Summary

Android 4.0, also known as the Ice Cream Sandwich (ICS) release, offers an exciting new array of user experiences and unprecedented performance and functionality by using the smart multicore OMAP™ 4 mobile processors from Texas Instruments Incorporated (TI). Android 4.0 unites smartphone and tablet solutions in a single software suite. At the same time, this latest Android release introduces significant software architecture changes, framework components, and performance enhancements. With more than seven million new or changed lines of software, Android 4.0 raises the bar by adding compelling user experiences, software complexity, and performance requirements that are best met with the OMAP™ family of applications processors.

To enable the fastest time to market with ICS, TI has already released the full-featured Android 4.0 OMAP 4 Board Support Package (A4O4 BSP) for the OMAP 4 platform. This BSP has been fully integrated and validated on the OMAP4460 processor-based Blaze™ Tablet2 development platform to ensure that OMAP platform-powered designs can fully leverage the capabilities of ICS. Together, the uniquely-balanced OMAP 4 architecture and Android 4.0 platform offer a truly aligned hardware and software solution.

Architectural Harmony

Beyond dual-core symmetric multiprocessing, Android 4.0 introduces several new components that enable efficient use of the OMAP 4 platform's asymmetric smart multicore architecture to maximize parallel computation performance at the lowest power consumption. These components are fully integrated with the new graphics and video composition architecture in ICS and are included in the A4O4 BSP to reduce system use by up to 47 percent compared to alternative solutions.

Incredible Imaging

The raw image processing performance of the OMAP 4 platform and the new zero shutter lag features in ICS ensure that when taking photos, what you see is what you get, whether you are taking still images or saving full resolution snapshots while recording HD 1080p video. Newly Android features provide applications with rich control of the sophisticated imaging algorithms provided by the OMAP 4 system architecture.

Power Optimized

The A4O4 BSP benefits from extensive system profiling to fully tune the OMAP processor's power management capabilities, providing the industry-leading set of power management capabilities and optimal system performance across the entire smart multicore architecture.

Secure Content Protection

TI's M-Shield™ mobile security technology is fully integrated with Android 4.0's new security API to protect content including HD video streams, private assets, and mobile payments. On OMAP 4 processors, DRM content is protected end-to-end throughout the decryption, decoding, and rendering process with hardware-enforced security. The OMAP 4 family is the only mobile processor family to achieve both Netflix HD (with Microsoft PlayReady™ DRM) certification and Widevine DRM compliance at the highest security levels required for HD content streaming.

Defining Open Development with Android

In addition to the community resources available from pandaboard.org, the Android Open Source Project has now added PandaBoard as the only low-cost mobile development platform supported directly on the AOSP mainline. This enables even more developers to provide innovative solutions for inclusion in differentiated OMAP 4 platform-based mobile products.

Differentiated Solutions

The latest A4O4 BSP also includes features that extend beyond the capabilities of Android 4.0 to enable truly differentiated products. The programmable graphics, imaging, video and DSP accelerators in the OMAP platform not only enable differentiation at product launch, but also ensure that your mobile device software can be upgraded as Android continues to evolve.

TI's author:

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OMAP Platform Business Unit

A Perfect Match: OMAP™ 4 Platform and Android 4.0 Ice Cream Sandwich

The OMAP Platform: Balanced for Performance

The OMAP platform is comprised of a carefully balanced system which gives customers distinct advantages when designing Android-based mobile devices. This system is designed for the highest performance at ultra-low power, using a differentiated smart multicore architecture honed by TI for more than a decade.

The OMAP 4 platform's smart multicore system uses two ARM® Cortex™-M3 cores to offload real-time control processing from the two main ARM® Cortex™-A9 CPU cores. It also relies on unique programmable accelerators—an embedded DSP, an imaging and vision IMX accelerator, and display controller—rather than hardwired accelerators to add flexibility and future-proofing to designs. Further, dual-channel memory provides an unparalleled bandwidth support necessary for HD multimedia, HD displays and multi-tasking—ensuring that OMAP 4 processor-driven designs can deliver the ultimate mobile experiences end-to-end.

Android 4.0-OMAP™ 4 BSP is Now Available

With the public release of Android 4.0, also known as Ice Cream Sandwich (ICS), in the Android Open Source Portal, Texas Instruments Incorporated (TI) simultaneously released the Android 4.0 OMAP 4 Board Support Package (A4O4 BSP) for the OMAP4430 and OMAP4460 smart multicore mobile processors. This BSP includes the Linux™ kernel v3.0.1, hardware-accelerated 1080p video decoders and encoders, imaging solutions for support of up to 20-megapixel raw camera sensors, power control, support for TI's quad-radio WiLink™ 7.0 connectivity combo solution, and more all integrated with Android 4.0.

