# Low Cost DSP Based System for Signal Processing and Control

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**Abstract**

For control and data acquisition systems, DSP(Digital Signal Processor) plays an important role in signal processing, data correction and bus control. This article describes a system built at the FELab (Fast Electronics Laboratory) which use DSPs as a core processor and PC as a host. It is a digital platform which can be used in high speed real time data processing and control. The authors also introduce some potential applications of the platform, especially an effective real-time image enhancing application.

The platform costs less than US$500 (PC is not included), for most research and even educational projects, this is affordable.

## 1 Introduction

Data acquisition and signal processing is now being broadly used in many fields. With the progress in the new techniques, people study fast, wide-band signals more and more. Under some conditions, signals are even required to be processed in real time, such as real time parameters extracting and feedback control. Thus it is necessary to develop a system to handle this task. Moreover, we need not only a system that can do it, but also a system we can afford.

A general purpose, low cost, easy to use, real time digital platform based on a DSP was made at our laboratory. It is assembled with three major parts: analog to digital converter(ADC), data processing chip, digital to analog converter(DAC). An ADSP2181 functions as a core processor to manage the whole system. The ADC and DAC are the interfaces to the real world. So this platform can acquire signals from the analog domain, process them in digital domain with a number of flexible, powerful DSP algorithms, then return the results to the analog domain. Accordingly, it is well suited for resolving some data acquisition, test and measurement, and feedback control problems.

## 2 System design

### *2.1 A brief introduction to the ADSP2181*

ADSP2181 is a 33MHz, 16bit fixed point DSP chip from Analog Device Inc.. It is based on the Harvard architecture, a processor architecture with separated program memory and data memory. This architecture enables it to get instructions and data at the same time. Besides, it has relatively big(80k bytes) on-chip memory. The core processing unit of the chip can neatly access the on-chip memory faster than with external memory. As a result, ADSP2181 can realize many algorithms such as correlation, convolution, accumulation, filtering etc. effectively.

Analog Device Inc. also provides an inexpensive kit for the convenience of users. The kit includes an ADSP2181,a set of CODEC chips, an RS-232 serial port interface, and a monitor program executed under Windows3.X. Users could take advantage of this kit to be familiar with the DSP.

### *2.2 Schematic design*

Because most of the instructions of ADSP2181 are executed in single clock period, the code executing time is easy to be predicted. We directly use the program timing to produce ADC sampling clock. By this technique, the handshaking between DSP and ADC can be done easily. Furthermore, the system sampling rate is flexible and the platform can give full play to its processing potential.

For general applications, the on-chip memory is big enough. But for some mass data applications, such as long period wide-band signals analysis, the on-chip memory is too small to attain the requirements. We add 512k x 16 bit off-chip memory to adapt this kind of applications.

## 3 System realization

### *3.1 System overall architecture*

The core of the whole system is ADSP2181. A Windows3.X based monitor program manages the serial communication between the ADSP2181 and PC. The DSP executable code and parameters can be downloaded into ADSP2181 via a serial port. A fast flash ADC(AD9048) and a fast DAC are included in the system as well. Fig1 indicates the system overall architecture.

### *3.2 Hardware design and realization*

The hardware architecture is indicated in Fig2. As we have mentioned, there are 512k x 16bit external memory built in this system. But, we have not directly connected the address bus of the RAM and that of the DSP together, as many others did. We add a counter to generate

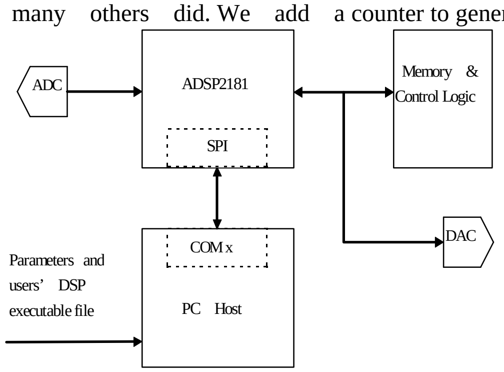


Fig1. Overall architecture of digital platform

addresses for the external memory. There are two reasons why we did this. Firstly, the ADSP2181 can manage only 32k external memory space. If it is beyond this limit, the users have to use page mode, however, page mode addressing will slow down the memory access speed and is not fit for mass data real time processing. Secondly, most of the real time data processing only needs to access data sequentially.

