USB-C PD 3.1 EPR: A Full System Design Solution, Wall to Battery

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Introduction

The USB-C Power Delivery (PD) 3.1 Extended Power Range (EPR) protocol represents a significant advancement in modern battery charging technology. With consumer electronics devices becoming increasingly powerful, the need for fast battery charging via compact and universal connectors has surged dramatically.

USB-C PD 3.1 EPR meets this requirement by enabling power delivery of up to 240W, a sensational improvement against the former 100W limit of earlier USB-C PD standards. This advancement broadens the already rich multitude of devices that can be powered through USB-C PD, such as high-performance laptops, power tools, vacuum cleaner, energy-demanding peripherals and even small appliances. Moreover, it enhances the user experience with one standardized connector and shorter battery charging time.

This article presents a complete Wall-to-Battery solution implementation of the USB-C PD 3.1 EPR standard. The paragraphs below highlight each of the fundamental blocks realizing the system, from AC-DC Adapter to USB-C PD Charger and finally describing the Battery Management System (BMS).

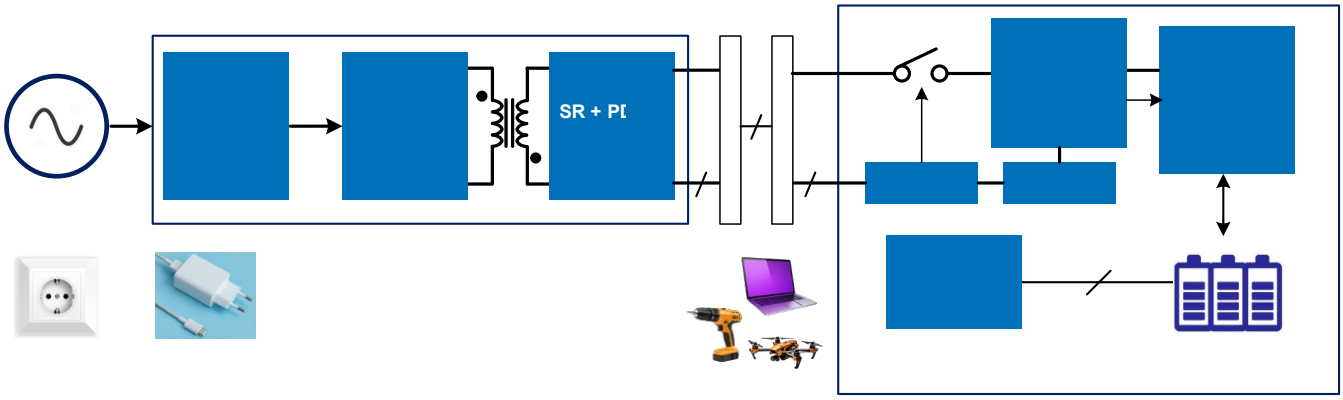

Figure 1: USB-C PD 3.1 EPR Wall-to-Battery System Block Diagram

USB-C PD 3.1 EPR: Solution Overview

USB-C PD technology plays a key role in simplifying power delivery for a wide range of devices, while significantly reducing charging time, improving energy efficiency and enhancing user experience. A typical USB-C PD 3.1 EPR complete system consists of:

- **High-Efficiency AC-DC USB-C 240W Adapter.**

  This adapter leverages Wide-Bandgap Semiconductor, such as Gallium Nitride (GaN), to deliver unprecedented efficiency performances while increasing switching frequency, hence reducing charger size. An interleaved Boost Power Factor Correction (PFC) stage is followed by an isolated DC-DC converter. Flyback and Asymmetric Half-Bridge are certainly among the most common isolated DC-DC topologies suitable for 240W output power range.

- **Extended Power Range (EPR) 48V Bi-Directional Charging Solution.**

  The Bi-Directional 48V capable switching charger enables both Sink and Source USB-PD modes of operation. A Controller IC drives four external MOSFETs in H-Bridge configuration to realize the power stage. This sub-system typically includes a Type-C Port Controller (TCPC), handling the Bus switch and the CC pins, plus a Type-C Port Manager (TCPM) that handles one or multiple ports. TCPC and TCPM are often integrated in one single package to optimize board footprint and cost.

- **Battery Management System (BMS).**

  The Battery Management System continuously monitors Battery State-of-Charge (SoC), State of Health (SoH), and multiple other parameters like temperature and charging/discharging current guaranteeing a safe and reliable operation. It also balances the amount of charge across the whole battery pack for enhanced performance and battery life.

