48V Datacenter Solutions
DC/DC Power Conversion for Datacenter, Open Compute & AI Applications
# Table of Contents

Overview ............................................................................................................................................. 3  
MPS 48V Power Structure .................................................................................................................... 4  
Lateral vs. Z-Axis Power Delivery™ .................................................................................................. 5  
First-Stage Solution: Power Modules .............................................................................................. 6  
Second-Stage Solution: Digital Multi-Phase Controller + Intelli-Phase™ or Intelli-Module .......... 10  
OAM Form Factor Power Solutions ................................................................................................ 16  
Quality Assurance ............................................................................................................................ 18  
About MPS ....................................................................................................................................... 19  
Contact & Ordering .......................................................................................................................... 20
Overview

Today’s datacenters use an average of 3kW to 5kW per rack to power server, storage, and networking racks. Most are designed to power basic CPUs and to operate at high levels of efficiency. Hence, the traditional 12V power architecture has been widely accepted and implemented (see Figure 1).

![Diagram of Traditional 12V Power Distribution](MonolithicPower.com)

As the demand for cloud computing, AI applications, machine learning, high-performance computing, and supercomputers grows, datacenters are evolving to accommodate new, higher power requirements. For example, an early AI market supercomputer required 3200W for the entire power system. The second generation’s power demand increased threefold, resulting in 10kW for the entire power system. Since the power lost in distributing high current increases by the square of the current ($I^2R$), more copper must be used in the backplane or wiring harness to control the distribution losses. Ultimately, this limits the power delivery of the system.

In order to meet the industry’s new power requirements, MPS has developed a new power architecture, using a 48V distribution voltage that is capable of a 16x reduction in power distribution losses, in addition to presenting a 48V datacenter solution to address new design challenges.
MPS 48V Power Structure
48V Power Structure: MPS’s New 48V to 4.8V System

- Total system efficiency is greatly optimized
- First-stage solution: MPS LLC power modules
  - 10:1 input-to-output ratio
  - Offered at various power levels
  - Parallel operation
- Second-stage solution: digital multi-phase controller + Intelli-Phase™ or Intelli-Module
  - The Intelli-Phase™ family offers continuous current ratings up to 90A
  - Intelli-Module solutions offer continuous current ratings up to 170A
- E-Fuse

Intelli-Modules are MPS’s latest open-frame power modules, and are part of our second-stage solution. Intelli-Modules can achieve high power density and optimize thermal performance in space-constrained applications.

Intelli-Phase™ is MPS’s state-of-the-art power stage technology. MPS’s DrMOS uses our monolithic process to drastically improve performance, and incorporates advanced features, including current sense, temperature sense, and fault reporting.
Lateral vs. Z-Axis Power Delivery™

Today’s datacenters use a lateral power delivery system, in which the power voltage regulators are placed on the top side of the board around the processor. As the current demand of CPUs and GPUs increases, the distance between the voltage regulator and the point of load become a significant factor for PDN losses. In addition, increased PDN means that the system requires a large amount of output capacitance for the voltage regulators.

Z-Axis Power Delivery™ is a method by which the voltage regulators are placed on the bottom side of the PCB below the processors. This results in a significant reduction (more than 10x) in PDN losses.

**Lateral Power Delivery <1000A**

**Z-Axis Power Delivery™ >1000A**

MPS offers power module solutions with <4mm height to fit in the limited space on the bottom side of the PCB.

