DLSU Engineering e-Journal
Vol. 1 No. 1, March 2007, pp.102-110

PC-Controlled Electronics Laboratory Multi-Apparatus

Eric Paul L. Basbas
Lanfrank M. Macalintal
Anthony T. Pena
Department of Electronics and Communications Engineering
De La Salle University, Manila

Engr. Antonette C. Roque
Department of Electronics and Communications Engineering
De La Salle University, Manila
E-mail : *roquea@dlsu.edu.ph*

This paper contains the design of an integrated voltmeter, ammeter, ohmmeter, logic probe, oscilloscope, DC voltage supply and a signal generator. All of these instruments are controlled using a personal computer through the PCI bus. The hardware needs to be supported by the equally important software for this system. The system in this case includes the GUI for the user to control the instruments as well as get feedback through the monitor. The same software is also responsible for doing the necessary adjustments and computations before displaying the measurements or waveforms on the screen. Programming is done in Visual Basic.

Discussions on the design, considerations and methodology are also included in this paper. Different experimentations done to test the various modules of the system as well as an analysis of the results are also presented. This paper will also touch on how this project differs from some of the previous work in the same area.

1. INTRODUCTION

An inevitable part of the study of any field of science, engineering in particular, is the need for experimentation to prove and/or demonstrate theories. Most of these experiments are performed in the laboratory with the use of different instruments.

Electronics laboratories may be used to verify theories and concepts as well as aid the students in troubleshooting during circuit implementation. The most common instruments used are the voltmeter, ohmmeter, ammeter, logic probe and oscilloscope. These instruments are not integrated and are, at times, troublesome to transport and setup. In addition, these equipment cannot be brought out of the laboratory by the students.

The objective of this study is to design and build a working prototype that integrates the different laboratory instruments into one system that will be controlled by a personal computer. This will allow students access to such instruments even in their homes with the use of their personal computer. The study is expected to be very useful to people who frequently use electronics laboratory instruments. This study does not aim to replace currently existing laboratory instruments, but rather aims to provide an alternative.

The prototype will be designed such that all of the multi-apparatus settings are controlled through a personal computer via the PCI bus. The outputs from the multi-apparatus are displayed and manipulated through the personal computer. The multi-apparatus will consist of the following instruments integrated into one system:

Instrument	Specifications
Dual-Trace Oscilloscope	0 to 5 KHz
Voltmeter	± 500V DC, AC Peak, AC RMS modes
Ammeter	5 Amperes
Ohmmeter	0 to 5 Mega Ohms
Logic Probe	CMOS and TTL
Direct Current Voltage Supply	3V, 4.5V, 6V, 9V and 12V (3 Amperes Max)
Signal Generator	Sinusoidal, Triangular, Square wave 0 to 5 KHz

Previous work on different measurement systems and signal generators were reviewed.

Chua et al. (1990) worked on integrating a logic probe, multimeter and an oscilloscope. The software of the said system was DOS-based and the interface used (ISA) is already outdated. Their research was more focused on the ADC concepts, the parallel comparator and dual-slope conversion techniques in particular.

The work of Diaz et al. (2003) was focused on the pulse and function generator, which forms part of the current project. The pulse generator implemented is capable of generating Binary counters, Johnson counters and customized 8-bit pulses. On the other hand, the function generator that was developed is capable of producing various analog signals such as sine, square and triangular waves with a maximum frequency of 2MHz. Note, however, that this project was microcontroller-based and thus, did not use a PC.

Macabuag et al. (2002) developed a system composed of a multimeter and a function generator. The multimeter can measure currents up to 1A, resistance up to 1 Megaohm and voltages up to 30V. The signal generator can produce sine, square and triangular waves with a frequencies of up to 200KHz.

In another research, Katalbas et al. (2000) designed a device that would display electronic waveforms on a personal computer. Maximum sampling rate of the system was at 15MHz with 8 clock speed selections.

2. DESIGN OF THE MULTI-APPARATUS SYSTEM

The system is composed of the data acquisition circuits, Analog-to-Digital Converters (ADC), Peripheral Component Interconnect (PCI), Graphical User Interface (GUI) and the supply circuits. Figure 1 illustrates the block diagram of the multi-apparatus system. Proper selection of analog-to-digital converters, IC's and different components are vital to the success of the study.

