

Multiphase Regulator Modules Yield Thin, Low-Noise Power Solutions

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Modern electronic systems including cloud servers, telecom infrastructure, and advanced industrial automation demand higher performance within increasingly constrained form factors. As point-of-load current requirements rise and board real estate shrinks, designers must deliver robust, high-current solutions without compromising efficiency, noise performance, or signal integrity. At the same time, the proliferation of sensitive analog circuitry and high-speed data interfaces makes low noise and minimal electromagnetic interference (EMI) more critical than ever.

The LTM4732 buck regulator module addresses these challenges through an ultra-thin, high-current multiphase architecture combined with Analog Devices' Silent Switcher 3 (SS3) technology (see the reference). Measuring just 6.25 mm × 4 mm × 1.92 mm, this μ Module regulator is well-suited for space-constrained, low-profile applications where every millimeter matters.

At nearly the height of a soldered-down 1206 case-size capacitor, it allows mounting on the back side of a PCB, freeing space on the top side of the board. By integrating SS3 technology, this device delivers output noise as low as 4 μ V rms, reducing both conducted and radiated EMI.

Unlike traditional low-dropout (LDO) regulators, which often trade efficiency for low noise and may require post-regulation after a switching converter, the LTM4732 delivers both high efficiency and ultra-low noise in a single, compact module. This capability can eliminate the need for an additional LDO stage, simplifying power system design while still meeting the stringent noise requirements of sensitive analog and high-speed digital systems. High conversion efficiency further minimizes power loss and heat generation, making the solution well-suited for applications where thermal performance and energy savings are critical.

This article demonstrates a practical implementation of the LTM4732. By leveraging multiphase interleaving and parallel operation, the solution achieves low output noise and EMI while scaling output current in a compact footprint. This approach is ideally suited for sensitive analog circuits, high-speed data interfaces, and densely packed PCBs in data center, 5G telecom, and industrial automation applications.

Among the topics discussed here are design considerations for paralleling multiple modules. Details of connecting the modules and signal routing for voltage sensing, compensation, clock synchronization and phase locking are covered here. Experimental results are also presented including measured efficiency, thermal performance, transient response and stability. Tips for troubleshooting faults are also given.

Multiphase Operation And Interleaving In Power Modules

Modern high-current power modules like the LTM4732 leverage multiphase operation to achieve superior performance in efficiency, noise, and transient response. In a multiphase topology, several converter phases operate in parallel, each switching at the same frequency but with a fixed phase shift relative to the others. This interleaving of switching events is at the heart of the architecture's advantages.

When N phases are interleaved, each phase is shifted in time by

$$\text{Phase shift (degrees)} = 360/N \quad (1)$$

For example, in a four-phase system, each phase is offset by 90°. This interleaving spreads the switching events evenly throughout the switching cycle, effectively increasing the output ripple frequency:

$$\text{Ripple frequency (Hz)} = N \times f_{\text{sw}} \quad (2)$$

where N is the number of phases and f_{sw} is the switching frequency of each phase.

As a result, the output voltage ripple is significantly reduced due to both the higher effective ripple frequency and partial cancellation of phase currents at the output node. For an ideal multiphase system, the peak-to-peak ripple voltage scales approximately inversely with the number of phases. This enables designers to meet stringent ripple targets with smaller output capacitance, reducing board area and component count.

During a fast load transient, the initial output voltage deviation is primarily determined by how quickly current can be delivered to the output capacitor before the control loop responds. In an interleaved multiphase converter, phase staggering increases the effective ripple frequency at the output, shifting ripple energy to higher frequencies and reducing the interval between successive current contributions to the load.

As a result, the transient load demand is distributed across multiple phases, lowering the instantaneous voltage deviation per ampere of load step. The measured results show stable recovery and controlled voltage excursion during large load transitions, even at higher output current levels.

Another benefit of multiphase operation is straightforward current scaling. The total output current capability increases linearly with the number of phases:

$$I_{OUT_total} = N \times I_{OUT_per\ phase} \quad (3)$$

By paralleling multiple modules, higher total current can be delivered while distributing thermal and electrical stress across phases, resulting in improved reliability and easier thermal management. Up to 12 phases can be implemented at 4 A each for a total of 48-A output.

Interleaving multiple converter phases reduces output ripple and distributes thermal dissipation across phases, enabling higher current capability and improved efficiency. This makes multiphase architecture especially valuable in high-performance applications where noise and thermal management are critical.

Design Considerations And Guidance For Multiphase Operation

Implementing the LTM4732 in multiphase applications requires careful attention to configuration, synchronization, and layout to ensure optimal performance and reliable current sharing. This section summarizes practical guidance and best practices for paralleling multiple modules, minimizing noise, and managing thermal performance in high-current applications.

