ARM's New Mali: An Integrated Multimedia Platform for Mainstream SoCs

Introduction

The mainstream smartphone and tablet markets are large and diverse. While ARM is widely known for its CPU cores, the company also ships a very large number of graphic processing unit (GPU) cores as well. In addition to the GPU, in 2013 ARM expanded their Mali family of products to include video and display processors.

The Mali GPU products have been available for several years and their volume has grown so that over 400M shipped in 2013, with over 60 licensed partners. The Mali GPUs are increasing their presence across a wide range of devices and can be found everything from low-end smartphones through to expensive DTVs. Mali has experienced a continuous expansion in the range of partners licensing Mali products, bringing out a wide variety of Mali-based implementations. ARM claims that Mali GPU IP is the number 1 shipping graphics IP in all Android devices.

With the development of smart device markets, there has been increasing SoC differentiation. The various sub-segments are now large enough for ARM partners to build a specific SoC to address specific performance and feature requirements – there's less need to repurpose the same silicon for different applications. These differences include a variety of screen sizes, resolutions, and form factors. The end consumers of these chips also expect ongoing and continuous improvement in features, and power reductions with each generation of new products. This continuous and relentless requirement to continue to innovate and diversify is a key focus for all of the silicon providers in the market. The diversity of SoC requirements is being addressed by the latest Mali cores that offer different optimization points for GPUs and scaling options for video and display, as well as reduced time-to-market.

On the GPU side, gaming continues to be one of the most popular activities on mobile devices and is the most popular in application downloads – dominating the list of top 10 iOS and Android paid apps[1]. Recent research reports from application store research company App Annie indicate that games generate the majority of the revenue for all Android apps. Improving the immersive experience of mobile gaming is difficult given the tight power constraints of a mobile device. ARM has responded with the new Mali products that continue to deliver performance efficiently across a wider range of devices, while offering a more unified graphics driver, no matter how small the GPU.

[1] As listed on the Apple ITunes Store and Google's Play Store 11/14.

Video on mobile devices has become the way we document and view important events in our lives. It is therefore important these devices efficiently encode and decode video with a quality of at least HD, and increasingly it will be 4K/Ultra High Definition (UHD). There's also potential for the adoption of streaming video content on mobile devices, whether on WiFi or cellular netweorks. Support for 4K video will also be increasingly important for TV set top and over-the-air boxes.

The challenge for ARM is that there is an ever increasing number of pixels, that need to be delivered at higher frame rates, and more work is required for each of these pixels, all at the same power. This translates into higher computational capabilities and more system and memory bandwidth. SoC designers need to think about this in advance when designing a media system to prevent more power being consumed than necessary when delivering a quality user experience. These new cores are focused on delivering innovative technologies to address this bandwidth bloat across a wide range of content types. Managing data bandwidth is a critical factor in being able to deliver console-quality graphics on a mobile device.

ARM supplies the three distinct IP blocks: GPU, video processor and display processor, each optimized for the graphics, video, and user interface (UI). To save energy, ARM includes advanced, efficient technologies (ARM Frame Buffer Compression (AFBC), Adaptive Scalable Texture Compression (ASTC), etc) that can be applied to multiple blocks. To help vendor time to market (TTM), ARM will provide comprehensive driver support, as software is critical to deriving the full benefit of the architecture. The drivers can be pre-integrated so that they work instantly with the final SoC. Another TTM advantage for ARM is consistent verification and validation processes for all Mali cores.

In this paper we will look first at the three main multimedia IP blocks ARM is providing: 3D graphics, HD video, and 2D display processing.

