Designing a Battery Charging System for Diversifying Applications

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Consumers are looking for more convenient ways to charge their devices. Designing with the right battery charger enables engineers to build rechargeable devices that leverage new technologies like bidirectional and solar charging to provide consumers with the best charging experience.

At a glance

1 Battery charging for new USB-C applications

Many applications are adopting USB-C PD inputs, and the battery charger must be able to handle the variety of power levels for USB-C PD. It is important to pick the right battery charger that can support all USB-C PD power levels to provide customers with an efficient, quick charging experience.

2 Optimizing the charging and discharging of portable power stations

Bi-directional charging enables engineers to design systems that charge and discharge a battery from the same USB-C PD port. Portable power stations are one example of an application that would benefit from a bi-directional battery charging system.

3 Battery charging for solar applications

As more applications adopt rechargeable batteries, the need to charge the batteries at any moments grows, and solar charging provides a way to charge an application even if there is no outlet around. In order to provide the best solar charging experience, the right battery charger must be chosen to optimize the performance of the solar panels.

With the increase in battery-powered electronics, consumers are looking for more convenient ways to charge. If a homeowner needs to fix a door but finds that the battery of their cordless drill has no charge, it will take much longer if they can't find the drill's power adapter.

One reason why products traditionally had a dedicated power adapter was to provide an input power range that the battery-charger input could support. But what if the battery charger integrated circuit (IC) input could support common household adapters (such as a laptop USB Type-C® cord) for charging power tools?

The increase in battery-powered electronics has also created a need for reliable, portable backup power. If a camper wants to watch a movie under the stars, it would be convenient to design a system that charges the backup battery source during the day so that the electronic product can be powered by the backup battery at night. What if you could design a portable power station that could charge from solar power?

These situations are very different battery-charging scenarios, but there are common ways to help mitigate the design challenges that would allow you to create systems for diversified battery charging applications.

Battery charging for new USB-C applications

USB Type-C charging is becoming popular amongst consumers because it's convenient to use the same USB

Type-C cord for many household items. USB Type-C is even expanding to support higher-power applications such as power tools and e-bikes. As shown in **Figure 1**, while USB Type-C used to support up to 100 W of power with Standard Power Range (SPR), it can now support as much as 240 W with Extended Power Range (EPR).

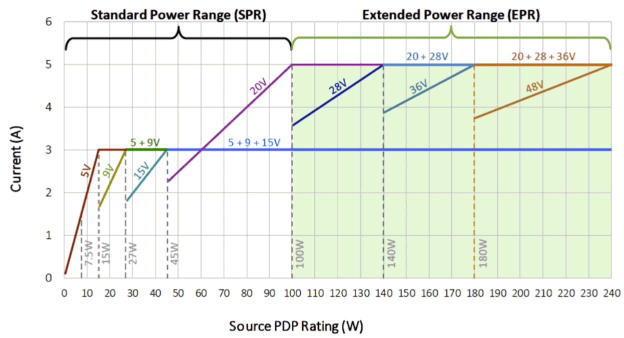

Figure 1. *USB Power Delivery (PD) ranges.*

Behind the goal to be able to get charge from different types of USB Type-C source including SPR and EPR comes the challenge of designing an application that can support the entire voltage range of USB Type-C PD EPR. Imagine a leaf blower designed with five-cell lithium-ion (Li-ion) batteries and a USB Type-C input. Because the batteries are Li-ion, the full charge voltage of each battery cell is 4.2 V, which means that the voltage of the battery pack (V_{BATT}) at full charge is 21 V. The owner of the leaf blower could use many USB wall adapters, but for this example, assume that they have a 45- or 140-W USB Type-C wall adapter, which means that the input voltage (V_{IN}) to the battery charger could be 15 V or 28 V. The question now is how to fulfill these requirements:

- Charge the battery when $V_{IN} > V_{BATT}$ or $V_{IN} < V_{BATT}$.
- Charge the battery as quickly as possible to minimize charging time.
- Keep the leaf blower cool during charging to help prevent overheating.
- Use one charger IC across different platforms with different cell counts.

The component that addresses each of these requirements is a buck-boost battery charge controller with external switching field-effect transistors (FETs). The buck-boost portion of the charger helps address the first requirement to have $V_{IN} > V_{BATT}$ or $V_{IN} < V_{BATT}$. Using four FETs and an inductor in the configuration shown in **Figure 2**, the battery charger can operate in buck mode when $V_{IN} > V_{BATT}$ shown in **Figure 3** and in boost mode when $V_{IN} < V_{BATT}$ shown in **Figure 4**.

The external FETs help address the second requirement. Selecting external FETs improves thermal performance and helps reduce charge times with a higher charge-current capability. In addition, external FETs provide a larger area to dissipate heat during charging. For these reasons, an external metal-oxide-semiconductor FET buck-boost battery charger enables applications that can handle the new USB PD EPR levels and help provide a quick charging experience.

