



Snapdragon S4 Processors: System on Chip Solutions for a New Mobile Age

White Paper

Executive Summary

A New Mobile Age is Here. Today, consumers are able to combine the full benefit of always-on, high-speed internet coupled with highly capable electronics designed to enrich their lives with information and entertainment. With high speed LTE networks being deployed globally, today's consumers expect their devices to go anywhere, do everything and run all the latest apps including browsing the web, email, chat and social networking, HD video and interactive gaming. It's no longer a world solely driven by megahertz or simply adding more CPU cores to solve the performance hurdles faced by device manufacturers. Ever higher demands for performance and longer battery life on mobile processors are making it more difficult for traditional PC solutions to keep pace with the fully connected future. A new approach is needed.

To fully meet this challenge, Qualcomm is taking the mobile industry to the next level of processing with the introduction of the Snapdragon S4 class of processors. The Snapdragon S4 class incorporates the latest in mobile architecture design and technology to address the demands for intelligent connectivity, high performance and energy efficiency.

- **First on 28nm process technology:** Snapdragon S4 processors are the first mobile processors to be manufactured using the latest 28nm process technology that provides inherent advantages in frequency scaling, power consumption and size reduction.

- **First Fully Integrated 3G/4G:** The S4 class includes the industry's first fully integrated LTE world mode/multi-mode modem.

- **Uses ARM® instruction set, software and eco-system:**

Snapdragon S4 processors are the first processors in the industry to be designed specifically for advanced process technology and uses the ARM instruction set architecture (ISA).

Snapdragon S4 processors are complete solutions that provide a superior balance of performance and power efficiency delivering:

- **Superior CPU performance:** Multicore CPUs with a frequency range of 1.5Ghz to 2.5Ghz per core and supporting asynchronous symmetric multiprocessing (aSMP) for the optimal balance of performance and power efficiency.

- **Superior modem performance:** The industry's first fully integrated LTE world/multimode modem with support for the widest range of frequencies and bands—including full multimode support for existing standards such as EV-DO and HSPA.

- **Superior graphics performance:** High performance programmable Adreno GPUs for the highest quality video and console quality gaming.

- **Superior power efficiency:** Tight integration of best in class components and use of highly efficient, low power engines such as Qualcomm's fully programmable Hexagon DSPs result in a highly power efficient system. Connectivity options also include integrated GPS, Bluetooth, WiFi, and FM.

With the next generation of Snapdragon S4 processors, consumers will experience the rich benefits of high-speed internet fully integrated into their mobile devices. The Snapdragon S4 processors combine outstanding performance and battery life with innovative technologies for the new mobile age.

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Snapdragon S4 System Overview

First Mobile Introduction of 28nm Process Technology.

Qualcomm designs its own custom CPU cores based on the ARM architecture, which allows greater design flexibility at both the CPU and system level. Snapdragon S4 processors are the first mobile processors manufactured in 28nm process technology using the ARMv7 Instruction Set Architecture (ISA) to establish a new generation of performance. By migrating to a 28nm process, Qualcomm is able to deliver a highly compact, efficient design able to scale across multiple form factors from mass market smartphones and tablets to compact laptops, delivering higher performance with less power.

Next Generation Technology Today. The S4 class represents the industry's only fully custom system on a chip optimized for the mobile experience and incorporates innovations such as per-core dynamic power management, next generation highly parallel and programmable GPU, LTE world multimode modem, high speed dual channel interleaved memory, and programmable DSPs. Snapdragon S4 processors will be available in single, dual and quad CPU configurations for maximum design flexibility. Customer samples are shipping now, approximately six months ahead of any comparable solutions.

Snapdragon S4 Processors: Superior Thermal Performance

Purpose Built for Mobile Applications. Snapdragon S4's compact design and next generation process technology provides a highly efficient thermal micro-architecture. Current generation ARM CPU designs cannot achieve the same level of power efficiency the new Snapdragon S4 class delivers. Snapdragon S4 benefits from 28nm process technology and newly developed cores which provide:

- Smaller size
- Lower power
- Improved thermal performance

We expect to see S4 processors hold peak performance longer than other processors under a constant workload due to the efficient use of power. Less power lost to leakage translates into better battery life.

