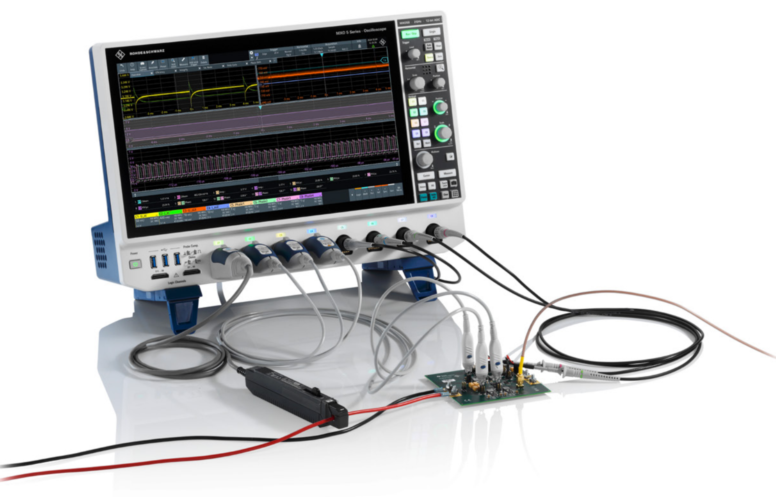
ANALYZING POWER DESIGNS FOR HIGH-SPEED SoCs WITH MULTIPHASE BUCK CONVERTERS

More functions, greater processing power and growing data rates make high-speed system-on-chips (SoCs) power designs challenging. The increasing number of power rails that supply the various function blocks of modern CPUs, GPUs, FPGAs, ASICs and such require precise sequencing during power-up and power-down. Supply voltage levels are also lowered to reduce power dissipation inside the SoC. Power integrity requirements are stricter and more supply current is needed on power rails. Multiphase buck converters continue to grow more popular for high-current power rails. The converters have many benefits, but designers also face challenges when it comes to power design and validation testing.



Power integrity analysis of a multiphase buck converter design with an MXO 58 8-channel oscilloscope (courtesy Texas Instruments)

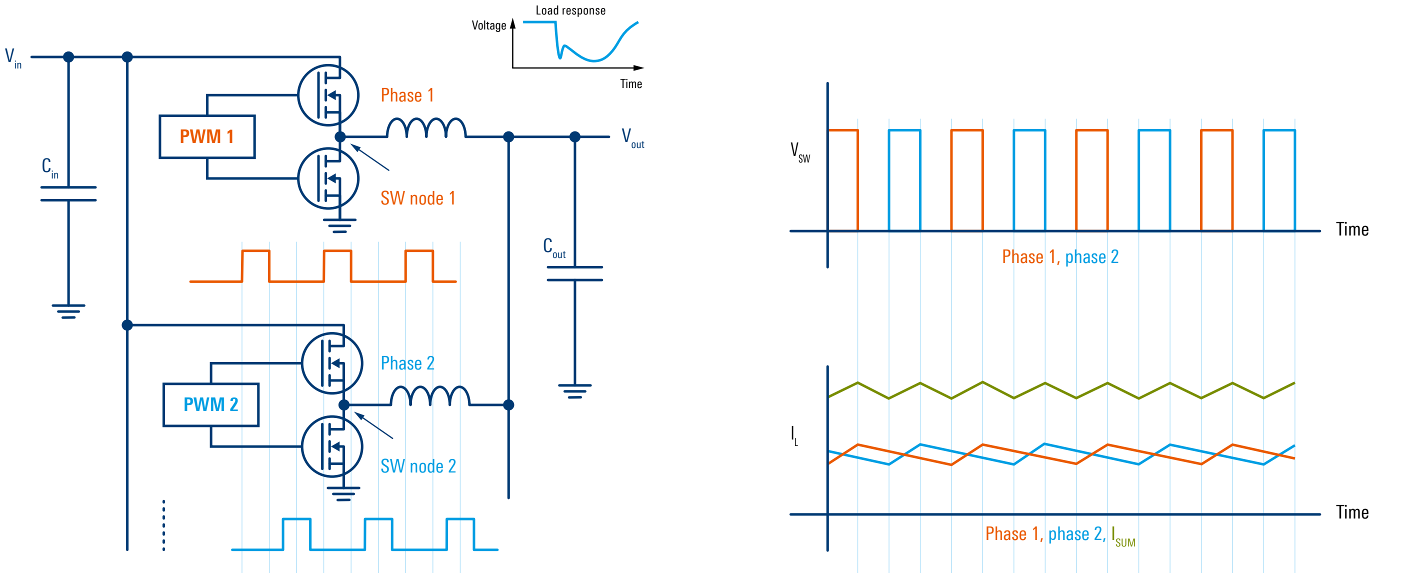
Your task

Each phase of a multiphase buck converter (interleaved converter) has at least one set of switching transistors and one inductor. To benefit from the multiphase properties, the on-times for the phases are shifted against each other. In high-load steady-state operation, all stages should be active and equally shifted against each other with the supply current balanced between stages. As a result, the inductor currents are also phase shifted to minimize ripple in both the supply current and the supply voltage. At high current levels, conduction losses dominate. So, multiphase buck converters have a superior efficiency and a lower heat dissipation than single converters, because the total current is distributed over multiple stages rather than a single stage.

