August 2020

System for Identifying Optimal Transition Points Between Charge Tiers of a Battery Pack

AleX Pelosi

System for Identifying Optimal Transition Points Between Charge Tiers of a Battery Pack

Abstract:

This publication describes systems and techniques for identifying transition points between charge tiers of a battery pack in a portable electronic device. Portable electronic devices, including smartphones, are often powered by rechargeable lithium-ion or lithium-ion polymer battery packs. Electronic devices charge a battery pack using a series of constant-current stages and constant-voltage stages. It is generally desirable to remain in a constant-current stage as long as possible, but identifying the optimal transition point from constant-current charging to constant-voltage charging usually requires specialized hardware components that increase the cost of the electronic device. This publication discloses charging systems and techniques to accurately determine the transition point between charging states without additional or specialized hardware. The disclosed systems and techniques also provide information about the state-of-health and impedance of a battery pack.

Keywords:

Battery pack, lithium-ion battery, Li-ion battery, Li-ion polymer battery, charger, charging unit, charging device, pulse current, current pulse, constant voltage (CV), transition, constant current (CC), state-of-health (SOH), health state

Background:

Portable electronic devices, including video game controllers, smartphones, tablets, laptops, handheld video game consoles, and wearable devices, generally operate with a rechargeable lithium-ion or lithium-ion polymer battery pack. Electronic devices usually charge such battery packs by repeating two main stages: a constant-current stage and a constant-voltage stage. In a constant-current stage, the electronic device applies a fixed current, and the voltage across the battery increases. In a constant-voltage stage, the electronic device maintains a fixed voltage, and the current steadily falls to the current level for a subsequent constant-current stage. Figure 1 illustrates the voltage and current of a battery pack during a constant-current stage and a constant-voltage charging stage.

