Virtual Instruments for Distance Learning

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Abstract- *Using the sound card and CD player that are virtually a standard on the personal computer, LabVIEW virtual instrument programs have been developed that transform these instruments into a dual-channel virtual oscilloscope and a virtual function generator. With the addition of an inexpensive analog multi-meter, and some simple signal-conditioning circuits, these instruments can be calibrated and used in both analog and digital electronics laboratories to perform some of the laboratory exercises at the remote location. Using readily available networking software, the student can interact with their instructor for help in troubleshooting circuits, and to exchange the essential information needed to complete the laboratory at the remote site.*

INTRODUCTION.

In order for students to be able to perform electronics laboratory experiments at a remote location, it is crucial that they can observe real data, and they have the opportunity to connect the required circuitry to perform the experiment. Real data has a noise component which simulation generally lacks, so a student testing a real circuit which he or she has constructed, may be surprised to find the output signals are very much different from those obtained from simulation. Also, without the experience of connecting a circuit, and making and correcting mistakes, the student will have little idea about what is wrong with a malfunctioning circuit and how to deal with a problem when faced with this situation on the job. However, the cost of the laboratory equipment such as an oscilloscope, an electronic breadboard and a function generator, are on the order of a few thousand dollars; asking the students taking the laboratory course at the remote site to purchase such equipment would be prohibitively expensive. Thus the goal of this effort is to develop some inexpensive tools that can be given to the students at remote locations, that will give them virtually the same laboratory experience as the students receive when physically attending the laboratory at the academic institution.

Since most PC computers have a sound card and CD player, it was decided to turn these instruments into a virtual oscilloscope and virtual function generator respectively. While the sound card can also generate signals, it was found early on that a typical sound card can not both generate a waveform and record it simultaneously. To use the CD player as a function generator, constant amplitude monotone signals at various frequencies and various shapes would be recorded on various tracks of a CD. When a signal of a given shape and frequency are required, the corresponding track would be played on the CD player and applied to the input of the circuit in question though the headphone jack. The amplitude of the signal, could be adjusted using the volume control of the CD player.

LabVIEW was chosen as the software to develop the program to run the sound card as a virtual 'scope and the CD player as a virtual function generator. LabVIEW is easy to program and has built-in drivers for both the sound card and the CD player. The resulting virtual 'scope and virtual function generator programs can be made independent of LabVIEW by making them into executable files using the Applications Builder feature of the LabVIEW 6.0 full development package, that is available in our laboratories. That means the students would not have to purchase LabVIEW to run these programs. These programs (or virtual instruments) would allow the students to download the data to spreadsheet files which could be used either in analysis of the data in a report, or to be sent back to the laboratory instructor at the host site to help the student trouble-shoot the circuit.

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BASIC INTERFACING OF THE SOUND CARD AND THE CD PLAYER WITH AN ELECTRONIC CIRCUIT.

To find the interfacing requirements and limitations of this scheme, a survey and some experimental tests were performed to determine the range of resistances, voltages, currents, and frequencies that are used in the electronics laboratory in the Electrical and Computer Engineering Department at ODU (i.e., ECE 382). In this laboratory, the range in resistance is between 0 ohms and 100 mega-ohms, the range of voltage is from – 15 V to + 15 V, the range of current is 0.0 to 0.5 A, and the range of frequency is 0 to 5 kHz.

The following parameters are characteristic of the Yamaha DS-XG sound card. The line input signal is typically sampled at a rate of 44100 samples per second. The bandwidth, over which the signal shape is preserved, lies between 100 Hz and 4 kHz. The useable range of input voltages, which can be observed with no distortion, is between 10 mV_{pp} to 0.5 V_{pp}. The input impedance of the sound card line input is 11 kilo-ohms. Finally, the eighth-inch stereo input connector provides two signal inputs through the left and right stereo channels. Note, to achieve true two-channel operation the line input must be selected on the Windows Record Control Panel. Also note, this operation, disables the microphone input.

For the CD player, the headphone output voltage range across a 35 ohm load was found to be 2 mV_{pp} to 800 mV_{pp} over a frequency range of 100 Hz to 5 kHz. The output impedance was found to be 2.3 ohms.

