Various Digital Signal Processing Tools: At a Glance

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Abstract

Rapid developments in computing field and semiconductor technology has enabled a DSP designers to make a choice from plenty of tools to implement their algorithms and designs. There are several Software and Hardware tools at a hand like Matlab, Scilab, Octet, LabVIEW in software and TI's TMS320X family of DSPs, ADI's SHARC/TigerSHARC family of DSPs, ARM7 family in hardware domain. These tools are incorporated with several functionalities which suit the needs of a designer. The present study of different software and hardware platforms for DSP analyses such functionalities of different hardware and software DSP tools.

Keywords: *DSP, DSP Software, DSP Hardware, Matlab, Scilab, LabVIEW, TMS320C6X, SHARC, TigerSHARC*

Introduction

Digital Signal Processing (DSP) is a field of Telecommunication which involves extensive manipulations of Signals (numbers). Generally the signals are in discrete-time domain, which are represented by a real number after being sampled. For the manipulation on these signals various mathematical and statistical operations such as Fourier Transform, Discrete Fourier Transform, Discrete Cosine Transform, Filtering, Windowing and Inverse Transforms are carried out.

There are several algorithms for performing above mentioned operations on signals. These algorithms can be implemented either on general purpose computers, microprocessors, microcontrollers or dedicated Digital Signal Processors (DSPs), Application Specific Integrated Circuits (ASICs) or Field Programmable Gate Arrays (FPGAs). The implementation of the algorithms is called programming. This programming can be done by Machine Language or Assembly language of the given platform or by using any high-level Programming Languages such as C/C++, Java or by visual programming and development environments like LabVIEW. Although a designer may use a general purpose computer or processor, there are dedicated Processors which are incorporated with advanced capabilities required for Signal Processing purposes which are known as Digital Signal Processors. This paper investigates some of the Software and Hardware platforms used in the area of Digital Signal Processing.

DSP SOFTWARE

Matlab

Matlab is a high-level language for numerical computation it provides interactive environment for programming and data/result visualization. Using Matlab as a tool, one can analyze data, develop/implement algorithms, and create models and applications. The language, tools, and rich stock of built-in math functions enable a programmer to develop a solution faster or traditional programming languages, such as C/C++ or Java. Matlab can be for a broad range of applications, including signal processing and communications, image and video processing, control systems, test and measurement and so on. Scientists & Engineers in industry and academia across the globe use Matlab.

Matlab is an abbreviation for "matrix laboratory." While other programming languages usually work with numbers one at a time, Matlab operates on whole matrices and arrays. Matlab provides various operators such as: Arithmetic operators for performing Addition, subtraction, multiplication, division, power, rounding; Relational Operations for Value comparisons; Logical Operations to evaluate Boolean conditions; Set Operations such as Unions, intersection, set membership; Bit-Wise Operations like Set, shift, or compare specific bit fields

By default Matlab stores all numeric values as double precision floating point values but it also supports wide variety of data types such as character and strings, date and time, tables, structures, cell arrays, function handles etc.

Matlab provides wide functionality for various numerical computations. It has a rich arsenal of functions for elementary mathematics, linear algebra, interpolation, numerical integration and differential equations, Fourier Analysis, Fourier Transforms, convolution and Digital Filtering.

Graphical interpretation and visualizations of data and results can be done with the help of Graphic functions of Matlab. Moreover graphic functions help in reading, writing and modification of images as well, which is essential in Digital Image Processing.

Matlab has powerful features for Data Import/Export with the help of which we can access data to and from files, applications and external devices, local network or internet.

The user can also build Graphical User Interface (GUI) applications using the Matlab Interactive Development Environment whereupon the common components such as push button, pull down menus and list boxes can be created.

Matlab provides support for a wide variety of hardware like DSPs, Microcontroller families, Data Acquisition Systems and more. This enables user to build his own system efficiently managing its hardware and software.

