Application Report
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Non-isolated point-of-load solutions for VR13.HC in rack server and data center applications

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ABSTRACT

Data centers are crucial for business continuity and reliable communications. Texas Instruments (TI) provides performance power management solutions, enabling high availability and efficiency when powering processors for data centers and rack servers. Advanced processors and platforms, such as the Intel® VR13.HC, need point-of-load solutions for memory, low-power CPU rails, and 3.3 V and 5 V rail requirements from a 12 V input bus. This document intends to highlight DC/DC converters and describe their features addressing performance processors power requirements. For specific information about Intel processors and their power requirements, log on to the Intel Resource and Design Center. Contact TI for information about multiphase controllers and power stages designed specifically for the VR13.HC platform.

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Trademarks

PMBus, D-CAP3, D-CAPx are trademarks of others.

1 Suggested VR13.HC DC/DC Converters

Table 1 highlights the latest point-of-load DC/DC converters with integrated FETs that are applicable to VR13.HC applications; however, they are designed to accommodate the requirements for a wide range of markets. These devices are designed to achieve fast transient response, high efficiency, good thermal performance, and high output voltage accuracy. Several devices feature PMBus with adaptive voltage scaling and margining. Devices integrating PMBus with telemetry report voltage, current, and temperature information to a host. Products with similar superscripts are pin-compatible.

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Table 1. Suggested VR13.HC Point-of-Load Converters

I_{OUT} RANGE	DEVICE	PMBus	PMBus WITH TELEMETRY
DC/DC CONVERTERS WITH INTEGRATED MOSFETS			
≤ 2 A	TPS62147		
2 A – 4 A	TPS54424*		
4 A – 8 A	TPS54824* TPS53513#	TPS53915#	
8 A – 12 A	TPS53515#	TPS53915#	TPS544B20
12 A – 15 A	TPS548A20#	TPS549A20#	TPS546D24
15 A – 25 A	TPS543B20%	TPS549B22+	TPS546D24
25 A – 40 A	TPS543C20A%	TPS549D22+	TPS546D24
DDR MEMORY ACTIVE BUS TERMINATION			
≤ 2 A	TPS51200		
2 A – 6 A	TPS53317A		
Low Drop Out Regulator			
1.5 A	TPS74801		

2 Voltage Regulation Accuracy

As the semiconductor process technology advances, processors require tighter voltage accuracy and lower operating voltages. The processor datasheet specifies the voltage tolerance as either a percentage or as a value in mV, which includes DC, AC and ripple variations over the entire operating temperature range. Designers also consider the tolerance of the resistor divider used by the DC/DC converter, the routing and trace losses of the circuit board, and the variations of the application, like the input voltage variations, temperature swings, and fast changes in the load.

Check the feedback voltage accuracy of the DC/DC converter in the datasheet rather than the front page. Table 2 shows the regulated feedback voltage specification of the TPS54424, which is a 4.5 V to 17 V, 4 A converter, and shows that the reference accuracy is +/- 50 mV or ±0.83% over the input voltage and temperature variations. The total output voltage accuracy is improved by choosing tighter tolerance resistors. If more headroom is needed, designers can choose 0.1% or 0.5% resistors, even though they may cost a little bit more. The additional headroom allows the total +/-3% or +/-5% output voltage variation to be met with less bulk and bypass capacitance. (1)

Table 2. Feedback Voltage Regulation of the TPS54424

PARAMETER	TEST CONDITION	MINIMUM.	TYP	MAXIMUM.	UNIT
Regulated FB Voltage	TJ = -40°C to 150°C, VIN = 4.5 V to 17 V	595	600	605	mV
	TJ = 25°C, VIN = 4.5 V to 17 V	596	600	604	mV

Layout constraints, connectors, and board density requirements often affect the total output voltage accuracy. A remote sense feature of a DC/DC converter compensates for voltage drops from long trace lines to accommodate processors needing high accuracy output voltage. This feature is especially useful when routing higher currents when the voltage drop can be a large portion of the overall DC error. Figure 1 shows the TPS543B20 using the remote sense feature with voltage feedback resistors used to program the output voltage. Figure 2 shows the TPS543B20 using the remote sense feature without voltage feedback resistors when the VSEL pin selects the reference voltage. The RSP and RSN pins are extremely high-impedance input terminals of a true differential remote sense amplifier.

(1) Power Tip #18: Your regulator's output-voltage accuracy may not be as bad as you think.

