Building High End Embedded SoCs using Energy Efficient Application Processors

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ARM Tech Symposium, China
Agenda

- Trends in Embedded Computing

- Cortex®-A processors in embedded applications
  - Use case: Smart home
  - Use case: Wearable devices

- Building Embedded SoCs using Cortex-A processors

- Summary
We Live in a Mobile and Connected World
Consumer Trends Driving Innovation in Embedded

- Rich User Interface
- Fast responsiveness
- “Always On” Connectivity
- Personalization
- Content On Demand
- Commerce
- Security
- Low Power
Use Case: Smart Home - Thermostat

- Programmable
- LCD Display
- Connected
- Rich display
- Learning
Use Case: Smart Home - Thermostat

Key Requirements
• Rich User Interface
• Higher performance than traditional embedded solutions
• Small is beautiful
• Connectivity to cloud

http://www.ifixit.com/Teardown/Nest+Learning+Thermostat+2nd+Generation+Teardown/13818/1

ARMv7-A architecture
NEON™ multimedia extensions
Floating Point Unit (FPU)
Thumb®
TrustZone®
Memory Management Unit (MMU)
Market Opportunity in Wearable Devices

Source: IMS Research, Juniper Research

- **Activity monitors account for about 65% growth in this market in 2016**
- **Smart Watches to drive volume growth**
- **Continuous Glucose Monitoring (CGM) largest market in 2016**

**Applications**

- **Fitness and Wellness**
- **Healthcare and medical**
- **Infotainment**

**Up to 210 Million**

- **$30B Revenue**
- **96 Million devices**
- **in 2018**
- **$ 8.5B Revenue**
- **in 2012**

CAGR 11-16%
ARM is at the Heart of Wearable Tech

- Nike Fuelband
- Samsung Gear
- Google Glass
- Oakley Airwave
- Fitbit
- MotoActiv
- Misfit
- Sony
- Pebble
- Kopin
- Golden-i
Wearable Device Categorization

- **Simple OS**
  - No Display
  - BT Tether

- **Simple OS**
  - E-Ink Display
  - BT Tether

- **Simple OS**
  - Colour Display
  - Touch Screen
  - BT Tether
  - Audio

- **Simple OS**
  - Colour Display
  - Touch Screen
  - BT Tether
  - Audio

- **Rich OS**
  - Colour Display
  - Graphics
  - Touch Screen
  - BT Wi-Fi
  - Audio
  - GPS
  - Camera

- **Rich OS**
  - Colour Display
  - Graphics
  - Touch Screen
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  - Audio
  - GPS
  - Camera

**Device power/complexity/Form factor**

- **Basic Wearable**
- **Mid range Wearable**
- **High End Wearable**

**Wearable Phone**
Use Case: Wearable Computing – Smart Glasses

The Google Glass probably needs no introduction!

And there are more of these……..
Use Case: Wearable Computing - Smart Glasses

Key Requirements
- High performance in very small form factors
- Very low power video and audio processing capabilities
- Low active power consumption
- Aggressive power management for extending battery life

Cortex-A9 Dual-core
- Symmetric Multiprocessing (SMP) support
- High efficiency superscalar pipeline
- NEON media processing engine
- Floating point unit (FPU)
- Thumb-2
- TrustZone support

http://www.catwig.com/google-glass-teardown/
# Key Requirements for Wearable Devices

<table>
<thead>
<tr>
<th>Video/Image</th>
<th>Audio</th>
<th>Display</th>
<th>Software/OS</th>
<th>Connectivity</th>
<th>Battery life (current products)</th>
<th>Battery life (future products)</th>
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<tbody>
<tr>
<td></td>
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<td>LED</td>
<td>Simple</td>
<td>BT LE</td>
<td>4 - 7 Days</td>
<td>Several months</td>
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<td></td>
<td></td>
<td>120x120</td>
<td>120x120</td>
<td>120x120</td>
<td>BT LE</td>
<td>Weeks to month</td>
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<td>LCD</td>
<td>LCD</td>
<td>LCD</td>
<td>BT LE</td>
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<td>Basic</td>
<td>Basic UI</td>
<td>BT</td>
<td>2 - 3 Days</td>
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<td>UI</td>
<td>LCD</td>
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<td>Camera</td>
<td>LCD</td>
<td>BT</td>
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<td></td>
<td>Commands</td>
<td>LCD</td>
<td>BT WiFi GPS</td>
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<td></td>
<td></td>
<td>Commands</td>
<td>LCD</td>
<td>BT WiFi GPS</td>
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</tbody>
</table>

**Performance, Functionality, User Interface**

- **SIMPLE**: Basic UI
- **BASIC**: Basic UI
- **RICH**: Rich OS
- **VOICE**: Voice commands
- **AUDIO**: Basic Audio
- **VIDEO**: Still camera
- **CONNECTIVITY**: BT LE, BT, BT WiFi GPS, WiFi GPS

**Battery Life**
- **Current Products**: 4 - 7 Days, 2 - 3 Days, 1 Day
- **Future Products**: Several months, Weeks to month, Week to few days
Which Application Processor for High End Embedded?

All Cortex-A series processors have a fundamental focus on high energy efficiency.

Cortex-A Series

- **Cortex-A57**
  - ARMv8
  - 64/32-bit
- **Cortex-A53**
  - ARMv8
  - 64/32-bit
- **Cortex-A12**
  - ARMv7
  - Mid-range mobile
- **Cortex-A15**
- **Cortex-A9**
- **Cortex-A8**
- **Cortex-A7**

**Performance, Functionality**

- Mature processors
- New processors

**High Efficiency Processors**

- Designed for maximum energy efficiency
- Simple, in order pipelines
- Maximum performance at sub 100mW power envelope
- Configurable to tiny sizes
- Ideal for high performance, low power embedded applications

ARM®

THE ARCHITECTURE FOR THE DIGITAL WORLD®
Why High Efficiency Cortex-A for High End Embedded?

