3D Graphics in Future Mobile Devices

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Market Trends

Mobile Computing Market Growth
Mobile Computing Market Trends

**Entry-level in 2015**
- >750 million devices
- 250% growth since 2012; >10x since 2010
- Nearly 4 times the 2013 Notebook PC forecasts

**ARM provides targeted solutions to deliver the best features and specs at every price point**

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**Smart Mobile Device Shipments (Smartphones and Tablets)**

- **Latest features**
- **Greatest specs**
- **Tailored to fit a given budget**

**Volume in millions**

- **<$150**
- **$200-$350**
- **>$400**

Source: ARM and Gartner Estimates
Driving Market Change

**Smart Mobile Device Shipments**
(Smartphones and Tablets)

- **80-100mm²**
  - Entry Level
  - Mid Range
  - Premium
  - $>400

- **50-80mm²**
  - Mid Range
  - $200-$350

- **25-40mm²**
  - Premium
  - $<150

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**Typical GPU**

- **ARM Mali™-T760 GPU**
  - Increased GPU & SoC energy efficiency
  - Increased performance scalability
  - Advanced memory system scalability
  - Reduced bandwidth consumption

- **ARM Mali™-T720 GPU**
  - Increased graphics area efficiency
  - Optimized for Android™
  - OpenGL® ES 3.0 support*
  - Reduced cost & Time-to-Market

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*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](http://www.khronos.org/conformance)
ARM Mali-T600 Series GPU Overview

- **Midgard Architecture** - the foundation of ARM’s GPU roadmap providing increased performance, flexibility and software compatibility

- **Innovation** – driving 64bit GPU Compute, bandwidth saving technologies

- **Scalability** - an ARM Mali-T600 Series GPU to suit every application

- **GPU Compute** - 64-bit double precision, IEEE-754 compliant floating point

- **Feature-rich** - all popular OSs, multiple APIs including DirectX® 11, next generation OpenGL ES, OpenCL™ Full Profile and RenderScript compute
Leading on Lowering System Power

- GPUs have a major impact on SoC architecture
  - Area, memory bandwidth, energy and implementation
  - ARM focuses on system wide power efficiency not just IP components

- Energy Saving Features in the Mali-T62x system:
  - GPU efficiency – 50% performance increase or less energy/frame in same area

- ARM Mali GPUs are leaders in balancing power, area and functionality

*Adaptive Scalable Texture Compression (ASTC)
**Transaction Elimination (TE)
Mali Momentum through 2013

- The most widely licensed GPU
  - 84 Mali licenses to date
- More than 10x Growth in volume in 2 years
  - 152M units shipped in 2012, in more than 230 devices
  - >300M units shipped YTD 2013
  - 2013 has already seen shipments double from 2012
- Strength in key market segments
  - #1 Android GPU IP supplier
  - >20% Android Smartphone
  - #1 in Android tablets (>50%)
  - #1 in Digital Smart TVs (>70%)
Premium Mobile Devices

Energy efficient 3D Graphics
Mali High-end GPU Solutions

- Designed for Graphics and GPU Compute
  - Full Profile, 64-bit Compute
- Closer CPU-GPU links
  - Efficient use of system resources
  - Coherent memory links
  - Cortex®-A15 / Cortex-A53 / Cortex-A57
- Protecting partner investments
  - Common software platform reduces costs and TTM
  - Multicore scales performance to address multiple form factors
- Advanced products get to market early
  - ARM Mali-T628 GPU silicon shipping now in consumer products
Premium Mobile Device Requirements

- Increasing screen size and content complexity demand increased performance
- Increased performance demands advanced memory technologies to achieve greater bandwidth
- Mobile computing devices thermal budget doesn’t increase with performance
- Rigid thermal constraints force the adoption of advanced silicon process and memory technologies to achieve greater performance
ARM Mali-T760 GPU Overview

- Increased performance and energy efficiency
  - ~400% increase in energy efficiency over ARM Mali-T604 GPU
- Multi-processor scalable graphics performance
  - Coherently scales up to 16 shader core configurations
- 3D graphics acceleration and Compute APIs
  - Khronos* compliant OpenGL ES 3.0/2.0, 1.1
  - Microsoft Windows compliant Direct3D 11.1
  - Full Profile OpenCL 1.1
  - RenderScript/FilterScript
- Major reduction in bandwidth and SoC power
  - Memory system optimizations
  - ARM Frame Buffer Compression (AFBC)
  - Smart Composition
- Proven software DDK quality and performance

<table>
<thead>
<tr>
<th># Shader Cores</th>
<th>L2 Cache Size</th>
<th>Clock Freq (MHz)</th>
<th>Pixel Fillrate</th>
<th>Triangle Rate</th>
<th>Floating Point Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to MP16</td>
<td>2 x 512kB</td>
<td>600MHz</td>
<td>9.6 Gpix/Sec</td>
<td>1066.6 MTri/s</td>
<td>326.4 GFLOPS</td>
</tr>
</tbody>
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ARM Mali-T760 GPU Scalability

- Coherent shader core scalability using an improved L2 Cache interconnect
  - Scalable up to 16 coherent shader cores
  - Significant reduction in wire count
  - Evenly distributed cache utilization
  - Single or Dual L2 Cache slice each with individual master port
  - Consistent ACE™-Lite interface
AFBC Application in SoC

