Application Note

Multi-Chemistry Charger in Low Battery Power Applications

ABSTRACT

Portable devices have benefited from advances in battery technology more than any other product category. The technology has made different battery chemistries available with different charging profiles. In this application note, we explore the common chemistries used in portable applications, tradeoffs in selecting these chemistries, and typical charging profiles.

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1 Introduction

This application note focuses on four types of battery chemistries that are commonly used in low power applications and readily available:

1. Li-Ion – widely used, light weight and high energy density, good fit for portable applications.
2. LFP (LiFePO4)- relatively new technology, long life, high peak currents.
3. NiMH – Mature technology, good availability, wide temp range, high peak current fast charge options.
4. Super capacitors – new option for power storage. High C value with low ESR, high peak currents, wide temp range.

The previos list shows benefits and liabilities that make them an excellent choice for low power applications. We have a number of charger options available in both linear and switching. For low power applications, linear battery chargers are a common choice due to ease of implementation and low parts count.

2 Li-Ion Overview

The Li-ion battery is widely used in portable applications for the high energy density vs. weight. Single cell voltage range is typically 3.0 V to 4.2 V which is high enough to reduce the need for a boost converter. The cell has a long life at 500 cycles before capacity drops by 80%.

The Li-Ion cells are sensitive to overcharge, discharge, high currents, overheating and other conditions. To provide safe operation, a protection circuit module (PCM) is required which increases the battery pack cost.

Due to risk of overheating and thermal run away, a number of shipping restrictions and safety requirements apply to the cells transport.

While 18650 size is well known, flat pouch form factor is also widely available to provide better physical fit to the mechanical design.

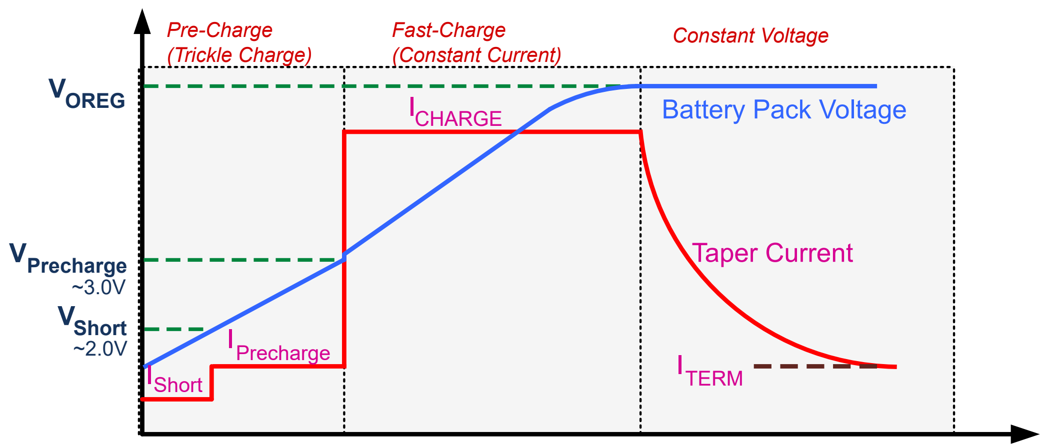

Figure 2-1. Typical Li-Ion Battery Charging Profile CC-CV

3 Li-Ion Applications

Li-Ion battery is used widely across all the market sectors from high power industrial applications, such as power tools, to low powered small solution size personal electronics applications, such as TWS (True wireless stereo) headsets.

The BQ25170 and BQ25175 are standalone linear chargers that are used for charging single cell Li-Ion battery with multiple different voltage settings via resistor the BQ25170 is available in QFN package which is used across industrial applications while the BQ25175 is available in WCSP package for space constrained applications.

Also available are the feature rich BQ25180 and the BQ25155 host-controlled chargers with integrated power path to prioritize powering system over charging the battery. The BQ25155 has integrated LDO as well as 16-bit ADC for battery monitoring. The BQ25180 can support peak discharge currents up to 2.5A for some of the industrial applications with motors as a load.