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Figure 1. Remote Sense Without Feedback Resistors

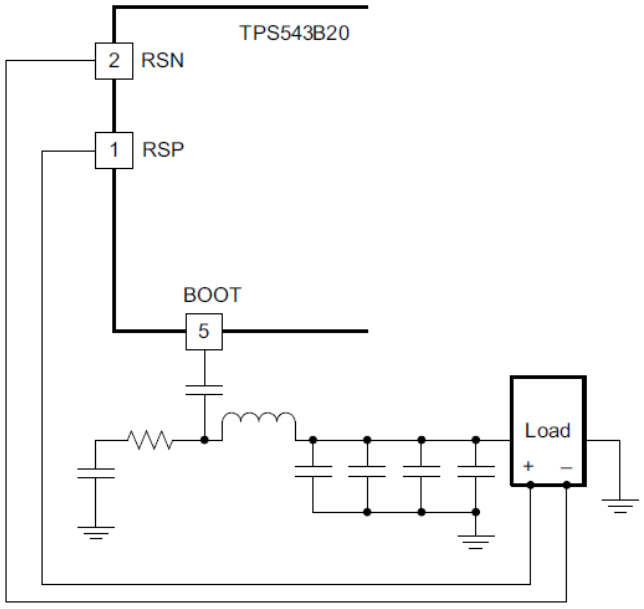
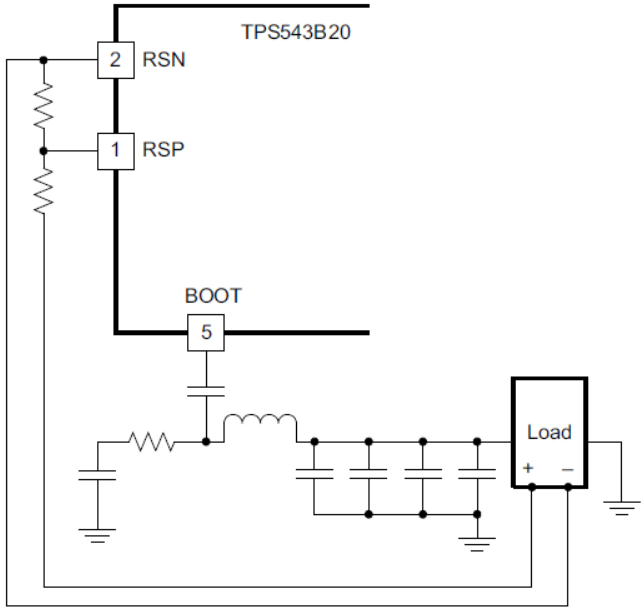


Figure 2. Remote Sense With Feedback Resistors



3 Load Transient Response

Since the load profile can change dramatically in an enterprise rack server, it is important to consider AC transient performance. Choosing a DC/DC converter with a fast transient response using non-linear control techniques, such as constant on-time or D-CAP3, allow a fast transient response with minimal output capacitance. A typical D-CAP3 converter design has three primary considerations for deciding the value of the output capacitance: transient (which includes load step and slew rate of the load step), output ripple, and stability. In applications where the load transient is stringent, the output capacitance is predominantly driven by the transient requirement. Today, a tight ripple requirement is becoming important in some high-end, high-performance application-specific integrated circuit (ASIC) and field-programmable gate array (FPGA) designs. The LC output power stage must be designed to meet the ripple criteria. For a D-CAP3-based design, there is a minimum capacitance requirement in terms of small signal stability. This requirement prevents subharmonic, multiple-pulsing behavior in all D-CAP modulators. Figure 3 shows how D-CAP3 control mode works in a load transient case. The *Calculating output capacitance to meet transient and ripple requirements of an integrated POL converter design based on D-CAPx modulators application report* shows how to design the output filter for a 1 V output to accommodate a +/-10 mV ripple requirement and a +/-30 mV transient voltage deviation using the D-CAP3 control mode. (2)

