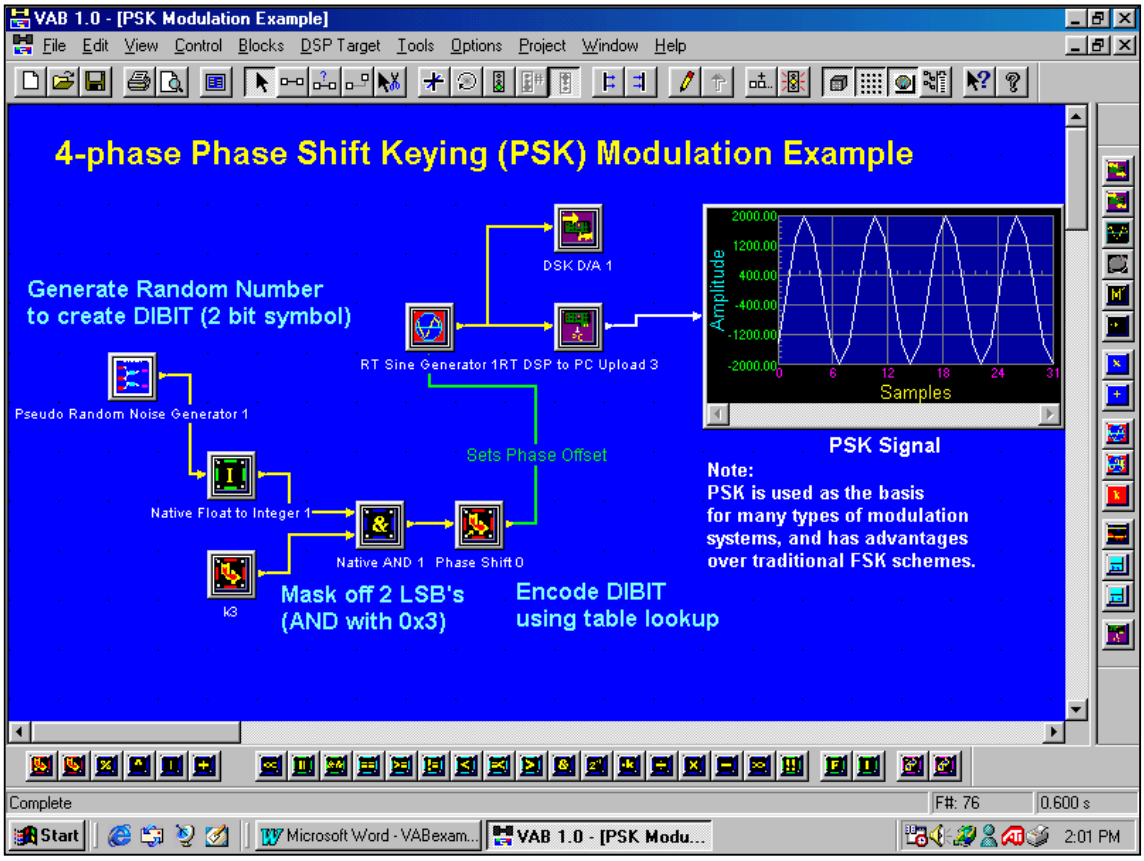
The use of Real-time DSP in Education made possible with VAB™



Example of a real-time DSP application for university level using VAB University Edition and low-cost DSP hardware

Overview of VAB

The VAB developed by Hyperception for Texas Instruments University Program is a DSP Educational Tool that builds applications in a graphical/visual environment and can show real-time DSP-based demonstrations on low-cost DSP hardware, namely the DSK type evaluation DSP boards. The VAB provides a software foundation/interface that shows the many features of real-time DSP within 5 minutes of taking a TI DSP product out-of-the-box. Examples are included to allow very quick loading and running of important real-time DSP demonstrations on the DSK.

