

White Paper

Understanding USB-C Buck-Boost Battery Charging

Introduction

When Apple unveiled their new MacBook on April 10, 2015, it opened a new era in power management for computing devices. The new MacBook features a USB-C™ port—a true all-in-one port capable of delivering bi-directional data and power at the same time. This technology eliminates the MacBook’s MagSafe charging port by integrating the charging function into the USB-C port.

Now, with the release of the 6th Gen Intel® Core™ processors, a new generation of ultrabook computers, tablets, 2-in-1s and external devices are ready to hop on the USB-C charging bandwagon. However, adopting USB-C charging requires a fundamental change to the existing power delivery architecture and presents a new challenge to system designers.

This article examines the traditional PC power architecture and describes how it will change with the adoption of USB-C power delivery using reversible USB Type-C™ cable connectors. We’ll explore different battery charging approaches and explain how a USB-C buck-boost charging topology can provide the flexibility, high efficiency and small solution size designers require.

Computing Power Delivery Today

Charging electronic devices through a USB-A/B port is widely used in low-power applications, such as smartphones and tablets. The traditional USB-A/B port is capable of providing 5V power supply with up to 2A current capability. But this power level is insufficient for charging a high-power device, which is typically charged through an AC adapter with tens of watts power rating.

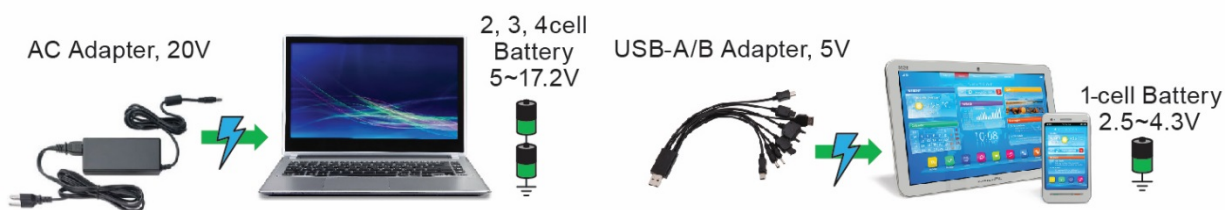


Figure 1. Existing power delivery architecture

Today’s typical computing power architecture is shown in Figure 1. It includes an AC adapter that converts AC voltage to a DC voltage and uses 20 volts to charge the main electronic device, in this case an ultrabook computer. The ultrabook may use different battery cell stacks ranging from a 1-cell battery to 4-cell batteries. Each Li-on battery has a typical operating voltage range of 2.5V to 4.3V, from discharged status to fully charged status. Therefore, the ultrabook may have a battery voltage range of 2.5V to 17.2V.

With a 20V DC adapter, the battery charger would use a so-called buck topology to step down the 20V DC to charge the battery. The ultrabook's 5V USB-A/B port is capable of charging an external USB device, such as a smartphone or tablet. To generate the 5V in the USB-A/B port, the ultrabook employs a similar buck topology to generate the 5V USB power rail from its internal 2-, 3- or 4-cell battery stack, or apply a boost topology if it has 1-cell battery stack.

The Move to USB-C

USB-C is changing the way we charge our electronics devices. It is a standard interface that connects anything to anything. In addition to data transfer, USB-C also supports bi-directional power flow at a much higher level. With a default 5V voltage, the USB-C port is capable of negotiating with the plugged-in device to raise the port voltage to 12V, 20V, or another mutually agreed on voltage, at a mutually agreed current level. The maximum power a USB-C port can deliver is 20V at 5A current, which is 100W power—more than adequate to charge a computer, especially since most 15-inch ultrabooks require just around 60W of power. With such appeal, it is not hard to understand why electronic device makers are flocking to USB-C for their next generation products, with Apple leading the way by racing out with the MacBook last year.



Figure 2. New power delivery architecture based on USB Type-C connector plug

By moving to USB-C charging, the traditional power architecture will need to change when mobile system manufacturers transition to the USB-C port. Figure 2 shows how a USB-C port can connect anything to anything. The USB-C adapter with a 5V-20V range can charge a main electronic device, such as an ultrabook, which may use a 1-, 2-, 3- or 4-cell battery stack. These main electronic devices can also charge external electronic devices such as tablets, smartphones, power banks and more.

Different USB-C Battery Charging Approaches

A unique challenge in the new power delivery architecture is how to use 5V-20V adapter voltage to charge a 2.5V-17.2V battery, because there is no definite “input to output” relationship, which requires the buck topology, and no definite “output to input” relationship, which warrants the boost topology.

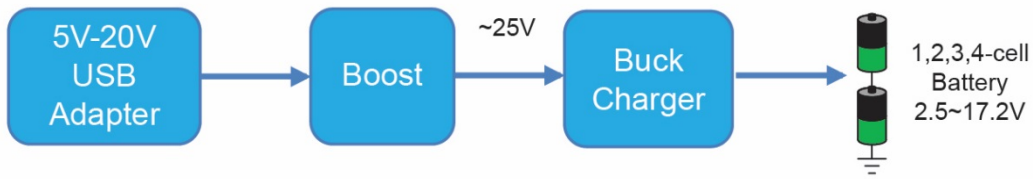


Figure 3. The pre-boost approach

Figure 3 shows an approach based on the pre-boost concept. This approach takes the USB adapter voltage and boosts it to a level higher than the highest USB adapter voltage, such as 25V, and then uses a buck charger to charge the batteries. This approach requires an additional boost converter, which increases solution cost and size, and reduces the overall efficiency due to the additional power loss in the pre-boost stage.