Contact MPS for more information on Z-Axis Power Delivery™ EVBs
First-Stage Solution: Power Modules
MPS offers multiple options for first-stage modules

10:1 IBC Modules
54V to 5.4V

Enables a higher frequency second stage due to lower switching losses, which allows the use of a smaller, shorter inductor
- Best for Z-Axis Power Delivery™ (ZPD)

4:1 IBC Modules
54V to 13.5V

Higher power density, established common footprint in the market
- Best for lateral power delivery (LPD)

All of MPS’s IBC modules can be paralleled to reach >1kW power levels. An application note with additional details is in development.
MPC1100C-54 – High-Efficiency, Non-Isolated, Fixed-Ratio Digital DC/DC 300W Power Module

The MPC1100C-54 is an open-frame digital DC/DC power module with continuous power up to 300W. This module accepts up to a 60V input, and is configured in a 10:1 input-to-output ratio. It offers a digital controller with multiple-time programmability (MTP), which can be easily configured to quickly bring up the system and nimbly adapt to system requirements.

Features:
- Input Voltage Range: 40V to 60V
- 10:1 Input-to-Output Ratio
- Power Level: Up to 300W
- Power Density: 1700W/in³
- LLC Topology
- Compatible with Serial Interface
- Supports Parallel Operation
- Built-In MTP to Store Custom Configurations
  - Under-Voltage Lockout (UVLO)
  - V_{OUT} Over-Voltage Protection (OVP) and Under-Voltage Protection (UVP)
  - OCP_TDC/SPIKE
  - Over-Temperature Protection (OTP)
- GUI Configuration Software Provided
- Great for High-Current and High-Power Applications
- Pin-to-Pin Compatible with the MPC1102-54

Dimensions:
27mmx18mmx6.1mm

<table>
<thead>
<tr>
<th>Part Number</th>
<th>V_{IN} (V)</th>
<th>V_{OUT} Range (V)</th>
<th>Power Density (W/in³)</th>
<th>P_{OUT} (W)</th>
<th>Peak Efficiency (%)</th>
<th>Efficiency @ 300W (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC1100C-54-0002</td>
<td>40 to 60</td>
<td>4 to 6</td>
<td>1700</td>
<td>300</td>
<td>96.7</td>
<td>95.3</td>
</tr>
</tbody>
</table>

Figure 3: MPC1100C-54
MPC11057-54-0750 – High-Efficiency, Non-Isolated, Fixed-Ratio Digital DC/DC 750W Power Module

The MPC11057-54-0750 is an open-frame digital DC/DC power module with continuous power up to 750W (see Figure 4). This module accepts up to a 60V input, and is configured in a 10:1 input-to-output ratio. It offers a digital controller with multiple-time programmability (MTP), which can be easily configured to quickly bring up the system and nimbly adapt to system requirements.

Features:
- Input Voltage Range: 40V to 60V
- 10:1 Input-to-Output Ratio
- Power Level: Up to 750W
- Power Density: 1840W/in³
- LLC Topology
- Compatible with Serial Interface
- Built-In MTP to Store Custom Configurations
  - V_in Under-Voltage Lockout (UVLO)
  - V_out Over-Voltage Protection (OVP) and Under-Voltage Protection (UVP)
  - OCP_TDC/SPIKE
  - Over-Temperature Protection (OTP)
- GUI Configuration Software Provided
- Great for High-Current and High-Power Applications

Dimensions:
53mmx18mmx7mm

<table>
<thead>
<tr>
<th>Part Number</th>
<th>V_in (V)</th>
<th>V_out Range (V)</th>
<th>Power Density [W/in³]</th>
<th>P_out (W)</th>
<th>Peak Efficiency (%)</th>
<th>Efficiency @ 750W (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC11057-54-0750-xxxx</td>
<td>40 to 60</td>
<td>4 to 6</td>
<td>1840</td>
<td>750</td>
<td>97.6</td>
<td>96.9</td>
</tr>
</tbody>
</table>
MPC12106-54-0750 – High-Efficiency, Non-Isolated, Fixed-Ratio Digital DC/DC 750W Power Module

The MPC12106-54-0750 is an open-frame digital DC/DC power module with continuous power, up to 750W. This module accepts up to a 60V input, and is configured in a 4:1 input-to-output ratio. It offers a digital controller with multiple-time programmability (MTP), which can be easily configured to quickly bring up the system and nimbly adapt to system requirements.

