

For AI and Cloud Servers, High-Precision and High-Reliability DDR5 Memory Power Solutions

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With the rapid development of cloud computing, big data, and AI applications, server memory power topologies are facing increasing challenges, including high precision, low noise, high reliability, and high energy efficiency. Richtek introduces a series of highly integrated power management IC solutions for DDR5 server memory. By leveraging fast compensation control loops, intelligent voltage regulation, and comprehensive protection mechanisms, our solutions ensure stable memory operation while enhancing overall system reliability and efficiency. This product family not only improves power efficiency and system robustness but also helps customers address diverse application requirements and accelerates the evolution of next-generation server platforms.

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1 Key Challenges in Server Memory Power Design

With the continued growth of cloud computing data analytics and AI workloads modern servers are required to support ever higher memory capacity and bandwidth. As memory density and speed increase, power delivery requirements become significantly more stringent. Server memory power design must therefore address a set of critical challenges, including voltage accuracy, reliability, efficiency, and thermal management.

1.1 Ultra-High Voltage Accuracy and Low Noise Under Low Voltage Tolerance

High voltage accuracy is essential to ensure stable memory operation. DDR5 memory exhibits extremely tight voltage tolerance, and even minor voltage deviations can lead to data corruption or system instability. Therefore, power supplies must deliver exceptional regulation accuracy and ultra-low output noise.

Table 1. Output Voltage Specific

	VDD	VDDQ	VPP
Typical Output Voltage	1.1V	1.1V	1.8V
DC + AC Tolerance	+/-2.5%	+/-2.5%	+/-2.5%
DC Accuracy	+/-0.75%	+/-0.75%	+/-0.75%

Note 1. Refer to JESD301-5 and PMIC5030 Specification for additional information.

1.2 Long-Term Reliability Under Hot-Plug and Transient Overvoltage Conditions

High reliability is a fundamental requirement in server power supply design. Servers are expected to operate continuously over extended periods and any power related failure may lead to data loss or service interruption resulting in substantial economic impact. As a result, power management ICs must incorporate comprehensive protection features including overvoltage, overcurrent, and over-temperature protection while system components must provide adequate overvoltage tolerance to support long term stable operation.

In server memory power applications, hot plug conditions are a critical reliability concern. Memory modules typically require both a high voltage 12V rail and a low voltage 3.3V rail. Due to the layout of the module golden fingers a temporary short circuit between these two supplies may occur during insertion or removal, as illustrated in Figure 1. This scenario places significant stress on the power management ICs, which must tolerate such fault conditions without damage. Sufficient overvoltage robustness is therefore essential to ensure system integrity and prevent module failure.

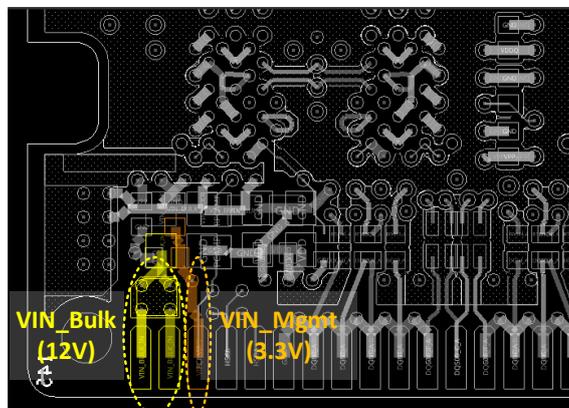


Figure 1. RDIMM Golden Finger Diagram (VIN_BULK and VIN_MGMT are Adjacent Pins)

1.3 Efficiency and Thermal Stability in High Power Density Architectures

Energy efficiency and thermal management represent additional critical challenges in server power design. Server environments consume substantial amounts of energy and improvements in power conversion efficiency directly reduce operating costs while contributing to lower overall carbon emissions. Furthermore, as power density continues to increase effective thermal management and the prevention of overheating become essential design considerations. In the DDR5 generation, the power management IC is mounted directly on the memory module, rather than on the motherboard as in previous DDR4 designs, as illustrated in Figure 2. This architectural change significantly increases the local power density on the memory module, which in turn places greater emphasis on efficiency optimization and accurate temperature monitoring to ensure reliable operation.

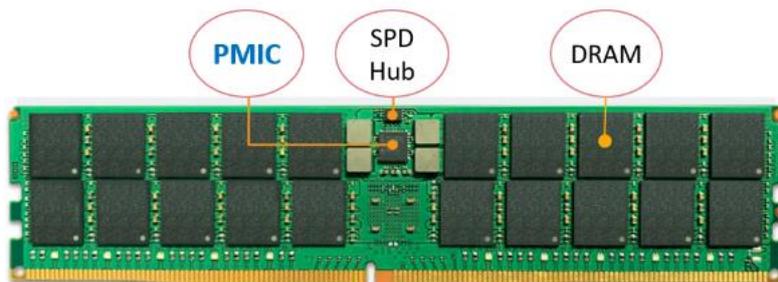


Figure 2. DDR5 RDIMM Memory Module

2 Richtek DDR5 Memory Power Solutions

To address the design challenges of reliability, voltage accuracy, efficiency, and thermal management discussed above, Richtek has developed a comprehensive range of server memory power solutions. Through careful circuit architecture design, component selection, system-level integration, and application-level validation, these solutions are designed to enhance overall performance and long-term reliability.

For each DDR5 server memory specification including different capacity and data rate configurations, Richtek provides optimized and application-specific power solutions to support a wide range of system requirements as summarized in Table 2 and Table 3. Detailed product specifications are available on the Richtek website or through our sales representatives.

