Flexible & Scalable
48V Solutions Powering Tomorrow’s Data Centers

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Maxim Integrated
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Rack Architectures are Changing from 12V to 48V
Why a New Rack Power Architecture is Needed

**Data Centers are Focused on Reducing Energy Consumption**

- 2% of Global Electricity use
  > Equivalent Electricity Usage of Italy
- US data centers forecasted to consume 140B KWhrs by 2020
- Rack Power is One of the Largest OpEx Consumers in Data Centers

**CPU & Memory Consume Most Power in Rack**

- CPU & Memory Represent ~80% of Total Server Power
- CPU Power & Dynamic Requirements Continue to Increase

**New 48V Rack Power Architecture**

- Google Introduced a 48V Rack Power Architecture at 2016 OCP Summit to Replace 12V Racks
- Requires New High Efficiency 48V to PoL Regulator for CPU & Memory

Racks are Moving from Typically 8kW Today to 20kW by 2020 Timeframe
High Performance Silicon Trends

CPUs, GPUs & FPGAs

Artificial Intelligence, Machine Learning, Big Data, Autonomous Cars & Cloud Computing
Driving Rack Power to 20kW+
48V to PoL DC/DC Regulator
Challenges & Requirements

• Eliminate a Conversion Step
  > Direct 48V to PoL DC/DC

• Scalable Output Voltage & Current
  > CPUs, Memory, GPUs, FPGAs and ASICS

• High Efficiency 48V to 1V

• Cost-Effective
48V OCP Rack
Performance & Features

• Energy Savings Achieved
  > Greater than 20% Less Conversion Losses
  > 16x Less Power Distribution Losses
    • Connectors, Cables, Board
  > Upstream Conversion & Distribution Savings

• Characteristics of Ideal 48V Solution
  > Fast Dynamic Response
  > High Efficiency
  > Scalable & Flexible

Conversion to 48V is Economical for Racks Greater than 12kW
Maxim Technology & Architecture Advantage

Scalable Single Stage Quick PWM Converter with Proprietary Magnetics & Power Stages
Maxim’s Unique Solutions Solve Customer Challenges

Monolithic Integration

Optimized Power Packaging

Integrated Magnetics
Leveraging Maxim Expertize for 48V Solutions

- 15+ years of Server Power Experience
  > Significant Market Share over Multiple Generations of Server CPU/Memory Power Products at 12V
  > Intimate Understanding of Server Systems & CPU Requirements
- Leveraging Same Core Technology to Implement 48V Solutions
  > Existing 12V Products Leverage Process, Package & Magnetics Expertize
  > Reduce Risk with Maxim’s System & Technology Experience
  > Combination of Unique Technologies Provides Best TCO @ 48V
Scalable Single Stage Quick PWM Converter with Integrated Magnetics & Power

Technology Building Blocks

- Optimized for Efficiency
  - Monolithic Power Stage with 2 Phases per IC
  - Integrated Loss-less Current Sensing
  - Energy Recovery
- Best-in-class transient response
  - Advanced ISO-Quick PWM Control Architecture
  - Proprietary Coupled Inductor Technology
- Supports Isolated or Non-Isolated Options
Scalable Single Stage Quick PWM Converter with Integrated Magnetics & Power

- **Primary Side HV:** 60V ≥ Vin ≥ 40V
- **Transformer Ratio** 6:1, 10V Secondary
  - Multiphase System up to 8 Phases
  - High Load Current per Transformer Stage
- **Secondary Side Controller**
  - Drive Up to 4 Scalable Transformer Stages
- **Secondary Side Power Stage**
  - Synchronous Rectifier
- **Optional Isolator**
  - Primary to Secondary Isolation: 600V – Noise Relief
  - Fast Response – Sub 15ns Transit Delay
Scalability & Flexibility of Maxim Solution

- Scalability & Flexibility:
  - Simply Add More Stages to Increase Power Level
  - No Tuning Required – Change Output Voltage and Current with No Design Changes
  - Multiple Magnetics Options Available
  - Meets all Intel Specifications
Regulator Performance
Transformer Load Line: $V_{\text{OUT}} = 1.80\text{V}$
Transient Response: 10A – 197A – 10A

CH1: \( V_{\text{OUT}} \) 40mV/DIV
Auto Phase Shedding: 6A to 63A @ Variable Load Repetition Rate

CH1: $V_{OUT}$ 20mV/DIV; CH2: $I_{LOAD}$
Dynamic VID Transition: 1.5V to 1.8V, $I_{LOAD} = 10\text{A}$

CH1: $V_{OUT}$, 60mV/DIV; CH2: ALERT, 90mV/DIV, CH3: SKIPB, 2V/DIV, CH4: SKIPDC, 2V/DIV
Design Support
Full Design & Verification Support

- Complete Reference Designs
- SIMPLIS Models
- PCB Layout Support
  > From Concept to Gerber Out
Full Design & Verification Support

- Verification
- Characterization
- Thermal Evaluation
Easy-to-Use GUI

GUI makes it easy for the user to monitor, control, and measure the parameters of interest.
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PM Bus Parameters
Easy-to-Use GUI

Plotting feature allows monitoring telemetry parameters in real time or record the data for analysis.
48V TCO Advantage
## 12V to 48V Rack TCO Assumptions

### Open Compute Rack

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Server Lifetime (Years)</td>
<td>4</td>
</tr>
<tr>
<td>Hours Per Day</td>
<td>24</td>
</tr>
<tr>
<td>Days per Year</td>
<td>365</td>
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<tr>
<td>Cost of Energy ($/kWhr)</td>
<td>$0.10</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>2017</th>
<th>2019</th>
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<tbody>
<tr>
<td>Efficiency &amp; Distribution Delta</td>
<td>2%</td>
<td>3%</td>
</tr>
<tr>
<td>CPU Power (W)</td>
<td>100 x 2</td>
<td>160 x 2</td>
</tr>
<tr>
<td>Memory Power (W)</td>
<td>30 x 4</td>
<td>80 x 4</td>
</tr>
<tr>
<td>Total Server Power (W)</td>
<td>400</td>
<td>800</td>
</tr>
<tr>
<td># of Servers per Rack</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Rack Power (kW)</td>
<td>8</td>
<td>20</td>
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<tr>
<td>Data Center PUE</td>
<td>1.1</td>
<td>1.05</td>
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## 48V TCO Savings Summary

### 48V TCO Cost Savings Summary (4 years)

<table>
<thead>
<tr>
<th>Rack Architecture</th>
<th>Open Compute</th>
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<tbody>
<tr>
<td></td>
<td>Year</td>
</tr>
<tr>
<td>Rack Power (kW)</td>
<td></td>
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<tr>
<td>Lifetime Savings per Server</td>
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</tr>
<tr>
<td>Payback Period (Years)</td>
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<td>100K Server Savings</td>
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</table>

**Full Payback in 1.1 Years**
Hyper-Scale Data Centers
48V Rack Architecture Driving Compute Density

Data Center Trends
• New Applications Driving need for Higher Power Compute Nodes
  > 200W+ CPUs with 100W+ Accelerators and 300W GPUs
  > 10kW Racks Today, 25kW Tomorrow

Our Solutions
• Two Decades of 12V Server Power Technology Leadership
• 48V to PoL Technology for High Power Rack Density
  > Passes all Intel’s Skylake Tests
  > Supports all CPUs, Memory, GPUs, FPGAs & ASICs
  > Best in Class Efficiency