VNU Journal of Science, Mathematics - Physics 26 (2010) 1-8

Multi-channel measurement based on DSP development

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Received 9 February 2010

Abstract. A real-time and simultaneous processing system with 8 analog inputs is designed. The system is based on the development of Texas Instrument TMS320VC5510 DSK kit. The analog input signals are converted into digital ones by 8 bit ADC module using ADC0809. The ADC module interfaces to the DSP in parallel, through the DSP's Memory Expansion Connector. The measurement with standard input signals fom FUNCTION GENERATOR LG1311 is also reported.

1. Introduction

Bases on special architecture with parallel and pipe-line techniques, the speed of signal processing of a DSP is manyfold faster than the speed of a specified CPU [1-3]. Because of this advantage, DSP is widely used in measurement and automation where real-time processing is required. Recently, Texas Instrument TMS320VC5510 DSK kit with DSP architecture, is introduced in Vietnam [4]. Mostly, the kit is used for audio and video studies in universities and/or laboratories. These applications are normally concentrated on exploitation of the current resources, supported by the DSP, such as audio processing through Line In Connector.... However, such kind of applications is suitable to processing only one input signal [5] (Fig.1).

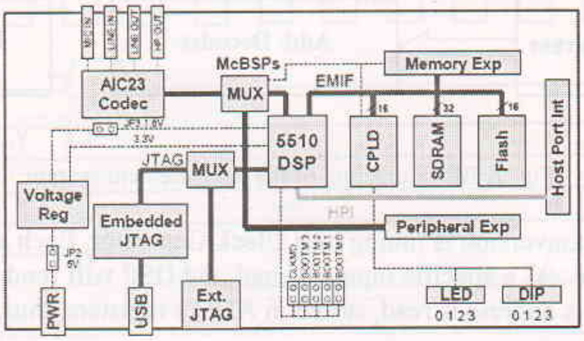

Fig. 1. Inside architecture of TMS320VC5510 DSK.

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In practice, many systems require a multi-channel signal processing. In these systems, multiplexers/ de-multiplexers with synchronous signals and a phase lock loop are usually used. As a result, these systems become more complicated and time consuming, while processing time is tended to be minimized.

In general, processing time of a multi-channel system depends on the data access time and the processing time of the processing unit. For an analog multi-channel access, ADC is normally used. For data processing, the processing unit could be developed based on a microprocessor or a DSP board.

In our experiment, Kubelka-Munk model [6] is used to calculate absorption coefficient μ_a, scattering coefficient μ_s and anisotropy g from three analog input signals: backward scattering R_d, forward scattering T_d and collimated light T_c [7]. The measurement does not require a high sampling rate (around 100Hz), thus, ADC0809 with the conversion time of 100μs is used. As the model requires a lot of time for data processing, the TMS320VC5510 DSP board is used to develop the processing unit.

In this paper, an approach to setting up a real-time measurement system that can simultaneously access some different analog inputs is presented. The system is based on the development of a DSP interfacing to a 8-input, 8-bit ADC module in parallel, through the used DSP's Memory Expansion Connector.

2. Experimental set-up

The block diagram of the as-designed measurement system is shown in Fig. 2.

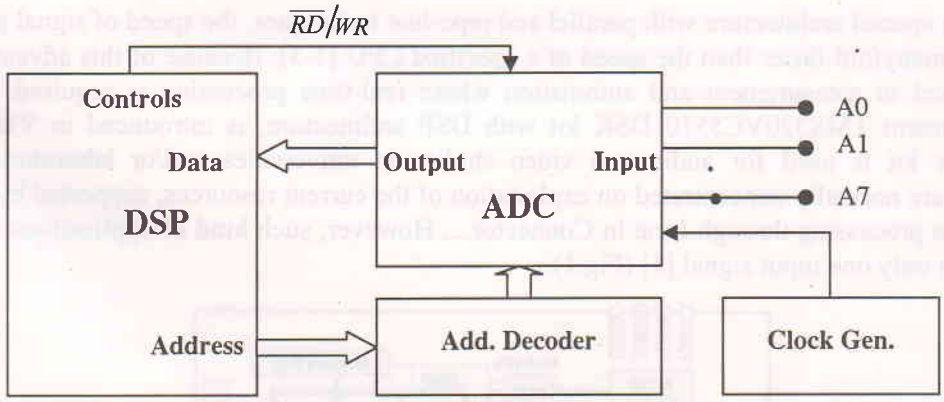


Fig. 2. Block diagram of the measurement system.