Scilab

Scilab is a scientific software package for numerical computations , it is a powerful open computing environment for engineering and scientific applications. Developed first in 1990 by researchers from INRIA (“Institut Nationale de Recherche en Informatique et en Automatique”, English – National Institute for Research in Informatics and Automation), France and ENPC (“École nationale des ponts et chaussées”, English – National school of Bridges and Roads), France. It is now maintained and developed continuously by Scilab Consortium. Scilab is a clone of Matlab, some of the other clones being Octave, RLab and Scipy. But the most popular of these clones is Scilab and it resembles Matlab to large extent and also due to the fact that it is open source software. Scilab like Matlab it is also a higher level programming language for numerical computation, providing a powerful computing environment for engineering and scientific applications.

The Scilab being an open source language is meant to be extended so that user-defined data types can be defined with possibly overloaded operations. The software comes with source code, so that the user has an access to Scilab's most internal aspects. Users can develop their own modules so that they can solve their particular problems. Scilab includes hundreds of mathematical functions with the possibility to add interactively programs from various languages (C, FORTRAN, and Matlab etc). It has sophisticated data structures (including lists, polynomials, rational functions, linear systems...), an interpreter and a high level programming language.

The operators and inbuilt functions found in Scilab have much resemblance with operators of Matlab, except a few. The operators found in Scilab are: Arithmetic operators for performing Addition, subtraction, multiplication, division, power, rounding; Relational Operations for Value comparisons; Logical Operations to evaluate Boolean conditions; Set Operations such as Unions, intersection, set membership; Bit-Wise Operations like Set, shift, or compare specific bit fields.

In Scilab, the default numerical variable is the double, that is the 64-bit floating point number. All the numeric variables in Scilab are stored as matrices, except Lists and other complex data structures such as ‘tlist’ and ‘mlist’ (however, tlist and mlist may contain matrices). Even a scalar is also a 1x1 matrix in Scilab.

Scilab has a wide range of functions required for various operations related to elementary mathematics, linear algebra, interpolation, numerical integration and differential equations, Fourier

Analysis, Fourier Transforms, convolution and Digital Filtering.

For visual interpretation and representation of data Scilab comes with several graphic functions which assist in the graphical display of data and results. Moreover a user can add-on the "guibuilder" module, for designing GUI applications.

SciNotes is a text editor embedded Scilab, which can be used to write, edit, modify scripts and save them for future use. Another tool available with Scilab is XCos, the hybrid simulation tool. XCos is used to create block diagram based simulations for various systems.

LabVIEW

LabVIEW stands for Laboratory Virtual Instrument Engineering Workbench is a system design platform and development environment introduced by National Instruments. It is a graphical programming language called 'G' which uses icons for programming. Instead of text based programming which is found in other languages, it has uses icons to create design applications. LabVIEW programs are called VIs (Virtual Instruments) because they resemble and imitate working of actual laboratory instruments.

It provides a plethora of Vis, functions, drag-and-drop controls and indicators for acquiring, analysing, interpretation, display and storage of scientific and technical data. Where a user can quickly build an interface as per the requirement where the required input can be given to the system, the data can be observed in real time and the results can be interpreted through indicators such as Graphs, Charts, Tables, Meters etc. LabVIEW haso has tools for a user to troubleshoot his programs.

LabVIEW can acquire data using devices like GPIB, Serial, Ethernet, Data Acquisition (DAQ), Image Acquisition (IMAQ), PDAs and Modular instruments to name a few. To analyse the data LabVIEW has numerous function for Calculus, Statistics, Statistics, Differential equations etc. For Signal Processing there are Express VIs like Filtering, spectral analysis, windowing, transforms, peak detection and harmonic analysis.

It can be connected with almost all the hardware platforms such as DSPs, Microcontrollers, sensors, FPGAs, DAQs, RS-232, RS485 devices and other instruments. It communicates with the hardware NI provides drivers not only for NI hardware but also for numerous third party hardware, which makes it an excellent tool for system development where a designer can implement the instruments and devices he wishes while designing a system.

