Application Report
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Non-Isolated Point-of-Load Solutions for Elkhart Lake in Industrial PC Applications

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ABSTRACT

Industrial computers serve to improve business continuity and streamline industrial process control. Advanced processors and platforms, such as the Intel® Elkhart Lake micro-achitecture, need point-of-load (POL) solutions 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 from Texas Instruments that provide performance power management solutions to extend battery life while addressing Elkhart Lake platform 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 Elkhart Lake Point-of-Load Solutions

Table 1 highlights the latest POL DC/DC converters with integrated MOSFETs and controllers suitable for Elkhart 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-hand column accommodate a maximum input voltage of 22V 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-hand column employ a fixed-frequency control mode with frequency synchronization useful in noise-sensitive industrial applications. If VID is required with alternative devices, consider the LM10011 VID voltage programmer in addition to the converter's resistor divider network.

Table 1. Suggested DC/DC Controllers and Converters for Elkhart Lake

Featured Device[1]	Type	Current	Rail	Note	Alternate Device[2]
TPS51285A	Dual Controller + LDOs	≤20A & 100mA LDO	V5	System Power	TPS51220A
		≤20A & 100mA LDO	V3P3		
TPS51393	Converter + LDO	≤8A & 100mA LDO	V5	System power	TPS54824
TPS51395	Converter + LDO	≤8A & 100mA LDO	V3P3	System power	TPS54824
TPS51215A	Controller	≤35A	V_{CCIN_AUX}	I/O power, 2-bit VID (0V support)	-
TPS51371	Converter	≤ 6.5A	VCCIO, V1P05, V_{NN}	Optional bypass power, 2-bit VID	LM43600
General Purpose DC/DC Converters					
-	Converter	≤25A	Various	I/O	TPS543B20
TPS51367	Converter	≤12A	Various	I/O	TPS54A24
TPS51396A	Converter	≤8A	Various	I/O	TPS54824
TPS566335	Converter	≤6A	Various	I/O, V1P8, V_{PP}	TPS54824
TPS56339	Converter	≤3A	Various	I/O	TPS54424
TPS62175	Converter	≤0.5A	V1P2, various	I/O	LM43600
DDR Memory Power Solutions					
TPS51486	Multi-Rail PMIC	≤8A	V_{DDQ}	DDR4 Memory	TPS65295
		≤1A	V_{PP}		
		±1A	V_{TT}		
		10mA	V_{TT_REF}		
TPS51487X	Multi-Rail PMIC	≤8A	V_{DD1}	LPDDR4/X Memory	TPS65296
		≤1A	V_{DD2}		
		≤1.5A	V_{DDQ_TX}		
TPS51716	Multi-Rail Controller	≤20A	V_{DDQ}	DDR4 Memory	Consider I/O devices
		±2A	V_{TT}		
		10mA	V_{TT_REF}		
TPS51206	LDO	±2A	V_{TT}	DDR4 Memory	-
		10mA	V_{TT_REF}		

(1) Note: Some 24-V rated devices require Mysecure access to download the datasheet. Click on the device link to request access. Users will require their my.ti.com account information.

(2) Alternative devices support input voltages up to around 17-V and feature fixed-frequency current-mode control.