Table 2. Richtek Server DDR5 PMIC Solution Series

Generation	Server Low Current	Server High Current	Server Extreme Current	Sever Extreme Current Gen2
JEDEC Standard	P5010	P5000	P5020	P5030
Richtek Solution	RTQ5119A	RTQ5150A	RTQ5152	RTQ5153
Application	RDIMM	RDIMM, CXL MM	RDIMM, MRDIMM, CXL MM	RDIMM, MRDIMM, CXL MM
Generation	Server Low Current	Server High Current	Server Extreme Current	Sever Extreme Current Gen2

Table 3. DDR5 PMIC Applications for Different DIMM Capacities and Transfer Rates

Card	Config.	DRAM Density	DIMM Capacity	DDR5 Transfer Rate (MT/s)																									
				4400	4800	5600	6400	7200	8000	>=8800																			
RDIMM	1Rx8	16 Gb	16 GB	RTQ5119A (P5010)			RTQ5119A or RTQ5150A (P5010/5000)		RTQ5152 (P5020)	RTQ5153 (P5030)																			
		24 Gb	24 GB																										
		32 Gb	32 GB																										
	2Rx8	16 Gb	32 GB	RTQ5150A (P5000)			RTQ5150A or RTQ5152 (P5000/5020)																						
		24 Gb	48 GB																										
		32 Gb	64 GB																										
	4Rx8 (DDP)	16 Gb	64 GB								RTQ5152 (P5020)																		
		24 Gb	96 GB																										
		32 Gb	128 GB																										
	2Rx4	16 Gb	64 GB	RTQ5152 (P5020)																									
		24 Gb	96 GB																										
		32 Gb	128 GB																										
	4Rx4 (3DS, SDP or DDP)	16 Gb	128 GB													RTQ5152 (P5020)													
		24 Gb	192 GB																										
		32 Gb	256 GB																										
8Rx4 (3DS)	16 Gb	256 GB	RTQ5152 (P5020)																										
	24 Gb	384 GB																											
	32 Gb	512 GB																											
MRDIMM	2Rx8	16 Gb									32 GB	RTQ5152 (P5020) MR - 8.8GT/s			RTQ5153 (P5030) MR - 12.8GT/s and above														
		24 Gb									48 GB																		
		32 Gb									64 GB																		
	4Rx8	16 Gb									64 GB											RTQ5152 (P5020) MR - 8.8GT/s			RTQ5153 (P5030) MR - 12.8GT/s and above				
		24 Gb									96 GB																		
		32 Gb									128 GB																		
	2Rx4	16 Gb				64 GB	RTQ5152 (P5020) MR - 8.8GT/s				RTQ5153 (P5030) MR - 12.8GT/s and above																		
		24 Gb				96 GB																							
		32 Gb				128 GB																							
	4Rx4 (3DS, SDP or DDP)	16 Gb				128 GB											RTQ5152 (P5020) MR - 8.8GT/s			RTQ5153 (P5030) MR - 12.8GT/s and above									
		24 Gb				192 GB																							
		32 Gb				256 GB																							

3 Advantages of Richtek DDR5 Memory Power Solutions

3.1 High-Precision, Low-Noise Power Control Architecture

First, in terms of high-precision voltage regulation, Richtek adopts an advanced A2RCOT voltage feedback control topology, combined with a high-precision reference voltage source and low-noise design, ensuring output voltage error is less than $\pm 0.75\%$. In addition, built-in compensation and automatic calibration mechanisms effectively minimize the effects of temperature drift and load variation on the output voltage, meeting the stringent power accuracy requirements of memory modules. The following sections explain temperature characteristics, load regulation, and dynamic response in detail. Further information on the A2RCOT voltage feedback control topology can be found in the relevant product datasheet.

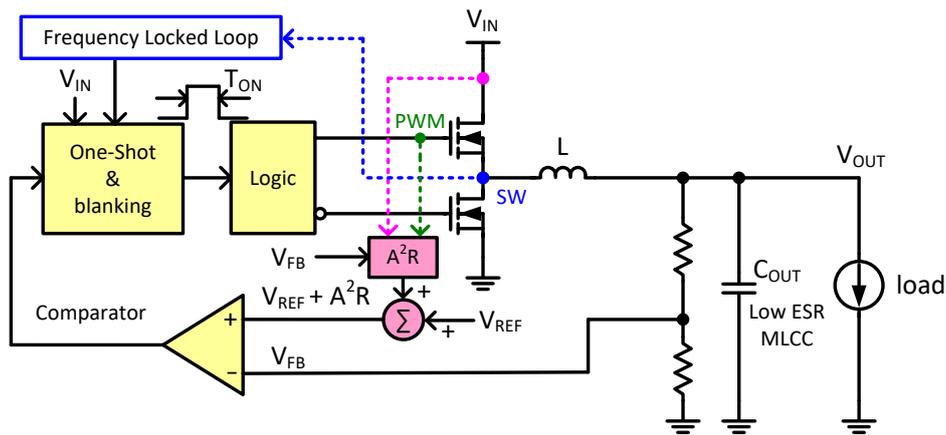


Figure 3. A²RCOT Control Loop

3.1.1 Excellent Temperature Compensation Characteristics Compliant with JEDEC Standards

Figure 4 to [Figure 6](#) compare the output voltage characteristics of the RTQ5153 with a major competing device across different temperature conditions. In server DDR5 applications, temperature stability of the power management IC is critical, as servers are typically required to operate continuously over extended periods under harsh thermal environments, including both high and low temperatures. Any deviation in output voltage may compromise memory data integrity and overall system stability.

