ITRS2.0 and Its System Drivers: Focus on System Trends and MTM

ITRS Design International Technology Working Group
Co-chairs: Andrew B. Kahng, Juan-Antonio Carballo
(Special thanks to Wei-Ting Jonas Chan, Siddhartha Nath (UCSD VLSI CAD Lab))

May 14, 2014   The Chaminade, Santa Cruz
Agenda

1. Evolution of ITRS System Drivers. MTM / Integration Focus.
   Why do we need drivers in the ITRS?

2. Systems drive devices: capturing the right trends?
   What drivers are really going to matter in next 10+ years?
   (Answer: Mobile)

3. Focus on Mobile systems: example first steps
   Since systems determine technology requirements, how do we connect system level to IC level for ITRS drivers, and then roadmap the drivers?

4. Conclusions and looking forward
Design, System Drivers History

1. Increasingly quantitative roadmap
2. Increasing maturity of driver set
3. Increasing More Than Moore content

- MTM Roadmap
- Updated Consumer Stationary, Portable, and Networking Drivers
- MTM Extension + iNEMI Synch + SW !!
- Updated Consumer Stationary, Portable, and Networking Drivers
- MTM Extension + iNEMI Driver Start

2004: Consumer Stationary, Portable Drivers
2005: Revised Design Technology Metrics
2006: More Than Moore (MTM) analysis + iNEMI
2007: Updated Consumer Stationary, Portable, and Networking Drivers
2008: MTM Extension + iNEMI + SW !!
2009: Updated Consumer Stationary, Portable, and Networking Drivers
2010: Updated Drivers (MPU, SoC, ...)
2011: Upgraded Cost, Low-Power Roadmaps
2012: iNEMI alignment
2013: More Than Moore “re-boot”

Design Chapter: Revised Design Metrics, DFM Extension, System Level Extension, Additional Design Metrics, Power Design Technology Roadmap

Major revisions MPU, CP-SOC, A-factor Design capability

Market-driven Updates
MPU, SOC Updates
Updated MPU, CP-SOC, A-factor Design capability
Updated Cost, Low-Power Roadmaps
Upgraded DfTest, Resilience, Memory DT

iNEMI alignment
Updated Cost, Low-Power Roadmaps
The New ITRS

In the 80s and 90s the Semiconductor Industry was constituted by Integrated Device Manufactures (IDM)

• Standard components (e.g. Memory and Microprocessors) were produced by IDM and assembled into systems by OEMs

In the past 10 years the Semiconductor Industry has evolved into a distributed industry

• Design team and manufacturing teams are no longer in a single company
• Custom SoC and SIP are the dominant building blocks of electronic systems
• Design houses and foundries represent the new foundation of the Semiconductor Industry

The 2014/15 ITRS has been restructured to represent the new ecosystem
# Beyond 2020

## Themes

<table>
<thead>
<tr>
<th>System Integration</th>
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</thead>
<tbody>
<tr>
<td>Outside System Connectivity</td>
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<tr>
<td>Heterogeneous Integration</td>
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<td>More than Moore</td>
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<td>Beyond Moore</td>
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<td>More Moore</td>
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<td>Manufacturing</td>
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</table>

## ITWGs

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<thead>
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<tr>
<td>Heterogeneous Components</td>
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<td>More Moore</td>
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<td>Manufacturing</td>
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</table>
Definitions of 7 Focus Topics

**System Integration**—studies and recommends system architectures to meet the needs of the industry. It prescribes ways of assembling heterogeneous building blocks into coherent systems.

**Outside System Connectivity**—refers to physical and wireless technologies that connect different parts of systems.

**Heterogeneous Integration**—refers to the integration of separately manufactured technologies that in the aggregate provide enhanced functionality.

**Heterogeneous Components**—describes devices that do not necessarily scale according to “Moore's Law,” and provide additional functionalities, such as power generation and management, or sensing and actuating.

