A Smarter Way to Power Wearable Devices

Introduction

Wearables have quickly become the latest “must have” gadgets for both personal and professional use. Today, consumers are effectively using these devices to perform a myriad of tasks, most notably to monitor fitness and manage busy schedules. In fact, wearables are such a hot trend that ABI Research forecasts the category is growing at a CAGR of 56.1% and will reach 487 million units in 2018. For aging baby boomers, wearables have arrived just in time as serious health issues can benefit from accurate healthcare monitoring. With device performance expectations growing day-by-day, system designers are constantly challenged to create smaller, more efficient and cost effective solutions that will place wearables on the wrists of many more people.

A wide variety of wearables are available, such as the Samsung Gear and Apple Watch, which provide connectivity, a high quality display and plethora of features, and there are the pure fitness-oriented wearables like the Fitbit Flex and Jawbone UP4, both optimized for data collection and fitness tracking. As popular as wearables have become, one of the biggest concerns for consumers is how long they can use the device without recharging it. Battery life is a key product differentiator for consumers reviewing the many available choices before deciding which wearable product to purchase.

This article provides an overview of a typical wearable system block design, and examines how a buck-boost regulator can increase power efficiency to extend battery life. Wearable system designers will learn how a new regulator’s use of adaptive current limit pulse frequency modulation (PFM) and forced bypass mode is able to deliver smooth transitions from buck-to-boost to prevent glitches in wearable applications where light load efficiency and fast transient response are critical.

Wearable Device Architectures

A typical wearable device architecture includes a microprocessor, memory, display, sensors, communication IC and battery charger blocks, among others. It uses at least three DC-DC converters and 3-5 low dropout (LDO) regulators, depending on the system application. Figure 1 shows a typical power system for a basic wearable device.

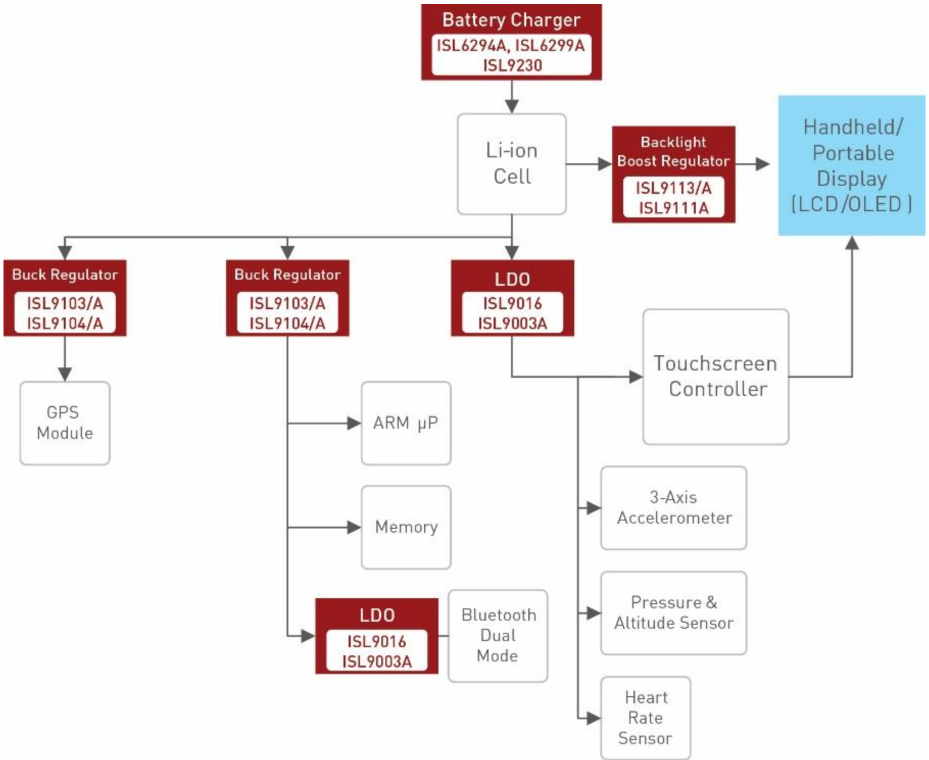

Figure 1. Typical power solution system blocks for a wearable device

First, we will discuss how a buck-boost regulator adds value in the wearable system. For an application requiring ~3.3V-3.6V input, a buck-boost regulator efficiently uses a broader range of a new battery chemistry, which varies from 4.375V to 2.5V. The buck-boost will work in the pure boost mode for Vbat from 2.5V-3V, and then in buck-boost mode for V_{IN} = >3V and <3.9V, and finally in pure buck mode for Vbat = 3.9V-4.5V.

Buck-Boost as a Pre-Regulator

Multiple applications like the Wi-Fi and display module are powered by an LDO, and if powered directly from the battery these peripherals experience a large power loss since the efficiency of an LDO is equal to the V_{OUT} divided by V_{IN}. At higher loads, the LDO has more power loss and dissipates more heat. Using a buck-boost converter as a pre-regulator for the LDO helps to increase the system efficiency. In addition, with this configuration, the LDO always sees a constant V_{IN} (buck-boost output) power loss instead of a larger power loss when the battery directly powers it.

In addition, adding more wearable features requires faster processing, which drives up the need for more efficient power management. When multiple applications are working in parallel, a short high current pulse can cause the local node voltage to drop below its recommended input range, and can cause it to shut down. This behavior is highly undesirable and can be avoided by using the buck-boost as a pre-regulator for these devices, like the liquid crystal display (LCD) and applications that are powered by LDOs.