Features:
- Input Voltage Range: 40V to 60V
- 4:1 Input-to-Output Ratio
- Power Level: Up to 750W
- Power Density: 3310W/in³
- LLC Topology
- Compatible with Serial Interface
- Built-In MTP to Store Custom Configurations
  - \( V_{\text{IN}} \) Under-Voltage Lockout (UVLO)
  - \( V_{\text{OUT}} \) Over-Voltage Protection (OVP) and Under-Voltage Protection (UVP)
  - OCP_TDC/SPike
  - Over-Temperature Protection (OTP)
- GUI Configuration Software Provided
- Great for High-Current and High-Power Applications

Dimensions:
24mmx18mmx8.6mm

<table>
<thead>
<tr>
<th>Part Number</th>
<th>( V_{\text{IN}} ) (V)</th>
<th>( V_{\text{OUT}} ) Range (V)</th>
<th>Power Density (W/in³)</th>
<th>( P_{\text{OUT}} ) (W)</th>
<th>Peak Efficiency (%)</th>
<th>Efficiency @ 750W (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC12106-54-0750-xxxx</td>
<td>40 to 60</td>
<td>10 to 15</td>
<td>3310</td>
<td>750</td>
<td>98.1</td>
<td>97.5</td>
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</tbody>
</table>
Second-Stage Solution: Digital Multi-Phase Controller + Intelli-Phase™ or Intelli-Module

MPS has a robust product portfolio of digital multi-phase controllers and Intelli-Phase™ and Intelli-Module solutions. For more information, visit monolithicpower.com/en/products/power-management/data-center.html

![Second-Stage Digital Multi-Phase Controller + Intelli-Phase™ or Intelli-Module Block Diagram](image)

**Digital Multi-Phase Controller Features:**
- Patented Constant-On-Time (COT) Control
- Multiple Loops, Flexible Phase Assignment
- Interface Options: SVID, SVI2/3, OVR, or Serial Interface
- Fault Handling and Telemetry Capabilities

**Intelli-Phase™ Features:**
- Family of Devices Ranges from 10A to 90A
- Wide \( f_{SW} \) Range: Balance between Transient and Efficiency
- Built-In ZCD, OCP, NOCP, OTP, and SCP
- Minimal External Components

**Intelli-Module Features:**
- High Power Density in Space-Constrained Applications
- Flexible Output Assignment
- Support Parallel Operation for Higher Power Delivery
- Optimized for Top-Side Cooling

<table>
<thead>
<tr>
<th>Power Structure</th>
<th>Type of Product</th>
<th>Part Number</th>
<th>Part Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>12V &amp; MPS’s new 4V to 6V architecture</td>
<td>Digital multi-phase controller</td>
<td>MP2888A</td>
<td>Single-loop, 10-phase digital multi-phase controller</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MP2882 (contact MPS for samples)</td>
<td>Dual-loop, 16-phase digital multi-phase controller</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MP2972 (contact MPS for samples)</td>
<td>Dual-loop, 12-phase digital multi-phase controller</td>
</tr>
<tr>
<td></td>
<td>DrMOS Intelli-Module</td>
<td>MP87006</td>
<td>16V, 90A Intelli-Phase™ in 4mmx6mm package</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MP87000</td>
<td>16V, 90A Intelli-Phase™ in 5mmx6mm package</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MPC22163 (contact MPS for samples)</td>
<td>16V, 130A Intelli-Module in 9mmx10mmx8mm footprint</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MPC22164 (contact MPS for samples)</td>
<td>16V, 130A Intelli-Module in 9mmx10mmx4mm footprint</td>
</tr>
<tr>
<td>MPS’s new 4V to 6V architecture</td>
<td>DrMOS</td>
<td>MP86972 (contact MPS for samples)</td>
<td>12V, 60A Intelli-Phase™ in 3mmx6mm package</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MP86976 (contact MPS for samples)</td>
<td>7V, 70A Intelli-Phase™ in 3mmx6mm package</td>
</tr>
</tbody>
</table>
MPC22163-130 – Two-Phase Intelli-Module with Quiet Switcher™ Technology