**Beyond CMOS**—describes devices, focused on new physical states, which provide functional scaling substantially beyond CMOS, such as spin-based devices, ferromagnetic logic, and atomic switch.

**More Moore**—refers to the continued shrinking of horizontal and vertical physical feature sizes to reduce cost and improve performance.

**Manufacturing** consists of tools and processes necessary to produce items at affordable cost in high volume.
System – Device Domain Space

System Demand will drive Device Demand
Typical System, Board Parameters

1. PCB Costs
2. Assembly Costs
3. Package Costs
4. Business Costs
5. Cycle Time
6. Reliability
7. Passive components, RF components
8. Display
9. Memory
10. Components / package
11. PCB / substrates / interconnect
12. Electrical and test
13. Power / environmental / thermal
14. Supply chain manufacturing
15. Simulation / tools

But where are the Application and Product requirements?
Bell’s Law – Spatial and Production Volumes

Size (mm³)


Mainframe 1 per Enterprise

Workstation 1 per Engineer

Laptop 1 per Professional

Smartphone 1 per person

mm-Scale Computing

Ubiquitous 1 per Family

Personal Computer 1 per Company

Mini Computer 1 per Company

Mainframe 1 per Enterprise

Acknowledgment:
Prof. D. Blaauw, U. Mich

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Learning From History: The PC Wave

- **Goal:** understand and predict technology, platform “waves”
- **Starting point:** analysis of PC system trajectory
- **Example:** Intel south bridge (ICH, ICH2, …, ICH10, and HM47)

**USB peripheral: #ports reverses in 2012**

- **Bandwidth:** monotone increase
- **Storage Capacity:** monotone increase

**Decrease due to new feature (USB3.0)**

[Source] Intel and Wikipedia
# PC System Integration Trends

## SYSTEM level: PC motherboard over last 15 years

- From 1998: L2 cache integrated to CPU (performance)
- From 2009: North bridge integrated to CPU (bandwidth)
- Bandwidth of system bus scales up: ISA → PCI → AGP → PCIe
- From 2011: PCI de-integrated, disappears in latest product
- USB interface scaling: (1) degree of integration, (2) bandwidth

### System Integration Trends

<table>
<thead>
<tr>
<th>Year</th>
<th>Chipset Model</th>
<th>Chipset Conf</th>
<th>L2 CACHE</th>
<th>AUDIO</th>
<th>AGP</th>
<th>PCIe</th>
<th>PCI</th>
<th>ISA</th>
<th>USB1.1 / 2.0</th>
<th>USB3.0</th>
<th>2nd USB3.0</th>
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<tbody>
<tr>
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- **Cache integrated**
- **USB BW scales up**
- **North bridge integrated**
- **PCI de-integrated**

[Source] Asus motherboard manuals

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A. B. Kahng, Santa Cruz 140514
# PC System Integration Trends

- Bandwidth of ethernet interface scales up
- Bandwidth of SATA interface scales up
- IDE interface de-integrated from 2005
- Integration and de-integration both observed in PC platform
- Functional, integration requirements drive design of chipset

<table>
<thead>
<tr>
<th>Year</th>
<th>Chipset Model</th>
<th>10/100M Ethernet</th>
<th>Gb Ethernet</th>
<th>2nd GbE</th>
<th>WiFi</th>
<th>IEEE 1394</th>
<th>IDE</th>
<th>SCSI Controller</th>
<th>SCSI IO</th>
<th>SATA 3G</th>
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<th>SATA 6G</th>
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- **Bandwidth of ethernet scales up**
- **IDE de-integrated**
- **SATA BW scales up**

[Source] Asus motherboard manuals

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ITRS System Drivers – Need to Focus

1. Applications drive technology
2. Need system input: mechanical, thermal, electrical, spatial

Fabrics

- MPU
- PE/DSP
- Memory
- AMS

Markets

- Medical
- Automotive
- Network
- Office/Server
- Mobile
- Consumer/Stationary
- A&D