(2) Calculating Output Capacitance to Meet Transient and Ripple Requirements

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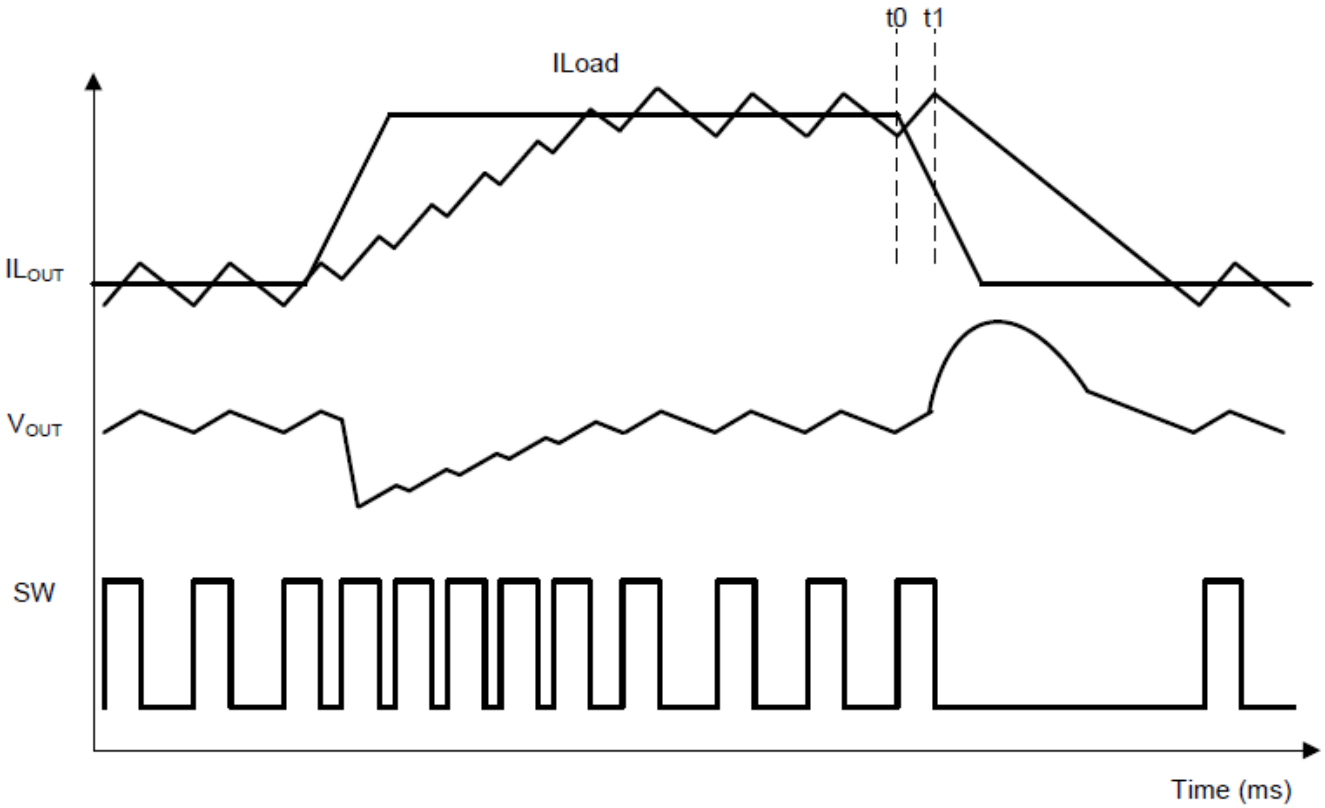
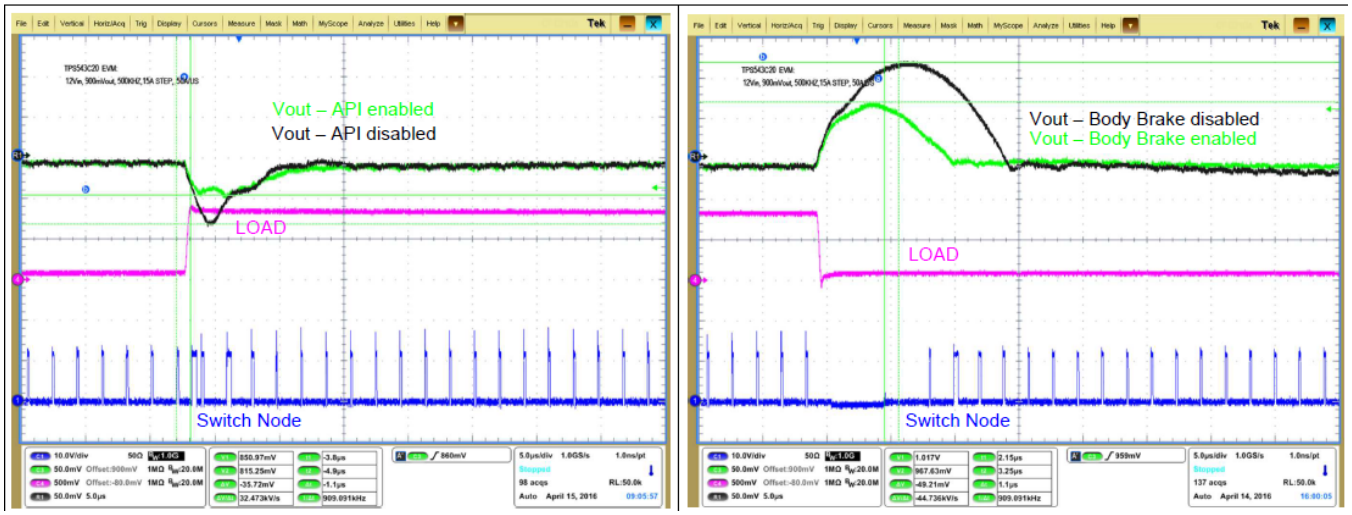
Figure 3. Load Transient Response of a D-CAP3 Converter