The analog-to-digital conversion is timing by a Clock Generator. Each analog input is addressed in the DSP's Memory. To access a specific input channel, the DSP will send out its address to the ADC module. Once decoded, this address is read, stored in ADC's registers, thus, the appropriate channel is selected.

After the conversion, the data is sent to and written into the DSP by using an interrupt processing technique. The schematic diagram of the system is shown in Fig. 3.

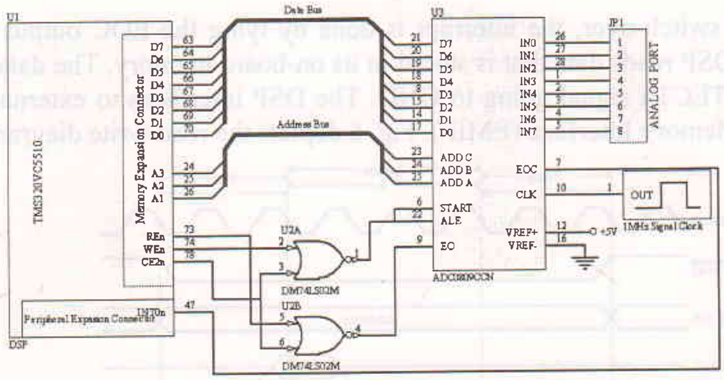


Fig. 3. Schematic diagram of the system.

From technical point of view, the ADC is considered as a DSP's asynchronous memory addressed in the range from 0x400000 to 0x40001C (Fig. 4).

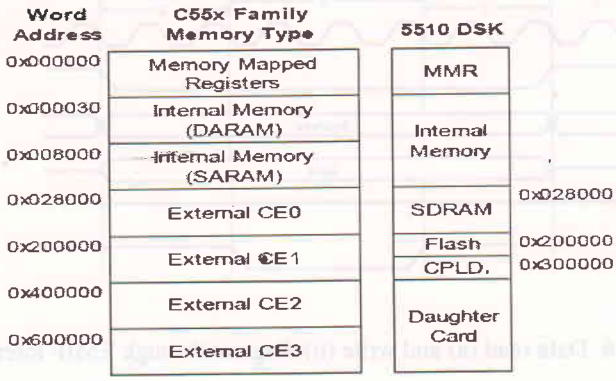


Fig. 4. Memory Map of TMS320VC5510 DSK.

The analog-to-digital conversion begins in the ADC module, on the falling edge of the conversion start pulse [8]. The end-of-conversion (EOC) output of the ADC is in "0" logical state during the conversion and goes to "1" logical state at the end of the conversion (Fig. 5).

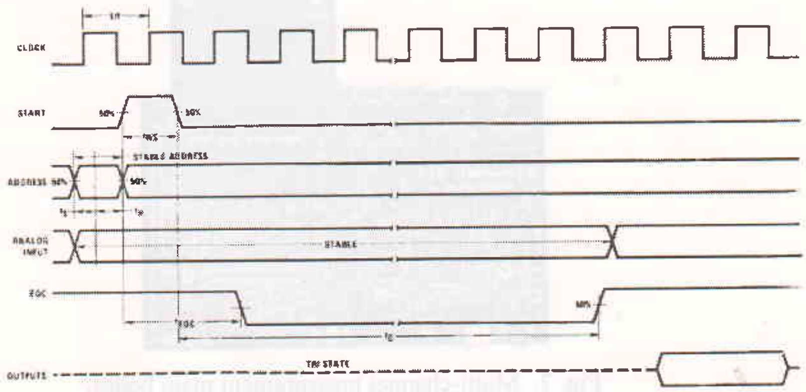


Fig. 5. ADC Timing Diagram.