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Mobile Proliferation

- > 100% penetration rates
- Complex ecosystem of operators, spectrum allocation

**France**

France has 75.5 million subscribers in total, or a 115.2% penetration rate September 2013.[39]

The Regulatory Authority for telecommunication in France is ARCEP.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Operator</th>
<th>Technology</th>
<th>Subscribers (in millions)</th>
<th>Ownership</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orange (Formerly Iliad)</td>
<td>GSM-900/1800 (GPRS, EDGE) UMTS, HSPA, HSPA+, DC-HSPA+ 800/2600 MHz LTE</td>
<td>28.768 (Sept 2013)</td>
<td>Orange S.A.</td>
</tr>
<tr>
<td>2</td>
<td>SFR</td>
<td>GSM-900/1800 (GPRS, EDGE) UMTS, HSPA, HSPA+, DC-HSPA+ 800/2600 MHz LTE</td>
<td>21.237 (Sept 2013)</td>
<td>Vivendi</td>
</tr>
</tbody>
</table>

**Germany**

Germany has 114.124 million subscribers in total, or a 140% penetration rate [21] (December 2011). The Regulatory Authority for telecommunication in Germany is the Bundesnetzagentur (BNetzA).

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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Telekom (Formerly D1 TeleMobil, T-Mobile)</td>
<td>GSM-900/1800 (EDGE) 2100 MHz UMTS, HSPA, HSPA+, DC-HSPA+ 800/1800/2600 MHz LTE</td>
<td>37.492 [28] (August 2013)</td>
<td>Deutsche Telekom</td>
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<tr>
<td>2</td>
<td>Vodafone (Formerly Deutche Telekom)</td>
<td>GSM-900/1800 (GPRS, EDGE) UMTS, HSPA, HSPA+, DC-HSPA+ 800/2600 MHz LTE</td>
<td>33.890 [31] (May 2013)</td>
<td>Vodafone</td>
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</table>
## Evolution of System Drivers Inventory

1. Coming years may see a smaller list of key Drivers  
2. With fab/tech consolidations, **Driver** applications consolidate too  
3. Remaining non-Driver applications ride the technology curve

<table>
<thead>
<tr>
<th>System Driver (Market based)</th>
<th>Technology Parameters Driven</th>
<th>Likely action</th>
</tr>
</thead>
<tbody>
<tr>
<td>High performance (computing) MPU</td>
<td>Frequency, number of cores, memory architecture</td>
<td>Keep</td>
</tr>
<tr>
<td><strong>Mobile / consumer MPU</strong></td>
<td><strong>Leakage power efficiency</strong></td>
<td>Keep</td>
</tr>
<tr>
<td>Low-power computing MPU “Microserver”</td>
<td>Operating power efficiency</td>
<td>Introduce</td>
</tr>
<tr>
<td>Networking switch</td>
<td>Number of I/Os / total I/O BW</td>
<td>Keep?</td>
</tr>
<tr>
<td>Various fabrics (eNVM, MEMS, AMS/RF)</td>
<td>Various fabric-specific parameters</td>
<td>Keep, expand</td>
</tr>
<tr>
<td>Networking MPU</td>
<td>Number of cores, I/O BW</td>
<td>Keep?</td>
</tr>
</tbody>
</table>
SOC-CP == The Right Driver??

