CDIO-based Reform of the Digital Signal Processor Course

Jizheng Zhao[1, 2, 3], Mintong Li[1, 2, 3], Huaibo Song[1, 2, 3], Yingang Shi[1]

[1]College of Mechanical and Electronic Engineering, Northwest A&F University, Yangling, Shaanxi 712100, China

[2]Key Laboratory of Agricultural Internet of Things, Ministry of Agriculture, Yangling, Shaanxi 712100, China

[3]Shaanxi Key Laboratory of Agricultural Information Perception and Intelligent Service, Yangling, Shaanxi 712100, China

Abstract: Digital signal processing is a pivot course for electronic information engineering major. It involves mathematics theory and algorithm realization on an integrated circuit (termed Digital signal processor, DSP). The DSP course is based upon a wide range of knowledge, and is difficult to be mastered in a short term. The paper introduces DSP course reform under the frame of Conceive-Design-Implement-Operate (CDIO) engineering education model. It proposes sixteen engineering projects for students. Five students grouped together to conduct a project. They divided each project into different tasks according to CDIO model. Each student conducted some of task and discussed in the team meeting. When the project was finished, they gave oral defense. Teacher gave comments on their work. The reform arouses students' initiative and promotes teaching quality of DSP course.

1. Introduction

Digital signal processing is a pivot course for electronic information engineering major [1]. Generally，This course includes two parts. One part introduces the mathematics theory of digital signal processing, which mainly introduces the theoretical courses of digital signal processing, including basic concepts, theories and analytical methods. The other part deals with its engineering realization on an integrated circuit (termed Digital signal processor, DSP). This part introduces the hardware structure of DSP chip and the engineering application of digital signal processing algorithms [1]. DSP course will enhance the understanding of digital signal processing theory, and improve students' mastery of integrated circuit.

The DSP course is based upon a wide range of knowledge from mathematics on signal processing to Microcontrollers. In order to process a large number of data at real-time, DSP chips include special hardware circuits to achieve high speed processing, storage and data throughput, such as hardware for multiplication and multi independent internal bus. The DSP chip is able to complete once multiplication and accumulation at a single machine cycle. In DSP course, students should master the DSP chip functional architecture, interface, hardware design, assembly language programming and CCS integrated development environment. Its foundation courses include digital signal processing, computer structure, C language programming, Microcontrollers and so on [1]. There are the following difficulties in DSP course: First, DSP course is based on a wide range of knowledge of computer hardware and programming and theory of digital signal processing, which requires that students master these foundation knowledge well. Second, the hardware structure of DSP is much complex, it costs a lot of time to learn. Third, DSP programing employs its own assembly language. Assembly instructions are not easy to master. The above difficulties limits the teaching quality of DSP course. Therefore, it is an important question how to promote the teaching quality of DSP [1].

2. Reform of DSP Course

In order to improve the teaching quality of DSP, many Chinese universities try to reform DSP teaching. One reform is to optimize the content of DSP course [2-4]. The class mainly introduces DSP hardware structure, and then trains engineering programming skills [2, 3]. Some schools employ real instances in class and introduce practice part only [4]. However, the reforms above is not involved with the students' initiative and attendance.

The Conceive-Design-Implement-Operate (CDIO) engineering education model is proposed by Massachusetts Institute of Technology and three Sweden universities [5, 6]. The CDIO engineering education emphasizes students' initiatives to learn and practice, in which the students should not only master a vast body of technical knowledge, but also develop personal, interpersonal and system building skills. Finally, the students is qualified to build systems and products --- the real job of engineers [5-7]. During the Conceive section, students are asked to set system goals and to define system function. They also need to model and manage the project. During the design section, students are required to arrange the process, approaches, the knowledge utilization, and multi-objective design. During the implement part, students model the implementation process, develop hardware and software, and do product test and validation. During the final operating section, students need to optimize the design and operate the product, manage and improve the system [8, 9].

We try to reform DSP course according to CDIO model [10]. We propose sixteen engineering projects for student to choose. For each project, the student should do survey on real application requirements, and draw up a blueprint for the project. Then, students hold a meeting to divide the projects into different functional module, such as the module for theoretical knowledge, technical knowledge, program development, system test and operation. The students learn the knowledge and develop C and assembly language program, and then optimize the hardware and software system. Finally, students operate their product and give an oral defense of the project. Each projects are conducted by a team of five students. One team leader are selected, who take in charge of the team meeting arrangement. Teacher takes part in the team meeting to help students to finish the project.