The following chapters describe the all sub-blocks implementing the Wall-to-Battery solution, i.e. the AC-DC Adapter, the USB-C PD Charger solution and the Battery Management System.

240W AC-DC USB-C PD Adapter

The recent USB-C PD 3.1 EPR protocol requires efficient AC-DC conversion and involves several key components. A Power Factor Correction (PFC) circuit ensures that the power drawn from the grid complies with the Power Factor (PF) and Total Harmonic Distortion (THD) regulations. It reduces reactive power, improving the overall power efficiency. A secondary Isolated DC-DC regulator efficiently converts the high-

voltage output of the PFC (typically in the range of 360V to 400V) to 48V level, the maximum voltage achievable by the USB-C PD 3.1 EPR standard.

AC-DC solutions from Renesas, as shown in Figure 2, enable fast charging time and efficient conversion using advanced controller in combination with Gallium Nitride (GaN) HEMT switches. The R2A20132SP Interleaved PFC Controller, in addition to the TP65H150G GaN HEMT switch, guarantees high efficiency, low ripple High-Voltage DC intermediate rail.
The iW9801 Zero-Voltage Switching (ZVS) Flyback converter, paired with the TP65H070G, 70 mΩ ON-resistance GaN HEMT, enables the needed power to supply the secondary-side controller, iW780, producing up to 48V/5A DC output.

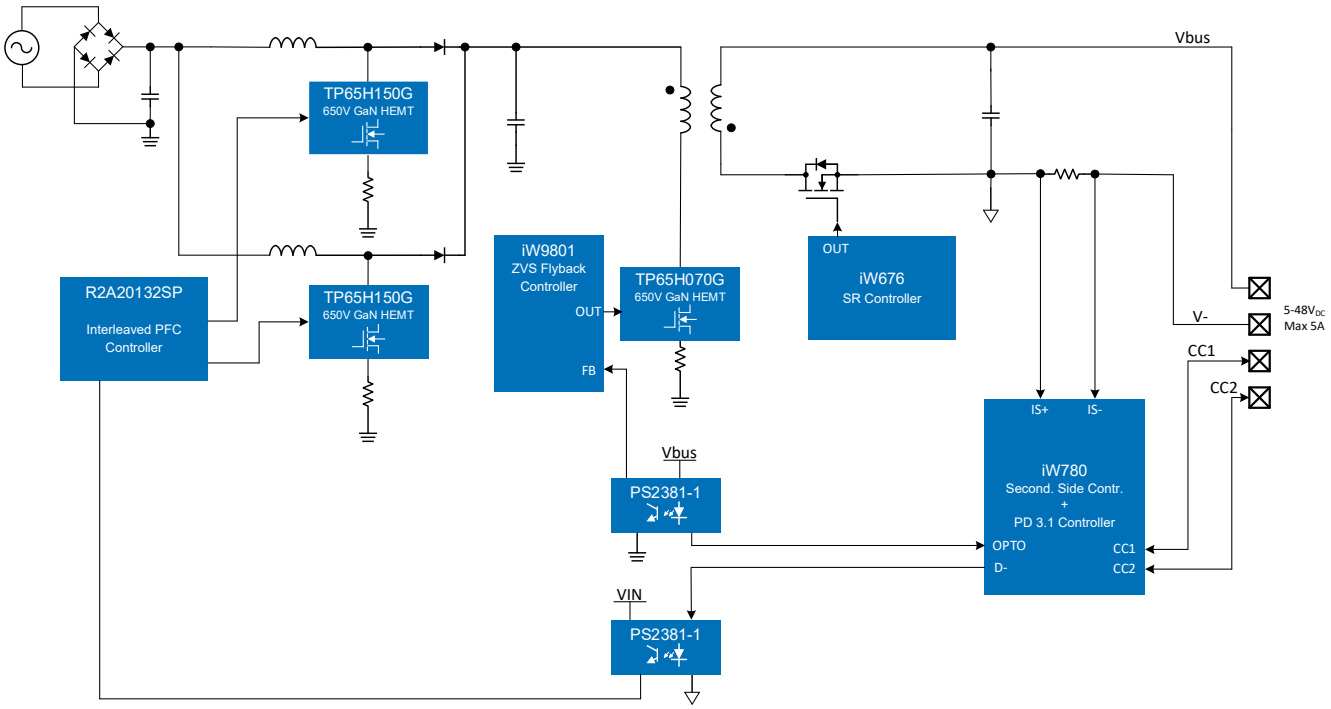

Figure 2: Block Diagram of 240W AC-DC Adapter for USB-C PD 3.1 EPR

The above mentioned secondary-side controller iW780, implements the USB-C PD 3.1 EPR protocol, making the AC-DC converter universally suitable for both single and multiport adapters, as shown in Figure 2. These certified solutions can be easily integrated into any product designs, providing manufacturers with reliable and efficient charging solutions that comply with the latest USB-C specifications and European standards for a common connector.