To support higher load current with a single output, two or more modules can be configured in parallel by connecting the V_{IN} , V_{OUT} , V_{OSNS} , and COMP pins of all devices together. This configuration ensures common voltage sensing and compensation across all phases, which is critical for accurate current sharing and stable operation. Fig. 1 illustrates a four-phase configuration with all modules connected in parallel.

For multiphase operation, multiple LTM4732 converters can be configured for clock synchronization of the subordinate phases with the main phase. To ensure reliable synchronization, the free-running oscillator frequency of the main phase (the master module) should be set at least 20% higher than the subordinate prior to synchronization, and the CLKOUT of the main is applied at the SYNC of the subordinate phase.

The PHMODE pin sets the relative phase shift between the converters. Grounding PHMODE sets a 180° phase shift, floating the pin sets a 120° phase shift, and connecting PHMODE to INTV_{CC} or to an external power supply of >3 V sets a 90° phase shift. For three-phase operation, PHMODE is floated to achieve the 120° phase shift, while for four-phase operation, PHMODE is tied to INTV_{CC} to achieve a 90° phase shift as shown in Fig. 2a and 2b, respectively.

This configuration ensures deterministic phase interleaving, reducing output ripple and improving EMI performance.

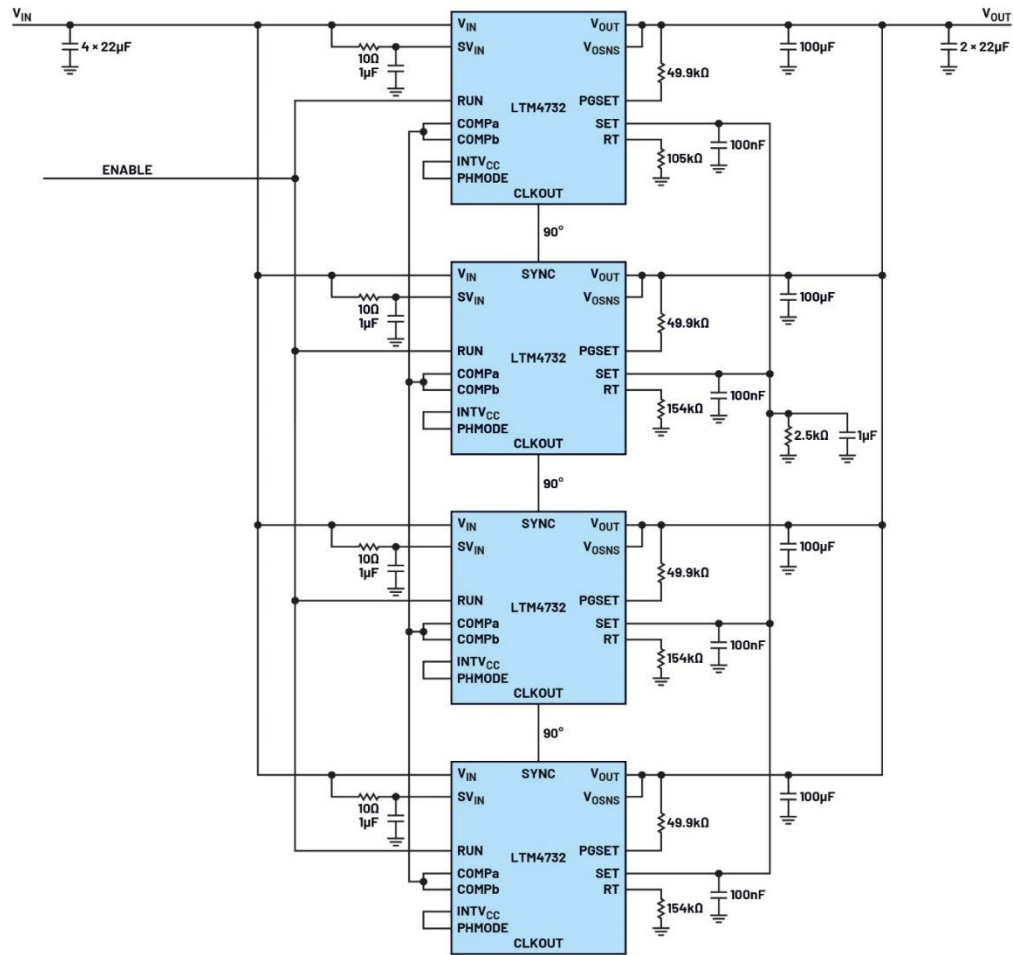


Fig. 1. Four-phase LTM4732 buck converter configuration using interleaved, paralleled modules.

