Innovative Power Solution Area Reduction for Server Applications with Intel® Enpirion® Power Solutions

Using an Intermediate Bus Converter in server applications results in dramatic space savings with little efficiency losses.

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Executive Summary

Server CPUs and the power components that power them are gradually becoming larger as they expand to meet increased data processing loads. Because the form factor of these servers is not changing, pressure is mounting on engineers to find the best solution options within the area available to them on the server motherboard. Intel has introduced a new intermediate bus converter (IBC), the Intel® Enpirion® EC2650QI device, to deliver board space savings and design flexibility for server applications. Using the two-stage solution to save board space allows designers to increase their investment in processing power, memory, graphics, and so on. This white paper outlines a case study in using the EC2650QI device with compatible Intel DC-DC buck converters on the low-current rails of a server reference design platform. Overall system efficiency and solution size are recalculated, and the difference in power loss is evaluated between the one and two-stage solutions.

In this example, there is minimal increase in power dissipation but significant board space savings when using the highly efficient EC2650QI device with Intel DC-DC step-down converters on the low-current rails of the example server reference design. This benefit is particularly important for designers operating in space-constrained systems.

When compared to a one-stage direct conversion solution, the two-stage system using the EC2650QI device:

- Is **64%** smaller in solution size (saving approx. **994 mm²** of board space)†
- Generates up to **2 W**† of additional power loss, an expected average increase of **0.5%** to **0.6%** in the overall server application (based on the average 2U rack mount server consuming 350 W to 400 W)[1]

Intel is heavily investing in meeting server power requirements and constraints in efficiency, cost, size, flexibility, and reliability.

Background

The global server market is predicted to grow largely due to the growth of cloud services and big data being adopted into hyperscale data centers. Businesses are also beginning to decentralize their networks and migrate their services to the cloud, reserving edge computing for time-sensitive data. The demand for rack optimized servers is expected to drive industry growth where the adoption of technologies such as artificial intelligence (AI), Internet of Things (IoT), and big data in end-user applications is accelerating.

As the enterprise server market grows, innovations in technology are expected to enhance the performance, speed, memory, and cost savings for high-performance computing. Core silicon components in these server racks have steadily increased in size to handle larger data processing loads, constraining available PCB board space. To meet these evolving requirements, Intel has developed a new 12 V bus converter, the EC2650QI device, for space-constrained server applications on low-current rails with minimal efficiency tradeoffs. Using Intel's high-power-density DC-DC step-down converters in conjunction with the EC2650QI device on low-current rails results in additional space savings.

Solution Overview

The EC2650QI is a 12V-to-6V IBC used for two-stage solutions. Using this two-stage approach with other Intel power products can reduce the total power solution size while having only a marginal impact on overall system power loss. This white paper will examine the size and efficiency benefits of replacing competitor components with the EC2650QI device and Intel buck converters on the low-current rails of a server reference design.

Intel PowerSoCs are fully integrated high switching frequency step-down DC-DC power modules with available output current ratings from 400 mA to 80 A+. The high level of integration makes them power dense and optimized for space-constrained systems. The PowerSoCs that are compatible with the EC2650QI device can be found in Table 1.

PART NUMBER	DESCRIPTION	V_{IN} Range (V)
EZ6301QI	Triple Output: 1 x 1.5 A switcher plus 2 x 300 mA low-dropout (LDO)	2.7 – 6.6 (Switcher) 1.6 – 5.5 (LDO)
EN5311QI	1 A PowerSoC	2.4 – 6.6
EN5335/36QI	3 A PowerSoC	2.4 – 6.6
EN6337QI	3 A PowerSoC compatible with EN6347QI device	2.5 – 6.6
EN6338QI	Ultra-small 3A PowerSoC	2.5 – 6.6
EN6340QI	4 A PowerSoC compatible with EN6363QI device	2.7 – 6.6
EN6347QI	4 A PowerSoC compatible with EN6337QI device	2.5 – 6.6
EN6363QI	Ultra-small 6A PowerSoC compatible with EN6340QI device	2.7 – 6.6
EN6362QI	6 A PowerSoC compatible with EN6382QI device	3.0 – 6.6
EN5364QI	6 A PowerSoC compatible with EN5394QI device	2.4 – 6.6
EN6382QI	8 A PowerSoC compatible with EN6362QI device	3.0 – 6.6
EN6360QI	8 A PowerSoC	2.5 – 6.6
EN5394QI	9 A PowerSoC compatible with EN5364QI device	2.4 – 6.6
EN63A0QI	12 A PowerSoC	2.5 – 6.6

