An Integrated and Scalable USB Type-C® Battery Charging Architecture

Abstract

This white paper introduces a modern USB Type-C® power architecture based on Renesas devices such as the RAA489800 and RAA489110/RAA489118, which integrate bidirectional power control and battery charging into a simplified solution. The proposed architecture reduces system complexity and BOM cost while improving performance, enabling efficient multi-port power sharing and scalable design. It also fully supports USB Power Delivery 3.1, including PPS, allowing dynamic voltage and current control to optimize power delivery in next-generation applications.

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Introduction

The USB Type-C® interface continues to transform the way electronic devices are powered and charged. Its reversible connector enables easy insertion regardless of orientation, while supporting true bidirectional connectivity where either end of the cable can be connected to either device. Electrically, system-level negotiation automatically determines the configuration and power direction, enabling seamless operation.

Beyond high-speed data transfer, USB Type-C® now supports significantly expanded bidirectional power delivery capabilities. While legacy implementations supported up to 100W (20V, 5A), the latest USB Power Delivery (USB PD 3.1) specification introduces Extended Power Range (EPR), enabling up to 240W with voltage levels of 28V, 36V, and 48V. This advancement allows USB-C to serve as the primary power interface for high-performance notebooks, tablets, and other power-hungry applications.

With the widespread adoption of USB PD and USB Type-C®, system designers face increasingly stringent requirements for power management and voltage regulation. Unlike conventional USB Type-A and Type-B interfaces with fixed voltage levels, USB Type-C® operates as a fully bidirectional port with dynamically adjustable voltage and current levels. This flexibility allows modern systems to replace traditional AC/DC adapters and multiple legacy ports with a single USB-C interface. As a result, many designs now incorporate dual or multiple USB Type-C® ports to enable higher power throughput and improved user flexibility.

However, legacy system architectures for multi-port USB Type-C® implementations are often complex, requiring multiple discrete components such as external buck-boost regulators and separate battery charger ICs. These approaches increase system cost, board space, and design complexity, while limiting scalability.

This white paper presents an updated system architecture based on the latest Renesas highly integrated power management devices, including the RAA489110[1]/RAA489118[2] buck-boost battery chargers and the RAA489800[3] family. These devices integrate charging, system power regulation, and bidirectional power path control into a single solution, significantly simplifying design while supporting full USB PD 3.1 functionality, including PPS and multi-port operation. In addition, this architecture enables efficient implementation of programmable power supply (PPS), allowing fine-grained voltage and current control to optimize power delivery across a wide operating range.

A New USB Type-C® Battery Charging Architecture

Figure 1 shows a USB Type-C® architecture that consists of the RAA489800 bidirectional buck-boost (BB) voltage regulator and RAA489110 or RAA489118 BB battery charger. It allows a system to charge its battery through USB Type-C® ports and supports fast charging when two PD chargers are connected to USB-C_1 and USB-C_2, while providing full USB 3.1 functionality on both ports without the need for additional complex port-control logic.

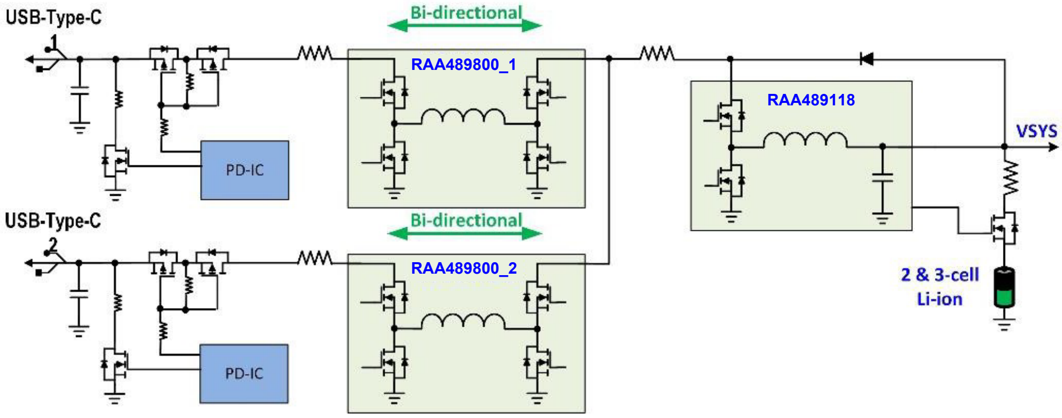

Figure 1. *Renesas battery charger architecture*
dual USB Type-C® ports with 2x BB regulator + buck charger

Comparing Figure 1 and Figure 2, it is clear that conventional battery charger architectures require more devices and complex external circuitry to achieve comparable functionality and performance relative to Renesas' advanced charger solutions. In traditional implementations, each charger path typically requires a dedicated USB-PD controller to manage ASGATE control and charging functions, which increases overall system cost and design complexity. In addition, implementing OTG or power delivery functions often requires extra control circuitry. By contrast, modern Renesas battery charger architectures integrate these functions more efficiently, reducing the need for external components and simplifying system design.