Upon this state switch-over, the interrupt is done by tying the EOC output to the DSP's INT0n input. Initially, the DSP reads data that is stored in its on-board memory. The data access is in progress after the DSP's DETECTn signal going to GND. The DSP interfaces to external peripherals through its 32-bit External Memory Interface (EMIF). Fig. 6 depicts the read/write diagram through the EMIF.

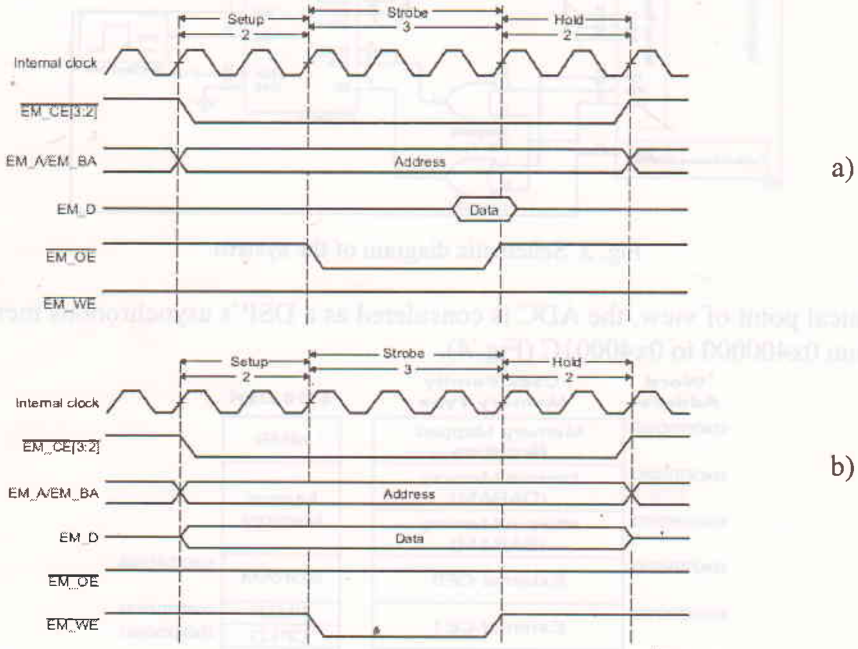


Fig. 6. Data read (a) and write (b) diagram through EMIF interface.

The as-designed multi-channel measurement main board with an ADC module interfacing to MS320VC5510 DSK through the DSP's Memory Expansion Connector is shown in Fig. 7.

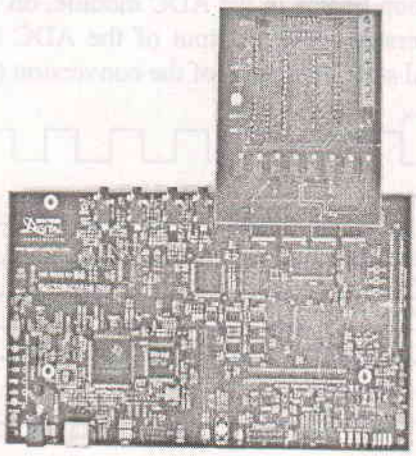


Fig. 7. Multi-channel measurement main board.

The signal amplitude at 8 ADC's analog inputs could be adjusted by potentiometers. 8 ADC's outputs are connected with the DSP's data inputs through the DSP's Memory Expansion Connector. 3

DSP's address inputs are connected with the ADC's address lines. Read/write process is activated by DSP's read/write enable signals.

3. Measurement with standard input signals

The measurement system is tested by a standard signal generator - FUNCTION GENERATOR LG1311 and an adjustable DC voltage source. The test signals are sent to each input of the ADC module. The input signals' amplitude is measured by a multimeter, their frequency by frequency counter HAMEG 8021 - 1GHz and their shape by an oscilloscope. At the same time, these parameters are calculated and displayed on the DSP's Code Composer Window (Fig. 8).