Later in the white paper we will review the following key new features ARM has brought to the new Mali Suite of IP:

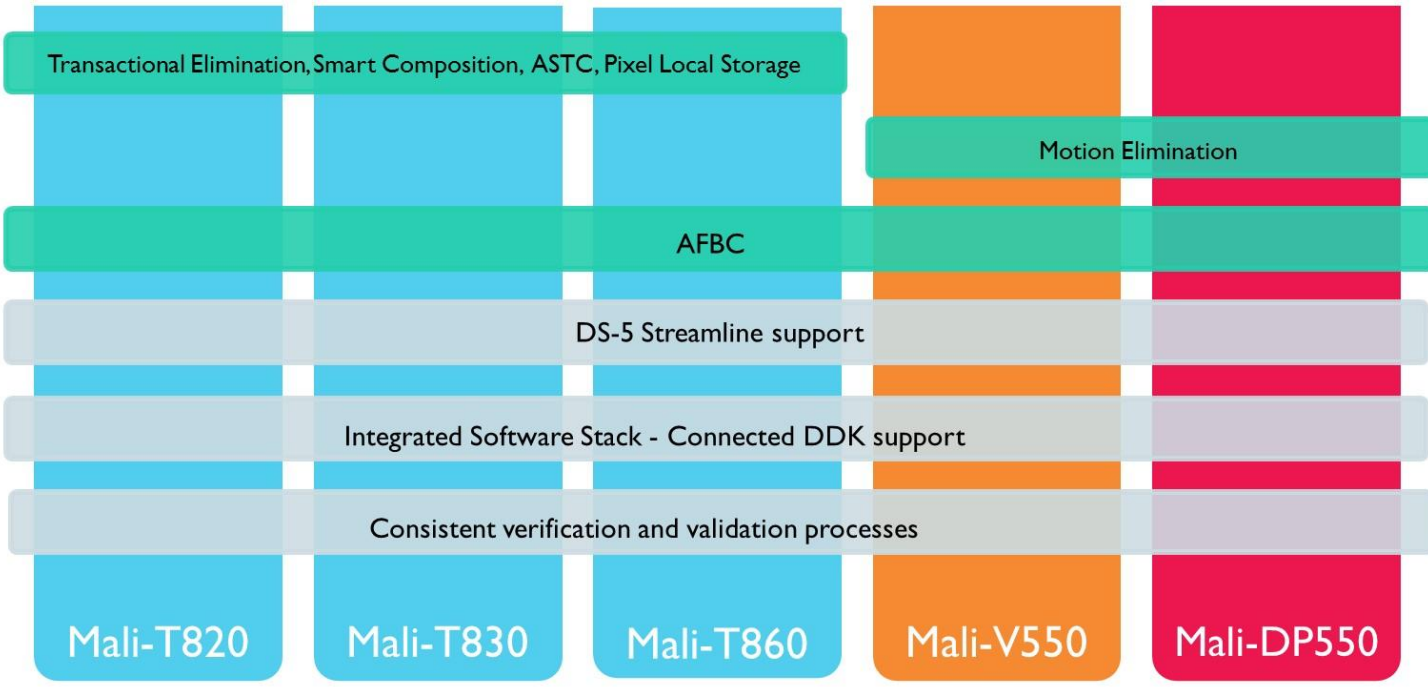
- ARM Frame Buffer Compression (AFBC) – available across the entire lineup
- Adaptive Scalable Texture Compression (ASTC) – available on the GPUs
- Smart Composition (SC) – available on the GPUs
- Pixel Local Storage – available on the GPUs
- Motion Search Elimination – available on the Video and Display processors

In addition, 10-bit YUV video for high dynamic range displays is available across the entire lineup. ARM also incorporates Transaction Elimination (TE) technology in the GPUs to reduce unnecessary graphics processing, which saves power.

Mali Platform Overview

The updated suite of Mali IP includes three new GPUs, an improved scalable video processor and an enhanced display processor, as seen in Figure 1. The Mali Midgard architecture, first introduced with the Mali-T600 family of GPUs, is now in its fourth iteration. The new Mali-T860 core is estimated to be 45% more energy efficient that the second generation Mali-T628 GPU, even in the same process node. The company expects significant energy efficiency improvement over the Mali-T700 family as well, given similar design implementation choices.

