A First Laboratory Course on Digital Signal Processing

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Abstract: In this paper a new laboratory course on digital signal processing, established at the Southern Taiwan University of Technology, is discussed. In this course students execute a series of laboratory exercises, involving programming signal processors, addressing mode practice and real time processing processes. In addition, an extension board for the TMS320C50 DSP starter's kit (DSK) is developed and used for use for the course. The control of peripherals such as a real time clock, a LCD display, a keypad and LED displays, are discussed. The peripheral programs and overall test software are provided in the course.

Keywords: digital signal processing, TMS320C50 DSP starter's kit

1. Introduction

Digital signal processors, such as the TMS320 family [1] of processors, are found in a wide range of applications such as communications and multimedia, speech processing, and so on. They are used in modems, Fax, cellular phones, etc. These devices have also found their way into the university classroom, where they provide an economical way to introduce real-time digital signal processing to the students.

Digital signal processing technology has been used broadly in all areas of industrial products, from household equipment, industrial machinery, medical equipment, and computer peripherals to all kinds of communication equipment. Currently the price of DSP (Digital Signal Processor) chips is very reasonable. We believe that in addition to developing an understanding of the general theory of digital signal processing it is quite appropriate for students to have a design projects based on DSP chips in order to learn hardware and interface technology skills and improve their software programming ability. We used TMS320C50 DSK [2] from Texas Instrument as the platform to develop a new laboratory course on digital signal processing.

The area of digital signal processing has consistently derived its vitality from the interplay between theory and applications. Correspondingly, university courses in digital signal processing have increasingly incorporated computer exercises and laboratories to help students to better understand the principles of signal processing and experience the excitement of applying abstract mathematical concepts to the processing of real signals. As we have seen, many textbooks [3-5] provide a collection of computer exercises for the course in digital signal processing. Most of those exercises are designed for personal computers commonly used at most universities. However, in our experience, teaching students how to use digital signal processors is also a very important topic.

In 1997, the author was awarded a National Communication Foundation's Faculty Enhancement grant for creating a follow-up lecture-laboratory course on digital signal processing for electrical engineering senior undergraduates. However, in the first time of the course was offered, it was not easy for students to learn the assembler code, addressing mode, and many DSP instruction sets. For the most part, a great deal of software program practice was required and only the remainder of the semester could be used for hardware implementation. With this situation in mind, it has been the goal of the Southern Taiwan University of Technology DSP group to bring the first laboratory course into the curriculum next year. The course design involves students gaining experience with hardware, software and firmware.

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The beginning of the semester is devoted to short programming examples and experiments, and the remainder of the semester is used for a final project. TI DSP development tools are used. These tools include an assembler and a debugger that are provided with the TMS320C50 DSP Starter Kit (C50 DSK).

This paper is organized as follows. In the next section, the contents of the first laboratory course are outlined. Section III briefly describes the development of an extension board for the TMS320C50 DSK. The paper ends with Section IV, where the main conclusions and possibilities for further extensions are described.

2. The First Laboratory DSP Course

2.1 Introduction to Course

The first laboratory DSP course was designed for DSP beginners. The ideal target audience is first year or second year electronic engineering and/or electrical engineering students at the Southern Taiwan University of Technology. The course assumes some degree of background knowledge in microprocessors. Some of the theoretical material in signal processing may prove difficult for some students. In such circumstances, it is best to concentrate on the practical aspects of the courses and ignore most of theory. In general, the course provides sufficient practical examples and demonstrations to capture the imagination of interested students. In addition, a target board with a software debugger is needed for real time training in the classroom. The aim of the course is to help students to very quickly become familiar with DSP terminology.

References are deliberately left out of the course. The book, *A Simple Approach to DSP Chips* [6], which was used during the course, contains a large selection of references on all topics. Interested students are invited to browse through the relevant sections of this uniquely simple and detailed book for further reference.