Significant Thermal Advantage. Figure 2 shows how S4 in 28nm process technology outperforms leading ARM based designs in 40nm G process by a significant margin, allowing greater OEM design flexibility.

Figure 1: MSM8960 Block Diagram

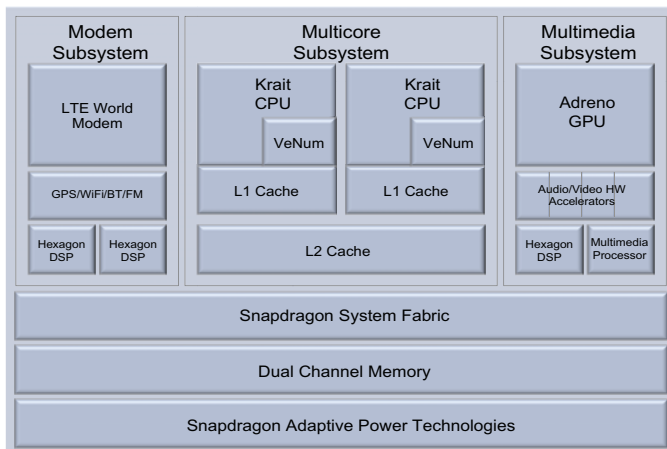
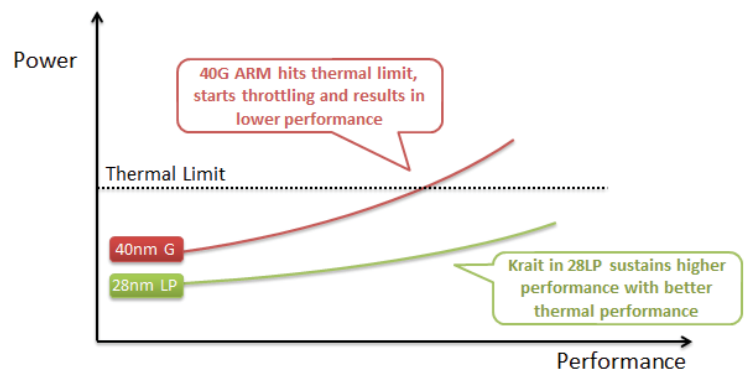


Figure 2: Enhanced Thermal Performance



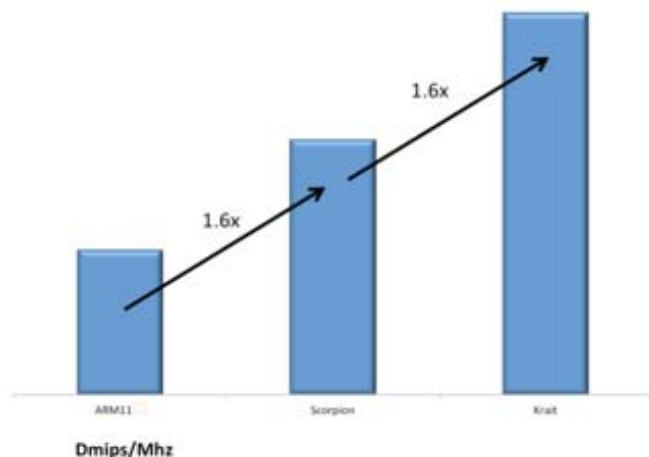
New CPU Architecture

The Snapdragon S4 processors introduce Qualcomm's second generation CPU, code-named "Krait." Krait represents a new class of high performance CPUs while delivering unmatched energy efficiency.

