

John B. Goodenough, considered the father of lithium-ion (Li-ion) batteries, became the oldest Nobel Prize winner when he was awarded the Nobel Prize in Chemistry in 2019 for his pioneering work. Nowadays, Li-ion batteries are utilized in all aspects of life for most consumers since they make electronic devices lightweight and long-lasting. For example, most mobile phones rely on a Li-ion battery for longer runtimes, portability, and convenient charging.

It is important to efficiently charge Li-ion batteries for maximum use.

How to Charge Lithium-Ion Batteries

First, let's analyze the Li-ion battery charging process. The charging process can be divided into four different stages: trickle charge, pre-charge, constant-current charge, and constant-voltage charge. Figure 1 shows the charging curve of a typical lithium-ion battery.

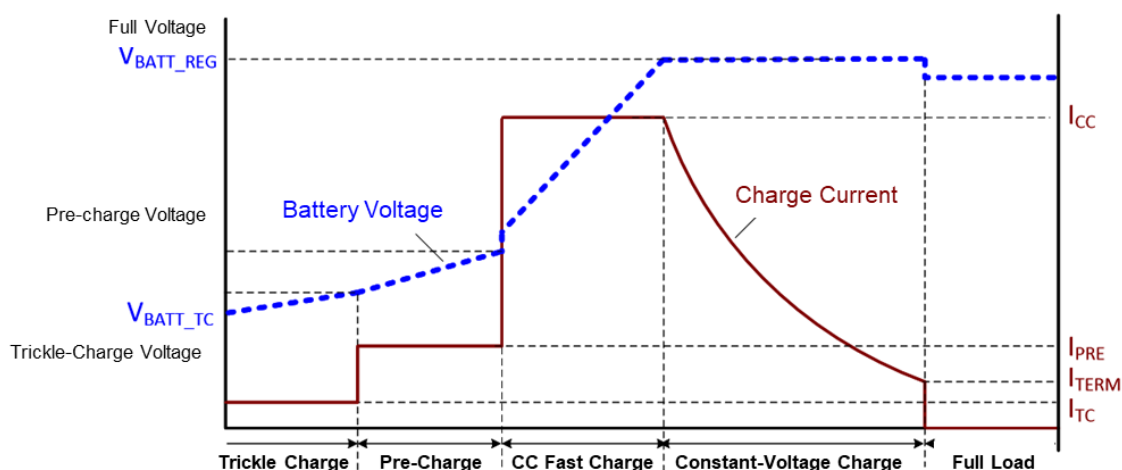


Figure 1: Lithium-Ion Battery Charging Curve

It seems simple, but there are many parameters to consider when choosing a battery charging solution. Figure 2 shows the four main considerations when selecting a solution.



Figure 2: Battery Charger Design – Key Considerations

These considerations are described in further detail below:

Topology

Battery charger system designers must choose the topology based on input voltage range, battery configurations, charging currents, and other system-level priorities (see Figure 3).

How many batteries are connected in series?

Input voltage range?

Charging power?

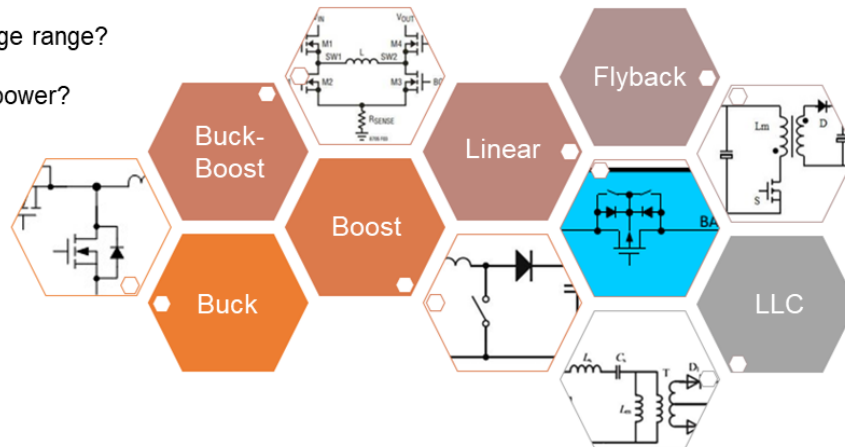


Figure 3: Battery Charger Topologies

For example, most portable devices charge from a USB port. There are two main USB types:

