ARM AND QUALCOMM:

Enabling the Next Mobile Computing Revolution with Highly Integrated ARMv8-A based SoCs

ARM QUALCOMM

Introduction

In the last five years, there has been a major revolution in how consumers access their digital life. People have moved away from bulky laptops with limited battery life, to smartphones and tablets. This revolution has been enabled by the availability of highly integrated SoCs (Systems on Chip) utilizing the ARM® architecture.

This unique ecosystem has been facilitated by the ARM business model combined with the SoC skills of ARM licensees such as Qualcomm Technologies, Inc.

This white paper examines the forces behind this mobile revolution and what will be required for companies to succeed in future evolutions of mobile computing. This paper will include how the next generation of the ARM architecture, ARMv8-A, will enable the next mobile revolution based around the ARM AArch64 64-bit instruction set while providing full support for today's mobile ecosystem. This includes the recently announced Android L (developer preview) release with ARMv8-A 64-bit support.

The ARM Business Model

ARM is at the heart of mobile computing, powering more than 95[1] percent of smartphones in the main application processor as well as other critical support and communication chips. The ARM business model and the energy-efficient ARM architecture have fostered a wave of innovation in mobile devices from the earliest days of feature phones, to smartphones, and now tablets and new compute form factors.

ARM believes its collaborative business model is a unique differentiator in which ARM licenses intellectual property (IP) designs for CPU processors, graphics processors, system components, and physical libraries to a network of ARM partners who deliver SoC solutions for a wide range of applications. This approach enables ARM partners to innovate, differentiate and deliver industry-leading technology solutions.

Because ARM doesn't specify a mandatory reference design or limit the innovation of chip designers, an extensive range of chips has emerged at a rapid and increasing pace, as original

1 ARM 2014.

equipment manufacturers (OEMs) experiment with design choices and optimizations. Partners license the IP components from ARM that they need for their SoC, while other licensees, such as Qualcomm Technologies, use a combination of custom architecture using the ARM instruction set as well as ARM® Cortex® processor implementations. Qualcomm Technologies, then integrates these CPU designs into SoCs along with other processors and technology blocks that comprise a modern mobile processor. These other blocks are designed to enable everything from fast 4G LTE connectivity to 4K Ultra HD capture and playback. This mix and match approach has allowed silicon partners to focus their resources on the parts of the SoC where they offer unique differentiation and utilize IP from ARM or other ARM ecosystem partners to build the rest.

The Mobile Computing Revolution

The smartphone and tablet revolution has changed the world's perception of what computing is today, and how consumers lead their digital lives. Since the launch of the first ARMv7-A based smartphone five years ago in 2009, the smartphone segment has grown from less than 200 million smartphones shipped to over a billion smartphones shipped in 2013. This growth is mirrored with tablets, starting in 2010 when the first ARMv7-A based tablets shipped, to 2013 in which 250M tablets were shipped, outselling laptop PCs.

FIGURE 1:
SMARTPHONE SHIPMENTS

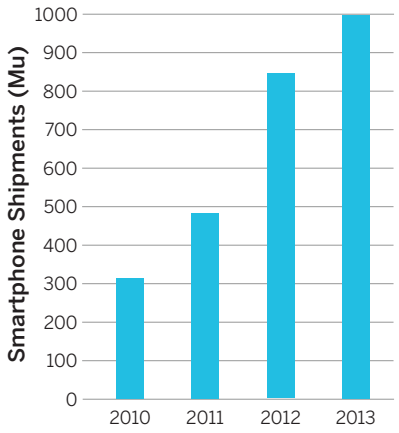
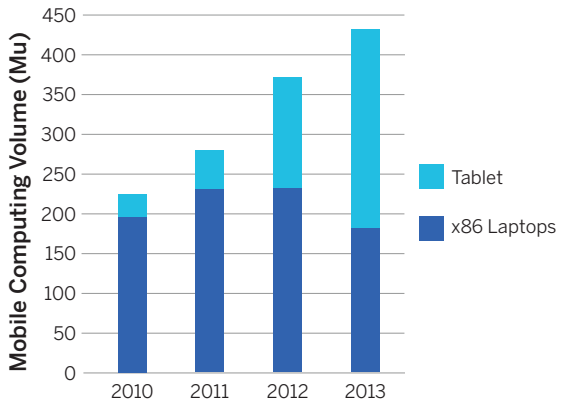


FIGURE 2:
MOBILE COMPUTING VOLUME



Source: ARM and Gartner estimates based on 2013.

The rise of the smartphone and tablet has resulted in a completely new software ecosystem based around mobile device application (app) development. This is now a $26 billion segment, according to Gartner, with over 1 million apps available and over 40 billion downloads to date. This app ecosystem has evolved and has been designed and coded specifically for the ARM architecture in the majority of cases. Emulating this vast application base on other CPU architectures results in significant performance and efficiency penalties as will be detailed later in this white paper.

The success of tablets and smartphones and the resulting app ecosystem is due to the availability of ARMv7-A based SoCs that have allowed end user devices to be built with the right amount of compute performance, the right form factor, and the right battery life for an incredibly diverse range of consumers. "Right" is, of course, a relative term when considering such a broad range of consumers as one size does not fit all. To address these diverse needs, a broad range of ARMv7-A based SoCs have become available to consumers.

