The Course Development for Microcomputer Systems Technology: Preliminary Study

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Abstract: The course of Microcomputer Systems Technology has been one of the core courses in the Computer Engineering Technology curriculum (Bachelor *of* Technology in CET) at the New York City College of Technology of the City University of New York. The Intel microprocessor in PC based computer was the chosen hardware in this course. The assembly and C++ languages were crucial tools in the study of microprocessor organization. We currently focused mainly on the topic of PC computer parallel interface technology. However, we did not pay particular attention to the integration of current programmable peripheral components, such as USB (universal serial bus) based input/output expansion peripheral for PC computers. Today, many microcomputers and laptops no longer use the parallel interface. Instead, they use the USB interface as an alternative. In this paper, an innovative Digilent PC-based USB I/O Explorer is being investigated for the Microcomputer Systems Technology course. The Digilent USB I/O Explorer provide various on-board I/O devices, which allows our students to write PC based software (C/C++) to interface to the external electronics devices, such as analog-to-digital and digital-to-analog converter. The laboratory development is intended to give students better understanding of USB peripheral device. From this experience, students are also able to write application programs on the Windows operating system to access from a personal computer to various external Input/Output devices. The new labs developed on Digilent USB I/O Explorer aims to increase students' competence in microprocessor system programming and improve the learning quality of Microcomputer Systems Technology course.

Key words: Computer Organization, Microprocessor, Computer Interfacing Technology, USB I/O Explorer, Lab Curriculum,

I. Introduction

Computer organization and Assembly Language are essential components for Computer Science [1], Computer Engineering [2], Software Engineering [3], and Information Technology [4]. Our Computer Engineering Technology Department of the New York City College of Technology of CUNY offers two plus two Bachelor of Technology program. After completing the first two years of Associate degree study on electrical circuits, digital logic, electronics, and Linux operating system, junior students must take Microcomputer Systems Technology (CET3510) with a laboratory component (CET3510L) to receive their bachelor of technology degree. This junior-level introductory course in microprocessors will allow students to: know how the hardware and software components of a microprocessor-based system work together; understand basic microcomputer architecture; identify the different binary data formats for the integer and the floating point number; to perform PC microprocessor ALU operations at the register level to study the x86 instructions of the Intel microprocessor; analyze the little Endian computer memory unit and memory address; explore the stack data structure; understand the relationship between C/C++ language to assembly language or machine instructions; gain hands-on experience with microprocessor parallel interface; and develop PC based software (C/C++ or assembly language programming) to interface to the external electronics devices. Currently the High Level Assembly Programming Language [5] for Intel x86 Intel processors [6] is used as the tools to study the above topics. This Assembly language helps our students to gain an overall understanding of the interaction between computer hardware, operating systems, and application programs. For projects and laboratory assignments in I/O systems to the microprocessor, one of our current approaches is to utilize the parallel port to sense the input and trigger the output for connecting our own circuits to personal computer. For the parallel interface, there are total 25 pins available for us. Some pins of the parallel port can be configures as either input or output, and some can be configured as bi-directions. We mainly focus on the PC computer parallel interface technology. We did not pay special attention to the integrating of current programmable peripheral components, such as USB (universal serial bus) based input/output expansion peripheral for PC computers.

However many recent laptops and PC computers no longer have parallel ports. A new platform is currently being investigated for the Microcomputer Systems Technology course partly aided by an equipment grant from Digilent Inc. The Digilent USB I/O Explorer (Figure 1) provides various on-board I/O devices. It can be used as a platform to learn different interface technology such as USB, parallel, and serial interfaces. In this work, we integrate the x86 microprocessor interfaces and the Digilent USB I/O explorer board to conduct the new laboratory experiments in Microcomputer Systems Technology course in a four-year computer engineering technology curriculum. Section II discusses Laboratory Environment and Preliminary Study. Section III outlines the planned labs of the USB I/O expansion peripheral for PC. The conclusion is included in Section IV.

II. Laboratory Environment and Preliminary Study

The x86 processor laptop or PC based computer consists of Visual C++ 2010 Express running Microsoft Window 7 Operating System. To expand the I/O capabilities of a PC, the Digilent USB I/O Explorer board (Figure 1) has to be connected to USB port of laptop or PC computer. This I/O Explorer is highly evolved device and provides various on-board I/O devices, such as switches, buttons, LEDs, speaker/buzzer. A number of connectors have up to 52 I/O pins for interfacing to off-board devices. It also has two channels10-bit A/D inputs and four channels 12-bit D/A outputs (Figure 2) that can be used with analog-to-digital and digital-to-analog converters. Digilent Adept System Software Developer's Kit (SDK) has to be installed to operate the I/O Explorer board itself, or through the I/O Explorer to devices external to the computer.