- USB Type-A: Usually 5V at a 1.5A maximum, this USB type can support fast charging (among other standards) up to 12V
- USB Type-C: 5V at 3A maximum. If USB-PD is supported, this can be increased to 20V at 5A

If the device is charging via the USB port, it must always support 5V operation. For example, for batteries in series (maximum $V_{BATT} \geq 8.4V$), use boost or buck-boost topology. If the device is not charging from a USB port, it is recommended to use buck topology because the input voltage always exceeds the battery voltage.

Control Loops

A major challenge for battery management ICs is that they have multiple control loops. Not only do they need to manage the input voltage and current, they must also manage the system's power, battery charging current and voltage, battery temperature, and other parameters (see Figure 4). For example, the system often has to adjust battery charging current according to the battery temperature.

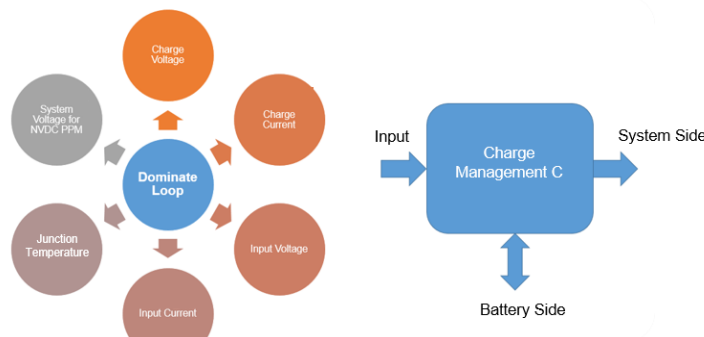


Figure 4: Various Control Loops in Battery Charger IC

Power Path Management

The power path management control loop adjusts the battery charge current dynamically, based on the input source current capability and the system load current requirements. This ensures that the system receives the required current while using excess charge to charge the battery.

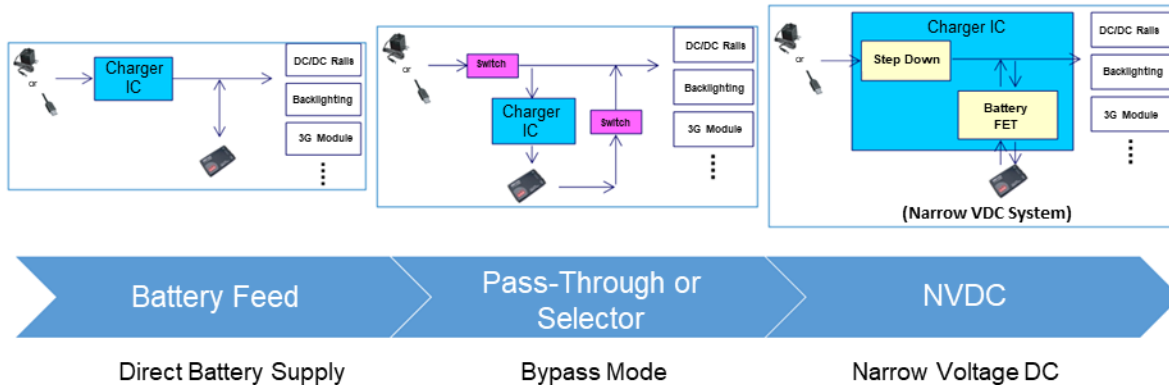


Figure 5: Battery Charger System Architectures

Depending on the battery charger features, there are three typical architectures.

