

DC/DC Point-of-load Power Solutions for Wired Networking Switch Systems

1 Introduction

Internet companies around the world are investing more in-cloud computing data centers to support the growing number of connected users and devices. The increasing demand for cloud computing and number of data centers has caused a need for upgraded wired networking switches. Switching manufacturers are burdened with designing switches to support even higher performance Application-Specific Integrated Circuits (ASIC), Field-Programmable Gate Arrays (FPGA), and Central Processing Units (CPU) than previous generation solutions. These processing units are as power hungry as ever, making the requirement for highly efficient and reliable power supplies even more critical. This application report details a high-level overview of wired network switches, the key power considerations switches designers need to solve, and what TI DC/DC solutions are available to help solve those problems.

2 System Description

Wired networking switches come in two main forms: data center switches and campus and branch switches. Data center and campus and branch switching infrastructures can perform similar functions since they are both TCP/IP and Ethernet-based, but each has very different requirements and need different hardware considerations to implement. Data center switches are where devices, such as servers, load balancers, and storage, connect to the network. These devices are typically in the 10G+ range and perform tasks such as database management, virtual machine management, and file transfers. These type of applications typically have a much higher bandwidth and lower latency than campus and branch switches. Campus and branch switches are where end-users connect to the network. These end-users can connect to the network via devices such as laptops, IP phones, printers, video conferencing systems, and so forth. These devices are typically in the 100 M to 10 G range and perform tasks such as email, internet access, and video. These types of applications typically have a wide range of bandwidth and a higher latency than data center switches. While reliability is a concern for both form factors, failure in a campus and branch switch in general impacts only the those who are in the failure area, whereas failure in a data center switch can impact those who are connected to the network, thus making mitigating failures in data center switches even more system critical.

3 System Requirements

Both networking switch systems require a heavy amount of analog and digital components, which can make a design bill of materials (BOM) rather large. ASICs, ASIC power, memory, clocks, I2C switches, Power over Ethernet (PoE) switches, temperature sensors, and many other devices take up Printed Circuit Board (PCB) space. Networking switch systems benefit from a DC/DC point-of-load (PoL) power solution that supports the needs of advanced analog and digital integrated circuits, offers high efficiency with good thermal performance, and reduces the overall component count and cost. In other words, power solutions with high-power density, or A/mm², superior thermal performance, and a high level of integration are the preferred option for networking switch designs.

4 IC Packaging for Power Density and Thermal Performance

As available board space is shrinking and target efficiency is increasing, DC/DC solutions are required to have competitive power density and thermal performance. Network switching power designers are looking for PoL solutions that are both increasingly small and more efficient, which combined is a challenging requirement for DC/DC power manufacturers. Networking switches in particular have to pay extra close attention to reliability since one failure can impact a wider area and larger number of people than campus and branch switches. To help minimize failures and increase reliability, system thermals must be taken into consideration when selecting DC/DC converters, since higher circuit board temperatures relate to lower reliability.

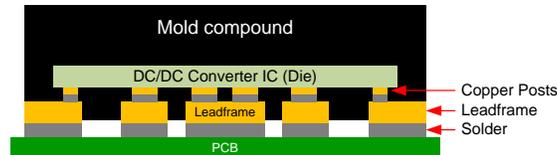


Figure 1. HotRod QFN Package Cross Section

One way TI buck converters are solving this problem is with innovations in package technology, such as using the benefits of the HotRod Quad Flat No-leads (HR QFN) package. The HR QFN package does not require internal wire bonds, so less clearance is needed between the die and the edge of the package, allowing the package size to shrink to be much closer to the size of the die. Also, wire bonds cause parasitic inductance/resistance, which causes additional power loss with standard QFN packaging. These low impedance connections between the die and the package leads also enables heat to flow from the die to the PCB through every pin of the IC. Figure 1 shows an example cross section for HR QFN package.

The TPS54824 is an update to the popular TPS54620 that takes advantage of the benefits of the HR QFN package. The TPS54824 offers a significant decrease in power dissipation, as shown in Figure 2. TPS54824 has larger MOSFETs with lower drain-source on resistance ($R_{DS(on)}$) but uses the HR QFN package to have the same 3.5-mm x 3.5-mm size and eliminates parasitic resistance of wire bonds. By taking advantage of HR QFN packaging, TI is a front runner for high-power density solutions. See the [HotRod QFN Package PCB Attachment Application Report](#) for more information on the HR QFN.