Bi-Directional 48V USB-C PD Charging Solution

The USB-C PD 3.1 Extended Power Range (EPR) charging solution is designed to deliver up to 240W of power in both Sinking and Sourcing operating modes. This solution operates with a bus voltage up to 48 V and a maximum current of 5 A.

In order to minimize power conversion losses and avoid potential thermal issues, a high-efficiency Bi-Directional Buck-Boost DC-DC converter is employed. It typically consists of a 4 control loops controller

(input and output CC/CV loops) driving 4 discrete 60/80V MOSFETs in H-bridge configuration. A TCPC controller is used to control the bus switches, read the CC signals and to send and receive the messages from and to the TCPM microcontroller. Often Port Controller and Port Manager are embedded in the same chip.

Renesas USB-C PD 3.1 EPR solution is depicted in Figure 3. The company portfolio offers cutting edge Buck-Boost controller: the RRB86848 supports bi-directional current flow and guarantees robust operation withstanding both input and output voltages up to 54V. The new Renesas Split-Gate MOSFET technology enables low RDS(on) and switching capability operation for high-power and high-frequency applications.

A Single USB Type-C Port Manager, the R9A02G0151, combines with multiple RAA489400 Type-C Port Controller devices to implement all USB PD functions (such as power negotiation and Alternate Mode support) for the management of multiple USB Type-C ports. This feature minimizes the overall solution size and cost by reducing the number of Port Managers in the design.

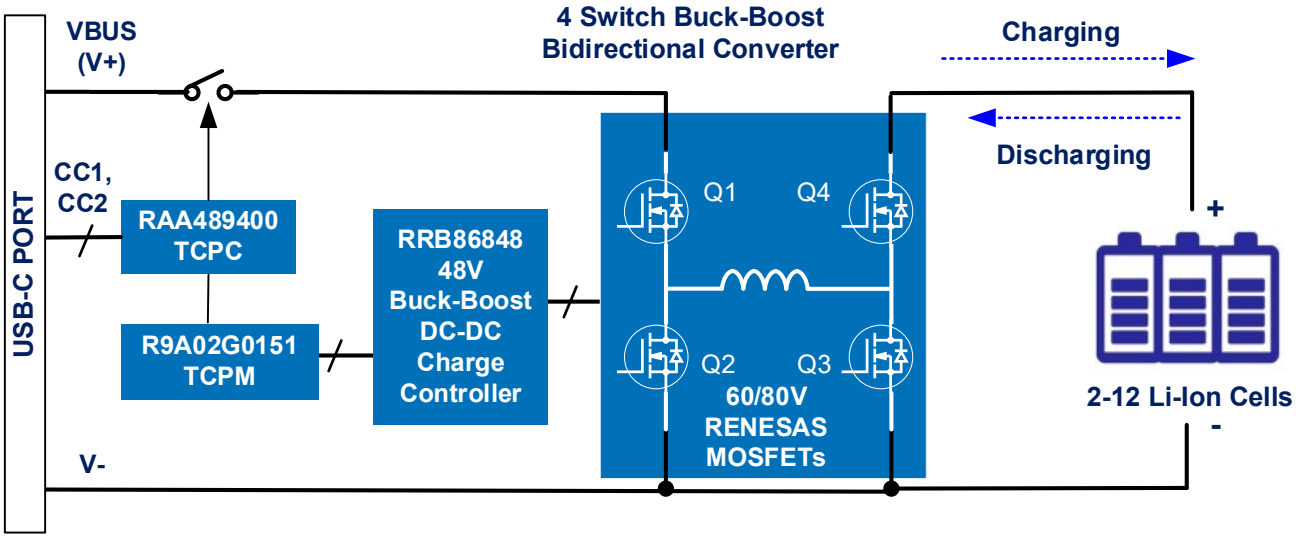

Figure 3: Block Diagram of USB-C PD 3.1 EPR Solution

Battery Management System (BMS)

The Battery Management System (BMS) is a crucial component in all battery powered devices, ensuring the safe and efficient operation of the battery pack. The three primary functions of a BMS include monitoring, protection, and cell balancing. The BMS continuously monitors the status of individual cells within the battery pack for voltage, temperature, and state of charge. It also prevents conditions such as over charging/discharging, short circuits, and thermal runaway. Finally, it ensures uniform charge distribution among cells to maximize battery life and performance. These functions can be done with discrete devices or a Battery Management Integrated Circuit (BMIC). Switches such as MOSFET transistors control the charging and discharging processes. They enable precise control over the current flow, which is essential for protecting battery cells and maintaining efficiency. Next, a method for obtaining and processing accurate data for voltage, current, and temperature measurements is done with Analog-to-

Digital Converters. Finally, a stable power supply to the BMS and its components is critical to maintaining reliability and accuracy in monitoring and control.