Likely the most influential driver in next 10+ years
Largest market will drive most technology innovation

- Reference application of SOC-CP is changing
  - WAS: feature phones with basic applications
  - IS: smartphones with rich multimedia/gaming applications
- GPU now key component in mobile AP
- Design challenge of SOC-CP → high diversity of functions

WAS: SOC-CP for mobile phone
Area: 49mm²

IS: SOC-CP for smartphone
Area: 140mm²

Main Memory Main Memory Main Memory Main Memory

Peripherals

Audio Bluetooth Modem
2D graphics

Memory

Audio Bluetooth Modem
Multi-mode modem

Video Wifi

GPU
Evolution of More Than Moore

Focus: mobile (SOC-CP) ($60B growth till 2025)
- Concrete, real; most important socket for foreseeable future
- Can roadmap “scaling of value” from MTM in this context

First target: inventory of top MTM IPs
- Look into historical trajectory of teardowns, BOMs
- Can roadmap year in which discrete components are introduced, when they go into silicon

Second target: roadmap of components’ evolution over time
- Associated “rules” to define “year of introduction”
  - E.g. 2 products in volume production, like rest of ITRS
Rise of Flash Content

[Source] Wikipedia; Apple press release library
Rise of the Application Processor

- Before 2007: Smartphones contain growing #ICs from different vendors
- After 2007: Smartphones contain multi-function integrated application processors (APs) (→ decreasing #ICs)

[Source: Google Trend, TechInsights]
Scaling of Application Processor Integration

**TREND:** Application processors are integrated with more features

**WAS:** Independent Bluetooth (BT), wireless, multimedia and baseband (BB) ASICs

**IS:** All features integrated into single application processor (AP)

[Source: Wikipedia]
Example Roadmapping Task: Split of AP SOC

• **Given:** An SOC design with blocks such as CPU, GPU, and memory controller (MC); performance requirements; memory interface technology; and multi-die integration technology.

• **Objective:** Model the number of inter-die connections (in future products) so as to predict the number of TSVs/micro-bumps (and, die area, power, thermal, cost) required.

  E.g., *interposer vs. stacked*?

  *(area inflection: \(\sim 140-150\text{mm}^2\))

  *(there is an integration inflection, as well...)*
Teardown – iPhone 5

1. Apple A6 processor
2. Touch screen controllers
3. LTE modem
4. Multimode RF
5. Three-axis gyroscope
6. WiFi
7. 16GB Flash
8. Audio amplifier
9. Power management IC

[Source: iFixit]
# Building Blocks of a Smartphone

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Components</th>
<th>Function</th>
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</thead>
<tbody>
<tr>
<td><strong>AP</strong></td>
<td>Application Processor</td>
<td>Multimedia, resource management</td>
</tr>
<tr>
<td><strong>BB</strong></td>
<td>Baseband</td>
<td>Communication protocols</td>
</tr>
<tr>
<td><strong>Memory</strong></td>
<td>Mobile DDR2-S4 SDRAM Memory - 512 MB</td>
<td>Data storage</td>
</tr>
<tr>
<td></td>
<td>MLC NAND Flash Memory - 4 GB</td>
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<tr>
<td></td>
<td>Memory Controller</td>
<td></td>
</tr>
<tr>
<td><strong>RF</strong></td>
<td>RF Power Amplifier</td>
<td>Radio signal synthesis / extraction</td>
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<tr>
<td></td>
<td>Power Amplifier Controller</td>
<td>Up/down frequency converting</td>
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<tr>
<td></td>
<td>WiFi 802.11n / Bluetooth (BT) / FM Radio</td>
<td>Radio band management</td>
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<td>GSM / CDMA / W-CDMA RxD Transceiver + GPS</td>
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<td>SP10T Antenna Switch</td>
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<td><strong>Sensor</strong></td>
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<td>Image capturing</td>
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<td>5 MP CMOS Image Sensor</td>
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<td>Accelerometer Processor</td>
<td>Position / orientation detection</td>
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<td>MEMS Sensor</td>
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<td>Ambient Light / Proximity Sensor</td>
<td>Environment sensing</td>
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<td><strong>Display / Input device</strong></td>
<td>Capacitive Touchscreen Controller</td>
<td>Touch control</td>
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<td>TFT-LCD Display Driver</td>
<td>Display</td>
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<td><strong>Power / Analog</strong></td>
<td>Power Management IC (PMIC)</td>
<td>Hibernation, power mode management</td>
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<tr>
<td></td>
<td>Audio CODEC / amplifier</td>
<td>Audio output</td>
</tr>
</tbody>
</table>