These ARMv7-A based SoCs from licensees such as Qualcomm Technologies deliver incredible integration and performance. For example, the latest Snapdragon 810 processor supports:

- Computing performance that is 30x greater than pre-ARMv7-A based smartphones
- Game console quality graphics performance on 2.5K resolution screens, with the ability to concurrently drive multiple displays
- Support for 4K video content
- Ability to support multiple camera sensors with resolutions and frame rates more typical of a Digital SLR
- Fast connectivity with 300Mbps LTE™, location, Bluetooth®, and WiFi® connecting your device locally to your home network, and the devices around the home

This compute revolution in smartphones and tablets would have not happened without the combination of both architecture and implementation expertise. The ARMv7-A architecture delivers highly scalable power efficient compute performance, which is implemented in the highly integrated SoCs that companies such as Qualcomm Technologies, build within that architecture. Yet, these resulting SoCs are just the starting point. The SoC capabilities rely on the strength and diversity of the software ecosystem to bring them to life.

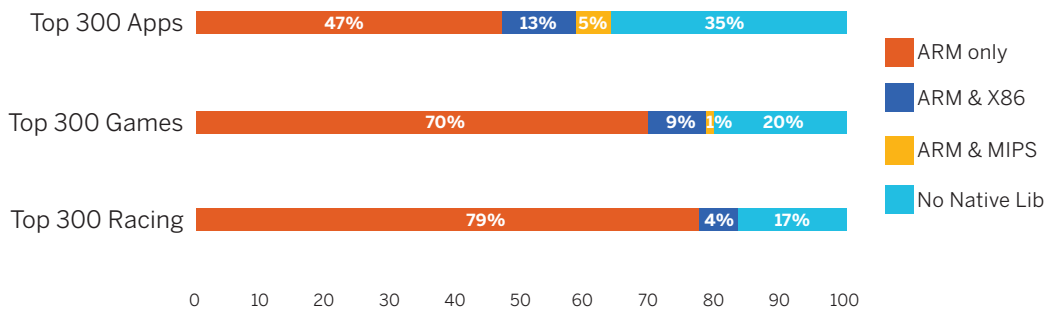
Android on ARMv7-A

The first Android devices were built with ARM-based SoCs and this trend has continued today where over 95 percent of Android devices are ARM-based, ranging from $25 entry-level smartphones to $600 premium smartphones.

ARM has worked closely with its partners to bring the performance and energy efficiency of ARM-based designs to Android devices. The vast ARM ecosystem brings with it a deep wealth of mobile knowledge in both hardware and software to maximize the benefits of the Android operating system (OS) to ensure the best possible experience for users. The combination of these benefits demonstrates why Android is better on ARM.

ARM licensees' leadership in delivering the leading mobile platforms for Android has led to the creation of millions of applications built and optimized for the ARM architecture (see Figure 3). This ability to optimize an application once, while targeting a huge target audience, is one of the strengths of the ARM-based-Android ecosystem.

FIGURE 3:
TOP FREE GOOGLE PLAY APPLICATIONS



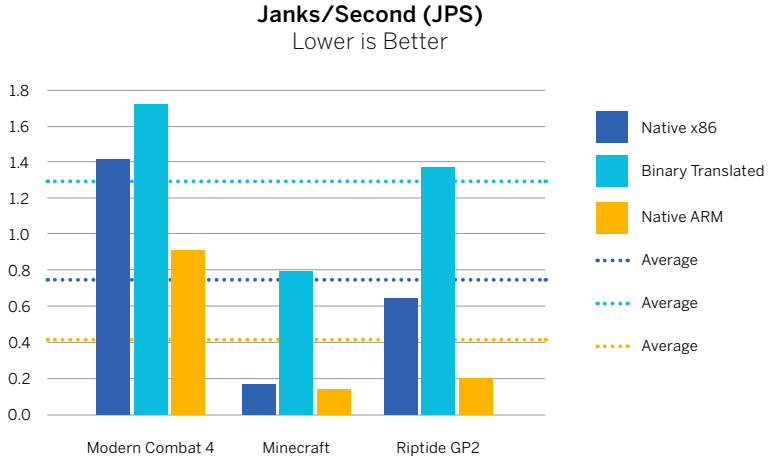
Source: Qualcomm Technologies, Inc., 2014.

In order for other architectures to try to be competitive, some have turned to translating the ARM native code into their own instruction forms within their architectural constraints. This comes at a cost in terms of performance, energy use and stability. This degrades the user experience and impacts battery life. Efficiency, the work done per unit of energy, is heavily impacted where translation between architectures is required.

Battery life is, of course, just one part of the user experience story. The overall perceived user

experience of a device depends in large part on how immediately and smoothly the device responds. Google has put significant effort into eliminating the stuttering on the screen (often known as "jank" in technical circles). Whether it's a simple scrolling of the screen or playing a game, a frame drop is readily noticed by a smartphone user and is detrimental to the user experience. Binary translation on other architectures introduces jank instead of delivering the smooth experience achieved on ARM-based Android devices (see Figure 4).

