AC 2008-2288: UTILIZING A PCI DAQ BOARD IN THE LABORATORY COURSE OF MICROPROCESSOR SYSTEMS AND INTERFACING

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Utilizing a PCI DAQ board in the Laboratory Course of Microprocessor Systems and Interfacing

Abstract

This paper describes five experiments using a PCI DAQ board in the laboratory course of "Microprocessor Systems and Interfacing." The five experiments involve basic digital input/output interfacing design using a 82C55, analog-to-digital (A/D) and digital-to-analog (D/A) design. The PCI DAQ board chosen is PCI DAS-1002, manufactured by Measurement Computing[1]. Based on this PCI DAQ board, five experiments were designed, including I/O interfacing design, programmable DC motor speed control system design using pulse width modulation (PWM), and A/D and D/A interfacing design. These five experiments were carried out by three groups of students in the fall of 2005, 2006 and 2007. At the end of fall 2007, a survey was conducted among the students to assess these five experiments. The assessment results are presented in this paper.

Introduction

"Microprocessor Systems and Interfacing" is a core subject in both Electrical and Computer Engineering curricula. Since there is large variety of microprocessors, an engineering program has to pick the ones that benefit students the most in their future career. With the rapid changes in microprocessor technology, laboratory courses associated with this topic have to be continuously kept up-to-date. Some years ago in the Department of Engineering at Indiana University – Purdue University Fort Wayne (IPFW) we decided on the Intel X86 family microprocessors because Intel is the leading manufacturer of microprocessors since 1970s. Before 2005, the digital I/O board associated with input/output operations in our experiments was designed for the ISA bus. However, in recent years the ISA bus has been replaced by the much faster PCI bus. To expose students to the contemporary technology, in the fall of 2005 we started to develop new experiments using a PCI board for topics that deal with digital input/output operations, analog-to-digital (A/D), and digital-to-analog (D/A) conversions.

After searching through different digital I/O boards designed for the PCI bus, we decided on a PCI DAQ board, the PCI-DAS1002, manufactured by Measurement Computing[1]. We picked this board so that students would get exposed to a commercial product that they will probably be using in the industry after they graduate. The Universal Library included in the software of the board provides libraries for Windows Visual C/C++ programming. Our students will then have the opportunity to program the board in C instead of assembly language, which has advantages and disadvantages. The disadvantage is that the students cannot get hands-on experiences using assembly language to access the low-level ports. However, the advantage is that the students can get the experience of using high-level language to control the low-level I/O ports, which is what most industrial applications do today.

The remainder of the paper is organized as follows. First, the selected PCI DAQ board and its necessary accessories are introduced in detail. Then the five experiments are described, followed by the assessment methods and the results. The conclusions are given at the end of the paper.

The PCI DAQ board and its accessories

The PCI-DAS1002 board as shown in Figure 1 is a multifunction analog and digital I/O board designed for the PCI bus. This board offers 24 bits of parallel and digital I/O (82C55A, two 8-bit ports and two 4-bit ports). Each port can be configured independently as input or output. This board has A/D and D/A capabilities in addition to the I/O ports. This feature provides an alternative to interfacing discrete A/D and D/A components. The PCI board is a plug-and-play board. After plugding the board into the PCI bus slot in the PC, we need to follow the instructions to install InstaCal, which is the software used to conduct A/D and D/A calibration. The Universal library provides libraries for Windows Visual C/C++ programming. The library contains a variety of functions for the users to program the board and conduct the basic digital I/O operation, A/D and D/A conversion.