Table 1. EC2650QI Device Compatible DC-DC Converters

Solution Architecture

The EC2650QI device features a total solution size of 150 mm² in a 5.5 x 5.5 x 0.9 mm QFN package with conversion efficiencies up to 94%[††]. Up to four bus converters can be paralleled for an operation of up to 144 W (36 W output each).

SPECIFICATIONS	FEATURES
V_{IN}: 8 – 13.2 V	Up to 94% efficiency[††]
V_{OUT}: V_{IN} /2	Only 0.9 mm height
6 A continuous output current	36 W output power per bus converter
150 mm² solution size	Parallel capable (up to four for 144 W total)

Table 2. EC2650QI Device Specifications and Features

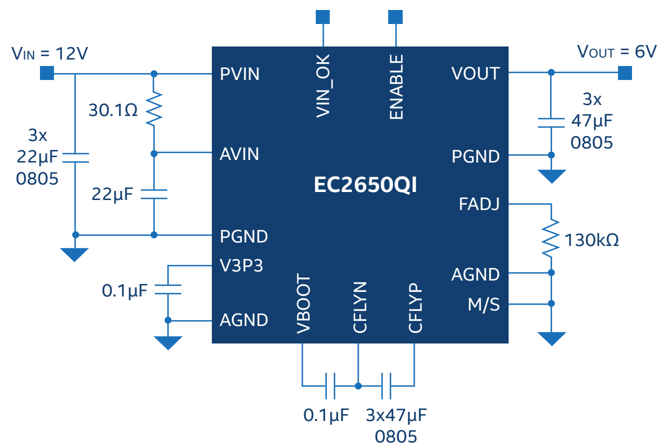

Figure 1. EC2650QI Device Pin-Out Diagram

Below is a list of Point of Load (P.O.L) low-current rails that are suitable (Rail V_{IN} = 12V) for a two-stage solution using the EC2650QI device on a recent example of a server reference design. These rails currently use a competitor part but can be replaced with the suggested Intel equivalent solution (EN-), indicated in Table 3 for each rail. The total solution size of each part is listed, as well as the operating efficiency at the rail's Icc TDC. The Intel parts chosen to substitute the competitor parts meet the rails required voltage and current requirements.

RAIL	RAIL V_{IN} (V)	I_{CC} TDC (A)	I_{CC} MAX (A)	PART NUMBER	PART V_{IN} (V)	MAX OUTPUT CURRENT (A)	TOTAL SOLUTION SIZE (MM²)	EFFICIENCY (%)
P3V3_STBY_DSW	12	0.5	0.5	TPS54326	2 – 18	2	175.57	86
				EN6340	2.7 – 6.6	4	60	86
P1V1	12	7.59	10.22	IR3895	1 – 21	16	504.49	87
				EN63A0	2.5 – 6.6	12	225	85
P5V_AUX	12	2.35	3.70	TPS54620	4.5 – 17	6	364.7	95
				EN6340	2.7 – 6.6	4	60	97
P5V	12	1.45	2.35	IR3895	1 – 21	16	504.49	94
				EN6340	2.7 – 6.6	4	60	96

Table 3†. Low-Current Rails on the Server Reference Design Suitable for IBC

Using the IBC on these four low-current rails requires only one EC2650QI device. The results of substituting these parts are summarized in Table 4.

	12 V_{IN}, ONE-STAGE SOLUTION	12 V_{IN} + EC2650QI, TWO-STAGE SOLUTION
Total Solution Size (mm²)	1549	555
Efficiency (%)	91.54	86
Power Loss (W)	2.68	4.77

Table 4. One-Stage vs. Two-Stage Results Comparison

Solution Benefits

Total Solution Size

This solution is particularly relevant for space constrained server applications. Replacing the one-stage competitor parts with Intel's two-stage bus converter solution on the above low current rails (< 11 A) results in approximately **64%** space savings†. The one-stage solution is approximately **1549.25 mm²†** in total solution size, while the Intel two-stage solution is approximately **555 mm²†**, including the bus converter.