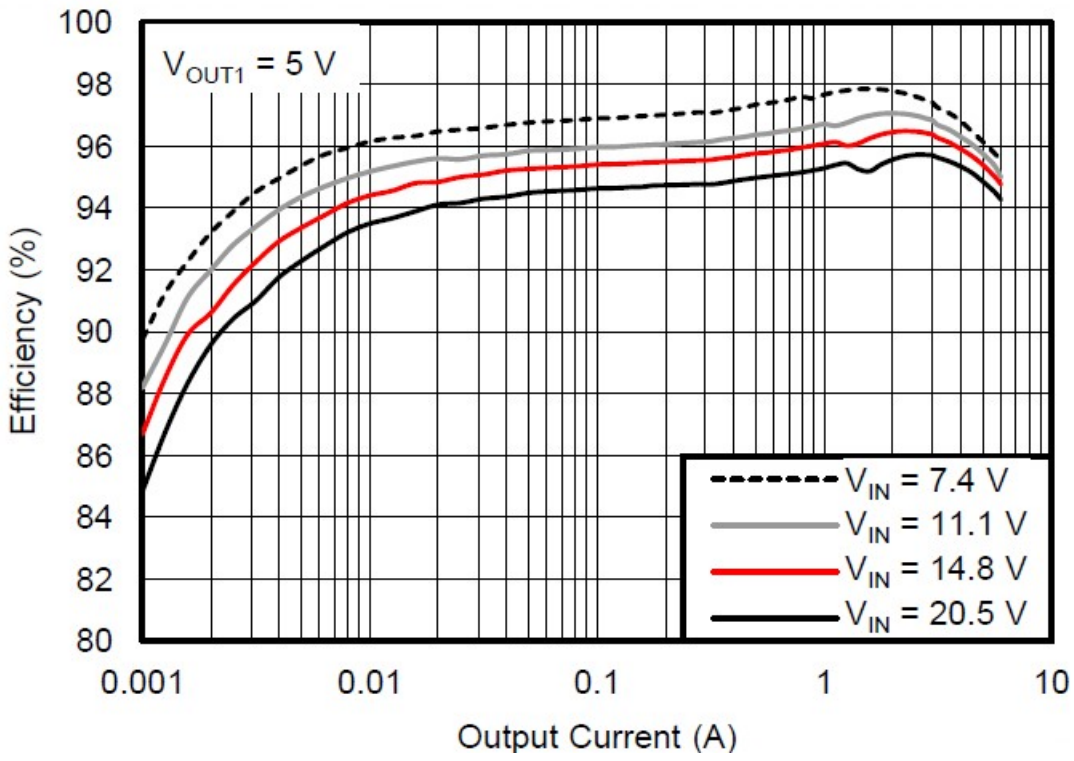
2 Light Load Efficiency and Low Quiescent Current

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 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. The point at which the DC/DC converter enters the light-load efficiency mode is shown in Equation 1.

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 TPS51285A features Ultra Low Quiescent current (ULQ) of 25-uA for longer battery life in system stand-by mode. Figure 1 shows 90% efficiency with 7.4-V input and 5-V output at 1-mA, illustrating the combined affects of Eco-Mode and ULQ.

$$IOUT(LL) = \frac{1}{2} \times L \times F = (VIN - VOUT) \times \frac{VOUT}{VIN} \quad (1)$$

Figure 1. TPS51285A Efficiency plot with Eco-Mode™ and ULQ™



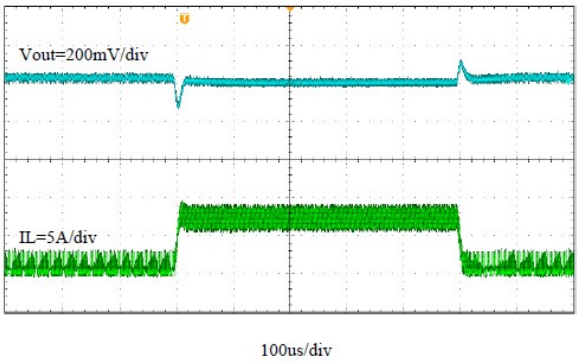
3 Voltage Identification (VID) with TPS51215A

The TPS51215A supports a 2-bit VID and Low Power Mode(LPM) to dynamically change the output voltage and satisfy Intel's IMVP8/9 applications for VCCIN_AUX, VCCIO_0, and VCCIO_1_2 rails. A fixed 0V output voltage and up to three voltage levels can be programmed externally by a voltage divider circuit. The device can also be configured to provide a 1-bit VID voltage. In the applications where fewer than four input voltage levels are needed, the remaining input voltage pins cannot be left floating. Please see the TPS51215A datasheet for more information.

