TWO NEW DSP TEACHING TOOLS: DIGIFILTER AND DSPLUS

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Abstract

Two window-based new digital signal processing (DSP) software packages, namely, DigiFilter and DSPlus are used as teaching tools at California State University, Long Beach (CSULB), DSP laboratory in conjunction with DSK31 of TI. First, DigiFilter is a digital filter design and processing software. The uniqueness of this package is that it is not only design digital filters, but also supports DSK31 for real-time filtering. Second, DSPlus is a data acquisition and processing software which supports DSK31 for real-time FFT and can be used as a digital scope. These two packages are employed as computer-aided design and analysis tools for DSP courses.

1. Introduction

DSP courses have been taught since late of 1960s at graduate schools. Many theory and practical applications have been found in the past several decades. Consequently, fundamental DSP and related materials are filtered down to lower level classes continuously. Today, DSP courses are being taught in both graduate and undergraduate (junior) levels.

In general, DSP is a combination of algorithms, software, and hardware. The algorithm portion is based on the difference equation and linear algebra. The software portion covers two categories: simulation program (such as C code) and real-time program (such as assembly code). The hardware portion indicates CPUs, ASICs, FPGA, or digital signal processors. As a results, it may be a good approach to use computers to teach DSP and related courses.

Since DSP requires heavily number crunching, it is becoming a trend to use computer-aided software as part of tools in order to improve teaching effectiveness. Both Matlab and Mathcad are good general mathematical tools and require some programming. However, they are good simulation tools only. They do not support any hardware in real-time directly. On the other hands, both DigiFilter and DSPlus require no programming and support real-time floating-point digital signal processor TMS320C3x operations.

In this paper, both DigiFilter and DSPlus are introduced. These two packages have been used as teaching tools at CSULB, DSP laboratory in conjunction with DSK31. The following sections discuss these two packages and their usage in classroom in details.

2. DigiFilter: Digital Filter Design and Processing

DigiFilter is a digital filter design and processing software. The uniqueness of this package is that it is not only design digital filters, but also supports DSK31 for real-time filtering. In other words, after filter has been designed, it downloads filter coefficients automatically into DSK31 and running the designed filter in real-time. Users are allowed to check filter performance in real-time by using external equipment (such as signal generator, scope, spectrum analyzer) simultaneously with the simulation plots on the computer screen.

2.1 Features and Benefits:

- Filter design and real-time processing with TMS320C3x boards in one single package
- Coefficients scaled for cascade/parallel, direct form I and II and quantization from 8-bit to 32-bit
- IIR design via bilinear transformation and impulse invariant methods
- FIR design via windows and equiripple approximation with D/A compensation

It provides lowpass, highpass, bandpass, and bandstop filter design. It also offers Hilbert transformer and differentiator via FIR design.

2.2 DSP Laboratory Applications

Teaching Example 1.

Design a multiband filter by using Park-McClellan (Equiripple) and run this filter via a DSK31 in real-time.

Step 1. Set-up laboratory equipment. Figure 1 shows the configuration of this real-time filtering experiment. The signal generator provides a sinusoidal waveform (with varied frequency) which is used as the input signal to the DSK31 board. The scope displays both DSK31 input and output signals, simultaneously.

Step 2. Design a 4-band FIR filter by using DigiFilter. Specifications are:
Sampling frequency: 4000 Hz.
Band 1: 0 Hz to 100 Hz (3 dB)
Band 2: 400 Hz to 600 Hz (45 dB)
Band 3: 900 Hz to 1200 Hz (3 dB)
Band 4: 1500 Hz to 2000 Hz (45 dB)

It is cleared that band-one and -three are pass bands, while band-two and -four are stop bands. The DigiFilter provides designed results in Figure 2. Figure 2 shows the log magnitude, magnitude, impulse, and step responses of a 29-tap linear phase FIR multiband filter.

Step 3. Load filter code from DigiFilter into DSK31 through printer port and run it in real-time. By vary the frequency of input sinusoidal signal (for example, from 300 Hz to 2,000Hz), the output signal shown in scope will be either the same as input signal (with delay) in the passband or rejected by the digital filter in the stopband.

