Application Note

Non-Isolated DC/DC Designs for Raptor Lake in Notebook Computing Applications

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ABSTRACT

Notebook, desktop, and industrial computers serve to improve business continuity, enhance consumer entertainment, and streamline industrial process control. Texas Instruments provides performance power-management designs for these applications to improve performance and extend battery life. Advanced processors and platforms, such as the Intel® Raptor Lake micro-architecture, need point-of-load (POL) designs for memory, low-power CPU rails, and 3.3 V and 5 V rail requirements from an array of rechargeable batteries, or a 12 V input bus. This document intends to highlight DC/DC converters and describe their features addressing general Raptor Lake 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 Intel Mobile Voltage Positioning (IMVP) requirements.

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1 Suggested Point-of-Load Designs

Table 1-1 highlights the latest POL DC/DC converters with integrated MOSFETs and controllers suitable for Raptor Lake applications. The suggested devices are selected to accommodate different input voltage and control mode requirements over a wide range of output current. The featured devices in the left column accommodate a maximum input voltage of 22 V or greater, and are designed to achieve fast load-transient response with an adaptive on-time control mode, high light and full-load efficiency, and low quiescent current.

Several devices include an integrated programmable voltage identification (VID) supporting the processor's adaptive voltage requirements. The alternate devices in the right column employ fixed-frequency current-mode control with frequency synchronization useful in noise-sensitive industrial applications, and operate up to a 17 V input. If VID is required with alternative devices, consider the LM10011 VID voltage programmer in addition to the converter's resistor divider network.

Table 1-1. Suggested DC/DC Controllers and Converters for Raptor Lake

Featured P/N(1)	Rail	Current Capability	Type	Note	Alternate P/N(2)
TPS51285A	5V	≤20A + 100mA LDO each rail	Dual Controller & 2 LDOs	System Power	TPS51220A
	3.3V				
TPS51386	5V	≤8A + 100mA LDO	Converter & LDO	System Power	TPS568230
TPS51383	3.3V				
TPS51215A	V_{CCIN_AUX}	≤32A	Controller	I/O power, 2-bit VID (0V support)	-
TPS566335	1.8V	≤6A	Converter		TPS566231
TPS51372	Optional Bypass	≤6.5A	Converter	2-bit VID	-
General Purpose DC/DC Converters					
TPS51367	Various	12A	Converter	General	TPS56C231
TPS51397A	Various	10A	Converter	General	TPS54A24
TPS51386	Various	8A	Converter	General	TPS568230
TPS566335	Various	6A	Converter	General	TPS566231
TPS62933	Various	3A	Converter	General	TPS62903
DDR Memory Power Designs					
TPS51486A	V_{DDQ}	≤8A	Multi-Channel Converter	DDR4 Memory	TPS65295
	V_{PP}	≤1A			
	V_{TT}	±1A			
	V_{TT_REF}	10mA			
TPS51487XA	V_{DD1}	≤8A	Multi-Channel Converter	LPDDR4/X Memory	TPS65296
	V_{DD2}	≤1A			
	V_{DDQ_TX}	≤1.5A			
TPS51488	$V_{DD2H/L}$	≤10A	Converter	LPDDR5 Memory	Consider general device for more/less current
	V_{DD1}	≤2A	Converter		TPS543320
	V_{DDQ}	≤2A	Converter		TPS543320

(1) Some featured 24-V devices require Mysecure access to download the data sheet. Click the device link to request access. Users will require their my.ti.com account information.
(2) Alternate converters operate up to 17 V input with a fixed-frequency control mode

2 Light Load Efficiency and Low Quiescent Current with TPS51383

The POL regulators generating low voltages from an array of batteries must employ an energy-saving pulse-skipping technique now referred to as Eco-Mode. The inductor current in a synchronous-buck converter is a triangle wave. As the output current decreases from a heavy-load condition, the inductor current is reduced and the rippled valley of the triangle wave eventually touches the zero level at the boundary between continuous conduction-mode (CCM) and discontinuous conduction node (DCM).

With Eco-Mode, the rectifying MOSFET is turned off when the converter detects zero current in the inductor. As the load current further decreases, the on-time is held nearly constant so that the off-time is extended, and the switching frequency is reduced to maintain regulation. As a result, the power MOSFETs and inductor are idle for longer time periods and conduction losses are greatly reduced. DC/DC converters and controllers with low quiescent current will have improved light-load efficiency performance and extended battery run-time, since less power is dissipated within the IC. The TPS51383 features Ultra Low Quiescent current (ULQ) of 80-uA for longer battery life in system stand-by mode.

Figure 2-1 shows 80% efficiency with 9-V input and 3.3-V output at 1-mA, illustrating the combined effects of Eco-Mode and ULQ.