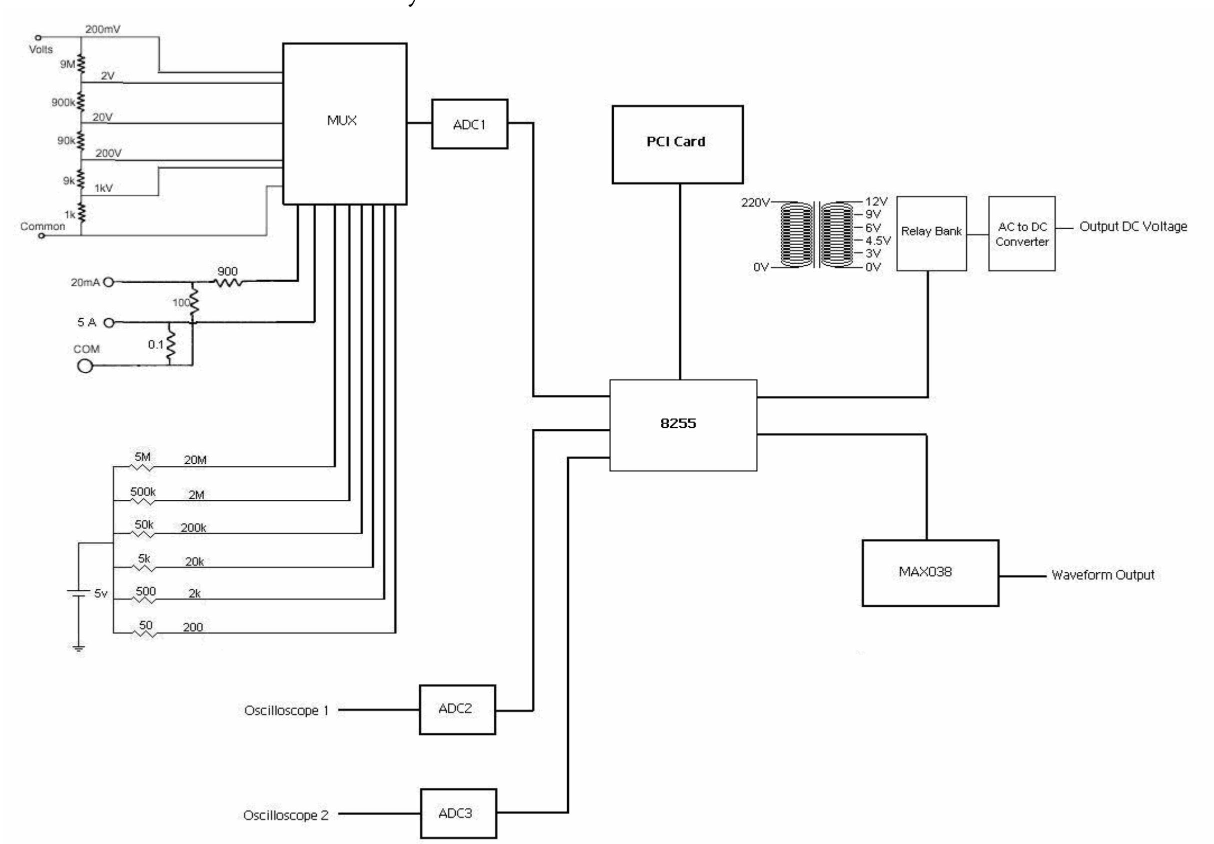


Figure 1: Block Diagram of the System

The ADC section is the one responsible for converting the analog inputs from the data acquisition circuits since the signals to be processed must be in digital form. Selection of the ADCs to be used is very critical in the sense that this will determine the accuracy and success of the project. The group had to revisit their ADC theories and determine what conversion method and ADC design would best fit their system's requirements. Through experimentation combined with research on the specifications and capabilities of various ADC chips, the group was able to select an appropriate ADC, the ADC0804. It is a CMOS 8-bit successive approximation A/D converter that uses a differential potentiometer ladder. The ADC0804 offers very good conversion capability whose linearity is very well suited for this application.

Two types of interface were considered, USB and PCI. It was later decided by the group to use PCI as this is available even on older personal computers. The PCI card interfaces the external hardware to the personal computer for them to be able to communicate. The 8255 was selected among several PCI cards, aside from being inexpensive, review of the specifications showed that this card meets all of the group's interfacing requirements.

The graphical user interface (GUI) allows the user to communicate with the system; this is where the user can view and manipulate the output and control the operation to suit the user's requirements. Designing the project's GUI not only harnessed the group's programming prowess, but also allowed them to gain new skills and techniques by means of studying and using another programming language, such as Visual Basic, for this implementation. The group chose Visual Basic as the programming language for the development of the GUI because of its simplicity and easy to understand programming structure compared to that of other programming languages. Aside from providing an interface for the user to control the different parts of the system, the same software is also responsible for translating and displaying the measurements taken by the various modules of the Multi-Apparatus project. The software is designed such that there is a main console that allows the user to select among the various instruments in the system as shown in Figure 2. Selection of an item from the main console launches a new window specific to the instrument selected. These will display all the necessary data and the user can then manipulate the data and control the system using these sub consoles.