- Employing AFBC throughout the SoC saves significant system bandwidth and power.
Smart Composition

- Better than 50% reduction of texture read bandwidth on simple Android UI use cases
- Significantly reducing read bandwidth and composition work by ignoring repetitive tile data
Additional Features

- Reduce system bandwidth when sending video output
  - YCrCb framebuffer output
- Hardware assisted global illumination
  - Improved Multiple Render Target
- Increased capabilities to support DirectX 11.1
  - HW super-sampling, TIR
- Continuing support for next generation APIs
  - Direct3D 11.1 Feature Level 11 and next generation OpenGL ES
- ARM POP IP for Mali is available from the Physical IP Division
- ARM’s EDA tool partners are working with our IP now to prepare for supporting our licensees
  - 28HPM and 16FF process libraries
Entry-level Smart Mobile Devices

Rapid Implementation of 3D Graphics
Mali Mid-range GPU Solutions

- Designed for cost-effective Graphics solutions
  - OpenGL ES, OpenVG

- Closer CPU-GPU links
  - Efficient use of system resources
  - Cortex-A7 / Cortex-A12 / Cortex-A53

- Protecting partner investments
  - Common software platform reduces costs and TTM
  - Multicore scales performance to address multiple form factors

- Proven solutions
  - ARM Mali-400 MP and Mali-450 MP GPU silicon shipping in hundreds of millions of consumer products

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Entry Level Smartphone Tomorrow

**ARM Mali-T720 GPU**
- Extends lead in area and energy efficiency
- Supports OpenGL ES 3.0*
- Area-efficient performance

Quad or Dual-core Cortex-A53/Cortex-A7
- Most energy-efficient 32-bit CPU
- 64-bit architecture for new software

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Time to Market Defines Profit Margin

- **Time-to-market becomes the key differentiator which protects profit margins**
- Engineering costs grow as process nodes advance
- ASPs sharply reduced as competition appears in low-cost markets

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**Basic SoC Silicon and Software Design Costs**

- Source: Semico Research, 2011

**Unit volume (M) to break even for Basic SoC Designs @28nm**

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**Average Selling Price ($)**

- $5.00
- $10.00
- $15.00
- $20.00
- $25.00
- $30.00

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**Design Costs ($M)**

- 90nm
- 65nm
- 45nm
- 32nm
- 28nm
- 22nm
- 14nm

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**Break even Unit Volume (M Units)**

- 20.0
- 15.0
- 10.0
- 5.0
- 0.0
ARM Mali-T720 GPU Overview

- Increased energy efficiency of previous cost optimized ARM Mali GPU
  - ~150% energy efficiency increase over previous cost optimized GPUs
- Android optimized version of ARM Mali-T62x
  - ~30% area reduction from previous Midgard generation
  - Up to 15% less dynamic power
  - Natural companion to quad core implementations of:
    - Cortex-A7 / Cortex-A12 / Cortex-A53
- Targeted optimizations for Android OS
  - OpenGL ES 3.0, Renderscript/FilterScript support
- Maintain the area efficiency leadership of ARM Mali-4xx GPU
  - Area efficient OpenGL ES 3.0* GPU
- Significantly decreased time-to-market
  - Ease of implementation & integration in SoC designs

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<th>Clock Freq (MHz)</th>
<th>Pixel Fillrate</th>
<th>Triangle Rate</th>
<th>Floating Point Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shader Core</td>
<td>600MHz</td>
<td>4.8 Gpix/Sec</td>
<td>533.2 Mtri/s</td>
<td>81.6 GFLOPS</td>
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<tr>
<td>L2 Cache Size</td>
<td>2x128kB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Shader Cores</td>
<td>Up to MP8</td>
<td></td>
<td></td>
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Decreased Time-to-Market

- Increased routing density significantly decreases die area
  - Constrained routing layers to minimize cost

- Crafted reference methodologies to match tool chain

- ARM POP IP available from the ARM Physical IP Division

- ARM’s EDA tool partners are working with our IP now to prepare for supporting our licensees on 28nm process libraries

Opportunities for optimizing layout utilization
ARM POP IP Exploration Worksheet

- Extensive exploration analysis to map the wide range of Vt/L options on a process to evaluate multiple PPA trade-offs.
- Determine most effective Vt/L choice for optimizing different design goals.
  - The dominant effects of Vt/L choice can be easily seen in this post-synthesis dataset.
  - Use datasheets to estimate GPU PPA
Extensive Mali Ecosystem
Summary

- ARM Mali-T760 GPU addresses the needs of high-end mobile and consumer devices by providing:
  - Scalable graphics and compute performance with up to 16 core configurations capable of twice the performance of previous generations
  - ~400% increase in energy efficiency over ARM Mali-T604 GPU
  - Included technology capable of greatly reducing SoC level memory bandwidth utilization and power consumption

- ARM Mali-T720 GPU solve the needs of semiconductor partners focusing on low-cost mobile devices by providing:
  - Significant reduction in shader core area and increased area efficiency
  - Greater facilities to assist licensees to drastically reduce time-to-market
  - Targeted optimizations for Android OS - OpenGL ES 3.0, RenderScript/FilterScript support
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