This is a simple demonstration. Students are not just design a digital filter but also see a digital filter running in real-time. Furthermore, students are allowed to measure the filter performance via spectrum analyzer or scope. The measured data can be used to compared with the simulation results which are provided by DigiFilter.

3. DSPlus: Data Acquisition, Spectrum Analyzer, and Scope

DSPlus is a data acquisition, real-time FFT spectrum analyzer and post processing software. It acquires data sequence for post processing (such as autocorrelation, cross-correlation, convolution) and supports DSK31 for real-time FFT. It can also be used as a simple digital scope. It provides three methods to get data sequences. First, it acquires signals via data acquisition boards (such as DSK31). Second, it imports data files from outside sources with specified header format. Third, it allows users to self-synthesis desired waveform. These data sequences can be filtered with filter coefficients file provided by DigiFilter.

3.1 Features and Benefits:

- Real-time Data Acquisition, Processing, and analysis with TMS320C3x DSP boards
- Signal Generator: sinusoidal, triangular, sinc, square, noise, windows
- Processing: decimation, interpolation, convolution, autocorrelation, crosscorrelation
- Transform: fast Fourier transform (FFT), average FFTs
- Signal Combination to create desired waveforms by manipulate data files through addition, subtraction, multiplication, square, etc..

The uniqueness features of this package is that it not only display the real-time spectrum by using FFT but it can also display the time-domain waveform simultaneously on the screen when a DSP board (such as DSK31) is employed.

3.2 DSP Laboratory Applications

Teaching Example 2.

Generate an amplitude modulation (AM) signal (double-sideband suppressed carrier).

Case a.

$$y(n) = \sin(2\pi n f_o / f_s)\cos(2\pi n f_c / f_s)$$
$$where$$
$$f_o / f_s = 1/200 \;\; and \;\; f_c / f_s = 20/200.$$

Both sine and cosine functions are created by using **SigGen** of DSPlus. The y(n) is created by using **Signal Combination** of DSPlus. This AM signal is created in time domain (from time 0 to 200) as shown in Figure 3. The 1024-point FFT (padding by zeros) is shown in Figure 4. Two peaks are located at 19 and 21 Hz, respectively. Note that the frequency axis is normalized with respect to sampling frequency. Note that, this magnitude response has many sidelobes due to the fact that the fundamental frequency f_o and carrier frequency f_c do not located exactly on the FFT bin. Consequently, the effect of rectangular window on FFT is shown in magnitude plot.

Case b. Same as Case a. except

$$f_o / f_s = 4/1024 \;\; and \;\; f_c / f_s = 64/1024.$$

By employing the same procedure as mentioned in Case a, a 1024-point AM signal sequence is created in time domain first. Then the corresponding 1024-point FFT is obtained and shown in Figure 5. Two peaks are located at 60 and 68 Hz, respectively. Note that there is no sidelobes at all due to the fact that the fundamental frequency f_o and carrier frequency f_c do locate exactly on the FFT bin.

The most attractive feature is that by using DSPlus in conjunction with DSK31, users are allowed to measure both real-time data and the corresponding real-time FFT in a PC, simultaneously.

4. Conclusion

Two new window-based DSP software packages, namely, DigiFilter and DSPlus are employed as teaching tools at DSP laboratory in conjunction with TI sponsored equipment. These two software packages can be used for both design and real-time DSP operations without any programming. Consequently, they are excellent self-learning tools for students.

References

1. Oppenheim, A. V. and Schafer, R. W., *Discrete-time Signal Processing*, Prentice-Hall, 1989.

2. Digital Filter Design and Processing, User's Manual, MultiDSP, Inc. 1996.

3. DSPlus: Data Acquisition, Spectrum Analyzer, and Scope, User's Manual, MultiDSP, Inc., 1996.

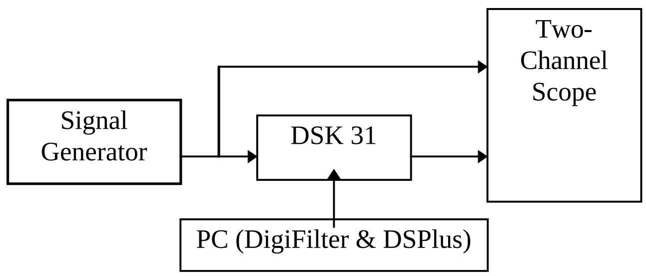

Figure 1. The laboratory set up for real-time filtering operation.