The first architecture connects the battery directly to the system supply, and requires the battery voltage to reach the minimum system voltage to operate.

The second is the pass-through approach, which uses external switches to manage the battery charging and system paths.

The third architecture is NVDC power path management, which is a common approach that has the following advantages over the previous two architectures:

- The system can start instantly, even with a low battery voltage
- The system voltage closely follows the battery voltage to reduce the voltage stress of the system components
- When the input power is limited, the battery can supplement the system
- The system can be disconnected from the battery to support transport mode

Figure 6 shows the NVDC charger charging curve operation.

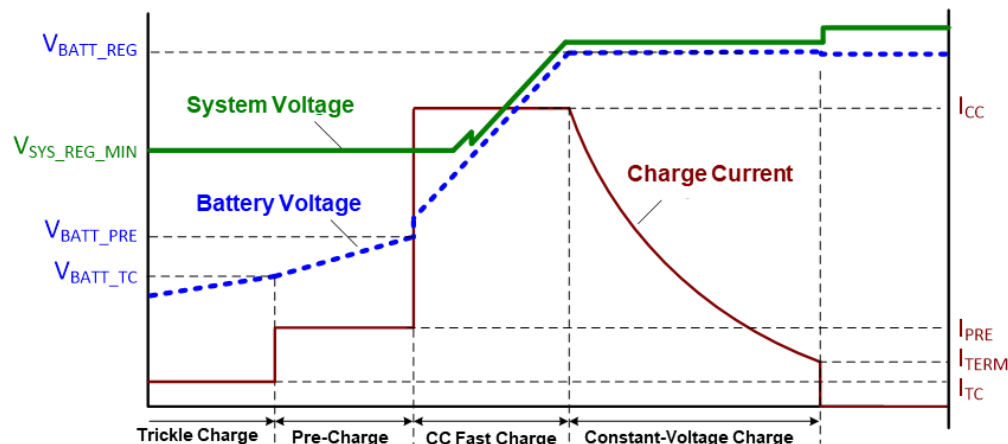


Figure 6: Li-Ion Charging Curve with NVDC Features

When the battery voltage is relatively low, the system voltage is regulated at the lowest operating point (VSYS_REG_MIN in Figure 6). When the battery voltage approaches VSYS_REG_MIN, the battery and system voltages closely track each other. Therefore, regardless of the state of the battery, the system voltage is always maintained in a narrow range. Figure 7 shows real-world scope plots.

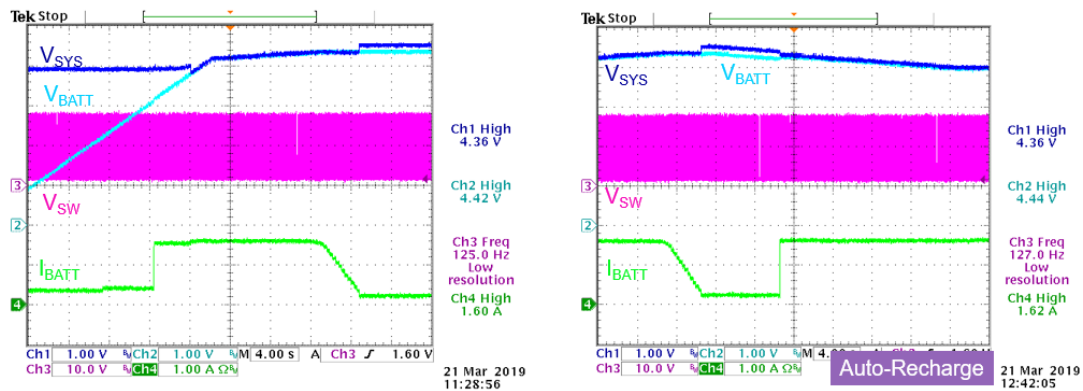


Figure 7: Typical Charging Curve (Working Conditions: V_{IN} = 16V, V_{BATT} Ramping from 0V, I_{CHG} = 1.84A, I_{sys} = 1A)

