waveform, [0], [1],
t0, 9/22/02 17:39:18.353000, 9/22/02 17:39:18.353000,
delta t, 1.000000E-4, 1.000000E-4,

time[0], Y[0], time[1], Y[1]
9/22/02 17:39:18.353000, 7.812500E-2, 9/22/02 17:39:18.353000, 2.050781E-1
9/22/02 17:39:18.353100, 7.812500E-2, 9/22/02 17:39:18.353100, 1.416016E-1
9/22/02 17:39:18.353200, 7.812500E-2, 9/22/02 17:39:18.353200, 2.050781E-1
9/22/02 17:39:18.353300, 7.812500E-2, 9/22/02 17:39:18.353300, 1.904297E-1
9/22/02 17:39:18.353400, 7.812500E-2, 9/22/02 17:39:18.353400, 2.001953E-1
9/22/02 17:39:18.353500, 7.812500E-2, 9/22/02 17:39:18.353500, 1.757812E-1

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Figure 8. Sample Log file from Labview<sup>12</sup>

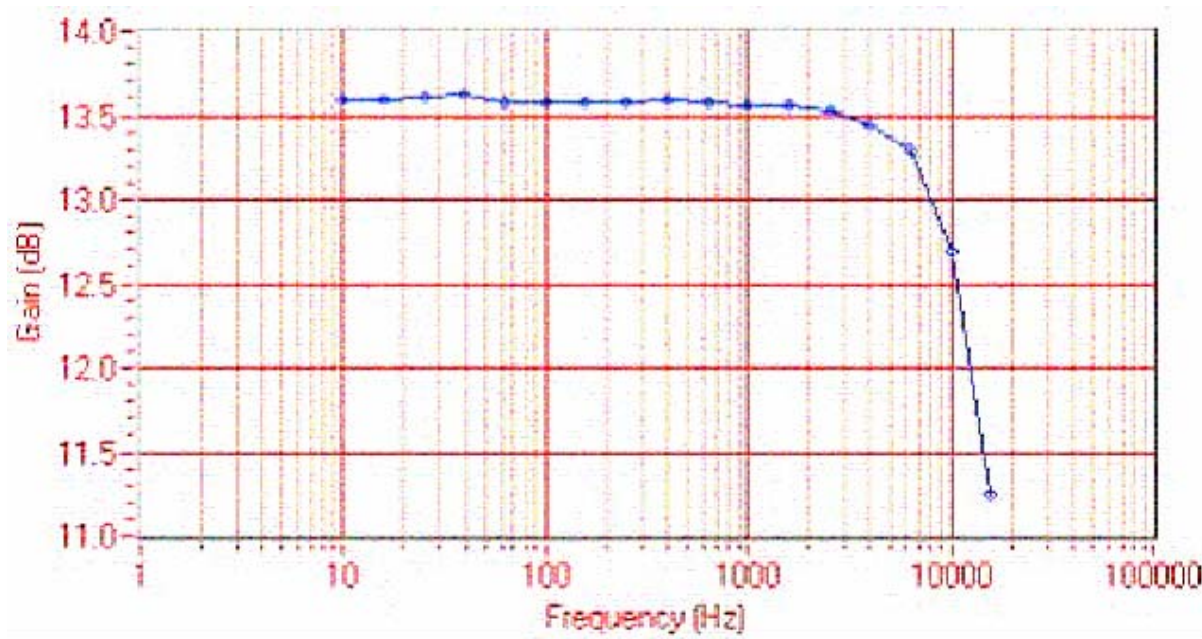


Figure 9. NI ELVIS Bode Analyzer<sup>13</sup>

Virtual Instruments also have the capability of instrument configurations that are difficult to obtain in direct hardware systems. The Bode analyzer in the ELVIS systems is a good example of that capability. Figure 9 shows the output of the Bode analyzer, which behaves as a simple instrument in the ELVIS system.

## VII Project Results

The following are comments from the final student presentations on describing NI ELVIS as compared to stand-alone physical instruments.

Advantages:

- The entire LabVIEW/ELVIS System costs much less than a complimentary set of physical laboratory tools.
- The Visual Based nature of the LabVIEW software allows for a shallow learning curve with the ease of customization.
- LabVIEW allows for testing of the “ideas” of a circuit even before actual construction.
- Ease of Use for:
  - Oscilloscope
  - Digital Multimeter
  - Variable power supply
  - Prototype Board
- Side connections are easy to find
- Breadboard on the system is a plus

### Disadvantages:

- Limited Operational Range
- Limited accuracy
- Oscilloscope is Digital ONLY
- Frequencies higher than 40kHz are difficult to process
- Only 9 time division settings on Oscilloscope
- Entire LabVIEW system is vulnerable to PC system speed (Slow Computer=Slow Signal Processing)
- Only a few LabVIEW or ELVIS resources can be used simultaneously without suffering from errors or decreased performance (PC dependence)
- While the relatively inexpensive LabVIEW/ELVIS system can simulate an entire workbench of tools, it does not simulate any one task as well as a physical tool.

### VIII Conclusion

Of course, there are many advantages and disadvantages to virtual instruments available today. By having the students go through the analysis of the instruments and compare the capability of the instruments, they can learn instrumentation and measurement techniques while doing a meaningful project.

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