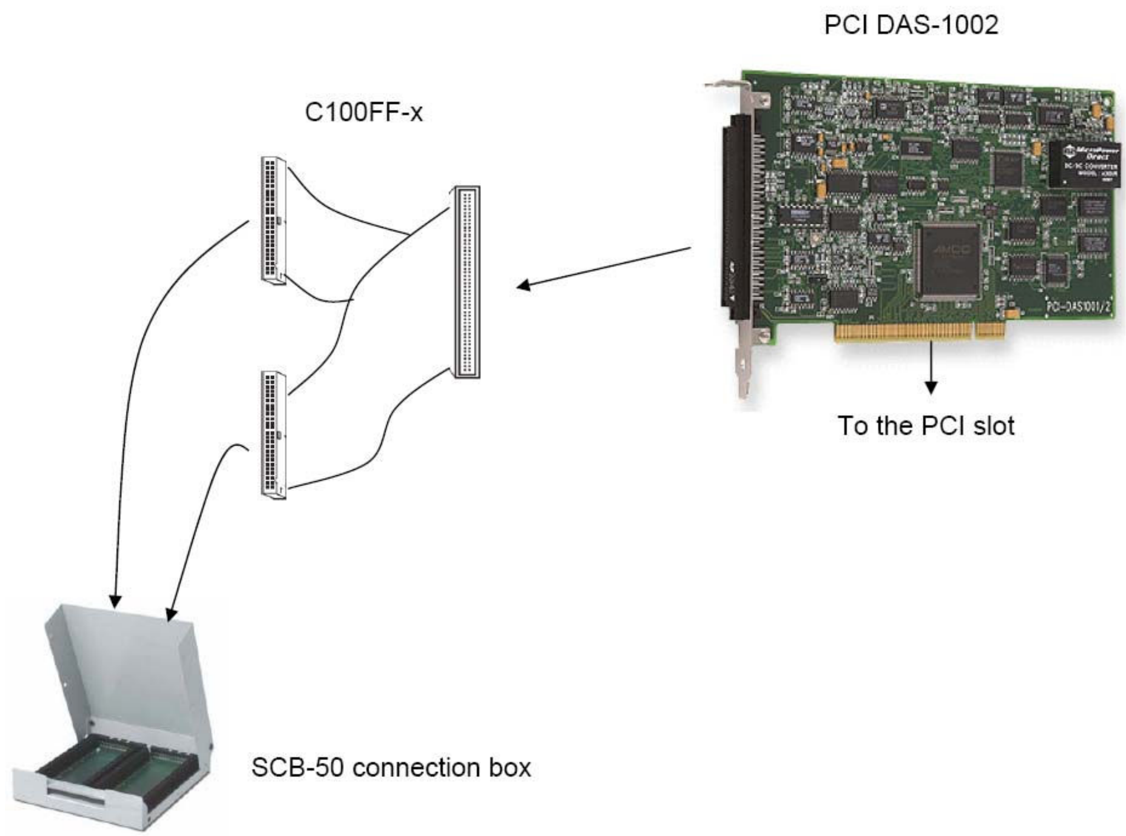

Figure 1: The PCI board and its accessories assembly

In order for the students to build their own circuits on the breadboard and interface with the PCI board, some components are needed. With this PCI board, we also purchased two other accessories: the SCB-50 connection box and the C100FF-x 100-pin and high-density connector to two 50-pin IDC (as shown in Figure 1), from the Measurement Computing. The PCI board is connected with the SCB-50 connection box through the C100FF-x cable. The SCB-50 connection box provides screw terminal connections for all 100 I/O pins of the PCI board. Hence, students could connect each specific pin to the breadboard and build the desired circuits for each individual experiment.

Experiments

There are a total number of five experiments using the PCI DAS-1002 board. Each laboratory takes 2 hours and 45 minutes. Experiment 1 is the foundation for the rest of the experiments. The primary goal of experiment 1 is to learn to program the PCI board and understand the basic digital input/output operations. In this section, the five experiments are described in detail.

Experiment 1

The first experiment is an informative one and is about basic digital input/output (I/O) interface design using the 82C55A built in the PCI DAS-1002 board. The objective is to get the students familiar with the process of programming, interfacing the PCI board and understanding basic digital input/output operations. The 82C55A contains two 8-bit ports (PORTA and PORTB) and two 4-bit ports (PORTCL and PORTCH). In this experiment, students will build two different circuits for digital input and output operations separately and then connect the circuits with the PCI board. The digital output circuit[2], shown in Figure 2, interfaces eight resistors and LEDs with PORTA of 82C55A (build-in the PCI board) to represent the digital output data from PORTA. The digital input circuit[2], shown in Figure 3, connects the DC voltage source (5V) through the 8-bit DIP switch and resistors to the pins of PORTB of 82C55A to generate digital input signal to PORTB.

