The Road to Data Center Power Efficiency

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Outline

• Fundamentals and trends of power and performance (PnP)
• Data center power and performance trends
• The Mobile World
• Power, power delivery & power management opportunities with chiplets
• Summary
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Moore’s Law

Linear dimensions scale by 0.7X
Area scales by 0.7x0.7=0.5 or number of transistors per unit area doubles
Voltage \( E = \frac{v}{d} \) scales by 0.7x to maintain a constant electric field in the oxide
Capacitance \( \varepsilon \frac{A}{d} \) scales by 0.7
Delay \( \frac{1}{f} \) scales by 0.7X
Power \( (cv^2f) \) scales by 0.5

Number of transistors doubles, frequency improves by 40%, and power reduces by \( \frac{1}{2} \)
The slowing down of Moore’s law

Dale Becker and Kanad Ghose: Heterogenous integration for HPC and data centers
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THE RELENTLESS DEMAND FOR MORE COMPUTE..

1 exaFLOP
LINPACK GFLOPS Trend
1 petaFLOP

2x EVERY 1.2 YEARS


SPACE EXPLORATION  CLIMATE CHANGE  CHEMICAL SCIENCES  ENERGY SOLUTIONS  MACHINE LEARNING  REAL TIME SIMULATION

Data center power efficiency trends

Today
- Data centers consume ~200TWH of total energy
- ~ 1 billion cores in use
- Best in class PUE ~ 1.1 but average industry @1.59
- Long way from compute energy proportionality
- Peak power is the number one limiter to performance of data centers, driver of e-waste, and provisional power

2025-2030
- 20% (~2% today) of total electricity in data centers by 2030 (IT Renew, OCP San Jose, Nov. 2021)
- 5 billion cores by 2025 (Intel-Zane Ball, OCP San Jose, Nov. 2021)
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Mobile devices from the 90’s to today

Early 90’s – first mobile ‘laptops’

- Very primitive power and thermal management schemes
- DOS-based 286 through Pentium® processor designs
- BIOS and then SMM-based power management

Hard to figure out basic things
- Is the user present? (timer/trap on KBD/mouse I/O)
- Is the HDD in use? (timer trap on disk I/O)
- Is the system compute busy? (timers based on all relevant I/O and processing)
- Is the CPU idle? (I don’t know, OS is always doing something!)

2-3 hours of battery life was great...

- > 10 Hrs. of active use battery life
- > Weeks of airplane mode/ Modern Standby
- Sophisticated platform power management

Barnes Cooper: Bits 2018 distinguished speaker
Client vs. data center power management

- Order of magnitude power reduction with single client power management

- Idle power is a very small percentage of total power
  - Leakage reduction and power management
  - Battery life is an end user experience

- Energy Star like benchmarks for environmentally conscious end users

- Multi-client power management is harder

- Idle power in data centers considerable percentage of total
  - Leakage reduction
  - No end user experience equivalent of battery life

- No end user sustainability metric equivalent to Energy Star
  - Energy Star VM?
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Power savings with chiplets

25% Power savings with 2 CPUs and 2 VRs instead of 1CPU and 1 VR

Challenges
- 2 VRs and 2 CPUs, higher cost and bigger real estate
- Cores allocation
Finer grain power distribution with more chiplets and/or integrated voltage regulators

- **FIVR**
  - Higher complexity
  - Lower current into the package
  - Higher efficiency over larger dynamic range

- **LDOs**
  - Lower complexity
  - Lower efficiency over large dynamic range
  - More efficient when dropout % is less than FIVR loss %
### Finer grain allocation software

<table>
<thead>
<tr>
<th>VM</th>
<th>Cluster</th>
<th># of Cores</th>
<th>Voltage</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Low Power</td>
<td>6</td>
<td>LV</td>
<td>2.5 GHZ</td>
</tr>
<tr>
<td>B</td>
<td>HPC</td>
<td>7</td>
<td>HP</td>
<td>3.5 GHZ</td>
</tr>
<tr>
<td>C</td>
<td>GP</td>
<td>7</td>
<td>MV</td>
<td>3 GHZ</td>
</tr>
</tbody>
</table>

Better MI based strategies for improved power management considering both the s/w & h/w aspects of the system.
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- Moore’s law slowed but performance did not
- Heterogenous integration (chiplets) helps performance scaling, but can add power and complexity
- Chiplet technology is inherently better suited for finer grain power delivery and management
- Fine grain (HW and SW) power management can reduce overall data center power significantly
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