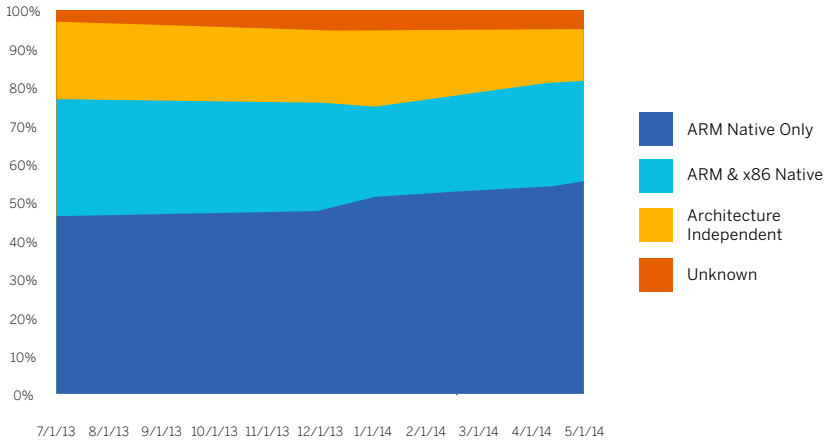
FIGURE 4:
TRANSLATION REDUCES QUALITY OF USER EXPERIENCE



Source: ARM, May 27, 2014.

The popularity of optimization for ARM-based SoCs shows no sign of slowing. Figure 5 shows that over 80 percent of the top 100 Android applications are explicitly targeted towards ARM devices. By comparison, only a few percent also are targeting other architectures. Moreover, other architectures do not have the same reach that ARM provides its developer ecosystem.

FIGURE 5:
CODE FORMAT OVER TIME FOR TOP 100 APPS US GOOGLE PLAY STORE



Source: ARM, May 27, 2014.

Android on ARMv8-A

For the last two years ARM has been working on preparing the way for Android support for the ARMv8-A architecture and 64-bit processing. At the end of 2013 ARM began the upstreaming process into the Android Open Source Project. The work that ARM has done in partnership with Linaro and the ARM ecosystem will enable OEMs and OS providers to take full advantage of the ARMv8-A architecture. On ARMv8-A 32-bit compatibility is fully native and apps co-exist with no performance impact.

Not only have the Linux kernel and tools for compiling Android been optimized for the ARMv8-A architecture, many of the Android subsystems like ART (the new Android runtime), Bionic, media codecs, Skia, and RenderScript have been optimized. Outside of the OS, application developers will also benefit from ARMv8-A improvements to GCC 4.9 and LLVM tools that will be included with the Android NDK. They will also have full, native, debug and analysis support.

In conjunction with Linaro and its ARM partners, Linux kernel support for the ARMv8-A architecture has matured and tools support (GCC 4.9/LLVM-Clang) generates highly optimized 64-bit and Advanced SIMD, NEON code from both regular C code and NEON Intrinsic C. Robust, mainstream Linux support enables ARMv8-A use in applications from servers, to network infrastructure to high performance embedded applications without requiring highly specialized tools and custom applications and libraries.

To understand how future mobile devices will benefit from the ARMv8-A architecture, it also is important to understand the enhancements that the ARMv8-A architecture brings.

ARMv8-A Architecture

ARM's latest architecture, ARMv8-A, is a significant expansion compared to the ARMv7-A instruction set that preceded it. Key features of the ARMv8-A architecture include:

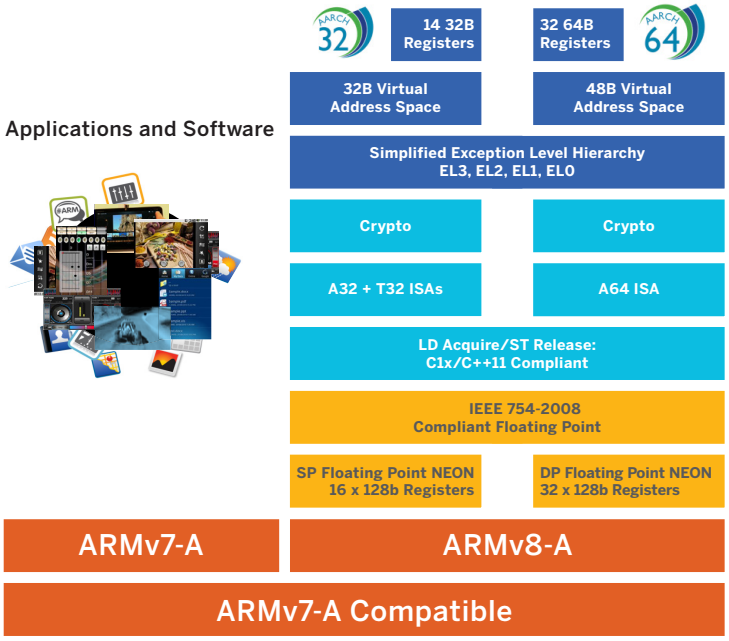
- New, modern, streamlined 64-bit instruction set, AArch64
- Full, rich 64-bit programming model
- Support for AArch32 code base to support today's ecosystem

64-bit allows support for larger memory which can significantly reduce the programming burden in modern operating systems. Many application types will also find native 64-bit processing improves performance even if the larger address space is not needed.