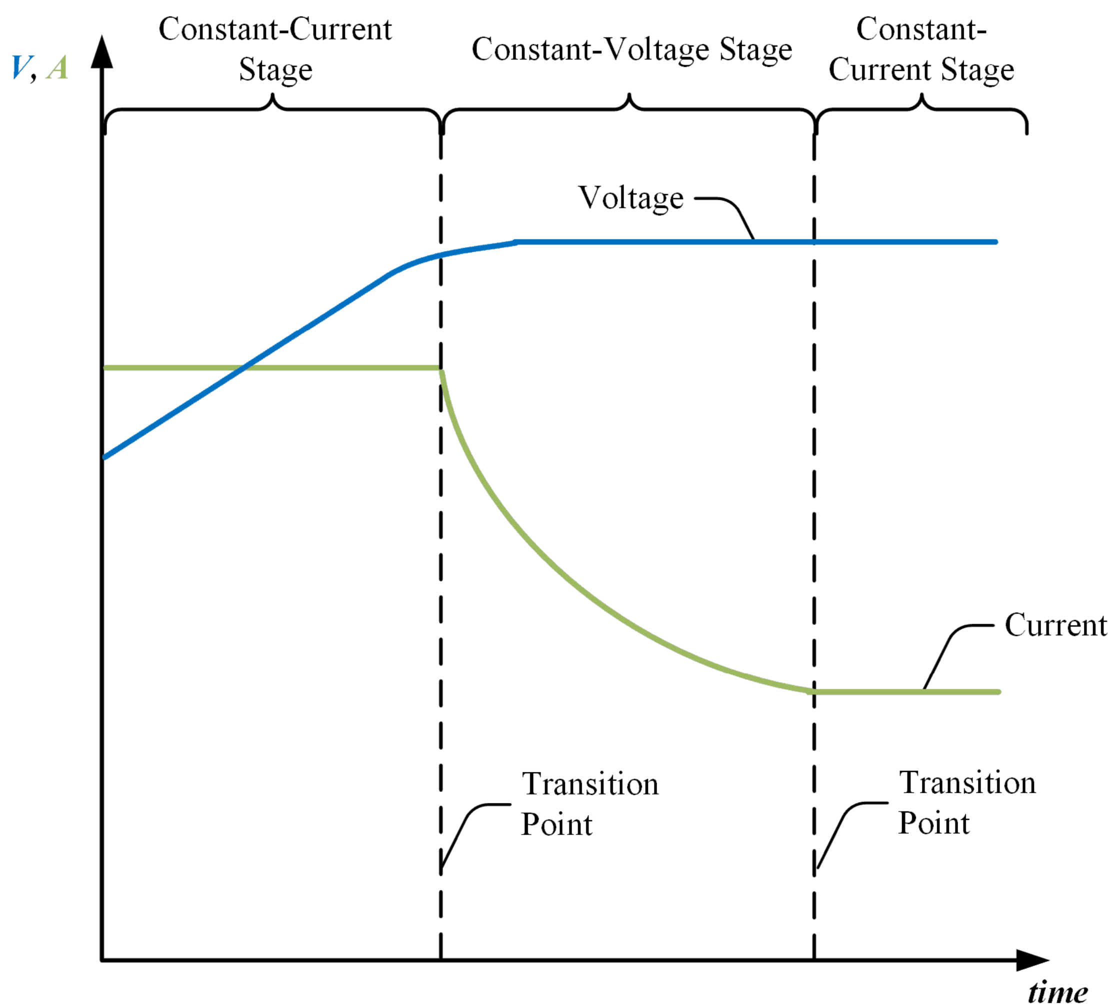

Figure 1

An electronic device can improve battery charging by maintaining the constant-current stage for as long as possible. Identifying the optimal transition point from the constant-current stage to the constant-voltage stage generally requires specialized hardware. Therefore, it is desirable to provide a technological solution to determine the transition point without incurring increased hardware costs.

Description:

This publication describes systems and techniques for identifying transition points between charge tiers of a lithium-ion or lithium-ion polymer battery pack. In particular, the described systems and techniques allow an electronic device to reduce the time a battery pack spends in a constant-voltage stage, wherein the current delivered to the battery pack decreases exponentially (as illustrated in Figure 1). The electronic device can also use the changes in the battery voltage to gain insights into the health of the battery pack.

The electronic device pulses the current at or near an expected transition from the constant-current stage to the constant-voltage stage. During the pulse, the electronic device monitors the change in the battery voltage to determine the end of the constant-current stage accurately. In particular, the electronic device monitors the charge state as the device enters the constant-voltage stage at a given charging voltage and cuts the charging current for a short, possibly variable, period (*e.g.*, milliseconds). The electronic device then resumes charging using a fixed current between the maximum current for the previous constant-current stage and the maximum current for the next constant-current stage. Figure 2 illustrates example current and voltage levels during the transition stage between constant-current stages.