The MPC22163 is a non-isolated, step-down power module with 130A of continuous peak output current. This module integrates driver MOSFETs and an inductor in a compact package to save layout space and achieve a higher power density. It is scalable for many modules in parallel, up to 2kW+ of power. The 8mm maximum height makes it suitable for many applications, such as OAM form factor boards.

Features:
- Input Voltage Range: 4V to 16V
- Output Voltage Range: 0.5V to 2V
- 130A Output Current
- Top-Side Cooling Package
- Current Sense: Accu-Sense™
- Temperature Sense
- Current Limit Protection
- Supports Parallel Operation
- Over-Temperature Protection (OTP)
- Fault Reporting
- Common Footprint LGA-72 (9mmx10mm) Package

Dimensions:
9mmx10mmx7.5mm

<table>
<thead>
<tr>
<th>Part Number</th>
<th>V_{in} (V)</th>
<th>V_{out} Range (V)</th>
<th>I_{out} (A)</th>
<th>f_{sw} (kHz)</th>
<th>Power Density (W/in^3)</th>
<th>Peak Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC22163-130</td>
<td>4 to 16</td>
<td>0.5 to 2</td>
<td>130</td>
<td>600 to 1500</td>
<td>2475</td>
<td>88.7</td>
</tr>
</tbody>
</table>
The MPC22166 is a non-isolated, step-down power module with 130A of continuous peak output current. This module integrates driver MOSFETs and an inductor in a compact package to save layout space and achieve a higher power density. It is scalable for many modules in parallel, up to 2kW+ of power. The 4mm maximum height makes it suitable for many applications, such as Z-Axis Power Delivery™ and PCIe form factor boards.

Features:
- Input Voltage Range: 4V to 16V
- Output Voltage Range: 0.5V to 2V
- 130A Output Current
- Top-Side Cooling Package
- Current Sense: Accu-Sense™
- Temperature Sense
- Current Limit Protection
- Supports Parallel Operation
- Over-Temperature Protection (OTP)
- Fault Reporting
- Common Footprint LGA-72 (9mmx10mm) Package
- Extremely Low Height: Maximum 4mm
- Pin-to-Pin Compatible with the MPC22163

Dimensions:
9mmx9.9mmx3.9mm

<table>
<thead>
<tr>
<th>Part Number</th>
<th>(V_{\text{IN}}) (V)</th>
<th>(V_{\text{OUT}}) Range (V)</th>
<th>(I_{\text{OUT}}) (A)</th>
<th>(f_{\text{SW}}) (kHz)</th>
<th>Power Density (\text{W/in}^3)</th>
<th>Peak Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC22166-130</td>
<td>4 to 16</td>
<td>0.5 to 2</td>
<td>130</td>
<td>600 to 1200</td>
<td>5034</td>
<td>90</td>
</tr>
</tbody>
</table>
MPC22167 – 130A, Two-Phase, Intelli-Module™ with Quiet Switcher™ Technology

The MPC22167 is a non-isolated, step-down power module with 130A of continuous peak output current. This module integrates driver MOSFETs and an inductor in a compact package to save board space and achieve a higher power density. It is scalable for many modules in parallel, up to 2kW or more of power. The 8mm maximum height makes it suitable for a wide range of applications, such as OAM form factor boards.