Across the temperature range from -20°C to 80°C , the RTQ5153 maintains a highly stable output voltage profile, with voltage variation well below the JEDEC specification limit of $\pm 0.75\%$. Compared with competing solution, the RTQ5153 exhibits smaller output voltage deviation at both temperature extremes, demonstrating superior temperature stability.

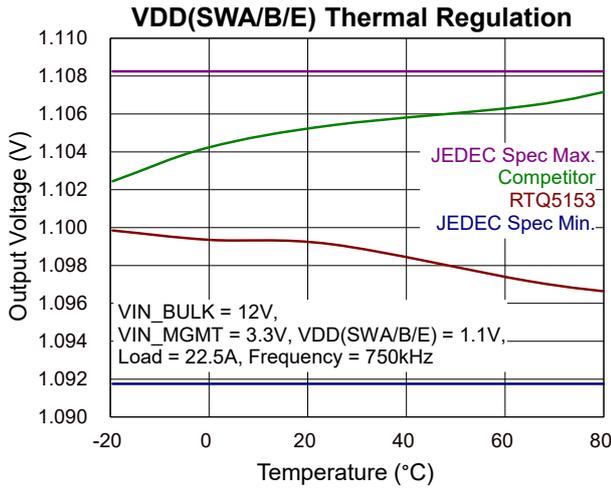


Figure 4. VDD(SWA/B/E) Output Voltage and Temperature Variation

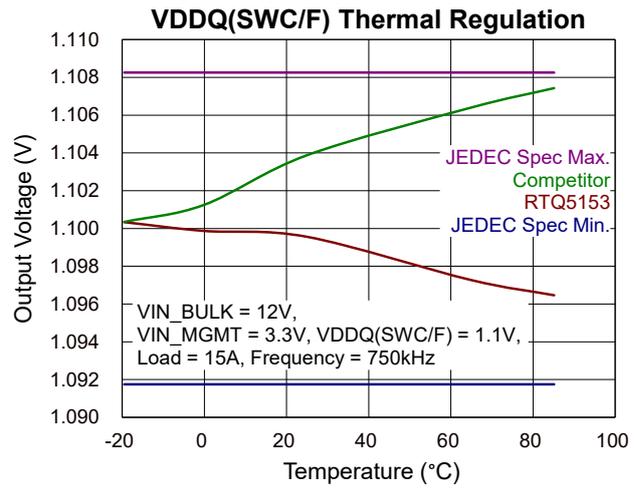


Figure 5. VDDQ(SWC/F) Output Voltage and Temperature Variation

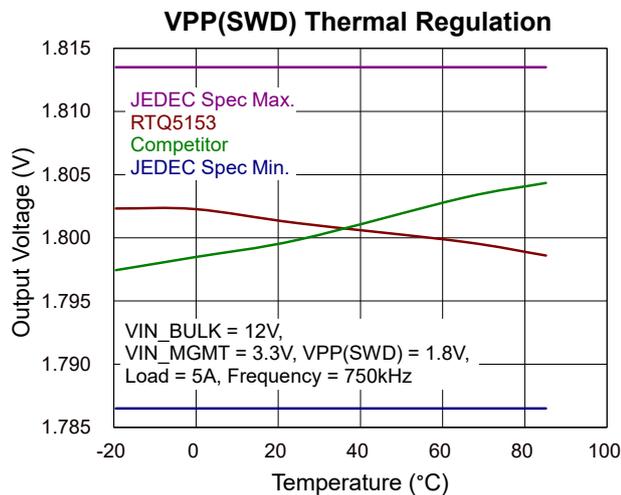


Figure 6. VPP(SWD) Output Voltage and Temperature Variation

3.1.2 Precise Output Voltage Regulation Compliant with JEDEC Standards

Figure 7 to Figure 9 compare the output voltage characteristics of the RTQ5153 with a major competing device under different load conditions. In server DDR5 memory applications, the power management IC must be capable of responding to dynamic memory load variations while continuously delivering stable and accurate output voltage. Excessive voltage deviation can result in data transmission errors system instability and degraded overall server performance.

Under a wide range of load transient, the RTQ5153 maintains a smooth and stable output voltage profile with voltage variation well below the JEDEC specification limit of $\pm 0.75\%$. Compared with the competing solution, the RTQ5153 exhibits superior load regulation performance.