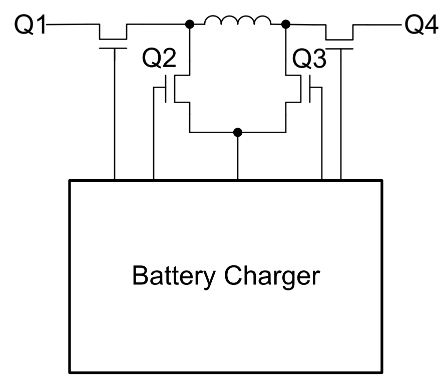

Figure 2. *H-bridge configurations of a buck-boost charge controller.*

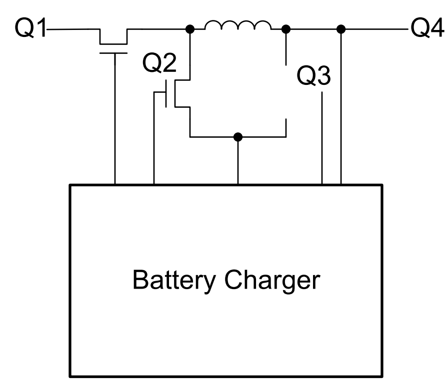

Figure 3. *Buck mode configuration when VIN > VBATT. Q1 and Q2 switch on and off, Q3 is off and Q4 is on.*

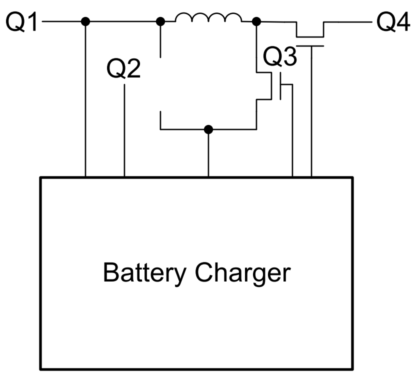

Figure 4. Boost mode configuration when VIN < VBATT. Q3 and Q4 switch on and off, Q2 is off and Q1 is on.

Optimizing the charging and discharging of portable power stations

Along with the growth of USB PD, demand for battery-powered electronics creates a need for portable power stations to charge them. In the past, portable power stations powered products such as TVs, radios and small refrigerators, but the expansion of USB PD EPR enables users to charge portable power station batteries for smaller personal electronics such as laptops and speakers with the same USB Type-C cord shown in Figure 5 and Figure 6. In Figure 5, the portable power station battery can be charged with as much as 240 W from the battery charger. Figure 6 shows the reversed power flow. Energy from the portable power station battery provides power out of the USB Type-C port through the cord to charge the laptop.

Figure 5. Charging a portable power station battery with 240 W of USB power.

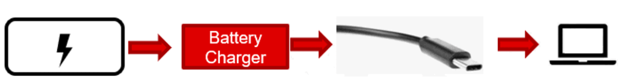

Figure 6. Discharging from a portable power station battery to charge a laptop with 140 W using the same USB Type-C® cord.

Achieving the optimized charging and discharging solution shown in Figure 5 and Figure 6 requires a bidirectional buck-boost battery charger. Bidirectional signifies that the battery charger can also perform in buck and boost modes when power flows from the output to the input, which is called reverse mode. To help visualize reverse mode, see Figure 2 and Figure 3. In reverse mode, Figure 2, which was buck mode, is now boost mode. Figure 3, which was boost mode, is now buck mode. Having a bidirectional buck-boost charger enables consumers to use a USB Type-C port to charge an application's battery and then reverse the power flow to charge another device, such as a laptop.

I have already discussed how a bidirectional battery charger is useful in portable power stations, but are there other applications where bidirectional power flow is useful? One emerging trend is e-bikes using USB Type-C to charge the main battery, and then using the main battery to charge a personal device through the same USB Type-C port. Imagine that you've taken your e-bike to the park and want to stream a movie on your smartphone, but it's only at a 10% charge. Designing the main battery of an e-bike with a bidirectional buck-boost battery charger and USB Type-C allows smartphone charging from the e-bike battery.

Battery charging for solar applications

More battery-powered electronics creates a need to charge batteries in any kind of environment. Referring back to the camping example, solar panels can charge a portable power station if no outlet is available; however, there are several factors that affect solar charging, including:

- Different solar panel ratings.
- Variable weather conditions.
- Partial shade.

It is important to find the maximum power point (MPP) from the solar panels – the point where the solar panel I_{OUT} multiplied by the solar panel V_{OUT} is the highest – in order to extract the highest charge current to charge the battery.