Using the IBC to first convert 12 V to 6 V allows designers to avoid using multiple higher voltage regulators, which are often much larger. Higher voltage regulators require a voltage process of 20 V or higher to maintain enough margin between operating range and device breakdown. In contrast, the bus converter's high efficiency minimizes power loss on the first stage, which can decrease the power loss on subsequent rails where smaller 6 V converters are used. This lower input voltage in the second stage allows each converter to use lower inductance while maintaining a comparable output ripple in a small solution size.

The EC2650QI device is also only 0.9 mm tall, particularly suitable for flexible layout options in applications with height constraints. The overall solution is only marginally impacted by the two-stage power conversion penalty because low-voltage regulators can be used to replace higher voltage ones, and both the EC2650QI device and Intel's DC-DC converters are highly efficient.

Additionally, we can substitute rails with other Intel power solutions that are unsuitable for the 12 V bus converter, such as the DDR4 VR PVTT rail with a V_{IN} of 1.23 V. Intel's DDR memory solution is only **9%†** the size and **7 points higher** in operating efficiency than the competitor part used. The total server design has four total PVTT rails that use the TPS53317A part, which would save over **3,000 mm²** if completely replaced with the Intel EV1320 solution.

Figure 2. 1-Stage vs. 2-Stage Block Diagram Configuration

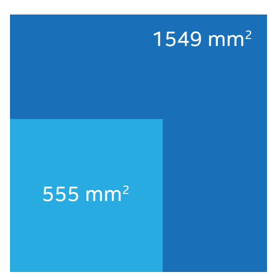

Figure 3a. Solution Size Comparison

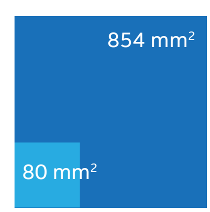

Figure 3b. PVT_xxx_CPUx Rail Comparison

RAIL	RAIL V_{IN} (V)	I_{CC} TDC (A)	I_{CC} MAX (A)	PART NUMBER	PART V_{IN} (V)	MAX OUTPUT CURRENT (A)	TOTAL SOLUTION SIZE (MM²)	EFFICIENCY (%)
PVT_xxxx_CPUx	1.23	2.27	2.27	TPS53317A	0.9 – 6	6	854.2	87
				2x EV1320	0.95 – 1.8	4	80	94

Table 5†. Additional Space and Efficiency Savings on VTT Rail

Total System Efficiency

By only replacing the low-current rails on the server reference platform with the two-stage solution, there is little additional power loss, approximately **2 W**[†]. A summary of the power loss calculations and total system efficiency of both solution approaches is shown below.

$PV_{OUT} = V_{OUT} * I_{OUT}$

$PV_{IN} = PV_{OUT} / Efficiency * 100$

$I_{IN} = PV_{IN} / V_{IN}$

$Efficiency = P_{OUT} / P_{IN} = V_{OUT} * I_{OUT} / V_{IN} * I_{IN}$

$P_{LOSS} = P_{IN} - P_{OUT}$

RAIL	V_{IN} (V)	I_{IN} (A)	PV_{IN} (W)	PV_{OUT} (W)	V_{OUT} (V)	I_{OUT} (A)	EFFICIENCY (%)
P3V3_STBY_DSW	12	0.15988	1.9186	1.65	3.3	0.5	86
P1V1	12	0.79971	9.5965	8.349	1.1	7.59	87
P5V_AUX	12	1.03070	12.368	11.75	5	2.35	95
P5V	12	0.64964	7.7956	7.25	5	1.45	93
	Total	**2.63993**	**31.6792**	**28.999**		**11.89**	**91.54**

Total Solution Efficiency of 1-Stage Solution = P_{OUT} / P_{IN} = 28.999/31.6792 * 100 = **91.54%**

Total Power Loss = $P_{LOSS} = PV_{IN\,(stage\ 1)} - PV_{OUT\,(stage\ 2)}$ = 31.63993 – 28.999 = **2.68 W**