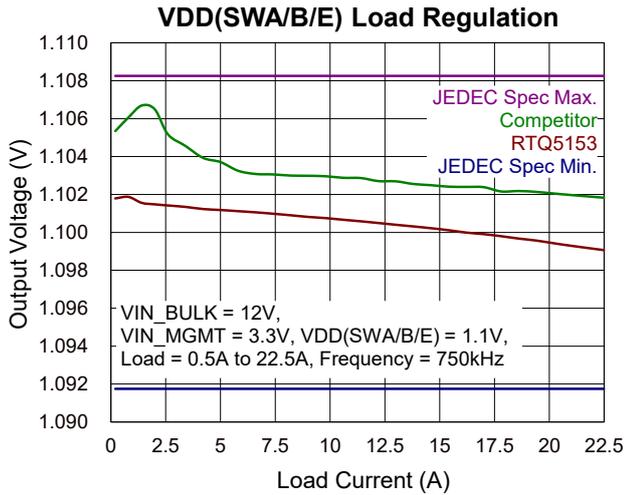


Figure 7. VDD(SWA/B/E) Output Voltage and Load Variation

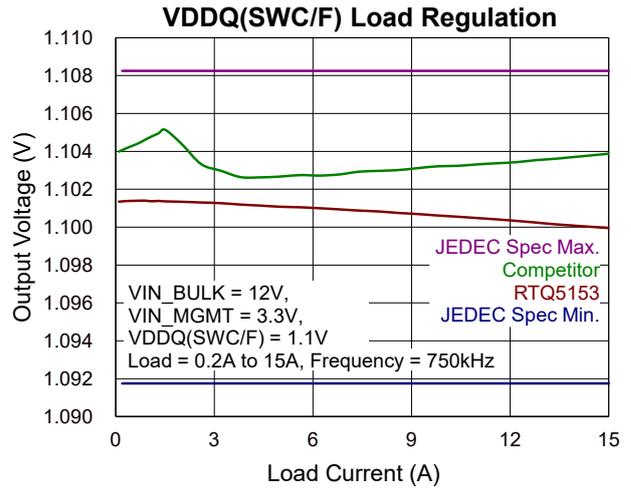


Figure 8. VDDQ(SWC/F) Output Voltage and Load Variation

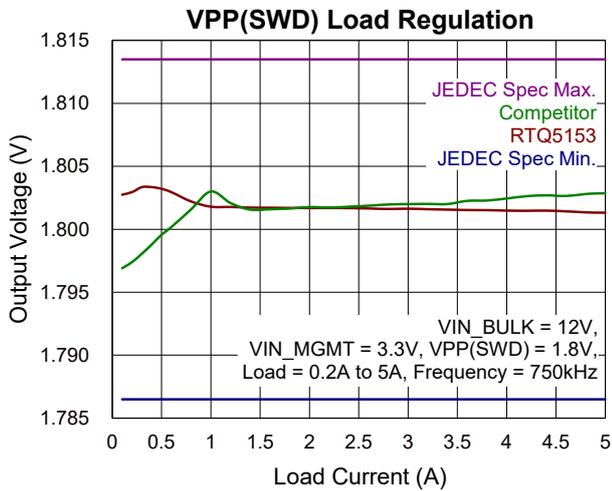


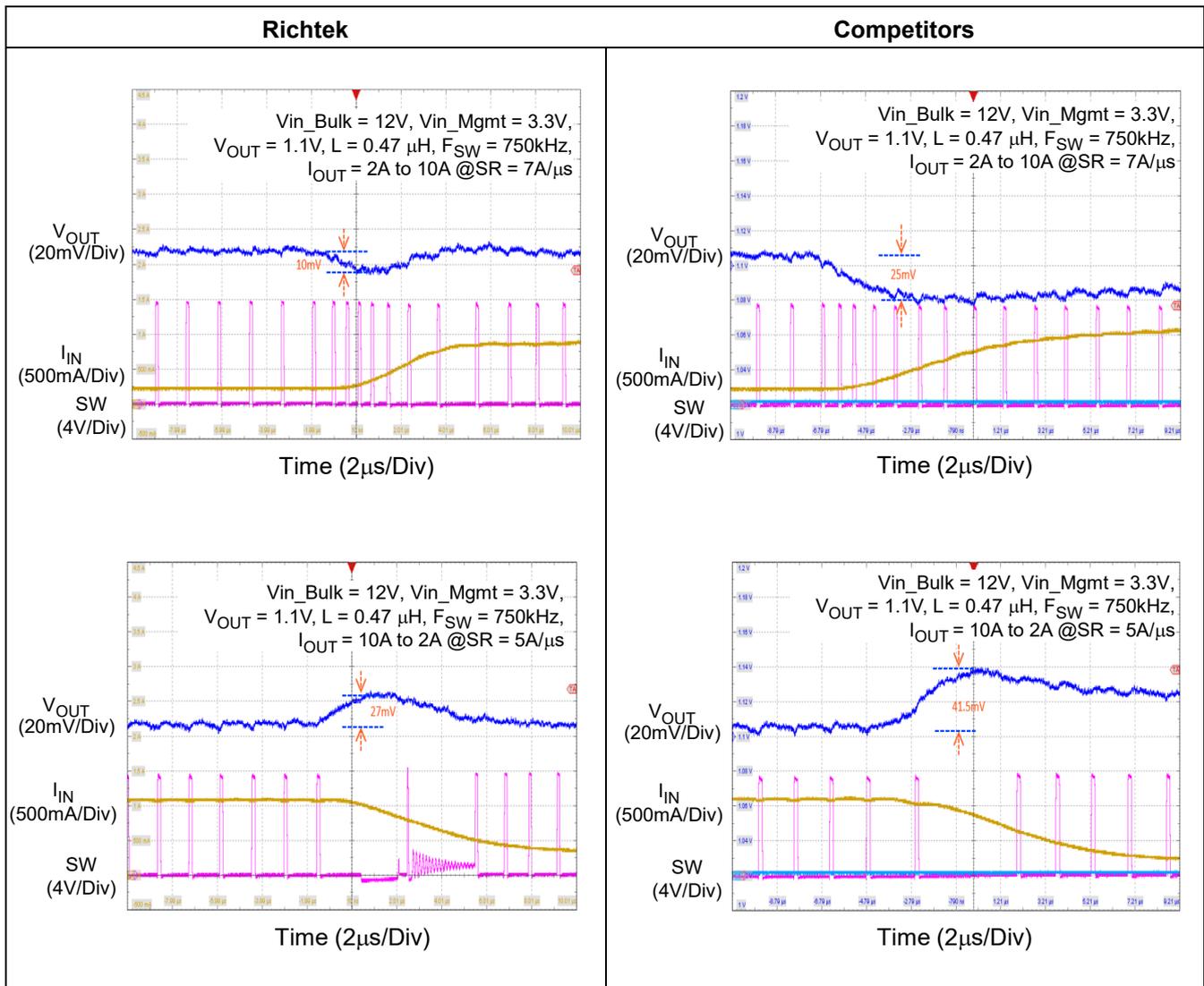
Figure 9. VPP(SWD) Output Voltage and Load Variation

3.1.3 Fast and Real-Time Dynamic Response

Richtek’s DDR5 power management IC series incorporates advanced power control topology to deliver high output stability. An integrated fast compensation loop enables rapid detection of load transients and immediate control response significantly reducing output voltage droop during sudden load changes and ensuring stable and reliable system operation.

