Multi Core ARM Processors in Mobile Devices

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ABSTRACT

In this era of a highly competitive market of mobile devices, ARM processors are in demand for their cutting edge power efficient processors. These RISC based processors, originally designed by Acorn Computers Ltd. , have evolved into a family of microprocessors, widely used in mobile electronic devices like phones, PDAs and multimedia players.

This paper gives a brief insight into the RISC architecture of ARM processors and their traits, which have made them very popular for use. It then briefly outlines the evolution stages of ARM processors from its nascent ARM1 to the Cortex A15 cores.

The paper then highlights the need and design of multiple core ARM processors. It explains the features of an example multi core arm processor, the ARM Cortex A9 MP Core processor, in detail. It gives an insight into how the mobile device companies harness the multi core features of these processors and help to provide numerous advantages in terms of internal device technical capabilities as well as the external user interface experiences.

Using the Cortex A9 as the base, it then discusses about new features of the newer multi core processors released and their applications. It concludes by outlining the planned features of upcoming processors, with an eye on how they will revolutionize the industry further.

1. INTRODUCTION TO PROCESSORS

A microprocessor is a single integrated circuit which executes the functions of a central processing unit. It accepts digital data, processes them based on instructions in the memory and outputs the result. Since it is a programmable device, it can be used for multipurpose applications. Integrating the central processing unit on a single chip significantly reduced the processing power and also helps in manufacturing them in large quantities. Over the years, microprocessors have undergone many design changes, making them faster and also equipped with a variety of functionalities to suit the applications they are used in.

Intel introduced the first 4 bit microprocessor in 1971. Over the years, it was succeeded by 8 bit designs, 12 bit designs, 16 bit designs, 32 bit designs and finally the 64 bit designs. Processors from Intel, AMD etc. used x86 family of instruction set architectures (with many additions and extensions added to it over the years, with full backward capability). These architectures are primarily Complex Instruction set computing (CISC) designs, where single instructions can implement numerous lower level operations. Soon, an opposing strategy called Reduced Instruction Set Computing (or RISC) originated in the 1970s based on the opinion that a simplified instruction set gives higher performance when used along with a microprocessor architecture implementing the instructions with fewer cycles per instruction. A British company ARM Holdings used the RISC instruction set architecture to develop ARM (formerly Advanced RISC Machines and Acorn RISC Machine). It is a 32 bit instruction set architecture, originally created by Acorn Computers for its personal computers. It was later used in the BBC Micro series of computers for their co-processor modules. In the late 1980s, Apple computer and VLSI technology, worked with Acorn, on newer versions of ARM core and in 1990, Acorn spun off the design team to form Acorn RISC Machines Ltd., which later became ARM Ltd.

2. NEED FOR ARM

Most of the embedded systems applications utilize the ARM processors since they provide a unique blend of features which best suit embedded applications. Firstly, compared to many general purpose processors, ARM cores are simple and hence can be manufactured with fewer numbers of transistors. They also free up a lot of space on the chip for application specific macrocells. Typically, an ARM chip consists of a digital signal processor, several peripheral controllers, a small area of on- chip memory and an ARM core. Secondly, both the ARM ISA and pipeline design aim at reducing energy consumption, which is a pressing need in mobile embedded systems. Thirdly, there is a lot of flexibility in building application specific ARM-based processors since the integer pipeline is the only compulsory component of the ARM processor whereas all other components like the memory management unit, caches, floating point unit and other co-processors are optional. Finally, the ARM processors deliver high performance for embedded applications, being small and low power. A typical example is the PXA225 XScale processor that runs at 400 MHz, which uses fifty times lesser energy than the Pentium 2 processor running at 300 MHz .

ARM has been licensing the ARM architecture to other companies for manufacturing silicon-on-chip products and also ARM-based CPU's. The two licenses ARM provides are the Implementation license and Architecture license. The implementation license presents the complete information needed by the licensee to design and manufacture the integrated circuits having ARM processor cores .There are two types of cores which are licensed by ARM. They are the hard cores and the soft cores. A hard core used in a specific manufacturing process and is optimized whereas a soft core is not fully optimized and is flexible since it can be utilized in any process. The architecture license allows the licensee to develop their own processors.

