Silicon Technology for 32 nm and Beyond System-on-Chip Products

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Intel Senior Fellow
Logic Technology Development

SPCS009
Intel Logic Technology Roadmap

~2 year cycle continues for introducing new technology generations
Intel Logic Technology Roadmap

Name: P1266
Products: CPU

Name: P1268
Products: CPU

Name: P1270
Products: CPU
45 nm High-k + Metal Gate Transistors

Intel is only company with high-k + metal gate transistors in production, starting in Nov. ‘07
45 nm is Intel’s highest yielding process ever
45 nm Microprocessor Products

Single Core

Dual Core

Quad Core

6 Core

8 Core

>200 million 45 nm CPUs shipped to date
Intel Logic Technology Roadmap

Name:
- P1266
- P1268
- P1270

Products:
- CPU
- CPU
- CPU
32 nm Technology Features

- 2nd generation high-k + metal gate transistors
- 9 copper + low-k interconnect layers
- Immersion lithography on critical layers
- ~0.7x minimum pitch scaling
- Pb-free and halogen-free packages

32 nm delivers the promise of Moore’s Law: Higher performing, lower power, and lower cost transistors.
Transistor Density

Intel 32 nm transistors provide the tightest gate pitch of any reported 32 nm or 28 nm technology.
Transistor Performance

Intel 32 nm transistors provide the highest drive currents of any reported 32 nm or 28 nm technology.
SRAM Cell Size Scaling

Transistor density continues to double every 2 years
Tick-Tock Development Model
Sustained Microprocessor Leadership

Intel® Core™ Microarchitecture

Intel® Microarchitecture codename Nehalem

Future Intel® Microarchitecture

65 nm

45 nm

32 nm

Merom

NEW Microarchitecture

TOCK

Penryn

NEW Process Technology

TICK

Nehalem

NEW Microarchitecture

TOCK

Westmere

NEW Process Technology

TICK

Sandy Bridge

NEW Microarchitecture

TOCK

Westmere, industry’s first working 32 nm processor, demonstrated in January ‘09

All dates, product descriptions, availability, and plans are forecasts and subject to change without notice.
32 nm Westmere Microprocessor

Dual core Westmere
First in a family of 32 nm microprocessors based upon the Intel® microarchitecture codenamed Nehalem
Intel’s 32 nm process is certified and CPU wafers are moving through the factory in support of planned Q4 revenue production.
32 nm Manufacturing Fabs

D1D Oregon - Now

D1C Oregon - 4Q 2009

Fab 32 Arizona - 2010

Fab 11X New Mexico - 2010

$7B invested in 32 nm manufacturing fabs
Intel Logic Technology Roadmap

Name:
P1266

Products:
CPU

45 nm

Name:
P1268

Products:
CPU

32 nm

Name:
P1270

Products:
CPU

22 nm
Intel is now developing both CPU and SoC versions of each technology generation.
Intel is now developing both CPU and SoC versions of each technology generation.
System-on-Chip Building Blocks

SoC products require a broader range of device types than mainstream CPU products
<table>
<thead>
<tr>
<th>Similarities</th>
<th>CPU</th>
<th>SoC</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-k + Metal Gate</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>Tight Transistor Pitch</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Dense SRAM Cell</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Lower Level Interconnects</td>
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<td>Same</td>
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<tr>
<td>Fab Process Equipment</td>
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<td>Same</td>
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<tr>
<td>Pb-Free Packages</td>
<td>Same</td>
<td>Same</td>
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<tr>
<td>Differences</td>
<td></td>
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<tr>
<td>Logic Transistors</td>
<td>High Speed</td>
<td>Low Leakage</td>
</tr>
<tr>
<td>I/O Transistors</td>
<td>Std Voltage</td>
<td>Std-High Voltage</td>
</tr>
<tr>
<td>Upper Level Interconnects</td>
<td>High Speed</td>
<td>Dense</td>
</tr>
<tr>
<td>Precision Passives</td>
<td>None</td>
<td>R, C and L</td>
</tr>
</tbody>
</table>
45 nm SoC Products

Lincroft
Mobile Internet Devices

Sodaville
Set Top Boxes

Initial 45 nm Intel® Atom™ processor based SoC products
Intel Logic Technology Roadmap

