# REAL-TIME DATA SAMPLE AND WAVELET ANALYSIS SYSTEM BASED ON DSP FOR AE SIGNAL PROCESS

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**Abstract:** AE (Acoustic Emission) testing is an important way in the NDT (Non Destructive Testing) field and wavelet analysis is demonstrated to be a promising method to process AE signal. A wavelet analysis module based on DSP (Digital Signal Processor) implementation is developed for AE testing system of the composite material to make the wavelet analysis system much more small and portable. The implementation of MALLAT algorithm with DSP system for wavelet analysis is discussed in detail. The DSP system is composed of TMS320VC5402 chip, AD 7865 with 400 kHz sample rating and clock circuit, etc. The AE signal can be sent directly into the DSP system. Wavelet analysis of the input signal can be done in the module to extract the feature of structure damage.

Keywords: AE Testing, DSP, CPLD (Complex Programmable Logical Device), ADC (A/D Converter), Wavelet Analysis

**Introduction:** Wavelet transform, which has good time-frequency analysis characteristic and can extract the detail information from the signal processed, has became one of the important methods for signal processing in recent years. Signal was analyzed on multi-scale by using wavelet transform. It solved many problems which were difficult to deal with by Fourier transform. That is the main reason wavelet analysis is widely used in NDT field. As we know, the primary purpose of AE testing is to identify the material characteristic or the defect state from the feature information of the AE signals by collecting and analyzing them. Some research on AE signal denosing of domestic scholars showed that by using wavelet transform, the AE signal could be decomposed into different frequency bands and reconstructed after removing the detail signals which had a great deal of noise in some scale according to the differentia between signal and noise in the different frequency[1]. Others research focusing on AE feature extraction and defect identifying discussed that the method for source location of AE signals by employing wavelet analysis [2]. But until now all applications of AE detection technique based on the wavelet analysis in the NDT field are only limited to computer simulation, for instance MATLAB emulation, and the processes are not real-time. Digital signal processor, a kind of programmable processor with good performance, has been rapidly developed and widely used in digital signal processing and other fields such as image processing, audio signal processing and communication. To make the AE signal testing system to be a real-time and a miniaturization processing system, an advanced digital signal processor is employed for integration of the wavelet analysis module in this paper.

**Principle of real-time data acquisition and process system of AE signal based DSP:** A DSP-based AE testing system will have many components shared by its analog counterpart, as shown in Figure 1. This is a dual-channel acquisition system. It will have two AE transducers, two preamps, two A/D converters and a wavelet analysis module which includes a DSP, a SRAM, a CPLD and a dual-port RAM. Because this DSP-based system is under some kind of CPU control, an industrial control computer is also utilized. It inherently has the ability to automate several test functions, in addition to its DSP capabilities that would include filtering, signal conditioning, and signal classification. The AE transducers situated near or coupled to the part or material under test. Preamps amplify original AE signal from transducers into amplitude that met the need of the A/D converter input. The AD7865 used as A/D converter in the system is a fast, low power, four-channel simultaneous sampling 14-bit A/D converter that operates from a single +5 V supply. It performs the initial amplitude discretization for the input analog AE signal prior to further conversion needed during processing by either a fixed or floating-point signal processor. This conversion process quantizes the signal amplitudes into a sequence of finite-precision samples. The precision or quantization error is determined by the number of amplitude quantization levels. The commercially available DSP-specific chips used for these various signal conditioning and classification functions are either fixed or floating-point processor. Typically, fixed-point processors have greater processing speeds but require careful scaling to avoid round-off errors due to numerical over/underflow. Recently, general-purpose chip manufacturers have started to add DSP capabilities to their floating-point processors to put DSP within easier reach of the overall programming community. However, because we are dealing with discrete time samples, care must still be taken when converting from the analog signal to the digital domain. In this AE testing system, the fixed-point digital signal processor, TMS320VC5402, is used as the wavelet analysis processor. It has some features as follow [3]:

- Advanced Multi-bus Architecture With Three Separate 16-Bit Data Memory Buses and One Program Memory Bus
- 40-Bit Arithmetic Logic Unit (ALU), Including a 40-Bit Barrel Shifter and Two Independent 40-Bit Accumulators
- 17-× 17-Bit Parallel Multiplier Coupled to a 40-Bit Dedicated Adder for Non-Pipelined Single-Cycle Multiply/Accumulate (MAC) Operation
- Compare, Select, and Store Unit (CSSU) for the Add/Compare Selection of the Viterbi Operator
- Exponent Encoder to Compute an Exponent Value of a 40-Bit Accumulator Value in a Single Cycle
- Two Address Generators With Eight Auxiliary Registers and Two Auxiliary Register Arithmetic Units (ARAUs)
- Data Bus With a Bus-Holder Feature
- Extended Addressing Mode for 1M × 16-Bit Maximum Addressable External Program Space
- 4K x 16-Bit On-Chip ROM, 16K x 16-Bit Dual-Access On-Chip RAM
- Single-Instruction-Repeat and Block-Repeat Operations for Program Code
- Block-Memory-Move Instructions for Efficient Program and Data Management
- Instructions With a 32-Bit Long Word Operand, Instructions With Two- or Three-Operand Reads
- Arithmetic Instructions With Parallel Store and Parallel Load; Conditional Store Instructions
- Fast Return From Interrupt ; On-Chip Peripherals
- Software-Programmable Wait-State Generator and Programmable Bank Switching
- On-Chip Phase-Locked Loop (PLL) Clock Generator With Internal Oscillator or External Clock Source
- Two Multi-channel Buffered Serial Ports (McBSPs); Enhanced 8-Bit Parallel Host-Port Interface (HPI8)
- Two 16-Bit Timers; Six-Channel Direct Memory Access (DMA) Controller
- Power Consumption Control With IDLE1, IDLE2, and IDLE3 Instructions With Power-Down Modes
- 10-ns Single-Cycle Fixed-Point Instruction Execution Time (100 MIPS) for 3.3-V Power Supply(1.8-V Core)
- Available in a 144-Pin Plastic Low-Profile Quad Flatpack (LQFP) (PGE Suffix) and a 144-Pin Ball Grid Array (BGA) (GGU Suffix)

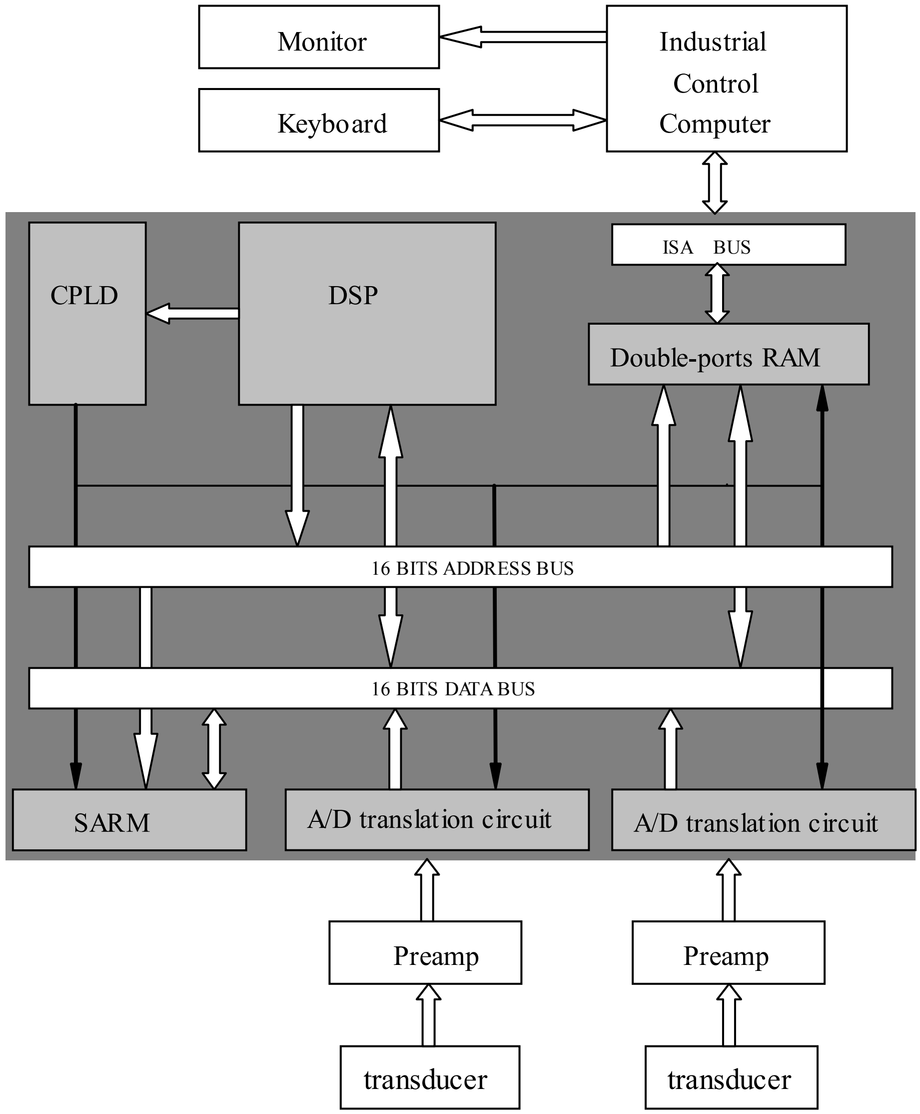


Fig.1 Wavelet analysis system of AE signal based on DSP

All the digital interface logic of the DSP-based wavelet analysis module is created by a CPLD. The SRAM is utilized for storage of AE data after quantized by A/D converter. The AE data processed by the wavelet analysis module can be transferred to the computer through the dual-port RAM. The result of process can be output to the monitor and testing parameter of system can be input through the keyboard [4].

