

## Digital Signal Processing/Image Processing: Freshman to Senior Year

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### Abstract

A hands-on project course, which focuses on Digital Signal Processing (DSP) hardware and applications through the use of standard kits, is introduced at the senior level. Since these DSP kits are important and relatively easy to interface, they can be used to introduce first year students to the design and application process of digital Signal/Image processing despite their lack of theoretical background in this subject. This paper discusses one of the experiments conducted by a group of freshman students, and shows that it is not too early to introduce some *practical* advanced topics to freshmen.

### Introduction

Digital Signal Processing and DSP Hardware are extremely important in many areas of industry. The use of these applications is expanding rapidly throughout the world, creating an extraordinary demand for professionals well versed in this technology. A hands-on project course, which focuses on DSP hardware and applications, is introduced at the senior level. The course material emphasizes the use of Application Specific Integrated Chips (ASIC) in standard kits, manufactured by Texas Instruments (TI). Since these DSP tools are important and relatively easy to interface, they can be used to introduce first year students to the design and application process of digital Signal/Image processing despite their lack of theoretical background in this subject. The process involves analyzing a problem, making a decision on how to approach it, trying different design procedures and comparing the different outcomes. This will keep the freshmen focused on their engineering major and help in increasing the overall retention. A NSF-

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## **Background**

The Texas Instruments TMS320C3x DSP starter Kit (DSK) comprises all the basic elements to learn and practice programming the TMS320C31 DSP. The C3x DSK board includes a 50 MHz TMS321C31 DSP and a TLC32040 Analog Interface Chip (AIC), which provides 14-bit Analog-to Digital (A/D) and Digital to Analog (D/A) conversions for one signal, at adjustable sampling rates. The C3x DSK has a host interface port that connects to a parallel port in the host PC. A “communications kernel” running in the C31 DSP manages the host interface, enabling the host to inspect and modify memory and start or stop execution of program segments. The software provided in the C3x DSK includes a DOS assembler that will convert a source ASCII file written using the appropriate mnemonics for C3x DSP processors into a loadable/executable file of type “.dsk”. The “.dsk” files can be loaded to DSP memory through the DSK3D debugger included with the kit. In addition the debugger will allow the user to inspect and modify all the registers in the DSP, as well as the DSP memory [1,2,3]. DSK3D also implements most of the functions found in execution, establishment of breakpoints and watches, single-step tracing, etc. The complete description of the hardware and software included in the C3x DSK is found in the TMS320C3x DSP Starter Kit User’s Guide [4,5,6] from TI.

As of the time this paper was written, freshman, senior and graduate students conducted several experiments/projects using the DSK kit. Freshmen were able, to mention few, to test the speed of multiplying two arrays and they went through the process of generating a signal, sending it, receiving it and finding its characteristics. On the other hand, seniors used the DSK kits to do data acquisition, FIR filters, IIR filters, adaptive filters, multirate filters, and active noise control. During this spring semester, freshmen will be conducting experiments in image processing centered on image enhancement. One of the experiments which, I felt, freshmen enjoyed the most, was

centered around generating a signal by a student and detecting it (including its characteristics) by his partner without any prior knowledge about the generated signal. The objectives, besides the hands-on experience, were to introduce students to the concepts of periodic signals, their magnitudes and frequencies. This experiment is explained next.

### The experiment

The TMS320C31 DSK kit can be used as a signal generator by using a program called DSK\_SG from TI. Various methods can be used to verify that a signal was indeed generated. One method that may be used is to connect the DSK kit output port to speaker while another method is to connect the output port to an oscilloscope. Instead of using commercial oscilloscope, a second DSK kit connected to another computer can be utilized as an oscilloscope by loading a program called DSK\_OSC, also from TI, on the second computer. As shown in Figure (1), the first DSK kit is used as the signal generator (SG) and the second DSK kit is used as the oscilloscope (OSC). The SG DSK kit's output port is connected to the OSC DSK kit input port via an RCA cable. Once the control bits, the TA, TB, RA and the RB parameters in the DSK\_OSC program are properly set, the second computer and the DSK kit act as an oscilloscope. It is worth mentioning here that the operator of the second computer does not know anything about the available generated signal in advance and that the operator of the first computer is free to choose any frequency as long as it satisfies the sampling theory. A group of freshman students working in pairs conducted this experiment. In each pair one was in charge of the SG and he was free to choose any signal (type, amplitude, and frequency), the other was in charge of the OSC and his task was to detect the signal he saw on his computer (type, amplitude, and frequency).

