About The Linley Group

• Microprocessor Report and Networking Report
  • Weekly online, monthly print edition.

• Guide To…
  • In-depth analysis of a specific semiconductor segment.

• Linley Tech Conferences
  • Data Center Conference: February 5 – 6
  • Mobile Conference: April 30 - May 1
  • Carrier Conference: June 10 - 11
  • Processor Conference: October 22 - 23

• Custom consulting projects
About Me

• Senior Analyst, The Linley Group
  • Focus on mobile processors, semiconductor IP

• Senior Editor of *Microprocessor Report*
  • Recent articles: ARM, Arteris, Broadcom, CEVA, Intel, MediaTek, Spreadtrum, et al

• 15+ years in semiconductor industry
  • Datel, GE R&D Labs, MicroNetworks, Texas Instruments

• 15 years in EDA industry
  • Antrim, Cadence, Nassda, Synopsys

• Also author of…
  • *High-Speed Analog-to-Digital Conversion, The Android Invasion, The Emerging 4G Wireless Landscape in the U.S.*
Trends in Mobile Processors

• Development of the mobile processor and Moore’s Law
• Top 5 Trends in Mobile Processors
  • Functional integration
  • LITTLE.big or Big.LITTLE
  • Heterogeneous Multiprocessing
  • Dual to Quad to Octa
  • The 64-bit question
• Conclusions
The Genesis of the Mobile Processor

- Sales of ICs for communications devices began to surpass PCs and computing as biggest revenue driver.
The Genesis of the Mobile Processor

- Moore’s Law was “stagnating”.
- “Transistor scaling will continue to be an important technology driver. But it will no longer be the sole driver – SOC integration will accelerate in the Internet age.” – Dennis Buss of TI, at ISSCC 2002

- The quest for a single-chip cell phone began.
Opportunities for Mobile SoC Integration

• Initially, goal was process technology convergence
  • Reduce cost by combining analog, digital, Flash, power, RF
• But a more significant convergence was underway
  • Deployment of 3G ➔ communications converged with computing
  • The internet was going mobile
• Other personal mobile devices came to market
  • PDAs
  • Digital audio/video players
  • Camera/recorders
  • Game players
  • GPS navigation
Opportunities Arose for Functional Convergence

Mobile Processor SoC
Moore’s Law and Processor Technology

The graph shows the increase in transistor count over time, with a curve indicating that the transistor count doubles every two years. The question “Mobile processors?” is highlighted.

Microprocessor Vendors Missed the Revolution

- ARMv6
- ARMv7 Cortex
- Cortex-A9 MPCore
- Cortex-A12
- Cortex-A50
- ARMv8
- Cortex-A15
- Cortex-A7

Date of Introduction

- 2000
- 2002
- 2004
- 2006
- 2008
- 2010
- 2012
- 2014
Moore’s Law was just one factor

• Billions of transistors were not required
• System partitioning for cost, power, efficiency
• Availability of SoC IP: CPUs, GPUs, DSPs, Memory
• Hardware & Software design
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Generic Smartphone

- Still separate analog, power, RF ICs
Generic Mobile Application Processor

- Integrates all functions needed to run user applications in smartphones and tablets.

![Diagram of Generic Mobile Application Processor]

- L2$ Main CPU
- Frame Buffer
  - Video Engine
  - 2D/3D Engine
  - Display Control
- Crossbar interconnect
- System I/O
  - USB, serial
- Audio Engine
  - audio I/O
- Imaging Engine
  - to camera
- Memory Control
  - SD/MMC/CE-ATA
- SDRAM
- Flash
Trend is To Integrated Smartphone Processors

- Adds cellular BB and (increasingly) wireless connectivity
Integration Trend Encompasses Wi-Fi

• Many high-end “hero” phones separate app processor (AP) and cellular baseband (BB) for “best of breed” design
  • iPhone, Galaxy S4 (int’l), LG Optimus, ZTE Grand, HTC One…

• But most smartphones use integrated AP+BB processors
  • Even some high-end models, such as Galaxy S4 (US version)

• Integration reduces BOM cost, power, and PCB area (size)

• More vendors are integrating BT + Wi-Fi + GPS connectivity
  • MediaTek, Spreadtrum, Qualcomm
CPU Trend: Cortex-A7

- Performance = 90% of 40nm Cortex-A9 in 81% less area
  - At only 20% the power
- Typically ~1.2GHz in 28LP process, up to 2GHz in 28HPM
- Features:
  - Limited dual-issue
  - MPCore coherent multiprocessing
  - Integrated L2 cache
  - Floating point and Neon extensions
  - Other architectural extensions to match Cortex-A15
CPU Trend: Cortex-A7

- Adopted by nearly all vendors for <$200 smartphones
- Performance + small area has driven multi-core to low-end
  - Allwinner\(^1\): dual A20, quad A31
  - Broadcom\(^1\): quad BCM23550
  - Marvell\(^1\): quad PXA1088
  - MediaTek: dual MT6572, quad MT6589, and octal MT6592
  - Qualcomm: quad MCM8226
  - Spreadtrum\(^1\)
- Highest growth is now in low-cost segment for emerging markets

note\(^1\) - manufactures in 40nm LP
Example: $150 Quad-Core Smartphone

Lenovo A820 Quad Core 1.2GHz 1GB RAM 4.5" QHD Dual SIM Standby 8MP Smartphone

by Lenovo
Be the first to review this item | 13 answered questions

List Price: $259.00
Price: $149.99
You Save: $109.01 (42%)

Note: Free shipping when purchased from Fude Trading Limited. Not eligible for Amazon Prime.

