

White Paper

Preventing Subsystem Brownouts in Mobile Devices

Introduction

With the ever-increasing performance of application processors and GPUs used in mobile devices, the need for a buck-boost regulator to stabilize the Li-ion battery supply-voltage terminals is becoming more and more important. Buck-boost regulators prevent brownout, a condition where power is momentarily lost, by boosting the supply voltage during the notching period. When the battery voltage is high, the buck-boost regulator can step down the terminal voltage to a lower level to reduce the power losses at the downstream subsystem voltage regulator.

This white paper examines a typical power subsystem architecture used in mobile device designs and the rationale for employing buck-boost regulators. We look at some system efficiency calculations to demonstrate the benefit of using a buck-boost converter as a pre-regulator. And a high efficiency buck-boost regulator is shown to offer superior results when running mobile applications.

Supply Bus: Voltage Notching (Brownout) Prevention

All mobile devices have one thing in common: batteries power them. The batteries have an internal resistance that may result in a different voltage signature on their terminals when subject to a burst current discharge. The internal resistance levels vary with a battery's state-of-charge and are highest at a low state-of-charge. When a Li-ion battery is near the end of its discharge at around 3.4V, the internal resistance can be as high as 200m Ω . Thus, a 4A burst current can cause an 800mV droop at the terminal, pushing the bus voltage down to 2.6V. If the target LDO output is 2.85V, the LDO input will reach the dropout range and a momentary brownout condition occurs.

Mobile system PMICs typically use 20-30 LDOs dedicated to specific subsystems, such as Bluetooth, eMMC memory, micro SD memory, Wi-Fi, RF transceivers, and more. Figure 1 shows a typical system block diagram and bus voltage notching under a heavy burst current discharge.

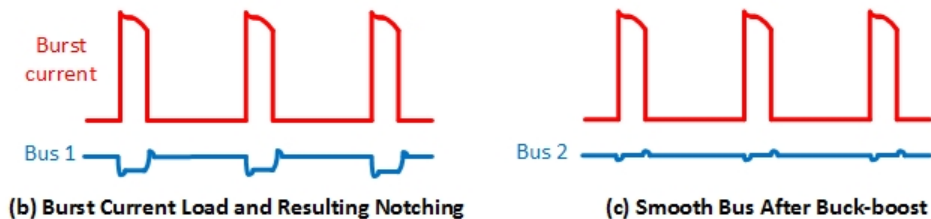
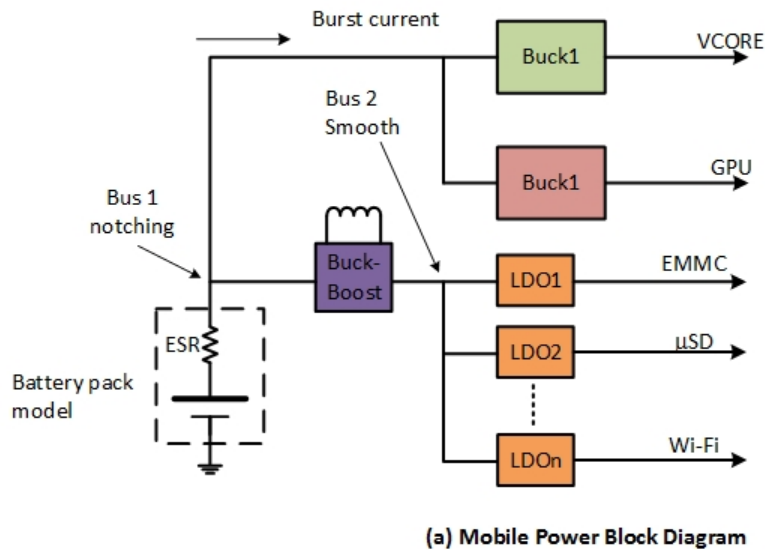


Figure 1. Mobile power block diagram and bus voltage notching

System Efficiency Improvement

Another benefit of using a buck-boost converter as the pre-regulator in a mobile power system is the efficiency improvement. LDOs can deliver smooth power rails because of their high power supply rejection ratio (PSRR). However, due to an LDO's linear nature for providing voltage regulation, the power loss can be excessive. This occurs when the battery is fully charged and the input voltage is high in comparison to the output voltage.

