RENESAS

HIGH END/ LOW POWER R4650 WITH DSP CAPABILITIES

APPLICATION NOTE AN-137

By Robert Napaa

INTRODUCTION

In the next few years, the market share of the portable systems is expected to increase steadily. Furthermore, users will demand that the performance of these systems matches the performance of desktop systems. The portable systems should be able to manipulate data, voice and video in a multimedia environment exactly like their desktop counter parts. Unlike the desktop systems, portable systems face another set of challenges. First, the power consumption of these systems is limited by the battery life. This implies that the components used should consume as little power as possible and have power management capability to reduce the consumed power even more when the system is idle. Secondly, the portable systems are becoming smaller and smaller, lighter and lighter. This implies that more functionality is implemented using a fewer number of devices. The trend is to implement as much functionality in software as possible to reduce the need for dedicate hardware solutions.

MULTIMEDIA

The definition of multimedia is somewhat vague. Multimedia refers to systems capable of manipulating digital voice, digital images and digital data such as speech, video and file transfers. Multimedia systems must be able to manipulate these applications in either a real time environment or in a play back environment. In the real time environment such as cellular telephony, the max delay can be 250 - 350 msec, because delays longer than that will result in a poor quality of sound. The voice will be chopped and hard to understand. Similar constraints apply to real time digital video.

The above applications involve large amounts of data to be manipulated and stored. Usually the data is compressed to minimize the storage requirements and to increase the effective bandwidth of the systems. Similarly, the data could be encrypted to preserve the content of the information. All these different techniques are based on various Digital Signal Processing (DSP) algorithms. As an example, video images are compressed using different algorithms. Motion-JPEG, MPEG1 and MPEG2 are used for motion video, while JPEG is used for still images. Similarly several algorithms have been developed for speech compression such as TrueSpeech™. All these techniques require a very fast real time DSP engine.

Along with the DSP capability, multimedia systems are general purpose systems that implement other tasks as well, such as interfacing to memory, storage devices or other types of I/O devices. These tasks require the use of a general purpose microprocessor tailored more towards these usages.

TRADITIONAL SOLUTIONS

Traditional implementations for portable systems separate the general systems functions from the specific functions such as DSP or graphics. This separation is accomplished both on the hardware level and on the software level. On the hardware level, two or more types of different compute engines are used. At the center of the design is a general purpose microprocessor or microcontroller responsible for various system tasks and overall system management. Other dedicated hardware modules such as DSP microprocessors, graphic accelerators and custom ASICs are used in the system. Each of these modules serves a particular function.

On the software level the same separation takes place. The general purpose tasks are separated from the specific tasks. Procedure calls link various tasks together. In most instances, different operating systems (OS) are executing in parallel on different microprocessors in the system. As an example, a portable system may be implemented using a real time kernel for general purpose and system administration while a DSP specific-OS is used for the DSP tasks.

These traditional solutions are not well positioned to meet the challenges of the future. Specifically, the power consumption of these systems is not in line with the requirements of true portable systems. Similarly, the use of multiple devices places constraints on the form factor, the development time and the resulting system.

The trend is to merge more and more hardware functionality into a smaller number of devices. These devices perform several independent tasks that once required separate hardware modules. In addition, there is more emphasis on a software approach. Several independent software modules are combined together to execute on a single device. The software solutions are much more flexible than the hardware ones. Applications can be easily added, modified and customized at will without the need for a complete redesign of a hardware module. To be as efficient and as fast as the hardware modules they are replacing, these combined software modules require extensive compute power.

THE IDT ORION™ R4650

The IDT Orion R4650 is the latest member of the RISController™ family from IDT. It is a derivative of the IDT Orion R4600 and is based on the MIPS architecture. The Orion R4650 is a highly integrated microprocessor specially designed for the embedded market. It includes 8 KBytes of Instruction Cache and 8 KBytes of Data Cache, both of which are two-way set associative. The Orion R4650 executes at speeds up to 133 MHz. The internal core of the R4650 is a full 64-bit implementation of the MIPS III Instruction Set Architecture (ISA) with 32 internal general purpose registers. It has a built-in floating-point accelerator unit. The raw performance of the R4650 is about 175 Dhrystone MIPS at 133 MHz. With these capabilities, the R4650 is an excellent general purpose microprocessor.

Most of the DSP algorithms rely heavily on a fast Multiply_and_Accumulate operation to perform effectively. To address the needs for multimedia applications, the Orion R4650 has a dedicated unit to perform integer Multiply_And_Accumulate (MAC) operations. This unit performs a multiply and add instruction every two clock cycles.