Krait Offers Unmatched Performance. Krait outperforms current ARM CPUs on a core-to-core basis. To achieve the best performance and power efficiency, Krait includes key advanced design approaches:

- **New CPU micro-architecture:** Krait was designed to provide the performance headroom for a new generation of smartphones, tablets and laptops. A new pipeline architecture increases the performance of Krait by over 60% compared to Qualcomm's existing Scorpion CPU micro-architecture.
- **SIMD/VFP performance:** Krait also includes a performance-enhanced floating-point and SIMD functional unit which maintains the industry leading 128-bit data-path. Optimized computational units, including those for double-precision calculations, speed through math intensive applications with minimal power consumption.
- **Optimized memory subsystem:** Krait includes dual-channel memory. Dual-channel memory is critical in order for the processor to handle the large bandwidth requirements in multicore systems. Figure 3 shows Qualcomm's CPU performance roadmap:

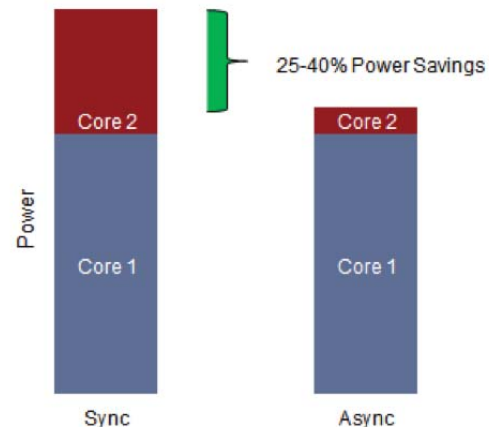
Figure 3: CPU Performance Roadmap



aSMP: Designing with Power Efficiency in Mind. To achieve better power, performance and thermal envelope, Qualcomm designed the Krait micro-architecture as an asynchronous Symmetrical Multi-Processor system or aSMP. The difference between an aSMP and a synchronous SMP system is:

- **Independent clock and voltage:** Each core in the aSMP system has a dedicated voltage and clock including the L2 cache. This enables each CPU core to run at the most efficient power point or voltage and frequency depending on the type of workload being executed.
- **25–40% power improvement:** As figure 4 shows, the aSMP architecture results in a 25–40% power improvement over current synchronous SMP architectures.
- **Standby power:** In aSMP, each core that is not being used can be completely collapsed independently resulting in no power consumption in idle state.
- **Reduced complexity:** aSMP also eliminates the need for "companion" or "little" cores since each core in an aSMP system can be operated in low power mode due to the independent voltage and frequency control per core thus reducing the need for hypervisors or more complex software management of disparate cores.

Figure 4: Async CPU Power Savings



Krait Outperforms Current Processors at Significantly Lower Power.

- **New circuit techniques:** Krait is also designed using a custom design flow that incorporates new circuit techniques to improve performance and power. The result is a very efficient and wide range of Dynamic Clock and Voltage Scaling (DCVS) which addresses usage models from active standby to mid and high level processing requirements. A Krait CPU can smoothly scale from low power, low leakage mode to blazingly fast performance.

- **Low power micro-architecture:** Krait also includes new micro-architectural optimizations throughout the design such as more efficient branch prediction and more balanced pipeline utilization that achieve a balance between energy efficiency and performance.

- **Thermal:** Krait power efficiency also results in a better thermal envelope. This allows Krait multiprocessor systems to run at peak performance for a longer time when compared to competitive solutions and simplifies the system level design like board designs, power delivery and overall system cost.

In summary, Qualcomm's Krait CPU sets a new bar when it comes to performance and energy efficiency.

New Adreno Embedded GPU

The S4 processor family incorporates the latest in GPU technology starting with the Adreno 225 Graphics Processing Unit (GPU).

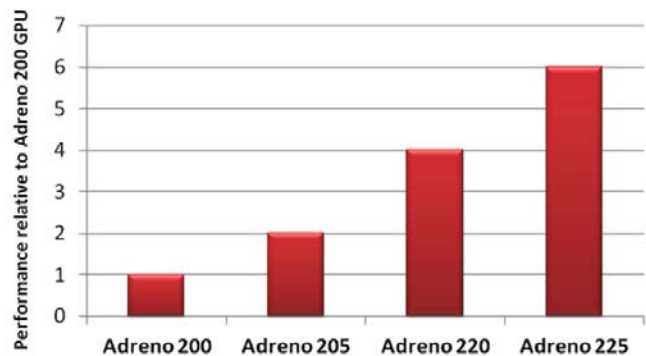
- **50% increase in GPU performance:** The Adreno 225 GPU delivers 50% greater graphics processing power over the previous generation Adreno GPU, Adreno 220, and six times the processing power of Adreno 200. As the chart below shows, Adreno continues to deliver significant performance gains. See Figure 5.