ARM processors are used in mobile phones, digital media, hand-held gaming systems, calculators, computer hard drives and personal digital assistants (PDA). ARM architecture is licensed for use by companies such as Cirrus Logic, Intel, Apple, LG, Microsoft, Nintendo, Nvidia, Sony, Samsung, Sharp, Texas Instruments and many others.

3. ARM ARCHITECTURES

The ARM classic processors have been available for 15 years. They consist of 3 processor families, the ARM 7, ARM 9 and the ARM 11 family which are still in use. From the mid-90s, the ARM7TDMI processor core was very successful, being adopted widely in the mobile industry and is still the highest shipping 32 bit processor on the market even today. From it, a large roadmap of products grew in the real-time embedded space. In the embedded space, there are 2 main families today. In embedded microcontrollers, where cost is at a premium, the Cortex- M family is being used. The other family is the Cortex-R family, which is at the upper end and provides high performance and throughput, in addition to precise timing properties. Hence making it apt for deeply embedded timing critical applications. On the application side, there is the Cortex-A family. These provide scalable higher performance in applications requiring platform operating systems, for example Linux.   They have extended instruction sets and sophisticated memory management for multimedia processes. Since the classic ARM 11MP processor, ARM has support for multi core systems. Accordingly, all Cortex-A processors have support for multi core systems, enabling them to unleash higher performance and power points.

The following graph gives a quick view on the performance and capability of the different ARM processors.
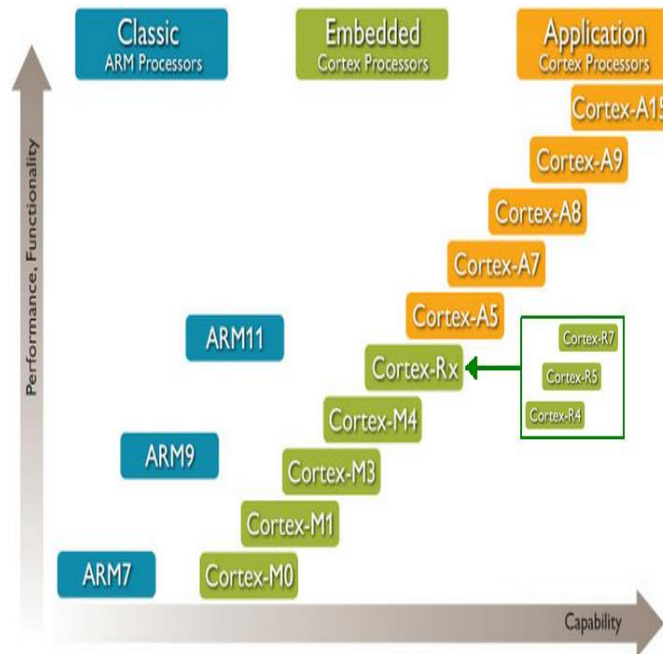

Figure 1. Performance, Functionality vs Capability of different ARM Processors.

3.1 Single Core and Multi Core Processors

A single core processor is a processor which has only one core. Hence it can run one process at a time. In some cases, it can start a new process before the earlier one is complete. Earlier all the processors were all single core.
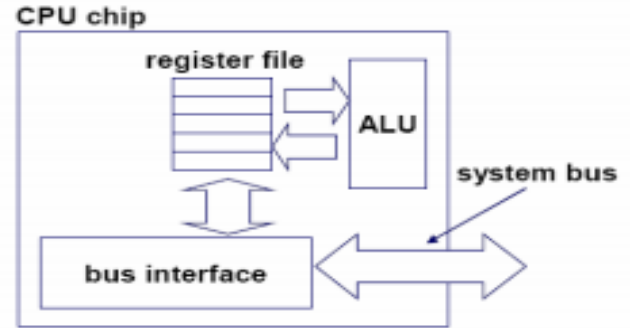

Figure 2. Single core CPU chip.