To start our first lab design, we read a set of manuals, examples, and technical literature that are available from SDK package, free download from the company website.

At the beginning, we download the SDK package and followed the instruction of "Building an Adept SDK Project in Visual Studio.pdf". Since the sample code is written by C++, we decided to download Visual C++ 2010 Express running Microsoft Window 7 Operating System. It took us for a while to navigate Configuration Properties > Linker > Input and add the required SDK library to Additional Dependencies field since the interface design for Visual C++ 2010 Express is different from early version of Visual Studio.

The first sample code we tested is *DgioDemo.cpp*. This program provided us the basic view to interact with I/O explorer via eight slide switches, four DIP switches, four push button switches, and sixteen LEDs. Then we explored the sample source code *DaioDemo.cpp* for measurement of analog input voltage. We observed the value of analog input voltage. However we can't continue to modify the sample code to enjoy the I/O features since we don't have the DAIO Module of the Adept SDK. Similarly, for the sample code *DpioDemo.cpp* and *DemcStepDemo.cpp*, we don't have the Pmod8LD and DEMC Module. There are two options for us to integrate the USB I/O Explorer in our lab curriculum. We can purchase the different extended components such as DAIO Module, Pmod8LD, DEMC Module, or our students can build external devices based on their first two year Associate degree study. The most challenging part for our students is software programming. At two-year associated program, students didn't have much opportunity to expose to C++ programming language. Most students are taking the introduction to C++ programming language in their junior level study.

III. Intended Lab for USB I/O Expansion Peripheral for PC

The ability to view a hardware and software system as an integrated whole is crucial for computer engineering technology education [7]. The labs focused on developing microprocessor interfacing and PC based software for external electronic devices control, addressing the need for integrating a hardware/software system. Some of the new interface lab applications are still under development. They are LED interfacing, bipolar stepper motor control, and sine wave signal generator [8]. These labs for USB I/O expansion peripheral have to include the Digilent libraries of *dgio.lib, dpio.lib, daio.lib* to the application.

LED Interfacing Lab: This lab introduces students to Digilent USB I/O Explorer board and PC based software C/C++ programming language. Students modify the *dgio.cpp* and explorer IO devices by Port 0 and Port 2. DGIO ports of 0 and 2 on the board provide general sensors and device interface (Table 1). The input can be received from slide switches, push button switches, and DIP switches. The computer software C++ programming processes the inputs by performing arithmetic and logic operation, looping, timing function. The outputs can be generated by different time periods. The sixteen LEDs were lit by different frequency duty cycle.

Bipolar Stepper Motor Control Lab: This lab identifies the port and channel to generate step pulses and direction signal to drive a bipolar stepper motor. Students need to develop the correct algorithms in order to generate the pulse sequence indicated in Table 2. The driver amplifies the command generated by DPIO port to energize the motor windings. A bipolar motor requires some external device such as an H-Bridge circuit (Figure 3) to reverse the polarity of the winding and thus, powering one end of the coil pair reverses the flux. Choosing different time interval and step sequences will generates clockwise and anticlockwise motor rotation.

Sinewave Signal Generation Lab: This lab clarifies that 12-bit D/A outputs are available to convert digital signal to analog signal. The 12-bit digital signal to analog signal converter (DAC) provides 4098 discrete voltage (or current) levels of output. In order to generate a sine wave signal from DAIO, we first need a table whose values represent the magnitude of the sine of angles between 0 and 360 degrees. The values for the sine function vary from - 1.0 to + 1.0 for 0 to 360 degree angles. Therefore, the table values are integer numbers representing the voltage magnitude for the sine of theta. This method ensures that only integer numbers are output to the DAC.. The Table 3 shows the angles, the sine values, the voltage magnitude, and the integer values representing the voltage magnitude for each angle with 30- degree increments. To generate Table 3, we assumed the full- scale voltage of 10V for the DAC output. Full- scale output of the DAC is achieved when all the data inputs of the DAC are high. Therefore, to achieve the full-scale 10V output, we use the following equation:

Vout = 5 V + (5 × sin θ). Since there are 4096 steps and full- scale Vout is 10 volts, we simply multiply the Vout voltage by 40.96

IV. Conclusion

We are currently developing new labs to apply USB based input/output expansion peripheral for PC computers. The lab applications implemented in this project reinforce the arithmetic operations, looping, subroutines, logical operations, LED interface, and traffic signals control. The lab projects are intended to give students a quick understanding of the instruction set, programming and operation of a microprocessor. A chosen lab is planned in the future academic year.