In addition, an intelligent output voltage overshoot suppression mechanism is implemented. During load release conditions, the control loop responds promptly by actively disabling the low side switch thereby effectively limiting excessive output voltage excursion and preventing potential component stress or abnormal system behavior caused by voltage overshoot. [Table 4](#) presents a load step comparison between Richtek solutions and a competing device demonstrating superior performance across a range of test conditions.

Table 4. Load Step Comparison between Richtek and Competitors



3.2 High Reliability and Multiple Protection Mechanisms

For high reliability design, Richtek’s solution features multiple protection mechanisms, including overvoltage, overcurrent, short-circuit, and over-temperature protection, as shown in [Figure 10](#), ensuring immediate response and system safety in abnormal conditions. In addition, for server applications, Richtek provides higher input pin voltage tolerance, addressing potential short-circuit and overvoltage issues that may occur during memory module insertion and removal, further enhancing system availability and fault tolerance.

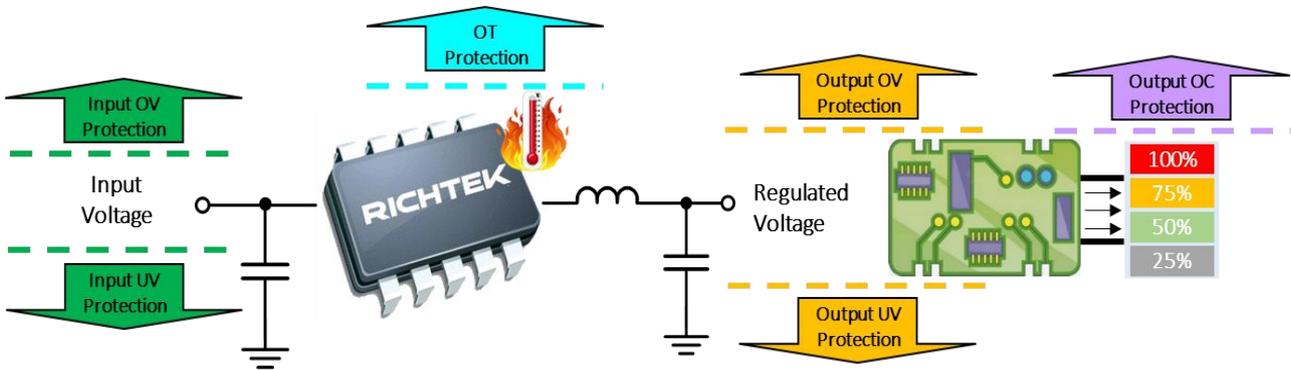


Figure 10. DDR5 PMIC Protection Features

3.2.1 Input Overvoltage and Undervoltage Protection Mechanisms

Input overvoltage and undervoltage protection are essential to prevent component overstress and abnormal operation during power fault conditions, such as surge events, hot plug spike, low input voltage, or power source mismatch, as shown in [Figure 11](#) and [Figure 12](#). Input overvoltage can lead to capacitor or MOSFET breakdown while undervoltage conditions may result in brownout, data read/write errors, and repeated system resets.

When an abnormal input condition is detected, the protection mechanism immediately disables the downstream VR and sets a corresponding fault flag in the register. This allows the system to transition rapidly into a safe operating state perform fault diagnosis and recover normal operation once the condition is cleared. Such protection improves long term system reliability and component lifetime, while reducing maintenance and warranty costs mitigating potential safety risks and maintaining overall operational stability.

Richtek products provide various threshold setting options for input overvoltage and undervoltage protection, enabling system designers to implement comprehensive and application specific protection schemes. Detailed information is available in the relevant product datasheets.