Figure 1 includes a few key software blocks in the A4O4 BSP that are central to providing unsurpassed system performance and power efficiency when delivering some of the new things people will love most about Android.

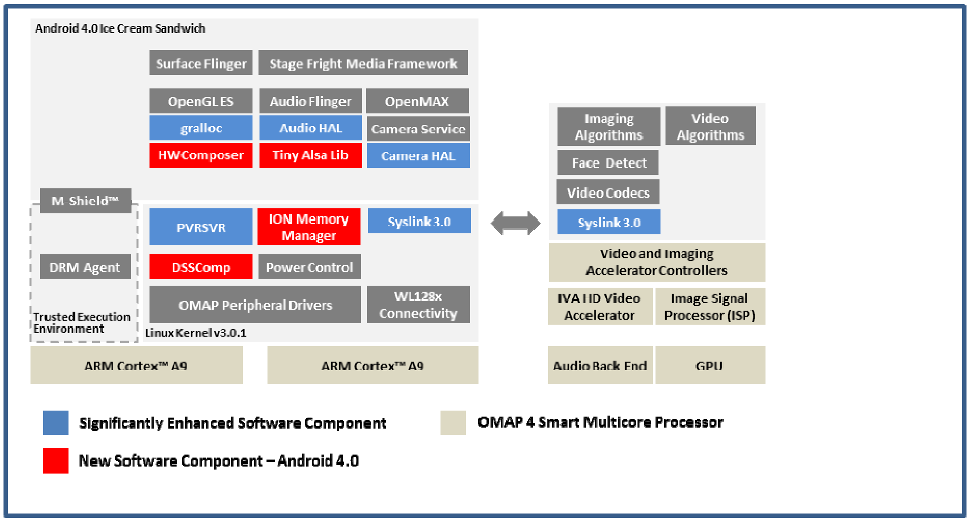


Figure 1 *- Android 4.0 OMAP 4 Board Support Package (A4O4 BSP) Architecture Overview (Selected Components)*

New Graphics and Video Composition Architecture

OMAP4460 mobile processors are uniquely suited to provide the smooth User Interface (UI) experience and powerful graphics performance expected with Android 4.0. For a high-performance UI that provides the best user experience, it is important to keep the composition rate of the UI layers very close to the refresh rate of the display no matter how many surfaces are involved in the composition. This eliminates any noticeable lag in UI responsiveness when used.

As mobile devices running Android are increasingly moving to support displays with higher resolutions and multiple simultaneous displays, the composition workload on the GPU is increasing as a result. At the same time, more of the UI content generation has been moved from the MPU to the GPU with Android 4.0 through the use of the OpenGL® ES application programming interfaces (APIs). All of this points to the benefit that can be achieved if some of the composition work is offloaded from the GPU. The OMAP4460 processor has the extended composition acceleration capabilities needed to offload much of the composition workload normally handled by the GPU in most UI and video display scenarios.

In Android 4.0, the composition and rendering of graphics and video layers to the final display has changed significantly to leverage hardware composition resources provided by the OMAP4460 architecture. Using the GPU for composition of UI layers ensures combined output including 3D objects and video, but using the GPU for all composition is often costly in both power and performance.

The OMAP4460 mobile processor provides increased composition acceleration capability, along with a large system memory bandwidth enabled by its dual-channel 32-bit LPDDR2 memory. Together, these architecture elements help provide the high composition rate required for the smooth user experience expected on today's high resolution displays. The OMAP4460 processor's features used for graphics content generation and display composition are:

- The PowerVR™ SGX540 graphics processing unit (GPU)
- A Display Subsystem (DSS) with four hardware display pipelines that are used to further offload composition work by composing graphics and video surfaces involved in the composition directly to the display in a single pass.

During composition, SurfaceFlinger now calls the new Android HWComposer HAL component to enable composition of graphics or video layers using the underlying OMAP system-on-chip (SoC) capabilities. The OMAP platform implementation of HWComposer works with DSSCOMP to dynamically assign layers for composition by the four DSS pipelines available in the OMAP 4 architecture and to configure the output destination for each layer. This provides the flexibility to assign the DSS pipes to different content and different display destinations for every display frame.