The TPS543C20A converter features a new control mode called the Advanced Current Mode (ACM), which is an internally compensated emulated peak-current-mode control, with a clock synchronizable, fixed-frequency modulator. The internal integrator and directly amplifying ramp tracking loop eliminates the need for external compensation over a wide range of frequencies. The TPS543C20A also features Asynchronous Pulse Injection (API) and body braking to improve transient performance by significantly reducing undershoot and overshoot, respectively, reducing the external capacitance requirement. When the API and body diode braking are activated, ACM delivers a similar transient performance as D-CAP3. Figure 4 shows examples of undershoot and overshoot reduction with API and body braking. (3)

Figure 4. Asynchronous Pulse Injection and Body Braking



(3) Comparing internally-compensated advanced current mode (ACM) with D-CAP3™ control

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4 High Efficiency and Thermal Performance

Rack servers are built on circuit boards with many PCB layers, depending on the form factor constraints. Since the rack server is designed to be used in tight spaces, be careful when selecting the DC/DC converters to ensure the server operates in thermally challenging environments with the available airflow. The ambient temperature inside a rack server is typically between 60°C and 70°C since forced airflow is usually available. Higher circuit board temperatures translate to lower reliability, and higher current DC/DC converters contribute to the overall thermal budget. Figure 5 shows the safe operating curve and Figure 6 shows the power loss plot of TPS543C20A. The TPS543C20A DC/DC converter delivers 40 A and 1 V output with an ambient temperature of 75°C, without airflow. At 25 A and 1 V output, the entire solution dissipates less than 3 W, which translates to around 90% efficiency when switching at 500 kHz. The TPS543C20A measured junction-to-ambient thermal resistance is 12°C/W based on a 6-layer, 2-oz Cu per layer and a 2.75 inch by 3 inch board size, which demonstrates low thermal resistance. However, many thermal metrics exist for semiconductor and IC packages, which range from RθJA to ψJT. Often, designers misapply these thermal metrics when trying to estimate the junction temperatures in their systems. Ultimately, thermal performance depends on the circuit-board layout and using standard JEDEC-referenced thermal numbers. (4)

Figure 5. SOA Curve for TPS543C20A

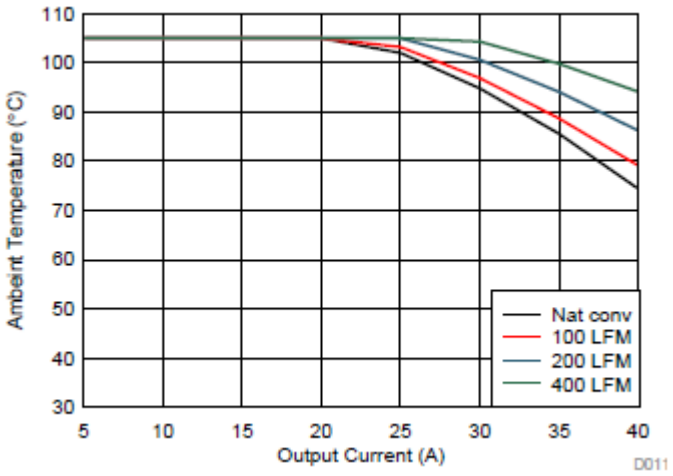
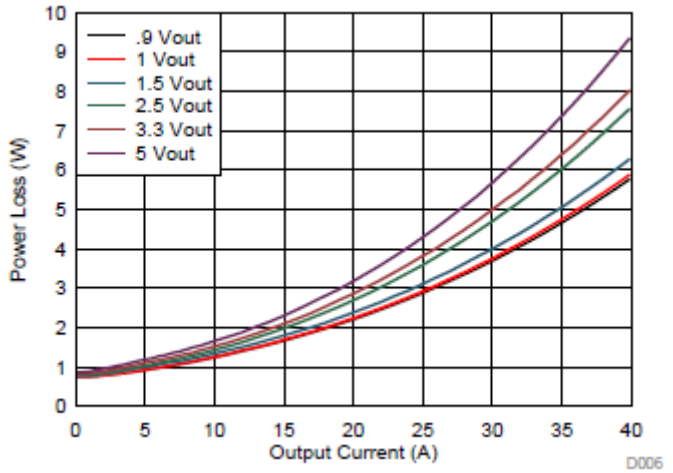


