48V: An Improved Power Delivery System for Data Centers

White Paper

June 2017

Copyright

Disclaimer

Contents

Introduction

The adoption of 48V for data center power distribution is accelerating within the data center ecosystem. Google, for example, has implemented 48V in its data centers and donated a 48V rack power specification to the Open Compute Project (OCP) community, and has also co-developed a 48V IBM POWER9-based server with Rackspace. Data center operators like Google are looking for opportunities to improve their Power Usage Effectiveness (PUE), lower their Total Cost of Ownership (TCO) and boost their computing density and rack utilization. Taking into account the growing demands of cloud computing, compute-intensive applications, and higher power processers and accelerators, the benefits of adopting 48V for data center power distribution become more significant.

The 48V solution architecture helps reduce power loss from the data center facility, to the rack, and the server board level. Compared with the current mainstream approach (12V power distribution), it provides better power conversion efficiency at rack level, and works at lower current levels to deliver a 16X reduction in power distribution.

This paper will discuss the challenges of 12V power delivery systems in data centers, introduce the proposed 48V power delivery architecture, and detail the 48V implementation in Wiwynn's new M1 server board.

The challenges of 12V power delivery systems in data centers

Data centers today use more kilowatts (kW) per rack or per square foot than ever before. A few years ago, data centers were designed for 4 to 5kW per rack and now typically can get to ~ 10kW per rack. Increasing rack power density up to 30kW or more will be the next trend in the future.

As the rack power climbs, conversion efficiency becomes more important. A 1% efficiency improvement can result in saving hundreds of watts at rack level~~,~~ and kilowatts at data center level. Existing racks are fed by AC voltage (typically 230VAC) and converted into lower voltage at the server. With the traditional 12V architecture, 83A of current is required to provide 1kW of power to a server rack. As server power demand increased, this current has gone beyond 200A. Since power lost in distributing current increases by the square of the current (I2R), more copper in the backplane or wiring harness must be used to control distribution losses. This ultimately limits the power delivery of the rack. A 30kW rack would need to provide over 2.5kA of 12V power to the server boards. This becomes a question of feasibility. To support a 30kW rack, a new power distribution system with higher voltage is required to limit distribution losses (or the amount of copper required to support the current).

Table 1: Distribution currents working at 12V vs. required rack power levels

Required power level of a rack	Currents (with 12V)
1kW	**83A**
5kW	**416A**
10kW	**833A**
30kW	**2500A**

The higher the currents, the more power distribution loss

Why 48V?

Choose 48V as the input voltage for new solutions because of:

1) **Better power conversion efficiency:**

Higher conversion efficiency compared to 12V (or lower voltages). A good AC-12V power supply will run at 96% efficiency, while a good AC-48V system can run at 98% efficiency (Table 2 & 3).

Table 2: Power conversion efficiency comparison

(80 Plus Platinum PSU)

12V and 48V PSU Efficiency SPEC				
	Voltage	12V	48V	Improved eff.
Load				
100%		92.49%	95.03%	2.54%
50%		94.54%	95.57%	1.03%
20%		91.73%	94.13%	2.40%
10%		84.23%	87.48%	3.25%

Note: 48V PSU change from 12V PSU Platinum.

Table 3: Power conversion efficiency comparison

(80 Plus Titanium PSU)

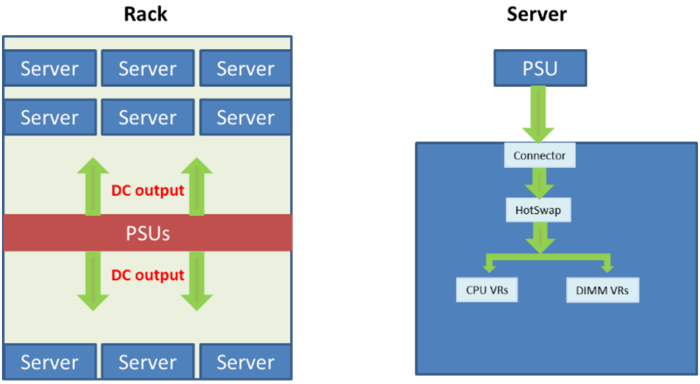
12V and 48V PSU efficiency SPEC				
	Voltage	12V(3kW)	48V(4kW)	Improved eff.
Load				
100%		94.00%	96.30%	2.30%
50%		96.50%	98.00%	1.50%
20%		95.50%	97.30%	1.80%
10%		93.50%	95.10%	1.60%

Note 1: 48V efficiency SPEC is target efficiency.

Note 2: 12V PSU is Titanium.