A multi core CPU is a processor which has 2 or more cores. Each core of the chip behaves as a separate computer and accordingly executes commands. The cores are all part of the same chip but work together in parallel and are self-governing. A multi core processor with two independent processors is called a dual core processor. Whereas, a multi core processor with four independent processors is called a quad core processor. The cores may or may not share caches and they may also execute memory passing or shared memory inter core communication methods. If the multicore systems include identical cores, they are called homogeneous multi core systems. Else if different, they are called heterogeneous multi core systems. Multi core processors are used in different application domains like embedded, network, digital signal processing, general purpose and graphics [6].
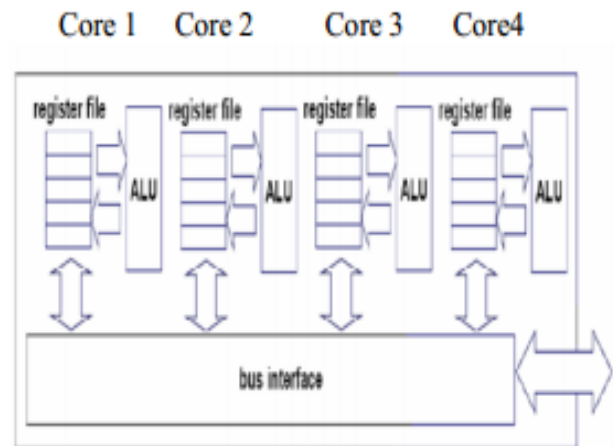

Figure 3. Multi core CPU chip.

The present day mobile devices perform a variety of tasks including mobile gaming, SMS texting, browsing on the web, playing audio and video and also numerous location based

services including GPS navigation, on-the-go reservations etc. There were all tasks that were earlier handled by traditional desktop PCs and now are being executed on the mobile devices with assistance from high speed mobile services and Wi-Fi networks. The current and next generation smart devices are further being required to do more intensive tasks like playing of HD videos, recording of videos in HD, editing of videos, flash based games, games with high definition and realistic visuals, audio conferencing and video conferencing.

To perform all these applications with a single core processor is not efficient. When using single core CPU, running all these applications simultaneously on it will result in slowing down of these applications or a decrease in quality of experience provided by these applications. Engineers try to use several methods to improve the CPU performance to make the experience better. These include increasing core voltage and frequency, using larger cores, using smaller and faster semiconductor processes or even using larger caches on the die. However, these may not be very effective as each of these have its own limitations. Increasing the CPU size or using larger cache can help to increase the performance to a certain extent, beyond which heat dissipation and thermal issues increase, limiting the extent of increase in the sizes of these [5]. On the possibility of increasing frequency and voltage, these tend to increase the power consumption of the devices. If the devices consume more power, bigger cooling solutions will be needed and this would need an increase in the device size itself. For mobile devices maintaining the size small is a big benefit. Even if engineers manage to get higher performance by increasing voltage and frequency, the battery life will be highly affected by the increased performance. Hence increasing the frequency is not a good option for the long run [1],[2].

Multi core CPU cores improve performance of cache snoop (meaning signals between different CPUs travel smaller distances and hence have lesser degradation). Also multiple CPU cores on same die allow cache coherency circuitry to operate at higher clock rate than if signals travel off chip. Multi core chips also allow higher performance at lower energy. This is an important factor especially on mobile devices running on batteries. Also since each core is energy efficient, the chip as a whole becomes more efficient than having a single core.

3.2 Illustration of Advantages of Multi Core Processor in Mobile Devices

Multi core CPU device provide the user with a desktop PC style Web browsing experience. Browsers like Mozilla Firefox and Google Chrome are multithreaded and hence have the capability to spawn multiple processes. If there are multiple tabs, each tab is a separate process, which in turn manages its own set of threads.