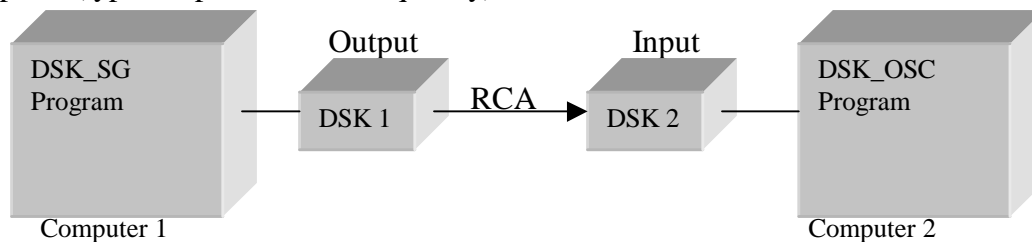


Figure 1: The connection of two DSK Kits

There are certain values and parameters needed to generate a signal using the DSK\_SG program and to detect it using the DSK\_OSC program. These values are associated with the Analog Interface Circuit (AIC) chip that connects to the serial port on the DSK kit. A program “aiccalt” is provided by TI to calculate these values and parameters. Using the “aiccalt” program the following values were calculated:

- DSK\_SG to generate a signal as shown in Figure (2).
  - A sine signal is selected by choosing number “7” from the keyboard
  - Amplitude = 3, Frequency = 30, Signal generated:  $+ 3.000 * \sin(30)$
  - Parameter settings:
    - A registers: consist of TA and RA and represents filter control  
 TA = 11,      RA = 31
    - B registers: consists of TB and RB and represent the A/D and D/A control  
 TB = 15,      RB = 55
    - The filter control register: an 8 bit register with a typical value of 11000011 (d7 d6 d5 d4 d3 d2 d1 d0)  
 d7 and d6 being 1 means gain control bits enabled  
 d5 being 0 means asynchronous enable  
 d4 being 0 means disable AUX IN + and AUX IN - terminals  
 d3 being 0 means disable the loopback function  
 d2 being 0 means deletes bandpass filter  
 d1 and      d0 is 11 to request a secondary communication