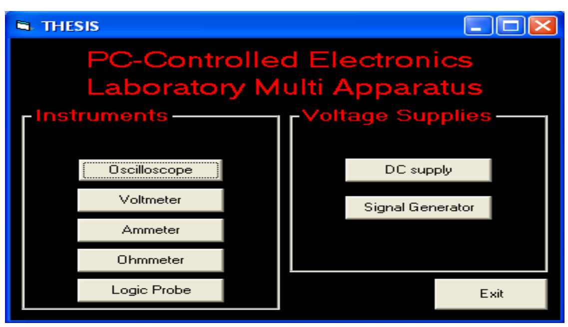


Figure 2: Main Console of the GUI

For the hardware part of the design, the authors had to study the different apparatus to be incorporated into their system. This includes the basic operations of each instrument as well as specific methodologies for data acquisition for each of the instrument types to be implemented. Although the authors have been using most of the instruments for years in the laboratory, working on this project requires not only knowledge of how to use the instruments, but how each instrument works is just as important. Among the other things that had to be considered is ranging for each instrument, not only for purposes of accuracy, but for circuit protection as well. Another important consideration for data acquisition is the quality of the signal or data being captured. Some signals require amplification, others filtering, and others require more than one type of processing. It is important that the signal is properly conditioned so that it is in the form and level expected, and free from unwanted components to ensure accuracy in the next stages.

The voltmeter, ammeter and ohmmeter circuits are composed of a network of resistors configured as either voltage or current dividers. Each of the meters would have multiple combinations available, the values of the resistors to be used have been computed to come up with the desired measurement ranges. Circuit protection has been considered as well, the resistors used ensure that the inputs fed into the ADC do not exceed its maximum voltage or current ratings.

The Oscilloscope displays waveforms, which are the voltages, with respect to time. This will utilize the same circuits described above, but will need additional software to be able to display the waveforms. All the functions of the oscilloscope will be developed within the program of the system's graphical user interface. This is the part where the fast sampling speed of the ADC plays a vital role. The conversion of the ADC is continuous and should be in a very fast manner especially for high frequency signals.

The logic probe of the system will just focus in determining the logic state of a circuit with TTL/CMOS levels. Selection between TTL and CMOS will just set the threshold levels accordingly. The logic probe will use the voltmeter circuit as its data acquisition circuit. The software will read the digital signal from the PCI and decide if it is a logic high or logic low.

The DC Voltage Supply will be composed of several parts namely the transformer, the relays and the AC to DC converter. From 220V, the transformer will output 5 different voltages, 3V, 4.5V, 6V, 9V and 12V. The voltage to be used is selected using relays that are controlled by the personal computer. The selected voltage will then be converted by the AC to DC converter to its DC form that will serve as the output DC voltage.

The group adopted a signal generator design from *MAXIM Semiconductor* in which the generator used a *MAX038 High-Frequency Waveform Generator.* The duty cycle of the output can be varied to facilitate pulse-width modulation and to produce another type of waveform, which is the sawtooth waveform.

3. EXPERIMENTS AND RESULTS

Many experiments were done during the development of the multi-apparatus system. Preliminary experiments performed were on the implementation of the control for the PCI card and on different analog to digital converters (ADC). This is crucial because the selected converter will be used for all the modules of the whole system. The group chose the ADC0804 because of its effectiveness and consistency in data conversion. The ADC0804 offers very good conversion capability, the linearity of which is very suitable for this application.

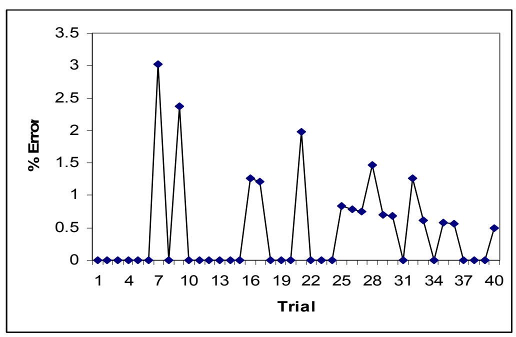
The DC voltage supply was the perfect source of voltage to test the voltmeter because it can be easily adjusted to the desired output. A commercial voltmeter was used to check if the output of the proposed voltmeter is acceptable or not. Two test circuits were used for the ammeter. The first circuit uses a DC motor as the load, which can accept a current of up to 20 mA. The second circuit uses six (6) 200-watt light bulbs that are connected in series as its load to draw a current of 5 Amperes to test the maximum range of the ammeter circuit. As for the ohmmeter, the group used standard resistors to test its functionality. The proposed ohmmeter was directly connected to the resistor, the readings were then compared to those of a commercial ohmmeter/multimeter.