2) **Lower distribution currents**:

48V offers a 16X reduction in distribution losses for the same amount of copper compared with 12V systems, and a similar 16X benefit in energy storage. This allows for the use of turbo caps to handle peak power requirements, allowing the AC supply to be sized lower. This also enables power levels in the rack to achieve the target 30kW, by a fourfold reduction in distribution currents.



$$P_{\text{Distribution Loss}} = I^2 * R_{\text{(distribution imped)}}$$

48V DC system power distribution loss is less than 12V DC system (1:16)

Figure 1: Power distribution

3) **Comparable safety requirement**:
Based on the UL-60950-1 standard, 60VDC is considered the SELV limit. Utilizing distribution voltages above 60VDC would require additional insulation, spacing, and testing (such as hi-pot or fault testing). Therefore, 48V has the same safety level as 12V without extra safety concerns for 48V application.

The challenges of adopting 48V direct input to server board

The benefits of 48V power delivery system are obvious at rack level, considering the lower currents required. However, there are challenges when delivering 48V directly to the server board. Compared with traditional 12V server power delivery solutions (Figure 2), there are still some limitations for 48V to overcome.

1) **Power conversion efficiency:**
Each power conversion stage within the rack, including AC-DC and DC to point of load (POL), must have a higher efficiency in order to drive better power efficiency at rack level. The power conversion efficiency of 48V DC to POL must be comparable with 12V.

2) **No increase in size:**
Server boards are becoming more dense (higher functionality, no increase in size), therefore the size of 48V voltage regulators (VRs) must be small enough to fulfill the trend toward higher power density.

3) **No increase in TCO**:

Any increase in cost of equipment must be offset by higher efficiency. The power conversion must “pay for itself” by enabling lower electricity usage (and significant cost savings) in the rack as a whole.

4) **No sacrifice in transient response performance**:

Changing architectures from 12V to 48V requires there be no change in transient response performance. In fact, new generation CPU transients are increasing in magnitude and making transient performance even more challenging to respond to faster and recover quicker.

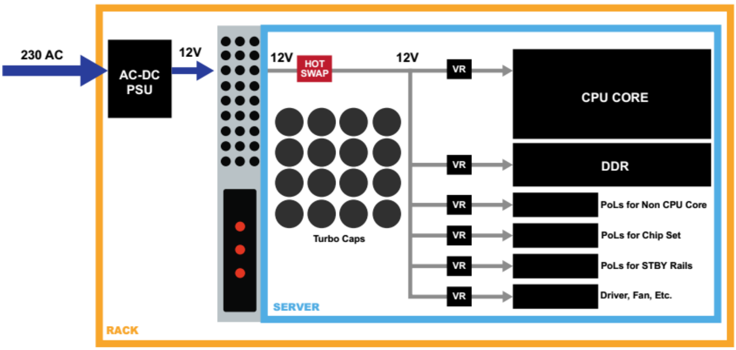


Figure 2: Today’s 12V server power delivery

Proposed server using 48V power delivery

Vicor’s 48V power solution helps to overcome the limitations of 48V at the server board level. It meets key criteria for higher efficiency, power delivery, smaller size, and lower TCO. This solution utilizes a fundamentally different architecture to perform the VR function. The VR solution for the processor and memory is comprised of three elements as shown in Figure 3.

The first element is a ZVS Buck-Boost regulator, called a PRM, which is compatible with the 36-60V OCP 48V standard input. This regulator operates at roughly 2.5MHz and produces a regulated output voltage ranging from 26-55V. It utilizes Zero Voltage Switching (ZVS) to enable high frequency operation without high switching losses. In typical operating conditions, the efficiency of this device is around 98%.

The second element is a Sine Amplitude Converter current multiplier, called a VTM, which is sourced by the output of the PRM. This device behaves like a DC transformer and provides a voltage step down between the PRM and the processor load. The VTM uses both ZVS and zero current switching (ZCS) and typically switches at 1.5MHz. A unique and important attribute of the VTM is that because it provides a voltage transformation (as opposed to DC voltage chopping), it has very low impedance and zero inductive energy storage.

The third element is a Control, Telemetry, and Observability device, called a CTO, which interfaces the PRM/VTM VR to the rest of the system. The CTO communicates with the load or processor and adjusts the PRM's voltage setpoint as needed.

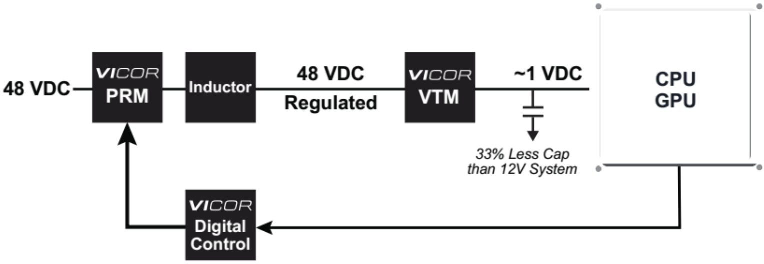


Figure 3: 48V VR for processor/memory applications

This new VR solution eases the burden on modern data centers by providing the following benefits:

1) This solution operates from a 36-60V OCP standard 48V input without any extra safety concern. Also, this offers an advantage in AC-DC conversion efficiency compared to 12V (or lower voltages). In addition, 48V offers a 16x reduction in distribution losses for the same amount of copper compared with 12V systems

2) This solution provides a similar footprint compared to a standard 12V VR solution. Of the three components comprising the solution, only the VTM needs to be placed in close proximity to the processor. This results in over 50% reduction in power component footprint at the processor and a 40% reduction in overall solution footprint.

