

Optimize your application with a power path battery charger

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Introduction

With so many options for batteries and differing system requirements, it can be challenging to design the best battery charging integrated circuit (IC) to maximize battery lifetime and enable optimum system performance. The decision to choose a power path or non-power path battery charger can have a big impact on the functionality of your charging IC.

Figure 1 shows non-power path devices have one path for charging, in which the system and battery connect to the same node. This makes non-power path charging an effective option when you do not need to use the system and charge the battery at the same time, since you cannot control how much current is devoted to powering the system vs. charging the battery. Applications such as shavers or electric bikes are a good fit for non-power path chargers.

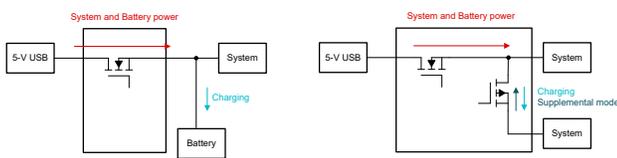


Figure 1. Non-power path and power path block diagrams.

Power path charging is a better option for products when both charging and use can occur simultaneously, since the integrated Q2 metal-oxide semiconductor field-effect transistor (MOSFET) in the battery allows you to customize the amount of current devoted to powering the system vs. charging the battery. This customization is also useful when a battery is deeply discharged. Because deeply discharged batteries are often charged with small currents, a power path device can independently regulate the system and battery current from the adapter

to provide small current into the battery, ensuring that the system is still getting the required power to turn on.

When there is high demand for system current while charging the battery, the Q2 MOSFET can also turn on to combine power from the input and the battery to support the system load. This feature is known as supplement mode, where the device will pull current from the battery to supplement the current from the input in case the system is pulling more current than what the input can provide. A typical application that would benefit from power path charger features would be a smartphone.

The following sections show how power path topology improves system performance and battery life.

Maximizing shelf life

A product can be in transit and on the shelf for months before its purchase by a consumer, who typically prefers to use the product right out of the box. With some countries adopting new shipping restrictions that restrict batteries to only a certain amount of charge before they're shipped, it is crucial to conserve every bit of battery capacity.

In a non-power path topology, the system has to go into a low-power mode, as the system connects directly to the battery. Low-power mode often imposes requirements for a load switch or some other way to isolate the battery from the system.

In the power path topology, the battery FET can disconnect the battery from the system in ship mode – that is the state in which the product is consuming the lowest battery current. Ship mode also prevents the battery from powering the system by shutting off the battery FET. Designing your charging IC with power path

and ship mode can enable instant turnon right out of the box when the consumer plugs in the adapter or presses the power button.

Performing a watchdog reset

In some scenarios, when the system processor or host is nonresponsive, a forced hardware reset or a power cycle might be necessary; you can accomplish this with a watchdog reset. For instance, on TI's BQ25180 charger device, a hardware reset is possible when meeting conditions such as:

- No I2C communication for 15 s or more after plugging in the adapter.
- The user pressed the reset button for an extended period of time.
- A duration >40 s from the last I2C communication.

During a hardware reset sequence, the charger IC disconnects the system from the battery and adapter (if present), waits for a configurable duration, and then turns the system back on, enabling system startup and initialization. Because the battery is physically connected to the system, an external load switch might be necessary in a non-power path charger device to perform a hardware reset.

Employing the full battery capacity

Getting the most battery capacity is a primary goal when designing a charger IC, since it translates to more time between charging for users. Inaccurate termination current (I_{TERM}) monitoring can lead to charge termination at values higher than the desired I_{TERM} value and prevent use of the full battery capacity, as shown in **Figure 2**.

Power path enables the most battery capacity with a higher-accuracy I_{TERM} . In a lithium-ion (Li-ion) charging profile, the charge current tapers down during the constant voltage phase until it reaches I_{TERM} and then shuts off. In order to maximize the battery capacity, it is important to have a low I_{TERM} and the ability to accurately measure low I_{TERM} values to precisely terminate charging. Power path enables accurate current

monitoring at low values by measuring the current passing through the Q2 battery FET.

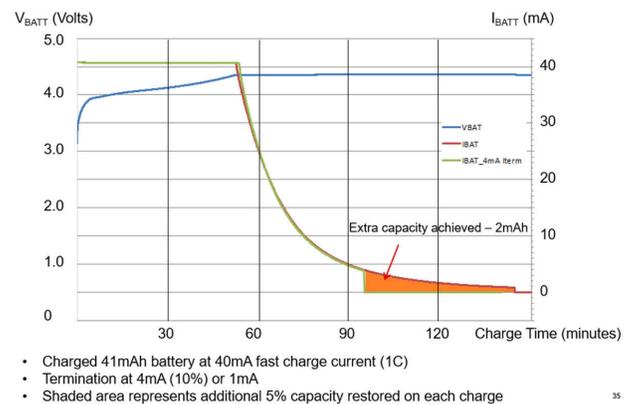


Figure 2. Extra capacity from a lower I_{TERM} .