Besides the 64-bit features, the ARMv8-A architecture also adds a number of significant upgrades to improve the programming experience including:

- 64-bit wide registers
- Number of general purpose registers increased from 14 to 32
- Number of SIMD/Floating point registers increased from 16 to 32
- Simplified instruction set to enhance support of compilers and virtual machines such as JavaScript
- Additional cryptographic extensions

FIGURE 6:
THE ARMV8-A ARCHITECTURE IS MUCH MORE THAN JUST 64-BIT



Source: ARM, 2014.

Many of these features will be immediately beneficial to mobile devices. With the memory sizes rapidly growing, the gains from the ARMv8-A architecture will only increase in the coming years.

Power efficiency is the key attribute that has always been front and center of the ARM architecture. The ARMv8-A architecture is no different. Power efficiency begins in the architecture itself—the register definitions are defined to cleanly overlay the existing ARMv7-A register set, allowing a quick and seamless switchover from 32-bit operating mode (AArch32) to the 64-bit operating mode (AArch64) (see Figure 6).

Backward Compatibility to ARMv7-A

One critical benefit of the ARMv8-A architecture is 100 percent compatibility with ARMv7-A architecture-based CPUs that came before, and with custom implementations of ARMv8-A architecture-based CPUs from ARM partners. There are millions of apps for mobile phones across a variety of OS ecosystems, and the overwhelming majority of those apps are compiled and written to target the ARM architecture by default, often the ARMv7-A architecture in particular. The ARMv8-A architecture is completely binary compatible with the ARMv7-A architecture in the AArch32 state, and a 64-bit OS can allow seamless interworking between 32-bit and 64-bit apps on a 64-bit OS.

ARMv8-A is described in further detail in this **white paper**.

ARM Cortex-A53 and Cortex-A57:
The First Two ARMv8-A Licensable Processors

ARM has delivered the first two ARM Cortex processor implementations of the 64-bit ARMv8-A architecture: Cortex-A57 and Cortex-A53.

At the high-end, the ARM Cortex-A57 uses techniques like out-of-order execution, wide multi-issue capacities, and larger memories to achieve unprecedented levels of performance in a power efficient mobile footprint. The Cortex-A57 delivers:

- 20+% more integer performance and 20-50% more NEON and floating point performance than today's premium Cortex-A15 CPU, based on the ARMv7-A architecture
- Higher power efficiency than Cortex-A15

Similarly, the Cortex-A53 CPU uses a simpler pipeline in a smaller configuration that targets a more efficient operating point while still delivering impressive performance, such as:

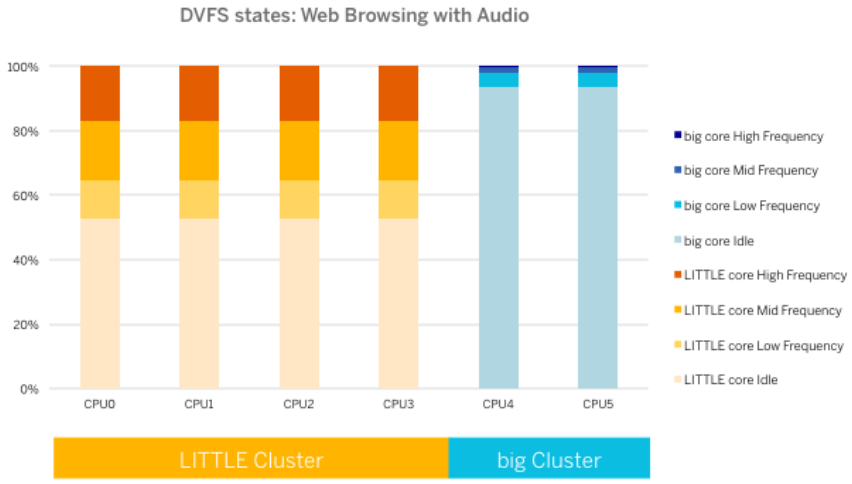
- 40+% more performance than the high-efficiency Cortex-A7 CPU based on the ARMv7-A architecture
- More performance than the previous generation premium Cortex-A9 CPU
- Smallest, highest power efficiency ARMv8-A based processor

Despite its simpler pipeline, Cortex-A53 is fully compatible with the ARMv8-A architecture. This pairing of two CPUs with different power-performance tradeoffs but complete architectural compatibility allows a unique innovation: ARM® big.LITTLE™ technology.

ARM big.LITTLE Technology

ARM big.LITTLE technology combines the high-performance CPUs and smaller CPUs in one CPU subsystem to allow software to dynamically move to the right size processor for the required performance. This combination saves up to 50 percent of the energy for common mobile workloads. A key advantage of big.LITTLE technology is that it maps to the performance peaks and valleys of typical mobile workloads: bursts of peak performance requirements interspersed with periods of relatively modest performance demand. It combines with dynamic voltage and frequency scaling to provide a greater range of performance at the high-end and power efficiency at the low-end, resulting in significant average power savings with essentially no loss of peak performance. Figure 7 shows the frequency states of the big and LITTLE CPU cores in a production big.LITTLE-based SoC while running a web browsing plus audio decode test. big.LITTLE saves power by spending more time running on LITTLE CPUs and powering off the high-performance CPUs except during the short bursts of high frequency operation like those shown in the two right-most columns.