3) This solution has no minimum output voltage limitation from a 48V input. It

is well-suited to address lower core voltage requirements for future systems.

4) This solution enables nearly instantaneous response times to transient loads. The VTM will begin to respond within hundreds of nanoseconds to a change in load current and transit to a new steady state operating point within 2-3 switching cycles. This allows for a reduction in capacitance needed at the processor, while still meeting a strict transient response.

Enabling a motherboard fed from 48V distribution voltage requires more than just a solution for the core voltage. Some loads on a motherboard, such as fans, can transit easily to 48V, while others, such as memory, also benefit from the proposed PRM+VTM approach. With the deployment of this new proposed solution, 80% of a typical motherboard load (CPU Core and DDR) will be powered directly from 48V using a PRM+VTM (Figure 4). The remaining 20% can be powered directly from 48V using a high efficiency 48 to 3.3V, 5V, or 12V regulator.

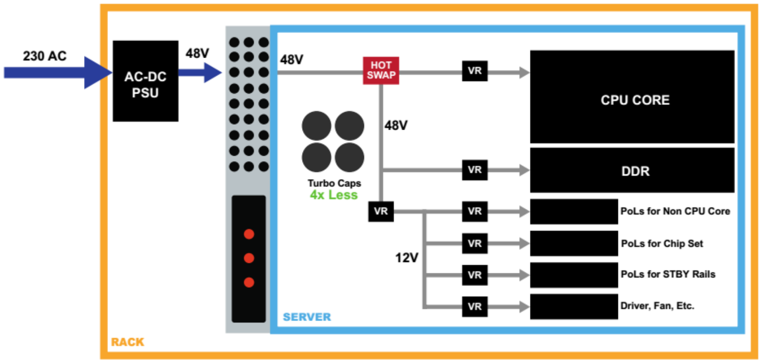


Figure 4: Proposed server using 48V power delivery

48V implementation on Wiwynn’s M1 server board

Wiwynn has developed a solution that provides more power capability, higher efficiency, higher power density, better rack utilization, and lower TCO using Vicor’s 48V voltage regulator solution. M1 is a 48Vin server board redesigned from a traditional 12Vin server board architecture. It implements a 48V direct to POLs solution for both CPU and memory. The efficiency test data has shown that the 48V direct solution is comparable with traditional 12V VR solutions. In terms of total efficiency (AC-DC-POL), M1 has shown ~1.5% efficiency improvement compared with 12Vin power systems and can save hundreds of watts per rack.

Table 4: System power efficiency comparison of 12V and 48V —No distribution loss

	PSU Eff	DC to Load Eff.			DC output Eff.	Total Efficiency
12V *System*	AC to 12V DC	12V to 1.8V (CPU core power)	12V to 12V	12V to POLs (other rails)	12Vin	(No Distribution Loss)
	94%	94.50%	100%	92%	93.65%	88.03%
48V *System*	AC to 48V DC	48V to 1.8V (CPU core power)	48V to 12V	12V to POLs (other rails)	48Vin	(No Distribution Loss)
	96%	93.60%	97%	92%	92.18%	88.49%

* Assumed 100% utilization-CPU 68%, others 32%

Table 5: System power efficiency comparison of 12V and 48V —With distribution loss

	PSU Eff	DC to Load Eff.			DC output Eff.	Total Efficiency
12V *System*	AC to 12V DC	12V to 1.8V (CPU core power)	12V to 12V	12V to POLs (other rails)	12Vin	(With Distribution Loss)
	94%	94.40%	100%	92%	93.65%	**86.94%**
48V *System*	AC to 48V DC	48V to 1.8V (CPU core power)	48V to 12V	12V to POLs (other rails)	48Vin	(With Distribution Loss)
	96%	92.70%	97%	92%	92.18%	**88.42%**

* Assumed 3mohm distribution imped

(bus bar+ cable + connector + HSC + input pcb impe

*Calculated by 600W system total power

- **48VDC system has 16X reduction in distribution loss**
- **1.5% better than 12V system**

