WHITE PAPER

Rahul Prabhu,
Application Engineer
Texas Instruments

TEXAS INSTRUMENTS

C6Accel: TI SoC developers accelerate performance with ready-to-use DSP kernels

Introduction

Texas Instruments (TI) has a long history in offering optimized production-quality Digital Signal Processing (DSP) software in the form of signal-processing libraries and math libraries that have enabled DSP users to achieve optimized application performance. ARM® developers using TI SoC processors expressed a desire to leverage this DSP software using a programming interface that is familiar to them. C6Accel is an algorithm that contains a library of signal processing and math functions that can be accessed from the ARM. C6Accel simplifies the ARM user experience in leveraging the DSP by providing a library of ARM APIs. These APIs abstract complexities of using DSP in a multi-core SoC environment. By using C6Accel, an ARM SoC developer can use the DSP as an accelerator and create a more compelling application by adding differentiating features to their application. Advanced users can explore maximum flexibility by adding their own custom DSP kernels to the C6Accel algorithm which is provided in complete source in the package.

SoC View with C6Accel

Many ARM application developers on TI SoC limit the DSP usage to multimedia codecs only. The ever growing performance of the DSP core and availability of specialized hardware accelerators imply that the DSP MHz may not be completely utilized by the just the codec operation. Thus an application developer can develop a more compelling application by making use of the remaining MHz on the DSP. The following diagram shows a SoC view of C6Accel sitting alongside other multimedia codecs.

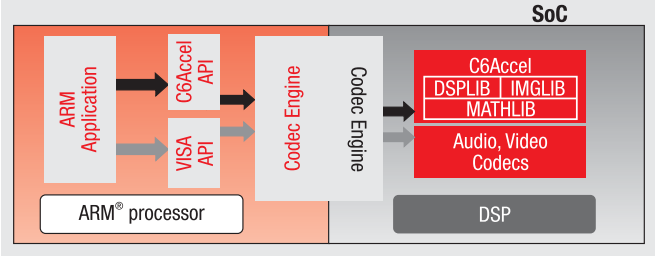

Figure 1. SoC view of C6Accel.

C6Accel is an algorithm that adheres to TI's specified algorithm interface called eXpressDSP™ Algorithm Interoperability Standard (xDAIS). TI provides a framework called Codec Engine that allows efficient execution of algorithms written with the xDAIS interface.

The application code calls C6Accel APIs. These APIs then pass through the Codec Engine interface and invoke the C6Accel algorithm on the DSP. On the DSP, the algorithm executes the appropriate DSP processing using the parameters. The C6Accel includes 100s of core DSP functions that are useful in various signal processing applications.

Building a C6Accel-based application

An application developer will start by identifying the processing steps that are better suited for execution on the DSP. These processing steps can be offloaded to the DSP by invoking C6Accel APIs. C6Accel provides two access methods for the ARM.

The simplest ARM interface involves use of C6Accel API calls which hide the Codec Engine details and allows the ARM user to leverage the DSP as a black box. This access method

allows the ARM® user to call a single DSP function per invocation. In addition, significant performance boost can be achieved by using these APIs in the asynchronous calling mode. The asynchronous calling feature is explained in later section of this document. This feature truly enables parallel operation of ARM and the DSP.

The second access method allows the ARM user to combine many API calls into a single C6Accel invocation. Such usage reduces the calling overhead associated with the API calls and thus improves the overall efficiency. This level of control requires basic knowledge of Codec Engine APIs and the C6Accel design. More details are provided in later section of this document.

Advanced users can maximize the DSP usage by adding their own custom functions to the C6Accel xDAIS algorithm. To enable this, the C6Accel is provided in complete source code and is accompanied by documentation that walks a user through this process. The user is expected to have basic understanding of the Codec Engine framework and the DSP architecture to explore this level of flexibility.

Application benefits

The C6Accel algorithm contains key kernels from floating- and fixed-point signal-processing libraries and math libraries. From the digital signal processing libraries it includes the key signal analysis and filtering kernels like the FFTs, IIR, FIR filters and vector/matrix operations. From the imaging library, it includes several color space conversion kernels, image analysis, filtering and enhancement kernels. C6Accel contains various arithmetic and trigonometric functions from the math libraries. Both fixed-point and floating-point math kernels are included. For the floating point, both single-precision and double-precision math operations are supported. Performance benchmarks are provided along with detailed documentation.