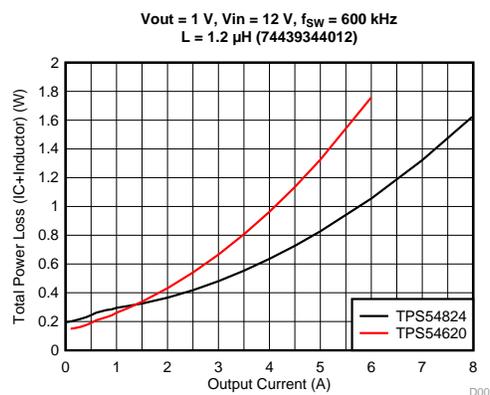


Figure 2. TPS54824 Reduced Power Loss Over TPS54620

Another way TI package technology is enabling higher power density and better thermal performance are DC/DC converters in clip-QFN Multi-Chip Module (MCM) packages. The clip-QFN package has the high-side MOSFET and is stacked on top of the low-side MOSFET for the highest power density. These clip-QFN packages also include a large ground pad to help dissipate heat. Figure 3 shows an example drawing for the clip-QFN package. This package is standard on high current DC/DC converters, like the TPS543C20 (40 A) and TPS543B20 (25 A), since higher current DC/DC converters contribute more to the overall system thermal budget. TPS546D24 is another 40 A DC/DC converter in an MCM package, but is equipped with full PMBus™ with telemetry. Designers can take advantage of the PMBus with telemetry feature to monitor output voltage, current, and temperature.

See the [Understand the Thermal-resistance Specifications of DC/DC Converters with Integrated Power MOSFETs Technical Brief](#) to learn more about thermal-resistance specifications.

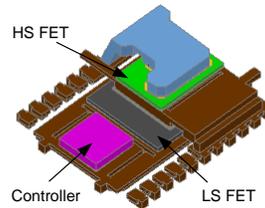


Figure 3. Clip-QFN Package Drawing

5 Solution Size and Component Control

TI DC/DC solutions can help lower component count and reduce solution size by introducing new devices with Advanced Current Mode (ACM) control. ACM control is a new DC/DC control mode that has fast transient response and is internally compensated, like D-CAP constant on-time control. Unlike D-CAP, ACM is a fixed-frequency control for a more predictable switching frequency and synchronization capability. This predictable characteristic makes it easier to use filtering to help manage noise-in-noise sensitive applications. Internally compensated control modes such as D-CAP, D-CAP2, D-CAP3, and ACM simplify designs and reduce external compensation components, making them the top choice for switch designs. To maximize ease of use, ACM is designed to be stable across a wide range of inductors and output capacitors. Another improvement with ACM is the low minimum on-time ensuring you can use higher switching frequencies at larger step down ratios to reduce solution size. Higher switching frequencies reduce the output inductance and the output capacitance required.

Take a scenario where $V_{in} = 12\text{ V}$, $V_{out} = 1.2\text{ V}$, and $I_{out} = 8\text{ A}$. On a typical peak current-mode control (PCMC) device, the minimum on-time is often around 150 ns (max) due to the blanking time required to sense the peak current. ACM emulates current ripple, allowing for a minimum on-time typically around 40 ns (max). With the minimum on-time (max), use [Equation 1](#) to calculate the maximum switching frequency (f_{sw}) the part can operate at. The maximum V_{in} in the given application must be used in this equation. In this scenario, the maximum f_{sw} for PCMC is 667 kHz and for the ACM is 2.5 MHz. With ACM, the minimum on-time limitation is essentially eliminated and thermal concerns largely dictate switching frequency and resulting inductor size.

$$f_{sw} \leq \frac{1}{t_{ON,min}} \times \frac{V_O}{V_{I,max}} \quad (1)$$

Assuming a K to set the ripple current in the inductor, where $K = \Delta I_L / I_o$ and is usually between 0.1 and 0.4, use [Equation 2](#) to see the different inductor value between switching frequencies. Using a K of 0.2 PCMC uses an inductance of 1 μH and ACM potentially uses an inductance as low as 330 nH. A 330 nH inductor has an approximately 67% smaller footprint area compared to a 1 μH inductor with the same DC resistance.

