Multi-function DSP Experimental System Based on TMS320VC5509

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Abstract. In this paper, the experimental system based on TMS320VC5509 is designed for “DSP system design” course for the electronic information and its related majors. The system has many functions such as signal acquisition, serial communication, speech signal processing, image processing, offline operation and so on. The characteristics, hardware components and functions of the experimental system and the experimental contents are described in this paper. The system not only can be applied to the practical teaching of DSP course, but also can be used as the development platform of DSP system.

Introduction

In recent years, with the rapid development of digital signal processing technology, the digital signal processor (DSP) has been widely used in various fields. New requirements on the DSP teaching in universities are put forward. In this paper, the experimental system based on high performance fixed-point chip TMS320VC5509, with complete peripheral equipment, powerful functions and rich peripheral resources, not only can be used for practices of DSP course teaching, but also for the development of DSP application. The experimental system has rich and reasonable experiment items, and can provide a good platform for students to improve the development and design capability of DSP chip.

Characteristics of the System

1) Taking DSP chip TMS320VC5509A as the main processing chip, the chip has low power consumption, dual core structure, fast operation, high accuracy, and low price. It is suitable for development of fixed point application.

2) Chip memory storage space of 128KB x 16Bits, large capacity of 4M x 16Bits for SDRAM design, extended FLASH of 8 Mbits can store a large number of solidified procedures and data.

3) Rich communication interfaces, including the host interface (HPI), multi-channel buffered serial ports (McBSP).

4) System logic control, decoding and other functions are achieved by a CPLD chip, with flexible design and compact structures.

5) DSP expansion bus conforms to 3U standards, including data, address, I/O and control.

6) Self-starting can be realized.

Hardware Components of the System

The system is composed of AD7656, TLV320AIC23, TMS320VC5509A, AM29LV800, TL16C550, TLC7528C and other chips.

TMS320VC5509[1]DSP chip is the core of whole system. Its main functions include sampling control of analog signal, program management and data scheduling for RAM, SRAM, FLASH, communication with PC through RS232 serial port, and control and display on the peripheral.

AD7656 is a digital conversion chip of AD with high speed and precision, 16 separate 6 bit ADC, bipolar analog input, and high throughput rate of 250K sampling values per second. In this system, AD7656 mainly completes the acquisition of signal.

TLV320AIC23 is a multimedia digital speech codec with high performances. Its internal ADC
and DAC conversion module have a complete digital filter. Data transmission width can be 20, 16, 24 and 32, and the sampling frequency ranges from 8kHz to 96kHz. High fidelity audio signal acquisition and playback.

TL16C550 is a standard serial interface chip. The control register based on address can be modified by CPLD, which is easy to learn. The register occupies 8 address units of TMS320VC5509. Serial interrupts are connected with INT0 of TMS320VC5509. Users can response to serial interrupt by use of interrupt 0.

The principle diagram is shown in figure 1.

![Figure 1. TMS320VC5509 experimental box diagram.](image)

Functions of System Design Modules

Signal Acquisition Function

Analog Signal Acquisition. Due to the excellent characteristics of TMS320VC5509 and AD7656, the system can complete the acquisition of analog signals easily and quickly. The parallel interface is adopted between AD7656 and DSP. The selected signals and read-write signals of AD7656 can be controlled by IO space and CPLD to complete the start and configuration of AD7656. When the conversion is finished, the INT0 is triggered, and sample data are read by the interrupt subroutine.

Speech Signal Acquisition and Playback. Speech signal acquisition and playback function is mainly completed by TLV320AIC23. The multi-channel buffered serial port 2 between TLV320AIC23 and TMS320VC5509 is configured as SPI mode for communication. The TLV320AIC23 clock signal is provided by the DSP timer 0, and the clock signal can be changed conveniently by modifying the setting of the timer 0.