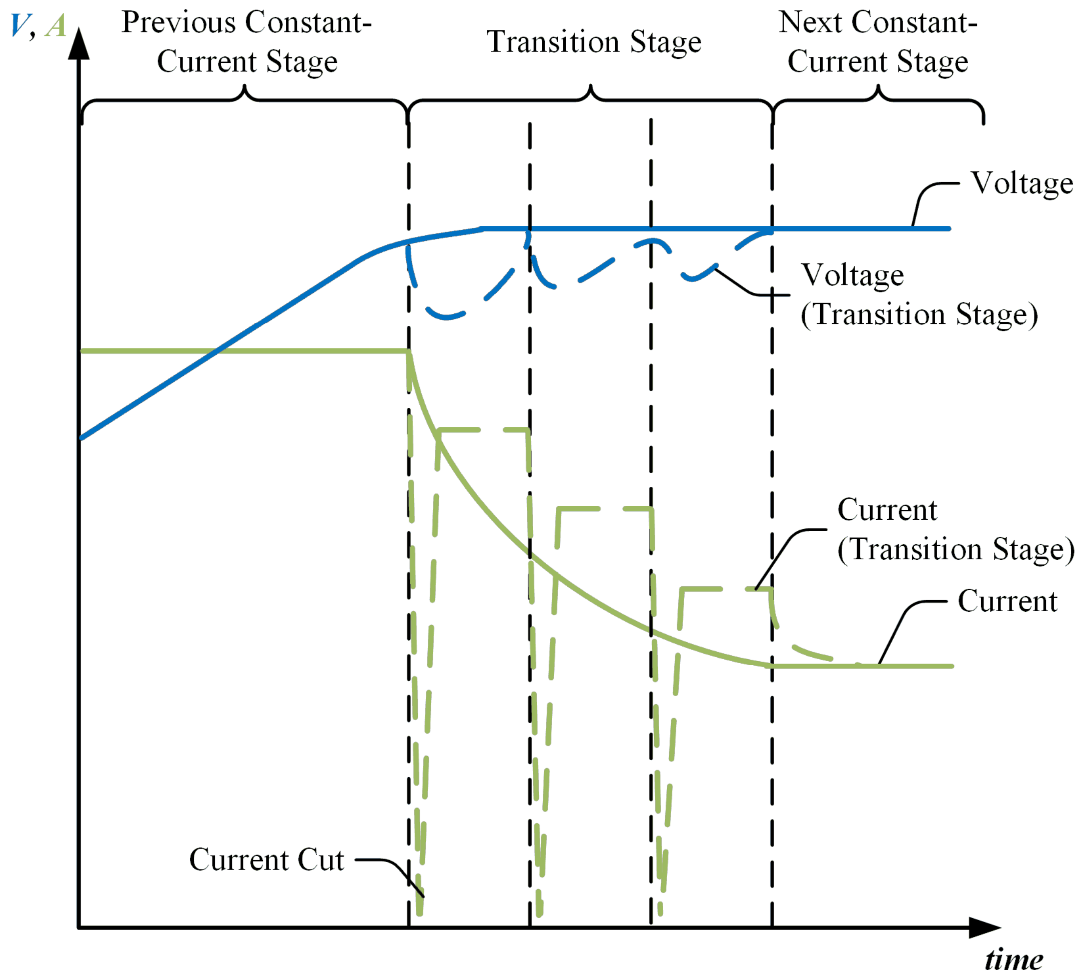

Figure 2

The current levels after the current cut in the transition stage can be determined in the following exemplary ways: (1) use the same current level as the previous stage, (2) use a current level that is a fixed proportion of the previous stage (*e.g.*, 75% of the previous stage), and (3) use a reduced current level based on a feedback loop (*e.g.*, based on the recovery amount, impedance of the battery, temperature profile of the battery). In comparison to a constant-voltage stage, an electronic device that uses current pulses during the transition stage can push an increased amount of current into the battery pack. The increased current is illustrated in Figure 2 by the area between the pulsed current line and the constant-voltage current line.

Figures 3 and 4 illustrate the behavior of a battery pack using aspects of the described systems and techniques. Figure 3 illustrates the battery behavior for several stages of a charge cycle, while Figure 4 illustrates a full charge cycle for a battery pack. The solid blue line illustrates the battery voltage; the solid green line illustrates the battery current. The purple line illustrates the trend line for the battery voltage in response to current pulses. As depicted, the change in the battery voltage decreases over time in response to the current pulses.