LDOs in mobile system PMICs have output voltages ranging from 1.2V to 3.3V. The Li-ion battery typically has a voltage range of 4.35V down to 2.5V when the dynamic line/load transients are taken into account, even though the VBAT stays around 3.7V most of the time. The large LDO voltage drop causes excessive efficiency loss.

When used as a pre-regulator for PMIC LDOs, buck-boost converters can play a major role in improving overall system efficiency and enhancing battery life. Switching regulators are much more efficient at providing voltage regulation than linear regulators. The battery voltage is first converted to a voltage slightly higher than the highest LDO output voltage of the target LDO array, which is typically 3.3V. The buck-boost output is then set to 3.4V, providing a 100mV headroom for the 3.3V LDO. The LDOs see a 3.4V input voltage, regardless of the battery voltage.

Efficiency Calculation Example

The following example uses five LDOs each with 300mA output current, or a total output current of 1500mA. The output voltages of these LDOs range from 1.7V to 3.3V, averaged at 2.5V. The battery voltage is 3.8V and the buck-boost output is set at 3.4V to accommodate the 3.3V highest output LDO in the LDO array. Finally, we'll use a 93% efficiency for the buck-boost regulator at this condition, as shown in the measured efficiency data in Figure 3. With the two-stage power conversion architecture, the overall efficiency can be calculated as follows.

LDO efficiency at 3.8V input powered directly from a 3.8V battery:

$$\eta_{LDO} = \frac{2.5 \times 1.5}{3.8 \times 1.5} = 65.8\%$$

LDO efficiency when powered through a pre-regulator with 3.4V output:

$$\eta_{BUCK-BOOST} = 93\%$$

$$\eta_{LDO} = \frac{2.5 \times 1.5}{3.4 \times 1.5} = 73.5\%$$

$$\eta_{TOTAL} = 0.93 \times 0.735 = 0.683 \text{ (68.3\%)}$$

The above example shows a 2.5% increase in efficiency. While the difference doesn't seem very large, it can significantly improve battery run-time (see Figure 5).

High Efficiency Buck-Boost Regulator

Intersil's high efficiency, high current buck-boost regulators are widely used as pre-regulators in mobile devices. The ISL91127 buck-boost regulator is capable of delivering over 2A current at 3.3V output at the lowest battery voltage of 2.5V, which is the highest current capability in its class. The device's typical application circuit is shown in Figure 2, and its typical efficiency graphs are shown in Figure 3.