The most severe restrictions that the sound card-CD player instruments place on the electronics experiments that could be performed, are the lack of response to DC signals, the relatively low input impedance to the line input of 11 kilo-ohms, and the relatively low amplitude of the maximum signal that can be generated and observed.

Since one of the most basic trouble-shooting tests for an electronic circuit is to measure the DC voltage levels at the various nodes, the inability to make DC tests with the sound card would make it hard to troubleshoot malfunctioning circuits. However, this limitation could be addressed by having the student purchase an inexpensive analog multi-meter for use in the course and other home projects. Such a multi-meter can also measure ac rms voltages, which would be useful in calibrating the virtual oscilloscope.

The moderate input impedance of 11 kilo-ohms for the line input of the virtual ‘scope, will cause the instrument to significantly load even a 10 kilo-ohm – 10 kilo-ohm voltage divider network, making the resulting display more difficult to interpret. This would not be the case for the student in the electronics laboratory at the academic institution, where the oscilloscopes would have an input impedance of 1 mega-ohms. This problem could be addressed, by having the students construct a pair of voltage follower amplifiers from a dual operational amplifier integrated circuit. These amplifiers have a voltage gain of 1 and a theoretical input impedance of 100’s of mega-ohms. Using these amplifiers as input buffers to the line input of the sound card, the student at the remote site would have an instrument which would load the electronics circuit much less than would a conventional oscilloscope. However, to avoid problems of cable capacitance, such amplifiers should be located in a probe tip, which then poses power supply problems. An alternative of a X10 probe with an input impedance of 110 kilo-ohms is a simpler alternative. As an added bonus to this approach, the maximum signal that could be input to this probe-oscilloscope system, would now be 100 mV_{pp} to 5.0 V_{pp}. X100 probes have also been investigated, but it was found that the maximum output signal of the CD-player virtual function generator, was insufficient to be able to trigger the virtual PC-sound card oscilloscope.

The low upper limits on signal amplitude for both the observation and the generation of signals with the sound-card CD-player instruments, while probably adequate for small-signal analog experiments, would definitely exclude digital circuits, where measurement and generation of 5 V signals is a must. To modify the line input, to observe 5 V signals, a simple voltage-divider attenuator, would work fine over the possible range of frequencies (= 2 kHz). Two voltage-follower buffer amplifiers could be used: 1) as a buffer between the signal source and the voltage divider to prevent the voltage divider from loading down the signal source, and 2) as a buffer between the voltage-divider output and the line input, so the 11 kilo-ohm input impedance of the line input would not load the divider. A rotary switch could be used to select the lower resistor of the divider to determine the attenuation, and by use of resistors of 1% tolerance, the required experimental accuracy could be achieved. To condition the headphone jack output of the CD player so that a 50 second train of 0 – 5 V pulses could be generated, a simple Schmitt trigger circuit using a comparator with a 0 – 5 V output could be constructed and tested as part of one of the earlier laboratories. In this manner, 0 – 5V digital pulses could be both generated and observed.

Using these PC-based laboratory instruments and an inexpensive analog multi-meter, it should be possible to develop electronics laboratory experiments, based on the present lineup of such experiments, that a student can perform at the remote site. It should also be possible to enable the student to send the data to the instructor during the laboratory, so the instructor can verify that the experiment was indeed performed and/or help the student troubleshoot a malfunctioning circuit.

THE VIRTUAL OSCILLOSCOPE.

As one of the basic tools in the analysis and testing of electronic circuits, a dual-channel oscilloscope at the remote site would be important in determining the voltage gain of a circuit, in determining the presence of phase shifts in the signals, and/or in determining whether any distortion is present in the observed signal.

At present, an internal trigger subroutine (called a sub vi) has been developed and tested (see, Figure 1). This feature was necessary (as it is on a conventional oscilloscope) so that for a steady-state input signal, each trace of the oscilloscope across the screen, lies on top of the previous trace. Due to the ac coupling, the lower limit on input frequency is about 50 Hz. This is the limit for signals where the amplitude displayed is within a few percent of that input; the signals at 12.5 Hz are still more than 80 % of the input signal. Due to the sampling rate of 44.1 kHz, the upper limit on the input signal frequency is about 4 kHz to avoid distortion caused by aliasing.