The sixteen projects are listed follow: (1) Digital finite impulse response filter design; (2) Digital infinite impulse response filter design; (3) Fast Fourier transform experiment; (4) Sinusoid wave generator by using of Taylor's series expansion; (5) Sampling theorem verification by audio signal acquisition; (6) Encoding and decoding of audio signal based on information theory; (7) Multimedia data (audio and image) transform and display experiment; (8) Digital filtering based on fast Fourier transform on audio signal; (9) Digital image filtering and noise reduction experiment; (10) Histogram and mutual information calculation of digital image experiment; (11) Digital image contrast adjustment with histogram equalization method; (12) Digital image edge detection; (13) Road detection based on digital image processing; (14) Face detection based on digital image processing; (15) Number recognition based on digital image processing; (16) Moving target detection experiment based on digital image processing. All the projects are conducted on TMS320C6748 DSP chip.

3. An Example of DSP Projects

The digital finite impulse response filter project require students to identify different sine signal with different frequency. At beginning, teacher helps students to ascertain the application situation, the project target and final assessment indices. Students discuss theoretical knowledge for digital filter design, filter design method in Matlab software, DSP program development by C and assembly language, the evaluation and optimization of the program with real-time operation on DSP. Then, Students assign task for each other and set the schedule. For knowledge on the digital finite impulse response filter, the students need to learn basic structure of finite impulse response filter (FIR), the advantages and disadvantages of FIR and infinite impulse response filter (IIR), the type I and type II conditions for linear phase of FIR, and the amplitude characteristics of linear phase FIR

filter. Then, they should select the most suitable filter model. In order to acquire the filter parameters, students need to master the filter design method with Matlab software, such as: the method of window function or frequency sampling, the characteristics of rectangular window, triangle window, Hanning window, the commands to using window function and frequency sampling method to design filter in MATLAB. Figure 1 shows an example of digital finite impulse response filter design in Matlab. Figure 1a shows an combined signal with two components with 50Hz and 1000Hz. In order to identify the signal with frequency of 50Hz. The students employ low-pass FIR to exclude the signal with frequency of 1000 Hz. For example, a 16-orders low-pass FIR could be realized with fir1funtiocn in Matlab. Figure 1b shows magnitude and phase characteristic. Figure 1c shows the input and output signal wave of filter. Figure 1d shows the input and output signal wave of filter in frequency domain. The component with frequency of 1000Hz is eliminated.
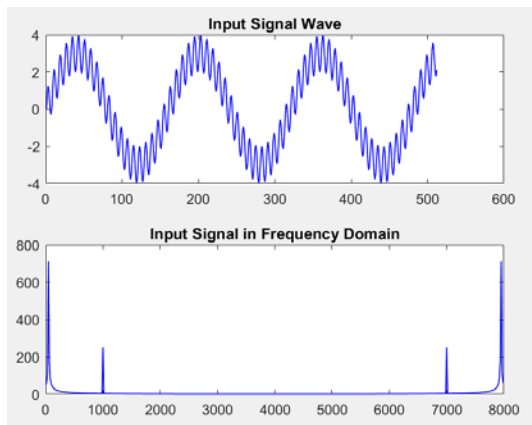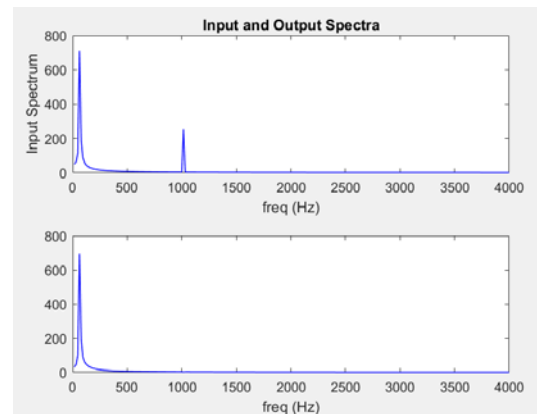