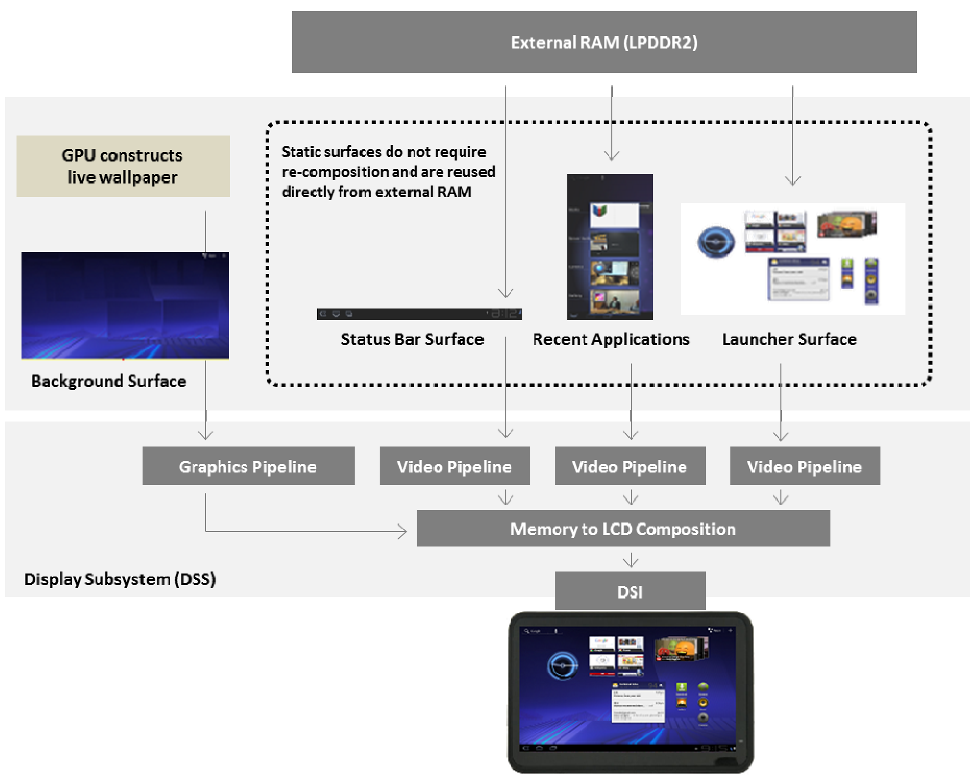
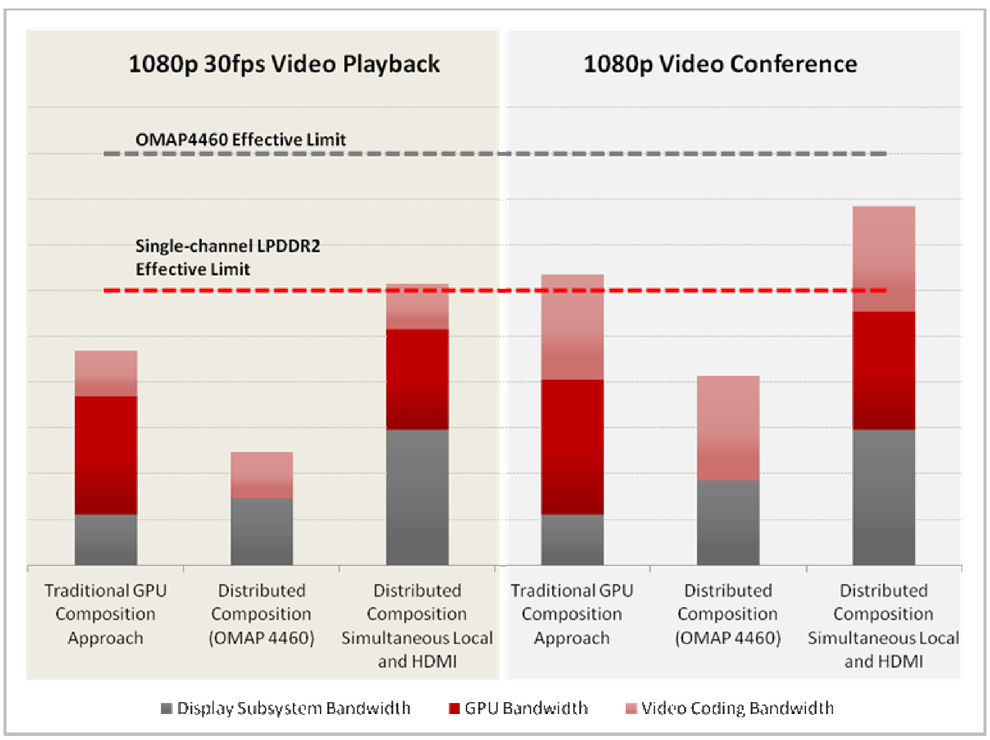