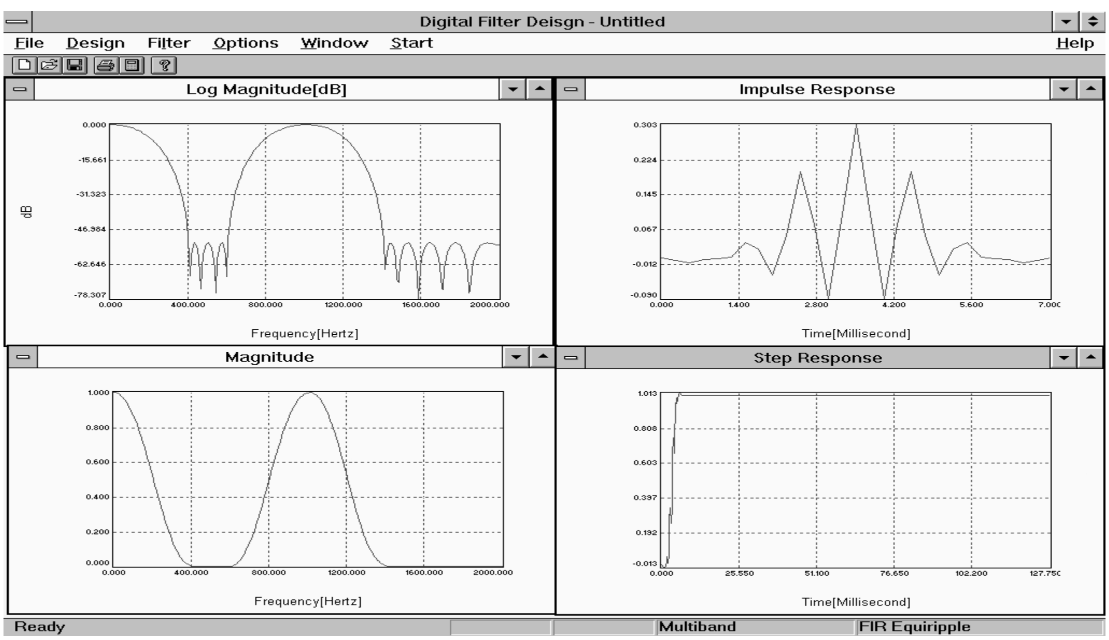

Figure 2. FIR multiband filter designed by using Park-McClellan method.

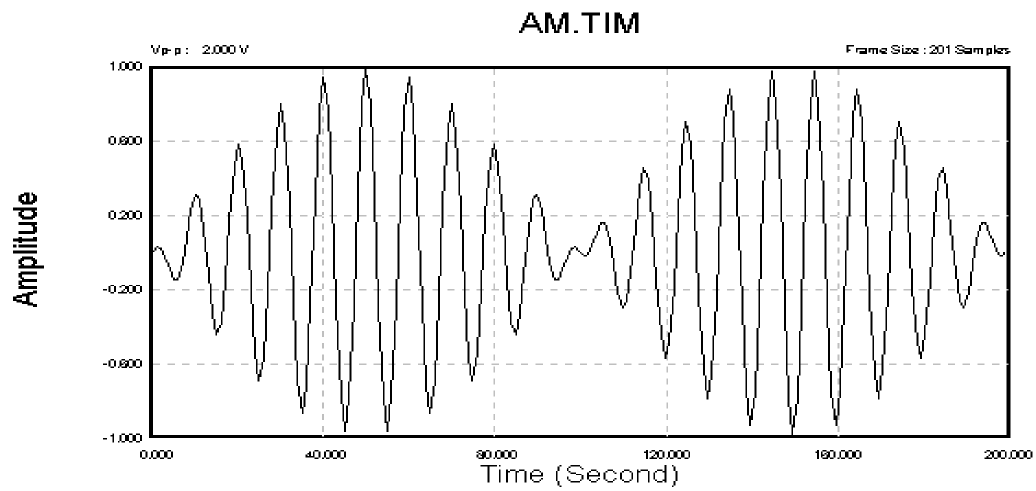

Figure 3. The AM signal (201 samples) generated by DSPlus.