- **Unified Shader Architecture delivers superior performance:** Built on a proven track record of highly capable Adreno embedded processors, the Adreno 225 GPU is a fully programmable OpenGL ES 2.0 GPU with a Unified Shader Architecture (USA). Adreno's USA maximizes the processing power of the GPU by offering flexible vertex and shader processing. This unique architecture is a significant leap forward in visual graphics quality from earlier "fixed function" OpenGL-Es 1.x GPUs. As Figure 5 shows, USA provides superior graphics performance.

The Adreno 225 GPU has twice the memory bandwidth of its predecessor, which further contributes to better graphics performance at higher display resolutions.

The APIs supported by Adreno 225 include OpenGL ES 1.1, OpenGL ES 2.0 and DX9.3.

Figure 5: Adreno Power Improvements



Adreno 225 Fully Supports Windows 8. Relative to Adreno 220, Adreno 225 includes more features, primarily to support DirectX 9.3 for Windows 8. These new features include:

- Increased unified shader flexibility and capability
- Improved texture engines with support for sRGB textures
- Enhanced rasterization hardware with support for multiple render targets, user clip planes, instancing and other advanced features improved blt and interrupt performance

Binning Provides Greater Efficiency in GPU Rendering. Adreno GPUs also utilize a unique binning-based approach to rendering, which contributes to lower memory bandwidth consumption and maximum concurrency capability. Figure 7 shows an example of binning.

Because of the fast pace of innovation occurring in the graphics industry, Snapdragon S4 processors will continue to evolve and incorporate the latest in GPU technology while maintaining tight integration and full system compatibility.

Integrated LTE World/Multimode Modem

Snapdragon S4 Processors include a brand new modem designed for speed, battery performance and worldwide network compatibility. The first Snapdragon S4 processor, the MSM8960™ chipset, includes:

- **Industry's first fully integrated 3G/4G world/multimode LTE Modem:** Supports all of the world's leading 2G, 3G and 4G LTE standards. It also includes integrated support for multiple satellite position networks (GPS and GLONASS) as well as short range radios via Bluetooth, WiFi, FM and NFC.

- **Designed for speed, compatibility and power savings:** Snapdragon S4 Processor MSM8960 chipset includes the industry's only complete platform that integrates all of the world's leading 2G, 3G and 4G mobile broadband modem technologies on a single chip. This new integrated multi-mode modem is based on an advanced, programmable architecture that is performance, size and power optimized for the fastest combination of modems available for:

- LTE FDD/TDD (Cat3)
- 3G (DC-HSPA+ Cat 24)
- EV-DO Rev. B
- 1x Advanced
- TD-SCDMA
- GSM/GPRS/EDGE

Figure 6: Unified Shader Architecture

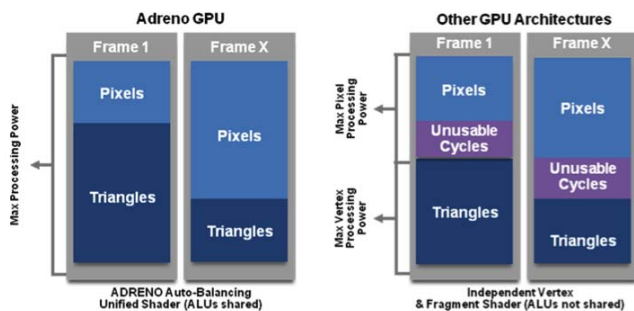
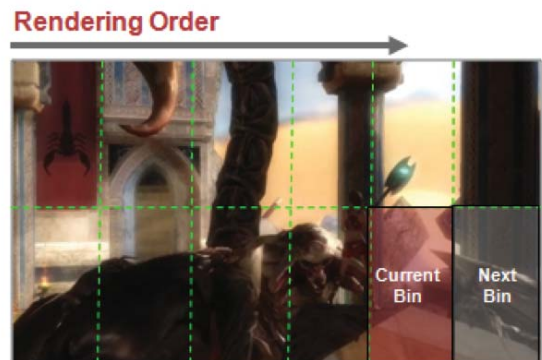


Figure 7: Binning Example



• **Connectivity flexibility:** Enables a rich roadmap of modem enhancements and features that can be implemented in software. In addition to mobile broadband connectivity, the Snapdragon S4 has integrated many other popular wireless technologies including:

- Bluetooth 4.0
- GPS (using both GPS and GLONASS networks simultaneously)
- WiFi a/b/g/n

• **Simultaneous voice and data:** For LTE handsets, the 8960 modem enables UMTS/GSM voice and LTE data (CSFB), as well as simultaneous CDMA voice with LTE data (SVLTE).

