Introduction

- What: SoC for Mobile Devices
- When: Q1 2010
- Where:
Architecture Overview

Source: NVIDIA

Figure 1 NVIDIA Tegra 2 with GeForce GPU

Source: NVIDIA
Overview on CPU

Source: NVIDIA
Arch. highlights

- Shallow pipeline with OoO
  - Improve ILP while reduce speculative penalty
- Multi-core configuration
  - Multi-threaded applications benefit a lot (Web browser, PC games)
- DVFS
  - Maximize battery life vs. Performance
Benefit of Multi-core in Tegra 2

- Faster Web page load times and higher performance per watt
- Lower power consumption
- Higher quality game play experience for advanced console
- Highly responsive and smooth
- Faster multitasking
Fast Webpage load

Source: NVIDIA
Low power with SMP

- **Single Core A9**
  - Single Core CPU 100% utilized due to workload
  - Needs to run at Max Frequency = 1GHz
  - Runs at Max Voltage = 1.1 V
  - Consumes Power = P
  - 40% Lower Power than Single Core CPU

- **Dual Core A9**
  - Two cores share Workload
  - Each core 50% utilized
  - Cores run at lower Frequency = 550 Mhz
  - Voltage = 0.8V
  - Consumes Power = 0.6P

Source: NVIDIA
GPU: Feature

- Early-Z support to filter out non-visible pixels
- Integrated Pixel Shader and Blend Unit for programming flexibility and higher performance
- Pixel Cache, Texture cache, Vertex, and Attribute Caches to reduce memory transactions
- Unique 5x Coverage Sampling Anti-aliasing (CSAA) technique that achieves higher image quality at lower memory bandwidth
- Advanced Anisotropic Filtering (AF) for high detail textures
- A custom Memory Controller developed in-house that improves GPU performance and reduces power consumption
- Numerous Power Management features for ultra low power consumptions.
Ultra Low power GeForce GPU

- 8 Shader cores
  - 4 pixel shader cores
  - 4 vertex shader cores

Figure 4 GeForce GPU Architecture in NVIDIA Tegra

Source: NVIDIA
Dynamic Clock Speed Control
- MC anticipates GPU needs and manages its operating levels

GPU centric Memory Arbitration

GPU Request Grouping
- Group together memory requests into groups based on bank access pattern
GPU: Power Management

- Multi-Level of Clock Gating
- Local Power Management
- Display Request Grouping
- Power-Optimized transistor design
- DVFS
GPU: Performance

![GeForce GPU Gaming Performance Benefit](image)

Source: NVIDIA

Figure 7 GeForce GPU Performance on Mobile games²

Source: NVIDIA
Other processors

- **Audio:**
  - NVIDIA acquired PortalPlayer in 2007

- **Video encode**
  - Able to encode 1080p H.264 video
  - Power consumption remain unknown

- **Video decode**
  - Decodes 1080p H.264 video at 20Mbps
  - Consumes 400 mW
Other processors

- Image signal processing
  - Support 2 cams: one 12MP, one 5MP
  - Can burst 12MP images at 11 frames/s

- One ARM 7 for chip management

- No cellular modem
SunSpider Javascript Benchmark 0.9
Overall Performance in ms (Lower is Better)

- LG Optimus 2X (2.2.1 - Tegra 2): 4435
- T-Mobile myTouch 4G (2.2): 4990
- Nexus One (2.2.1): 6140
- Nexus S (2.3): 6410
- T-Mobile G2 (2.2): 6907
- Motorola Droid 2 (2.2): 7278
- HTC EVO 4G (2.2): 7703
- Apple iPhone 4 (4.2.1): 10255
- Apple iPad: 10475
- Apple iPhone 4 (4.1): 10557
- HTC Droid Incredible (2.1): 13193
- HTC EVO 4G (2.1): 13436
- Apple iPhone 3GS (4.2.1): 13580
- Apple iPhone 3GS (4.1): 14029
- Motorola Droid X (2.1): 14532
- Nexus One (2.1): 14564
- Samsung Epic 4G (2.1): 15532
- Samsung Fascinate (2.1): 15835
- BlackBerry Torch 9800: 26228
- Dell Streak (1.6): 27768
- Motorola Droid (2.1): 38955
- Samsung Focus: 44795
- LG Optimus 7: 45326
- HTC Surround: 46877