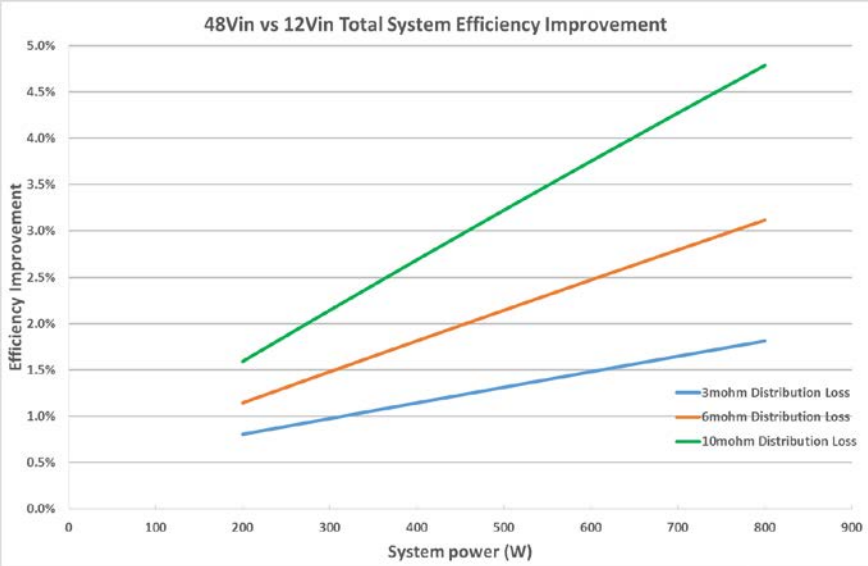


Figure 5: 48Vin vs 12Vin total system efficiency improvement

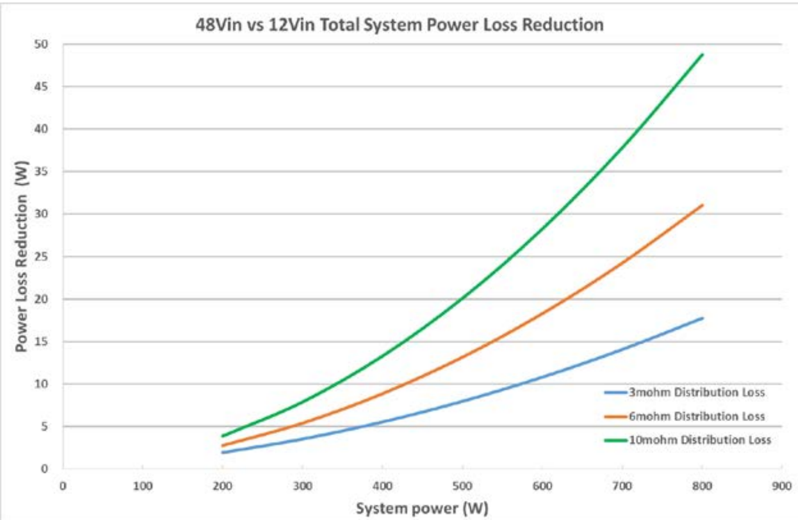


Figure 6: 48Vin vs 12Vin total system power loss reduction

Conclusion

The increasing demands of cloud computing, compute-intensive applications and higher rack utilization are compelling data center operators to rethink their power delivery strategy. With Vicor’s VR solution and Wiwynn’s server board design, the 48V solution can provide better power conversion efficiency at rack level (230AC to 48V DC: 98%) and maintain similar efficiency at server level compared with traditional 12V. Adopting 48V power delivery systems will help data center providers improve PEU and TCO by saving hundreds of watts per rack. At the same time, the 48V solution will enable data center operators to use higher density solutions to fulfill the growing demand for cloud computing applications.

Contact sales@wiwynn.com for more details.

About Wiwynn

Wiwynn® is an innovative cloud IT infrastructure provider of high quality computing and storage products, plus rack solutions for leading data centers. We aggressively invest in next generation technologies for workload optimization and best TCO (Total Cost of Ownership). As an OCP (Open Compute Project) solution provider and platinum member, Wiwynn® actively participates in advanced computing and storage system designs while constantly implementing the benefits of OCP into traditional data centers.

For more information, please visit http://www.wiwynn.com/english or contact sales@wiwynn.com

Follow Wiwynn® on Facebook and Linkedin for the latest news and market trends.

References

A high efficiency high density voltage regulator design providing VR 12.0 compliant power to a microprocessor directly from a 48V input, Paul Yeaman, Applied Power Electronics Conference and Exposition (APEC), March 2013

48V Power Delivery to Grantley Reference Board, Donghwi Kim, Jiangqi He, David Figueroa, Applied Power Electronics Conference and Exposition (APEC), March 2016

Optimized Power Delivery Architecture for Data Center Scale Server Application, Neilus O'Sullivan, Open Compute Project Summit, March 2016

48 V: the new standard for high-density, power-efficient data centers, Robert Gendron, Electronic Products, August 2016