Communication Function

The system has a very rich communication function, which is reflected in the DSP, other microprocessors and information transfer between micro-control units and PC. DSP communicates with other micro-processors mainly through HPI, as long as the corresponding pins are connected according to the requirements. The communication of the micro-controllers with a serial interface can be realized by setting the McBSP. In addition, because the HPI interface and McBSP both can be configured as GPIO mode, communications with the corresponding devices can be completed as long as there is the support of corresponding underlying and top-level protocols.
**Real Time Analysis of Signals**

The system takes VC5509 as the main controller and processing core. It can complete the fast fourier translation in real time. The VC5509 transmits results to the display module and display them in a graphic way. Structures of signal frequency can be understood by spectrum analysis [2].

**Extended IO Function**

TMS320C5509 DSP has seven dedicated general-purpose i/o pins and one general output pin XF. These general i/o pins can be controlled by software, such as the specified input or output, output value, etc. The general output control module of ICETEK-CTR board connects with a indicator light and general i/o pins of DSP on the board directly through the extended sockets of ICETEK-VC5509-A board. The pin belongs to the McBSP1 and can be set to a general i/o pin.

**Simulation/Offline Operation**

**Soft Simulation**

Users can adopt COMPOSER CODE (CC), a fully integrated development environment (IDE) to achieve soft simulation. Users can select TI from the menu bar for the source program editing, debugging and compiler. The compiled results can be seen directly from the window. Users can choose to compile a single file, or add all the files to a project. C expressions and gel functions can be added to the viewing window and executed at each break point. Signals also can be observed by the probe or adding/extracting data to/from the state or the algorithm.

**Hard Simulation**

TMS320VC5509 has on-chip scanning simulation interfaces (JTAG) conforming to the IEEE1149 standards, so the system is configured with hardware emulator XDS-PCI externally. The simulator has very high speed, with standard PCI bus interface. The simulator supports multi-DSP debug in parallel, various computer operating systems and on-chip flash programming. Every processor running in the system can be controlled, each chip can be tested, and the status of each register can be observed through the hard simulation. The real online simulation can be realized.

**Offline Operation**

External flash is used to achieve self - lifting of VC5509. The .Out files are conversed into data files which can be used to burn the EEPROM format files by the format conversion tool before offline operation, and written to flash after finishing. Flash space address 0x8000- 0xFFFFH are mapped to the DSP data space address 0xFFFFH - 0x8000. If MP/MC=0 after the system was powered on and reset, the internal 4K * 16 bits ROM is valid, the program jumps to the FF80 automatically, and DSP is initialized. Therefore, when the FLASH is burned, 8000 is written to the FFFF unit of FLASH .The 8000 is a address of the EEPROM or flash mapping to the DSP data space and a starting address of the program code loading [3].

**Experiments Based on the System**

Experiments based on the system are as follows:

1). CCS software application experiment. Familiar with the Composer Studio Code integrated development environment. Learn DSP software development process through the demonstration program compiling, loading and running,

2). Data storage experiment. Master TMS320VC5509 programming space allocation. Master TMS320VC5509 data space allocation. Familiar with the operation of TMS320C5509 data space.

3). I/O experiment. Get knowledge of the expansion of I/O ports, master the operation method of I/O port, and master the use of I/O space.

4). Indicator light experiment. Get knowledge of DSP TMS320VC5509 external extended storage
space, understand the indicator light principle, and learn the method of using extended control register in C language.

5). Dial switch control experiment. Get knowledge of the external expansion storage space of DSP TMS320VC5509 and the principle of dial switch expanding. Learn the method of using extended control register in C language.

6). DSP timer experiment. Master the method of controlling VC5509A timer. Master the interrupt structure of VC5509A and the processing flow of interrupt. Learn interrupt program design in C language and control program flow by the use of interrupt program.


8). Digital image signal processing experiment. Master the principle and program design of histogram statistics. Learn the program design method of edge detection with sobel operator. Learn the program design method of Laplace sharpening operation. Realize the inverse operation of the image, and master the principle and program design of histogram equalization enhancement.