The Orion R4650 is also designed for low power systems. It consume less than 1.6 watts peak at 100 MHz, even less power at lower frequencies. It also incorporates active power management mode to further reduce the consumed power. This mode is dynamically invoked through the software. Figure 1 illustrates the simplified block diagram of the R4650.

Thus, the Orion R4650 offers the best of both worlds. It is a powerful general purpose compute engine for overall control and management tasks. It also executes DSP algorithms effectively, reducing the need for a dedicated DSP microprocessor. Its power consumption is very limited and can be dynamically adapted to the portable applications.

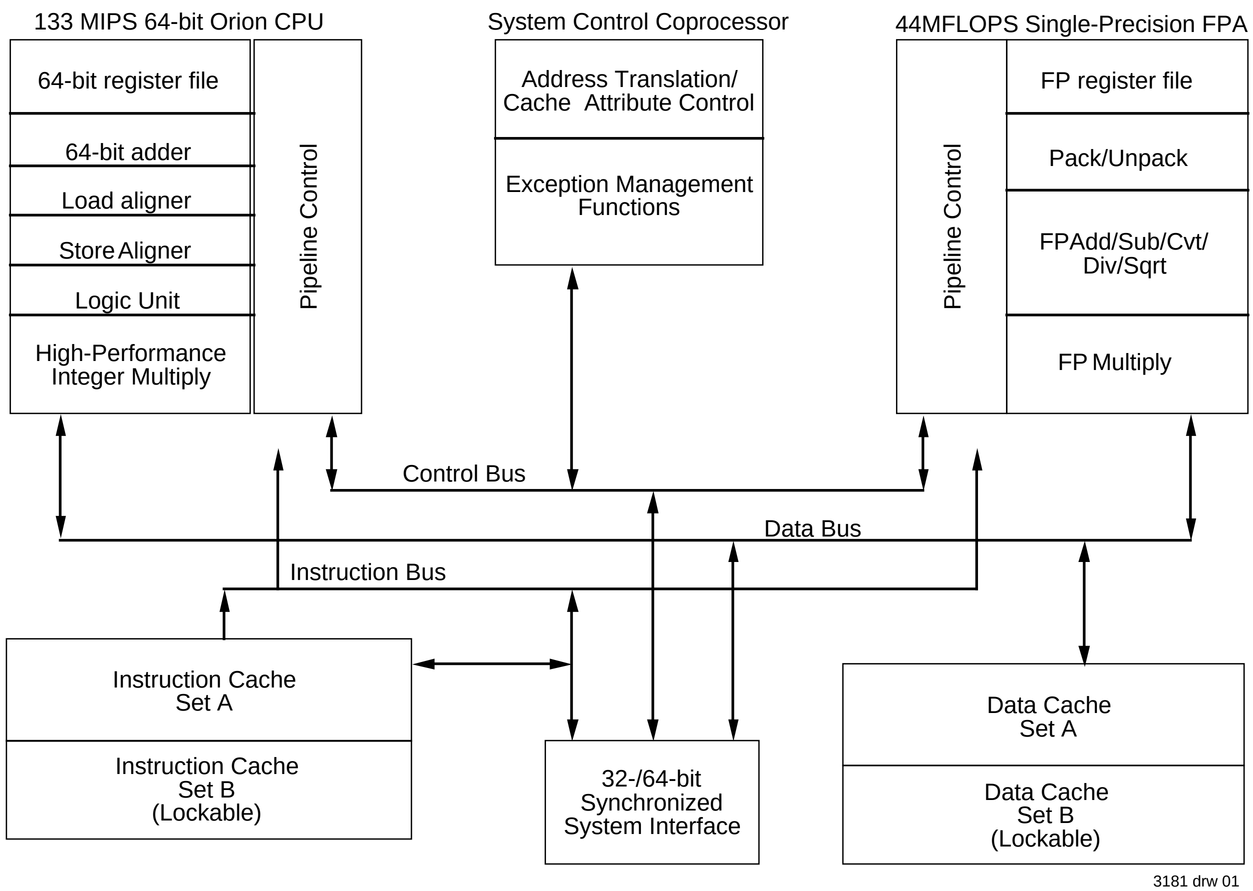

Figure 1. R4650 Block Diagram

SOFTWARE CONTROL

The R4650 is a true RISC compute engine, where the software has control over most functionality of the device. The software can manipulate the internal instruction and data cache to optimize the performance of the system. By using the "CACHE" instructions, the software can control the contents of any cache line. This fine control over the contents of the caches enables the OS to ensure that the data is always available for the different tasks it is scheduling.