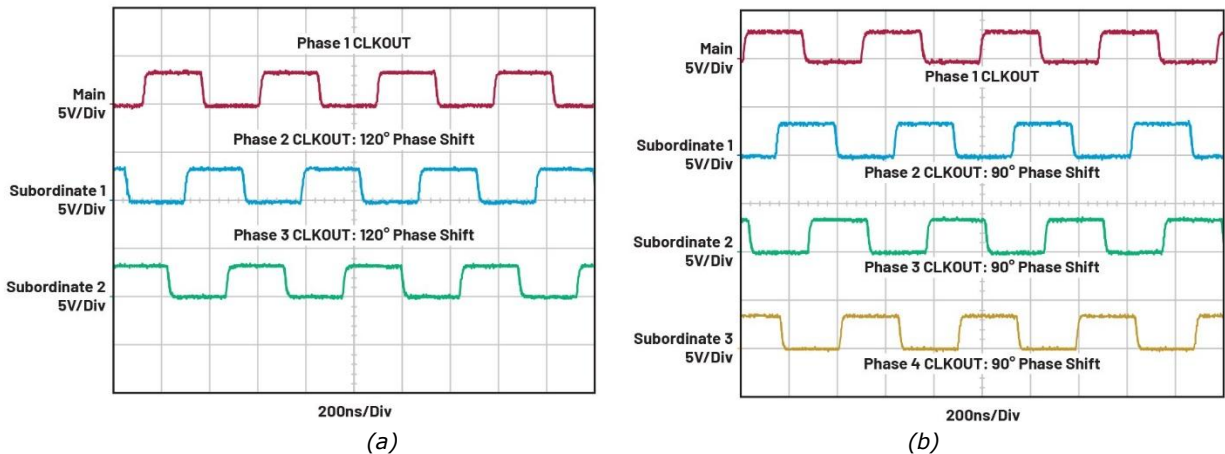


Fig. 2. Measured waveforms depicting 120° and 90° phase shifts between each phase of a three-phase configuration (a) and a four-phase configuration (b).

Measurement Results And Performance Validation

Fig. 3 compares the efficiency of single phase and four phase as a function of load current. At 4-A load, four-phase configuration improves efficiency from 75.5% in single-phase configuration to 83% in four-phase configuration. This improvement is consistent with per phase reduced RMS current and lower conduction loss when the load is shared across phases.

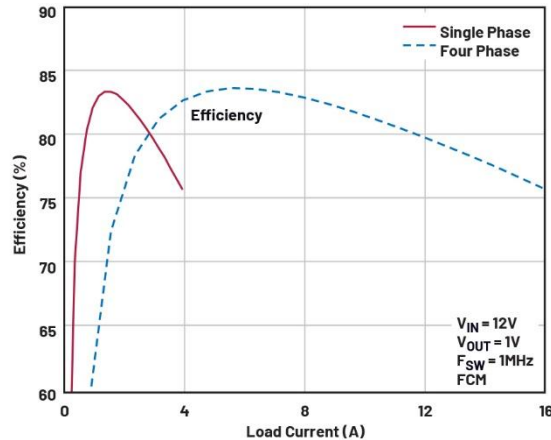


Fig. 3. Efficiency of single-phase vs. four-phase LTM4732 configurations.

The efficiency, power loss, and thermal behavior of the four-phase configuration were evaluated under steady-state load conditions to characterize system-level performance at high output current. Measured efficiency remains high across the operating load range, with total power loss increasing gradually with output current as expected (Fig. 4). Distributing the load current across four interleaved phases reduces per-phase current stress, which helps limit conduction losses within each module and contributes to stable operation at higher load levels.

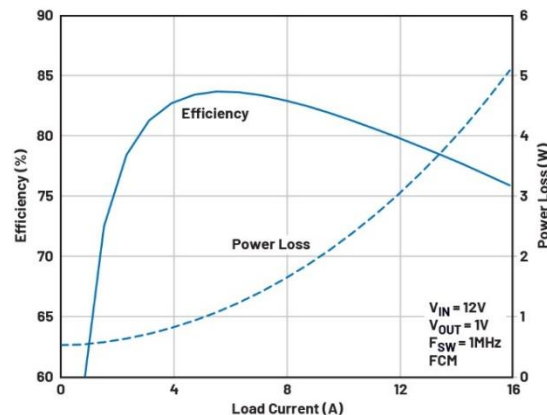


Fig. 4. Efficiency and power loss of a four-phase interleaving the LTM4732 at 1-MHz f_{SW} , 12-V V_{IN} , and 1-V V_{OUT} .

Thermal imaging shows uniform temperature distribution across four modules, with no localized hotspots observed during operation (Fig. 5). Peak device temperatures remain well controlled, indicating effective current sharing and thermal spreading in the multiphase configuration. This balanced thermal profile supports higher current delivery and improves reliability in thermally constrained applications.

Overall, the measured efficiency, power dissipation, and thermal results confirm that the four-phase LTM4732 implementation provides robust high-current performance with manageable losses and well-distributed thermal stress.