Figure 1. ARM Mali Media System Features



Graphics Processing

The Mali-T800 family of GPU cores have had some microarchitecture enhancements over the Mali-T700 family and incorporate proven bandwidth reduction technologies. These include improved utilization of texture and cache. The design is also focused on reducing redundant data reads. To save GPU processing, the GPU can do Forward Pixel Kill (FPK), which stops the processing of a pixel if a following pixel will overlap/over write it. ARM offers additional cache

size tuning with up to a 1MB L2 cache and general memory interface tuning. The higher-end GPU core is the **Mali-T860** suitable for high performance devices. Its key focus is energy-efficient performance within a limited thermal budget. The Mali-T860 is scalable to 16 coherent shader cores. For high fidelity content, 4K and beyond, the Mali-T860, the rest of the T800 family, the Mali-DP550, and the Mali-V550 all support 10-bit YUV input and output. The 10-bit YUV support gives Mali the extended color gamut necessary for Ultra-High Definition displays.

The core is designed to also support high performance functions, including OpenGL ES 3.1 and Microsoft Windows DirectX 11 FL11_1 for graphics and OpenCL 1.2/1.1 Full Profile[2] and Google's Renderscript for computing.

The midrange **Mali-T830** balances die area efficiency with 3D and compute performance. The Mali-T830 offers the best tradeoff for mainstream mobile devices. The GPU is capable of scaling to four coherent shader cores. The Mali-T830 still offers the bandwidth reduction technologies of the Mali-T860 and selected high-end features in a cost-efficient footprint. It's up to 55% faster and 50% more area-efficient than the second generation Mali-T622 Midgard GPU.

The Mali-T830 will support the graphics APIs up to OpenGL ES 3.1 and DirectX 11 FL9_3, which is a subset of the DirectX support available in the Mali-T860. Compute APIs include OpenCL 1.2/1.1 Full Profile and Renderscript. The Mali-T830 can optionally support 10-bit YUV color for 4K/UHD applications.

When cost and die area are the primary design criteria, the **Mali-T820** is focused on area-efficiency. But while performance is constrained by area, the core is still capable of advanced UI and casual gaming. One way ARM saved die area is by cutting the number of ALUs in each shader core from two (in the Mali-T830) to one. Despite the die area constraint, the company included AFBC, a new feature for the low-end range of GPUs. The addition of AFBC across the entire graphics, video, and display pipeline simplifies driver development for the new Mali platform.

Video Processing

The new video processing element of the Mali family is the **Mali-V550.** The new video processor adds support for multiple codec standards, including HEVC/H.265, as well as encode and decode capabilities in a single, scalable video processor. Many HEVC IP solutions today are either single codec blocks (requiring multiple additional IP blocks for other codecs) or require

[2] Product is based on a published Khronos Specification, and is expected to pass the Khronos Conformance Testing Process. Current conformance status can be found at www.khronos.org/conformance.

separate blocks for encode and decode. The Mali-V550's multi-codec and encode/decode capability maximizes hardware re-use while minimizing silicon area and cost and reducing the integration effort for both hardware and software.

The Mali-V550 is a multi-core solution that can scale from 1080p 60fps with one core all the way to 4K at 120fps (or 1080p at 480fps) with an 8-core implementation. Performance is scalable; for example, a single core can support either 1080p 60fps encode or decode, or simultaneous 1080p 30fps encode and decode. The cores are flexible and can stream using different coding standards simultaneously – both encode and decode. Streams are time multiplexed on a frame-by-frame basis. In the Mali-V550, ARM also added Motion Search Elimination to minimize memory bandwidth and processing for external displays over Wi-Fi, for example using Miracast.

While system power, performance and silicon area are all critical, visual quality is also essential. The Mali-V550 is designed to hide longer memory latencies without losing frames which could result in poor visual playback quality.

Display Processing

Pulling all the video streams together is the **Mali-DP550** display processor. New features in the Mali-DP550 include a 7-layer composition engine (up from 4 layers) and a new co-processor interface. The co-processor interface allows SoC vendors to differentiate with their own plug-in hardware IP or algorithms. The Mali-DP550 also supports scaling and rotation of the display buffer, offloading that function from the GPU. The composition, rotation, scaling, post-processing and display output is performed in a single pass, minimizing memory bandwidth. Like the rest of the new Mali IP Suite, the Mali-DP550 supports system-wide AFBC, as well as Motion Search Elimination.

The Mali-DP550 has a robust set of rotation, high quality scaling, and image enhancement. It supports a wide range of YUV/RGB pixel formats including 10-bit YUV for 4K/UHD. Essential features include single or dual display outputs and compatibility with all major display standards.