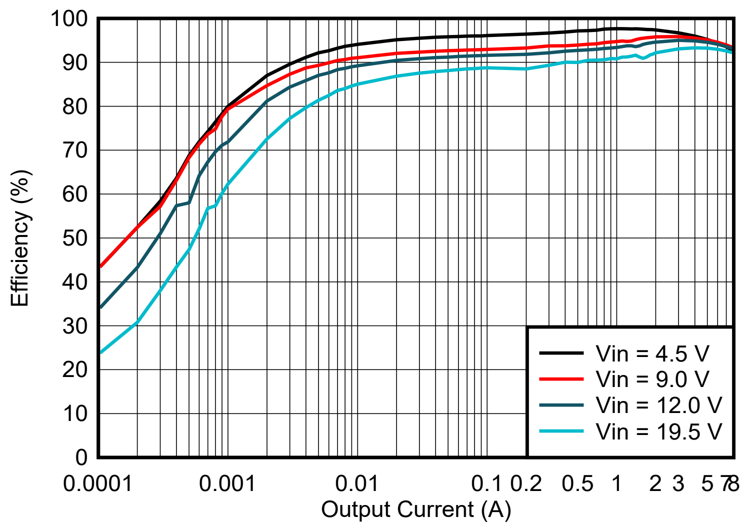

Figure 2-1. TPS51383 Efficiency Plot

3 Voltage Identification Capability with TPS51215A

The TPS51215A supports a 2-bit Voltage Identification Capability (VID) and Low Power Mode (LPM) to dynamically change the output voltage to satisfy Intel's VCCIN_AUX rail. A fixed 0-V output voltage and up to three voltage levels can be programmed externally with a voltage divider circuit. The device can also be configured to provide a 1-bit VID output voltage. Please see the *TPS51215A Single Phase, D-CAP2™ Controller with 2-Bit VID Control and Low Power Mode* data sheet for more information. The *Power solution for Alder Lake and Raptor Lake VCCIN_AUX rail in PC applications reference design* describes how to use this device to meet Intel's VCCIN_AUX rail requirements in more detail.

4 Fast Load Transient Response with D-CAP3 and D-CAP2 Control

Since the load profile can change dramatically in Notebook and Desktop PC applications, 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™, allows a fast transient response with minimal output capacitance. A converter using D-CAP3 control mode 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. 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 the modulator.

Figure 4-1 shows the transient performance of the 8-A TPS51383 with a 3.3-V output, less than 300mV overshoot, and less than a 30µs recovery with output capacitance of 4x22 µF. The 0.8-A to 7.2-A load step has a slew rate of 2.5-A/µs.

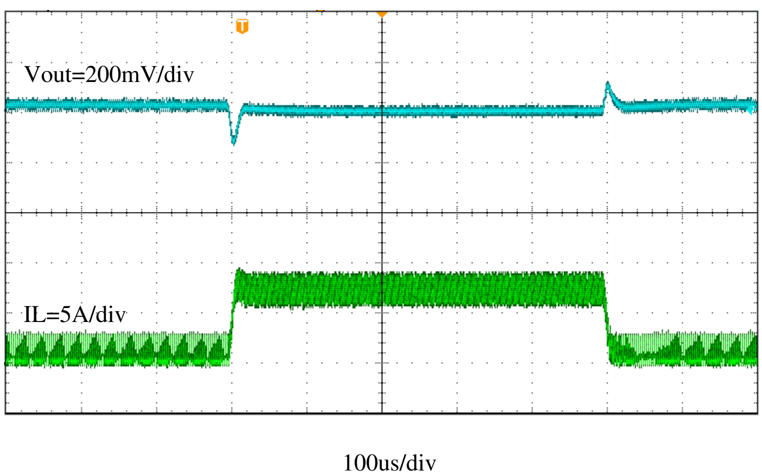

Figure 4-1. TPS51383 Transient Waveform

The TPS51215A supplying V_{CCIN_AUX} features adaptive on-time D-CAP2™ control allowing ceramic output capacitors and achieves a fast load transient response shown in Figure 4-2 under the noted conditions below the waveform. The over-voltage and under-voltage test results also meet the target design specification, and the results are shown in Table 4-1 under the same conditions as the TPS51215A load transient waveform. The TPS51215A waveform conditions are V_{IN}=12.6V, slew rate=12A/µs, F_{SW} =600kΩ, L=0.22µH, and C_{OUT}=220µF + 22*12µF.