Figure 2 *– Distribution Composition of Home Screen*

This distributed composition architecture ensures that SurfaceFlinger can use GPU composition of UI and video for complex UI transitions, while optimizing power during normal composition using DSS pipelines. When required, SurfaceFlinger composites UI layers through the GPU to provide smooth video rotation, effect filters, or texture mapping to 3D surfaces. At other times, SurfaceFlinger can conserve energy by reducing GPU computations by sending layers directly to a DSS pipeline, allowing the GPU to sleep, reducing system memory bandwidth consumption, and eliminating up to 48 percent of MPU load. This Android enhancement provides a more unified solution for GPU and DSS rendering than was possible with SurfaceFlinger and TI Overlay Object used in Android 2.4.

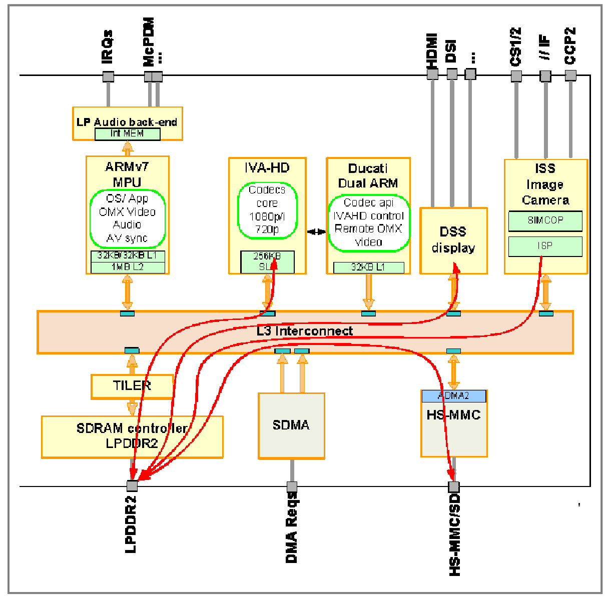
Figure 3 shows that while playing back 1080p video content, the distributed composition architecture on the OMAP4460 processor requires up to 47% less memory bandwidth than the GPU-based composition approach used by other leading ARM-based designs. In the case of simultaneous local LCD and external HDMI output, the DSS pipelines can render separate video and GPU-generated UI content to both of the local LCD and HDMI ports. We expect that on single-channel LPDDR2 systems and systems with fewer DSS pipelines, this ICS scenario and HD video conferencing will exhaust the system memory bandwidth.



'h Requirements

Enhanced Imaging and Video

Whether capturing still images or video, camera applications are extremely system intensive, requiring megabytes of data to be manipulated for every frame. OMAP4460 processors leverage a new, optimized camera software architecture to bring exciting new use cases to Android utilizing powerful, yet energy-efficient hardware that avoids interconnect bottlenecks.



Because not all hardware platforms will support these use cases, the majority of the new imaging features in Android 4.0 are optional for application developers in the latest Android SDK, API Level 14. As shown in Table 1, OMAP4460 processors fully support all new camera APIs that are introduced in Android 4.0 ensuring that Android products built on the OMAP platform will support the broadest set of features in the standard Android Camera Application as well as the imaging applications available from application marketplaces.

Android 4.0 Feature	OMAP 4 Platform	Android SDK Level 14 API
HD Video Camcorder	**1920x1080**	setVideoSize()
Auto Exposure Lock	**Yes**	isAutoExposureLockSupported()
Auto White Balance Lock	**Yes**	isAutoWhiteBalanceLockSupported()
Video Snapshot	**Yes**	isVideoSnapshotSupported()
Multiple Focus Areas	**> 10**	getMaxNumFocusAreas()
Multiple Metering Areas	**> 10**	getMaxNumMeteringAreas()
Max Number of Detected Faces	**> 20**	getMaxNumDetectedFaces()
Continuous Auto Focus mode for still images and video recording	**Yes**	getSupportedFocusModes () : FOCUS_MODE_CONTINUOUS_VIDEO FOCUS_MODE_CONTINUOUS_PICTURE

***Table 1** – Optional Imaging Features in Android 4.0 supported by OMAP4460 Processors*

The OMAP 4 platform's imaging subsystem also boasts several real-time enhancement algorithms that are enabled by default in the BSP to provide unprecedented image quality from a raw CMOS sensor:

- Image and video noise filter to remove the grainy nature inherent to many electronics image sensors and to enhance image quality in low light conditions
- Digital image and video stabilization to compensate for hand and wind vibration
- Lens shading compensation to remove vignetting

1080p Video Camcorder

The programmable IVA-HD encoding hardware in OMAP 4 platform supports offloading *1080p HD H.264 capture at 30fps* freeing the dual ARM Cortex-A9 cores and GPU to enter low-power sleep mode or perform application tasks in Android. As a result, high frame rate HD recording is performed with high quality, while user responsiveness is kept instantaneous. Captured videos are sharp and clear, without unwanted peripheral shading.