(a) The input signal wave and expression in frequency domain
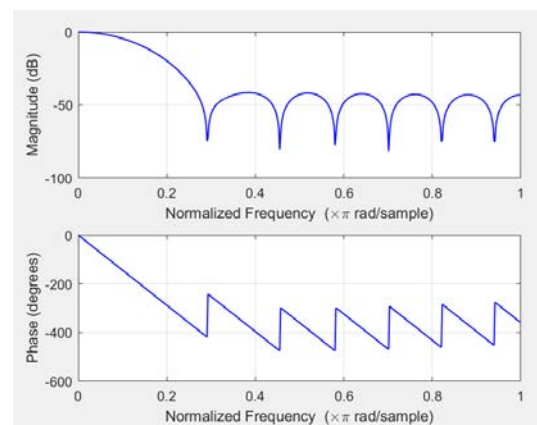
(b) The magnitude and phase characteristics of filter
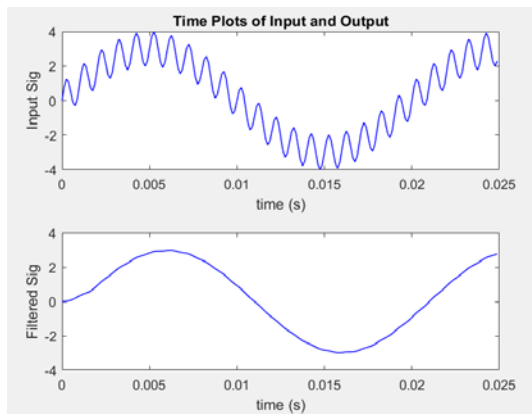
(c) The input signal wave and output signal wave being filtered

(d) The input signal and output signal being filtered in frequency domain

Figure 1 an example of digital finite impulse response filter design in Matlab

In order to realize the filter on DSP chip, the students should ascertain the range and accuracy of data and filter coefficients, the method to set the decimal point for fixed-point DSP, the difference between linear buffer and cyclic buffer data storage, the assembly commands for linear buffers storage and addressing, the assembly command for circular buffers storage and addressing. With regard for DSP program development, the students need to learn how to configure the working mode of DSP, how to configure the DSP memory chip, and how to use C and assembly language to develop the DSP program. When filter parameters were calculated with Matlab software, the students should transform the parameter value to Q15 fixed-point format and select the parameter value storage mode. For example, there are 17 parameters in the current filter, and all parameters need to be addressed for each signal point, it is better to store the parameter value in a linear buffer

region and to address the parameter in the manner of circular addressing. For each output value, 17 data points are needed, it better to store the input signal in a circular buffer region（the newest signal value replaces the oldest signal value） and to address the parameter with circular addressing. All these operations should be realized with DSP assembly language (Table 1). When program is developed, students should to validate it on computer with CCS Integrated Development Environment, and then load it on DSP chip to further optimize the speed and memory costs. When the project is finished, the students write projects report and to prepare slides for oral defense. They should introduce the designing method and ideas, the software function and system error, the possible method to reduce the error. For each team, all the students take part in preparing of report and slides, and give oral defense together. The teachers take part in the defense and give their comments.

4. Conclusion

The paper introduce DSP course reform under the frame of CDIO engineering education model. The applications of CDIO mode in DSP course will deep the basic theoretical knowledge and engineering experience in signal processing for students, and has a positive effect on promoting teaching quality for electronic information major.

Table 1 the example program with assembly instructions of TMS320C5416

```
_fir:nop
STLM   A, BK            ;load BK with 17
LD      *SP(1), A        ;load parameter RESULTS into A
SUB        #1, A            ;subtract 1 from the number
STLM   A, BRC           ;set the signal length
MVDK  *SP(2),*(AR1)   ;load ARn with &y
STM    #1, AR0          ;the increase step for circular addressing
STM    #_a, AR2         ;set the storage address of filter parameters to AR2
STM    #_x, AR3           ;set the storage address of input signals to AR2
RPTB   done-1           ;conduct the instructions before the done instruction
MPY     *AR2+0%,*AR3+, A      ; the product of the first filter parameter and the
                               current input signal
RPT         #15                ;conduct multiply and accumulation 16 terms
MAC     *AR2+0%,*AR3+,A   ; the product of each filter parameter and the
                              corresponding input signal
MAR    *AR3(-16)        ;point to the next signal
STH         A,*AR1+          ;store result
done:   RSBX   FRCT
RET          ;return
```

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