Table 1. Table illustrates type of functions in different categories of functions in C6Accel

Categories	Types of functions
DSP library	Filtering /FFT Vector/Matrix functions
Image library	Color space conversion Edge detection/Image filtering Image analysis and arithmetic
Math library	Datatype conversion Arithmetic (addsp, subsp, divsp, mulsp, intsp, etc.) Trignometic (expsp, logsp, powsp, sinsp, cossp, atansp, etc.)

There are many applications that will find value in using C6Accel. For example, audio applications can be enhanced by implementing high-quality audio algorithms that utilize high-precision IIR and FIR filters. Additional audio channels can be added and with more compelling effects by leveraging the DSP. Complex analytics can be implemented in imaging systems by adding algorithms to do image enhancement or object detection. The various math kernels are useful in test and measurement and Human Machine Interface (HMI) systems. The FFTs and data filtering kernels help offload key signal-processing steps in power protection systems from the ARM to the DSP.

Features and benefits of using C6Accel

- **Simple design**: C6Accel design provides a simple mechanism for identification and execution of a functionality to be executed on the DSP. C6Accel xDAIS algorithm code can be used as a template to add custom DSP algorithms which can then be accessed from the ARM® application.
- **Easy to interface**: C6Accel simplifies the ARM user experience in leveraging the DSP by providing a library of ARM side APIs that abstract complexities faced in a multi-core environment. C6Accel can be configured into an application like any other multimedia codec.
- **Differentiated feature from DSP architecture**: DSP kernels included in C6Accel are optimized for the DSP core allowing ARM users take advantage of the DSP performance on their SoC device. The C6Accel also allows the ARM developer to exploit the unique architectural features of the DSP. For example, on an OMAP-L13x device, C6Accel allows a fixed-point ARM to perform efficient floating-point processing using the floating-point C674x DSP.
- **Parallel processing**: Asynchronous execution feature of the C6Accel APIs enables parallel execution of the ARM and the DSP. This feature helps developers maximize the overall system performance.

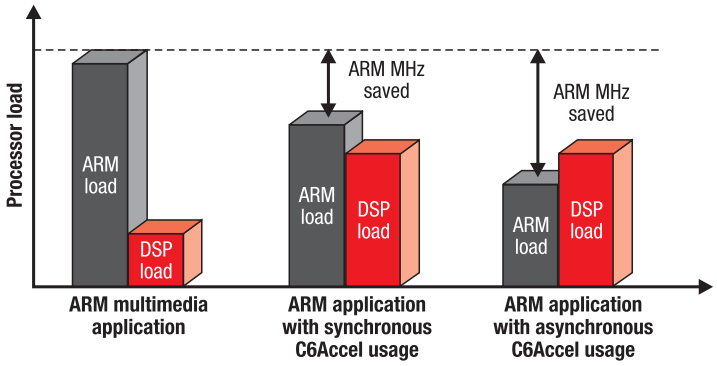

Figure 2. Processor load view to demonstrate benefits of C6Accel usage.

- **Efficient task list form of C6Accel invocation**: In case of multiple DSP kernels call, C6Accel design supports an efficient calling technique of combining multiple kernel calls into a task list that helps reduce the calling overheads.

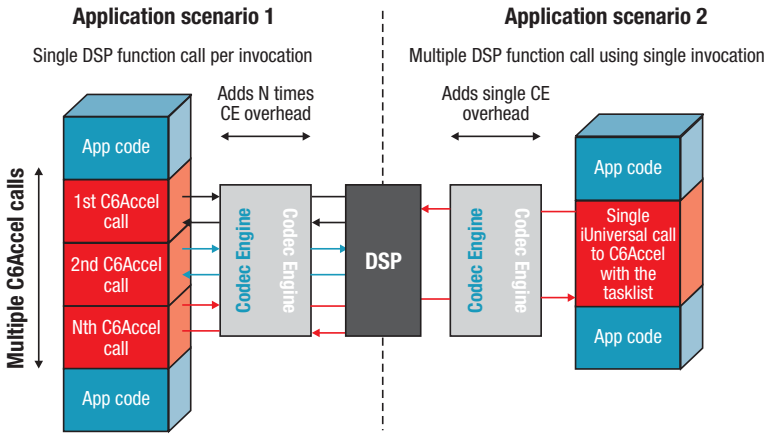

Figure 3. Diagram shows a calling multiple DSP function using a single DSP function per invocation and benefits of calling multiple DSP functions using a single invocation.