FIGURE 7:
FREQUENCY STATES OF BIG AND LITTLE CPUS RUNNING WEB BROWSING AND AUDIO DECODE



Source: ARM, May 27, 2014.

big.LITTLE is described in further detail in the **ARM Community**. Together this enables developers to begin taking advantage of 64-bit and the improved ARMv8-A architecture features today.

The Transition to the ARMv8-A Architecture

2014 will see the arrival of numerous devices featuring the latest ARMv8-A architecture opening the door for developers to take mobile applications in as yet unseen directions.

Integrating 64-bit compatibility into premium processors has required collaboration with partners and the ARM ecosystem to accelerate the adoption and reduce the time to production of ARMv8-A architecture-based devices. In addition to architectural specifications ARM has developed Fast Models for rapid simulation, reference software and an ARMv8-A architecture-based development platform. Partners have been using **Fixed Virtual Platforms (FVP)** models to run and develop support for both Android and Linux for highly specific, but virtual 64-bit hardware. ARMv8-A **Foundation Models** are freely available and capable of running Linux from Linaro as another way for independent developers and partners to prepare software in advance of ARMv8-A based SoCs. Development tools for compilation, debug and system analysis are also available such as ARM Development Studio 5 (DS-5™) Ultimate Edition, which includes support for ARMv8-A, as well as open-source tool chains such as GCC and LLVM. Together this enables developers to begin taking advantage of 64-bit, and the improved ARMv8-A architecture features today. In addition to understanding the underlying CPU architecture, it is important to understand entire SoC to appreciate the modern mobile experience.

Qualcomm Technologies:
Transitioning to 64-Bit with Integrated Mobile Design

While moving to take advantage of the new capabilities of the ARMv8-A architecture, Qualcomm Technologies, is able to rely on the same design philosophy that has made ARMv7-A based Snapdragon™ processors an unparalleled success in mobile computing. The basis of this philosophy is integration—the principle that in order to give consumers the experiences they demand, a holistic approach is required, with many specialized technology blocks designed to work together to meet the unique demands of modern smartphones.

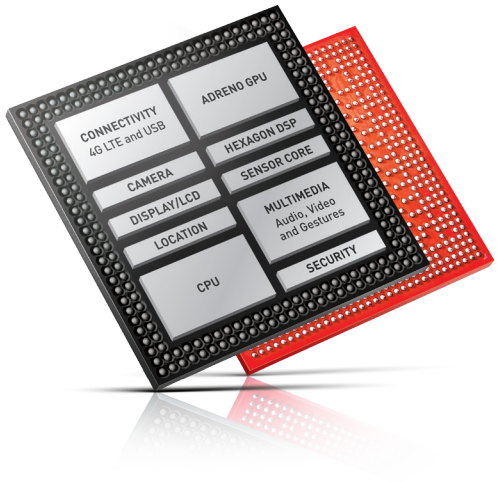
More than anything, mobile design requires an expertly-balanced mixture of performance and efficiency. Expected to act as a communications device, entertainment center, camcorder, navigation device, game console and more, a smartphone or tablet must have a range of capabilities that would have been unthinkable in consumer hardware just five years ago. Because people rely on their devices for so much, those capabilities must be paired with the power efficiency required to work through a full day of heavy use on a single charge. Further, modern smartphones and tablets are subject to some of the most extreme engineering challenges ever faced by consumer hardware. Users demand that mobile hardware fits into ever-thinner, sleeker enclosures that stay cool and work all day.

Because of these heightened expectations and constraints, mobile system design is a fundamentally different challenge than traditional PC hardware design. Where the PC could use virtually unlimited power, straight from the wall, and dissipate heat with large fans and heat sinks, modern mobile design requires a commitment to getting the most out of every milliwatt and every millimeter of silicon.

Integration is the key to solving these challenges. Qualcomm Technologies takes a comprehensive approach to mobile hardware design and develops custom, proprietary technology blocks that make up the complete SoC instead of focusing on the CPU alone. Qualcomm Technologies uses a mixture of custom and ARM designed CPU cores, in addition to other processing blocks. For example, the graphics processing unit (GPU) is custom-designed by Qualcomm Technologies from the ground up to provide the horsepower needed for cutting-edge games and applications. The 3G/4G modem is also custom-made to enable the broad range of always-online functionality expected of a mobile device. Qualcomm Technologies also designs its own powerful purpose-built processing engines like the digital signal processor (DSP), image signal processor (ISP), and video engine, which power the many multimedia and camera-based