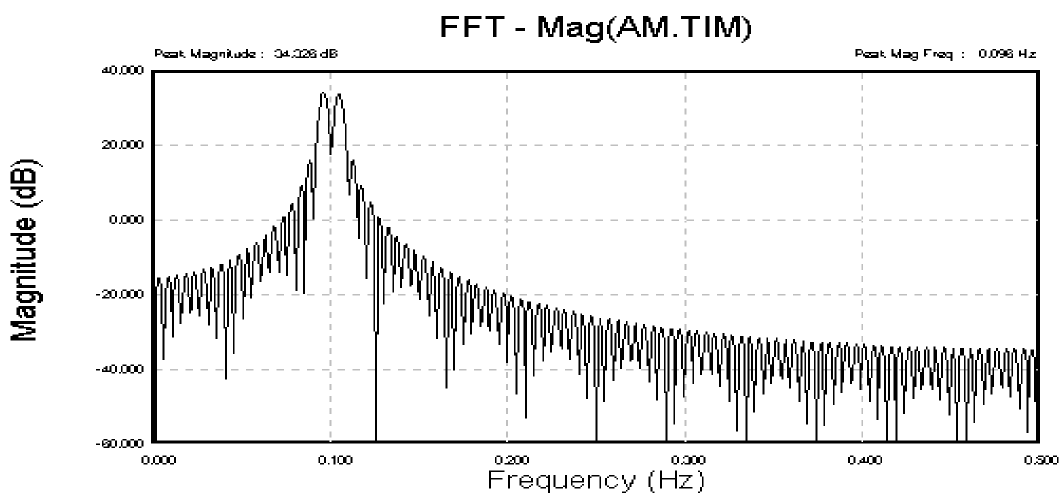

Figure 4. The FFT-Magnitude of the AM signal (f_o and f_c are not located on the FFT-bin).

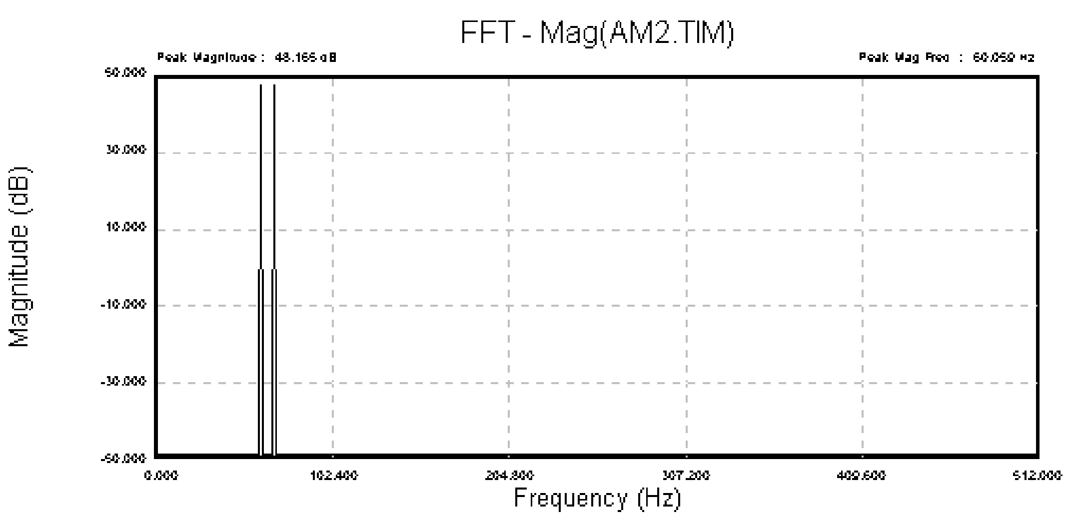

Figure 5. The FFT-Magnitude of the AM signal (f_o and f_c are located on the FFT-bin).