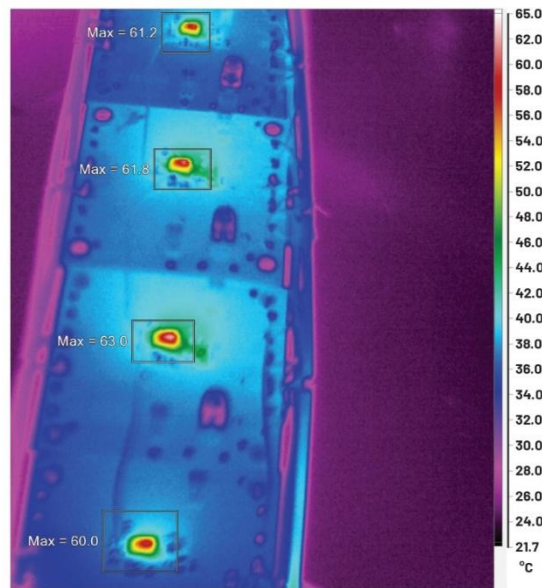


Fig. 5. Thermal image of a four-phase interleaving the LTM4732 demo boards at 1-MHz f_{sw} , 12-V V_{IN} , and 1-V V_{OUT} .

Fig. 6 shows the output voltage response of the four-phase configuration for an 8-A to 16-A load step. The converter maintains controlled voltage deviation and stable recovery during the large load transition. The output settles quickly without sustained oscillation, indicating adequate loop stability and effective current distribution across phases.

The measured voltage deviation, when normalized to the applied load step, demonstrates efficient current delivery and a reduced effective output impedance inherent to the multiphase architecture. The distributed current contribution of each phase minimizes instantaneous voltage droop and supports fast transient recovery under high dynamic loading conditions.

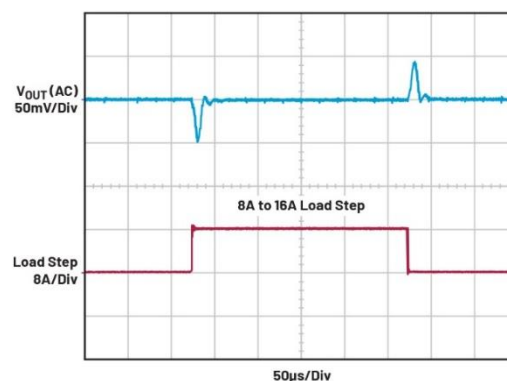


Fig. 6. Load step transient waveforms for four-phase operation.

Fig. 7 shows the measured control loop gain and phase response of the four-phase configuration under nominal operating conditions. The loop exhibits a well-defined single crossover frequency with adequate phase margin, indicating stable operation across the frequency range.

The measured crossover frequency is approximately 66 kHz, with a phase margin of 53°, providing a balance between transient response and stability. No low-frequency instability or excessive peaking is observed, and the loop gain rolls off smoothly beyond crossover, consistent with expected current-mode control behavior.

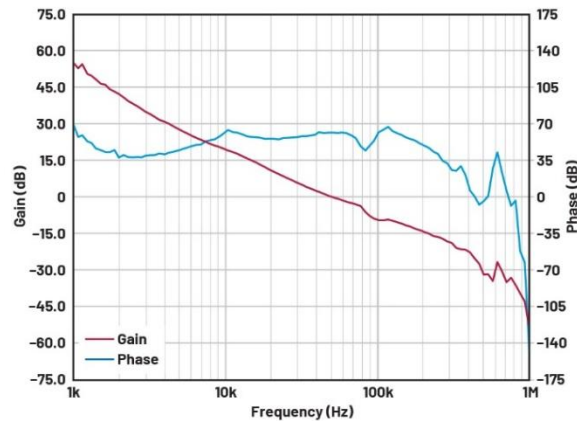


Fig. 7. Bode plot of four-phase LTM4732.

Troubleshooting And Tips

To avoid errors in operation, or to fix those that occur check the following:

- Verify all shared pins (V_{IN} , V_{OUT} , V_{OSNS} , COMP) are properly connected across modules.
- Confirm the correct phase locking by observing CLKOUT/SYNC waveforms on an oscilloscope.
- If phase locking fails, check the RT resistor values and ensure the subordinate's frequency is set lower than the main modules.
- Monitor output voltage and current sharing during operation to detect any imbalance.
- Use thermal imaging to identify hot spots and validate even heat distribution.

Conclusion

By following the design considerations and best practices outlined in this article, engineers can confidently implement the LTM4732 in demanding systems, optimizing both performance and reliability. As power density and noise requirements continue to tighten, multiphase solutions such as this provide a flexible, future-ready approach for next-generation electronics.

Reference

LTM4732 Ultralow Noise Silent Switcher 3 μ Module Regulator product [page](#).

About The Authors



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