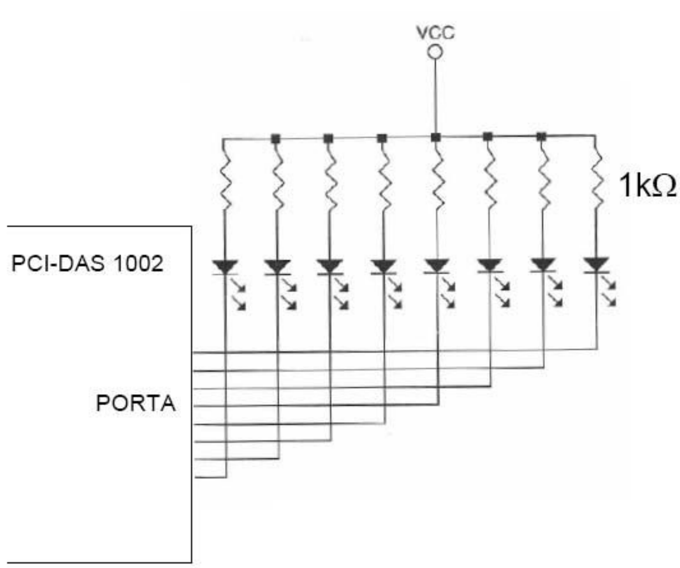

Figure 2: basic output interface connected to a set of LEDs

In the software side, the sample C codes provided by Measurement Computing for digital input/output are modified and given to the students. The digital input code is renamed as "in_bytes.c", which reads the digital input from the 8-bit PORTB and displays each bit and the corresponding decimal value on the monitor screen. There are two programs for the digital output operations. "send_bits.c" and "send_bytes.c". The "send_bits.c" allows the user to set/reset any specific pin of the 8-bit PORTA. The "send_bytes.c" asks the user to enter a decimal number from 0-255 and then sends the input decimal number to PORTA. Both programs can only receive input and output the signal once. After the signal is sent through the port, the program exits automatically.

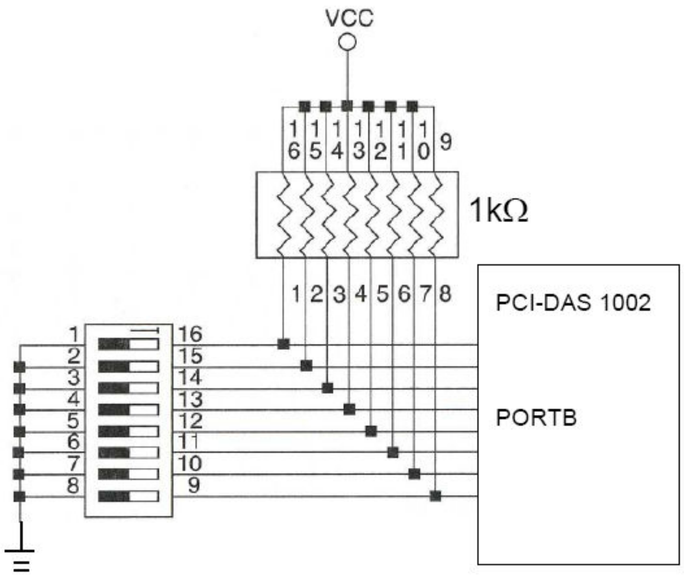

Figure 3: DIP switch circuit

Students follow detailed procedures to create a new project in Visual C/C++, add the provided codes to the project, and change the configurations to add the directories for the header files and library files provided in the Measurement Computing software. Students then compile and build the project. After passing the building process, students will run the executable files. For the "send_bytes.c" and "send_bits.c" program, students need to observe the results in the circuit as shown in Figure 2 to see if the LEDs lighten up as anticipated or not. For the "in_bytes.c" program, the students use the DIP switch in the circuit shown in Figure 3 to select different input values and observe if the results on the screen match the actual input.

Once students understand how to program the PCI board for digital input/output operations, they are required to complete two assignments. The first assignment is to modify the "send_bytes.c" and "send_bits.c" programs so that the signal is only output for 2 seconds. The modified code should also allow the users to reconfigure the bits or bytes by prompting a message, such as "Do you want to exit or not?" The second assignment is to combine the "in_bytes.c" and "send_bytes.c" together and modify the new program such that the resulting program reads the data from the DIP switch through PORTB, display this data on the monitor screen and then output the data through PORTA to turn on the appropriate LEDs.