Features:
- Input Voltage Range: 10V to 16V
- Output Voltage Range: 0.5V to 2V
- 130A Output Current
- Top-Side Cooling Package
- Current Sense: Accu-Sense™
- Temperature Sense
- Current Limit Protection
- Supports Parallel Operation
- Over-Temperature Protection (OTP)
- Fault Reporting
- Common Footprint LGA-72 (9mmx10mm)

Dimensions:
9mmx9.9mmx7.65mm

<table>
<thead>
<tr>
<th>Part Number</th>
<th>V_{in} (V)</th>
<th>V_{out} Range (V)</th>
<th>I_{out} (A)</th>
<th>f_{sw} (kHz)</th>
<th>Power Density (W/in^3)</th>
<th>Peak Efficiency (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MPC22167-130</td>
<td>4 to 16</td>
<td>0.5 to 2</td>
<td>130</td>
<td>500 to 1200</td>
<td>2475</td>
<td>91.3</td>
</tr>
</tbody>
</table>
MP2891 – Dual-Loop, OVR4i+ 16-Phase Controller

Features:

- Highest Phase Count
  - Dual-Loop, 16-Phase Controller Provides Power for NVIDIA PWM-VID Core Power
  - Max 16 Phases for Rail 1 and 8 Phases for Rail 2

- Digital Control
  - Digital Loop Compensation and Load-Line Regulation
  - Nonlinear Control Reduces Output Capacitor Requirements for Transients

- Digital Configurability and Monitoring
  - Compatible with Serial Interface
  - $V_{\text{OUT}}, I_{\text{OUT}}, V_{\text{INV}}, P_{\text{INV}},$ and Temperature Telemetry
  - Intelli-Phase™ Fault Diagnosis
  - Integrated NVM to Store VR Configurations and for Black Box Capability

- Design Flexibility
  - Switching Frequency Up to 3MHz
  - Automatic Phase-Shedding Improves Light-Load Efficiency
  - Configurable Voltage, Current, and Temperature Protection

Package:
QFN-56 (7mmx7mm)
MPQ8645P – 16V, 30A, Scalable, Digital, Synchronous Step-Down Converter with Serial Interface

Features:
- Digital Point-of-Load (POL)
  - \( V_{IN}, V_{OUT}, I_{OUT}, \) and Temperature Telemetry
  - Rich Feature Selection
  - User-Accessible NVM to Save Configurations
- Flexible for Multiple Rails in System
  - Scalable Up to 8 Phases
  - Input Voltage Range: 3.1V to 16V
  - Supports 3.3V, 5V, and 12V Inputs
  - Supports Zero-ESR, MLCC Output Capacitors
  - Configurable Current Limit Offers Flexible Inductor Choice
- Adaptive Constant-On-Time Control
  - Minimizes Number of Required Output Capacitors
  - 0.5% Accurate Reference

MP5048 – 60V, 15A, 7m\( \Omega \) \( R_{DS(ON)} \) Hot-Swap Intelli-Fuse Solution

Features:
- 60V E-Fuse with Highest Industry Current
- Flexible for Multiple Phases in System
  - Input Voltage Range: 24V to 60V
  - Scalable for Standalone or Parallel Operation
  - Configurable Output Voltage Soft Start Supports Inrush Current Control
  - 1.5% IMON Reporting Accuracy Supports Accurate System Power Reporting
- Full System Protections
  - Configurable Over-Current Protection (OCP) Limit
  - Accurate On-Die Temperature Sensing and Thermal Shutdown
  - Pin-Configurable Latch-Off and Hiccup Protections
  - Fault Pin Indicator (FLTB)
Second-Stage Module vs. Traditional Discrete Solution

As the current demand of CPUs and GPUs increases and package sizes expand, designers are often left with very small areas on the board to fit multiple phases of voltage regulators (VRs). The Intelli-Module approach to VR design increases power density by 2.5x and allows placement of the voltage regulators closer to the processor to reduce PDN losses.