Table 6. Calculations for One-Stage Solution

STAGE 1, 12V INPUT AND 6V OUTPUT							
RAIL	**V_{IN} (V)**	**I_{IN} (A)**	**PV_{IN} (W)**	**PV_{OUT} (W)**	**V_{OUT} (V)**	**I_{OUT} (A)**	**EFFICIENCY (%)**
EC2650QI	12	2.8141	33.77036	6	6	5.2344	93

STAGE 2, 6V INPUT							
RAIL	**V_{IN} (V)**	**I_{IN} (A)**	**PV_{IN} (W)**	**PV_{OUT} (W)**	**V_{OUT} (V)**	**I_{OUT} (A)**	**EFFICIENCY (%)**
P3V3_STBY_DSW	6	0.3198	1.9186	1.65	3.3	0.5	86
P1V1	6	1.6371	9.8224	8.349	1.1	7.59	85
P5V_AUX	6	2.0189	12.113	11.75	5	2.35	97
P5V	6	1.2587	7.5521	7.25	5	1.45	96
	Total	**5.234**	**31.41**	**28.999**		**11.89**	**92.334**

Total Solution Efficiency of 2-Stage Solution = $PV_{OUT\,(stage\ 2)} / PV_{IN\,(stage\ 1)}$ = 28.999/33.7703 * 100 = **85.87%**

Total Power Loss = $P_{LOSS} = PV_{IN\,(stage\ 1)} - PV_{OUT\,(stage\ 2)}$ = 33.77036 – 28.999 = **4.77 W**

Table 7. Calculations for Two-Stage Solution

Although the efficiency drops approximately 6 points between the two low-current solutions (91.54% vs. 85.87%), the actual power loss is small. The additional **2 W**[†] that is lost is a very small percentage of the overall server power solution. The average typical power consumption for a 2U rack mount server is approximately 350 W to 400 W[1], so this two-stage solution produces only an expected total increase of **0.5%** to **0.6%**.

As mentioned earlier, replacing the VRTT rail with the Intel EV1320 device would further reduce the 2 W of power loss gained by using the Intermediate Bus Converter.

Conclusion

Intel is accommodating technology space constraints as the demand for modern electronics to be smaller and more efficient accelerates. The new EC2650QI 12-to-6 V IBC can be particularly useful for server applications where board constraints are especially stringent. The IBC has a very high efficiency rating of up to 94% and can be used in parallel with other EC2650s for up to 144 W capacity.

In this case study, replacing high-voltage regulators with the IBC and smaller voltage regulators from Intel on low-current rails results in dramatic space savings of **64%**[†]. By substituting low-current rails with the highly efficient IBC and Intel DC-DC converters, there is only an expected increase of **0.5%** to **0.6%**[1] increase in total system power loss. Additionally, the IBC is only 0.9 mm tall, and 150 mm² in size for flexible layout options in applications with height constraints. These space savings provide power designers with layout flexibility and real estate for greater investment in processing power, memory, graphics, and so on.

Replacing rails not suited for the IBC with another compact, efficient Intel solution could also reduce conversion losses and further increase space savings. For example, replacing all PVTT rails with the Intel EV1320 device would save over **3,000 mm²** and reduce the 2 W of additional power loss mentioned earlier.

Intel's product portfolio continually meets the server market's evolving standards. These power products are competitively designed to empower customers by surpassing the market's requirements in efficiency, reliability, cost, and space savings.

Learn More

To learn more about the Intel Enpirion EC2650QI device:

- Visit the EC2650QI: 6-A, 12 V DC-DC Step Down Voltage Bus Converter product page
- Watch this short video: Save PCB Space and Reduce Costs When Powering FPGAs and ASICs from A 12 V Bus
- Read the Application Note (AN895): 12V Power Solution 1-Stage vs. 2-Stage

Call to Action

To learn more about the ways in which Intel is meeting server customer power needs, visit www.intel.com/power.

[†] Based on internal Intel estimates using part device datasheets.

[††] Solution size estimate for single-sided PCB including all suggested external components. Smaller size may be possible with double-sided PCB design. This solution is qualified over the industrial ambient temperature range of -40°C to +85°C.

[1] For details, refer to www.vertatique.com/average-power-use-server.