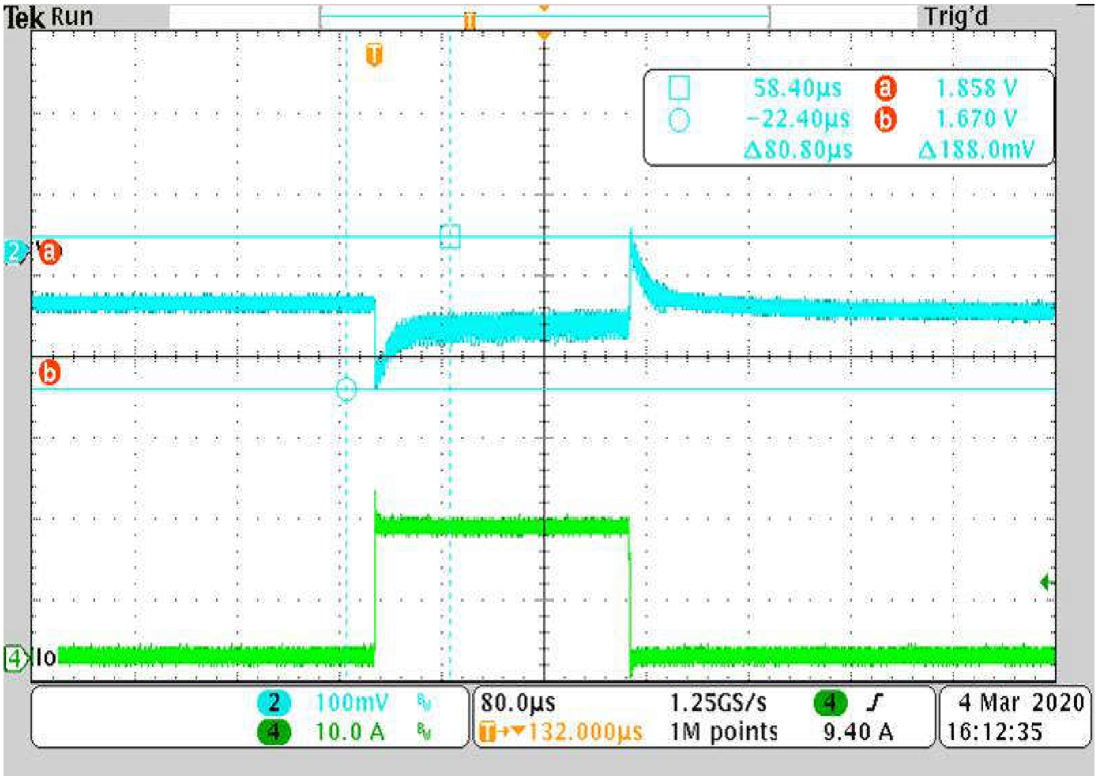

Figure 4-2. TPS51215A Load Transient Waveform

Table 4-1. TPS51215A Load Transient Test Results

Voltage Rail	Type	Load Transient	Validation Result (V)	Target (V)
0.8 V	Undershoot	0 A to 16 A	1.67	1.62
	Overshoot	16 A to 0 A	1.858	1.89
1.8 V	Undershoot	17 A to 29 A	1.678	1.62
	Overshoot	29 A to 17 A	1.882	1.89

5 Small IC Packaging

Integrated circuit packaging technology must keep pace with semiconductor wafer fabrication as process technology advances. TI released flip-chip on leadframe packaging that reduce package footprint, power loss, and parasitic effects. Traditional bond wires are replaced with copper posts attached directly to the leadframe which shortens current path from the IC to the lead frame, which allows a larger die in the small package cavity, reduced package resistance, and reduced parasitic package inductance loops. Consider the 8-A TPS51383, housed in a small 2x3mm QFN package.

Figure 5-1 shows ample pins for power conversion and I/O features while maintaining a 0.5mm pin pitch, allowing simplified circuit board manufacturing.

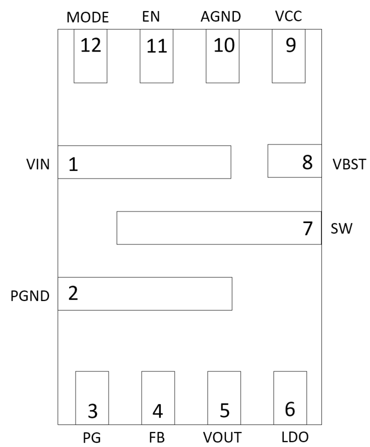

Figure 5-1. TPS51383 in 2x3mm QFN Package

6 Summary

Performance processors, such as the Raptor Lake SoC for notebook and industrial PCs, need DC/DC converters that offer fast transient response, small packaging, low quiescent current, and high light and full-load efficiency. TI offers high performance point-of-load designs to address these requirements while lowering the total system cost.

7 References

- Texas Instruments, *LM10011 VID Programmer* data sheet.
- Texas Instruments, *Accuracy-Enhanced Ramp-Generation Design for D-CAP3 Modulation* application note.
- Texas Instruments, *Power tips: Iq (quiescent current) and Light Load Efficiency* training video.
- Texas Instruments, *HotRod QFN Package PCB Attachment* application note.
- Texas Instruments, *Power Solution for Alder Lake and Raptor Lake VCCIN_AUX rail in PC Reference Design*.

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