4 LiFePO4 Overview

The Lithium Iron Phosphate Battery(LFP) is a relatively new type and has a chemistry similar to Lithium Li-ion battery. LFP advantage is the longer life and higher number of charge cycles, 4X or 2000 vs 500 for Li-Ion. The chemistry has a higher degree of chemical stability with a reduced risk of thermal run away which makes them safer.

LFP has lower cell voltage 3.6 V to 2 V results in lower power density. This can require a boost converter or two cell configurations for some applications.

While risk of thermal runaway and fire is much lower with LFP, shipping restrictions are the same as Li-Ion due to lithium and risk of fire.

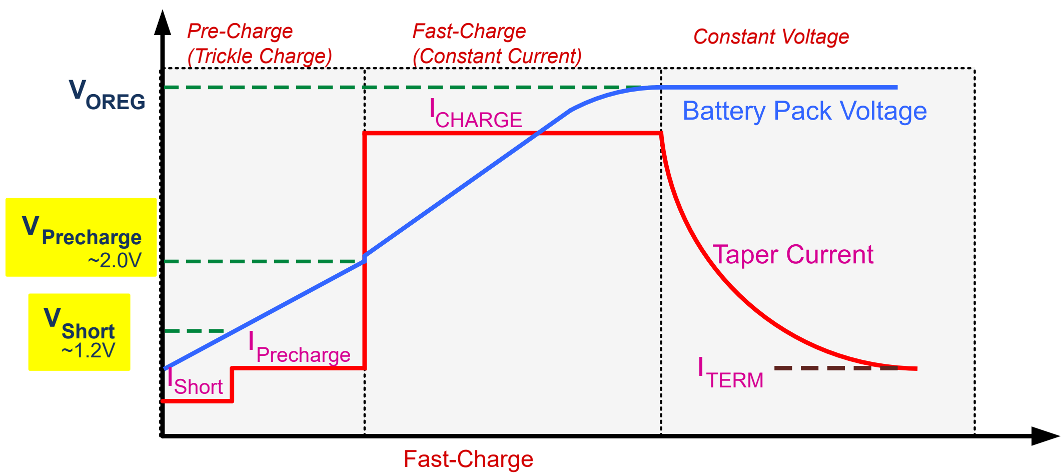

Figure 4-1. LiFePO4 Charge Profile

5 LiFePO4 Applications

Applications require longer life cycle and higher current whereas weight and size are less critical are good applications for LFP.

Higher discharge current capability of the LFP makes them a good fit for portable power tools, motor driven devices and other peak power applications.

Larger multi-cell configuration is equivalent to 12 V lead acid batteries. A 4-cell LFP configuration, 12.8 V is an alternative to a 6-cell lead acid battery, 13.6 V. This makes application in electric vehicles and UPS systems possible.

The BQ25170 can support both LiFePO4 and Li-ion single cell configurations via single resistor programmability option. The BQ25180 and BQ25155 as mentioned earlier are both host-controlled chargers, and battery voltage can be set via MCU to support LiFePO4 battery charging. The BQ25171-Q1 on the other hand can support up to 2 cells of LiFePO4 in series. The BQ25180 and the BQ25155 have shutdown IQ of 10 nA to extend the battery's shelf life, and the BQ25170 and BQ25171-Q1 has Battery only IQ of 350 nA to extend the operation of the battery and extend the battery's run time.

6 NiMH Overview

NiMH battery chemistry is a mature technology and readily available. These type of batteries are lower cost than lithium-based batteries and available in a number of sizes and capacities. Charging options are flexible with fast charge that can be over 1C (1hr or less) or low rate charge (reducing system power supply demand and simpler charger designs). NiMH is capable of high current discharge applications, 2C is common and higher is because the internal impedance is lower.

Discharge at as low as -40 degC is possible with some types of NiMH battery.

Limitations are self-discharge of about 1% a day requires a refresh or topping off charge to bring the cells back up to full charge. This feature is incorporated into a number of chargers.