9). Speech acquisition and playback experiments. Familiar with the performance of TLC320AD50 and ADC/DAC interface. Familiar with the communication application that McBSP multi-channel buffered serial port being configured as SPI mode. Master a complete voice input and output channel design. Understand voice signal acquisition and playback design.

10). Double DSP communication experiment. Understand the basic principle of HPI interface. Master basic methods and procedures of the communication between two DSP chips.

11). Data acquisition experiment. Familiar with the performance, interface and use of AD7656. Master the design of a complete data acquisition module.

12). DMA data transmission. Learn the use of DMA.

13). Offline operation. Understand the bootload principle and conversions from .out files to .Hex files. Write to the EEPROM and make the whole system run out from the emulator.

In the DSP experimental teaching, the first eight experiments need to be observed by students through running the given demo programs. Experiments related to the signal transmission or data storage needs to observe the changes in memories and registers with one-step operation function of CCS (Code Composer Studio), observe the signal waveform and spectrum with CCS graphics display and animation functions. For the first eight experiments, expansion requirements can be added in addition to the basic requirements, such as modifying the program, changing LED flash frequency, adjusting the serial communication baud rate or running different filtering algorithms. The last five experiments are taken for enhancing abilities of students. Through a series of experiments, students can consolidate the understanding of DSP theory, and learn how to debug programs and master design and development process of DSP basic system. Therefore the students’ practical ability is trained and knowledge in DSP system and its peripheral is broaden.

**Typical Examples of Comprehensive Experiments**

Students can start integrated design experimental projects by themselves or combing with practical engineering. This paper presents a practical comprehensive experiment: the vibration sensor of 4-20mA current output is used to collect the surface vibration signals of the transformer. Analog signals are conversed to digital signals by AD7656 after signal conditioning circuit. The data is sent to DSP in parallel for storing and calculating and the result is sent to the remote host by GPRS. At the same time, the alarm or early warning information is transmitted to the patrol personnel via GSM interface [4]. Experimental system block diagram is shown in figure 2.

![Figure 2. Block diagram of integrated experiment system.](image)
System work process is as follows:

1). Take DC-DC chip TLV1117 as the system power module. The input is +5V voltage, output is 3.3V and 1.6V, which is available by 56 ohm and 200 ohm resistances.

2). The original analog signals are converted into signals can be identified by signal processing module, including amplifying, reshaping, signal parameter transformation and so on.

3). Start AD conversion by interrupt trigger mode and read data. The sampling frequency is determined by the timer interrupt. Because the highest sampling frequency is 21.5 kHz, 128 points are collected in a sampling circle so the sampling frequency is 12.8 kHz. Set PLL clock frequency as 128MHz, TDDR=2, PRD=0X0d00, so that the interrupt frequency is 12.8kHz. Each time the interrupt occurs, A/D collects a data, so the sampling frequency is equal to the timer interrupt signal frequency 12.8kHz. Data is processed after the acquisition of 128 points in a signal cycle.

4). TLC6C550C asynchronous serial communication module is adopted. Serial port interrupt is connected with INT0. Interrupt 0 responses to serial port interrupt. The baud rate can be set by the divisor register DLM and DLL. 8 bus transceiver SN74LVC245A with three state output applied to long distance data transmission. Pin 1 is connected to high level choosing bus A to B, pin 1 is connected to low level choosing bus B to A. Standard asynchronous serial level conversion chip (MAX232) can transmit signals through the serial ports.

Summary
This paper presents a relatively complete DSP experimental system. With high performance digital signal processor TMS320VC5509 and extended rich peripherals, it not only supports fixed-point DSP development projects, but also can be used as signal generator, data collector, etc.. At present, the system has been successfully applied to the DSP practice teaching of undergraduate and graduate students in North China Electric Power University.

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Reference