Furthermore, conventional buck converter–based OTG implementations are limited to fixed output voltages, typically 5V. This limitation does not meet the requirements of many USB Type-C® applications, which demand a wide and dynamically adjustable output voltage range (for example, 5V to 20V or higher under USB PD specifications).

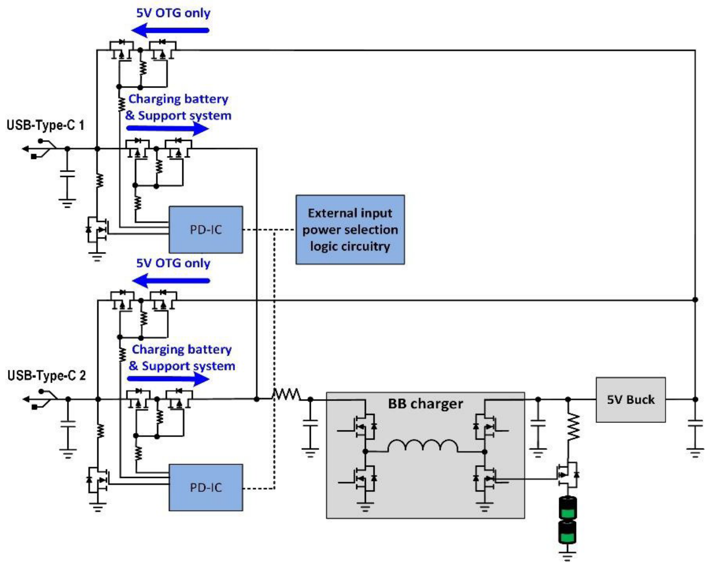

Figure 2. *Conventional battery charger architecture*
single BB charger + complicated external logic

The proposed Renesas architecture overcomes the limitations of conventional charger implementations by providing a highly integrated and scalable power solution. As shown in Figure 1, dual bidirectional buck-boost controllers such as the RAA489800 can be configured in parallel to interface two USB Type-C® ports with a system battery charger such as the RAA489118 or RAA489110. This architecture significantly simplifies the system design and reduces overall BOM cost by eliminating the need for multiple discrete components, including independent power path management circuitry and additional external control logic. Despite the reduced component count, system performance is fully maintained or even enhanced.

In a typical operating condition, energy from the USB Type-C® input is efficiently transferred through the buck-boost stage directly to the system charger. By paralleling two RAA489800 controllers, the system can flexibly utilize multiple power sources. For example, when two USB Type-C® adapters with different power capabilities are connected, the control loops of the two devices automatically manage voltage and current distribution to maximize total available input power without requiring external coordination circuitry.

For instance, two USB Type-C® inputs with different power ratings can be utilized to achieve higher battery charging power, enabling the total charging power to exceed that of a single USB-C input. As shown in Figure 1, this can be accomplished using two RAA489800 devices operating in parallel, interfacing with a RAA489118 system charger. One RAA489800 (connected to the higher-power USB-C source) operates in the voltage regulation loop to maintain a stable input voltage (V0) for the RAA489118, while the other RAA489800 (connected to the lower-power source) operates in the current regulation loop to automatically deliver its maximum available power. This approach enables automatic power sharing between the two input sources without requiring additional external circuitry or control logic to manage different power ratings. The RAA489800 devices dynamically adjust their control modes based on the characteristics of each connected source, ensuring optimal utilization of available input power.

Bidirectional power capability is inherently supported in the modern architecture, allowing battery energy to be efficiently transferred back to the USB Type-C® ports through the RAA489800 when required. This eliminates the need for dedicated 5V buck converters and additional OTG gate control circuitry used in conventional designs. In addition, system-level communication (such as SMBus or I²C) between the RAA489800 devices, the RAA489118 charger, and the USB-PD controllers enables flexible configuration and dynamic voltage control, rather than relying on fixed output settings. This supports the wide and programmable voltage range required by USB Power Delivery specifications.

