Google 48V Power Architecture
Xin Li & Shuai Jiang
March 27th 2017
Overview

- Data Center Power Delivery Revolution
- Why 48V power architecture
- Challenges (and opportunities)
- 48V-to-PoL technology
- Closing
- Q&A
Growing Energy Usage in US Data Center

Number of data centers is increasing exponentially driven by cloud and big data

<table>
<thead>
<tr>
<th>Year</th>
<th>Billions of Kilowatt Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>60</td>
</tr>
<tr>
<td>2013</td>
<td>91</td>
</tr>
<tr>
<td>2020 (E)</td>
<td>190</td>
</tr>
</tbody>
</table>

>6% Annual Growth

* Data from EPRI

Saving a fraction of this energy is substantial
Data Center Power Delivery Evolution

**Building**
- AC
- DC
- Battery

**Rack**
- AC
- AC/12V on tray
- AC/12V + Battery on tray
- AC/DC + Battery modules
- IT Tray

**Traditional Power Delivery**
- UPS in Tray
- Centralized Rack Power Delivery
Centralized Power Delivery Challenges @ 12V

- High power trend - HPC / GPU / ASIC
- Copper loss / cost
- Voltage drop
- Connector / bus bar sizing
Why 48V Power Architecture?

- Supports higher power
- Less distribution losses & voltage drop - Reduction of 16X (I2R losses)
- Higher efficiency
- Better deployment flexibility
- 48V telecom ecosystem
- Cost effective in-rack UPS
- “Safe” voltage
History of Google Power Evolution

- **2003**: 12V High Eff PSU
- **2004**: UPS Off Tray
- **2005**: Gen 1: 48V-12V-POL
- **2006**: Multi 48V to PoL solutions
- **2007**: Gen 2: 48V Rack & UPS
- **2008**: Released Open Rack V2.0 48V through OCP
- **2009**: Gen 3: Li-ion
- **2010**: Beyond 2017: Increasing innovation on the 48V architecture and wide adoption by the ecosystem.
- **2011**:
- **2012**:
- **2013**:
- **2014**:
- **2015**:
- **2016**:
- **2017**:
Challenges (Opportunities)

● Major Challenges
  ○ Deliver power from 48V to Point of Load efficiently
  ○ Still meet high dynamic power requirement

● Others
  ○ Power design for non-core or memory rails (Small rails)
  ○ Power design for 12V - Disk, PCIE and so on
Power Delivery Challenges

A typical server design

- Efficient power conversion from 48V
- Power density at the point of load
- I2R losses from VR to load chip
- Power distribution network impedance (power integrity)
48V Board Level Power Delivery

Direct conversion approach

2-stage conversion approach

* Efficiency data are targeting numbers based on existing solutions
Transformer-Based 48V VRs

Transformer design and I2R loss are the top challenge.
Transformer-Less 48V VRs

Stacked-cap or hybrid SWCap buck

Google’s proprietary Switched-Tank Converter (STC)

STC scalable to higher ratio & power, 98%-99% efficiency

Hybrid SWCap buck applicable for higher density

Low reliance on magnetics, low Vds rating MOSFETs are key enablers
Technology Evaluation Metrics

- **Efficiency**
- **Conversion & power distribution**
- **Scalability**
  - Flexibility over power specs (Vo, Io, transients)
- **Sustainability**
  - Ability to leverage technology advancement
- **Density**
  - X-Y-Z dimensions, interference to high speed routings
- **Cost effectiveness**
  - Component cost, customization cost, respin cost
- **Ease of design**
  - Design, manufacturing complexity; time to market

**Ultimate goal is to optimize for TCO**

*Benchmarking several existing solutions in different colors*
Closing

● 48V architecture enables higher power and efficiency system with opportunities to further improve in cost, efficiency, density and scalability
● Encourage additional participation to further expand the ecosystem
Thank you!