This powerful new and exciting educational tool has been designed especially for the university environment so students can learn and experience DSP in a fast, easy-to-navigate, fun environment. The intuitive drag-and-drop interface along with a set of powerful DSP software components allows users to build DSP applications in minutes. A familiar graphical user interface with easy to use tools and wizards allows students to instantly transform DSP block-diagrams to running real-time DSP code quickly.

This tool has the potential to dramatically change the way students learn DSP. Students can easily build real DSP solutions to solve real problems on real-time DSP hardware. Low cost DSP hardware and the low cost of the VAB (priced similar to a textbook) enables every college student to purchase one. This revolutionary way to introduce DSP to beginners reduces the learning curve and encourages hands-on experimentation; **this program has the capacity for growing the future supply of DSP engineers, thereby increasing the number of new and innovative designs, and overall growing the future DSP Marketplace.**

The debate of Real-time DSP versus simulation in today's education

There has been an ongoing debate for years about the relative merits/problems associated with using real-time DSP as opposed to (or even in addition to) simulation in the classroom. Both critics and supporters of real-time DSP in the classroom certainly recognize the potential merit of real-time DSP, and at the same time, the potential pitfalls associated with this sometimes complex facet of DSP.

Critics argue that real-time is too expensive, detracts from the learning experience by spending too much time on the teaching of the tools at the expense of the teaching of the concepts, and is not needed for a good education in signal processing. They further believe that in order to fit time schedules in teaching, the real-time must be so down-sized and trivialized as to be completely void of any real substantive learning value.

Supporters believe that the time spent on the tools for real-time DSP is manageable, but that even if not, it is worthwhile because the tools are important themselves as they are part of the design process for DSP engineers in the work force.

This paper will attempt to add a new wrinkle into this debate, by showing that it is possible to use real-time DSP in an advantageous fashion, without the high cost, formidable learning curve, and detraction from fundamental concepts typically associated with real-time DSP in a classroom setting. If successful in accomplishing the task of using real-time DSP in the classroom, the very real benefit to us all becomes quite obvious.

The Importance of Real-time DSP in today's education

The desire for real-time DSP in the classroom stems from a number of important issues. The relevance of real-time DSP to today's society and industry labor needs in the area of skilled DSP engineers is one concern. Another is related to the ability of real-time DSP to elicit excitement in the students and a sense of accomplishment and overall appreciation for the power and flexibility of DSP's today. In addition, the nature of DSP from a practical application standpoint, is constantly changing due to the fact that the Digital Signal Processors are constantly changing, increasing the number and types of DSP applications; certainly having a sense of this dynamic nature of DSP is important to convey, and real-time DSP is a prime candidate for getting this message across.

Real-time DSP hardware setup with speakers, microphone, and power supply

Relevance

One of the considerations that may seem obvious is what is meant by 'DSP'. Does the acronym stand for "Digital Signal Process*ing* " or "Digital Signal Process*or*"? If one considers that Digital Signal Processing has been around for a while, but that there seems to be more motivation/emphasis placed on teaching DSP today than ever before, it might have something to do with the number of applications using DSP today – and this is directly related to "Digital Signal Process*ors*".

Without the high performance, low cost, low power Digital Signal Processors, the numbers of applications would be much reduced, and therefore, much of the motivation for teaching DSP. Therefore, I would suggest that having the Digital Signal Processor actually being used within the course is quite relevant, and it is difficult to achieve this without using real-time DSP.

Relevance to Society

Today's society is inundated with consumer products and applications directly tied to real-time DSP. Some of these include the Internet (many facets, including DSL technology, compression technology, etc.), MP3 players, DVD's, cell phones, and many more. The fact that real-time DSP is fundamental to these devices, and that the students are quite familiar (and typically in a favorable manner) with them, adds a somewhat 'modern' relevance to the course.

Relevance to Industry

When one studies the type of work being performed in the DSP engineering labor market, it is likely more heavily weighed towards practical working products

based on real-time DSP, than it is on pure R&D and simulation.