NiMH has lower cell voltage of 1.2 V and typically requires multiple cells in series. Common configuration is 3 to 4 cell reach voltages similar to Li-Ion single cell.

NiMH cells are non-flammable with fewer shipping restrictions.

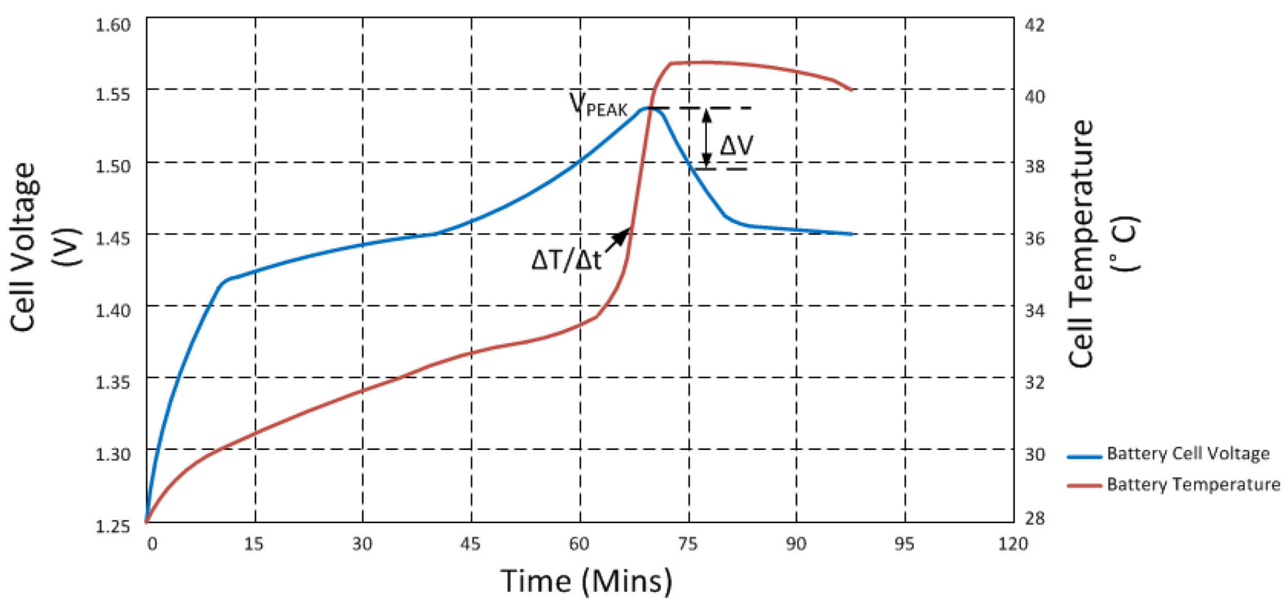

Figure 6-1. NiMH Fast Charge Profile

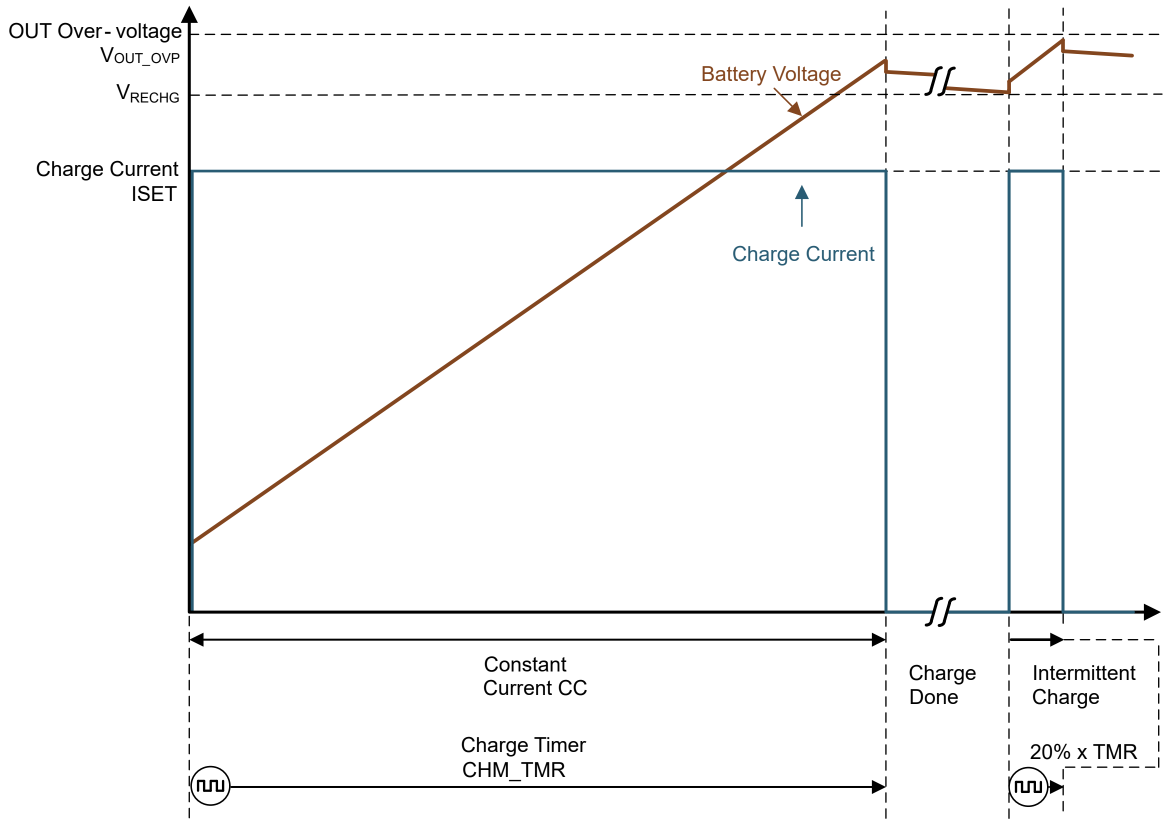

Figure 6-2. Timer Based NiMH Profile

7 NiMH Applications

Similar applications as previously discussed apply to NiMH batteries. The advantage of higher peak currents and lower operating temp expands the options. If we were to look at a battery back up applications using NiMH then a timer based charge profile can work well. Low charge current for larger cells that can support higher current for the application.

The BQ25171-Q1 and BQ25172 support NIMH timer based charge with timer options from 4 to 22 hr. Below is a typical charge profile without recharge feature.

