Lecture 24:
Case Study: Intel Processors
Outline

- Evolution of Intel Microprocessors
  - Scaling from 4004 to Core i7
  - Courtesy of Intel Museum
First microprocessor (1971)
- For Busicom calculator

Characteristics
- 10 µm process
- 2300 transistors
- 400 – 800 kHz
- 4-bit word size
- 16-pin DIP package

Masks hand cut from Rubylith
- Drawn with color pencils
- 1 metal, 1 poly (jumpers)
- Diagonal lines (!)
8008

- 8-bit follow-on (1972)
  - Dumb terminals
- Characteristics
  - 10 $\mu$m process
  - 3500 transistors
  - 500 – 800 kHz
  - 8-bit word size
  - 18-pin DIP package
- Note 8-bit datapaths
  - Individual transistors visible
8080

- 16-bit address bus (1974)
  - Used in Altair computer
    • (early hobbyist PC)
- Characteristics
  - 6 μm process
  - 4500 transistors
  - 2 MHz
  - 8-bit word size
  - 40-pin DIP package
8086 / 8088

- 16-bit processor (1978-9)
  - IBM PC and PC XT
  - Revolutionary products
  - Introduced x86 ISA

- Characteristics
  - 3 μm process
  - 29k transistors
  - 5-10 MHz
  - 16-bit word size
  - 40-pin DIP package

- Microcode ROM
80286

- Virtual memory (1982)
  - IBM PC AT
- Characteristics
  - 1.5 µm process
  - 134k transistors
  - 6-12 MHz
  - 16-bit word size
  - 68-pin PGA
- Regular datapaths and ROMs
  Bitslices clearly visible
80386

- 32-bit processor (1985)
  - Modern x86 ISA
- Characteristics
  - 1.5-1 μm process
  - 275k transistors
  - 16-33 MHz
  - 32-bit word size
  - 100-pin PGA
- 32-bit datapath,
  microcode ROM,
  synthesized control
80486

- Pipelining (1989)
  - Floating point unit
  - 8 KB cache

- Characteristics
  - 1-0.6 µm process
  - 1.2M transistors
  - 25-100 MHz
  - 32-bit word size
  - 168-pin PGA

- Cache, Integer datapath,
  FPU, microcode,
synthesized control
Pentium

- Superscalar (1993)
  - 2 instructions per cycle
  - Separate 8KB I$ & D$

- Characteristics
  - 0.8-0.35 $\mu$m process
  - 3.2M transistors
  - 60-300 MHz
  - 32-bit word size
  - 296-pin PGA

- Caches, datapath, FPU, control
Pentium Pro / II / III

- Dynamic execution (1995-9)
  - 3 micro-ops / cycle
  - Out of order execution
  - 16-32 KB I$ & D$
  - Multimedia instructions
  - PIII adds 256+ KB L2$

- Characteristics
  - 0.6-0.18 μm process
  - 5.5M-28M transistors
  - 166-1000 MHz
  - 32-bit word size
  - MCM / SECC
Pentium 4

- Deep pipeline (2001)
  - Very fast clock
  - 256-1024 KB L2

- Characteristics
  - 180 – 65 nm process
  - 42-125M transistors
  - 1.4-3.4 GHz
  - Up to 160 W
  - 32/64-bit word size
  - 478-pin PGA

- Units start to become invisible on this scale
Pentium M

- Pentium III derivative
  - Better power efficiency
  - 1-2 MB L2$
- Characteristics
  - 130 – 90 nm process
  - 140M transistors
  - 0.9-2.3 GHz
  - 6-25 W
  - 32-bit word size
  - 478-pin PGA
- Cache dominates chip area
Core2 Duo

- Dual core (2006)
  - 1-2 MB L2$ / core
- Characteristics
  - 65-45 nm process
  - 291M transistors
  - 1.6-3+ GHz
  - 65 W
  - 32/64 bit word size
  - 775 pin LGA
- Much better performance/power efficiency
Core i7

- Quad core (& more)
  - Refinement of Core architecture
  - 2 MB L3$ / core
- Characteristics
  - 45-32 nm process
  - 731M transistors
  - 2.66-3.33+ GHz
  - Up to 130 W
  - 32/64 bit word size
  - 1366-pin LGA
  - Multithreading
- On-die memory controller
Atom

- Low power CPU for netbooks
  - Pentium-style architecture
  - 512KB+ L2$
- Characteristics
  - 45-32 nm process
  - 47M transistors
  - 0.8-1.8+ GHz
  - 1.4-13 W
  - 32/64-bit word size
  - 441-pin FCBGA
- Low voltage (0.7 – 1.1 V) operation
  - Excellent performance/power
### Summary

- $10^4$ increase in transistor count, clock frequency over 3 decades!