Extending Battery Life

The ISL9120 buck-boost regulator offers excellent efficiency for both low load and high load conditions. Its adaptive PFM operation helps it attain up to 98% efficiency at higher load and greater than 86% at lower load conditions, as shown in Figure 2. This ensures less power drain and less heat buildup, which extends the battery life and saves board space by eliminating the need for external heat sinks. To optimize efficiency across the output current range, the ISL9120 implements a multi-level current limit scheme with 32 levels between 350mA and 2A.

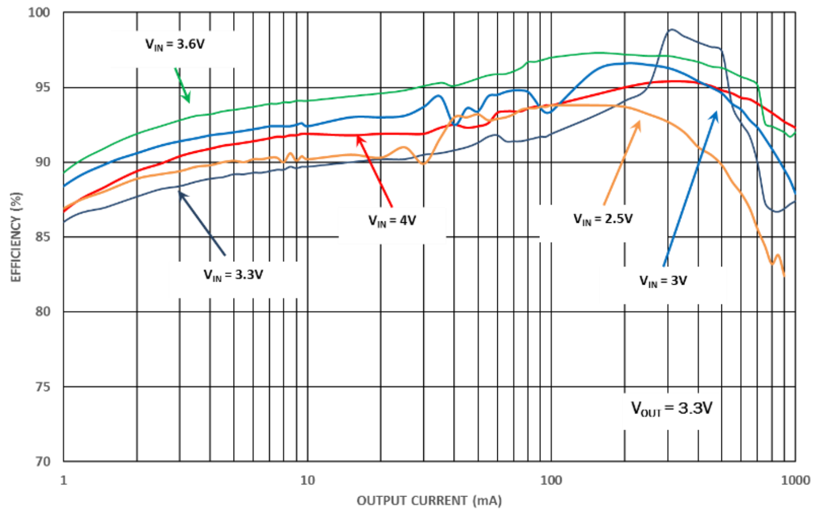

Figure 2. ISL9120 buck-boost regulator efficiency plot

As seen in Figure 3, the transition from one level to the other is determined by the number of pulses in a PFM burst (pulse count). At a given peak current limit level, the pulse count increases as the output current increases. When the pulse count reaches the upper threshold of the existing current limit, the current limit switches to the next higher level. Similarly, if the pulse count reaches the lower threshold of the existing current limit, the device will switch to the next lower level of peak current limit. If the pulse count reaches the upper threshold at the highest current limit, the current limit will not rise any further. The ISL9120 also features a forced bypass mode when output regulation is not required. Its system stay alive operation enables ultra-low quiescent current consumption of less than 0.5µA. For example, the buck-boost regulator applies its forced bypass mode when powering an LDO and the LDO is in standby mode with near zero output current. Under this condition, putting the buck-boost regulator in bypass mode essentially has no impact on the LDO but saves the regulator 41µA of quiescent current consumption.

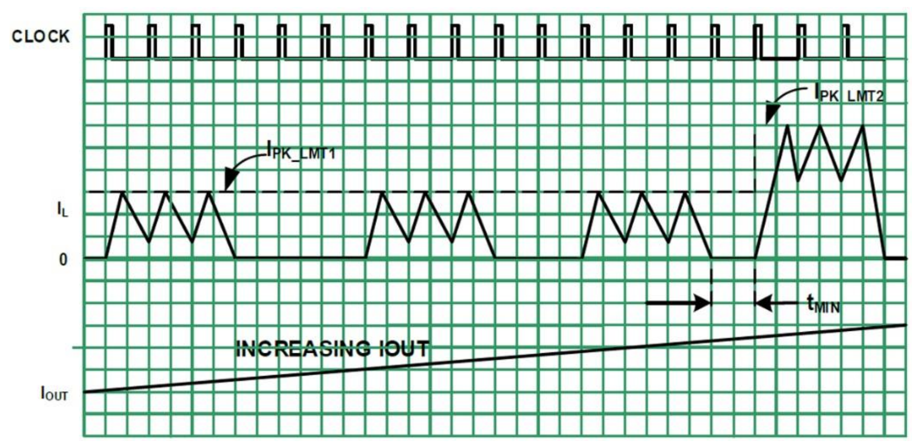

Figure 3. Adaptive current scheme provides smooth transitions from buck to boost

Buck-Boost Application Examples

By taking a closer look at Figure 1, we can see the wearable applications where using a buck-boost regulator is beneficial. For example, a heart rate monitor sensor system requires a ~3.3V input, and system designers typically recommended using 2-3 LEDs for accurate heart rate monitoring as it provides less dependence on the wearable placement and accommodates a wider cross section of end users. However, this configuration requires higher current consumption. Using the ISL9120 as a pre-regulator is a good fit for this application as the battery can directly power it, creating higher system efficiency (longer battery life), higher immunity to input perturbations, and very low output ripple. When the heart rate monitor is not active, the ISL9120 can be put into forced bypass mode where it consumes a mere 0.5µA, until it is woken up.

The wearable LCDs are small and typically use one white LED for backlighting. As you can see in Figure 1, the current solution uses a 5V boost to power the LCD block. A wide range of small (1-2 inch) LCDs can be powered using a 3V-3.6V instead of 5V. This makes a buck-boost regulator very attractive for implementing a more efficient power supply design. Lastly, there is a growing trend of wearable devices integrating Wi-Fi -- this system block typically requires a supply of 3.3V, and low input ripple. With the space constraint in wearables, a small, compact design is mandatory. Once again, using the ISL9120 as a pre-regulator fits very well.

Conclusion

With smaller form factors, higher integration and faster processors managing a growing list of wearable functions, higher efficiency solutions have never been more critical. A new class of buck-boost regulators, featuring an adaptive current limit PFM are proving to keep up with these growing requirements, while extending battery life and keeping the next generation of wearable devices running longer and cooler.

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