ARM® Mali™-450 MP

Next generation graphics performance for Smart-TV and smartphone applications

Taipei Multimedia Seminar

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Bringing Visual Computing to Life

Delivering:
- Ultimate user experience
- Mobile, tablet and DTVs
  - Extensive system-level knowledge
  - Right-sized performance across CPU & GPU

Providing:
- Market leading graphics performance
- Visually exciting applications
- Innovative devices
Ultimate user experience with ARM

- Stereoscopic 3D gaming in 1080p on a mobile device is already a reality with ARM Cortex™-A9 and Mali™-400 MP!

Imagine mobile phones with HDMI output and fill rate for 2K… and punch to render in stereo 3D!
Constrains on power efficient platforms

- Bandwidth consumption is also the primary drain of power in consumer devices.
- Limited system bandwidth will largely dictate the appropriate level of complexity for graphics use cases.

<table>
<thead>
<tr>
<th>Resource</th>
<th>Mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel processing fill-rate</td>
<td>Appropriate for high-end</td>
</tr>
<tr>
<td>Vertex processing</td>
<td>Appropriate for high-end</td>
</tr>
<tr>
<td>CPU</td>
<td>Appropriate for high-end and often scalable (2-4 cores)!</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>Limited and shared with CPU, video etc. Affecting power consumption</td>
</tr>
</tbody>
</table>

- Resource Mobile
ARM Graphics Architecture

- Design principles
  - Tile-based immediate rendering is the best choice for power-efficient designs
  - Multicore delivers true performance scalability
  - Compute performance for advanced content
  - Common ISA across a family of GPUs

- Delivering industry leadership
  - Performance, memory bandwidth
  - Area and power efficiency

- Constant innovation
  - Common software driver to protect software investment
  - Improved performance per core in each generation
  - Increased architectural efficiency (performance/area and power)
Best for Graphics and GPU Compute

- Enabling next generation use-cases
- Combine Cortex and Mali processors into an efficient unified computing subsystem

Aligned with market to give uncompromised choice balancing
- Die area (cost)
- Compute capability
- Software requirements

Extend Mali leadership in graphics performance, power & cost
Midgard for Graphics and GPU Compute

Mali-T604
First Midgard architecture product
Scalable to 4 cores

Mali-T658
High end solution
Maximum compute capability

Skrymir
Designed for GPU Compute
- Uncompromised support for OS / API choice

Closer CPU-GPU links
- Efficient use of all device resources
- Maximize performance and battery life

Protecting partner investments
- Common software platform reduces costs and TTM
- Multicore delivers performance scalability over multiple form factors

Roadmap for further share gains
- Mali-T600 silicon shipping in consumer products 2H 2012
- Skrymir driving design wins in next generation super-smartphones and mobile computers
Best for Graphics

Performance

Mali-400 MP
First OpenGL ES 2.0 multicore GPU
Scalable from 1 to 4 cores
Low cost solution with Mali-300

Mali-200
OpenGL® ES 2.0 compliant

Mali-450 MP
2x Mali-400 performance
Scalable up to 8 cores
Leading OpenGL ES 2.0 performance

Best balance of graphics performance, power and cost

Multicore delivers performance scalability over multiple form factors

Fastest growing entry-level and mid-range smartphone markets

Common software platform reduces costs and TTM

Mali-450 MP will drive volume in next generation products in CE and mobile markets
Mali-450 MP Overview

- Multi-processor scalable graphics performance
  - Up to 8 fragment processors and 2 vertex shader cores

- 2D and 3D graphics acceleration
  - Khronos compliant OpenVG® 1.1, OpenGL ES® 2.0/1.1

- High performance and image quality
  - Scales to HD 4k resolutions with anti-aliasing

- Efficient energy and bandwidth usage
  - Integrated configurable L2 cache
  - Leading bandwidth efficiency and latency tolerance

- Production quality drivers
  - Single optimized driver for all configurations and compatibility with Mali-200/300/400
  - Extended multi-core scaling transparent to software developers

<table>
<thead>
<tr>
<th># Fragment Processors</th>
<th>L2 Cache Size</th>
<th>Process Technology</th>
<th>Area Incl. All SRAMs &amp; L2 Full Place &amp; Route</th>
<th>Clock Frequency</th>
<th>Pixel Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mali-400 MP1</td>
<td>32KB</td>
<td>40LP</td>
<td>2.0 mm²</td>
<td>250 MHz</td>
<td>250 MPix/s</td>
</tr>
<tr>
<td>Mali-400 MP2</td>
<td>64KB</td>
<td>40LP</td>
<td>3.6 mm²</td>
<td>250 MHz</td>
<td>500 MPix/s</td>
</tr>
<tr>
<td>Mali-400 MP4</td>
<td>256KB</td>
<td>40LP</td>
<td>6.8 mm²</td>
<td>250 MHz</td>
<td>1000 MPix/s</td>
</tr>
<tr>
<td>Mali-450 MP6</td>
<td>512KB</td>
<td>40LP</td>
<td>11.6 mm²</td>
<td>250 MHz</td>
<td>1500 MPix/s</td>
</tr>
<tr>
<td>Mali-450 MP8</td>
<td>512KB</td>
<td>40LP</td>
<td>15.1 mm²</td>
<td>250 MHz</td>
<td>2000 MPix/s</td>
</tr>
</tbody>
</table>
Mali-450 MP compared to Mali-400 MP