Still Image Capture

With a dedicated Imaging Subsystem (ISS), JPEG encode/decode hardware, and superior memory bandwidth via the high-speed data interconnects, OMAP4460 processor provides high-quality image capture at resolutions up to 16 megapixels. OMAP 4 technology allows instantaneous preview with continuous digital zoom, image stabilization and rotation.

Advanced Auto Focus and Metering

The A4O4 BSP also provides unique and patented continuous auto focus mode that maintains images and video in focus at all times; even when shooting objects in macro mode. Focus speed is optimized to get the best focus transition. As stated in Table 1, the OMAP 4 architecture also supports advance camera mode operations like focus lock, exposure lock, white balance lock, burst mode image capture, and time bracketing. Support for multiple focus and metering regions enable the user to focus on a specific subject by tapping the region on the touch screen during capture preview. Together, these modes provide the control and creativity of a digital still camera experience with the exposure, focus and subjects you want.

Low Light Photography

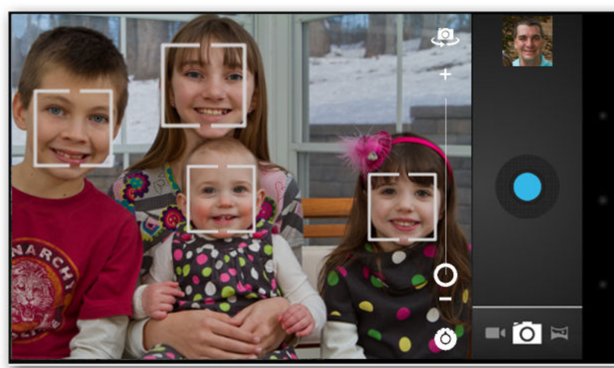
TI's IVA-HD programmable video accelerator subsystem, in combination with an image quality tuning algorithm, supports a mode that can set optimal variable frame rate based on the illumination level of the scene. Low-light conditions also benefit from a constant emission of light in torch mode (Camera.Parameters.FLASH_MODE_TORCH).

Zero Shutter Lag Image Capture and Video Snapshot

With the high performance processing capabilities and ultra-low processing latency of the OMAP4460 Imaging Subsystem (ISS), OMAP4460 processors can input camera sensor data at resolutions at least 25 percent greater than HD 1080p. By sustaining full 5-megapixel camera resolution input at 30fps, images can be captured with "zero shutter lag." In this mode, a full resolution still image is captured exactly at the time the shutter is pressed without any delay. Using the Video Snapshot feature of the Android 4.0 Camera Application, by simply tapping the screen, full resolution images can also captured while simultaneously recording 1080p HD video. Whether shooting still images or video, OMAP 4 technology makes it is easy to capture moments that may be missed with other ARM-based mobile application processors.

Face Detection and Face Tracking

State-of-the-art face detection hardware continuously detects and track faces in real time. When multiple subjects are present, multiple detected regions are used for exposure metering and auto focus. The OMAP4460 processor's ISS supplies the captured preview images to the Face Detection hardware block while supplying full resolution YUV frames to the display. The detection hardware is also used to identify areas for face recognition in applications, including unlocking your mobile device using your face. TI provides an end-to-end, fully integrated solution for face detection and tracking in Android 4.0.



Incredible Imaging Responsiveness

Android 4.0 is the first available Android version to include an optimized imaging data path. The A4O4 BSP optimized software paths enable ultra-fast reactivity including shot-to-shot delay less than 380ms and a standby-to-shot delay of less than one second. Figure 4 shows measured comparison against the baseline OMAP4430-Android 2.4 of key performance indicators including camera application boot time, shot-to-shot delay, shutter lag, and touch AF lag. In all cases, at comparable sensor resolution, the OMAP 4 platform stands up to industry leading performances from a leading digital still camera (DSC) and iPhone 4S so your device is always ready for action.