<table>
<thead>
<tr>
<th>Intelli-Modules: DrMOS + Inductor</th>
<th>DrMOS (Discrete Approach)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intelli-Module Solution Offers the Best Combo of Efficiency and Size 90mm² Layout Area</td>
<td>Traditional VR Solution, 225mm² Layout Area</td>
</tr>
</tbody>
</table>

OAM Form Factor Power Solutions

MPS provides end-to-end power solutions following OCP standards for common designs, such as OAM form factors. These capabilities are demonstrated with this reference design (max 2000A), which features our 4:1 first-stage modules and second-stage Intelli-Modules.

**2000A Reference Design**

**Specs:**
- 54V Input Voltage, 0.8V Nominal Output Voltage
- 1000A Output Current, Max 2000A
- Embedded Load Slammer for Transient Testing
- Second Stage Uses the MP2891 16-Phase Controller and the MPC22167, the Next Generation of the MPC22163 Module with the Same Footprint and Higher Efficiency
- This 2000A EVB Is Now Available for Sampling

**AI Accelerator Card:**
- OAM
- SXM
- etc.

For samples and more information on Z-Axis Power Delivery™ solutions, contact MPS
Adapting Power Solutions to the Increased Current Requirement of AI Processors

Z-Axis Power Delivery™
Ex: MPC22166

Lateral Power Delivery Using Modules
Ex: MPC22163

Lateral Power Delivery Using DrMOS
Ex: MP87006
Quality Assurance & Reliability Commitment

The MPS Quality Assurance organization develops, coordinates, and champions strategic quality initiatives throughout MPS Inc., its foundries, and subcontractors. Its mission is to enable MPS to design, develop, manufacture, and deliver products to our customers with world-class quality and reliability that meet and exceed our customers’ expectations.

MPS and Its Supplier Quality Systems and Certificates:
- ISO9001:2008 (MPS)
- EU RoHS/HF/REACH Compliant (MPS)
- Sony Green Partner (MPS & Suppliers)
- TS16949 (Suppliers)
- ISO14001 (Suppliers)

Product Quality:
- Automotive Products Qualified per AEC-Q100 Standard
- Standard Products Qualified per JEDEC and Military Standard
- Reliability Failure Rate <10FIT
- Product Quality Level <1.0ppm

Quality Control and Monitor:
- On-Site Foundry and Assembly Teams for Real-Time Actions
- Quarterly Supplier Quality Review and Annual Supplier Audit
- Short-Term Reliability Monitor Test – Daily
- Long-Term Reliability Monitor Test – Monthly
- Real-Time Engineering Actions on Monitor Failure
- Quarterly Reliability Monitor Reports
About MONOLITHIC POWER SYSTEMS

Who we are
We are creative thinkers. We break boundaries. We take technology to new levels. As a leading international semiconductor company, Monolithic Power Systems (MPS) creates cutting-edge solutions to improve the quality of life with green, easy-to-use products.

What we do
We make power design fun! With our innovative proprietary technology processes, we thrive on reimagining and redefining the possibilities of high-performance power solutions in industrial applications, telecom infrastructures, cloud computing, automotive, and consumer applications.

Where we come from
It started with a vision. Michael Hsing, pioneering engineer and CEO, founded Monolithic Power Systems, Inc. in 1997 with the belief that an entire power system could be integrated onto a single chip. Under his leadership, MPS has succeeded not only in developing a monolithic power module that truly integrates an entire power system in a single package, but also it continues to defy industry expectations with its patented groundbreaking technologies.

Our values
We cultivate creativity
As a company we believe in creating an environment that encourages and challenges our employees to collaborate and think outside the box to excel beyond their preconceived capabilities.

We do not accept the status quo
We do not believe in limitations. It is not about what is, but what can be. Possibilities are endless at MPS.

We are passionate about sustainability
It’s about the future. From materials to finances, we are committed to conservation. We will not tolerate waste in an effort to improve and preserve the quality of life.

We are committed to providing innovative products to our customers
Let us do the heavy lifting. We relentlessly strive to make system design versatile and effortless to meet our customers’ specific needs. We’ll do the work, so our customers can have the fun!