Example: smartphone from major manufacturer, 2013

[Source: TechInsights]
Smartphone Block Diagram Evolution -- 2007

**Notes:**
1. GSM and WCDMA RFs merged
2. One more media processor added
3. More audio output circuits
4. WiFi, FM, and GPS are provided by > 5 ICs
5. Sensor functions are significantly enhanced
6. Memory is scaling up

**Blue:** appearing  
**Green:** scaling up

[Source: TechInsights]
Smartphone Block Diagram Evolution -- 2013

Notes:
1. All multimedia features are on AP
2. Audio output circuits integrated into one IC
3. BT, WiFi, and FM (baseband) integrated into one IC
4. Touch screen introduced
5. Memory scaling up

[Source: TechInsights]
**Mixed Technology Nodes Will Merge (*)**

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Components</th>
<th>Model</th>
<th>Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP / BB</td>
<td>Applications Processor + Baseband</td>
<td>Qualcomm MSM8227</td>
<td>CMOS 28nm</td>
</tr>
<tr>
<td>Memory</td>
<td>Mobile DDR2-S4 SDRAM Memory - 512 MB</td>
<td>SK Hynix H9TKNNN4GDAR</td>
<td>DRAM process</td>
</tr>
<tr>
<td></td>
<td>MLC NAND Flash Memory - 4 GB</td>
<td>Samsung K9ABGD8UOC</td>
<td>??</td>
</tr>
<tr>
<td></td>
<td>Memory Controller</td>
<td>Samsung S4LJ211X01</td>
<td>??</td>
</tr>
<tr>
<td>RF</td>
<td>RF Power Amplifier</td>
<td>TQM7M9053</td>
<td>GaAs HBT</td>
</tr>
<tr>
<td></td>
<td>Power Amplifier Controller</td>
<td>TriQuint (??)</td>
<td>??</td>
</tr>
<tr>
<td></td>
<td>WiFi 802.11n / Bluetooth / FM Radio</td>
<td>Qualcomm WCN3660</td>
<td>?? (Paid report on Chipworks)</td>
</tr>
<tr>
<td></td>
<td>GSM / CDMA / W-CDMA RxD Transceiver + GPS</td>
<td>Qualcomm WTR1605</td>
<td>??</td>
</tr>
<tr>
<td></td>
<td>SP10T Antenna Switch</td>
<td>Skyworks 36524</td>
<td>??</td>
</tr>
<tr>
<td></td>
<td>GPS LNA</td>
<td>Renesas C8236</td>
<td>??</td>
</tr>
<tr>
<td>Sensor</td>
<td>LED Flash Driver</td>
<td>AMS AS3646</td>
<td>High voltage process (15V)</td>
</tr>
<tr>
<td></td>
<td>5 MP CMOS Image Sensor</td>
<td>STM 5955AA</td>
<td>CMOS (sensor process)</td>
</tr>
<tr>
<td></td>
<td>Accelerometer Processor</td>
<td>STM V655B</td>
<td>ST MEMS process</td>
</tr>
<tr>
<td></td>
<td>MEMS Sensor</td>
<td>STM CSL23A</td>
<td>ST MEMS process</td>
</tr>
<tr>
<td></td>
<td>Ambient Light / Proximity Sensor</td>
<td>AMS E2703C</td>
<td>??</td>
</tr>
<tr>
<td>Display / Input</td>
<td>Capacitive Touchscreen Controller</td>
<td>Synaptics T1321B</td>
<td>??</td>
</tr>
<tr>
<td>device</td>
<td>TFT-LCD Display Driver</td>
<td>Orise R242</td>
<td>??</td>
</tr>
<tr>
<td>Power / Analog</td>
<td>Power Management</td>
<td>Qualcomm PM8038</td>
<td>?? (Paid report on TechInsights)</td>
</tr>
<tr>
<td></td>
<td>Audio CODEC</td>
<td>Qualcomm WCD9304</td>
<td>??</td>
</tr>
</tbody>
</table>