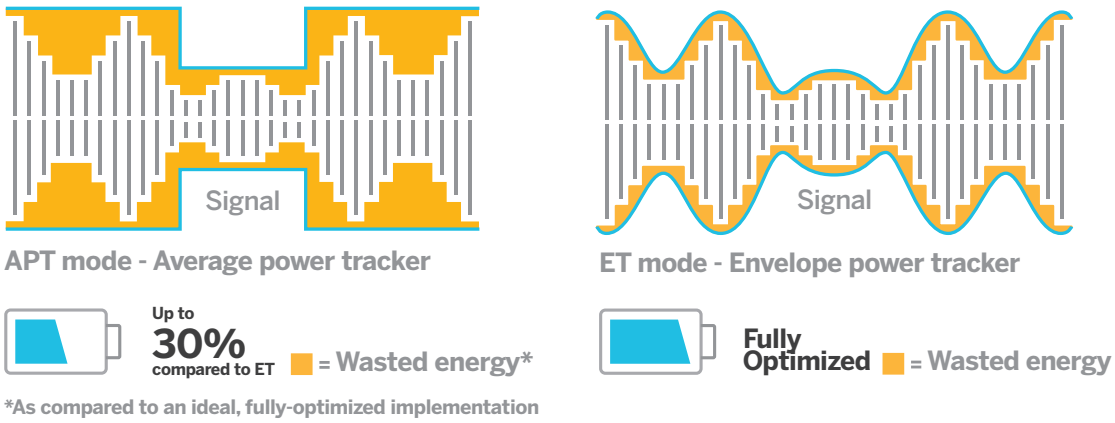
apps available to consumers. Other custom technology blocks include Qualcomm Technologies' own display engine, sensor engine, and other dedicated processing engines that drive the hardware in a modern smartphone or tablet platform.

FIGURE 8:
QUALCOMM TECHNOLOGIES CUSTOM-DESIGNS THE MANY PROCESSING ENGINES THAT MAKE UP A SNAPDRAGON PROCESSOR



By designing and customizing these individual blocks, Qualcomm Technologies secures low-level efficiencies that add up to across-the-board battery life improvements. For instance, Qualcomm Technologies was the first mobile SoC designer to offer Envelope Tracking technology, as part of Qualcomm® RF360™ radio front-end, which reduces the power usage of the Radio Frequency (RF) amplifier by up to 20 percent and its thermal emissions by up to 30 percent. These savings wouldn't be possible without the custom development and integration of the modem, transceiver, and radio front-end.

FIGURE 9:
ENVELOPE TRACKING BENEFITS

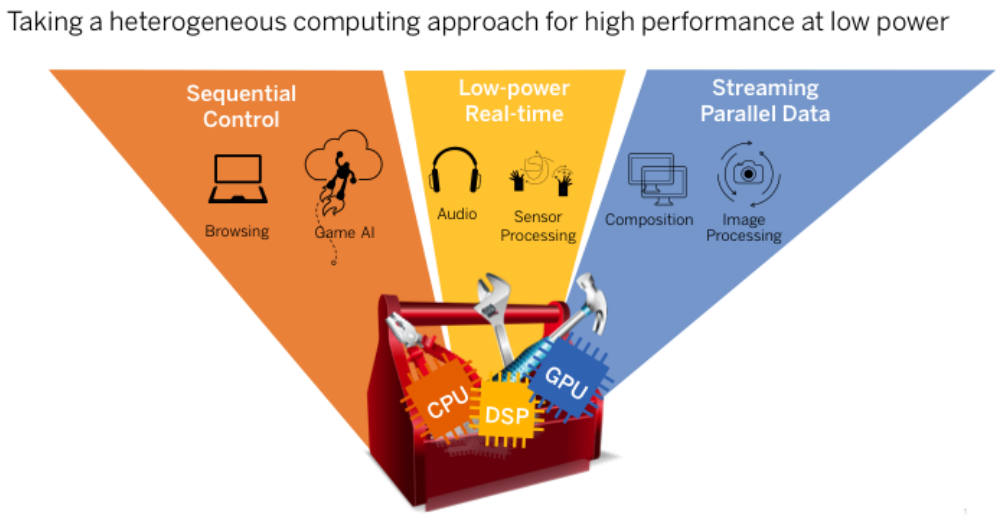


Source: QTI, 2014.

By developing the key technology blocks in tandem, both at the circuit and system level, Qualcomm Technologies is able to create further efficiencies by optimizing the interworking of the many processing engines. The system architecture itself is designed to take full advantage of heavily integrated technology blocks with custom interconnects, caches, memory systems and more.

In mobile design, where user experience is determined more by system efficiency than by raw power, it makes sense to offload as much functionality as possible from the CPU. For many tasks, a specially-designed processing engine can be an order of magnitude more efficient than a general-purpose CPU by itself. In video playback, for instance, a specialized decoding engine can consume one fifth the power used by a CPU performing the same task.

FIGURE 10:
SPECIALIZATION IS KEY FOR MOBILE



Another great example of the benefits of this principle is found in the Snapdragon sensor engine, which is based on the Hexagon Digital Signal Processor (DSP). The DSP is a processing engine ideally suited for the unique challenges of processing data from the wide variety of sensors found in a modern smartphone or tablet. Because Qualcomm Technologies custom-designs the DSP, it consumes very low power and can be integrated more closely with shared system resources, providing a direct path from the DSP to shared DRAM. This direct path means that the CPU doesn't have to wake up when sensor-processing tasks are underway, reducing power consumption and allowing for more of the always-on sensors that are important for new breakthrough consumer experiences. As the number of sensors and other specialized hardware increases with each new generation of mobile device, these sorts of hardware efficiencies will be key to maintaining long battery life.