Source: AnandTech.com
### WiFi Performance
Local WiFi transfer speed - Mbit/s (higher is better)

<table>
<thead>
<tr>
<th>Device</th>
<th>Speed (Mbit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>iPad - 802.11n</td>
<td>30.4</td>
</tr>
<tr>
<td>LG Optimus 2X - 802.11n</td>
<td>30.3</td>
</tr>
<tr>
<td>iPhone 4 - 802.11n</td>
<td>29.6</td>
</tr>
<tr>
<td>iPhone 4 - 802.11g</td>
<td>24</td>
</tr>
<tr>
<td>HTC Surround - 802.11n</td>
<td>24</td>
</tr>
<tr>
<td>Samsung Epic 4G - 802.11n</td>
<td>22.4</td>
</tr>
<tr>
<td>Samsung Fascinate - 802.11n</td>
<td>20</td>
</tr>
<tr>
<td>iPad - 802.11a</td>
<td>20</td>
</tr>
<tr>
<td>iPhone 3GS - 802.11g</td>
<td>18.4</td>
</tr>
<tr>
<td>myTouch 4G - 802.11n</td>
<td>16.9</td>
</tr>
<tr>
<td>Droid X - 802.11n</td>
<td>16.8</td>
</tr>
<tr>
<td>Motorola Droid 2 - 802.11n</td>
<td>15.7</td>
</tr>
<tr>
<td>Nexus S - 802.11n</td>
<td>15.5</td>
</tr>
<tr>
<td>AT&amp;T Nexus One - 802.11n</td>
<td>14.4</td>
</tr>
<tr>
<td>BlackBerry Torch 9800 - 802.11n</td>
<td>9.8</td>
</tr>
<tr>
<td>Streak - 802.11g</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Source: AnandTech.com
3G Web Browsing Battery Life
Time in Hours - Higher is Better

- Apple iPhone 4: 6.65
- Dell Streak: 5.7
- LG Optimus 7: 5.13
- MyTouch 4G: 4.88
- Apple iPhone 3GS: 4.82
- BlackBerry Torch 9800: 4.77
- HTC Surround: 4.22
- Motorola Droid X: 4.12
- Motorola Droid 2: 4.07
- LG Optimus 2X: 4.07
- Motorola Droid: 3.89
- Samsung Fascinate: 3.77
- Google Nexus One: 3.77
- Nexus S: 3.76
- Samsung Focus: 3.75
- Samsung Epic 4G (4G): 3.67
- HTC EVO 4G: 3.58
- T-Mobile G2: 3.52
- Samsung Epic 4G: 2.92
- HTC Droid Incredible: 2.83

Source: AnandTech.com
Reference

- The benefits of Multiple CPU Cores in Mobile Devices, NVIDIA Whitepaper.
- Bringing High End Graphics to Handheld Devices, NVIDIA whitepaper.
- AnandTech reviews
  - Nvidia introduces Tegra2
  - Architectural details and design wins
Backups
Target Market

- Smartphone, tablet, and other embedded devices
- Notable devices using Tegra2
  - LG Optimus X2 (cell phone, Feb. 2011)
  - Motorola Xoom (tablet, Feb. 2011)
  - Samsung Galaxy Tab II (tablet, 2011)
  - 2011 Audi A8
- Competitor
  - TI’s OMAP 4 (ARM Cortex A9)
  - Qualcomm Snapdragon/Armamda (ARMv7)
Architectural Overview

CPU

Coprocessors
A9: differences from A8

- Shallower pipeline (13 stages -> 8 stages)
- OoO capability
- Improved FPU with pipeline
- No SIMD engine (a.k.a NEON)
  - Impact minimal code with 30% die penalty.
  - Maybe added in the future.
Details on CPUs

