DESIGN NOTES

Advanced Topology USB Battery Charger Optimizes Power Utilization for Faster Charging – Design Note 336

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Linear Technology offers a variety of parts to simplify the task of extracting power from a USB cable, including the new, easy-to-use LTC®4055 high performance Li-Ion charger and power controller. The LTC4055 seamlessly manages power flow between an AC adapter, USB cable and Li-Ion battery, all while maintaining USB power specification compliance.

Thanks to its sophisticated intermediate voltage bus topology, the LTC4055 charges batteries faster with less heat generation than a traditional charger-fed topology. Better yet, a typical LTC4055-based USB charger solution is compact and requires only 10 external components and $100mm^2$ of PCB real estate.

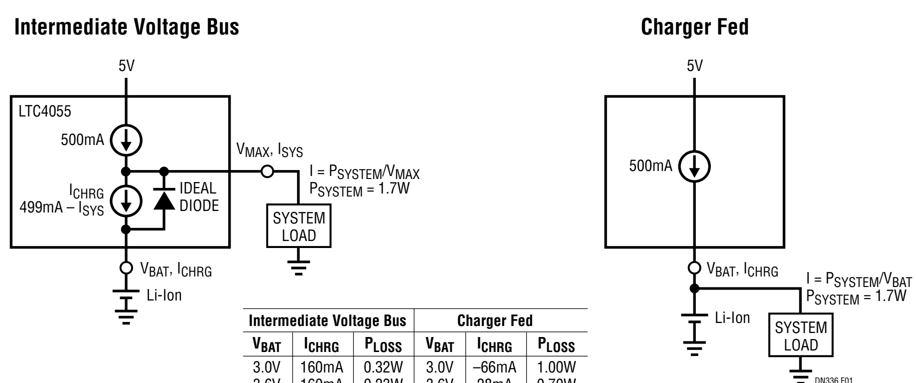
Benefits of the LTC4055

In order to fully appreciate the benefits of the LTC4055, let us first analyze the difference between the intermediate voltage bus topology and a charger fed topology. Figure 1 is a simplified block diagram of the two power topologies. In the intermediate bus voltage topology, the output called V_{MAX} is derived from one of the three available power sources—wall adapter, USB or battery. The system load, usually consisting of DC/DC converters, LED drivers or disk drives, is powered from V_{MAX}.

In order to simplify the analysis, the voltage drop of the input current source is assumed to be zero. The current drawn by the system is then the power required divided by the voltage input to the system. In the case of the LTC4055, that voltage is the highest of the adapter, USB or battery. Excess current, beyond what is required to power the system loads, is available to charge the battery.

In contrast, charger fed systems place the system loads in parallel with the battery. The voltage input to the system load is the battery voltage. The current drawn by the system is the power requirement divided by the battery voltage. Like in the intermediate bus voltage topology, excess current not required by the system is available to charge the battery.

Figure 1 shows these two topologies and compares their power losses at typical system loads and battery voltages. It is clear that the intermediate voltage bus topology has advantages over the charger fed topology. In the presence of system loads, the intermediate bus voltage topology is able to charge in situations where the charger fed topology would actually be discharging the battery. The intermediate bus voltage topology also reduces power losses in the LTC4055, which means less heat generation in the



Intermediate Voltage Bus			Charger Fed		
V_{BAT}	I_{CHRG}	P_{LOSS}	V_{BAT}	I_{CHRG}	P_{LOSS}
3.0V	160mA	0.32W	3.0V	–66mA	1.00W
3.6V	160mA	0.23W	3.6V	28mA	0.70W
4.0V	160mA	0.16W	4.0V	75mA	0.50W

$P_{LOSS} = (5 – V_{BAT}) \bullet 0.5A$

Figure 1. LTC4055's Topology Optimizes Power Utilization by Reducing Power Loss

system enclosure. In addition to these clear advantages, the intermediate bus voltage topology offers other more subtle benefits. For instance, the battery is isolated from the rest of the system—as long as system current draw is within limits, the system can run even if the battery is missing or deeply discharged.

Simple Circuit Automatically Selects the Best Power Source

Figure 2 shows a typical LTC4055 implementation. This charger provides power to the OUT (V_{MAX}) pin from the best of the three available power sources: wall, battery or USB.

Operation with Wall Adapter Present

If a wall adapter is present, it powers the intermediate V_{MAX} bus providing power to the system load and the battery charger. The battery, if present, is charged via the LTC4055 with a constant current, constant voltage, timer terminated charger. The charge current, when powered by an adapter, is programmable up to 1A. When the adapter is present, the $\overline{ACPR}$ status pin is pulled low. Pulling the SHDN pin high disables charging. The $\overline{CHRG}$ status pin is pulled low while the battery is being charged (timer has not terminated).

Operation with No Wall Adapter, but USB Available

If wall power is not available, but USB power is, then the USB power is switched through to OUT via a current limiting circuit in order to enforce USB current limit compliance. Like the case where a wall adapter is present, the voltage at V_{MAX} is used to power the system load and charge the battery. If the load does not completely use all the available USB power, then the extra power is used to charge the battery. As the system load increases, the battery charging current decreases enough to maintain USB input current compliance. If the load current exceeds the allowed USB current, battery charging ceases and the battery discharges through an ideal diode, internal to the LTC4055, into OUT (V_{MAX}). In this way, USB power provides what current it can, while the battery shoulders the rest of the load.

The maximum current drawn from the USB bus is simply programmed via a resistor. Grounding the HPWR pin reduces the maximum current draw by a factor of five, for compliance with the low power USB mode. Grounding the SUSP pin further reduces USB current consumption to 200µA, to comply with the USB suspend requirements.

Unplugged Operation

During unplugged operation, the LTC4055 minimizes power losses by supplying the system load through an "ideal" diode function. The device also maximizes battery run time by powering V_{MAX} through an ideal diode connected to the Li-Ion cell.

Conclusion

The LTC4055 uses an intermediate voltage bus topology to yield faster charging and less heating than less sophisticated charger fed systems. Further, its use greatly simplifies PowerPath™ control in handheld USB compatible products. The typical schematic of an optimized complete three-supply (wall/USB/battery) selection/charger system is shown in Figure 2.

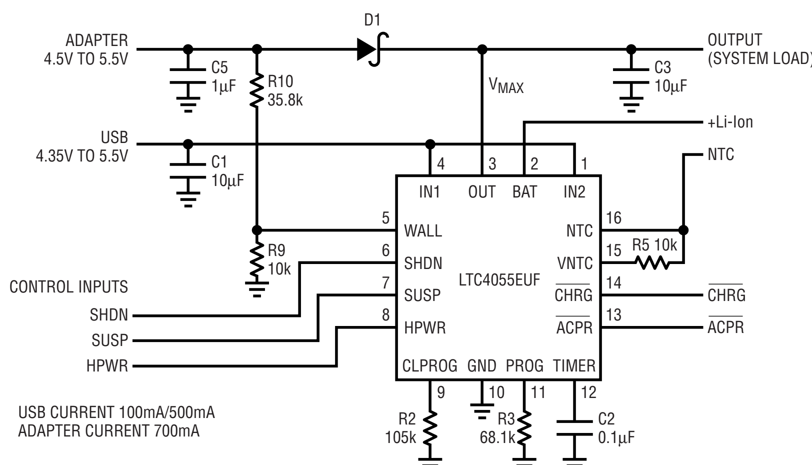


Figure 2. The LTC4055 Implementation Is Compact and Simple

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