On a modern Snapdragon processor, less than one-third of the total silicon real estate is taken up by the CPU. The rest is carefully allotted to the many dedicated technology engines like the DSP that help improve the consumers' experiences with their mobile devices. They support reliable networking, multimedia playback and immersive graphics that consumers expect from their devices.

Custom and ARM Designed Processors: The Right Technology for Any Market

The world of smartphones and tablets is diverse, with demand for hardware at a wide range of price points. Qualcomm Technologies is able to address these diverse segments by smartly employing proprietary, custom-designed technology blocks in concert with either a custom design CPU or ARM Cortex CPU designs. The ability to custom-design where it provides the greatest boost to performance and efficiency, while simultaneously taking advantage of the breadth of ARM designed processors available for the ARM platform is a huge advantage for Qualcomm Technologies, and core to Qualcomm Technologies' ability to be competitive at every spot along the price/performance spectrum.

The use of ARM CPUs also gives Qualcomm Technologies the flexibility to respond quickly to the needs of customers. Consumer expectations and use-cases can shift rapidly, and when they do, having access to the huge ARM ecosystem allows Qualcomm Technologies to address those new expectations, shipping silicon faster than if the CPU was custom-designed.

The Snapdragon line of processors, for instance, currently uses a mixture of custom CPUs, ARMv7-A and ARMv8-A Cortex based designs. This mixture provides the right level of technology across all tiers. Today all Snapdragons use ARMv7-A. For Qualcomm Technologies' lower price-ranged SoCs, the entry-level Cortex-A CPUs designed to provide reliable, economical performance, while the Krait family of custom CPUs creates a significant increase in performance efficiency in the high-end phones and tablets segment. With the next generation of products, the use of ARM Cortex-A53 and Cortex-A57 CPUs and big.LITTLE has allowed Qualcomm Technologies to accelerate its plans to bring 64-bit processing across the product line-up.

The key to this flexibility is, of course, the ARM instruction set architecture, which acts as a compatible foundation on which Qualcomm Technologies can build the right technology for consumers. Qualcomm Technologies can either use ARM designed cores, or build designs with

custom microarchitectures that differentiate on performance, efficiency, and features, while preserving interoperability with other technology blocks. A good example of a customization is Asynchronous Multi-Processing (aSMP), a proprietary technology that is designed to allow each Snapdragon processor to dynamically adjust the voltage and speed of each CPU core independently, decreasing wasted power and heat.

Multiple Foundries, Flexible Production

Qualcomm Technologies is fabless, but still committed to advancing manufacturing and process technology. At Qualcomm Technologies, the advantages of the flexible ARM architecture are paired with a unique, versatile production system called integrated fabless manufacturing (IFM). By working closely with select foundries as well as test and service providers, Qualcomm Technologies is able to produce high performance chips in a way that meets the volume and cost demands of the exceptionally competitive mobile industry.

Different chips in a modern mobile device have different process demands, and the IFM model is uniquely capable of meeting those needs. In a Snapdragon processor, the CPU and modem benefit from cutting-edge manufacturing, and are sourced from the most advanced nodes in the network. The RF chip, on the other hand, requires less advanced manufacturing, and can be made at a 65nm process node, and the PMIC can be manufactured at an older-still 180nm node. By sourcing parts from many different process nodes, Qualcomm Technologies can take advantage of less expensive manufacturing at generations-old nodes, while only employing bleeding-edge processing for the chips which will actually benefit from it. Integrated device manufacturers (IDMs) may not have this flexibility, if they are unable to keep multiple-generation-old nodes online.

For more examples and data, see the **IFM white paper**.

Additionally, the IFM model provides the flexibility required to efficiently adapt to changes in demand. When an IDM faces a sudden decrease or increase in demand, they are either left with expensive fabs sitting idle, or have to bring more capacity online to increase volume. Without fabs to fill, Qualcomm Technologies does not accrue extra losses if manufacturing slows, and can quickly bring additional nodes online in order to meet customer demand.