The contents of the caches can also be locked. This means that a particular section of the instruction cache will never be replaced. This ensures that a time sensitive routine such as the interrupt service routine or a dedicated task such as a DSP algorithm is always in the cache. This minimizes the time interval between procedure calls. Similarly, a section of the data cache also can be locked. This ensures that the data is available for real time DSP algorithm for example. This minimizes the need to access the main memory and thus makes the response of the system more predictable, since the instruction and the data are local to the internal caches.

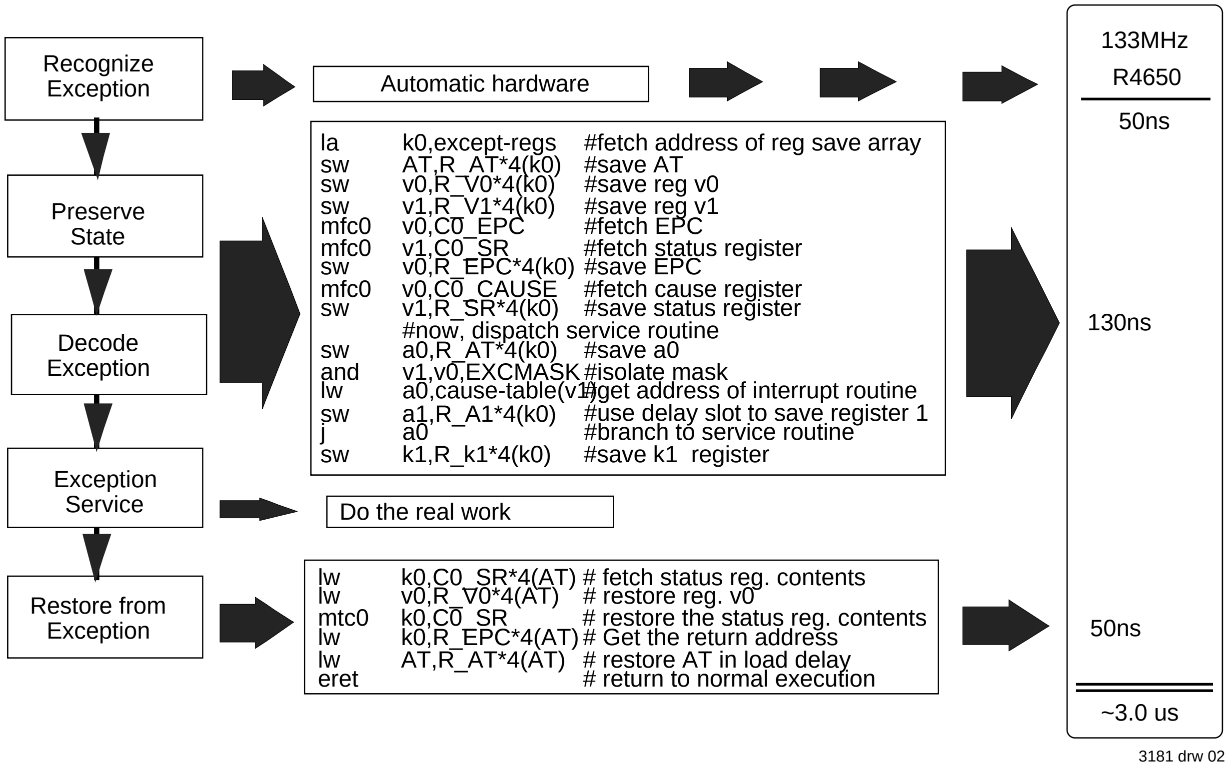

Figure 2. R4650 Interrupt Response Time
Real-Time Interrupt Response

To combine several independent software modules, such as a general purpose OS and a DSP algorithm, onto a single execution engine requires extensive use of interrupts. Usually, the task swapping is triggered by an external event. The interrupt driven approach is much more efficient and dynamic than a polled system. For real time applications, such as multimedia with large amounts of data to be serviced at high bandwidth, polling might not even be an option.

Usually an interrupt is asserted to request the R4650 to swap the tasks. To meet the real time requirements of the application or external event the task swapping must be accomplished as fast as possible.

The R4650 at 133 MHz can respond to interrupts in less than 250 nsec. This time includes recognizing the exception, preserving the state, decoding the exception and restoring the state at the end of the exception. Sample code to accomplish these steps is illustrated in Figure 2.