Example 1: While browsing the New York Times Website, the utilization of each core of the quad core CPU system is shown in the figure below [4].
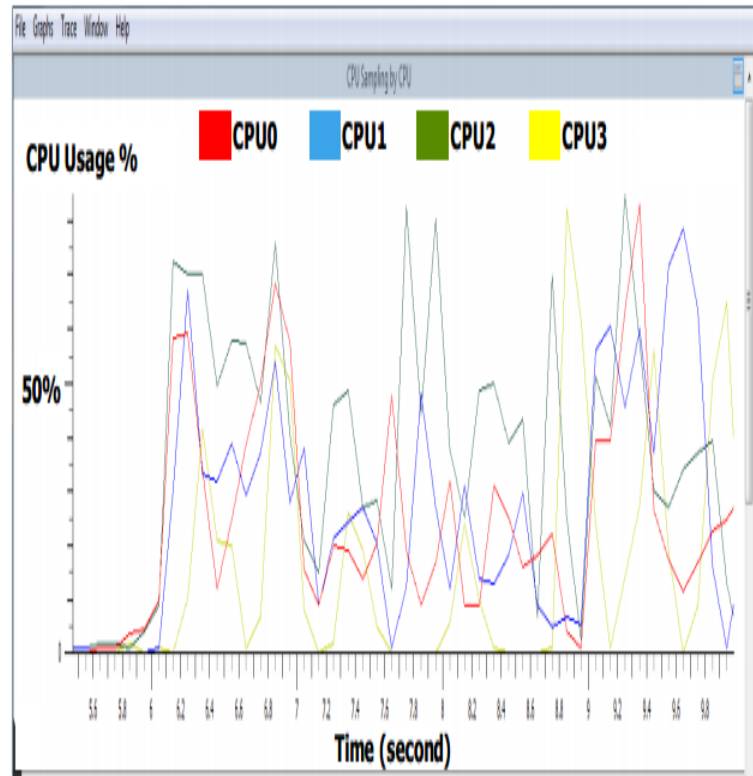

Figure 4. CPU usage percentage vs Time of one browser in quad core

As seen above, the browser utilizes each of the cores of the quad core CPU. This in-turn helps to give the user a faster web browsing experience when compared to a dual core or single core based mobile device.

Example 2: If the same web browser has multiple tabs open, then the tabbed browser uses much more CPU processing. Even the 4 cores of a quad core CPU may be saturated. Hence the effect, if this was to be executed on a single core CPU mobile device would be drastic. The following figure illustrates this case.

Figure 5. CPU usage percentage vs Time of one browser with multiple tabs in quad core.

4. OVERVIEW OF A WIDELY USED MULTICORE ARM PROCESSER IN MOBILE SYSTEMS

One of the most widely used multicore ARM processors today is the ARM Cortex-A9 MPCore processor. Its popularity is due to the fact that it has several features which are new or are huge developments when compared to the earlier generation ARM processors. Therefore, it helps to provide increased performance scalability and increased control over power consumption. This has made it ideal for use in several areas including mobile applications, auto-infotainment, high performance networking, set top boxes and enterprise applications.

The Cortex-A9 architecture has evolved from the ARM Cortex-A8 processor. This processor implements the ARMv7 instruction set architecture. It is scalable up to 4 cores with its advance MPCore technology. The CPU cores are optimized to operate at 1GHz and have the ability to scale up to higher frequencies. It has a 32KB instruction cache and a 32 KB data cache per core, with both cores sharing a 1MB L2 cache. This 1MB L2 Cache helps to even load the entire memory footprint of a browser onto it and hence gives a fast web browsing experience.

One of the unique features of this processor is the presence of speculative out of order execution supported by dynamic 8 stage pipeline. This particularly helps the processor to reorder instructions dynamically and avoid stalls due to resource conflicts or instruction latencies. This helps to increase performance to a great extent. In older generation processors including the Cortex

A8, they used an in-order pipeline. Hence these processors were unable to avoid the issues due to cache misses or branching. In addition, to avoid branching penalties, there is also support for speculative branch predictions.