**TBR:** In what years will critical merging “inflections” occur? (2015-2030)
Scaling of Memory Blocks  
(Implicit: Long-Term Requirements)

Capacity scaling  
≈1.67× / per year

#Memory ICs  
Baseline configuration remains similar

1 or 2 DRAM  
1 or 2 NAND flash  
1 NOR flash

%ICs = Memory ICs  
Varies due to different system architecture

[Source: TechInsights]
Scaling of Memory Bandwidth

**DRAM density & Data rate trend**

Wide I/O will start from 12.8GB/s (200MHz) and soon 17GB/s (266MHz).


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# Scaling of pJ / Bit

<table>
<thead>
<tr>
<th></th>
<th>LPDDR2</th>
<th>LPDDR3</th>
<th>WideIO</th>
<th>LPDDR4</th>
<th>WideIO2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BW (Gbyte/s)</td>
<td>8.5(^{(1)})</td>
<td>12.8 (^{(1)})</td>
<td>12.8</td>
<td>34(^{(1)})</td>
<td>51.2</td>
</tr>
<tr>
<td>possible BW evolution</td>
<td>-</td>
<td>17 (^{(2)})</td>
<td>17 (^{(3)})</td>
<td>Not yet defined</td>
<td>Not yet defined</td>
</tr>
<tr>
<td>max package density (Gbit)</td>
<td>4x4</td>
<td>4x4</td>
<td>1x4</td>
<td>Not yet defined</td>
<td>Not yet defined</td>
</tr>
<tr>
<td>power efficiency (mW/Gbyte/s)</td>
<td>78</td>
<td>67</td>
<td>42</td>
<td>Not yet defined</td>
<td>Not yet defined</td>
</tr>
<tr>
<td>volume maturity</td>
<td>2011</td>
<td>2012</td>
<td>2013</td>
<td>Not yet defined</td>
<td>Not yet defined</td>
</tr>
<tr>
<td>relative memory cost for equivalent density (^{(4)})</td>
<td>1</td>
<td>~1.1</td>
<td>~1.2</td>
<td>Not yet defined</td>
<td>Not yet defined</td>
</tr>
</tbody>
</table>

\(^{(1)}\) 32b dual channel configuration assumed  
\(^{(2)}\) LPDDR3E: clock from 800 to 1066MHz. Standardization at JEDEC in progress  
\(^{(3)}\) WideIO clock frequency from 200MHz to 266Mhz: already specified at JEDEC  
\(^{(4)}\) Estimates based on memory supplier survey (memory cost only)


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Scaling of Subsystem Functions and Bandwidth

Scaling of #functions
- Metric: \[ \text{#functions} = \frac{\text{Die Area}}{\text{Normalized Transistor Density}} \]
- Memory and AP grow faster than other components

Scaling of #pins (“bandwidth”)
- Metric: #pins of ICs in category
- 2007-2013: bandwidth for display has significant jump
- 2007-2013: bandwidth for RF decreases (e.g., more highly integrated RF subsystem)
- Bandwidth of other subsystems remains similar from 2007-2013

[Source: TechInsights]
Scaling of #ICs for Each Subsystem

Scaling of #ICs
- 2002-2007: #ICs for each subsystem increases → increasing content requirement → integration cannot keep pace
- 2007-2013: #ICs significantly decreases → integration pace delivers required content in fewer ICs

Scaling of #ICs as %Total ICs
- 2002-2007: %power/analog flat
- 2007-2013: %power/analog drops significantly → highly integrated power/analog
- 2007-2013: %RF increases → multi-mode RF
- 2007-2013: %sensors increases → sensor-rich functionality

