Buck Boost vs. Buck Converter Battery Life for Portable 3.3V Micro Hard Disk Drive Applications

Introduction

Many of today's MP3 players, multimedia players, digital video recorders, and other portable electronic devices have found the micro hard disk drive to be the optimum device for memory storage requirements.

Given the Lithium-ion battery voltage range of 2.5V to 4.2V and the typical micro hard disk drive voltage of 3.3V, an obvious dilemma associated with this application is whether to use a low dropout DC/DC step-down (buck) converter or a step-down/step-up (buck-boost) converter.

A buck converter (Figure 1) provides the most efficient solution with the smallest external components, but drops out near 3.3V. At this point, the converter transitions to 100% duty cycle operation and tracks the battery voltage. A buck-boost solution has the advantage of regulating the output voltage over the full Lithium-ion voltage range, but suffers from lower efficiency and a larger total footprint. Additionally, most Lithium-ion batteries have a plateau from 3.5V to 3.6V and very little charge below the plateau, limiting the usefulness of the buck-boost converter and its wide input voltage range.

Theory

The buck-boost converter uses a four-switch configuration, operating as a buck, boost, or buck-boost converter. It has four power switches, only two of which switch at any given time, with a third that remains on continuously throughout the switching period (Figure 2). For a battery voltage greater than 3.6V, the buck-boost operates as a buck converter while, for an input voltage less than 3.6V, it behaves similar to a buck-boost or boost converter. Below 3.6V, the buck-boost converter input current increases beyond the load current, while the buck converter enters the 100% duty cycle dropout where the input current is limited to the load current and the output voltage tracks the input.

So, which converter will provide the best battery life for this application?

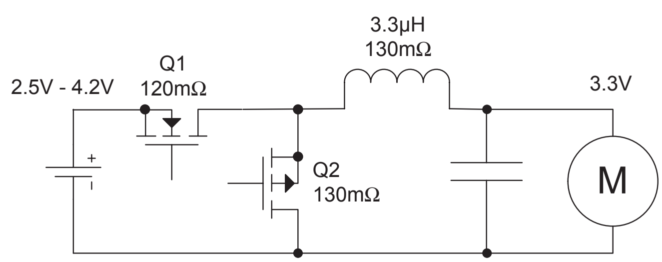

Figure 1: Lithium-Ion to 3.3V 1.3MHz Step-Down Buck Converter.

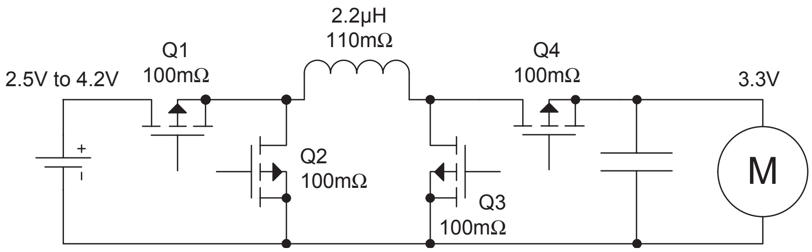

Figure 2: Lithium-Ion to 3.3V 1.5MHz Buck-Boost Converter (Buck: Q1 and Q2 Switching, Q4 On; Boost: Q3 and Q4 Switching, Q1 On).

Experiment

This application note examines the Lithium-ion battery life of both a multi-mode buck-boost converter and a buck converter for a 3.3V micro hard disk drive application.

An arbitrarily large converter would provide better efficiency and a longer battery life than a smaller converter, regardless of topology. Therefore, for a fair comparison with meaningful results, converters of equal size were tested. Both converters had similar power MOSFET $R_{DS(ON)}$ and inductor DCR resistance, resulting in roughly equal losses and battery discharge characteristics above 3.6V. Both converters also used a 3x3mm IC package with similar sized external inductors and capacitors, so that the total solution footprint area was the same.

The buck battery life was defined as the time required for the output to decay to 5% below the nominal 3.3V output. The buck-boost converter battery life was defined as the time at which the battery and converter shut down.

A fully charged battery was applied to the input of the converter and a constant current load was applied to the output. The battery and converter voltage were recorded at specific intervals until the battery was fully discharged.

	Buck Integrated Converter	4 Switch Buck Boost Integrated Converter
$R_{DS(ON)}$	125mΩ 3x3mm TDFN	2 x 100mΩ 3x3mm TDFN
Inductor DCR	3.3μH 130mΩ 3x3x1.4mm	2.2μH 110mΩ 3x3x1.4mm
Total	255mΩ	310mΩ

Table 1: Converter Characteristics.

Results

Throughout most of the battery discharge curve, both converters operate in a buck mode (Figure 3). This gives the performance advantage to the buck converter, which has one less power MOSFET in the power conversion process. Below 3.5V, the buck-boost converter input current increases (Figure 6). This increasing current, compounded with the characteristic increasing battery discharge rate, quickly discharges the battery below 3.5V (Figure 4).

In summary, the buck converter consistently displayed equal or better battery life. At 300mA, the buck output voltage remained within the 5% tolerance for up to nine minutes longer than the buck-boost. Additionally, the buck converter continued to operate in dropout mode, tracking the battery voltage for an additional four minutes. At 800mA, the battery life was identical for both converters. See the results in Table 2.