$$L = \left(\frac{V_{IN,MAX} - V_O}{K \times I_O} \right) \left(\frac{V_O}{V_{IN,MAX} \times f_{sw}} \right) \quad (2)$$

D-CAP control modes have similarly low minimum on-times and are still great solutions for powering switches, since they are internally compensated and have the best transient response. However, the fixed frequency control scheme ACM must be considered as well. See the [TI's Internally Compensated Advanced Current Mode \(ACM\) White Paper](#) for more information on the ACM control mode. See the [Comparing Internally-compensated Advanced Current Mode \(ACM\) with D-CAP3™ Control Technical Brief](#) if you are using D-CAP COT control.

6 Complete Solution

The DC/DC converters in [Table 1](#) are ideal for powering network switching applications. These converters feature high efficiency, small overall solution size, good thermal performance, power good pins, and enable pins. Some of the devices listed are also stackable for a compact and cost-effective solution for powering high current rails. Devices denoted with a letter after the part number are pin compatible for design flexibility.

7 Final Remarks

Our world is undergoing a movement to a more connected world. More users and devices are on a network than ever before and need an infrastructure to support it. With increasing pressures on solution size and efficiency, network switch power designers are in the middle of it. Selecting the highest power density converter solutions is paramount to a successful networking switching design. Either by using control mode schemes, such as D-CAP and ACM, where compensation is integrated into the IC, using higher switching frequencies to reduce inductor size, or by using advanced packaging such as HR QFN or clip-QFN, TI has several DC/DC solutions that are great options for switching power designers to consider.

Table 1. Device Recommendations for Networking Switches Systems

DEVICE	I _{OUT} MAX	INPUT VOLTAGE	CONTROL MODE	PACKAGE	OTHER NOTABLE FEATURES
TPS82130	3 A	3 V to 17 V	DCS-Control	2.8-mm x 3-mm MicroSiP™ power module	Light-Load Efficiency (LLE), Internal Compensation
TPS62135	4 A	3 V to 17 V	DCS-Control	3-mm x 2-mm QFN	Selectable LLE, Internal Compensation
TPS54424 (a)	4 A	4.5 V to 17 V	PCMC	3.5-mm x 3.5-mm HotRod QFN	Synchronizable
TPS54824 (a)	8 A	4.5 V to 17 V	PCMC	3.5-mm x 3.5-mm HotRod QFN	Synchronizable
TPS568215 (c)	8 A	4.5 V to 17 V	D-CAP3	3.5-mm x 3.5-mm HotRod QFN	Selectable LLE, Adj. Current Limit, Internal Compensation
TPS54A24	10 A	4.5 V to 17 V	PCMC	4-mm x 4-mm QFN	Synchronizable
TPS56C215 (c)	12 A	3.8 V to 17 V	D-CAP3	3.5-mm x 3.5-mm HotRod QFN	Selectable LLE, Adj. Current Limit, Internal Compensation
TPS53319 (b)	14 A	1.5 V to 22 V	D-CAP	5-mm x 6-mm clip-QFN	Selectable LLE, Adj. Current Limit, Internal Compensation
TPS544B25	20 A	4.5 V to 18 V	Voltage Mode	5-mm x 7-mm clip-QFN	PMBus with Telemetry, Synchronizable, Remote Sense
TPS543B20 (d)	25 A	4 V to 19 V	ACM	5-mm x 7-mm clip-QFN	Synchronizable, Remote Sense, Stackable
TPS543C20 (d)	40 A	4 V to 14 V	ACM	5-mm x 7-mm clip-QFN	Synchronizable, Remote Sense, Stackable, Internal Compensation
TPS546D24	40 A	2.95 V to 16 V	Average CM	5-mm x 7-mm clip-QFN	PMBus with Telemetry, Synchronizable, Remote Sense, Stackable, Internal Compensation

8 References

- [Comparing Internally-compensated Advanced Current Mode \(ACM\) with D-CAP3™ Control Technical Brief](#) (SLYT732)
- [TI's Internally Compensated Advanced Current Mode \(ACM\) White Paper](#) (SLYY118)
- [HotRod QFN Package PCB Attachment Application Report](#) (SLUA715)
- [Understand the Thermal-resistance Specifications of DC/DC Converters with Integrated Power MOSFETs Technical Brief](#) (SLYT739)

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