POWER CONSUMPTION

The components used in a portable system must consume as little power as possible. The R4650 is designed with this goal in mind. It is available in both 3.3V and 5V versions. The 3.3V has a peak power consumption of about 1.6 watts at 100 MHz. Furthermore, the R4650 uses an advanced power management scheme to further reduce the average power consumed. In this mode, the unused sections of the device are powered down. This mode is entered automatically when the internal logic determines that are no activity involving some section of the device. Thus average active power consumption in reduced to about 1 watt.

Finally, the R4650 provides a “Stand-By” mode, which is invoked by the software. In this mode, all of the internal clocks and the pipeline are frozen and the bus activity is stoped. This mode reduces the consumed power to less than 200 mwatts.

The OS can take advantage of all these power saving features on the R4650 by entering the “Stand-By” mode, when there is no system activity to reduce the average power consumption. If on the average, a portable system is active 25% of the time and idle the remaining 75%. The average power consumed by the R4650 will be in the order of 400 mwatts. It is important to note that the R4650 replaces several dedicated hardware modules in the system. This means that the average power consumed is substantially less than the traditional solutions. In addition, I/O power is alos reduced because the interface to the system is stopped.

DSP CAPABILITIES

The DSP algorithms are designed to manipulate large amounts of data effectively. At the heart of any DSP algorithm is a Multiply_And_Accumulate instruction. The R4650 is designed to execute DSP algorithms efficiently. It has a dedicated integer Multiply_And_Accumulate unit that executes at 133 MHz. A new multiply-accumulate instruction can be started every two cycles. As a result, the R4650 can perform 66.7 M multiply-accumulate instructions per sec. This integer DSP performance of the R4650 exceeds the performance of any other DSP microprocessor available on the market today. Table 1 illustrates the peak integer DSP performance of several architectures.

This type of DSP performance allows the R4650 to implement all the major DSP algorithms effectively. As an example the speech compression algorithm TrueSpeech™ from the DSP Group requires about 10 MIPS or less than 8% of the R4650 compute power to execute.

TABLE 1. COMPARISON OF VARIOUS DSP ARCHITECTURES

PRODUCT	FIXED POINT MACs (In Millions)
TI - TMS320C25	12.50
TI - TMS320C50	40
ATT - DSP16	54
MOT - 56K	40
IDT - R4650	66.7

3181 tbl 01

This example illustrates that the R4650 can mix general purpose tasks along with dedicated DSP algorithms in an efficient way. This powerful DSP engine reduces the need for dedicated external DSP microprocessors.

CONCLUSION

The R4650 is a general purpose microprocessor geared towards the portable applications. It implements a fast multiply-accumulate unit to speed up the different DSP algorithms. It can mix general purpose control tasks with DSP specific applications in an efficient way. These capabilities reduce the need for external dedicated DSP hardware modules. These features, combined with the average low power consumption, makes it ideal for portable applications.

IMPORTANT NOTICE AND DISCLAIMER

RENESAS ELECTRONICS CORPORATION AND ITS SUBSIDIARIES (“RENESAS”) PROVIDES TECHNICAL SPECIFICATIONS AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES “AS IS” AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS OR IMPLIED, INCLUDING, WITHOUT LIMITATION, ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR NON-INFRINGEMENT OF THIRD-PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for developers who are designing with Renesas products. You are solely responsible for (1) selecting the appropriate products for your application, (2) designing, validating, and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. Renesas grants you permission to use these resources only to develop an application that uses Renesas products. Other reproduction or use of these resources is strictly prohibited. No license is granted to any other Renesas intellectual property or to any third-party intellectual property. Renesas disclaims responsibility for, and you will fully indemnify Renesas and its representatives against, any claims, damages, costs, losses, or liabilities arising from your use of these resources. Renesas' products are provided only subject to Renesas' Terms and Conditions of Sale or other applicable terms agreed to in writing. No use of any Renesas resources expands or otherwise alters any applicable warranties or warranty disclaimers for these products.

(Disclaimer Rev.1.01)

Corporate Headquarters

TOYOSU FORESIA, 3-2-24 Toyosu,
Koto-ku, Tokyo 135-0061, Japan
www.renesas.com

Contact Information

For further information on a product, technology, the most up-to-date version of a document, or your nearest sales office, please visit www.renesas.com/contact-us/.

Trademarks

Renesas and the Renesas logo are trademarks of Renesas Electronics Corporation. All trademarks and registered trademarks are the property of their respective owners.