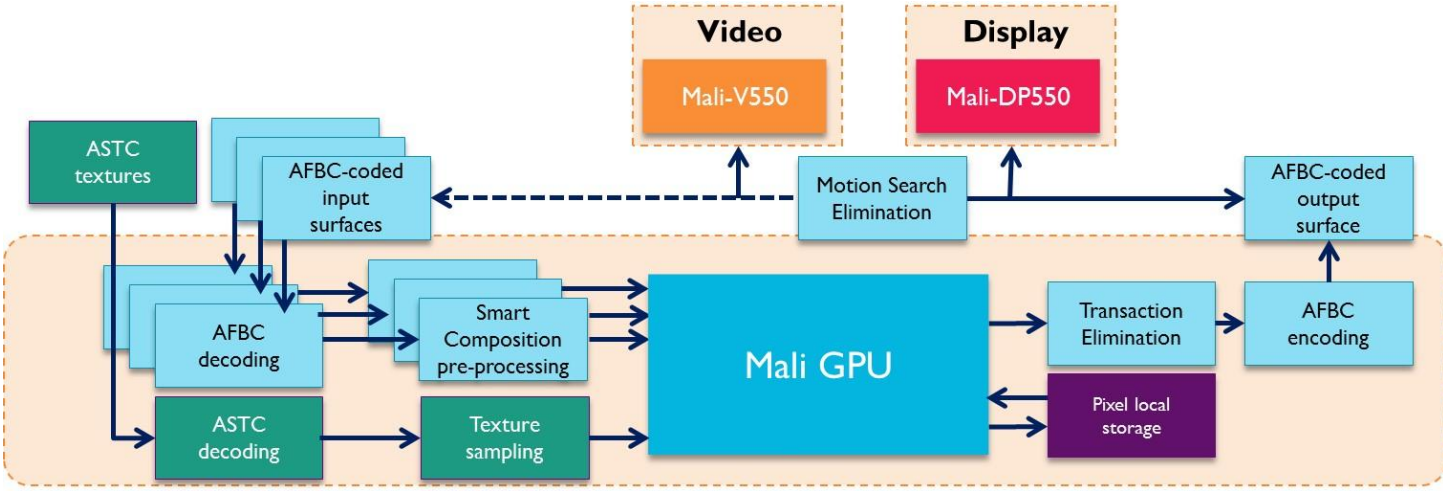
Advanced Mali Features

ARM Frame Buffer Compression (AFBC)

AFBC (Figure 2) is a significant contributor to reducing SoC energy consumption. Depending on content, it can reduce frame buffer and intermediate renders bandwidth on average by more than 50%. AFBC is a lossless compression format, the exact compression rate varies depending on the data patterns, with some aberrant data patterns achieving no compression at all and some others

achieving compression of 80% or even higher. ARM has also extended AFBC beyond the GPU, to the video and display processors, so that all images transferred from one IP to the other can be in AFBC compressed format – maximizing the system benefits.