Even much of the R&D today is performed on live working DSP hardware, due to the fact that the constraints of running on today's Digital Signal Processors is critical to the success of the R&D, which is aimed at a real-world commercial success (product).

Obviously, much of the motivation on DSP is driven by the large DSP semiconductor houses, and their motivation is to move high volume numbers of DSP chips, which implies successful real-time DSP products and applications.

One of the key challenges for DSP taught at the university level, is to produce an increased number of capable engineers, both motivated and equipped to deal with practical DSP as it relates to industry. The DSP industry has labor needs which must be filled, and it should be a goal of the educational system to produce enough DSP engineers to satisfy the demands from industry.

Excitement Factor

Another reason to consider using real-time DSP is the excitement factor it can bring to a course, assuming it is not fraught with a large learning curve. Having a student actually construct an algorithm and see it running real-time not only creates interest and excitement in the student, but also affords the student a sense of satisfaction and confidence in ability.

In addition, many students today have grown up in likely a more interactive world, with video games, the Internet, and cellular technology being commonplace to them. Real-time DSP allows for a more interactive method of study, with the student able to see and hear the results of their algorithm running in real-time on actual DSP hardware. This interaction keeps the student interested, and allows for a higher retention of knowledge – much easier to remember how a low-pass filter sounds than to remember the equation for it.

Development of a more savvy engineer

The practical nature of real-time DSP forces a certain amount of real-world savvy into a student. Simply having to connect cables and power to actual DSP hardware is sometimes an interesting experience for someone new to real-time DSP. Realizing that there exist actual input and output paths to/from DSP hardware is itself sometimes educational, and lends to the overall sense of the power, flexibility, and ability for DSP to address real-world things, not just equations in a book.

The student is made aware of important concepts such as how many instructions per second the device is capable of, and how many instructions per second does a particular algorithm (which the student may be listening to in real-time) require? Or how much memory does the DSP chip have, and how much does the particular algorithm require.

These processor specific timing and memory sizing issues are of fundamental importance when designing real-world DSP products and applications; having a sense, or feel, for these types of design issues is sometimes equally important (if not more) than knowing how to design an IIR filter in assembly, or write FFT algorithms in C. As the world moves quickly towards component-based DSP design, more time should be spent on the real-time nature of algorithms running on real-world DSP hardware.

Keeping up with Technology Driven Advances

Another aspect of using a real-time DSP-based curriculum is that it provides some incentive for the course to stay current, which is probably more important for DSP-related classes as opposed to history, or English, for example. VAB allows for the student identify a particular DSP chip that is used, and to associate that with a feel for the performance in the real-time examples the student has seen/done.

Problems with including Real-time DSP in a course

Learning Curve Barrier

Probably the largest problem encountered with using real-time DSP in a traditional DSP course is the typically high learning curve associated with using live DSP hardware. Many times the instructor spends more time on teaching the basics of the tools (Assemblers, C-Compilers, linkers, debuggers, etc.) than on the actual DSP concept.

In addition, if the instructor is not careful, the 'DSP course' they are teaching may turn into a training session on assembly programming or the C language. Keeping the instructor and student focused on the applied results of real-time DSP on live hardware, and not on the implementation details is the constant (and often times losing) battle with conventional real-time DSP approaches.

Losing Interest (lack of excitement)

Likely related to the steep learning curve, the next problem area encountered in using real-time DSP in a university course is the waning interest level as students are moved from good interesting concepts to the drudge of programming, debugging, and testing. Often times, the student is not able to achieve anything running in real-time without blatant 'borrowing' from the instructor (or a stellar student).

In addition to building their own real-time applications, VAB allows instructors or students to choose from a variety of pre-built examples

Sometimes the frustrated student is never able to appreciate the power and beauty of a working real-time system. Worse, the student may actually be left with a bad taste for real-time DSP - which never should have happened. This is the worst possible outcome, because it is likely that this individual will not pursue a career in one of the DSP-related engineering areas.