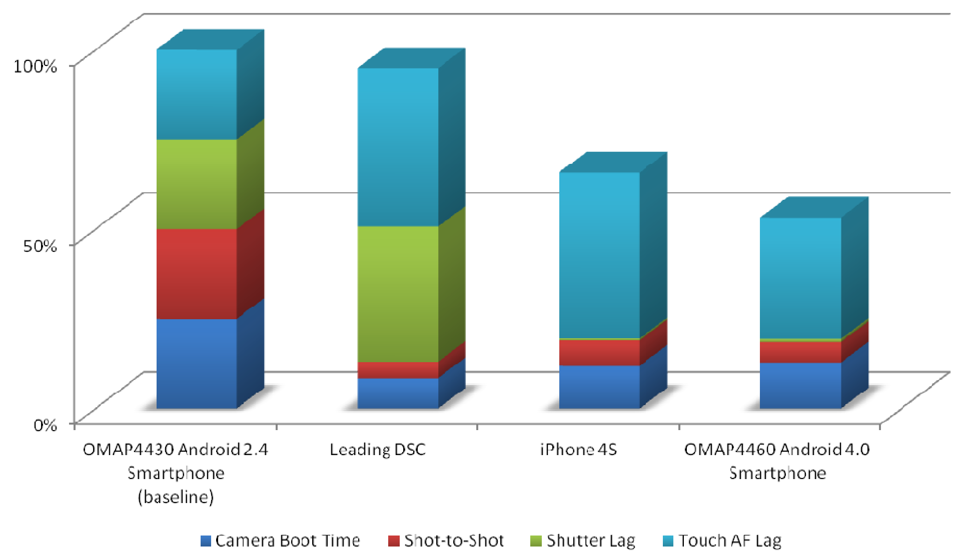


***Figure 4** –Key Camera Performance Indicators compared to OMAP4430-based device running Android 2.4.*

Video Editing

Video editing is a new Android 4.0 application and framework experience giving users the capability to edit and post-process recorded video. The video editing framework supports the following features:

- Join and convert videos, images and music tracks:
  - Supports H.263, H.264, MPEG4, JPEG, and mp3 content formats
- Preview playback with color effects (negative, sapient).
- Save color effect (negative, sepia) output video in H.263, H.264 and MPEG4 formats.
- Preview playback with color effects at full 1080p 30 fps

This framework takes benefit of the OMAP4460 processor's powerful IVA-HD to support smooth 1080p HD H.264 capture and playback. During preview of the video composition Android 4.0 leverages the OMAP4460 processor's IVA-HD ability to simultaneously decode two 1080p HD streams while the powerful SGX540 GPU applies various video filters to keep real time preview experience. The OMAP4460 processor's IVA-HD can support 1080p HD H.264 or MPEG4 simultaneous record and playback without the dual ARM Cortex-A9 processors performing a single data calculation. With smart multicore processing, all of this video editing occurs without requiring the dual Cortex-A9 processors to perform a single data calculation.

Efficient Utilization of GPU and System Resources

The PowerVR™ SGX540 GPU in the OMAP4460 processor adds a 25 percent performance boost to the proven 3D graphics acceleration capabilities of the OMAP 4430 architecture. The accompanying SGX DDK v1.8, including OpenGL ES 2.0, is fully integrated with Android 4.0 and optimized for performance and power to enrich the most demanding ICS user experiences.

To further improve system efficiency, Android 4.0 includes support for the OMAP 4 platform's innovative Tiler memory management unit (MMU) and seamlessly blends buffer management across the smart multicore architecture. The Tiler MMU block provides contiguous virtual memory access to non-contiguous physical memory thereby reducing memory fragmentation of encoded and decoded video buffers. Additionally, through Tiler, 2D buffers can be directly accessed in a 0, 90, 180, and 270 degree orientations. This provides an efficient means to avoid costly rotation and mirroring of video frames, allowing the GPU to sleep longer between video frames.

Android 4.0 includes a new memory manager, called ION, which unifies the allocation and management of multimedia buffers. In the A4O4 BSP, the ION Linux kernel component is integrated with SGX DDK v1.8 to enable the allocation of graphics and video surfaces through Android's gralloc interface. By providing centralized management of memory for video and camera use cases across all system domains, ION further reduces development and software engineering complexity.