LabVIEW offers the same performance of a traditional programming language such as C/C++ or BASIC as its constructs are same as of other traditional languages like variables, data types, objects, branching and looping and error handling. The code can be reused through DLLs and libraries and it can also be incorporated with other software through TCP, ActiveX and other standards.

DSP HARDWARE

Digital Signal Processors (DSPs) are used in several devices and applications such as Cell Phones, Digital Audio Systems, Speech Recognition Systems, Image Processing Systems, Digital Cameras and many more to count.

The programmable Digital Signal Processors are equipped with features which are meant for Digital Signal Processing applications. Conventional Microprocessors and other programmable devices which are used for general purpose applications lack the features essential for Signal Processing applications, however they may be used for the same but with limited functionalities and may lack the real time capabilities. Until late 1970s there were many chips intended for Digital Signal Processing but due to lack of few capabilities such as hardware multipliers and also due to their limited programmability they were not accepted as Digital Signal Processors. The first chip to be accepted as DSP was MPD7720 by NEC in 1981.

For a Microprocessor chip to be considered as Digital Signal Processor (DSPs) following are the characteristics which are desirable:

- It should have Real-time digital signal processing capabilities.
- It should have High throughput to be able to withstand multimedia streaming
- IT should have Deterministic operation.
- It should be Re-programmability by software.

DSPs in their initial phase of development were based on Harvard Architecture and maintained the same for first two generation. Although the second generation DSPs such as TI's TMC320C10 and Motorola's DSP56002 had additional features like multiple arithmetic unit, pipelining, Direct Memory Access (DMA), special address generator unit. Also the earlier DSPs were restricted to fixed point operations only, but DSPs like Motorola DSP96001and TI's TMS320C30 had floating point operation capability.

Further developments in DSPs saw emergence of the architectures like Very Large Instruction Word (VLIW) and Single Instruction Multiple Data (SIMD). The first DSPs to possess VLIW were TI's TMS320C6X DSPs and SIMD was first incorporated in ADI's TigerSHARC. The following section reviews some of the key features of above mentioned DSPs, namely TMS320C6X and TigerSHARC.

TMS320C6X Family

As discussed in the previous section TMS320C6X processors are VLIW architecture processors meant for multichannel and multifunctional applications. This family has variants like TMS320C62X and TMS320C64X DSPs which have fixed point operation and TMS320C67X which has floating point operation. The Integrated Development Environment which can be used for programming TMS320C6X family DSPs is known as Code Composer Studio (CCS).

TMS320C62X Processors

The TMS320C62X processors are fixed point processors from the TMS320C6X family. It has eight functional units consisting of two hardware multipliers (.M Unit; .M1 and .M2) and six ALUs (.L Unit – .L1 and .L2; .S Unit – .S1 and .S2; .D Unit – .D1 and .D2) and 32 general purpose registers of 32 bit word length each.

As there are eight functional units, the CPU is capable of executing eight 32-bit instructions per cycle. The execution speed for this processor is 1600 MIPS (Million Instructions per Second). They have 32-bit, byte addressable memory space. On-chip memory is divided into program and data space, whereas there is no separation in memory space when off-chip memory is used. The cache is also having two levels, one for program and one for data. Other features of C62X processors are enhanced direct memory access (EDMA) and 16-bit host port interface (HPI) which can access the entire memory map. The TMS320C62X family supports two addressing modes only: linear addressing mode and circular addressing mode.