Output	Battery Life (minutes) Buck	Battery Life (minutes) Buck-Boost
3.3V @ 300mA	236	227
3.3V @ 800mA	77	77

Table 2: Battery Life Test Results.

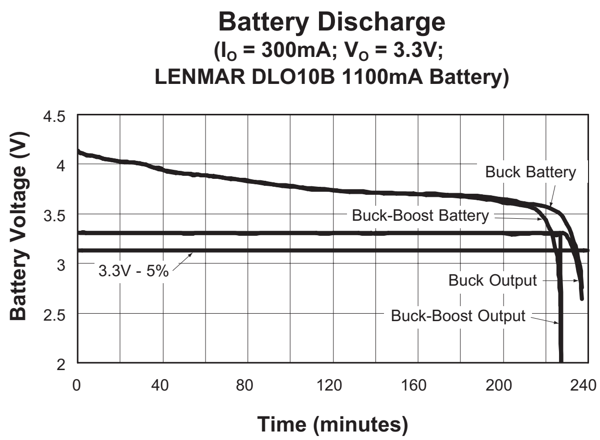

Figure 3: Lithium-Ion Battery Discharge.

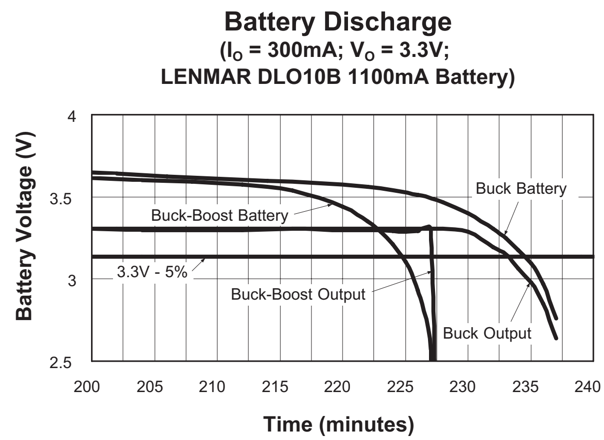

Figure 4: 300mA Lithium-Ion Battery Discharge.

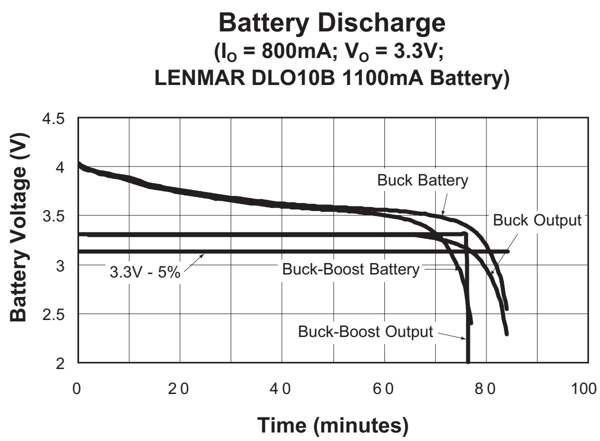

Figure 5: 800mA Lithium-Ion Battery Discharge.

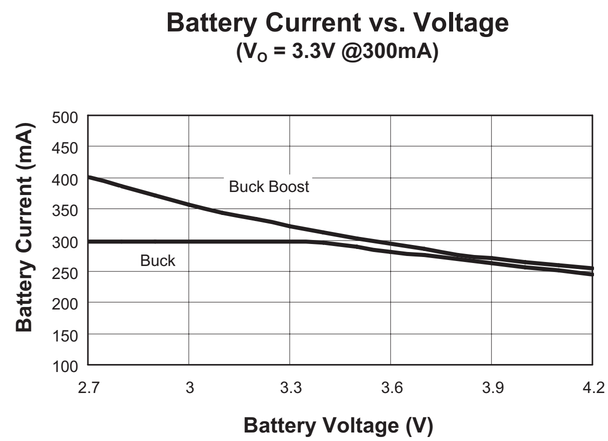

Figure 6: Lithium-Ion Battery Discharge.

Summary and Conclusions

Portable Lithium-ion applications that require 3.3V for a micro hard disk drive will not always show extended battery life when substituting a buck converter with a buck-boost converter. In this test, the buck battery life exceeded the buck-boost battery life by nine minutes when powering a 3.3V output loaded to a typical micro hard disk drive level of 300mA.

Due to the increased dropout voltage of the buck converter and the lower plateau voltage of the Lithium-ion battery, there was effectively no difference in battery life between the two converters at 800mA.

Most Lithium-ion batteries plateau at a voltage level sufficient for a buck converter to regulate at 3.3V throughout most of the battery life. Past the plateau region, very little battery charge remains, minimizing the advantage of a buck-boost converter's wide input voltage range. A battery with a plateau below 3.3V is better suited for a buck-boost converter and more likely to provide increased battery life for 3.3V applications.

When considering the type of converter best suited for battery life in an application it is important to evaluate the battery and converter characteristics (e.g., plateau, efficiency, etc.) at specific load conditions. Finally, laboratory tests help to provide real results that can help select the optimum converter for the application.

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