Controller based multiphase buck converters have even greater efficiency since they can dynamically activate stages during high-load periods and remove stages during low-load periods.

Application Card | Version 01.00

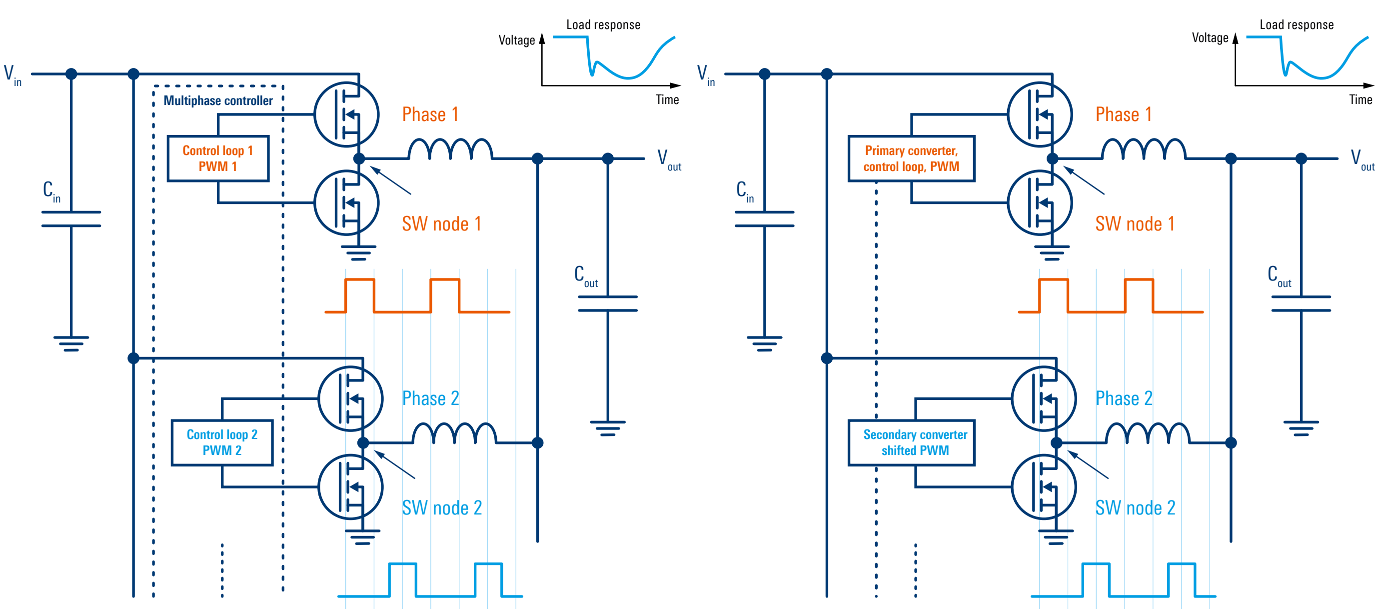
Schematic view of a multiphase buck converter and corresponding voltages and currents in a steady-state operation with two active phases



Multiphase buck converters also have superb response to load steps. Since on-times for the phases are shifted against each other, a multiphase buck converter can quickly react to a load step by adjusting the pulse width modulation (PWM) signal for the phase immediately following the load step.

In stacked designs, the primary controller provides the PWM signal for all phases. The design keeps a predefined phase shift between stages. Controller based multiphase designs can dynamically phase-align or activate/deactivate PWM signals for the corresponding stages to further minimize undershoots and overshoots from these load transients.

Schematic view of a multiphase buck converter with dedicated multiphase controller for maximum flexibility (left) and in stacked topology with primary and secondary converters (right).



Even though they are a powerful tool for improving performance and efficiency of high-speed SoC power design, multiphase buck converters can make validation and debugging tests more challenging when analyzing phase management under various static load conditions or under dynamic load step scenarios.