Experiment 2

After the first informative experiment, the second experiment is to let students use their knowledge into an application. The application is to design a programmable DC motor speed control system using the pulse width modulation (PWM) technique. The PWM technique is a popular technique used to control the motor speed. The duty cycle of the PWM signal, which is the "on" time within a period divided by the period time (T), determines the motor speed. In this experiment, the driving circuit for the motor (as shown in Figure 4) is given to the students. Students are allowed to use the output from any of the digital ports of PCI DAS1002 board to drive the motor. Students' code should ask users to input a number from 0 to 9. Each input corresponds to a different duty cycle for the PWM signal, i.e. different speed of the DC motor. Students will observe how the speed of the motor changes. In this experiment students are required to try three different period time T = 10ms, 100ms, 200ms and observe the difference.

This experiment also requires students to connect an 8-bit DIP switch to another digital port of the PCI board and configure this port as an input port. Students should write a program to allow the users to use the DIP switch to select one of the 255 different possible speeds, and display the decimal and corresponding hex value on the monitor. For six different switch settings corresponding to the decimal values 1, 50, 100, 150, 200, and 255, students need to measure the voltage on the terminals of the DC motor and observe how the speed of the motor changes.

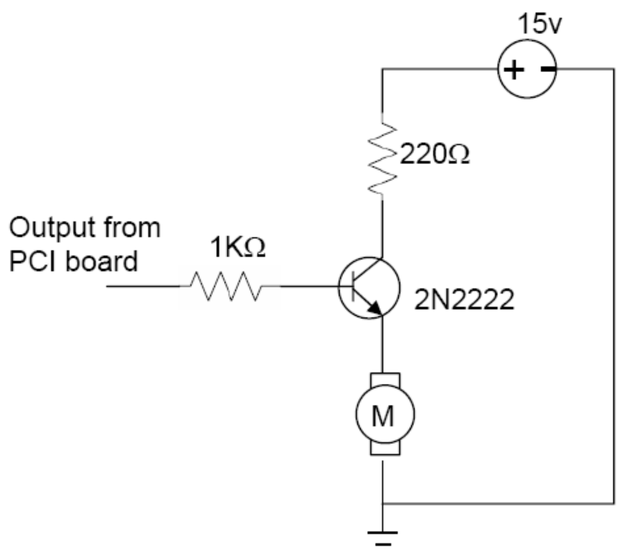

Figure 4: motor driving circuit

Experiment 3

This experiment is about the A/D, D/A interfacing design using the A/D and D/A converter embedded in the PCI-DAS 1002 board. The PCI-DAS 1002 board has one 12-bit A/D converter (ADS7800) and one 12-bit D/A converter (AD7847). The PCI-DAS 1002 board provides either 16 single-ended or 8 differential analog inputs. Input ranges are software-selectable as either bipolar or unipolar. The PCI-DAS 1002 also provides two channels of 12-bit analog output. Analog output ranges are ±10V and ±5V (bipolar) and 0-10V, 0-5V (unipolar).

The first assignment is to conduct the analog test using InstaCal. Students are required to conduct analog tests under 8 differential and 16 single-ended analog input modes separately and observe the difference. The actual ranges of the test signals help students understand better about these two different modes.

The second assignment is the A/D design. The program “analog_in.c” that is used to read in the analog data is provided. The function of the “analog_in.c” program is to read in an analog voltage signal, perform A/D conversion and display the analog voltage signal and the corresponding decimal value on the monitor screen. Even though the code is provided, students need to read through the code and figure out how the code works and how the “read analog data in” function works. For the software task, students create a new project in Visual C/C++, add “analog_in.c” to the project and complete the necessary steps described in experiment 1 to pass compiling and building. For the hardware task, students need to connect a variable DC voltage source (5V) to the analog input channel 0 of PCI-DAS1002, run the program, increase the voltage at 0.25V interval starting from 0 and record the corresponding decimal integer output from the monitor screen.