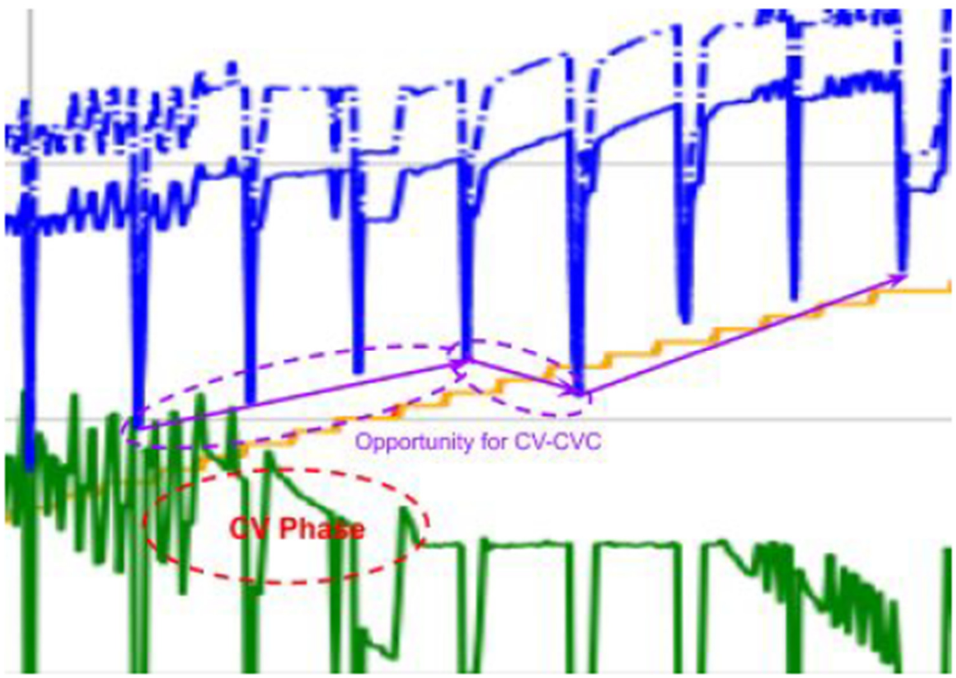

Figure 3

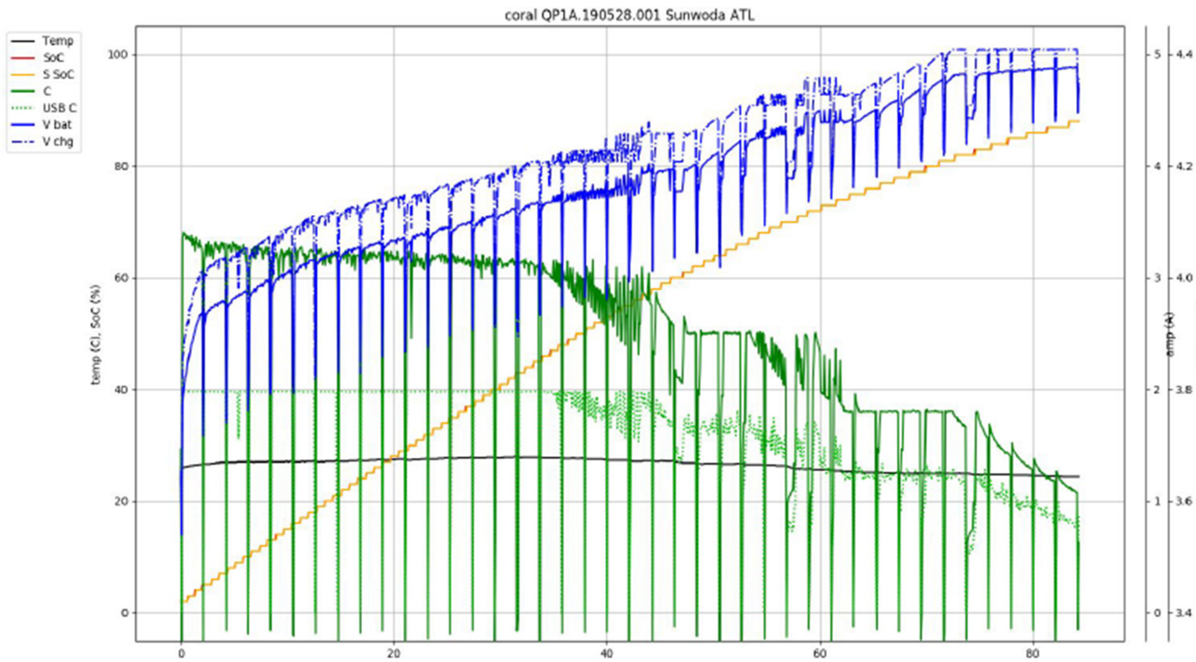

Figure 4

The described systems and techniques can also be used to determine the health of the battery pack. The electronic device can determine the internal resistance of the battery pack based on the drop in voltage when the current is cut and the current required to keep the battery pack under the current tier.

The described systems and techniques can accurately determine the transition point between charging states of a battery pack in electronic devices. In this way, an electronic device can push increased current amounts into a battery pack, thus reducing the charging time. The electronic device can also determine state-of-health information based on responses of the battery pack to the described current pulses.

References:

[1] Patent Publication: US20140184173A1. Battery charging method and circuit. Priority Date: December 30, 2011.

[2] Patent Publication: US20130241494A1. In-situ battery health detector and end-of-life indicator. Priority Date: October 19, 2009.

[3] Patent Publication: US20130314054A1. Context aware battery charging. Priority Date: November 25, 2010.