As illustrated in Figure 3, this scalable architecture can be extended by paralleling multiple RAA489800 devices with a single RAA489118 charger to support higher power systems. Each USB Type-C® port can operate independently as either a power sink or source, depending on system requirements. Furthermore, this architecture allows seamless integration of conventional adapters as additional power sources, without increasing system complexity or BOM cost, providing a highly flexible and efficient solution for modern multi-port USB Type-C® applications.

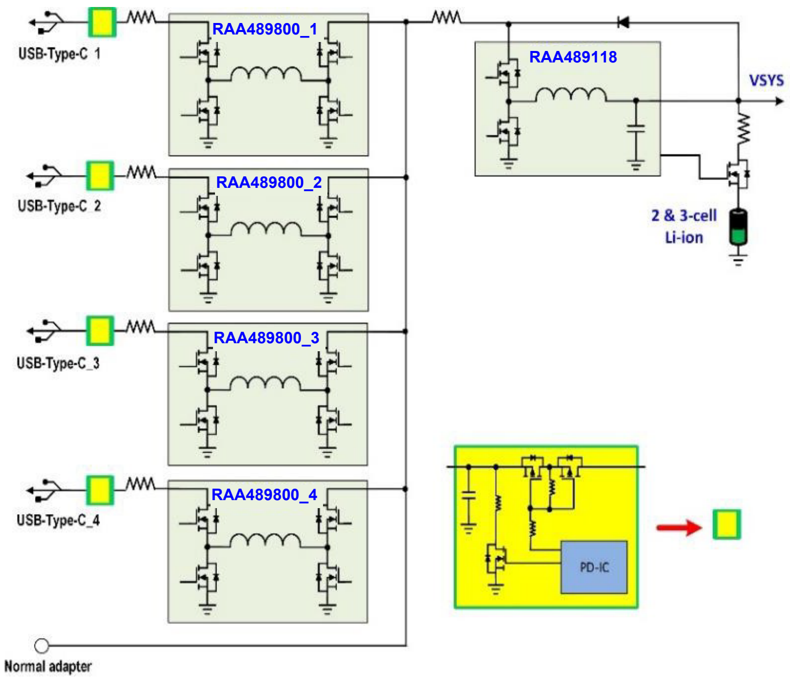

Figure 3. *Renesas battery charger architecture for four USB Type-C® ports 4x BB regulator + buck charger*

Programmable Power Supply Solution

The programmable power supply (PPS) function defined in the USB Power Delivery specification enables dynamic adjustment of output voltage and current in fine steps (e.g., 20mV / 50mA), allowing the system to optimize power delivery efficiency. As shown in Figure 4, the RAA489800 bidirectional buck-boost controller is well suited for PPS operation, supporting a wide, dynamically adjustable voltage range and bidirectional power flow. In combination with a USB-PD controller such as the R9A02G011[4], and via digital communication (SMBus or I²C), the system can precisely regulate voltage and current to meet PPS requirements, maximizing overall system efficiency and performance.

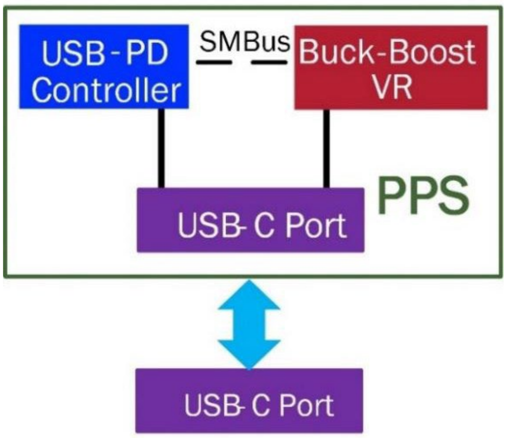

Figure 4. *Renesas PPS architecture*

Conclusion

Applying the RAA489800 in a multiport USB Type-C® battery charging system enables a simplified and highly integrated charging architecture. Compared to conventional charging approaches, Renesas' advanced architecture reduces system cost while delivering higher performance, faster charging, and improved overall efficiency. Furthermore, the solution fully complies with USB Type-C® and USB Power Delivery requirements, including support for Programmable Power Supply (PPS), which is a key feature for optimizing power delivery in next-generation applications.

References

[1] Renesas RAA489110 https://www.renesas.com/en/products/RAA489110

[2] Renesas RAA489118 https://www.renesas.com/en/products/RAA489118

[3] Renesas RAA489800 https://www.renesas.com/en/products/RAA489800

[4] Renesas R9A02G011 https://www.renesas.com/eu/en/products/R9A02G011

Revision History

Revision	Date	Description
2.00	Jan 18, 2026	USB spec related information and product information updates.
1.00	Feb, 2018	Initial release.

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