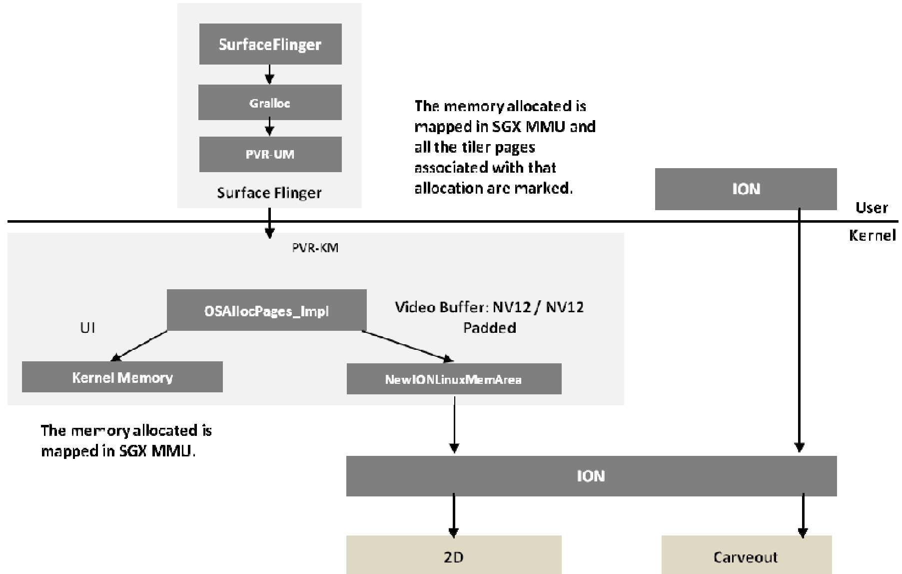


Figure 5 *- Overview of Buffer Management Components in A4O4 BSP.*

Hardware-Enforced Security

Mobile devices have become intimate appliances, serving as consumers' connecting points to the outside world. They store personal and professional data, provide always-on connectivity, execute payment transactions, access and render high-definition (HD) content and much, much, more. Content management begins and ends with trust. Content providers such as film, music and game publishers – who feed these applications with media – are concerned with protecting their creative assets, especially when highest fidelity and highest definition is offered. Service providers such as music portals, television broadcasters and financial institutions also want to protect and control access to the services and assets they provide. The whole value chain relies on the confidence that the consumers and content providers place in the mobile device, applications, and services.

M-Shield™ technology is TI's sophisticated system security technology optimized for the high-performance low-power OMAP platforms, combining hardware, software and development tools to ease deployment of security solutions on mobile and consumer devices. The M-Shield security architecture is developed to bring hardware robustness to the overall security scheme, and to provide efficient protection for executing security demanding applications. Specific hardware mechanisms, secure boot and secure run-time ensure that only trusted code can access the secure resources, such as specific regions of memory, some peripherals and hardware accelerators.

When running Android 4.0 on OMAP 4 processors, DRM-protected video streams are secured within the OMAP platform by firewalling the complete decryption, decoding and rendering playback process from the rest of the system. The Trusted Execution Environment (TEE) is a separate secure run-time execution environment that resides alongside the Android platform and provides security services to the Android framework and applications. Before decrypting protected content, the OMAP 4 platform enters M-Shield Secure Mode and executes the Widevine DRM Agent in the system's TEE. In this mode, the OMAP 4 platform's hardware firewalls enforce strict memory and peripheral access boundaries to ensure the DRM and video decrypting executing in the M-Shield TEE is isolated from internal and external snooping. This ensures that high-value content is not comprimised by malicious applications, rogue processes, or untrusted root access to the operating system.

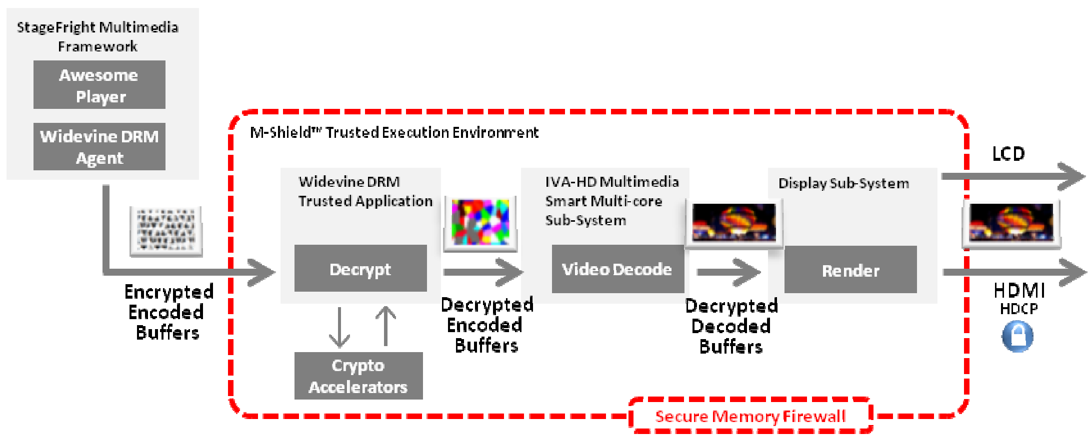


Figure 6 *- OMAP 4 Platform HD 1080p Secure Video Playback*

Widevine defines three security levels. The implementation of Widevine DRM on the OMAP 4 platform with M-Shield technology is compliant to the most secure of Widevine Levels, Level 1. In this highest Widevine security level, DRM encryption keys are provisioned in the factory and are never exposed unprotected to the host CPU. Additionally, security must be enforced by hardware mechanisms to protect the entire video playback path.