Name:
- P1266
- P1266.8
- P1268
- P1269
- P1270
- P1271

Products:
- CPU
- SoC

45 nm
- P1266
- P1266.8
- P1268

32 nm
- P1269

22 nm
- P1270
- P1271
32 nm SoC Technology Feature Menu

- **Logic Transistor**
  - High Performance
  - Std Performance
  - Low Power

- **I/O Trans Voltage**
  - 1.2V Low Power
  - 1.8V Thick Gate
  - 3.3V Thick Gate

- **Metal**
  - 9 Layer High Perf
  - 7-11 Layer Hi Dense

- **Advanced Passives**
  - Precision Resistor
  - Precision Capacitor
  - High Q Inductor

- **Embedded Memory**
  - Dense SRAM
  - Low Voltage SRAM
  - High Speed SRAM

32 nm SoC process offers a rich mix-and-match feature set
High-κ + metal gate transistors provide Intel an advantage for both high performance and low leakage
High Voltage I/O Transistors

Low Voltage Digital Transistor

High Voltage I/O Transistor

Dual gate oxide process enables low voltage and high voltage transistors together on the same chip.
CPU vs. SoC Interconnects

Interconnect system optimized for high performance CPUs vs. low power SoCs
Passives Device Elements

- Linear Resistors
- Noise Isolation
- Finger Capacitors
- High-Q Inductors

**Precision passive devices and other on-chip features added to enable analog-digital mixed signal and radio frequency circuits**
Performance vs. Power Landscape

32 nm SoC covers a broad performance/power landscape
# Intel Logic Technology Roadmap

<table>
<thead>
<tr>
<th>Name:</th>
<th>45 nm</th>
<th>32 nm</th>
<th>22 nm</th>
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<td>Products:</td>
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22 nm Shuttle Test Chip

Intel is first in the industry to demonstrate working 22 nm circuits
22 nm SRAM Test Chip

- 364 Mbit array size
- >2.9 billion transistors
- 3rd generation high-k + metal gate transistors
- Same transistor and interconnect features as on 22 nm CPUs

Demonstrating working 22 nm SRAMs is an important milestone towards building working 22 nm microprocessors
22 nm SRAM Test Chip

0.092 $\mu m^2$ SRAM cell for high density applications

0.108 $\mu m^2$ SRAM cell for low voltage applications

0.092 $\mu m^2$ is the smallest SRAM cell in working circuits reported to date
22 nm SRAM Test Chip

Test chip includes logic and mixed-signal circuits to be used on 22 nm microprocessors
On-Time 2 Year Cycles

90 nm  
2003

65 nm  
2005

45 nm  
2007

32 nm  
2009
CPU and SoC Product Lines

90 nm  65 nm  45 nm  32 nm  22 nm

CPU and SoC process versions will support separate product lines at each generation
Summary

- Intel leads the industry in introducing new technology generations every 2 years
  - 32 nm process is certified and has started production
  - Intel is first to demonstrate working 22 nm circuits

- Intel has added process features to our advanced logic technologies to enable low power System-on-Chip products
  - High-k + metal gate transistors provide a wide range of high performance to low leakage capabilities
  - 45 nm HK+MG SoC products are entering the market
  - 32 nm HK+MG SoC technology provides industry-leading process features for next-generation SoC products

- Intel process technologies continue to deliver the promise of Moore’s Law: higher performing, lower power, and lower cost transistors
Additional Information

Intel will be presenting two papers on our 32 nm technology at the International Electron Devices Meeting in Baltimore, MD on Dec 7-9, 2009:

- C. Jan, “A 32nm SoC Platform Technology with 2nd Generation High-k/Metal Gate Transistors Optimized for Ultra Low Power, High Performance, and High Density Product Applications”

- P. Packan, “High Performance 32nm Logic Technology Featuring 2nd Generation High-k + Metal Gate Transistors”
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The gross margin percentage could vary significantly from expectations based on changes in revenue levels; capacity utilization; start-up costs, including costs associated with the new 32nm process technology; variations in inventory valuation, including variations related to the timing of qualifying products for sale; excess or obsolete inventory; product mix and pricing; manufacturing yields; changes in unit costs; impairments of long-lived assets, including manufacturing, assembly/test and intangible assets; and the timing and execution of the manufacturing ramp and associated costs. Expenses, particularly certain marketing and compensation expenses, as well as restructuring and asset impairment charges, vary depending on the level of demand for Intel’s products and the level of revenue and profits. 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