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MS-DOS Prompt - DSK_SG
Auto
F1:F2  TA = 11 (xmit=dac)
F3:F3  TB = 15
SF1:SF2 RA = 31 (recv=adc)
SF3:SF4 RB = 55
F9:F10 TIM0= 02 (timer 0 )
[1-6] set AIC ctrl bits
11000011
7,8,9,0 Keys change waveform
Sine, Ramp, Triangle, Rand
Fdac=18939.39
(Q)uit (R)eset [F5:F6](F)requency [F7:F8](A)mplitude
0.000000 Vdc offset
+ 0.000000 Vac random
>> + 3.000000 * sin(30.000000) Edit>
+ 0.000000 * sin(0.000000)
  
```

Figure 2: a setup for generating a signal

- DSK\_OSC oscilloscope to detect the unknown signal as shown in Figure (3).

The same calculated values from the DSK\_SG were used.

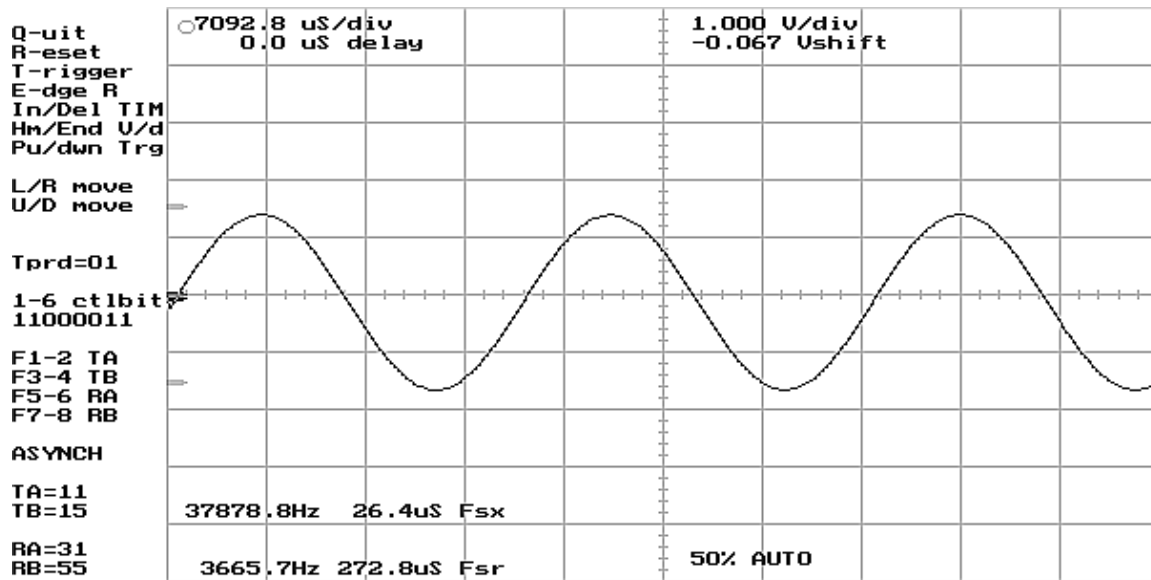


Figure 3: the OSC display as seen on the second computer

## Results

When the two DSK kits were linked and a signal of  $+3 * \sin(30)$  was generated using the DSK\_SG program as shown in Figure (2), the amplitude and the frequency of the generated waveform was properly displayed using the DSK\_OSC program as shown in Figure (3).

## Discussion

What did the students achieve? The objective of this experiment, as mentioned earlier, was to introduce first year students to digital signal processing applications hence trying to increase their enthusiasm about their major. By performing this experiment the students were exposed to the concepts of periodic signals, frequency, amplitude, the different type of functions, and sampling frequency. Also, it exposes them to the concept of master clock, clock, register, control bits, interface, function generator, and

oscilloscope. For example, the students were able to actually “see” how increasing the frequency will increase the number of times the signal repeats itself in the a time period. Since they made the connections and ran the programs they became more aware and familiar with what it takes to run an experiment in their field. Suddenly, a sophisticated tool is used as a toy and a competition was in place between the different groups trying to find out who can determine the frequency of the incoming signal faster. Since this experiment was performed by the ECE freshmen only, other students wanted to get in and play with this “toy” and a plan to do so is in place for this spring semester. This leads me to conclude that it is not too early to introduce some practical advanced topics to freshman students. In fact, it might be the way to connect freshmen to their major.

Finally, it is important to mention here that, in addition to what has been mentioned earlier, freshmen have used MATLAB to perform several other experiments centered on signal processing and image processing concepts. Also, a plan is underway to introduce digital signal processing and its applications to sophomores and juniors since seniors are already required to take a course in DSP.

### **Acknowledgments**

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### **Bibliography**

- [1] “Digital Signal Processing Laboratory Experiments Using C and the TMS320C31 DSK”, Rulph Chassaing, Wiley Interscience, 1998.
- [2] “Digital Signal Processing with C and the TMS320C30”, Rulph Chassaing, Wiley Interscience, 1992.
- [3] “Low-Cost Personal DSP Training Station based on the TI C3x DSK” A. Barreto & C. Aguilar, DSPS Fest 97, Texas Instruments Inc. 1997.
- [4] “TMS320C3x Users Guide” Texas Instruments Inc. 1996.
- [5] “TMS320C3x DSP Starter Kit Users Guide” Texas Instruments Inc. 1994.
- [6] “DSPS Fest ‘97” Texas Instruments Inc. 1997.

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