TMS320C67X Processors

The TMS320C67X processors are the floating point processors in the TMS320C6X family. Like their ancestors they are also based upon VLIW architecture. They operate at 225 MHz delivering the execution speed of 1800 MIPS and as they are floating point processors they can perform 1350 Million Floating Point Operations per Second (MFLOPS) and they can execute 450 million multiply-accumulate operations per second (MMACS)

The functional units and general purpose registers of TMS320C67X family are similar to those of TMS320C62X family processors, with only exception that the six units out of eight namely .L1, .L2, .M1, .M2, .S1 and .S2 having the capability to execute floating point instructions as well. The C6713 uses a two-level cache-based architecture and has a powerful and diverse set of peripherals. It consists of the Level 1 program cache (L1P) and the Level 1 data cache (L1D). The 256KB Level 2 memory/cache (L2) is shared between program and data space. The 64K Bytes out of the 256K Bytes in L2 memory can be configured as mapped memory, cache, or combinations of the two, while the remaining 192K Bytes serves as mapped SRAM.

The TMS320C6713 has a rich peripheral set that includes two Multichannel Audio Serial Ports

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(McASPs) each supporting one transmit and one receive clock zone. The serial port supports time-division multiplexing on each pin from 2 to 32 time slots. The C6713 has sufficient bandwidth to support all 16 serial data pins transmitting a 192 kHz stereo signal; two Multichannel Buffered Serial Ports (McBSPs), two Inter-Integrated Circuit (I2C) buses, one dedicated General-Purpose Input/Output (GPIO) module, two general-purpose timers, a host-port interface (HPI), and a glueless external memory interface (EMIF) capable of interfacing to SDRAM, SBSRAM, and asynchronous peripherals.

SHARC/TigerSHARC Family

SHARC (Super Harvard Architecture Single-Chip Computer) and TigerSHARC processors are Digital Signal Processors produced by Analog Devices Inc. While each one of them is a different family, sometimes they are virtually considered to be of the same family as they are based on the same architecture, Super Harvard Architecture. Yet there is a fine line of difference between them.

While SHARC processors (ADSP-21XXX) are 32-bit floating point processors, TigerSHARC processors (ADSP-TSXXX) processors are floating and 8/16/32-bit fixed point processors. The DSPs from this family can be programmed in its IDE known as Visual DSP++.

TigerSHARC Processors

TigerSHARC processors are static superscalar DSPs intended and optimised for executing one to four 32-bit instructions simultaneously, which have been encoded in a single instruction line. An instruction line except some cases may have one, two, three or four 32-bit instructions, which executes with a throughput of one cycle. Programmers have to follow some rules for instruction parallelism while encoding the instruction line.

As mentioned earlier the TigerSHARC processors are having SIMD (Single Instruction Multiple Data) processors. They support SIMD operations by suing both the computational blocks in parallel with SIMD specifications. These blocks can be operated independently, in parallel or as SIMD Engines. Each computational block contains four computational units namely an ALU for performing arithmetic operations in both fixed and floating point formats and also logical operations; a multiplier for multiplying fixed and floating point numbers and multiply and accumulate fixed point numbers; a 64-bit shifter for logical and arithmetic shifts and other bitwise operations; a 32-bit register files used to store intermediate results, transfer of data between computational blocks and databuses; and a CLU (Communications Logic Unit only in ADSP-TS201S), a 128-bit unit containing enhanced acceleration instructions specially meant for increasing amount for complex multiplications per cycle and improving decoding efficiency.

The TigerSHARC processors are equipped with two IALUs (Integer Arithmetic Logic Units), which are meant for many general purpose integer operation and also provide powerful address generation capabilities. The IALUs also facilitate implementation of hardware circular buffers, which are helpful in implementation of digital filters and for operations like Fourier Transforms.