High Cost

Historically, real-time DSP has been quite expensive, with real-time DSP hardware and software costing thousands of dollars per station. For many universities, the simple fact is that there hasn't been the budget available to outfit a real-time DSP lab; the large majority of schools have a hard time coming up with tens of thousands of dollars for undergraduate real-time DSP labs.

Addressing the problems in using Real-time DSP with VAB

VAB was designed to reduce or eliminate the problems historically facing those instructors who chose the path of using real-time DSP in their course. Significantly, the learning curve of VAB is dramatically lower, eliminating the learning bottleneck of assembler, compiler, linker, and debugger development tool required expertise. In addition, conventional textual-based software language is not required (though it may be used optionally as an exercise). The interactive nature of VAB in conjunction with a DSP hardware board allows for a much more interesting, even exciting, learning experience. Finally, the expense for VAB and associated real-time DSP hardware has reached an unprecedented low cost level. By removing these obstacles to the use of real-time DSP in teaching, VAB allows for a much more dynamic, synergistic method of enticing and teaching students about DSP.

Learning Curve Reduction

The task of getting development tools and hardware hooked-up, configured, and running is reduced from days (or weeks) to minutes. The VAB Software provides access to the DSP that lets one "play" without prior programming experience; thus, the student has a feeling of accomplishment in programming a DSP which will excite them to pursue DSP learning further, without the necessity of having prior experience in standard software languages (such as C or Assembly). In addition, the instructor may spend more time on the concepts associated with real-time DSP and eliminate the typically steep learning curve associated with the conventional real-time DSP software tools (Assemblers, C-compilers, Debuggers, etc.) .

Keeping Interest - Excitement Factor

In addition to easily displaying the time and frequency-domain versions of the input and output, the development tool platform used will respond in real-time to all the changes the user makes, thereby letting them instantly hear and see the changes. This 'on-the-fly' nature of VAB allows for quick satisfaction by the student and an appreciation of the power and flexibility of real-time DSP.

Low Cost

Removing the high cost associated with the physical DSP hardware and software was another problem area addressed by VAB. With VAB, very low-cost DSP hardware platforms may be used, with some less than $100. The VAB software itself is priced lower than standard engineering textbooks, such that students may actually purchase the software directly. In addition, the host platform is a simple PC, generally already available at most academic institutions.

Host Platform

The requirements for the host platform are a modest PC, with a minimum suggested machine being 100 MHz 486, capable of running Windows 95, Windows 98, Windows NT, or Windows 2000. The faster the machine, the faster screens will update, though the real-time nature of VAB is not actually affected much, since it is running on the DSP hardware.

Software - Low cost of VAB University Edition

The VAB University Edition is priced less than most engineering textbooks, and includes a host of examples that may be loaded and run by even the very beginner at DSP. Since it is a standard Windows application, the learning curve is quite minimal.

Hardware - Low cost of DSP Hardware

The VAB directly supports Texas Instruments DSK hardware, including the **TMS320C31 DSK, TMS320C5402 DSK, TMS320C6211 DSK, and TMS320C6711 DSK** boards, which are all less than a few hundred dollars each, one of which is less than $100. The instructor has the ability to choose from among these various types of DSP hardware, to allow for certain special areas of interest.