[Source: TechInsights]
Scaling of Display and Imaging

Scaling of imaging sensor
→ Another metric of multimedia processing capacity

Scaling of display size
→ Metric for system bandwidth and memory requirement
→ Also metric for multimedia processing capacity and GPU performance

[Source: Wikipedia]
## Emerging sensor functions

<table>
<thead>
<tr>
<th>Accelerometers</th>
<th>Motion Processing (MPU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gyroscopes</td>
<td>Memory</td>
</tr>
<tr>
<td>Magnetometers</td>
<td>Wireless Communications</td>
</tr>
<tr>
<td>Pressure</td>
<td>Display</td>
</tr>
<tr>
<td>Humidity</td>
<td>Speakers</td>
</tr>
<tr>
<td>Temperature</td>
<td>Microphones</td>
</tr>
<tr>
<td>eNose</td>
<td>Camera</td>
</tr>
<tr>
<td>Galvanic Skin Response</td>
<td>pH Sensor</td>
</tr>
<tr>
<td>Heart Rate</td>
<td>Blood Pressure</td>
</tr>
</tbody>
</table>

- **Roadmapping task** = develop mapping **functions** ⇔ **available technologies**
  ⇔ **application-specific performance, size, power requirements** ⇔ **identified gaps**
  ⇔ **required new device and manufacturing technologies**

- **(Still need to place future sensor functions onto a timeline)**

[Source: ITRS MEMS ITWG]
Scaling of Sensor, RF and MEMS IC in Smartphones

- **#Sensor ICs: slow but steady growth**
  - Recently introduced sensors → gyroscope (2010), fingerprint (2013)

- **#RF ICs: no clear trajectory**
  - Two trends seem to cancel each other out
    - (−) Technology improvement → fewer RF ICs
    - (+) Multi-standards support → more RF ICs

Sensor Roadmap in Smartphones

[Source: http://www.ecnmag.com/articles/2013/05/evolution-light-sensor-integration]
Sensor Integration in Smartphones -- 2013

[Source: http://electronicdesign.com/boards/sensor-fusion-play-and-profit]
Notional: 4 Scaling Sub-Laws in Smartphone?

Digital

≈1.4x per year

Memory

≈1.4x per year

Analog and PMIC

≈1.31x per year

RF

≈1.44x per year

Revert scaling!

Revert scaling!
Toward System Driver Integration Roadmaps

- One Example = Smartphone
  - High-value, high-volume driver for next 10+ years
- First step: Analysis of data
  - Doable with effort
  - *Same spirit as 2013 A-factor recalibration from Chipworks data*
  - Similar first steps needed for IoT, cloud (“AWS”), …
- Next steps: Looking **forward with models**
  - #APs vs. #sensors (gesture recognition, security, …)
  - Thermal and memory power limits vs. how far a bit can physically move
  - Human psychophysical limits (display size/resolution, rate of scrolling, bandwidth, form factor, …)
  - Sub-laws of scaling: digital, RF, analog/PMIC, memory, …
    - MTM = arena for reconciliation
  - Q: Package-level (DRAM+AP), chip-level (multimedia + LTE BB), TSV-level (CIS + image proc) integration: how do these drive SOC evolution, with what inflection points?
  - Q: What drives analog IPs to merge? What drives digital IPs to merge?
Toward System Driver Integration Roadmaps

- **Important:** find the key metrics to roadmap!
  - Proportion of memory in overall BOM
  - \#die-to-die wires / $
  - BW / ($-Watt)

- **Important:** don’t get stuck on “applications pull”!
  - Unforeseen new possibilities enabled by technology push

- **Important:** integration can reverse itself!
  - 16nm and analog don’t like each other 😞
  - There will be dis-integration …
    (e.g., how to split the ModAP SOC)
  - … and MTM is all about “how do you re-integrate”
    (POP, Si interposer, TSV (COCOS, COWOS), …)
  - A&P and bump pitch, BW/pin etc. metrics become critical

- **Important:** A journey of a thousand miles begins …
THANK YOU!