**Algorithm of wavelet analysis for AE signal:** Wavelets can be gotten through scaling and shifting the basic wavelet function $\Psi(t)$

$$\Psi_{a,b}(t) = |a|^{-1/2}\Psi\left[\frac{t-b}{a}\right], \qquad a,b \in R, \quad a \neq 0 \qquad (1)$$

They are band pass filters with two parameters. Parameter $a$, called scale parameter, is related to the frequency. Parameter $b$, called position parameter, determines the time-domain or space-domain information in the transformed results. Suppose $f(t)$ is a function with independent variable $t$, its wavelet transform can be represented by

$$W_f(a,b) = |a|^{-1/2} \int_R f(t) \overline{\Psi\left[\frac{t-b}{a}\right]} dt \qquad (2)$$

There are two kinds of wavelet transforms: continuous wavelet transform and discrete wavelet transform. The latter, that is suitable to multiresolution analysis and time-frequency decomposing, is employed in the AE signal processing. In the discrete wavelet transform, dyadic numbers are often chosen to be scale parameters: $a = 2^j$, $j \in Z$,where $Z$ is the set of integers. This kind of wavelet transform is called discrete dyadic wavelet transform

It is implemented through the finite impulse response filter called a "quadrature mirror filter" (QMF) pair designed by Daubechies [5]. Scale function $\phi(t)$, which is a low pass filter, can be gotten from the basic wavelet function. In frequency domain, the following condition is satisfied

$$\left|\hat{\phi}(\omega)\right|^2 = \sum_{j=1}^{\infty} \left|\hat{\Psi}(2^j \omega)\right|^2 \qquad (3)$$

The "quadrature mirror filter" (QMF) pair $h(n)$ and $g(n)$ can be formed through the inner product of scale function $\phi(t)$ and wavelet function $\Psi(t)$

$$\left.\begin{aligned} h(n) &= \left[\tfrac{1}{2}\phi\left[\tfrac{t}{2}\right], \phi(t-n)\right] \\ g(n) &= \left[\tfrac{1}{2}\psi\left[\tfrac{t}{2}\right], \phi(t-n)\right] \end{aligned}\right\} \qquad (4)$$

Wavelet packet uses the QMF to decompose the signal to be analyzed. Suppose signal is $f(t)$, there are the following recursions for formula

$$\left.\begin{aligned} f_{2m}(t) &= \sqrt{2}\sum h(n) f_m(2t-n) \\ f_{2m+1}(t) &= \sqrt{2}\sum g(n) f_m(2t-n) \end{aligned}\right\} \qquad (5)$$

The function series $\{f_m(t)\}_{m \in Z^+}$ is called quadrature wavelet packet. A series of wavelet coefficients and the components, which reflect the characters of the original signal in different frequency ranges, are obtained by decomposing the AE signal with the discrete dyadic wavelet transform mentioned above. Reconstruct the AE signal with the wavelet coefficients processed by using an adaptive threshold value method to eliminate noise [6]. Then extract the feature information from the reconstruct the AE signal to identify fault type of the materials which is detected. The program of the wavelet analysis is written in the CCS (Code Composer Studio) based on WINDOWS. Algorithm wavelet analysis for AE signal is realized by a mixed program with C and compilation language. The flow chart of wavelet analysis based on DSP is shown in figure 2.

**Results:** By using the testing system, experiment had been done on a composite material board made of carbonous fibre which has alveolate paper structure in the middle. The composite material board is sized 120mm x 400mm x 5mm. Figure 3 illustrates waveform of AE signal data acquisition by the DSP-based testing system. The result of wavelet analysis for AE signal is shown in figure 4. The two waveforms express the components of wavelet transform for AE signal in different scales.