Shown in Figure 3 are the percentage error graphs for the voltmeter (2V DC Range), ammeter (20mA range) and ohmmeter, respectively. These percent errors are between the prototype results and commercial multimeter readings. Percentage error was computed using this formula:

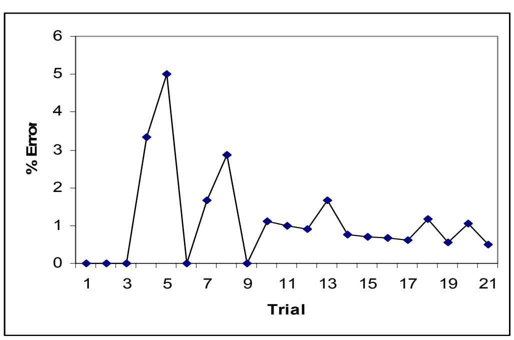
$$\%error = \frac{\left| meas_{std} - meas_{prototype} \right|}{meas_{std}}$$

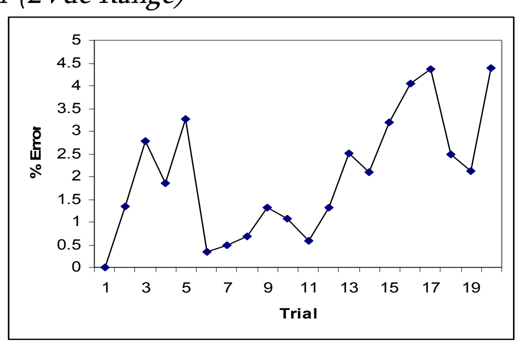
where: $meas_{std}$ = measurement using commercial meter
$meas_{prototype}$ = measurement using prototype

As seen in the figures, the highest percentage error for the multimeter is about 5 percent. Based on the data gathered, errors occurred randomly using different ranges but were all within tolerable values.



Voltmeter (2Vdc Range)





Ammeter (20mA Range) *Ohmmeter (20kohm Range)*

Figure 3: Multimeter Percentage Error Graphs

The oscilloscope function of the system was tested with a commercial signal generator. As seen in Figure 4, the output from the GUI is basically similar compared to commercial oscilloscopes. There were some noise and distortion as can be seen in the figure, these are due to quantization errors, low sampling rate and resolution of the ADC. The prototype also provides X-Y mode.

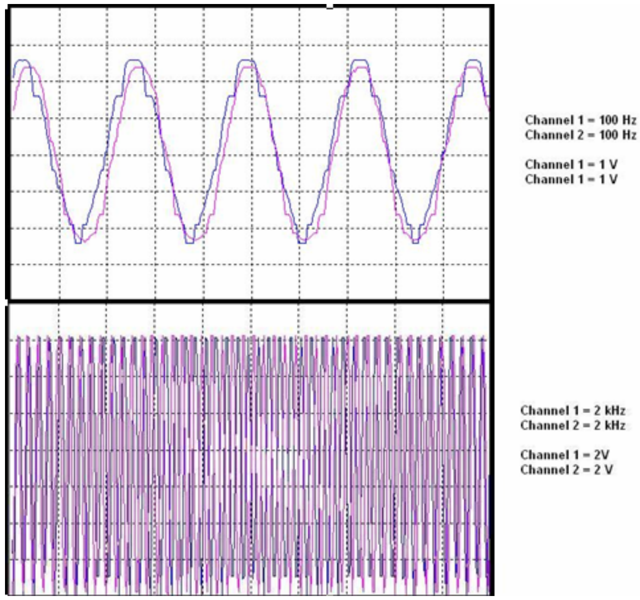
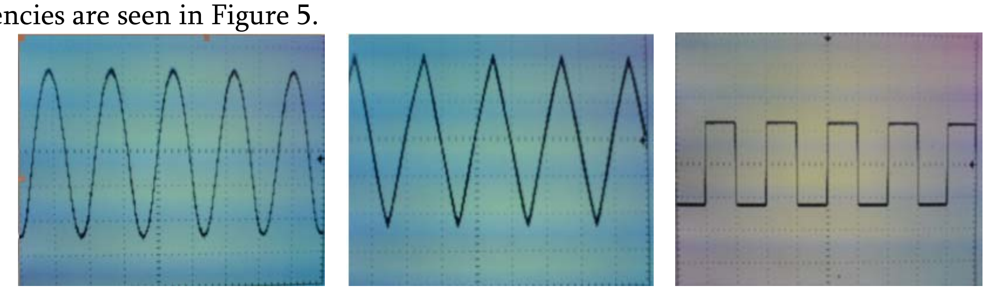