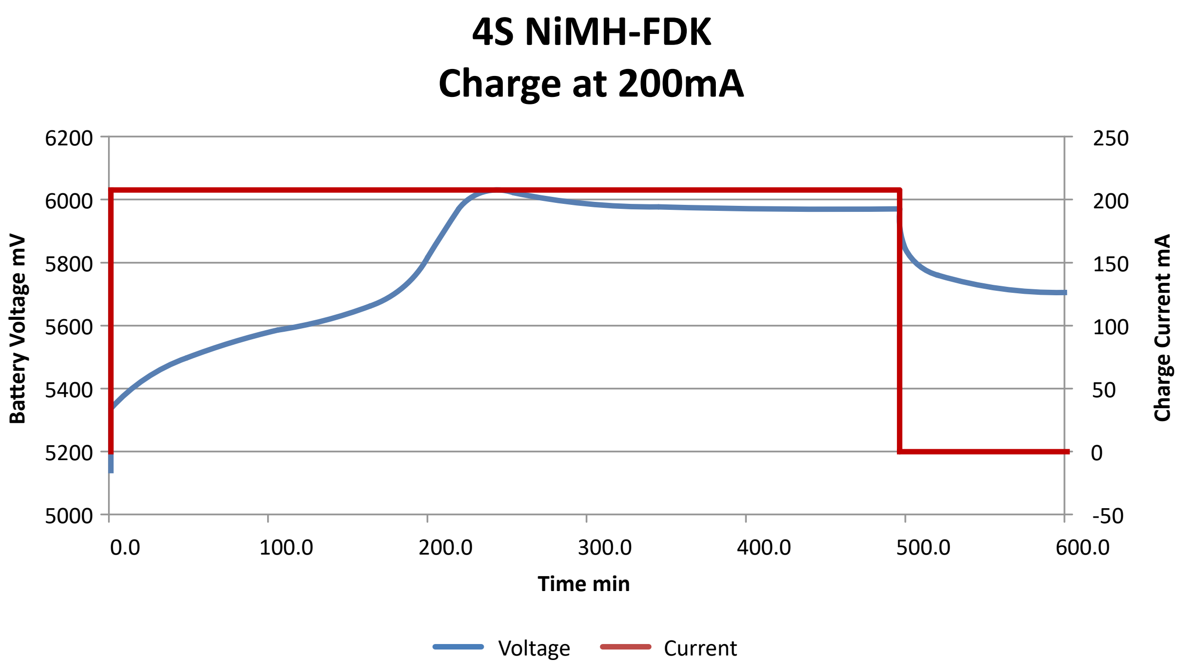

Figure 7-1. BQ25171 NiMH Charge Profile with 4 S FDK HR-AAULT Cells. 8 hr Timed Charge at 200 mA

8 Super Capacitors

Super Capacitors are relatively new options for power storage. Capacity of the devices have increased and ESR has decreased making them competitive with the other battery chemistries in some applications.

Super Capacitors are long life without wear-out factors and can be discharged to 0 V without degradation. Operation over a wide temp range is possible. Charging is flexible, can fast charge with high current or trickle charge, only voltage regulation is required.

Typical capacitor max voltage is 2.7 V and series capacitors can be required for higher voltage with possible cell balancing.

Energy storage vs. volume is low compared to other chemistries. Voltage on capacitor changes sharply with SoC, steep discharge curve. This requires a converter to provide stable output voltage as charge changes. No shipping restrictions for Super capacitors.

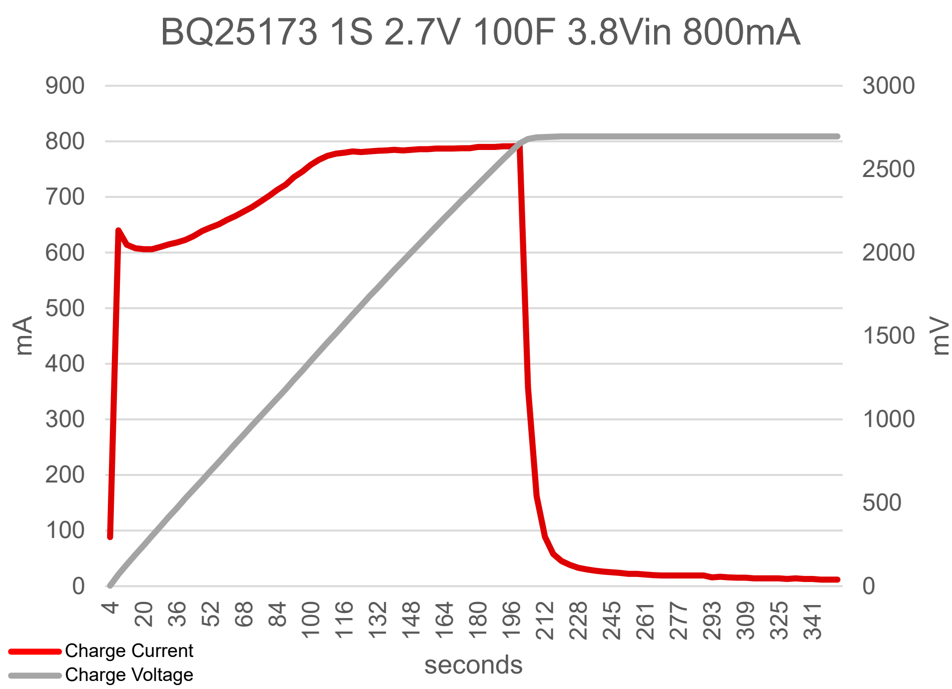

Figure 8-1. Super Capacitor Charge Profile

The typical constant current charge profile increases capacitor voltage at a linear rate followed by a voltage regulation phase, see Figure 8-1.