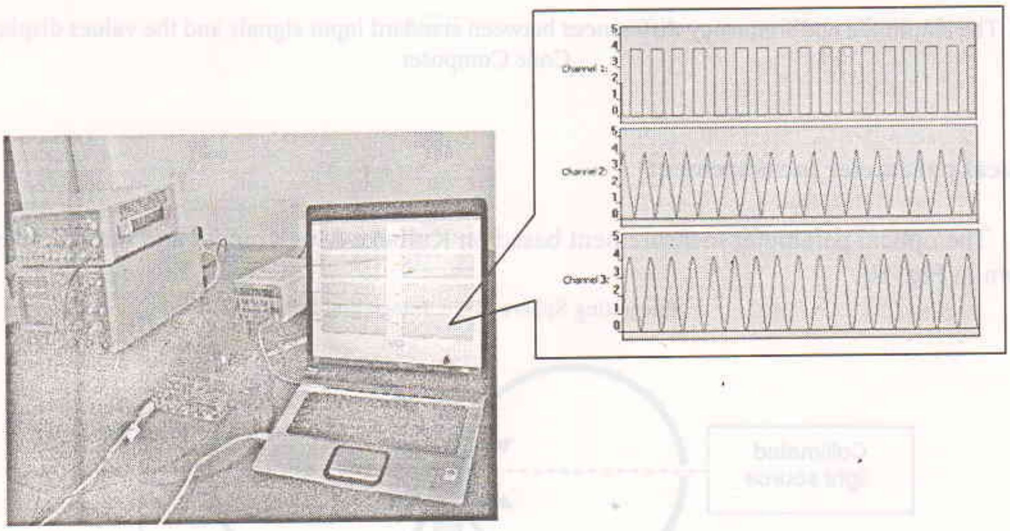


Fig. 8. Test of the measurement system by standard input signals.

For comparison, the input signals are sampled and displayed on the Code Composer Window with 400 sampling points on each Window. The amplitude test is carried out by following steps: i) measuring the input signals' amplitude by a multimeter; ii) calculating the data on the Window to find out the average of maximum values of the sampling points and the absolute error; iii) comparing the measured read-out with the calculated value. The amplitude difference and the committed absolute error are also displayed on the Window.

The frequency test is more complicated with an algorithm developed as followings: i) verifying the point where the signal graph passes "0" DC voltage level on the Code Composer Window; ii) determining the number of sampling between two adjacent "0" passed points; iii) dividing the sampling frequency to the found number. The frequency difference and the committed absolute error are also displayed on the Window.

The obtained data shows that the amplitude and frequency differences are turned out to be less than 1% (Fig. 9).

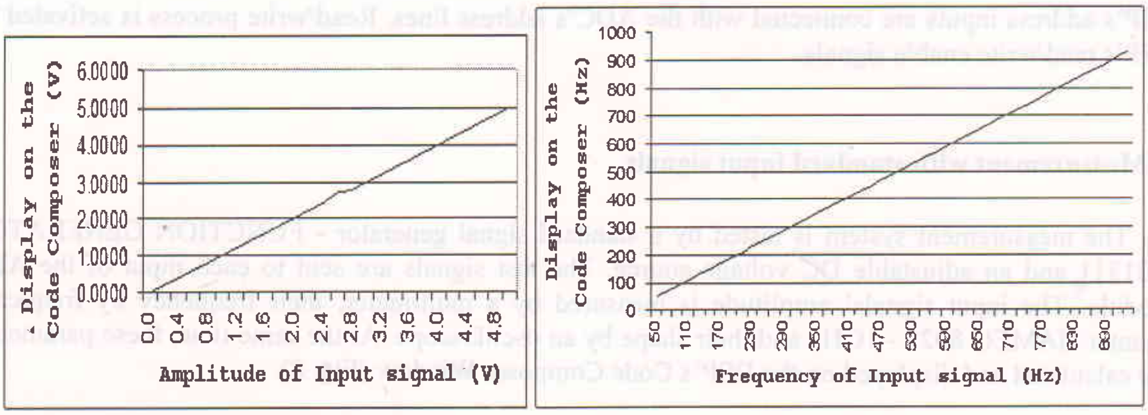


Fig. 9. The amplitude and frequency differences between standard input signals and the values displayed on the Code Composer.