Application

Typical power design measurements with multiphase buck converters include:

- **Efficiency measurements**
  The system performs efficiency measurements of the multiphase buck converter over different loads and across typical dynamic load scenarios.
- **Power integrity analysis of supply voltage for high-speed SoCs**
  Measurements under various static load conditions as well as under dynamic load step scenarios ensure power rail voltage complies with the required noise, ripple, undershoot and overshoot tolerance. The measurements typically take place in the time and frequency domains.
- **Phase analysis of the stages inside the multiphase buck converter**
  Measurements are done in static load conditions and under defined load step scenarios to verify that the multiphase buck converter stages react to the load steps with a low latency and to verify the overall phase management across all stages.

Power integrity analysis in time and frequency domain, showing the 2.24 MHz switching frequency and its harmonics

Phase alignment and PWM track in a dynamic load step scenario, continuously turning on/off a 160 A load. Waveform and PWM track show an immediate reaction of the phases on the load steps.

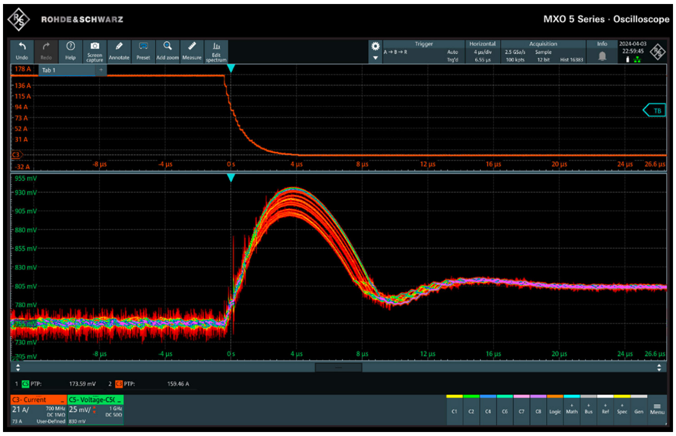
Rohde & Schwarz solution

The MXO 58 series oscilloscope provides a total of 8 analog channels and bandwidths up to 2 GHz (interleaved mode). The R&S®MXO5-B1 option lets 16 digital channels be added without sacrificing any of the eight analog channels. Thanks to built-in hardware-acceleration, the MXO 58 has an unrivaled speed and acquisition rate of up to 4.5 million waveforms/s and an FFT rate of up to 45 000 FFTs/s.

The instrument has an adjustable offset of up to 2 V (at 50 Ω) or up to 5 V (at 1 MΩ), even when set to the highest sensitivity of 0.5 mV/div. Together with a 12 bit resolution (up to 18 bit in HD mode) this provides maximum accuracy for measuring small disturbances on a DC power rail.

The MXO 5 comes standard with a powerful and versatile digital trigger system, with everything from a basic edge trigger via A/B/R sequence trigger to powerful zone triggers. Specific events can be captured by triggering on a combination of user-defined zones from different signal sources (acquired waveforms, math waveforms or spectrum views) with the zone trigger.

As with the MXO 5C, the instrument is also available without display in a compact, 2 HU form factor for remote control of the unit in automated test applications.



Measurement of a voltage overshoot on a 160 A load step with the A/B/R sequence trigger in MXO 58. The overshoot varies, depending on the position of the load transient inside the switching cycle of the multiphase buck converter (courtesy Signal Edge Solutions)

Perturbations on power rails are best measured with a dedicated power rail probe such as the R&S®RT-ZPR. Since it is a 1:1 probe, it has the sensitivity needed for this measurement. The probe comes with a built-in DC meter to easily measure power rail DC voltage and automatically subtract it in the offset circuitry. With this, the optimum sensitivity can be used in MXO 5 to accurately measure disturbances on a power rail, while still showing the actual DC values for the power rail voltage. Measurement errors stemming from ground loops in the test setup for power designs with high supply current are possible. Combining R&S®RT-ZPR with the Picotest J2115A, coaxial isolator significantly reduces these ground loop errors.

R&S®RT-ZPR20 power rail probe with Picotest J2115A coaxial isolator (courtesy Signal Edge Solutions)

Ground loop effects, caused by the high current levels in the various stages of the multiphase buck converters also need to be taken into consideration when measuring the switch node voltage. Differential probes such as the R&S®RT-ZD eliminate these effects and are ideal for such measurements.

R&S®RT-ZCxx current probes and Rogowski coils can be used to measure current and calculate the instantaneous power in power efficiency measurements.

Summary

The MXO 5 and MXO 5C series oscilloscopes are ideal for analyzing power integrity in high-speed SoC power designs. Up to 8 analog and 16 digital channels as well as a wide range of probes help the instruments accurately measure noise, ripple, undershoots and overshoots with excellent sensitivity. The unrivaled measurement speed and the powerful trigger system efficiently detect power rail disturbances in the time and frequency domains to help analyze PWM signals across all stages of a multiphase buck converter.

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