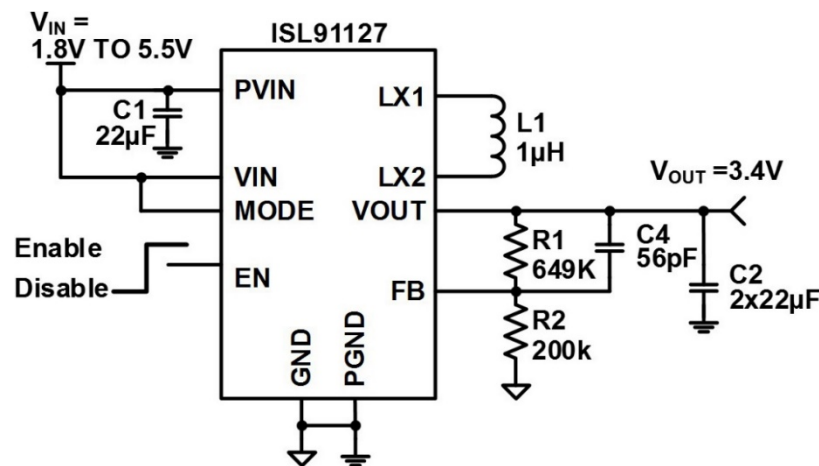


Figure 2. ISL91127 typical application circuit

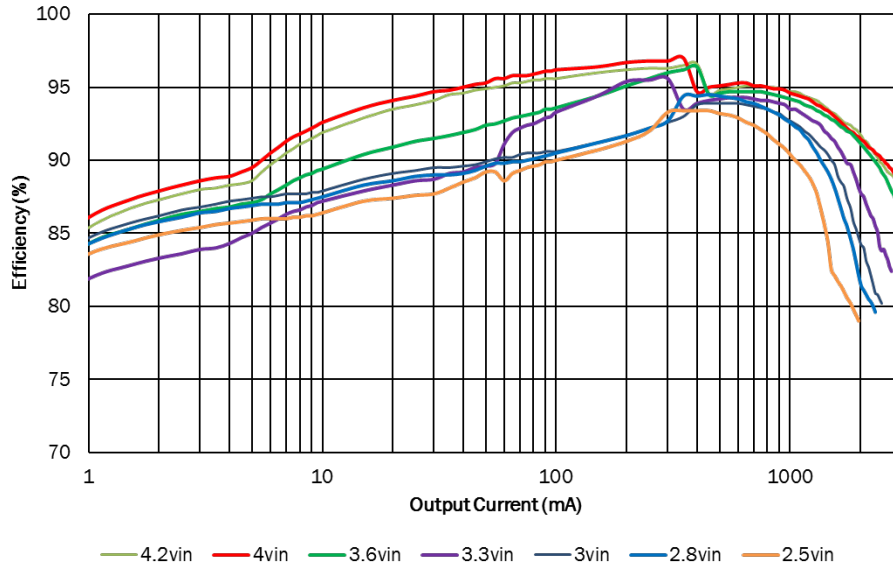
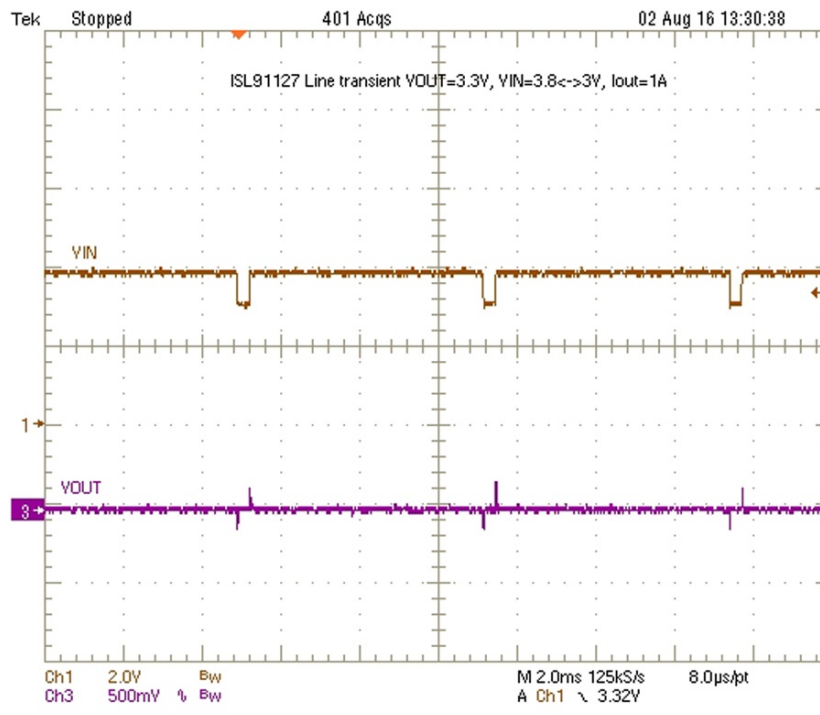


Figure 3. ISL91127 buck-boost regulator efficiency ($V_{OUT}=3.3V$)

In addition to offering high efficiency power conversion as shown in Figure 3, the ISL91127 provides superior transient response to eliminate the notching at the output. Figure 4 shows the ISL91127 line transient response to an 800mV line disturbance at its input bus. The top trace represents the battery terminal voltage with high burst current loading, while the bottom trace represents the bus voltage at the buck-boost output where the LDOs receive their power. Due to its fast transient response, the notching effect is significantly reduced on the battery terminal voltage.