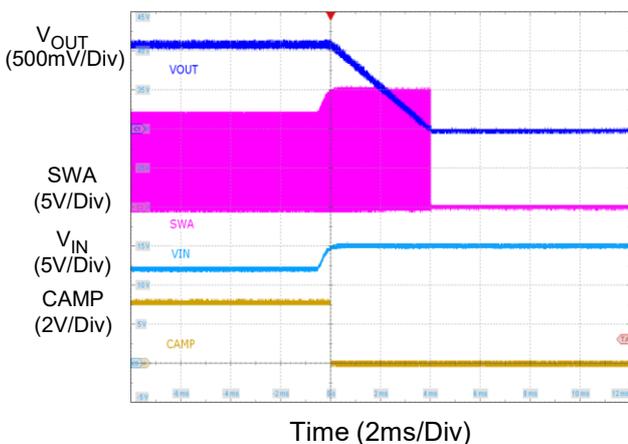


Figure 11. Input Overvoltage Protection

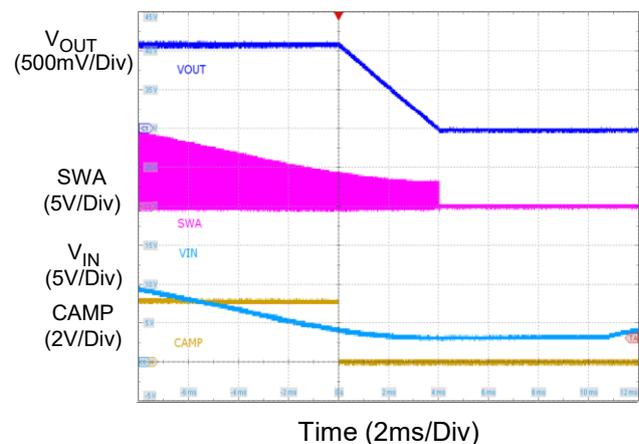


Figure 12. Input Undervoltage Protection

3.2.2 Output Overvoltage and Undervoltage Protection Mechanisms

Output overvoltage and undervoltage protection are required in the system to ensure that downstream DRAM is not damaged by abnormal voltages and to maintain overall stable operation, as shown in [Figure 13](#) and [Figure 14](#). Output overvoltage may cause component breakdown and overheating, while output undervoltage can lead to data read/write errors and repeated system restarts. When the output voltage exceeds the allowable range, the system immediately shuts down and withdraws the Power-Good signal to report a fault, allowing the system to quickly enter a safe state, prevent fault propagation, and facilitate diagnosis and recovery. This also improves reliability and meets DRAM voltage range specifications. Richtek products offer various threshold settings for output overvoltage and undervoltage protection, making it convenient for system designers to plan comprehensive system protection. Detailed information is available in the relevant product datasheets.

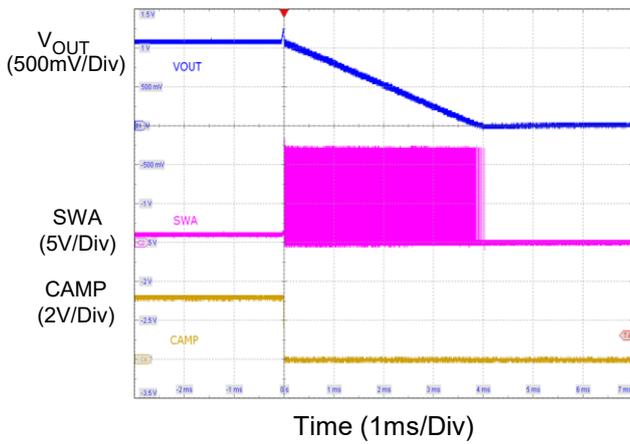


Figure 13. Output Overvoltage Protection

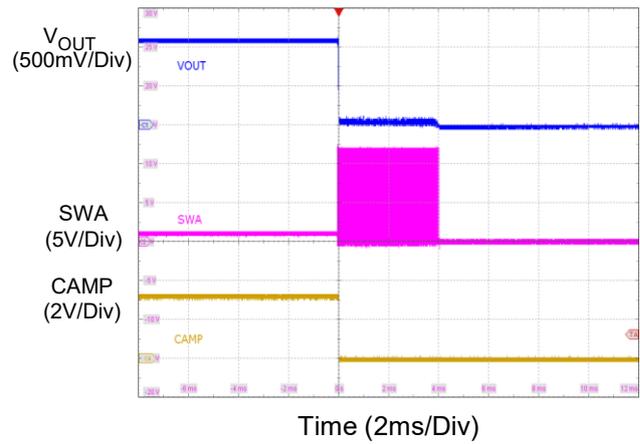


Figure 14. Output Undervoltage Protection

3.2.3 Output Overcurrent Protection Mechanism

Output overcurrent protection is necessary because situations, such as output short circuits, overloads, or inrush currents during parallel loading can cause the output current to exceed the design limit. This may lead to overheating and damage of the IC, inductor, and PCB traces, as well as voltage drops, instability, or even safety risks. As shown in [Figure 15](#), the overcurrent protection mechanism limits the current when an abnormal condition occurs. If necessary, it immediately shuts down the output and withdraws the Power-Good signal to report a fault, quickly cutting off energy to prevent fault propagation. Working together with over-temperature and undervoltage protection, it enables controlled recovery, improves reliability and lifespan, meets safety and quality requirements, and reduces maintenance costs. Richtek products offer various threshold settings for output overcurrent protection, allowing system designers to plan appropriate overcurrent protection according to actual system loads. Detailed information is available in the relevant product datasheets.