<table>
<thead>
<tr>
<th>Processor</th>
<th>Year</th>
<th>Feature Size ($\mu$m)</th>
<th>Transistors</th>
<th>Frequency (MHz)</th>
<th>Word Size</th>
<th>Power ($W$)</th>
<th>Cache (L1 / L2 / L3)</th>
<th>Package</th>
</tr>
</thead>
<tbody>
<tr>
<td>4004</td>
<td>1971</td>
<td>10</td>
<td>2.3k</td>
<td>0.75</td>
<td>4</td>
<td>0.5</td>
<td>none</td>
<td>16-pin DIP</td>
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<tr>
<td>8008</td>
<td>1972</td>
<td>10</td>
<td>3.5k</td>
<td>0.5–0.8</td>
<td>8</td>
<td>0.5</td>
<td>none</td>
<td>18-pin DIP</td>
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<tr>
<td>8080</td>
<td>1974</td>
<td>6</td>
<td>6k</td>
<td>2</td>
<td>8</td>
<td>0.5</td>
<td>none</td>
<td>40-pin DIP</td>
</tr>
<tr>
<td>8086</td>
<td>1978</td>
<td>3</td>
<td>29k</td>
<td>5–10</td>
<td>16</td>
<td>2</td>
<td>none</td>
<td>40-pin DIP</td>
</tr>
<tr>
<td>80286</td>
<td>1982</td>
<td>1.5</td>
<td>134k</td>
<td>6–12</td>
<td>16</td>
<td>3</td>
<td>none</td>
<td>68-pin PGA</td>
</tr>
<tr>
<td>Intel386</td>
<td>1985</td>
<td>1.5–1.0</td>
<td>275k</td>
<td>16–25</td>
<td>32</td>
<td>1–1.5</td>
<td>none</td>
<td>100-pin PGA</td>
</tr>
<tr>
<td>Intel486</td>
<td>1989</td>
<td>1–0.6</td>
<td>1.2M</td>
<td>25–100</td>
<td>32</td>
<td>0.3–2.5</td>
<td>8K</td>
<td>168-pin PGA</td>
</tr>
<tr>
<td>Pentium</td>
<td>1993</td>
<td>0.8–0.35</td>
<td>3.2–4.5M</td>
<td>60–300</td>
<td>32</td>
<td>8–17</td>
<td>16K</td>
<td>296-pin PGA</td>
</tr>
<tr>
<td>Pentium Pro</td>
<td>1995</td>
<td>0.6–0.35</td>
<td>5.5M</td>
<td>166–200</td>
<td>32</td>
<td>29–47</td>
<td>16K / 256K+</td>
<td>387-pin MCM PGA</td>
</tr>
<tr>
<td>Pentium II</td>
<td>1997</td>
<td>0.35–0.25</td>
<td>7.5M</td>
<td>233–450</td>
<td>32</td>
<td>17–43</td>
<td>32K / 256K+</td>
<td>242-pin SECC</td>
</tr>
<tr>
<td>Pentium III</td>
<td>1999</td>
<td>0.25–0.18</td>
<td>9.5–28M</td>
<td>450–1000</td>
<td>32</td>
<td>14–44</td>
<td>32K / 512K</td>
<td>330-pin SECC2</td>
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<tr>
<td>Pentium M</td>
<td>2003</td>
<td>130–90 nm</td>
<td>77–140M</td>
<td>1300–2130</td>
<td>32</td>
<td>5–27</td>
<td>64K / 1M</td>
<td>479-pin FCBGA</td>
</tr>
<tr>
<td>Core</td>
<td>2006</td>
<td>65 nm</td>
<td>152M</td>
<td>1000–1860</td>
<td>32</td>
<td>6–31</td>
<td>64K / 2M</td>
<td>479-pin FCBGA</td>
</tr>
<tr>
<td>Core 2 Duo</td>
<td>2006</td>
<td>65–45 nm</td>
<td>167–410M</td>
<td>1060–3160</td>
<td>32/64</td>
<td>10–65</td>
<td>64K / 4M+</td>
<td>775-pin LGA</td>
</tr>
<tr>
<td>Core i7</td>
<td>2008</td>
<td>45 nm</td>
<td>731M</td>
<td>2660–3330</td>
<td>32/64</td>
<td>45–130</td>
<td>64K / 256K / 8M</td>
<td>1366-pin LGA</td>
</tr>
<tr>
<td>Atom</td>
<td>2008</td>
<td>45 nm</td>
<td>47M</td>
<td>800–1860</td>
<td>32/64</td>
<td>1.4–13</td>
<td>56K / 512K+</td>
<td>441-pin FCBGA</td>
</tr>
</tbody>
</table>