The ADSP-TS20X family has four variants in terms of memory ranging from 24-Mbits DRAM (ADSP-TS201S), 12-Mbits DRAM (ADSP-TS202S) and 4-Mbits DRAM (ADSP-TS203S). Which are divided into blocks of six blocks of 4-Mbits (128 K words x 32-bits), six blocks of 2-Mbits (64 K words x 32-bits) and four blocks of 1 M-bits (16K words x 32-bits) respectively. The programmer can configure the memory in a manner he wishes as all the blocks can store program, data or both. The on chip DMA (Direct Memory Access) controller of TigerSHARC processors has fourteen DMA channels, transfers the data without the involvement of processor with zero overhead. In addition to this the DMA controller performs other routine tasks like data block transfers through external ports and link ports, AutoDMA transfers, flyby transfers, 2 dimensional transfers and DMA chaining.

TigerSHARC processors come with full duplex link ports, with 4-bit transmit and 4-bit receive I/O capability. Each link port can be operated at double data rate rendering the maximum throughput of 4-Giga Bytes/Second. The core of DSP can directly access to Link ports transmit and receive registers for R/W operations. And as mentioned before the DMA

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controller can also perform transfer operations via Link Ports. Link ports are the means for supporting multi-processor systems.

In addition to the Link ports, the External port of TigerSHARC processors are meant for connecting the processor in a multi-processor system. The external port of ADSP-TS20X family is 64-bit wide and operates at 125 MHz. Upto 8 TigerSHARC processors can be connected and their host and global memories can be shared without any external logic.