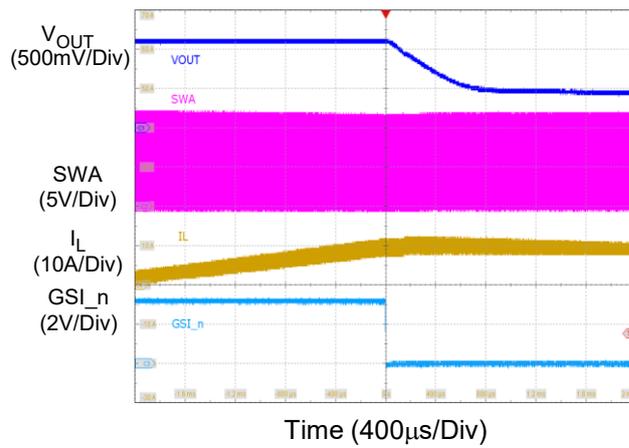


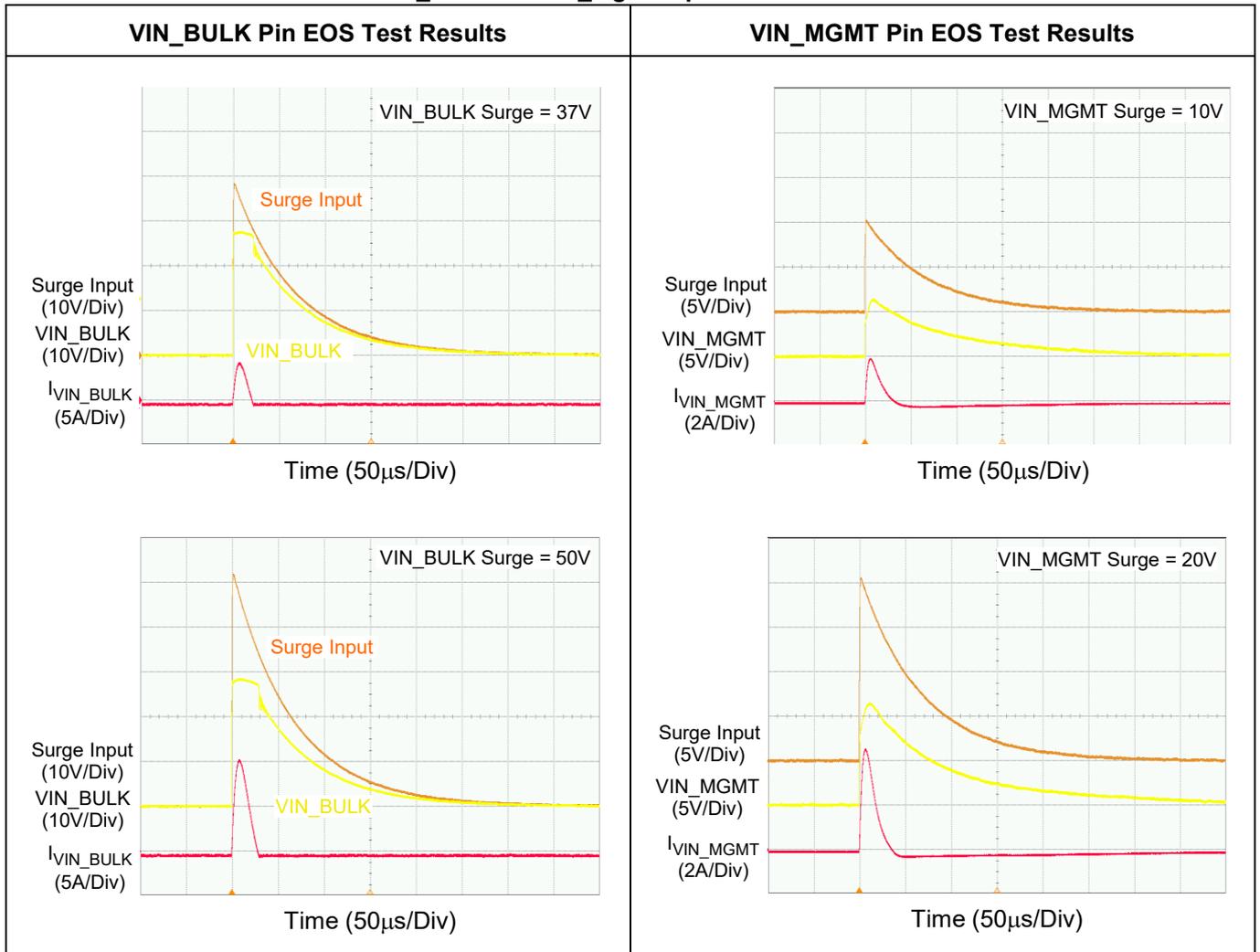
Figure 15. Output Overcurrent Protection

3.2.4 JEDEC-Compliant EOS Component Withstand Voltage Test

EOS (Electrical Overstress) protection capability is a key indicator for ensuring product reliability. For the two input terminals of the DDR5 server power solution series, pulse voltage tests of 37V and 10V were conducted in accordance with JEDEC standards to simulate possible transient high-voltage scenarios, as shown in [Table 5](#).

After rigorous testing, Richtek products not only fully meet the standard requirements but also demonstrate higher tolerance. This enhanced robustness allows the devices to withstand electrical overstress events encountered in real world operating conditions while maintaining stable operation thereby providing improved safety margin and long-term reliability for system designers.

Table 5. Vin_Bulk and Vin_Mgmt Input Pin EOS Test Results



3.3 High Efficiency and Enhanced Thermal Management

In server DDR5 memory applications, the efficiency of the power management IC has a direct impact on overall system energy consumption, thermal design margin, and operating cost. To address efficiency and thermal management requirements, Richtek implements high-efficiency synchronous rectification, achieving power conversion efficiency above 92%, thereby reducing both power loss and heat dissipation.

In addition, accurate ADC-based temperature monitoring, together with over-temperature protection, ensures stable operation under high load conditions and prevents junction temperature from exceeding component limits. This approach extends component lifetime and enhances long-term server system reliability.

Through optimized circuit design and advanced semiconductor manufacturing processes, Richtek products further improve conversion efficiency. As demonstrated by the test results in [Figure 16](#) to [Figure 18](#), Richtek products not only exceed JEDEC specification requirements but also outperform the average efficiency level of comparable competing solutions. Under identical operating conditions, this higher efficiency translates into lower overall server power consumption, reduced thermal stress, and eased thermal management design constraints, resulting in lower system energy cost.