Note the current reduction due to thermal regulation of the BQ25173. This is a protection feature when power dissipation on device is high, see data sheet for more information on this feature.

9 Super Capacitor Applications

Super capacitors are usually used in applications where last second functionality is required when the main power is lost. For example, sending data over communication modules in data concentrator applications. Other applications such as barcode scanner which requires quick charge and discharge when cashier removes the scanner from the cradle for checking out a customer is also a good fit for super capacitors.

The BQ25173 is a simple to use linear charger for super capacitors that can charge 1-4 cell super capacitors in series from 0 V at charging currents up to 800 mA. The BQ24640, on the other hand, is a switching charger controller that can charge 1 to 8 S supercap with up to 10 A charging current.

10 Summary

Applications for battery products have increased sharply and designers have options on which battery chemistry to use. The variation of different charging requirement for different type of battery chemistries drive another design decision for designers. TI can support your battery-charger requirements with a number of devices.

Table 10-1. Low-power Multichemistry Charging | Trade-offs

	Li-ion	$LiFePO_4$	NiMH	Supercapacitor
Energy density	High 150 to 180 Wh/kg	Medium 90 to 120 Wh/kg	Low 60 to 120 Wh/kg	Low 4.5 Wh/kg
V(nom)/cell	3.6 V	3.2 V	1.2 V	2.7 V
V(charging)	3.9 V to 4.2 V	3.5 V to 3.65 V	1.4 V to 1.6 V	2.7 V
Area	Low	Medium	High	High
Price	High	Medium	Low	Medium
Benefits	• High energy density. • High voltage/cell at 3.6 V can lead to single-cell use and space savings. • Long lifetime.	• High current rating. • Long cycle life. • Good thermal stability. • Safer Li-ions: enhanced safety/tolerance if abused. • Tolerant to full charge conditions.	• Reliable and durable. • Safe: Overcharge and discharge do not create high temperatures. • More cost-effective.	•Safe: No volatile chemicals; overcharge and discharge do not create high temperatures. • Long life, no wear-out mechanism.
Limitations	• Fragile: requires protection circuit for safe operation. • Peak voltage limited during charge. • Temperature needs to be monitored.	• Lower voltage of 3.2 V/cell. • Higher self-discharge, which can cause balancing issues with aging.	• Quick self-discharge; needs to be charged more frequently. • Lower voltage (1.2 V/cell) requires multiple cell packs and larger solutions.	• Voltage will have large change with discharge, SoC. • Low cell voltage will require series cell and possible balancing circuit.
Charge temperature	0°C to 45°C	0°C to 45°C	0°C to 40°C	–40°C to 65°C
Discharge temperature	–20°C to 60°C	–20°C to 60°C	0°C to 50°C –20°C to 85°C possible	–40°C to 65°C

11 References

For additional resources and information:

1. Texas Instruments, Battery Management ICs overview page
2. Texas Instruments, Battery Charter Ics. overview page
3. Texas Instruments, BQ25171 Automotive, 800-mA Linear Battery Charger for 1- to 2-cell Li-ion, LiFePO4, and 1- to 6-cell NiMH data sheet
4. Texas Instruments, BQ25170 800-mA Linear Battery Charger for 1-Cell Li-ion and LiFePO4 data sheet
5. Texas Instruments, BQ25172 0.8-A, One- to Six-Cell NiMH Stand-Alone Linear Charger in a QFN package data sheet
6. Texas Instruments, BQ25173 800-mA Linear Charger for 1-Cell to 4-Cell Supercapacitor
7. Texas Instruments, BQ24640 Standalone 1-8 cell Buck Battery Charge Controller for Super Capacitor data sheet