Flexible design practices in action

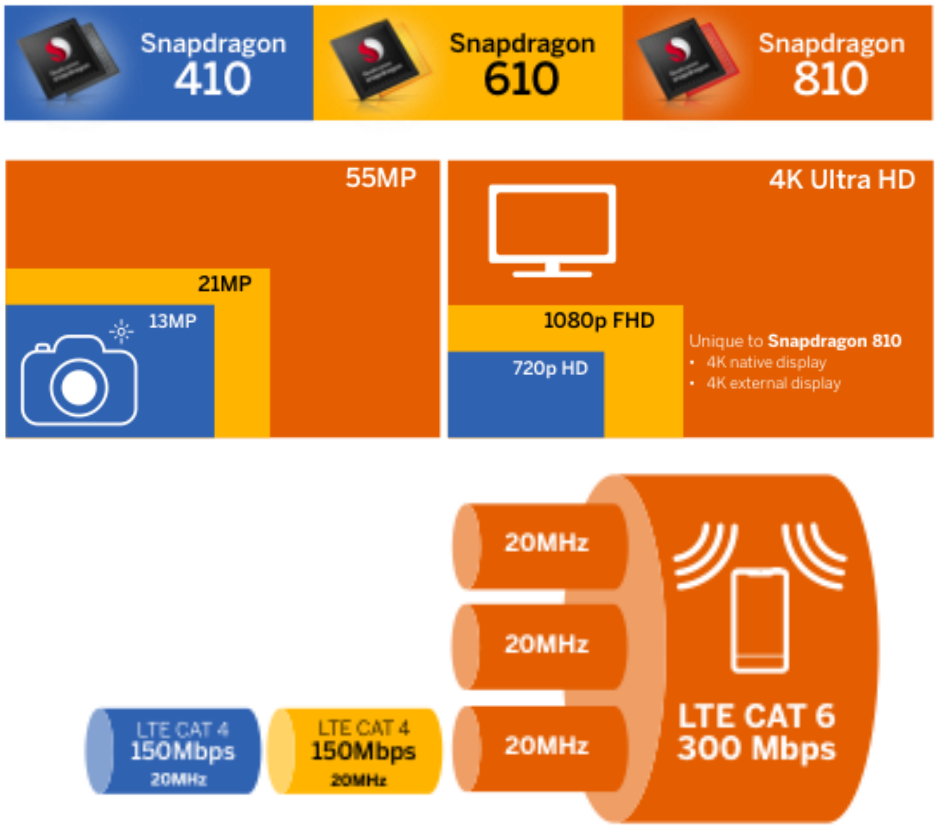
The result of Qualcomm Technologies' flexible approach to design and manufacturing is a set of real advantages. The Qualcomm Technologies design philosophy provides a competitive edge in a number of ways:

Performance and features

Customers have many options when choosing a mobile device, and they're not going to settle for a product that doesn't give them the sorts of experiences they want. Qualcomm Technologies' integrated approach to system design supports phone and tablet platforms that are simply unsurpassed in new, high-performance user experiences. With a wide array of efficient, custom-designed processing engines, Qualcomm Technologies is able to provide the horsepower required for rich multimedia experiences, responsive navigation and engrossing games, without sacrificing battery life—the feature that consumers rate as most important.

The Snapdragon line covers a range of segments, with capabilities that are highly competitive at each price point. The Snapdragon 410 processor supports a 720p HD display, a 13 megapixel camera, and up to 150 Mbps downloads over LTE. The Snapdragon 610 offers additional performance, with support of for full 1080p HD, as well as a 21 megapixel image signal processor (ISP). In the premium smartphone and tablet tier, the Snapdragon 810 processor provides exceptional performance for high-end phones. The Snapdragon 810 can drive a 4K Ultra HD display and a 55 megapixel camera with support for 4K video recording, and its 4G LTE Advance modem supports 3x20MHz carrier aggregation for speeds up to 300Mbps. The Snapdragon 410, 610, and 810 all include 64-bit ARM Cortex CPU cores with support for the ARMv8-A instruction set architecture.

FIGURE 11:
INCREASING CAPABILITY ACROSS QUALCOMM TECHNOLOGIES SNAPDRAGON PROCESSOR TIERS



Price point and development time

The low-priced smartphone and tablet segment is extremely competitive, and calls for hardware that can provide uncompromised user experiences for a very aggressive price. Again, it's Qualcomm Technologies' integrated, flexible design philosophy that makes the 200- and 400-series Snapdragon processors successful in entry-level smartphone tiers. By integrating cost-effective ARM Cortex cores with custom processing engines, Qualcomm Technologies is able to keep prices low while still offering efficient, powerful hardware.

Additionally, the flexible IFM production model allows Qualcomm Technologies to optimally serve a wide range of customers, reduce overhead and to quickly respond to changing consumer demand. At the low end and at the high end, Qualcomm Technologies is uniquely positioned to provide exactly the right hardware at exactly the right price.

Conclusion

The ARMv8-A architecture represents an exciting new frontier for the ARM ecosystem and Qualcomm Technologies in mobile devices and how they compute. In recent years, this combination of superior architecture with top-notch hardware design has made the ARMv7-A architecture an industry-leading success and transformed the way that consumers use their mobile devices. The ARMv8-A architecture isn't starting from a blank slate, but rather is an opportunity to build on the success of the ARMv7-A architecture with hardware that's 100-percent backwards-compatible with the massive ecosystem of Android software.

Qualcomm Technologies is an early leader in hardware design which takes advantage of the strengths of the ARMv8-A architecture. The flexibility of licensing the ARM instruction set or the Cortex CPUs helps to address a full and diverse product portfolio. Snapdragon processors with integrated 64-bit ARM CPUs, when combined with the benefits of the ARM ecosystem and the many other custom technology blocks, will enable an entirely new generation of user experiences.

The ingredients of success in mobile computing include a pervasive and efficient ecosystem and the combination of integrated and customized SoCs. Through this relationship, ARM and Qualcomm Technologies will help to advance and evolve the ARM for Android ecosystem, including for the recently announced Android L (developer preview) release with ARMv8-A 64-bit support.

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