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

Since the load profile can change dramatically in industrial 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 adaptive 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 2 shows the transient performance of the 8-A TPS51395 with a 5-V output, less than 100mV overshoot, and less than a 30µs recovery with output capacitance of 0.1 µF and 4x22 µF. The TPS51395 transient waveform conditions are 0.8-A to 7.2-A load step with 2.5A/µs slew rate.

Figure 2. TPS51395 Load Transient Waveform



The TPS51215A for the V_{CCIN_AUX} rail features adaptive on-time D-CAP2 control allowing ceramic output capacitors and acheives a fast load transient response shown in Figure 3 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 2 under the same conditions as the TPS51215A load transient waveform. The TPS51215A transient waveform conditions are V_{IN}=12.6V, Slew rate=12A/µs, F_{SW} =600kΩ, L=-.22µh, and C_{OUT}=220µF + 22*12µF.

Figure 3. TPS51215A Load Transient Waveform

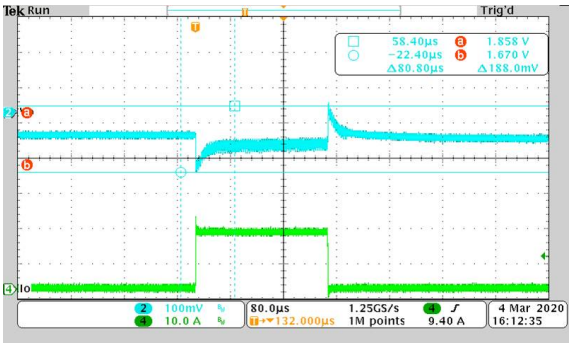


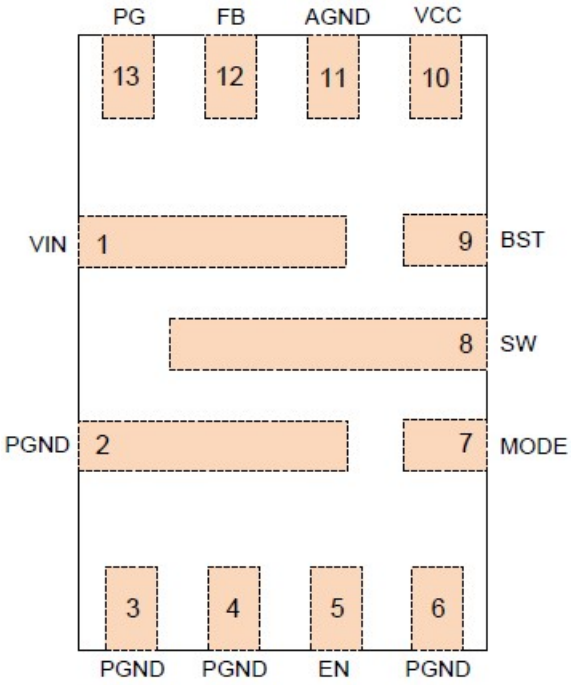
Table 2. TPS51215A Load Transient Test Results

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

5 Small IC Packaging

Integrated circuit packaging technology must keep pace with semiconductor wafer fabrication as process technology advances. TI has 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 6-A TPS566335, housed in a small 2x3mm QFN package. Figure 4 shows ample pins for power conversion and I/O features while maintaining a 0.5mm pin pitch, allowing simplified circuit board manufacturing.

Figure 4. TPS566335 2x3mm QFN package view



6 Conclusion

Performance processors, such as the Elkhart Lake platform in Inductrial 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 solutions 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
- Texas Instruments, Power tips: Iq (quiescent current) and light load efficiency
- Texas Instruments, HotRod QFN Package PCB Attachment

Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (May 2020) to A Revision	Page
• Changed TPS51393 to TPS51395	4
• Deleted 0.8 A to 7.2 A load step with s.4/Vµs slew rate	4
• Added cross-reference to TPS51215A Load Transient Waveform image	4
• Added The TPS51215A transient waveform conditions are V_{IN}=12.6V, Slew rate=12A/µs, F_{SW} =600kΩ, L=0.22µH, and C_{OUT}=220µF + 22*12µF.	4
• Added TPS51215A Load Transient Waveforms title	4

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