<table>
<thead>
<tr>
<th>Improvement over Mali-400</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wider range of performance points</td>
<td>Up to eight Pixel Processors with linear performance scaling</td>
</tr>
<tr>
<td></td>
<td>Doubling the Geometry Processor throughput</td>
</tr>
<tr>
<td>Bandwidth optimisations</td>
<td>Increased cache locality, coherency and latency tolerance</td>
</tr>
<tr>
<td>Power reduction</td>
<td>Ultra-low power architecture with general purpose registers</td>
</tr>
<tr>
<td></td>
<td>Dedicated DMA engine for low power configuration</td>
</tr>
<tr>
<td>Increased rendering efficiency</td>
<td>Improved architectural efficiency and optimised job management with</td>
</tr>
<tr>
<td></td>
<td>dedicated Dynamic Load Balancing unit</td>
</tr>
</tbody>
</table>
High Quality Anti-Aliasing

- 4x multi sampled anti-aliasing “for free”
  - 0 – 10% performance drop for typical OpenGL ES content
  - No additional output bandwidth or resolve overhead
- 16x combined multi- and super-sampled anti-aliasing
  - No change in output bandwidth
  - Outperforming other implementation of comparable quality
Mali-450 MP - Power-efficient Graphics

- Memory bandwidth is the #1 power drain in graphics
- Mali-450 MP reduces memory bandwidth and lowers power
  - Combines best of immediate-mode and tile-based rendering
  - Shared L2 cache with unified memory access
  - Multiple levels of power management

Power down cores between frames or use fewer cores for light-weight graphics scenarios

Internal clock gating ensures only required functionality draws power
Graphics APIs on Mali-450 MP

- Open standards are at the heart of embedded graphics
  - Enables royalty-free development & cross-platform portability

- ARM delivers a complete set of graphics APIs on Mali
  - OpenGL ES 2.0 & 1.1, OpenVG 1.1
  - *Any code written according to these standards will run on Mali*

- Support for Linux™, Android™ and X11™
  - Partners have done ports to other OSes based on the Linux DDK and Mali Software Porting Guide

- Provides out-of-the-box acceleration for a wide range of existing middleware and 3rd party apps
  - Android Surface Flinger, Adobe® Stage3D®, WebGL™
  - User Interface engines, Games, ..
Mobile Gaming

- Games compatibility with Mali across multiple devices
  - High-end gaming with award winning Samsung Galaxy SII
  - Momentum in smartphones driven by Samsung, MediaTek, Spreadtrum and MStar
  - Mali GPUs are number one graphics processors in Android tablets
  - Same software DDK for Mali-200/300/400 MP/450 MP

- Higher performance and quality per pixel with Mali
  - Free 4x anti-aliasing enables higher image quality for all games
  - High performance density allows developers to add more effects
Mali-450 MP delivers 60fps on 2K screen

Rendered at 2K screen resolution with 4xFSAA

Post-processing techniques including bloom and depth of field

100+ objects per scene

From wireframe up to full lighting with normal and environment maps and self-shadowing

Soft-edged particles with dynamic flow and volumetric appearance

Real-time deformable terrain

Full camera freedom in real-time; no assumptions can be made

Ghost car of recorded telemetry with advanced lighting effect

Fully-Interactive physical objects such as cones and barrels
User Interface Acceleration

- User interfaces are main use case for GPU acceleration
- Multiple partners using Mali GPUs in DTV and Mobile for UI
  - Samsung, LG, MediaTek, MStar, ST and Amlogic
- Stand-alone engines running on top of OpenGL ES / VG
  - UI frameworks & OS window systems
  - Android, Linux, X11 and others
- Numerous graphics operations that can be accelerated
  - Rendering UI elements (text, icons)
  - 2D/3D transitions & eye candy effects
  - Window composition & video textures
- Ranging from basic UIs at low resolutions to 3D effects at 4K with multiple video streams
UI with Mali-450 MP on 4K screen

Efficient video texturing and surface compositing

- “No copy” texturing for acceleration of window managers

Best-in-class fill rate:
Multi-core scalable beyond 3GPix/s

- High screen resolutions and multiple window layers

Bandwidth savings and latency tolerance

- Rendering efficiency and high performance in memory constrained environments

Blending and anti-aliasing at no extra cost

- High quality text and icons, smooth window transitions, semi-transparent graphics layers
Web Browsing and Mali-450 MP

- Accelerate different parts of the browsing experience
  - Browser interface rendering
  - Web content / plugins

- Accelerated browser rendering with WebKit™
  - GPU utilized for page scrolling, image scaling, window compositing, font rendering

- Adobe Stage3D – Low-level GPU-accelerated APIs enabling advanced 2D and 3D capabilities
  - Integrates with Mali OpenGL ES for accelerated rendering

- WebGL – New Khronos standard for 3D in browsers
  - Interface which exposes OpenGL ES 2.0 hardware capabilities to web developers
Rich Developer Tools Portfolio

Asset & Content Creation
- Texture Compression Tool
- Binary Asset Exporter
- Asset Conditioning Tool

Software Development
- OpenGL ES 2.0 SDK for Linux & Android
- OpenGL ES Emulator
- Shader Development Studio
- Offline Shader Compiler
- Shader Library

Performance Analysis & Debug
- DS-5™ Toolchain & Streaming Performance Analyzer
The Mali Ecosystem
Summary

- ARM has the right technology roadmap for the right markets
  - Best graphics for fast growing markets such as entry-level smartphones and DTV
  - Best graphics and GPU compute for high-performance apps processors in smartphones and mobile computing
- Mali GPUs in mass production with multiple customers world-wide
- Mali-450 MP enables the next generation of graphics performance
  - Wider range of performance points
  - Bandwidth optimisations
  - Power reduction
  - Increased rendering efficiency
- ARM and ARM Partners are bringing visual computing to life