Mobile companies use the multi core Cortex-A9 microprocessor and add certain features to enhance the usage of their functionalities. Say, we have a dual core Cortex-A9 microprocessor as shown below [3].
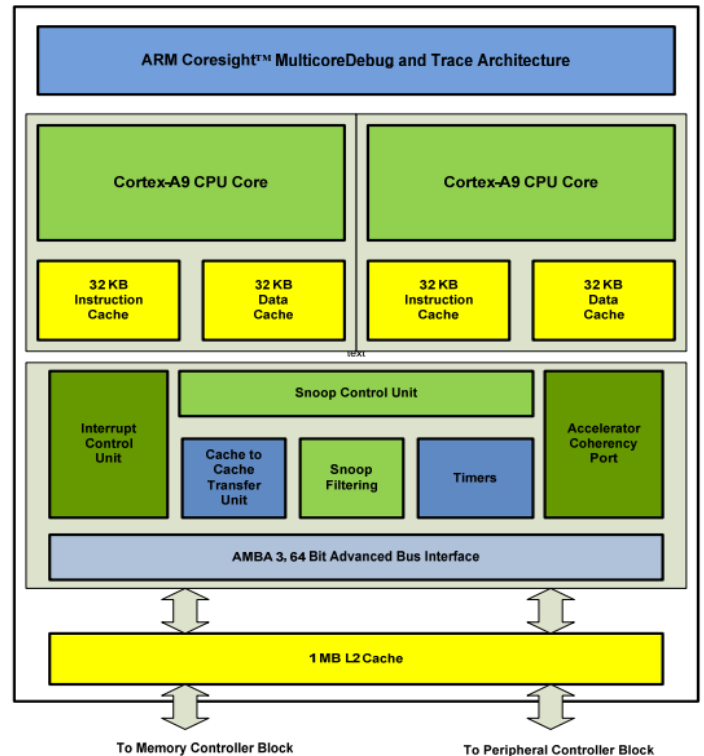

Figure 6. Dual core Cortex-A9 microprocessor

Companies develop intelligent frequency scaling and dynamic voltage algorithms, at both software and hardware levels, to manage the power of the CPU cores. They ensure both the cores are always functioning at the optimal frequency and voltage levels, so that they provide the required performance at the lowest power. And these also ensure that when the system is idle, the cores are operating in low power mode.

5. FUTURE MULTICORE MOBILE PROCESSORS, THEIR FEATURES AND APPLICATIONS

ARM is constantly developing its architecture and has released other multicore ARM architecture processors every year. The ARM Cortex-A15 MPCore is 40 percent more powerful than Cortex- A9 core with the same number of cores at the same speed. The Cortex A-15 is also built on ARMv7 architecture. This processor gave rise to the big.Little technology. This is a power optimization technology where high performance but power hungry ARM CPU cores are combined with slower, low power ARM cores, to give a multicore processor which can adjust to dynamic computing needs but use lesser power. This finds its use

in high end mobile devices as it ensures mobile SOCs can be designed with new levels of peak performance, with all day battery life, expected by the consumers. ARM first announced Cortex-A7 to be architecturally compatible with Cortex-A15. Samsung Exynos used this technology, by creating an SOC combining a 1.6 to 1.8GHz quad core Cortex-A15 with 1.2GHz quad core Cortex-A7 [7].

ARM then released the Cortex-A17. This is considered to the right successor for Cortex-A9. ARM claims Cortex-A17 is 60 percent more powerful than Cortex-A9 and also 20% more energy efficient. This also supports the big.Little multi core architecture and are planned to be used in mid-range mobile devices releasing in 2015.

6. CONCLUSION

The mobile processors are faced with power and performance challenges, like the notebook and desktop processors faced few years ago. The single core processors are being stretched by the new applications like streaming video, 3D games, HD video playback etc. Inevitably all mobile processors will have multi core processors, in order to stay within power budgets and to further increase the performance. The widely used mobile software already support multithreading and multitasking. Both Android and iOS have also added several features which help to improve the ability of the operating systems to leverage the processing capability of multi core CPUs. Mobile browser like the android browser supports multi-threading and tabbed browsing. In addition, they harness the tremendous power offered by multi core CPUs, to provide a faster web browsing experience. In addition, all popular games on PC as well as Xbox and PS consoles are being ported to mobile environment. They will now transition from using the multi core processors in the PC to multi core CPUs in the mobile processor.

This will enable them to retain the advanced graphics and visual effects, to give the user an experience similar to playing the games on a console. In short, the multi core CPUs will help to further revolutionize the mobile systems and will pave the way for developing significant applications that will catapult the user experience to a whole new level.

7. REFERENCES

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