Advanced Receiver Technology.

• **Increased user throughput and network capacity:** In addition, the modem incorporates Qualcomm's latest generation of advanced receiver technology, such as Q-ICE™, QLIC and gRICE™, which equalize multipath signals and suppress multi-cell interference to significantly increase user throughput and network capacity for UMTS and CDMA respectively.

• **Power savings of 20–30%:** The modem achieves its low power consumption through the use of standards-based power saving methods such as Continuous Packet Connectivity (CPC), in addition to Qualcomm developed techniques such as Average Power Tracking (APT) to manage power and thermal heat more efficiently, lowering power consumption by up to 20–30% based on QCT internal lab and field data. This allows OEMs to design smaller, thinner and sleeker devices with longer battery life.

Multimode/Multiband Means Worldwide Coverage.

• **Support for multiple radio frequencies:** Mobile broadband technologies are growing increasingly complex in their implementation. LTE is currently being implemented in over 40 different radio frequency bands throughout the world. To complement its wide range of modem standards supported, Qualcomm has designed the Snapdragon S4 Processor MSM8960 CHIPSET platform to address all commonly-used frequencies (from 700–2600 MHz) and bandwidths up to 20 MHz, allowing its customers to address any mobile network opportunity whether the simplest single frequency implementation to the most extensive multi-frequency global mode, whether 4G, 3G or 2G.

• **Solving signal interference:** Though supporting multiple radio frequencies on the same chipset can present problems with signal interference, the MSM8960 utilizes Qualcomm's expertise in radio and modem design to enable coexistence of many operating frequencies and modem concurrency scenarios.

• **Multimode for seamless handover:** Qualcomm's multimode "smart" modems can identify the best available network technology and quickly and seamlessly change to that technology in a way that's transparent to the end user. For data, the 8960 modem utilizes reselection, redirection and packet switched (PS) handover to facilitate seamless handover to EV-DO and HSPA when users move out of LTE coverage. For voice, the 8960 modem can initiate circuit switched (CS) fallback to UMTS, 1x or GSM when the user is in an LTE data session. Qualcomm's CS fallback solution implements the latest version of the standard—release 9 with system information (SI) tunneling—to reduce incremental call setup time to less than one second. CS fallback is a widely adopted standard for LTE voice and global roaming.

Hardware and Software Integration.

• **First fully integrated world mode/multimode LTE:**

Qualcomm's modem is jointly-designed to work intelligently with high performance application processors such as the Snapdragon S4 Processor. It is the industry's first LTE/3G multimode modem to be integrated with an application processor on a single chip platform for handsets, tablets and other consumer devices. The modem is Qualcomm's second generation LTE/3G multimode modem and its MSM8960 chipset implementation will include the latest LTE release 9 features, such as SI tunneling for enhanced CSFB performance, eMBMS, enhanced position location for E911, as well as several IMS-based features such as VoLTE, SR-VCC, RCS and video telephony.

• **Real time adaptability for the best network connection:**

In addition to seamless inter-RAT cellular mobility, the MSM8960 chipset can automatically make real-time choices to connect to the best network currently available—whether 3G, 4G/LTE, WLAN or BT. This is done through a software stack in the modem that actively identifies and chooses the best available channel for any wireless communication.

- **Optimizing upload and download capacity:** The software also employs real-time traffic control to optimize upload and download capacity for the smoothest connections. This is especially important for connected applications like interactive gaming and streaming media, where demands on connection capacity vary from moment to moment, yet smoothness and speed are critical. Qualcomm modems also go through an extensive pre-testing, network interoperability testing and network certification process. This helps to ensure that in combination with their extensive set of modem optimized APIs, Qualcomm modems also provide an end-to-end solution that is compatible with the widest range of networks (public and private) with the best total connected experience while using the lowest battery power.