While the horizontal time base calibration is made easy by the 44.1 kHz sample rate, the vertical scale would have to be calibrated for the virtual oscilloscope to be useful. This could be accomplished by using a signal generated by the CD player connected to both the line input of the sound card and the input to the analog multi-meter in the ac-voltage measurement mode. From this procedure the vertical scale calibration factor could be determined and entered into the appropriate digital control input on the front panel of the virtual oscilloscope program (or vi, i.e., virtual instrument). This could be one of the first experiments performed at the remote site, whereby the students learn how to use the analog multi-meter, the virtual function generator and the virtual oscilloscope.

THE VIRTUAL FUNCTION GENERATOR.

The software for making the CD player a function generator in the LabVIEW format, was taken from a program in National Instruments' LabWindows/CVI, Version 5.5, which is equivalent to LabVIEW (also made be National Instruments), but the program is written in C/C++ instead of the graphical user interface (GUI) format used in LabVIEW. The CD player CVI contains neither a volume control nor a continuous playback mode. The latter is important since the "source" waveforms are to be recorded as one minute tracks on CDs, so to have a steady-state signal, a continuous playback mode would be important. The original CD player CVI goes on to the next track as one track is completed. Since one would like to have a range of frequencies and functions (i.e., sinusoidal, triangular, and square waves), one could envision around 24 tracks at a variety of frequencies, for each of the wave functions on a 74 minute CD. Thus going on to next track, would significantly alter the applied signal, making testing more difficult.

The use of signals recorded on a CD, to generate signals on the speaker output of the sound card has been implemented, tested, and found to perform satisfactorily.
The Windows Volume Control has been used to continuously vary the amplitude of the speaker output, and the CD Player LabWindows/CVI program was modified so it would continuously replay a single track unless a new track was selected. At present the CD player sends out a signal for fifty seconds, then pauses for 10 seconds, and then repeats the original signal, etc. Since the virtual oscilloscope is a digitizing unit, this pause has not been found to be a problem. The next step was to convert this CVI program into a stand-alone executable file, which has been done with the CVI software.

THE INTERNET CONNECTION.

A group of the faculty in the Engineering Technology Department at Old Dominion University[1], has developed a method of networking students and instructors over the internet, using conventional software, for conducting a wide variety of courses over the internet, including laboratories. This method been tested in several courses and found to work successfully.[1] At present, the overall interaction is by students accessing the course web page over the internet. The overall communications package is DataBeam. Under this umbrella, there are four programs running to assist the interaction between students and the instructor. These programs are: DataBeam's Appshare, DataBeam's Presentation Whiteboard, DataBeam's General Function Package, and MS NetMeeting 2.1. Appshare enables the instructor to demonstrate an applications program to the students and then relinquish control to a selected student. This can be used to give the student control of an experiment at the instructor's or host site, and perform the experiment, even though the student does not have the application located on their remote-sight computer. DataBeam's Presentation Whiteboard permits the instructor to broadcast and manipulate a Windows application program to all the students in the class. DataBeam's General Function Programs include Chat, Quiz, and HandRaise, whose functions are self-explanatory. Finally, MS NetMeeting 2.1, permits the exchange of audio and video data so as to make the virtual classroom much more like a real classroom.

These programs were tested and generally found to perform as desired.. Camera pictures from an inexpensive digital camera were sent both ways via the camera software provided by the manufacturer. However a 56K modem was found to be inadequate for a decent audio transmission. While it would transmit adequate pictures of people, it would not transmit pictures with enough detail to observe what is the configuration of a circuit constructed on a circuit board. It was hoped that the error in circuit construction on a circuit board would be detectable by the instructor from an inexpensive camera located at the remote sight, so the instructor could assist the student in 'trouble-shooting' the circuit. In contrast, a direct satellite link DSL, gave good audio transmission and circuits on a circuit board at the remote could be examined by an instructor at the host site.