To discuss this further, let's talk about the current-voltage (IV) graph for solar panels in Figure 7. The y-axis represents the IOUT of a solar panel, while the x-axis represents the VOUT of the solar panel. The objective of the IV graph is to find the MPP that the solar panel can produce based on weather conditions. Figure 7 demonstrates how the IV graph can change depending on weather conditions.

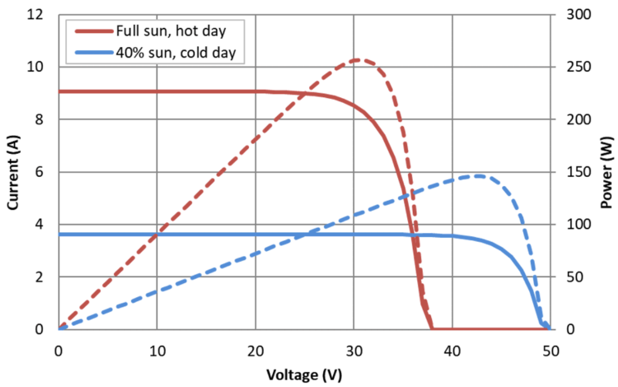

Figure 7. *IV curve based on weather conditions.*

Diversifying battery-charger applications

Again, there are many battery-charger design challenges associated with the growth of USB PD and portable backup power; however, the **BQ25756** buck-boost battery-charge controller can help address each challenge, specifically because it has these three features:

- Up to 70-V support on the input and output.
- Bidirectional power flow.
- An autonomous MPPT algorithm.

The 70-V support on the input supports the full USB PD voltage range, and the buck-boost controller topology enables any USB Type-C input regardless of the battery voltage, since the device will automatically switch between buck and boost modes depending on the values of V_{IN} and V_{BATT}. The 70-V support on the output allows the BQ25756 to charge up to 14 Li-ion series cells and up to 16 Li-ion phosphate cells.

Bidirectional power flow enables charger system designs that charge and discharge the battery pack with the same USB Type-C port. The BQ25756 can buck and boost in the reverse direction for discharging from the battery pack, regardless if the V_{OUT} in reverse mode is smaller or greater than the battery pack voltage. This feature allows consumers to charge accessories such as laptops and speakers from battery packs for products such as portable power stations and e-bikes using the USB Type-C port.

The BQ25756 comes with MPPT for solar charging applications, with three improvements:

- Autonomous start.
- A full VIN sweep.
- A perturb and observe feature.

The autonomous MPPT can run with default settings, or you can customize features of the MPPT with I2C, such as the time between MPPT algorithm cycles. Once the MPPT algorithm ends, the timer restarts and begins a new cycle once the time you have chosen runs out. During the algorithm, the charger does a global sweep of the V_{IN} to find the absolute MPP. As shown in **Figure 8**, having multiple solar panels in series or in parallel can result in multiple peaks that you can choose as the MPP. In order to find the true MPP, the algorithm must traverse every peak. The BQ25756 sweeps all of the V_{IN} values to find the maximum MPP, even if there is more than one peak.

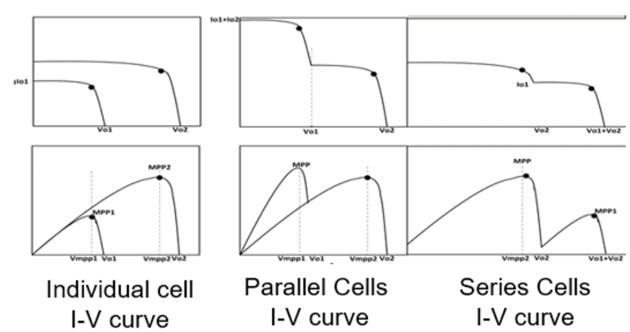

Figure 8. *Solar-cell curves with more than one peak.*

Conclusion

With the increase in larger applications using rechargeable batteries, it is now possible to design applications that:

- Support input power for the USB PD EPR standard.
- Optimize the charging and discharging of multicell battery applications with USB Type-C.
- Facilitate solar compatibility for on-demand charging from anywhere.

The convenience of using the same USB Type-C port and the new USB PD EPR enable larger battery devices such as vacuums, e-bikes and power banks to charge with USB Type-C In addition, having a bidirectional power flow charger allows battery pack charging and discharging from the same USB Type-C port. This functionality can turn any battery pack into a power bank. Finally, a battery charger that can take solar panel input and MPPT enables applications that consumers can charge from anywhere.

The BQ25756 – combined with a TI PD controller such as the TPS25750 – can help you design diversified rechargeable battery applications. The advanced MPPT algorithm in the BQ25756 finds the MPP for solar panels based on current light levels to help optimize the solar charging experience.

References

- **Battery charger fundamental videos**

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