VAB Details and Capabilities

Easy to Use

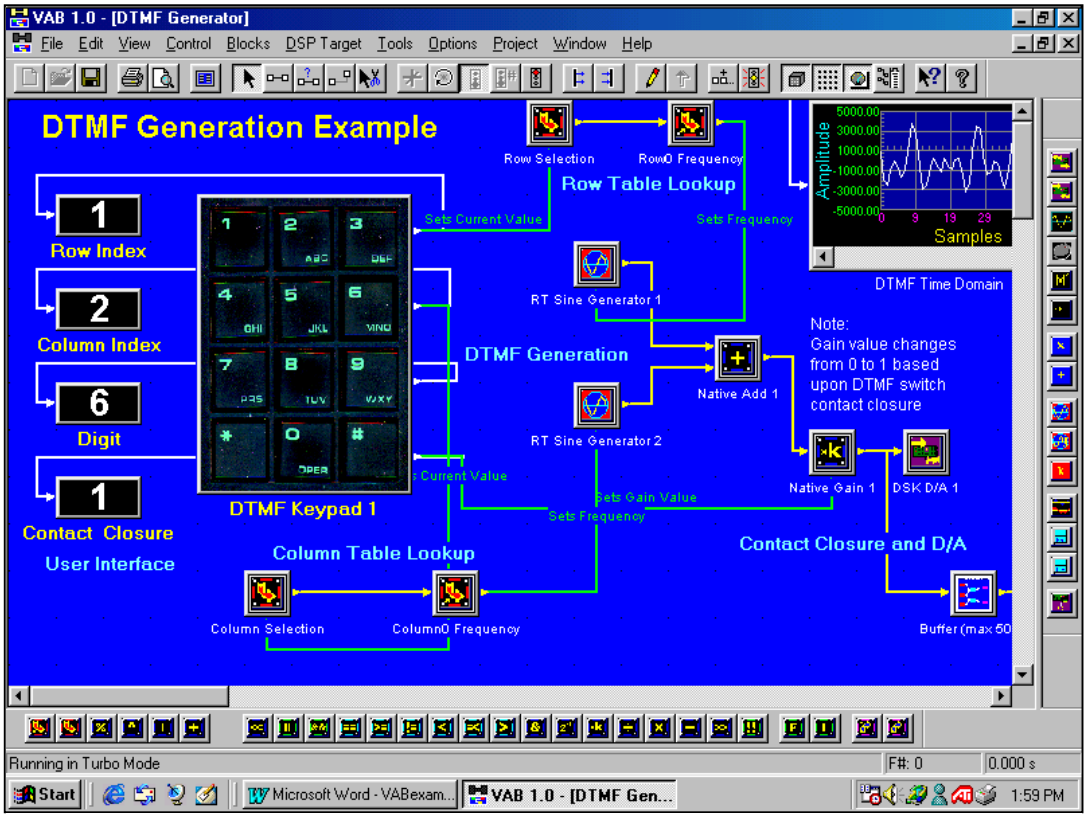
A primary consideration for VAB was ease-of-use. This translates not only into quick understanding on the part of the student, but also to more available time to teach **DSP** for the instructor. With VAB it is possible to actually teach fundamental DSP and related concepts using real-time DSP hardware, without having to teach the C language, Assembly, or debugging technologies. In fact, in addition to allowing instructors and students the ability to create their own real-time DSP applications, upon starting the VAB software, a dialog box is displayed which allows the user (instructor, student) to select from a number of pre-built examples, by category.

Functionality to see the power of DSP

This tool provides a gallery of proven DSP components and a sophisticated graphical drawing environment. It produces customized DSP code depending on settings that the user selects for each component. The user can design DSP algorithms and utilize the I/O capabilities of the actual DSP hardware, such as the A/D and D/A converters, allowing for an interactive nature of design/learning.

Fun and Exciting Real-time Feedback

The direct feedback allowed by real-time DSP systems is difficult to forget from a student's point of view. The ability to see and hear what the DSP is doing in real-time may make the difference for many students between what is often rote memorization of equations, to the actual understanding of a concept. The direct interaction and feedback provided by VAB may likely make the learning experience more interesting to the student. Our belief is that the interactive nature of VAB provided by its real-time support for DSP can provide a positive, synergistic reinforcement to traditional DSP theory.