Figure 4: Oscilloscope Data from prototype

The group used a commercial variable DC voltage supply as source to test the logic probe function of the system for both TTL and CMOS logic families. The input voltage was set at different levels, the values of which were measured using the system's voltmeter. The logic probe was able to successfully identify the correct logic levels for all of the set input voltages.

The DC Voltage Supply provides 5 different voltages, 3V, 4.5V, 6V, 9V and 12V, and the voltage to be used is selected using the relays that are controlled by the personal computer.

The signal generator was able to produce sine, triangle and square waveforms with minimal noise and distortion. Some of the snapshots of sample waveforms for different frequencies are seen in Figure 5.



50 Hz Sine Wave *5KHz Triangular Wave* *50Hz Square Wave*

Figure 5: Function Generator Output Waveforms

4. CONCLUSION

The researchers were able to implement their design of a PC-Controlled Electronics Laboratory Multi-Apparatus. The prototype is an improvement over previous work. The primary difference is that this project integrates more instruments into one system. The system is PC-based, which offers a GUI that allows easy navigation and quick access the different instruments. The different meters have wider ranges for measurement and the DC supply can produce higher voltage/current output than previous designs.

Measuring instruments that were included were the voltmeter, ammeter, ohmmeter, logic probe and oscilloscope. The system also features a DC Voltage Supply and a signal generator. Each module or instrument was tested individually, after which these were integrated, and tested as one whole system. Performances of the modules were the same whether tested individually or as a system.

Improved accuracy compared to previous work was also observed during experimentation, with errors ranging from 0% to less than 5% when compared to standard laboratory equipment. This level of accuracy is sufficient for the prototype to be used for most experimentation and laboratory activities.

REFERENCES

Boylestad, R. and Nashelsky, L. Electronic Devices and Circuit Theory (7th Ed.). Prentice Hall. 1998

Shanley, Tom and Anderson, Don. PCI System Architecture (4th Ed.). Mindshare, Inc. Addison-Wesley Professional. 1999

Wakerly, John. Digital Design, Principles & Practices (3rd Ed.). Pearson Education, Asia Pte Ltd. 2002

K.L. Chua, A.L. Pe, E.T. Uy, C.L. Yao, M. Andaya, "The Omniprobe System:An Integration of Logic Probe, VOM and Oscilloscope," Electronics and Communications Engineering Department of De La Salle University – Manila. 1990

C. Macabuag, J. Moa, G. Tiu, A. Gonzales, "A Single Portable Multimeter and Function Generator," Electronics and Communications Engineering Department of De La Salle University - Manila. 2002

R.C. Chua, J.A. Cu, E.M. Diaz, S.I. Kung, and A.N. Santos, " Design of a Function Generator Plus an MCU-Based Pulse Generator," Electronics and Communications Engineering Department of De La Salle University - Manila. 2003

K. Katalbas, M. Que, M. Tabas, A. Cruz, "Full-Featured Digital Storage Oscilloscope," Electronics and Communications Engineering Department of De La Salle University - Manila. 2000

T.J. Byers, "PC Based Test Equipment," Electronics Now. 1993

Digital Multimeter Kit Model M-2665K Service Manual

http://www.national.com

http://www.discovercircuits.com

http://www.tpub.com/content/neets/14188/

http://www.jmargolin.com/mtest/LJfigs.htm

http://www.pci8255.net

http://www.interfacebus.com/voltage_threshhold.html

ABOUT THE AUTHORS

Eric Paul L. Basbas, Lanfrank M. Macalintal, Anthony T. Pena earned their BS Electronics and Communications Engineering degrees from De La Salle University – Manila in October, 2005.

Engr. **Antonette C. Roque** is an Assistant Professor and currently the Chairperson of the Electronics and Communications Engineering Department of De La Salle University-Manila. She obtained her Bachelor of Science and Master of Science Degree in Electronics and Communications Engineering from De La Salle University-Manila. Her research interests include Digital System Design, Interfacing, Computer Internetworking and Technology.