Figure 2 also highlights how inaccurate I_{TERM} monitoring can lead to termination at 4 mA instead of 1 mA, which means that the user would lose 5% of the available 41-mAhr battery capacity. Because a power path charger regulates charging and system currents separately, any variations in system current will have no effect on the charging current. Charge termination can thus occur at a consistent pre-determined value, maximizing the battery's state of charge.

Using power path to enable accurate, low I_{TERM} is analogous to filling up a cup of water from a faucet. In the analogy, the cup is the battery, the water in the cup is the charge in the battery, and the water coming from the faucet is the charge current. The goal is to fill up the cup as much as possible without the water overflowing. It is much easier to do so by slowly decreasing the flow of water coming from the faucet as the water gets closer to the top, so that you can easily control the water level. Allowing the fastest flow from the faucet at all times will likely cause the water to overflow, or you will pull the cup away from the faucet before you've used all of the cup's capacity. Translating back into battery charger terminology, reducing the charge current (water from the faucet) to a controlled, measurable I_{TERM} allows the charger to fill the battery (the cup) with as much charge (water in the cup) as possible, without overcharging or undercharging the battery.

Minimizing battery fatigue

When a rechargeable battery is exposed to multiple charge and discharge cycles, its ability to power the system degrades, which can negatively affect its performance and run time. In order to maximize the lifetime of both the battery and the system, it is important to design the IC to limit the overall cycle count of the battery.

Figure 3 shows that the cell capacity of a Li-ion battery decreases as the number of recharge cycles increases. Designing a power path battery-charging IC enables you to maximize its lifetime by shutting off the battery FET – powering the system directly from the adapter and preventing the system from using the battery for power eliminates the need to discharge and recharge the battery. With power path, you can choose to power the system with only the adapter if the adapter is present, which reduces the number of recharge cycles on the battery and maximizes its lifetime.

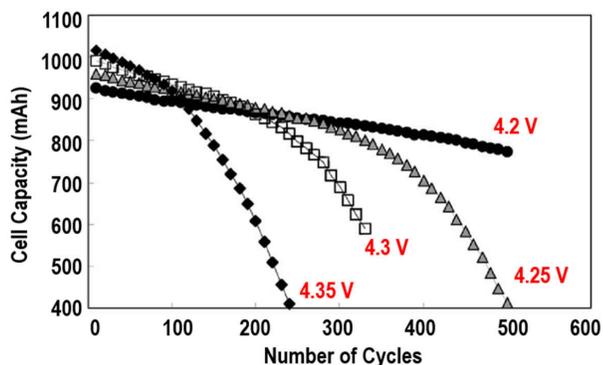


Figure 3. Li-ion cell capacity vs. number of recharge cycles.

Note

Factors that affect cycle-life and possible degradation mechanisms of a Li-Ion cell based on LiCoO₂,” Journal of Power Sources 111 (2002) 130-136 .

TI power path battery chargers

Linear chargers such as the **BQ25180** are useful in charge current applications <1 A. The BQ25180 comes equipped with ship mode to provide a low-power mode to conserve the battery. In ship mode, the battery quiescent current is only 15 nA, which is significantly lower than the 3- μ A battery quiescent current in the BQ25180’s normal operation. It is possible to program the BQ25180 to have an extremely low I_{TERM} of 0.5 mA, which helps charge the battery to its full capacity. Adjusting the I_{TERM} is simple, as it is a fixed 10% of the programmed fast charge current, and easily changeable through I²C communication. This charger also prioritizes system power with supplement mode.

The **BQ25620** is a switching buck charger that comes equipped with power path. Switching chargers are useful in applications that need a charge current >1 A, since switching chargers are better for higher-power applications. The BQ25620 can support up to 3.5 A of charge current. It also has ship mode for battery conservation, with 150 nA of battery quiescent current, while supplement mode optimizes system performance. In order to maximize battery capacity, the BQ25620 has an I_{TERM} as low as 10 mA and can be easily customized with I²C communication.

Conclusion

There are trade-offs between a power path or a non-power path battery-charger IC. Battery-charger ICs with power path provide additional functionality with the integrated battery FET: additional power modes such as ship mode to conserve the battery, full system reset capability to recover unresponsive hosts, and the ability to maximize both the battery capacity for longer run times and minimize battery fatigue. These types of charger ICs will help increase battery and system performance in applications that need simultaneous charging and system use.

Related Websites

- For an overview of the differences between linear and switching chargers, watch the video [Introduction to Battery Charger Topologies and Their Applications](#).
- The video [Fast-Charging Trends and Challenges for Single-Cell Batteries](#) has more details on charger battery safety features.
- To learn more about ship mode, read the technical article, [Pull the Tab: How to Implement Ship Mode in Your Lithium-Ion Battery Design](#).

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