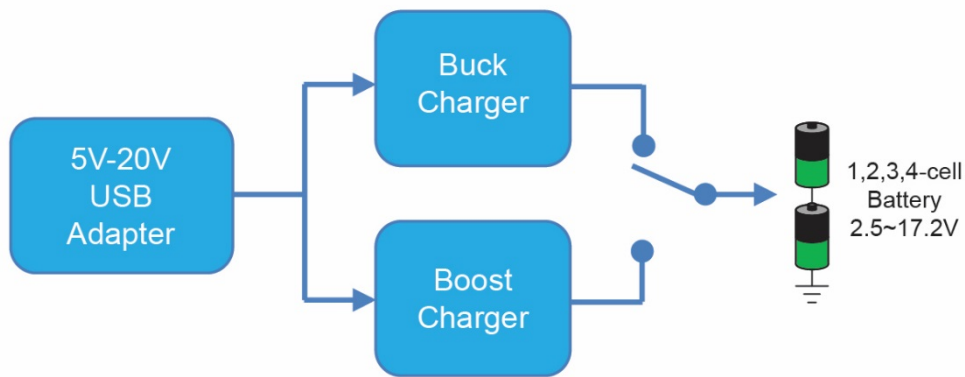


Figure 4. The buck charger or boost charger approach

Figure 4 shows an approach based on a buck charger or boost charger concept. It takes the USB adapter voltage and uses a buck charger or a boost charger, depending on the input/output voltage relationship. While this approach eliminates the additional power loss in the pre-boost approach, it still requires an additional boost charger, which adds solution cost and size.

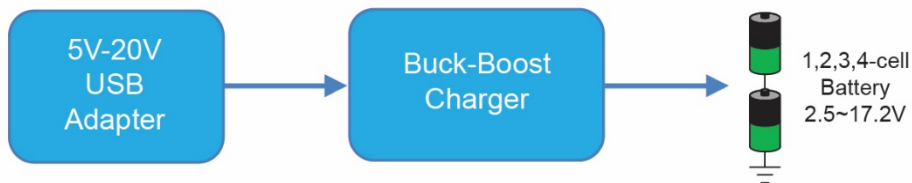


Figure 5. The buck-boost charger approach

Enter the buck-boost topology approach, as shown in Figure 5. A buck-boost topology can operate in buck mode when there is “input to output,” in boost mode when there is “output to input” or in buck-boost mode

when there is two-way “input \approx output.” Such flexibility allows for a better design with the smallest solution size and best overall efficiency. It achieves all of the system designer’s requirements.

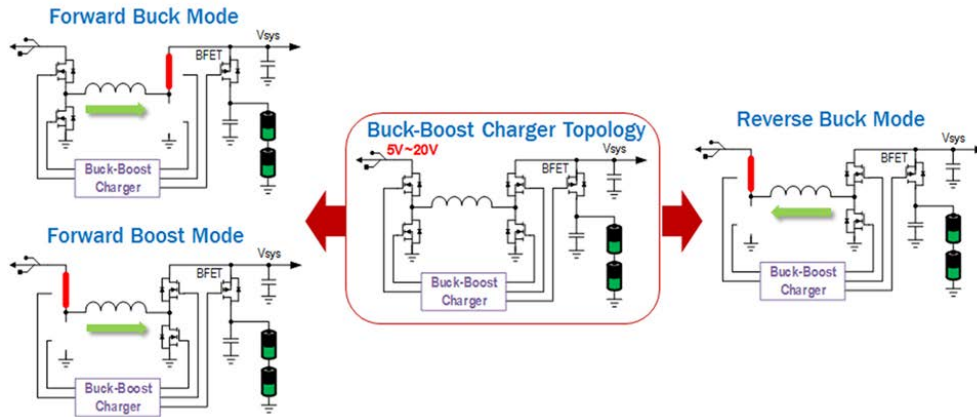


Figure 6. A buck-boost charger topology

The first USB-C buck-boost battery charging solution on the market is the Intersil ISL9237. Figure 6 shows the topology of the ISL9237 buck-boost charger. The device consists of four switching FETs and an inductor, as well as a battery connecting FET (BFET). The four switching FETs are grouped into a forward-buck leg and a forward-boost leg. By operating either leg, this topology can operate in forward buck mode or forward boost mode for charging the battery. It can also operate in reverse buck mode to deliver power out of the USB port for charging an external electronic device, such as a tablet, smartphone or the emerging portable power bank products that can charge any device.

The ISL9237 offers a rich feature set and is an SMBus charger capable of communicating with an SMBus host. It is compliant with USB 3.1 and the latest Intel IMVP8 PROCHOT# and PSYS requirements for protection against battery voltage drop, adapter over-current, battery over-current and overheating. It provides two-level adapter current limit with fully programmable magnitudes and durations to take advantage of the adapter’s surge current capability. It also supports external power banks and any travel adapter, including those that do not disclose their current handling capability.

Conclusion

With the arrival of the ISL9237 USB-C buck-boost battery charger, mobile PC systems and other portable devices will now be able to employ optimal two-way power delivery using the reversible USB Type-C connector. USB-C simplifies the way computers and external electronic devices deliver bi-directional power and data. The USB-C ecosystem is ushering in a future where just one tiny cable is needed for any device.

Next Steps

- [Learn more about the ISL9237](#)
- [Get the data short](#)
- [Watch a demo video](#)

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