For the A/D design part, students are also required to show the converted digital data by lightening up LEDs. In order to represent a 12-bit binary data, two digital ports from the 82C55A are used. Hence, continuing from the previous task, students modify “analog_in.c” program to configure 8-bit PORTA and 4-bit PORTCL as output ports, split the converted digital data (a 12-bit data) into an 8-bit one and a 4-bit one, and then output the 8-bit and 4-bit values through PORTA and PORTCL. A circuit that has the same structure as Figure 2 except using 12 resistors and LEDs needs to be built and then connected to each pin of PORTA and PORTCL. Students then run their program, slowly adjust a variable DC voltage source (5V) from 0 to 5V, and observe the different pattern of the LEDs.

The third assignment is about the D/A design. Students start by modifying the digital input code “in_bytes.c**”** to write the digital input value to the D/A output channel 0. For the hardware task, students connect the DC voltage source (5V) through the DIP switch and resistors to the pins of PORTB as shown in Figure 3. Students then run their program, use the DIP switch to select six different settings corresponding to the decimal values 1, 50, 100, 150, 200, and 255, and record the output voltage signal from D/A output channel 0. In the lab report students are required to plot the analog outputs as a function of the decimal value and explain.

Experiment 4

This experiment is to interface an ADC0809 chip[3] with the microprocessor via a 82C55 (built in the PCI DAS-1002 board). The ADC0809 will be used to implement a positional sensor based on a potentiometer. For the hardware task, students wire up the circuits[4] as shown in Figure 5. For the software task, students write a program to configure PORTB as the input port, continuously check PORTB and display the value on the monitor in both binary and decimal numbers until the users enter a key to exit. Then students run the program, increase the voltage at 0.5V intervals starting from 0 and record the corresponding decimal output from the monitor screen. In the lab report students are required to plot the supply voltage as a function of the decimal output, observe what kind of relationship is between them and explain.

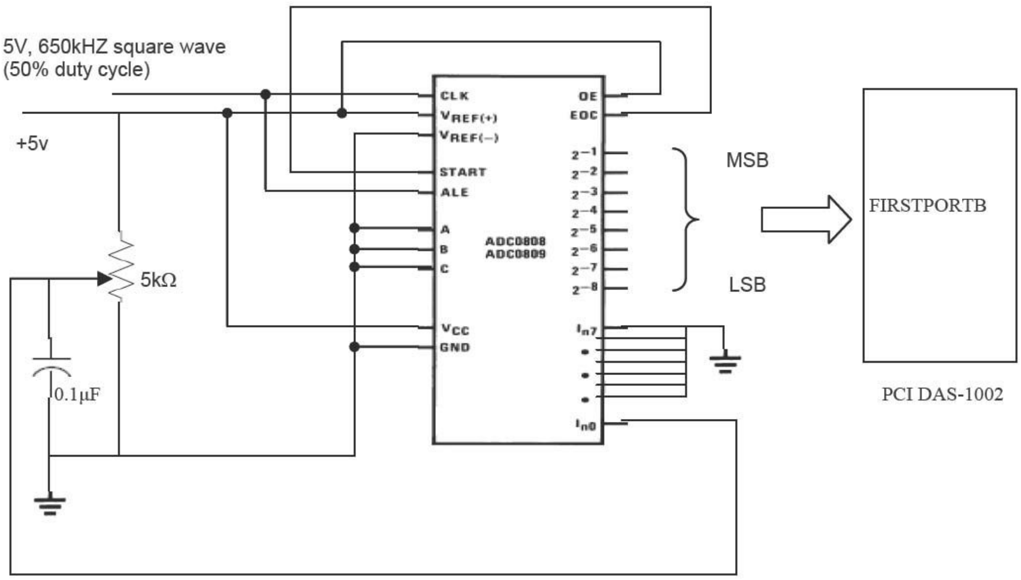

Figure 5: ADC0809 interfacing pin connections

Experiment 5

This experiment is about the D/A interface design using a DAC0808 chip[5]. Students are required to wire the DAC0808 as shown in Figure 6, construct a digital input circuit using a 5V power supply, a DIP switch and resistors, and connect the circuit to the digital inputs of the DAC0808. Then they adjust the inputs and measure the output voltage to verify that the D/A conversion circuits work properly.