By means of address decoding of a DSP external memory read operation, we can produce a pulse to act as an ADC sampling pulse and can similarly produce address counter increasing pulse. Generating these pulses by decoding makes program timing more feasible and makes the ADSP2181 and the ADC work synchronously. Then the platform is able to do real time mass data sampling without any additional timing.

For the sake of result observation or feedback control, a high speed DAC(AD9700) is included in the system. The DSP can read a data from internal or external memory and strobe it into the DAC data latch. Then the DAC converts the digital signal to an analog signal. The analog signal is driven to output via a buffer amplifier(AD9617).

## 4 System characteristics and applications

### *4.1 Characteristics*

This system is a general purpose digital platform which can be used in many fields with two main characteristics: firstly, it can do much processing work at high speed in real time; secondly it can process mass data in real time. The Table shows its real time processing ability.

### *4.2 Applications*

Above all, this platform is a high speed DAQ system with 16.67MSPS sampling rate and 512k x 16 bit very deep buffer. Because of the powerful DSP core and existing DSP algorithms, this system can be applied in many arenas. We list several applications:

(1)Flexibility. For its real time ability, users can get not only digital filters but also real filters with digital flexibility. Many kinds of filters including linear or nonlinear, such as FIR, IIR, multirate, adaptive etc. are easily implemented.

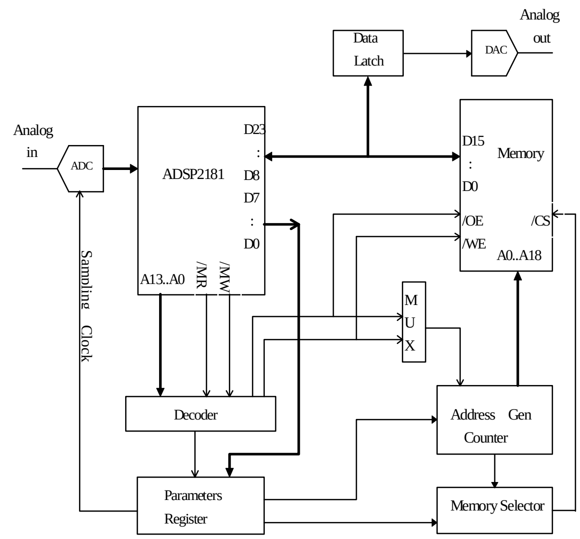


Fig2. Digital platform hardware blocks

| Processing | Max. Speed in real time (MHz) | |
|---|---|---|
| | Single precision | Double precision |
| FIR | 33/[N+6] | 33/[3*N+19] |
| IIR(direct) | 33/[M+N+12] | 33/[3*(M+N)+13] |
| IIR(cascade) | 33/[7*N/2+6] | 33/[10*N+9] |
| LMS(SG) | 33/[2*N+9] | 33/[4*N+9] |
| PID | 4.25 | |
| Convolution | 33/[N+6] | 33/[3*N+19] |
| Accumulation | 16.67 (512k depth) | |
| FFT(256-point,complex) | 0.203ms | |

Table Maximum real-time processing speed of general algorithms

(2)Digital controllers can be used in servo motor control, progress control, flight control, general servomechanisms and so on.

(3)Real time accumulator can be used to accumulate signals in real time to improve SNR or even extract periodic signals from heavy noisy background.

(4)Spectral analyzer can be used to study signal spectrum and can display the spectrum on a computer screen or an oscilloscope.

Of course, others could find more applications in their own research fields. Here, we would emphasis the real time accumulation application. It is interesting and effective. As we know, the SNR of a signal can be improved $10\lg N$ by means of accumulating the signal N times. Moreover, real time accumulating can extract period from periodic signals and is especially suit to long period signals[6]. For example, a video signal of a still or very slowly changed scene is a long periodic signal (the frame period is its period). In many cases, a video signal is polluted by noise for some reasons and the image on monitor becomes obscure. Like a video signal from a faint light camera, due to the dark current, noise is relative heavy, and many "snow" flickers on the monitor screen. There are thousands of effective image processing methods which may be utilized to deal with "snow" noise, such as two dimensional low pass filter, mid-value filter and so on. But, unfortunately, these methods are all non-real-time. Because it is simple and easy, accumulating is well suited for reducing "snow" noise.

In [7], the authors introduced a two-dimensional image system based plastic scintillation fiber. It is expected to substitute for a traditional detector in biomedical equipment, industrial CT, custom detector in future. The read-out subsystem in a faint light camera and the output is

noisy too. To enhance the image with noise reduction, the digital platform is able to fully develop its skill.

**Reference**


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