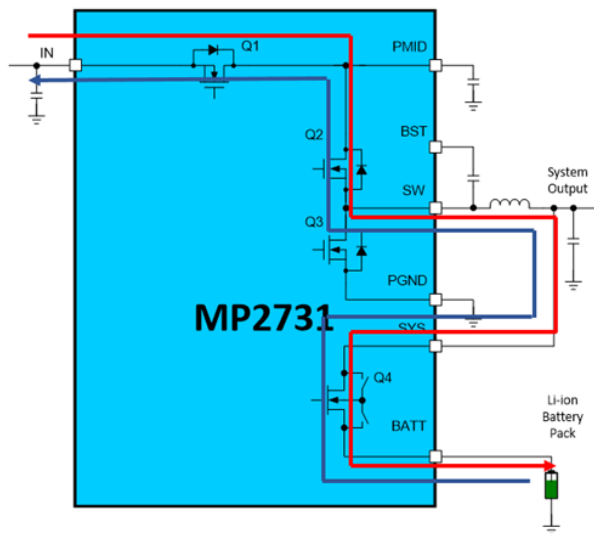
Reverse Operation

The battery charger operations discussed above have used the input source to charge the battery or power the system. It is also possible to provide operation in the reverse direction, such as USB On-the-Go (OTG) function. A battery charger with USB OTG functionality allows the device's internal battery to power devices back through the device input port.

MP2731 Battery Charging IC

If your application requires NVDC power path management and OTG function, the [MP2731](#) battery charger IC can perfectly meet your needs (see Figure 8).

MP2731 Family



Topology	➡	Buck
Power Path	➡	BFET for NVDC
Bidirectional	➡	OTG Mode
Loops	➡	Six + Two Loops

- Fully integrated power stage
- Supports fast charging and wide input voltage range
- USB DM/DP detection
- NVDC power path management
- Programmable NTC thermal protection
- Reverse OTG operation
- Supports transportation mode
- I²C control

Figure 8: MP2731 Schematic and Main Features

The MP2731 is a fully integrated battery charger that supports these modes and provides high efficiency, as well as impressive thermal performance (see Figure 9).

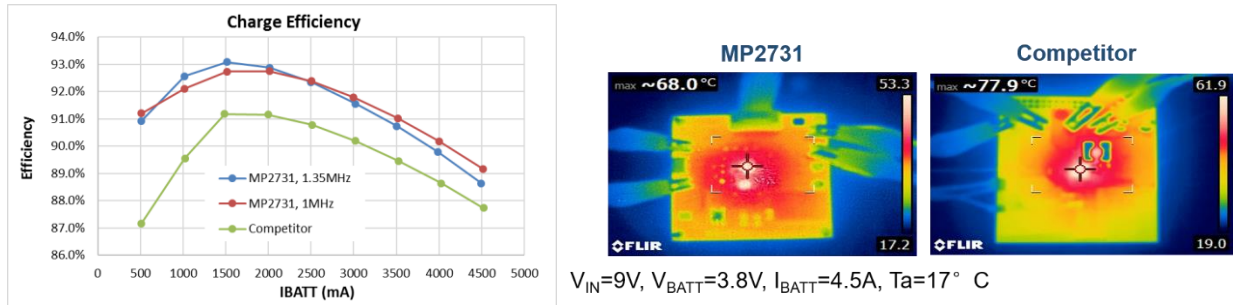


Figure 9: High Efficiency and Thermal Performance

As Li-ion batteries continue to be used in modern appliances and systems, it is vital to continuously evaluate how to make them more efficient and cost-effective. With so many architectures and chargers to choose from, MPS can streamline the process with products like the [MP2731](#).