Cortex-A5
- 8 stage in-order
- Single issue
- ARMv7-A
- AMBA® 3

Cortex-A7
- 8 stage in-order
- Partial dual issue
- ARMv7-A Extended
- 40b PA, Virtualization
- AMBA 4 ACE

Cortex-A53
- 8 stage in-order
- Full dual issue
- ARMv8-A (64/32-bit)
- AMBA 4 or AMBA 5

Different Performance Points
- Large workload
- Great user experience

Tiny Sizes
- < 0.5 mm²
- Low silicon cost, low power

Very Low Power
- Long Battery Life
- Power saving in each mode

*28nm
Example of a Smart Watch Platform

Cortex-A5 UP Application Processor

Implementation requirements:
• **Small Area (<0.4 mm²)**
  • Small L1 cache sizes (16K/8K)

• **Low frequency**
  • 250-500 MHz
  • Low active power

• **Very low power consumption**
  • Sub 50mW active power
  • Low power modes
    • ~95% standby power reduction

• Low power Cortex-M4 CPU
  • Always On
  • Very low active power
  • Collects data from sensors
Example of a High End Wearable Device Running Rich OS

Cortex-A7 MP Application Processor
- Dual core cluster provides scalable performance
- Sub 100mW active power for entire cluster
- Low power modes reduce standby power
- Energy efficient L2 subsystem reduces overall system power
- Energy efficient NEON engines provide audio and DSP capabilities

Mali™-400 MPI GPU
- Supports rich OS and better graphics capabilities
- Low power modes to reduce standby power
- LPDDR for lower memory power consumption
Lots of Smart Devices Generating Lots of Data

- **Bluetooth LE – Personal world**
  - Personalized ultra low power comms
  - Low latency data connection

- **LTE – Mobile broadband**
  - Permanently connected
  - Enables wireless HD streaming

- **WiGIG – Personal broadband**
  - HD video streaming
  - Split screen gaming

- **NFC – Touch to connect**
  - Touch to pay
  - Touch to share
  - Enables highly secure localized comms
  - Personal notifications
  - Controlling content

- **Sport & Lifestyle**
- **Gaming & toys**
- **Personal devices**
- **Mobile payments**
- **Touch to pay**
- **Touch to share**
- **Recreation**
- **Healthcare**
- **Security**
- **Consumer goods**
End To End: Linking Smart Devices to Cloud

Wearable Devices

Smartphone 'My Personal Hub'

Access Network

Low Energy e.g. BT Smart, 6lowpan, Ant+ etc

Wi-Fi, 3G, LTE

Device Provisioning and Diagnostics

Access Network: e.g. 3G, LTE WiFi

Management Platform

Higher Computing Requirements

Cloud Services

Apps

'Big Data' Storage

Cloud Hosting
Software Development Challenge for High End Embedded

- Conventional embedded systems had simple software requirements
- Embedded applications now integrate more functionality
- Huge increase in software development costs
- Software development from scratch impacts time-to-market significantly
ARM’s Software Ecosystem Advantage for High End Embedded

- The ARM® Connected Community
  - Making easier to design with ARM
    - [http://community.arm.com](http://community.arm.com)

- Linaro
  - Collaborative engineering enables development of optimized open source devices ([www.linaro.org](http://www.linaro.org))

- Embedded Software Store: A marketplace developed by ARM & Avnet

ARM’s strong software ecosystem offers several choices and a fast time-to-market for new high end embedded solutions
Silicon Choice Available Today

- Embedded computing spans diverse applications
  - Peripherals to meet application needs
  - Competition and constant innovation

<table>
<thead>
<tr>
<th>Silicon Vendor</th>
<th>Family</th>
<th>ARM Processor</th>
</tr>
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<tbody>
<tr>
<td>Texas Instruments</td>
<td>Sitara AM3x</td>
<td>Cortex-A8 processor</td>
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<tr>
<td></td>
<td>OMAP</td>
<td>Cortex-A9/A8 processor</td>
</tr>
<tr>
<td>NVIDIA</td>
<td>Tegra</td>
<td>Cortex-A9</td>
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<tr>
<td>ALTERA</td>
<td>Arria V</td>
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<td>XILINX</td>
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<td>Atmel</td>
<td>SAMA5D3x</td>
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<td>Freescale</td>
<td>Vybrd</td>
<td>Cortex-A5 processor</td>
</tr>
<tr>
<td></td>
<td>i.MX</td>
<td>Cortex-A9 processor</td>
</tr>
</tbody>
</table>
One Size Does Not Fit All Embedded Applications

Performance

Energy efficiency

Application processors

32-bit, ARMv7
Cortex-A12

64/32-bit, ARMv8-A
Cortex-A53

Cortex-A9

Cortex-A8

Cortex-A7

Cortex-A5

For high end embedded applications in 2015 and beyond

Enabling innovation for a whole new class of high end embedded applications today
Summary

- Trends in consumer are driving innovation in embedded

- High end embedded products shipping with ARM application processors today

- One size does not fit all embedded applications
  - Different ARM application processors available for wide range of embedded applications

- ARM’s strong software ecosystem offers significant advance of lower cost and fast turn around time for new embedded solutions
Thank You