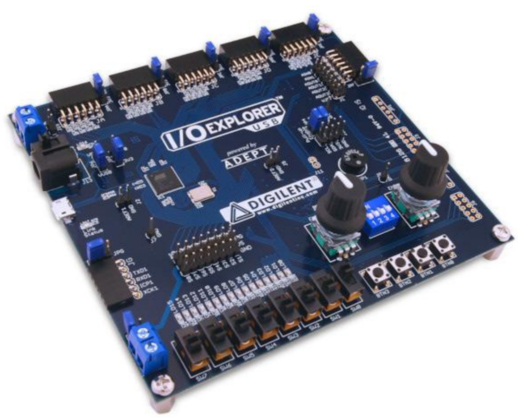

Figure 1 USB I/O Explorer Board

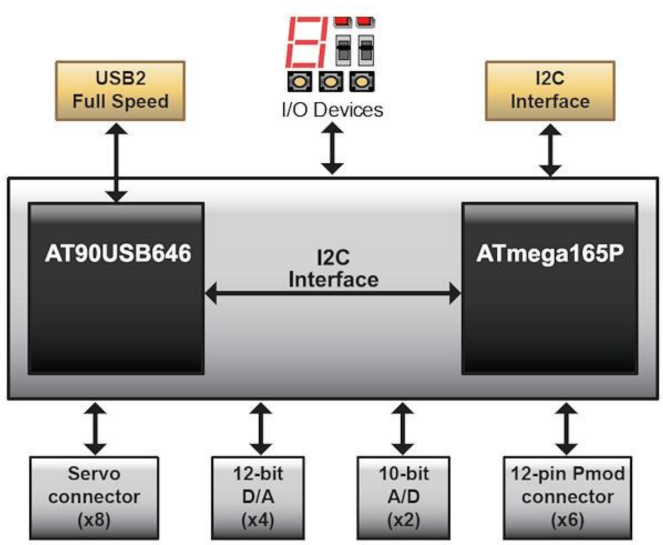

Figure 2 USB I/O Explorer Block Diagram

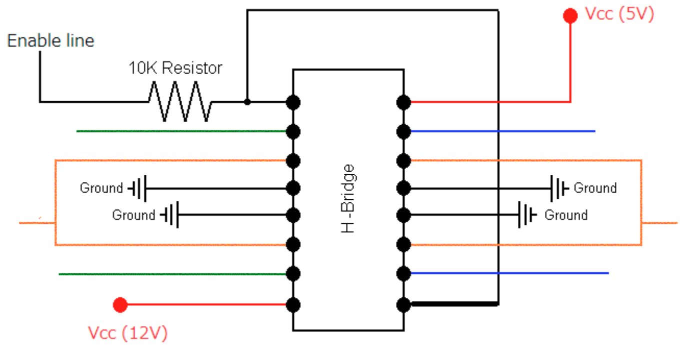

Figure 3 H-Bridge (SN754410) schematics

Port 0	Channel 0	16 bits digital OUT	16 LEDs
	Channel 1	8 bits digital IN	8 Switches
	Channel 2	4 bits digital IN	4 Push Button Switches
	Channel 3	4 bits digital IN	4 DIP Switch
Port 2	Channel 0	Single value, ranged OUT	Speaker/Buzzer frequency

Table 1 DGIO Port

Step	Bit 3 ($\overline{\Phi}_b$)	Bit 2 (Φ_b)	Bit 1 ($\overline{\Phi}a$)	Bit 0 (Φa)
0	0	1	0	1
1	1	0	0	1
2	1	0	1	0
3	0	1	1	0

Table 2 Bipolar Step Sequence

Angle θ (degrees)	**Sin θ**	**Vout (Voltage Magnitude) 5 V + (5 V × sin θ)**	**Values Sent to DAC (decimal (Voltage Mag. × 25.6)**
0	0	5	128
30	0.5	7.5	192
60	0.866	9.33	238
90	1.0	10	255
120	0.866	9.33	238
150	0.5	7.5	192
180	0	5	128
210	−0.5	2.5	64
240	−0.866	0.669	17
270	−1.0	0	0
300	−0.866	0.669	17
330	−0.5	2.5	64
360	0	5	128

Table 3 Angle v. Voltage Magnitude for Sine Wave

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