2.2 Lectures in the Course

The course consists of a total of six lectures. Lecture 1 compares analog and digital technologies and attempts to answer the very important question of why we need DSPs. Subsequently, the introduction of the Texas Instruments' TMS320 family of Processors is described. The TMS320C5x generation of fixed-point digital signal processors (DSPs) is discussed. Lecture 2 provides an overview of the architectural structure of the TMS320C5x, which consists of buses, on-chip memory, central processing unit (CPU), and on-chip peripherals. Lecture 3 describes the addressing mode and TMS320C5x/assembly language fast code production. Several programming examples included in this lecture illustrate the architecture, assembler directives, and the instruction set of the TMS320C5x processor and associated tools. To perform the above experiments, the Texas Instruments' DSP Starter Kit (C50 DSK), which includes a board with the TMS320C50 fixed-point processor and input and output (I/O) support, is needed in lectures 4 and 5. A number of the demonstrations given in this course include:

- (1) Tone generation;
- (2) DSK oscilloscope;
- (3) Tone generation with filter;
- (4) DSK spectrum analyzer;
- (5) Signal generator.

There are weekly lectures three hours in length.

Lecture 6 describes the board with a number of typical Micro-Controller peripherals [7] and with components to enhance the functionality of the DSP board, which are discussed in the following section. The lectures in the course are presented in Table 1.

Table. 1 Curriculum for the course

Topics	Contents
◆ Fixed point DSP	Lab. 1 Testing the TMS320C50 DSK tools
◆ Architecture and Instruction set of TMS320C5X Processor	Lab. 2 C50 Architecture and Memory Organization Lab. 3 Instruction set and Assembler Directives
◆ Addressing Mode	Lab. 4 Direct Addressing practice Lab. 5 Indirect Addressing practice Lab. 6 Circular Addressing
◆ DSP and Multiplication	Lab. 7 LT, MPY, and APAC instructions practice Lab. 8 LTA, LTP, and MPY instructions practice Lab. 9 MAC instruction practice
◆ Advance Programming Drills	Lab. 10 DSK Oscilloscope Lab. 11 Tone generator with filter Lab. 12 Spectral display Lab. 13 Sine wave demonstration
◆ Basic I/O controller	Lab. 14 Traffic lights controller Lab. 15 Dot Matrix display controller Lab. 16 LCD controller Lab. 17 Step motor controller
◆ Application	◆ DSK project

3. TMS320C50 DSK Extension Board

3.1 structure definition

A TMS320C50 DSK extension board is used in the first laboratory course on digital signal processing at Nan-Tai Institute of Technology for DSP beginners. C50 DSK is a simple DSP Starter package with an analog interface circuit (AIC). Most signals are available on pin headers, which allow the board to be expanded. The aim of this Section is to describe the board with a number of typical Micro-Controller peripheral [7] and with components to enhance the functionality of the DSP board. This board can be extended by an external ROM to enable self-standing operations. The block diagram of the extension board is shown in figure 1.