Figure 6. Power Loss Curves for TPS543C20A



(4) Understanding the thermal-resistance specification of DC/DC converters with integrated power MOSFETs

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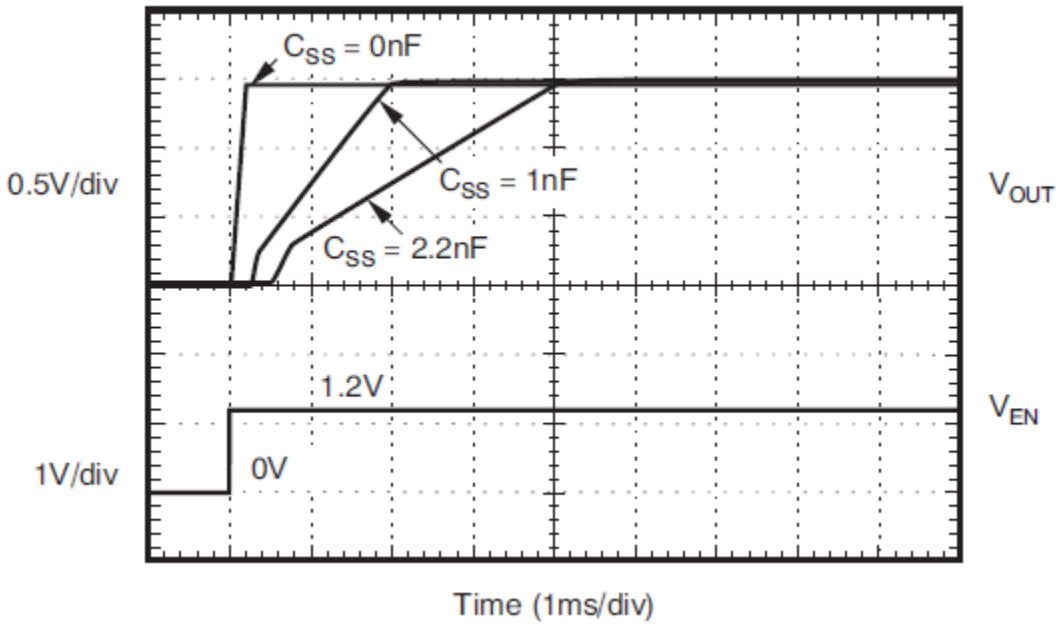
5 Linear Regulator with Adjustable Soft-Start

For low current rails, a linear regulator with a user-programmable soft-start minimizes stress on the input power source by reducing the capacitive inrush current on start-up, especially from highly capacitive loads or with processors requiring many bypass capacitors. The TPS74801 adjustable linear regulator provides a monotonic (non-negative slope) soft-start that is well-suited for powering many different types of processors. Figure 7 illustrates the start-up waveform showing the start-up times varying over several soft start capacitor values.

Figure 7. TPS74801 Start-up Waveforms



6 Conclusion

Performance processors, such as the VR13.HC platform in data centers, need DC/DC converters that offer improved output voltage accuracy, fast transient response, reduced external component count, high efficiency and excellent thermal performance. TI offers high performance point-of-load solutions to address these requirements.

7 Additional Resources

- *How to meet DC voltage accuracy and AC load transient specification?*, TI training video, https://training.ti.com/how-meet-fpgas-dc-voltage-accuracy-and-ac-load-transient-specification
- Texas Instruments, *Accuracy-enhanced ramp-generation design for D-CAP3 modulation application report*"
- Texas Instruments, *Internally compensated advanced current mode white paper*
- Texas Instruments, *Control mode quick reference guide*
- *TI Rack Server page*, http://www.ti.com/solution/server

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