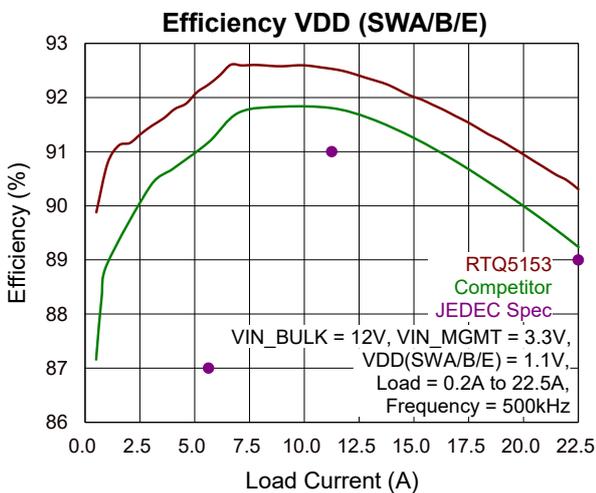


Figure 16. VDD(SWA/B/E) Efficiency

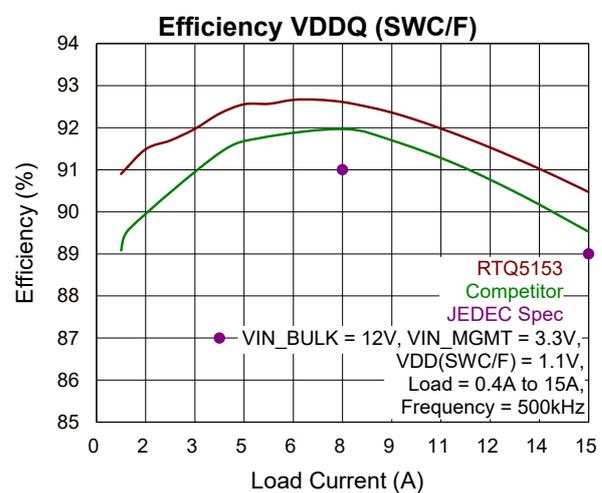


Figure 17. VDDQ(SWC/F) Efficiency

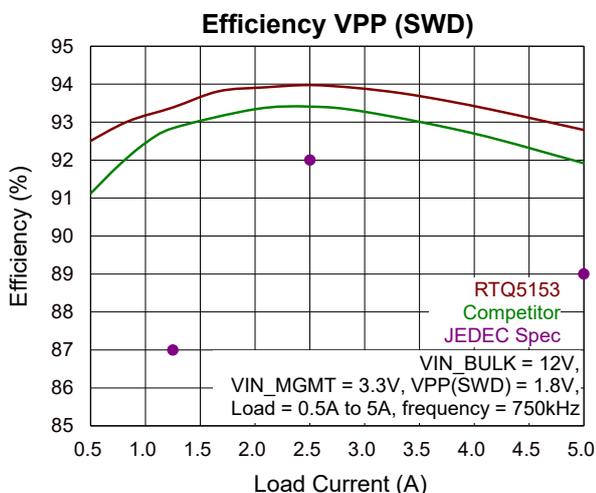


Figure 18. VPP(SWD) Efficiency

3.3.1 High Temperature Warning Reporting Mechanism

Richtek products for DDR5 server applications feature high-precision temperature reporting, automatically activating protection mechanisms when the temperature reaches 85°C to ensure safe system operation. The temperature reporting error at each stage is controlled within $\pm 5^\circ\text{C}$, as shown in [Table 6](#), providing accurate and reliable temperature monitoring. This feature not only meets stringent regulatory requirements but also greatly enhances product safety and stability in various application environments.

Table 6. Temperature Measurement

PMIC Ambient Temperature	PMIC Temperature Measurement
85°C	85°C
95°C	96°C
105°C	106°C
115°C	117°C
125°C	127°C
135°C	138°C

3.3.2 Over-Temperature Protection Mechanism

Richtek products feature a built-in over-temperature protection mechanism. When the temperature exceeds 145°C, the system immediately activates protective measures, shutting down all output voltages, as shown in [Figure 19](#), and accurately reports the fault status through the Power-Good signal. This design effectively prevents damage caused by overheating, ensures safe operation of the equipment, and allows users to promptly monitor the system’s health status, thereby enhancing overall reliability.

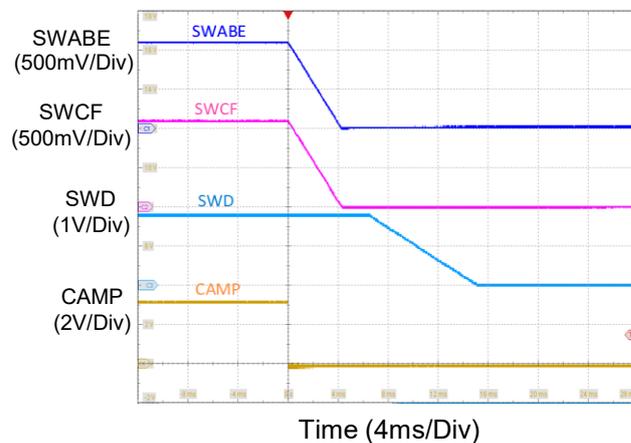


Figure 19. Over-Temperature Protection

4 Conclusion

Richtek's server memory power solutions satisfy the requirements of high-end server platforms across key performance metrics, including voltage accuracy, dynamic response, reliability and efficiency. By employing high-precision feedback and a fast compensation topology, stable output is maintained across load and temperature variations, providing sufficient power margin for DDR5 memory during high-speed operation and reducing the risk of system instability.

Multiple protection and status reporting mechanisms are integrated to enhance platform fault tolerance and support long-term reliable operation. In parallel, high-efficiency, low-loss power design reduces power consumption and heat dissipation, easing thermal design requirements and improving overall system energy efficiency.

All solutions comply with Intel power specifications and AVL requirements, and have been validated at system level by multiple DRAM manufacturers. This enables direct integration into mainstream server platforms while shortening development and validation timelines.

By combining core power management expertise with extensive server platform experience, Richtek continues to optimize power architecture and circuit design to deliver competitive memory power solutions. Ongoing R&D investment, together with close collaboration across the ecosystem, further drives improvements in server platform performance and reliability.

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