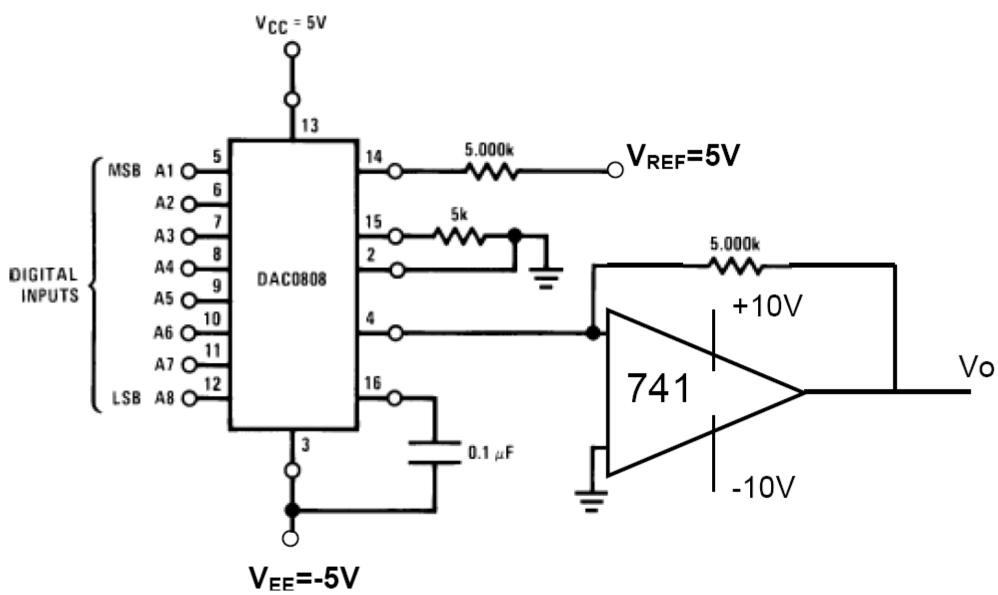

Figure 6: DAC0808 interfacing pin connections

After successfully constructing the DAC0808 circuit, students need to disconnect the digital input circuit from the DAC0808 and connect the 8 digital input pins of DAC0808 with PORTB in the PCI board. For the software task, students need to write a program to configure PORTB as the output port, send out a decimal value (0-255) through PORTB, and display the value on the monitor screen. Students need to record the output voltage for 0, 50, 100, 150, 200 and 255, plot the output voltage as a function of the decimal input, observe what kind of relationship is between them and explain.

Laboratory assessment

These five experiments were carried out by three groups of students in the fall semesters of 2005, 2006 and 2007. During the fall of 2007, a total number of 12 students took the course. A survey was conducted in the end of the semester and the following Likert scaled questionnaires[6] were asked. The students were asked to rate the questions from 1 to 5. There were a total of eight students taking the survey. Five of them major in electrical engineering, two of them are in computer engineering, and one of them is in the dual degree (electrical engineering and computer engineering). The questionnaires and the results are listed below.

1. **The PCI board is easy to work with. If not, please specify.**

   The average rating for this question is 4. Some students complained about Visual C++ and one PCI board with a nonfunctional port A. Since there was a spare board, the students were able to be relocated to other computers and finish the experiments successfully. The laboratory room used for this course is extremely busy during the semester. Since this course is only taught every fall semester, we would wait till the summer of 2008 to fix the problem.

2. **These experiments expose you to a way how data acquisition is done in real industrial applications. If not, please elaborate.**

   The average rating for this question is 4.3.

3. **These experiments are reasonable in content and length. If not, how can we improve it?**

   The average rating for this question is 4.6

From the assessment result, we can conclude that the students are very satisfied with these experiments. In addition one of the students who took this course in the fall of 2005 used a similar PCI DAQ board manufactured by Measurement Computing in his capstone project to design and build a Software Controlled Radio. The experiments in this course provided him with important knowledge for his senior design project.

Conclusions

This paper presented the idea of introducing a PCI DAQ board to the laboratory course of "Microprocessor Systems and Interfacing". The PCI DAQ board chosen is PCI-DAS 1002, manufactured by Measurement Computing. Based on this PCI-DAS 1002 board, five experiments were designed. These five experiments involved basic digital input/output interfacing design using 82C55A, A/D and D/A design. The experiments were described in detail. This paper also discussed the survey that was conducted among the students to assess the experiments. The results of the survey showed that the students were very satisfied with the experiments.

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