4. Optical parameter measurement

The optical parameter measurement based on Kulbeka-Munk model and the DSP development is shown in Fig. 10.

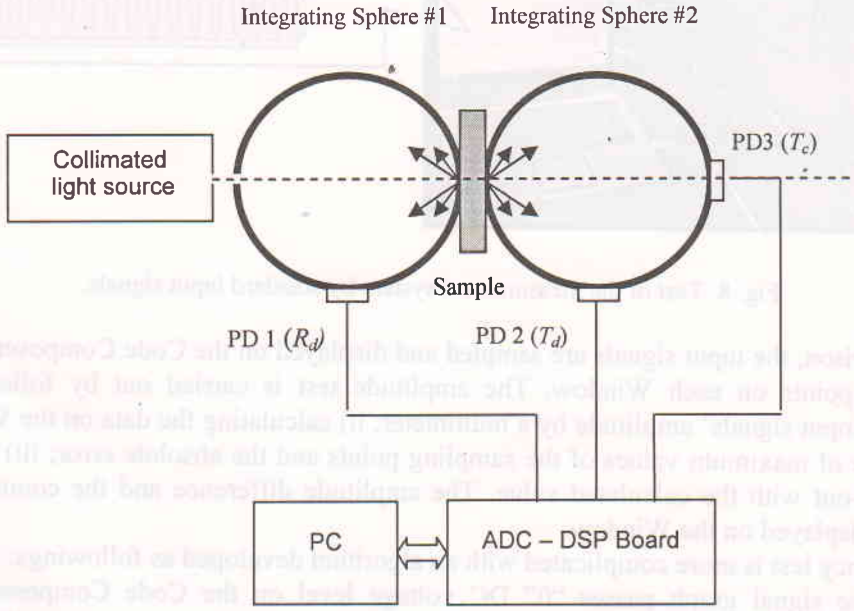


Fig. 10. The optical parameter measurement based on Kubelka-Munk model and DSP.

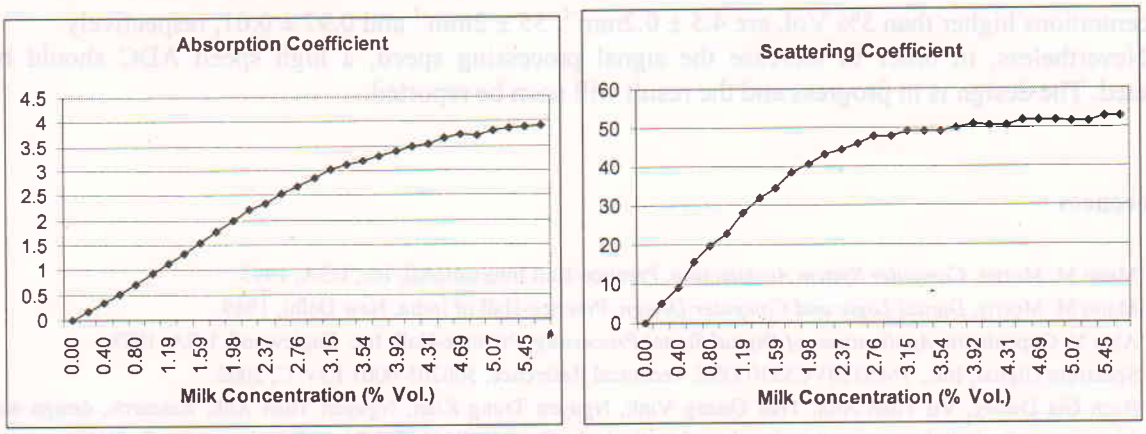
The light from the collimated light source is sent to the sample, hold in the middle of two integrating spheres. The light then is divided into three parts: backward scattering R_d, forward scattering T_d and collimated light T_c. From these parameters, the absorption coefficient μ_a, scattering coefficient μ_s and anisotropy g are calculated by Kubelka-Munk model:

$$\begin{cases} S = \dfrac{1}{bd}\ln\left[\dfrac{1-R_d(a-b)}{T_d}\right] \;;\; K = S(a-1) \\ a = \dfrac{\left(1+R_d^{\,2}-T_d^{\,2}\right)}{2R_d} \;;\; b = \sqrt{\left(a^2-1\right)} \\ \mu_a = \dfrac{K}{2} \;;\; \mu_s = \dfrac{-\ln T_c}{d} - \mu_s \;;\; g = 1 - \dfrac{(\mu_a + 4S)}{3\mu_s} \end{cases} \tag{1}$$

where b is the light path, S and K are the Kubelka-Munk scattering and absorption coefficients, respectively.

The under-test sample is homogenised fresh milk at different concentration [9].

Fig. 11 depicts the dependence of μ_a, μ_s and g on milk concentrations.



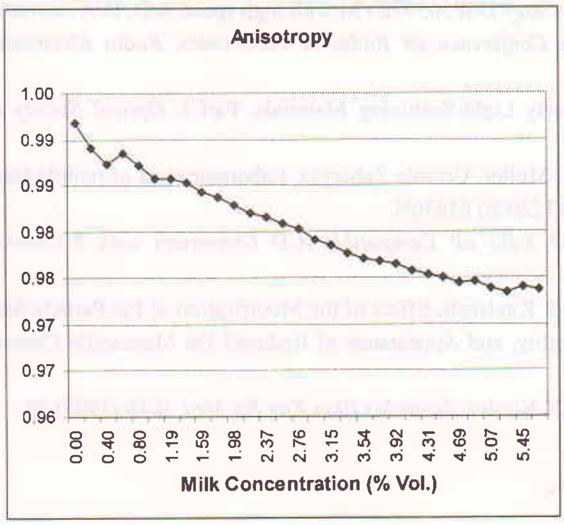


Fig. 11. The dependences of absorption coefficient μ_a, scattering coefficient μ_s and anisotropy g on homogenised fresh milk concentrations.

The obtained results show that when milk concentrations lower than 2%, absorption coefficient μ_a and scattering coefficient μ_s depend linearly on milk concentrations. When milk concentrations higher than 5%, the quantities μ_a, μ_s and g reach their saturated values at 4.5 ± 0.2mm^{-1}, 55 ± 2mm^{-1} and 0.97 ± 0.01, respectively. These values are nearly the same as reported in [10].

5. Conlusion

A multi-channel measurement system is designed on Texas Instrument TMS320VC5510 DSK kit interfacing to a 8-input, 8-bit ADC module through the DSP's Memory Expansion Connector. The as-designed system permits to combine the high processing speed of a DSP and the multi-channel access of an ADC. The system meets the requirements of real-time processing and simultaneous analog input access of some signals.

The differences between standard input signals' parameters including amplitude and frequency and the data of the graphs displayed on the DSP's Code Composer Window reveal less than 1%.

The optical parameter measurement of homogenised fresh milk based on Kulbeka-Munk algorithm and the DSP board has shown that the dependences of μ_a and μ_s on milk concentrations are leaner for the concentration lower than 2% Vol.. The saturated values of μ_a, μ_s and g when the concentrations higher than 5% Vol. are $4.5 \pm 0.2\text{mm}^{-1}$, $55 \pm 2\text{mm}^{-1}$ and 0.97 ± 0.01, respectively.

Nevertheless, in order to increase the signal processing speed, a high speed ADC should be selected. The design is in progress and the result will soon be reported.

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