In Stock.
Ships from and sold by Fude Trading Limited.

- Lenovo A820 Quad Core 1.2GHz 1GB RAM 4.5" QHD Dual SIM Standby 8MP Smartphone
- CPU & GPU: MT6592 Cortex-A7 Quad Core 1.2GHz, PowerVR SGX544
- Memory: RAM 1GB, ROM 4GB
- Screen: 4.5" QHD, 960 x 540; 16M Colors, 8 MP/ Auto Focus, LED flash
- Network: WCDMA /GSM, Android V4.1.2, battery 2000 mAh

14 new from $149.50 1 used from $155.00
Smartphone Price Distribution (Conceptual)

- Traditional smartphone market is $400+ price (unsubsidized)
- Emerging market (mainly China today) is <$250 price
- Most growth will be at lower price points

(Source: Microprocessor Report, 2/25/13)
CPU Trend: Multiprocessing with ARM’s big.LITTLE

- Cortex-A15 = 1.7x performance of 40nm Cortex-A9, 22% less area
  - But at 110% the power
- Cortex-A7 is 3.5x more efficient in MIPS/W and 2x in MIPS/mm²
- Dynamically shift processing to the most efficient cores
  - Power down other cores when not needed
big.LITTLE in Samsung’s Exynos Octa

- OS sees only 1 cluster of CPUs
- Big CPUs are treated as a high-performance DVFS operating point by power management
- Tasks are “migrated” from little to big cluster for peak performance
- Plus
  - Saves average power
  - Continuous A15 operation risks thermal limiting
- Minus
  - No mixing of big & little CPUs
  - Can only run one cluster at a time
big.LITTLE in Samsung’s Exynos Octa

- Quad-A15 cluster = 19mm\(^2\)
- The quad-A7 cluster (with 512KB of L2) occupies only 3.8mm\(^2\)
- The total die area in Samsung’s 28nm HKMG process is 122mm\(^2\)
- Point of comparison:
  - Haswell quad-core = 177mm\(^2\) (1.6B xtors)
Alternatives to Cortex-A15 and big.LITTLE

- Apple designed Swift CPU (A6 - iPhone 5), Cyclone (A7 - 5s)
- Qualcomm designed Krait CPU for its 28nm processors
  - About 1/3 power per MHz than A15, but worse perf per MHz
  - Krait has better performance than A15 within 1W limit, but A15 scales to higher performance at higher power

Sources: Qualcomm (Krait), Nvidia (T4 800MHz), Linley Group est

Sources: Nvidia (T4), third-party testing (APQ8064), Linley Group est
CPU Trend: Heterogeneous Multiprocessing

- Big.Little in MediaTek’s MT8135
- ‘True’ heterogeneous multiprocessing
- Quad-core tablet processor
  - 2x Cortex-A15 CPUs @1.5GHz
  - 2x Cortex-A7s CPUs @1.2GHz
- Multicore load balancing
  - Global task scheduler can assign or move a task to any of the A7 or A15 CPUs
  - Big-little transition takes 80μsec
  - All CPUs can run simultaneously
CPU Trend: The Battle for ‘True Octa’ Processor

- Symmetric multiprocessing in MT6592 smartphone processor
  - ARM MPCore limited to 4 CPUs/cluster
  - 2x4 Cortex-A7 CPUs running at maximum 2.0GHz (28HPM)
  - Integrated 3G cellular BB, BT, Wi-Fi, GPS, FM
- Global task scheduler allows all 8 CPUs to run simultaneously
- Targeting multi-window Android
• Measurement of multicore utilization on Qualcomm APQ8064
• Source: Chinese smartphone test service Testin Inc.
CPU Trend: 64-Bit Mobile Processors

- ARMv8 ISA
  - 32b instructions
  - 64b general purpose registers
  - 64b addresses to access >4GB memory
  - 64b operands
  - 32x 128b registers
  - Advanced SIMD and Floating Point
  - Architectural cleanup from ARMv7
  - *Net 10 – 20% performance improvement*
- ARMv7-based processors can already use NEON SIMD instructions to perform 64-bit arithmetic
CPU Trend: 64-Bit Mobile Processors

• Apple’s A7: 1st 64b ARMv8 processor
  • Dual-CPU @1.3GHz, Quad-GPU
  • Up to 2X perf of Cortex-A15 class A6
• Most of performance gain from μArch customizations
• Benefit from 28nm in A7 from 32nm in A6, 102mm²
• But – same clock rate!
• 2x the area devoted to Imagination Rogue GPU
CPU Trend: 64-Bit Mobile Processors

- Intel - new 22nm FinFET processors
- Silvermont update for Atom CPU
- Predicted 50% IPC improvement
- Quad-core Bay Trail for Tablets
  - Maximum 2.4GHz clock rate
  - 32b/64b Windows or Android
  - Intel HD graphics
- Dual-core Merrifield for smartphones
  - Estimated 2.1GHz
  - 32b/64b Android
  - Imagination PowerVR GPU
- Estimated in production 1Q14
Trends in Mobile Processors - Conclusions

- Market is bifurcating into low-cost and high-performance tiers
- Low-cost segment
  - Higher functional integration, cellular BB + connectivity
  - Multi-core has come to the low-end
  - Small area, low-power CPUs
- High-performance
  - Architectural alternative to stay within power envelope
  - Big.LITTLE
  - Customized CPUs by ARM architectural licensees
  - Heterogeneous multiprocessing
- Octa wars?
- 64-bit: Hype versus reality
You have questions?

We have answers.