DataBeam Appshare software permited the students at the remote sites, to alternately take control of the LabVIEW program running on a host PC. The LabVIEW program, enables the host PC to run and/or control an electronics experiment. Since a typical data acquisition (DAQ) card could easily have 8 single-ended analog inputs, virtually every node in a simple circuit could be monitored. The student controlling the VI, either from the remote site or in the laboratory, could select from which node they want data, download the data to a spreadsheet file, and send that file to themselves for further analysis. MS NetMeeting and Data Beam are free and can be downloaded from a site on Old Dominion University's web page,[2] and installed on their PC, so they can take part in the laboratory course.

Using this system, a student at a remote site could exchange messages with the instructor to help diagnose circuit problems and to successfully complete the part of the experiment to be performed at the remote site. The student could also take control of the experiment at the host institution and take data into a spreadsheet file as if he were present in the laboratory, and send the file back to himself at the remote sight for analysis.

SUMMARY.

Using the sound card and CD player that are virtually a standard on the personal computer, LabVIEW virtual instrument programs have been developed that transform these instruments into a dual-channel virtual oscilloscope and a virtual function generator. With the addition of an inexpensive analog multi-meter and some single signal-conditioning circuits, these instruments can be calibrated and used in both analog and digital electronics laboratories to perform some of the laboratory exercises at the remote location. Using readily available networking software the student can interact with their instructor for help in troubleshooting circuits and to exchange the essential information needed to complete the laboratory at the remote site.

REFERENCES.

1. Jones, R.L., Pardus, B., Swart, W., Wells, S.C., and Williams, F.M., "Live Engineering Technology Lectures and Labs Delivered over the Internet," accepted for publication in Proc. ASME International Engineering Congress, New York, NY, Nov. 11-13, 2001.

2. www.lions.odu.edu/~fwilliam/

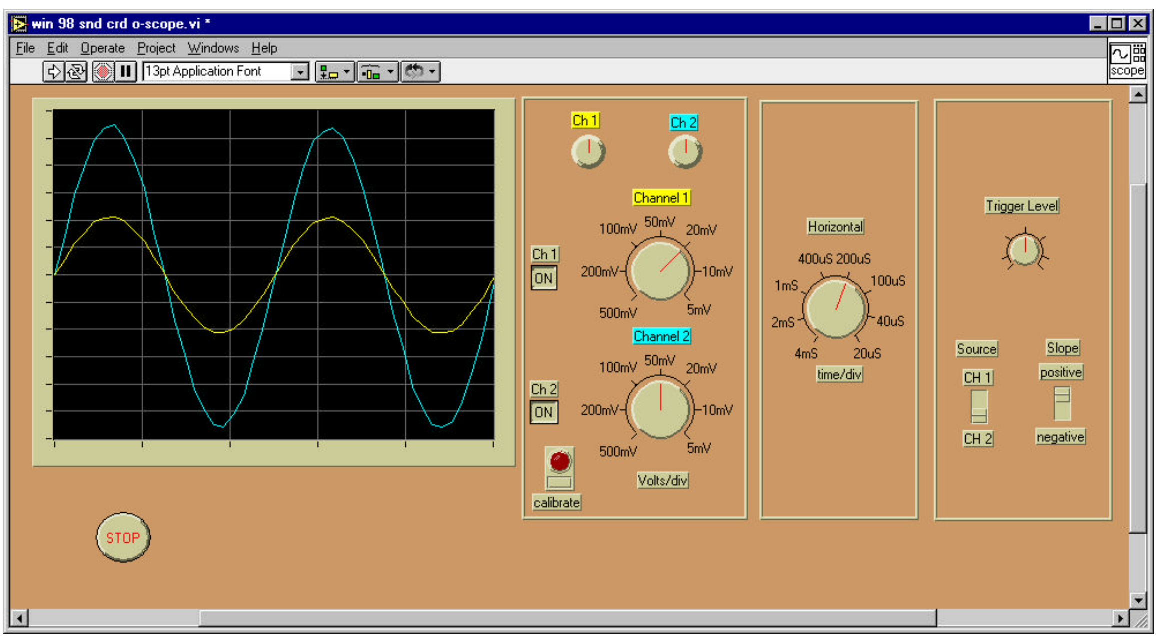

Figure 1. The front panel of the virtual oscilloscope using the line input of the sound card showing two channel operation.