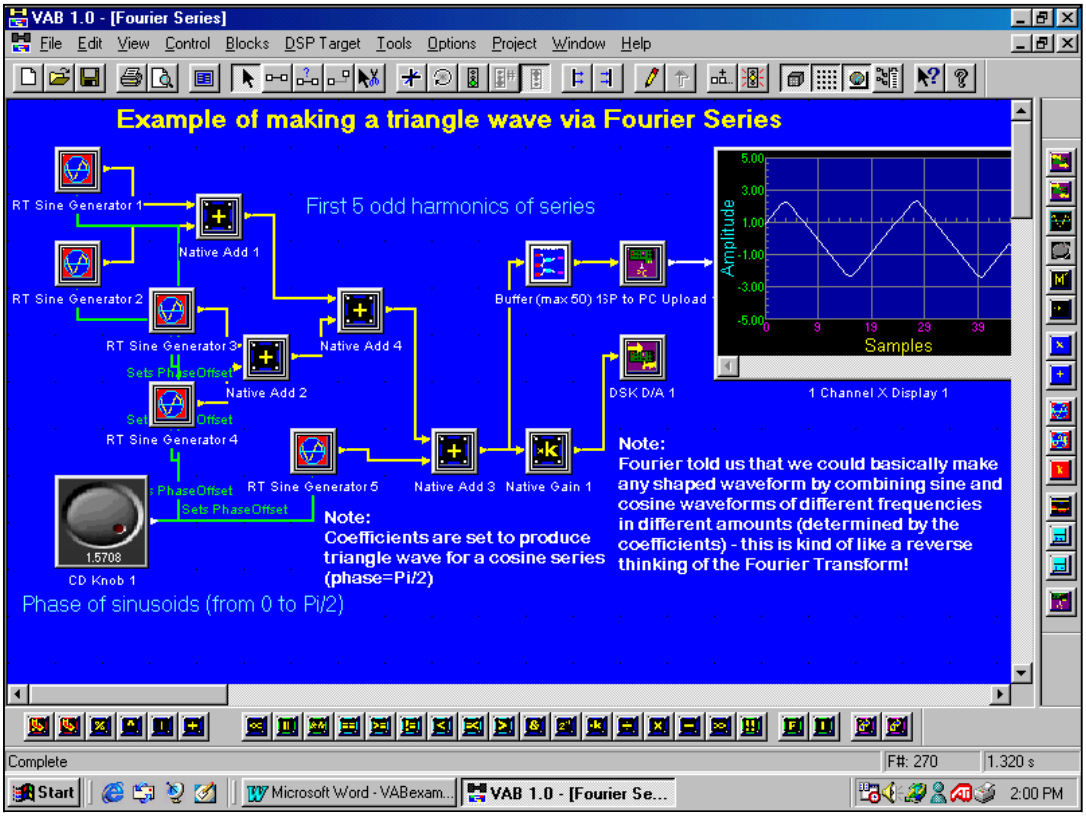
Real-time DTMF example showing the simple composition of a 'touch-tone' signal

Graceful Resource Exhaustion

It is possible for the user to ask the DSP to do too much, especially on the limited memory DSK platforms. Rather than prevent such action, the system is designed to let the user *know* why the system is not running. Students will then have the choice of reducing the number of processes, or the sampling rate, etc. Thus, even in 'failure', the students will be learning important conservation principles for practical DSP algorithm development.

Example of using VAB

Many example real-time DSP applications exist, and may be obtained via the VAB web site, www.hyperception.com/VAB_Univ. A simple example demonstrating Fourier Series in real-time follows:



Real-time example showing a triangle wave composed from the first 5 odd harmonics using Fourier Series; the signal may be modified by changing the phase of the sine waves, and is always heard through a speaker, even while the signal is changing.

Background

VAB was created by Hyperception, Inc. in partnership with Texas Instruments. Hyperception, involved in advanced software development tools for DSP since 1984, leveraged over a decade of experience in graphical component-oriented DSP software to create VAB. Texas Instruments, world leader in the DSP semiconductor market worked with Hyperception to help define, shape, and guide the development of VAB University Edition in support of Texas Instruments advanced DSP architectures and hardware platforms.