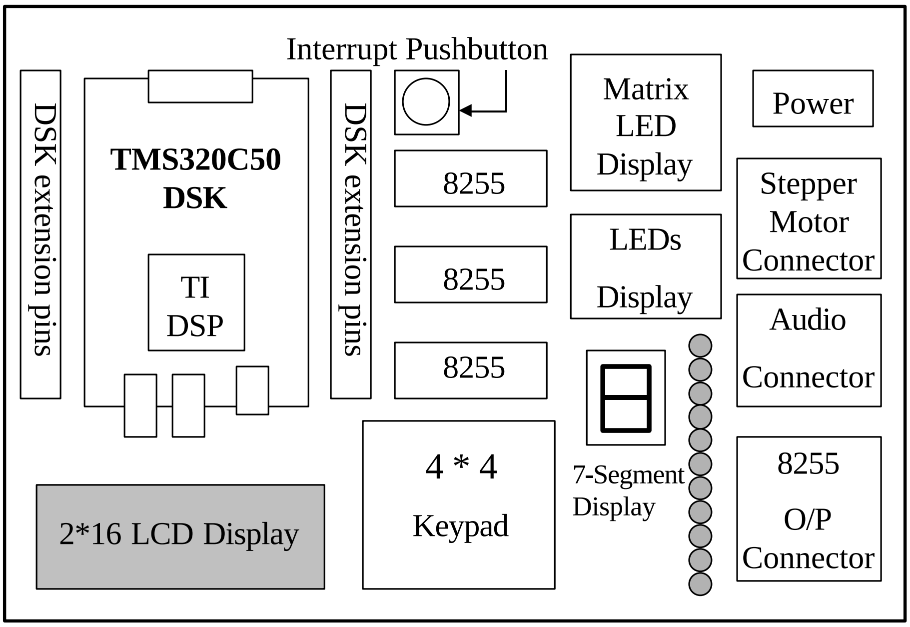

Fig.1 DSK50 Extension Board

The LED display is used to show the data bus bits. The LCD display is an alphanumerical display that can be used for a wide range of purposes. The keypad has the minimal keys to allow the introduction of numerical data to the DSK, and menu functions. Peripherals, which are micro-controller based and extend the functionality of the DSK, were chosen. Figure 2 shows the C50 DSK extension board layout.

3.2 Design Implementation

The design work was divided into two distinct parts. The first part involves the hardware design, PCB making and board testing. The second part involves software design.

Hardware Description

(1) The AC/DC converter provides a +5volts to the extension board and a 9 volts AC to DSK board.

(2) The LCD display can be a 2*16 or 2*20 characters display. The LCD micro-controller is compatible with 8255AC chip from NEC.

(3) The LEDs display consists of 8 LEDs driven by 8255 latches.

(4) A MM74C922 circuit controls the Keypad.

(5) The interrupt pushbutton can be used for external interrupt.

The user interface circuits are accessed inside the I/O space and inside the memory mapped register space of the data memory. This feature allows a more flexible choice of addressing instructions.

Software Description

The software is designed around a simple real time kernel. The kernel controls the overall operation and runs each module in sequence to completion.

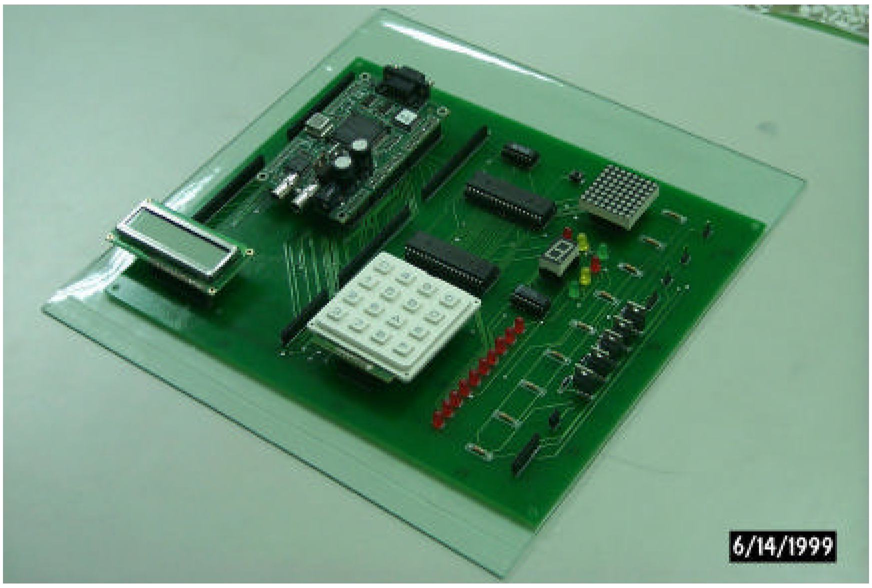

Fig.2 C50 DSK extension board layout

4. Conclusion

In this paper a new laboratory course, using a digital signal processing extension board established at the Southern Taiwan University of Technology, was discussed. There is a real need for an easy-to-learn DSP environment. Students execute a series of laboratory exercises on the board, involving programming signal processors, addressing mode practice, and real time processing processes. The peripheral controls on the board, such as a real time clock, a LCD display, a keypad and LED's display, are discussed. The peripheral programs and the overall test software are provided in the course.

5. References

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6. Acknowledgment

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