- **Availability of tested and benchmarked kernels**: Availability of production-ready DSP kernels reduces learning curve and time to market for ARM® SoC developers. All the C6Accel kernels are tested and benchmarked in a sample application included in the package. The ability to easily benchmark the C6Accel kernels allows application developers to make informed decisions on when using DSP acceleration is suitable. The calling overheads associated with C6Accel may imply that for very small buffer sizes, using C6Accel may not be most efficient.

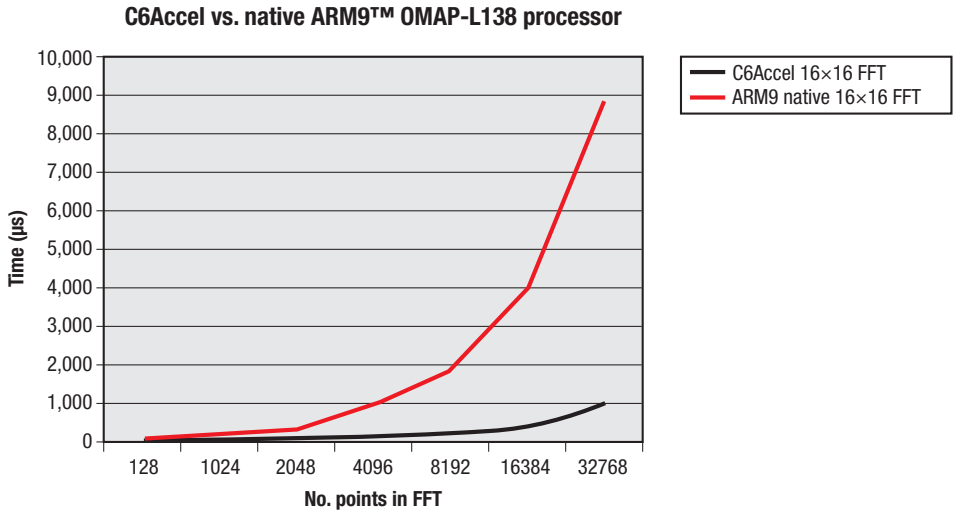

Figure 4. Graph of execution time vs. data size while using C6Accel and ARM for data processing.

- **Extensibility**: C6Accel provides a common method and API to add other or custom signal processing features to the application to fully utilize the performance of the DSP core, or to further enhance the features of the existing codecs with pre-/post-filtering capabilities.

Conclusion

C6Accel is a powerful tool that enables ARM application to leverage the DSP as an accelerator on TI TMS230C6000™ DSP + ARM devices. C6Accel is built in a standard xDM Codec Engine-compliant iUniversal interface which allows execution alongside other multimedia codecs thereby allowing applications to do more processing on the DSP. C6Accel`s simple design and ease of use makes it an ideal tool for SoC developers to leverage the DSP with varying levels of control and flexibility. For more information on the tool and specific details on any of the topics covered in this article, please refer to the online documentation hosted on TI's embedded processors wiki site. **processors.wiki.ti.com/**

Important Notice: The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

Sitara is a trademark and Stellaris is a registered trademark of Texas Instruments Incorporated. All other trademarks are the property of their respective owners.

© 2010 Texas Instruments Incorporated

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DLP® Products	www.dlp.com	Communications and Telecom	www.ti.com/communications
DSP	dsp.ti.com	Computers and Peripherals	www.ti.com/computers
Clocks and Timers	www.ti.com/clocks	Consumer Electronics	www.ti.com/consumer-apps
Interface	interface.ti.com	Energy	www.ti.com/energy
Logic	logic.ti.com	Industrial	www.ti.com/industrial
Power Mgmt	power.ti.com	Medical	www.ti.com/medical
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Space, Avionics & Defense	www.ti.com/space-avionics-defense
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video and Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless-apps

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2010, Texas Instruments Incorporated