- Dual-core ARM Cortex A9 at up to 1GHz
- Dual-issue out-of-order execution
- Clock gated.
- DVFS enabled
- No NEON instruction set (SIMD extension)
- 1MB shared L2 cache
<table>
<thead>
<tr>
<th></th>
<th>Apple iPhone 4</th>
<th>Motorola Droid 2</th>
<th>Samsung Galaxy S Fascinate</th>
<th>Google Nexus S</th>
<th>LG Optimus 2X</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Height</strong></td>
<td>115.2 mm (4.5&quot;)</td>
<td>116.3 mm (4.6&quot;)</td>
<td>106.17 mm (4.18&quot;)</td>
<td>123.9 mm (4.88&quot;)</td>
<td>123.9 mm (4.67&quot;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Width</strong></td>
<td>58.6 mm (2.31&quot;)</td>
<td>60.5 mm (2.4&quot;)</td>
<td>63.5 mm (2.5&quot;)</td>
<td>63.0 mm (2.48&quot;)</td>
<td>63.2 mm (2.40&quot;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>9.3 mm (0.37&quot;)</td>
<td>13.7 mm (0.54&quot;)</td>
<td>9.91 mm (0.39&quot;)</td>
<td>10.0 mm (0.43&quot;)</td>
<td>10.9 mm (0.43&quot;)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>137 g (4.8 oz)</td>
<td>169 g (5.9 oz)</td>
<td>127 grams (4.5 oz)</td>
<td>129 grams (4.6 oz)</td>
<td>139.0 grams (4.90 oz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CPU</strong></td>
<td>Apple A4 @ ~800MHz</td>
<td>Texas Instruments OMAP 3630 @ 1 GHz</td>
<td>1 GHz Samsung Hummingbird</td>
<td>1 GHz Samsung Hummingbird</td>
<td>NVIDIA Tegra 2 Dual-Core Cortex-A9 (AP20H) @ 1 GHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GPU</strong></td>
<td>PowerVR SGX E35</td>
<td>PowerVR SGX E30</td>
<td>PowerVR SGX 540</td>
<td>PowerVR SGX 540</td>
<td>ULV GeForce @ 100-300 MHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>RAM</strong></td>
<td>512MB LPDDR1 (?)</td>
<td>512 MB LPDDR1</td>
<td>512 MB LPDDR1</td>
<td>512 MB LPDDR1</td>
<td>512 MB LPDDR2 @ 600 MHz data rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NAND</strong></td>
<td>16GB or 32GB integrated</td>
<td>8 GB integrated, preinstalled 8 GB microSD</td>
<td>2 GB, 16 GB microSD (Class 2)</td>
<td>16 GB Integrated</td>
<td>8 GB integrated (5.51 GB internal SD, 1.12 phone storage), up to 32 microSD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Camera</strong></td>
<td>5MP with LED Flash + Front Facing Camera</td>
<td>5MP with dual LED flash and autofocus</td>
<td>5 MP with autofocus and LED flash</td>
<td>5 MP with Autofocus, LED Flash, VGA front facing, 720P Video</td>
<td>8 MP with autofocus, LED flash, 1080p24 video recording, 1.3 MP front facing</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Screen</strong></td>
<td>3.5&quot; 640 x 960 LED backlit LCD</td>
<td>3.7&quot; 854 x 480</td>
<td>4&quot; Super AMOLED 800 x 480</td>
<td>4&quot; Super AMOLED 800 x 480</td>
<td>4&quot; IPS-LCD 600x480</td>
</tr>
<tr>
<td></td>
<td>Cupping Tightly</td>
<td>Holding Naturally</td>
<td>On an Open Palm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
<td>----------------</td>
<td>------------------</td>
<td>-----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LG Optimus 2X</td>
<td>13.7</td>
<td>9.3</td>
<td>5.9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nexus S</td>
<td>13.3</td>
<td>6.1</td>
<td>4.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Droid 2</td>
<td>11.5</td>
<td>5.1</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BlackBerry Torch</td>
<td>15.9</td>
<td>7.1</td>
<td>3.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dell Streak</td>
<td>14.0</td>
<td>8.7</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Droid X</td>
<td>15.0</td>
<td>5.1</td>
<td>4.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iPhone 4</td>
<td>24.6</td>
<td>19.8</td>
<td>9.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>iPhone 3GS</td>
<td>14.3</td>
<td>1.9</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HTC Nexus One</td>
<td>17.7</td>
<td>10.7</td>
<td>6.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: AnandTech.com