The Renesas FGIC, RAJ240100, integrates all the aforementioned blocks, reducing size and cost. It also includes an MCU for fuel-gauging purpose. It supports 3 to 10-cells battery pack, widely used in power tools, high-performance drones, professional laptops, and many more. A block diagram can be found in Figure 4.

The RAJ240100 is shipped with the fuel-gauge firmware already uploaded inside the IC. The provided firmware allows designers to reduce Research & Development (R&D) time together with test and validation process, resulting in shorter time-to-market of the final product.

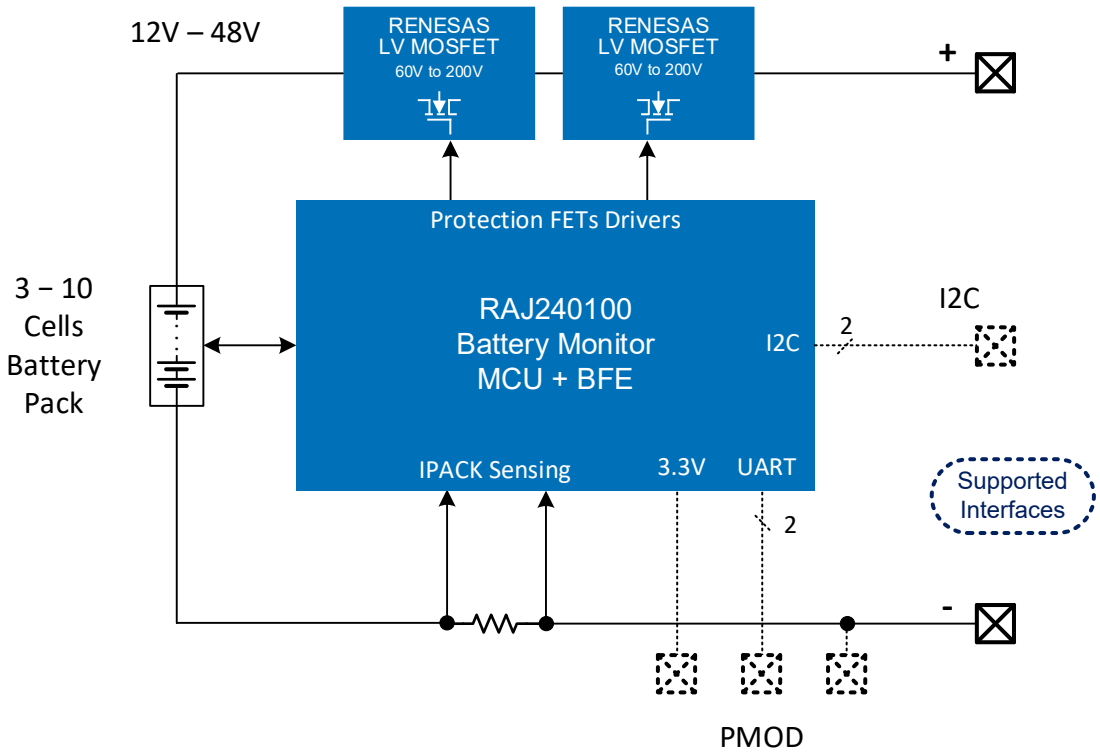

Figure 4: Block Diagram of BMS, particularly Fuel-Gauge IC (FGIC)

Summary

Renesas is the ideal design partner for systems and applications that require comprehensive expertise in power management, embedded processing, connectivity solutions, analog circuitry, and sensor integration.

Our diverse power portfolio includes DC-DC converters, AC-DC converters, and power discretes such as silicon MOSFETs and GaN HEMT, ensuring high efficiency and reliability tailored to diverse power requirements. This makes us an ideal partner for AC-DC adapter, USB-C PD charger and Battery Management System designs across any application.

We also offer extensive technical support and development tools, facilitating seamless integration of systems across a broad range of industries.

References

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(Rev.1.0 Mar 2020)

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Doc Number: R16WP0009EU0100