Android 4.0 also introduces a new keychain API and underlying encrypted storage that are protected by M-Shield hardware-enforced security on the OMAP 4 platform. Private keys and the cooresponding certificate chains that are stored in the platform Key Boxes are secured by M-Shield to protect the established root-of-trust.

Although M-Shield technology is specific to OMAP processors, it complies with industry standards such as OMTP TR1, GlobalPlatform TEE and FIPS 140-2, with regards to APIs and security quality. Compliance to these standards is important for cross-platform portability of security-demanding Android applications, and to grow a large ecosystem of security application developers. To that extent, M-Shield offers tools (M-Shield DK) and APIs conformant to GlobalPlatform specifications[1] enabling development and deployment of security applications.

Power and Thermal Management

Designed to prolong battery life in always-connected devices, the OMAP 4 family of mobile processors minimize power consumption during the most demanding of new Android 4.0 user experiences and while idly performing background tasks. The A4O4 BSP includes the most aggressive set of power management controls available in the industry employing Adaptive Voltage Scaling, Dynamic Power Switching, Static Leakage Management, and Dynamic Voltage and Frequency Scaling across the OMAP 4 smart multicore architecture.

The flexibility of the OMAP 4 Power Control software design reduces development complexity by abstracting the system nuances of independently controllable clock, voltage, and power domains. Power control governors maintain the optimal scaling of voltage and frequency across all isolated domains; including the GPU and Video as well as the dual Cortex-A9 cores. When Android is idle, OMAP4460 enters OFF Mode, disabling all power and voltage domains to further reduce static leakage current. That's smart multicore technology.

System Profiling

In addition to the external measurement facilities available on OMAP platform-based Mobile Development Platforms (MDPs), the A4O4 BSP provides system profiling capabilities directly through the Linux kernel's CPUfreq subsystem, through the sysfs interface, and through additional utilities available from TI. Utilizing these tools, TI has already completed exhaustive system profiling of Android 4.0 on OMAP 4 processors. Profiling multicore load (CPU, GPU, Video), operating points, system interrupts and thermal reaction across Ice Cream Sandwich applications resulted in optimizations to system power and thermal governors for maximum efficiency.

Development Platforms

The first low-cost OMAP 4 mobile development platform, PandaBoard, has attracted a community of thousands of developers during its first year in the wild. Now PandaBoard has achieved another milestone by becoming the first open mobile development platform included by Android Open Source Platform (AOSP). Building Android for OMAP 4 processors is as easy as following the instructions on http://source.android.com:

```
$ mkdir android; cd android
$ repo init –u git://android.git.kernel.org/platform/manifest.git
$ repo sync
$ source build/envsetup.sh ; lunch full_panda-eng
$ make
```

So, in addition to the community resources available from http://pandaboard.org, developers can now leverage the device configuration in AOSP mainline and directly reference hardware schematics to deploy innovative OMAP platform-based Android designs. For mobile smartphone and tablet product development, the A4O4 BSP for the full-featured OMAP 4 Tablet II Development Platform is also available from TI.

Summary

Android 4.0 introduces significant platform advancements and improvements in user experience which are tightly integrated in the OMAP 4 platform software. The full featured A4O4 BSP is available now from TI. The OMAP family of processors provide the high-performance, energy-efficient solutions required for rapid development of next generation mobile devices that seek to fully leverage the capabilities offered in Android's Ice Cream Sandwich release.

References

[1] GlobalPlatform, "The Trusted Execution Environment: Delivering Enhanced Security at a Lower Cost to the Mobile Market", February 2011

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As a product line manager for the Texas Instruments Incorporated (TI) Wireless Business Unit, Eric Thomas is responsible for defining the future of OMAP software platforms, overseeing related software product requirements, and driving communications strategies. In recognition of his impact at TI, Thomas was elected as Senior Member Technical Staff (SMTS) in 2005. This group is composed of TI's top six percent of technical achievers company-wide. With more than 15 years of experience in the wireless industry, software development and engineering, Thomas has a rich background in mobile communications, software frameworks, and product development.

For more information on the technologies presented in this paper, visit www.ti.com/omap and www.ti.com/wirelessconnectivity.

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