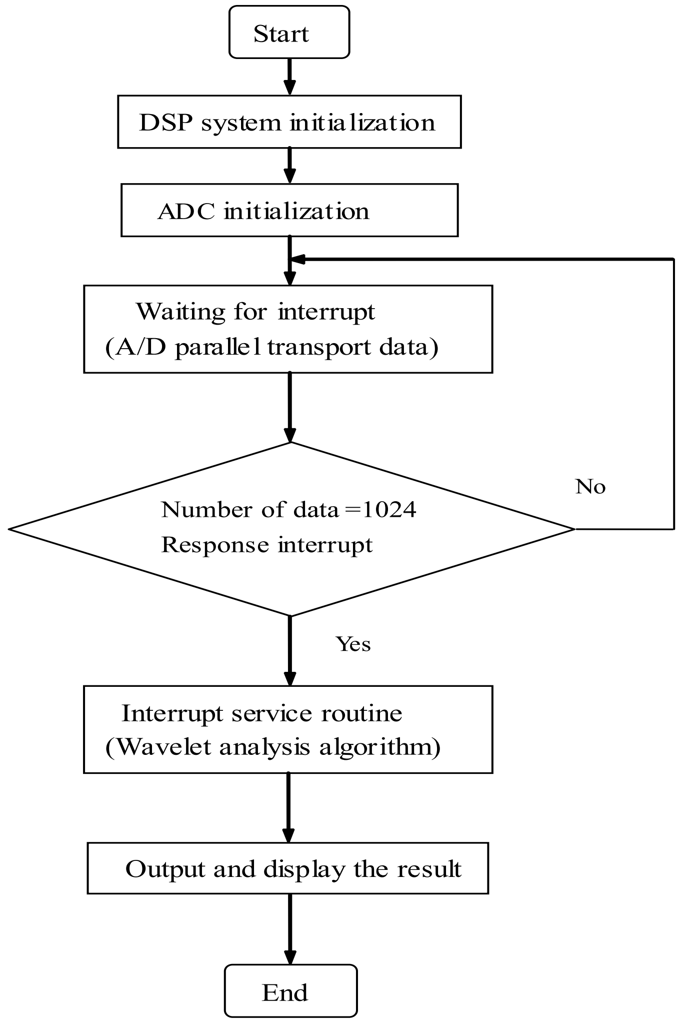


Fig.2 Flow chart of wavelet analysis based on DSP

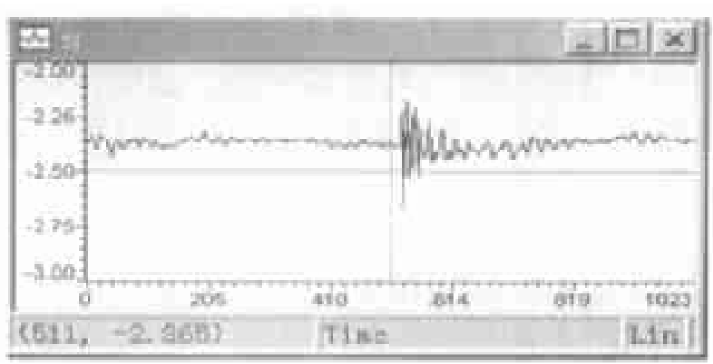


Fig.3 Result of data acquisition of DSP system

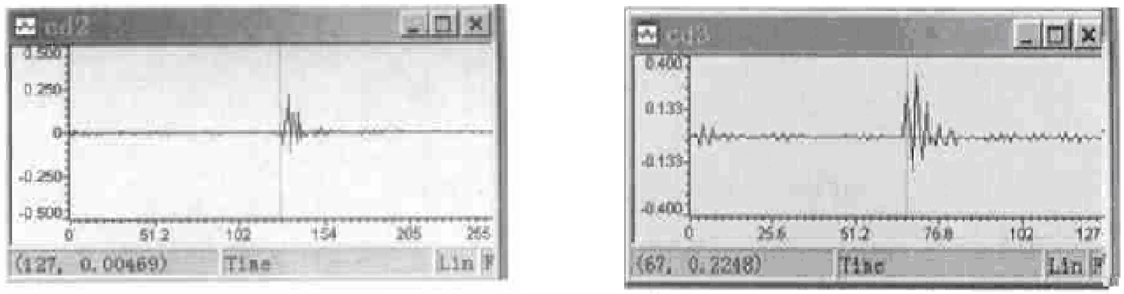


Fig.4 the components of AE signal processed with wavelet transform

**Discussion:** The results show that the DSP-based AE testing system realized the testing structure of composite material. It processed 1024 samples with wavelet analysis every time. The entire process only took 2ms which met the need of real-time.

**Conclusions:** The wavelet transform is proposed as a processing tool for testing AE signal. Employing DSP in the AE signal processing with wavelet analysis improved the practicality and accuracy of the system.

**References:**

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