Figures

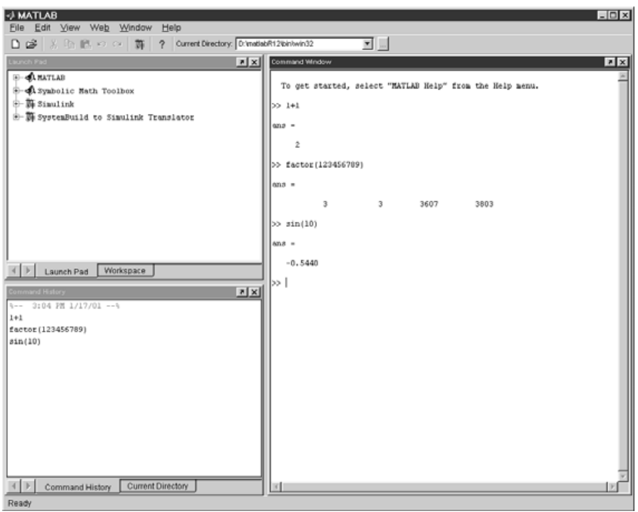

Fig. 1. Matlab Desktop

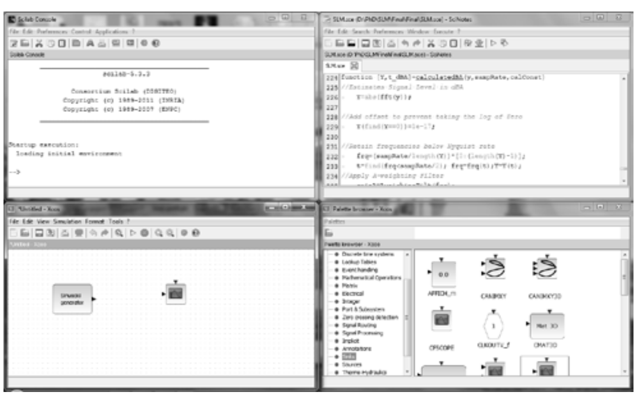

Fig. 2. Scilab Console, Scinotes, XCos with Palette browser

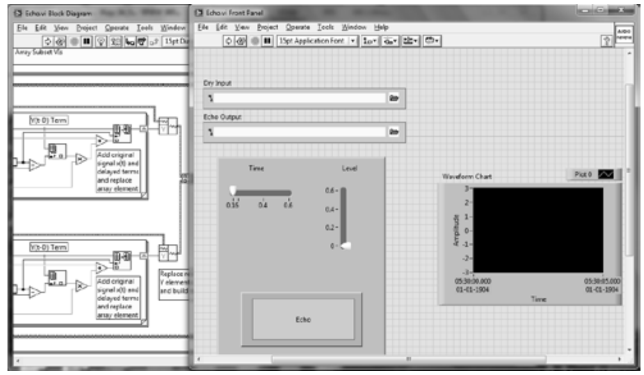

Fig. 3 LabVIEW VI front panel and background

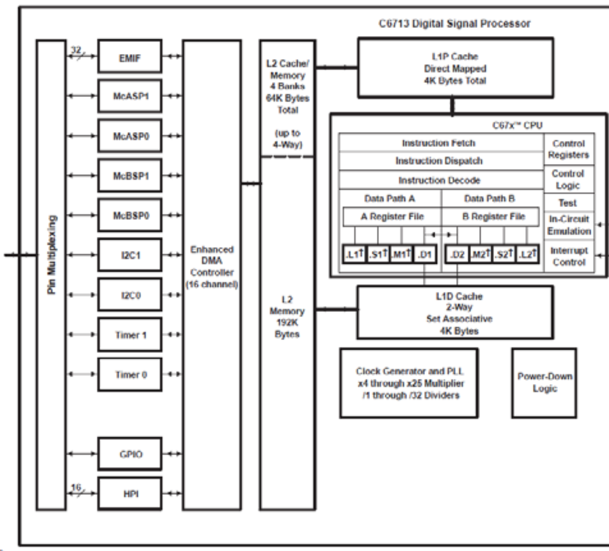

Fig. 4 TMS320C6713 DSP Core Diagram

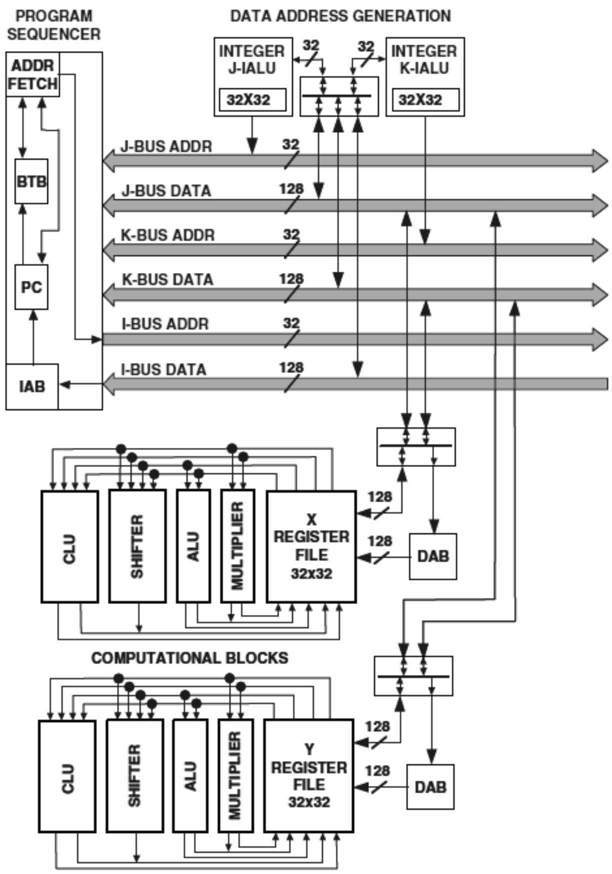

Fig. 5. ADSP-TS201TigerSHARC DSP Core Diagram

Conclusions

The Present study investigates various aspects about selected Software and Hardware tools for Digital Signal Processing applications. Software and Programming languages like LabVIEW and Matlab are extremely powerful tools in terms of their processing power and realtime capabilities, whereas tools like Scilab are cost effective as they come free of cost. Hardware platforms like TMS320C6X family of DSPs are widely used in and powerful processors and so are ADI's SHARC/TigerSHARC family processors, both are powerful and have excellent real time processing functionalities. Ultimately it is designers choice for the tool and platform which he want to choose based on functionality, processing power and cost effectiveness.

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