**Figure 4. ISL91127 line transient response (top trace V_{IN} 2V/div, bottom trace V_{OUT} 0.5V/div)
 $V_{IN} = 3.8V\text{-to-}3V\text{-to-}3.8V$, $V_{OUT} = 3.3V$, $I_{OUT}=1A$**

Real-Time Mobile Application Performance

We've seen the efficiency improvement using the ISL91127 as a pre-regulator in a mobile system. In this run-time comparison, we ran two high current subsystems, the Wi-Fi module and SD card reader, to stream video over Wi-Fi, and to execute read/write operations to the SD memory card. The battery run-time with a pre-regulator and without a pre-regulator was recorded and compared. In this case, it was found that the setup with a buck-boost pre-regulator increased run-time by more than 12%. Figure 5 shows the comparison of battery discharge with and without a pre-regulator, while running the same applications with the same battery.

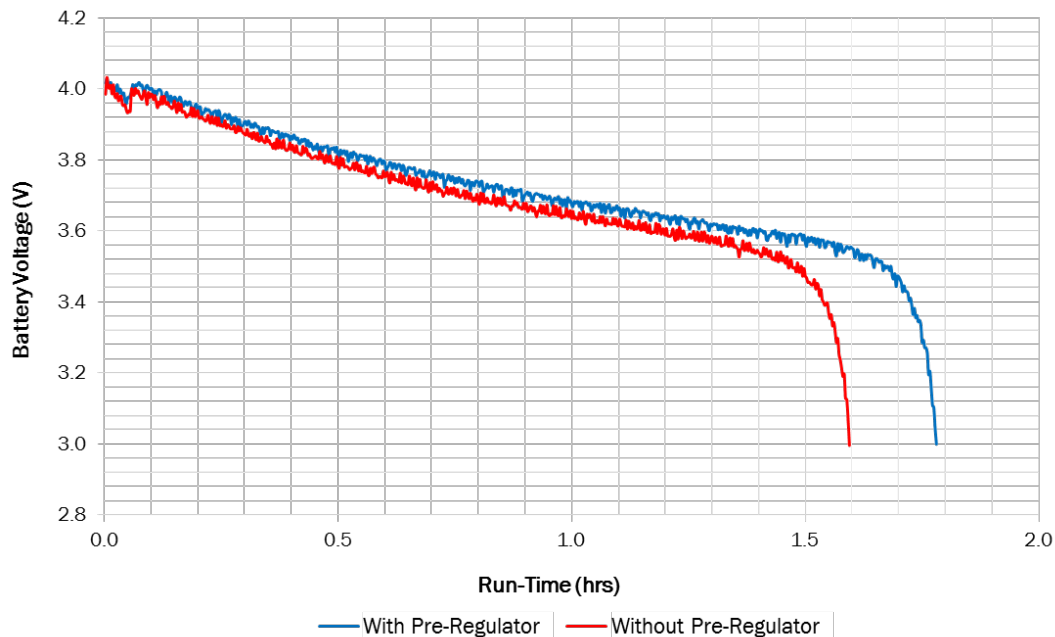


Figure 5. Run-time comparison with and without pre-regulator

Conclusion

Using a buck-boost regulator as a pre-regulator in mobile devices is a critical component to providing a stable and well-regulated voltage bus for the subsystems. Pre-regulators can prevent momentary brownout conditions due to bus notching on the battery terminals, while also improving system efficiency by minimizing the voltage headroom across the subsystem LDOs. We've illustrated how Intersil's ISL91127 buck-boost regulator with high current capability provides efficient power delivery and fast line transient response for mobile device designs.

Next Steps

- [Learn more about the ISL91127](#)
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