Figure 2. Bandwidth Saving Features

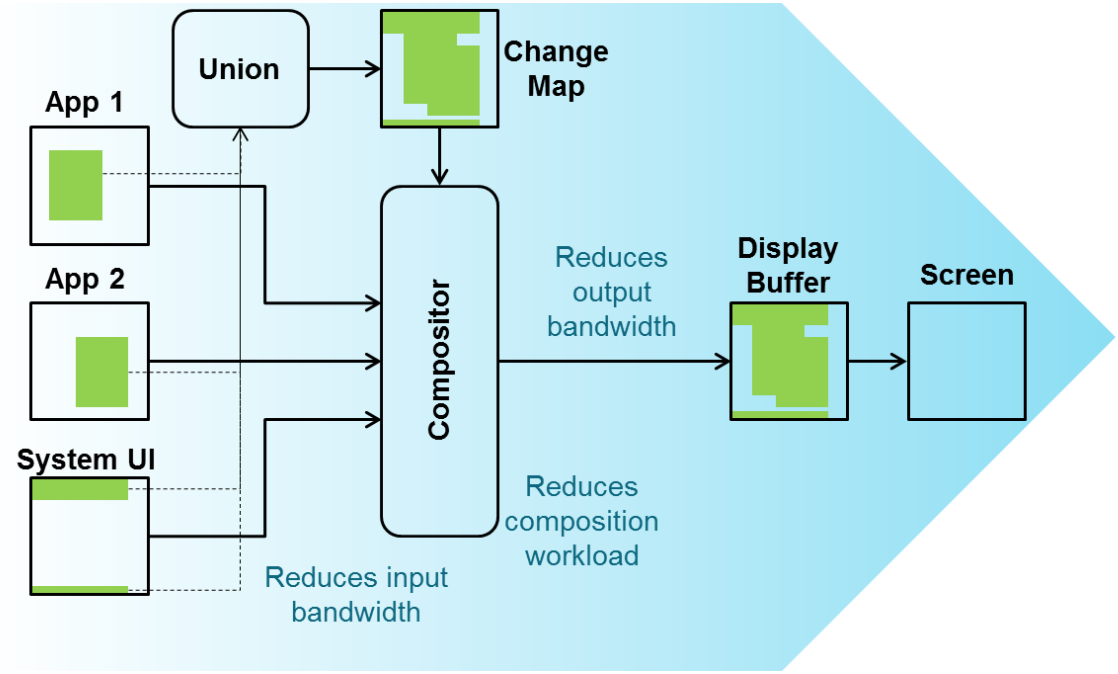


ARM's AFBC will be supported in current and future ARM IP for the GPU, video and display processors. In addition, the company licenses the AFBC format for 3rd Party media IP. With the new family, ARM is now offering AFBC even to the cost efficient Mali-T820 core.

Smart Composition

ARM's Smart Composition (Figure 3) significantly lowers read bandwidth and reduces shader workload by eliminating unnecessary composition. Using change maps, the processor can ignore tiles that have not changed. By integrating it with the window manager, the composition engine can eliminate processing for hidden and static regions on the display, reducing bandwidth and GPU workloads. ARM has modeled bandwidth reductions up to 90% for the Chrome browser and 70-80% on social media apps.

Figure 3. Smart Composition



Motion Search Elimination

Using Motion Search Elimination, ARM extends its Transaction Elimination technology. The display and video processors maintain a signature for each display tile (Mali processors use tile-based deferred rendering). Comparing the tile signature from frame to frame, when the signatures match no motion search is required. This is a significant bandwidth saving because motion search is bandwidth intensive. It can also save dynamic power because when the motion search hardware block is not being used, automatic clock-gating causes the block to enter into an idle state.

Adaptive Scalable Texture Compression (ASTC)

Mali GPUs also incorporate the ARM-inspired ASTC image compression technology. ASTC was adopted as an official, optional extension for both OpenGL and OpenGL ES by the Khronos Group in August of 2012. Using ASTC requires that gaming applications use the standard, but the benefits include better looking games through better scalable textures. ASTC is also a free and open standard that can be used by other GPUs.

Shader Pixel Local Storage

This is a new extension-based OpenGL ES 3.0 support that allows additional flexibility in pixel data formats. This enables reading and writing data that is persistent throughout the lifetime of the frame buffer, across draw calls and fragment shader invocations - allowing data to be passed between fragment shader invocations and adding flexibility in how in the final pixel value is built. It can be used to keep more data on-chip, reducing memory bandwidth.

Conclusion

What sets the new Mali media suite apart from the rest of the industry is that it brings state-of-the-art texture and frame buffer compression to a complete family of graphics and video IP products, along with other advanced bandwidth savings techniques. In total, these techniques reduce system bandwidth needs and reduce system power while also increasing system performance. The scalability of the Mali-V550 video processor is impressive, allowing a SoC design to tailor the video performance from 1080p all the way to high frame rate 4K. The Mali-DP550 brings advanced features to 2D processing, offloading those functions from the GPU and video processor. The integration of all three elements together allows a designer to build an extremely capable multimedia platform.

ARM continues to advance its multimedia capabilities with solutions to support the very latest video and graphics standards with scalable solutions for mainstream mobile and DTV devices. The entire Mali platform works better together than the individual blocks by utilizing the new bandwidth efficient technologies across the new platform.