Programmable Hexagon DSP™ Architecture

Custom DSP: An Integral Partner in Overall System Performance. In addition to designing custom CPUs, GPUs and modems, Qualcomm also designs its own custom digital signal processors (DSP). Hexagon™ DSPs have been an integral part of Snapdragon processors. Figure 8 shows the Hexagon DSP evolution and roadmap.

- **High-capability, low power engine:** The Hexagon DSP combines the best features of both CPU and DSP architectures to achieve a high performance, ultra low power processor. Unique to Qualcomm's Hexagon DSPs is the addition of a memory management unit, symmetric multiprocessing support and a hypervisor for increased capability. The Hexagon DSP's used in Snapdragon S4 Processors have dedicated L1 instruction and data caches, a dedicated L2 cache and are designed using an interleaved multi-threading (IMT) architecture, meaning each thread is resourced with independent program counters and registers. The Hexagon DSP is capable of running multiple applications concurrently much like a CPU but, because it's designed for ultra low power, is optimally positioned for offloading specific tasks like audio, sensors, video, and imaging enhancement.

- **Highly efficient workload management:** By leveraging the Hexagon DSP within the Snapdragon S4 processor, Qualcomm is able to achieve significant performance improvements without having to use additional CPUs or factor in having to dynamically switch tasks between cores which can introduce inefficiencies in performance and power.

Enhanced Multimedia Efficiency using DSP Offloading. Hexagon DSPs have a substantial role to play in the area of multimedia. Most multimedia functions can be more efficiently processed using Qualcomm DSP technology.

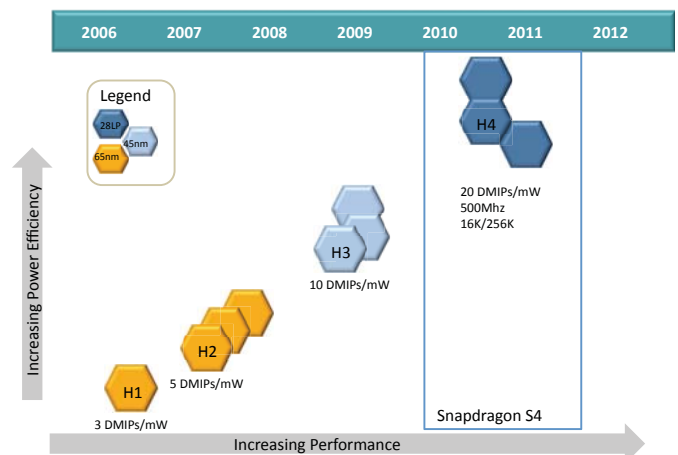
- **Improving overall system performance:** Hexagon DSPs are designed to ensure that the number of compute cycles needed to execute each function is very predictable. This high level of predictability ensures that Hexagon DSPs are extremely reliable and low power in multimedia applications. Once a function has been offloaded to a DSP on the Snapdragon S4 Processor, they are unaffected by user application loads on the CPUs.

- **Lower power:** Hexagon DSPs not only free up cycles on the CPU, but also improve overall system performance by taking on additional tasks such as multimedia, imaging enhancement, augmented reality, and other multimedia functions.

- **Robust tool chain:** The unique capability of the Hexagon DSP is the result of custom blending both CPU and DSP architectures. This allows Qualcomm to provide a robust tool chain to allow optimized programming in higher level languages (C, C++, etc.) targeting a powerful real-time operating environment.

- **DSP access program:** Qualcomm's DSP Access Program also allows OEM's and ISV's to independently develop customized DSP applications to further enhance Snapdragon processor operation.

Figure 8: Hexagon DSP Evolution and Roadmap



Summary

Snapdragon S4 Processors introduce key technology innovations in CPU, GPU, Modem and DSP technologies. Qualcomm's highly integrated and customized solution approach enables the deployment of next generation technology today. Snapdragon S4 Processors deliver the performance, energy efficiency and the scalability required for the new mobile age.

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