Understanding Quiescent Current and Shutdown Current with a Boost Converter

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Introduction

For battery-powered applications, an excellent user experience depends on a long battery life and high-performance terminal devices. Quiescent current (I_Q) is an important parameter to consider when optimizing these applications; in particular, an improved I_Q increases battery life.

This article will describe the difference between a boost converter's I_Q and shutdown current (I_{SD}) to provide a deeper understanding of how I_Q and I_{SD} can be utilized in battery-powered applications.

Battery Types

In many battery-powered applications, the battery output is relatively low, such as a 1.5V output voltage (V_{OUT}) from a single AA battery. Meanwhile, the back-end IC or subsidiary circuit requires a higher input voltage (V_{IN}). In these systems, a step-up converter (also known as a boost converter) is typically used to step up the voltage from a battery output. Otherwise there is an insufficient V_{IN} for the IC or subsidiary circuit.

Figure 1 shows a few different battery types, such as cylindrical batteries, coin batteries, and phone/tablet batteries.

Figure 1: Battery Types

Table 1 shows battery types and their typical output voltages.

Table 1: Battery Types and their Typical V_{OUT}

Type/Spec	Cylindrical Batteries				Coin Batteries			Phone/Tablet Batteries
	NiMH	Lithium-Iron	Lithium-Ion	NiCd	CR	SR	LR	Lithium-Ion
V_{OUT}	1.2V	1.5V	3.7V	1.2V	3V	1.55V	1.5V	3.7V
Sizes	A, AA, AAA, AAAA, C, D, N, and F				Varies			

Batteries should be selected based on the application needs. However, note that the maximum V_{OUT} among these batteries is 3.7V, which may be insufficient for a number of applications. This is when a boost converter becomes vital.

Boost Converters

MPS provides a variety of synchronous step-up (boost) converters that can be used to step up a battery's V_{OUT} such that it can provide a sufficient V_{IN} for the receiving system. The remainder of this article will focus on the differences between a boost converter's I_{SD} and I_Q while using the MP28600, an ultra-low I_Q, synchronous boost converter. The MP28600 is a brand new IC solution with nA level quiescent current and a small SOT563 (1.6mmx1.6mm) package. It is well-suited for wearable devices, industrial sensors, and battery-powered, handheld medical instruments.

Shutdown Current (I_{SD})

I_{SD} is the current drawn by the IC from a battery when the IC is switched off and the battery is still connected to the system. Consider the scenario in which the MP28600's enable signal is set to 0V, and it is connected to a battery with a V_{IN} that is equal to 3.3V. I_{SD} is the current measured from the input (see Figure 2).

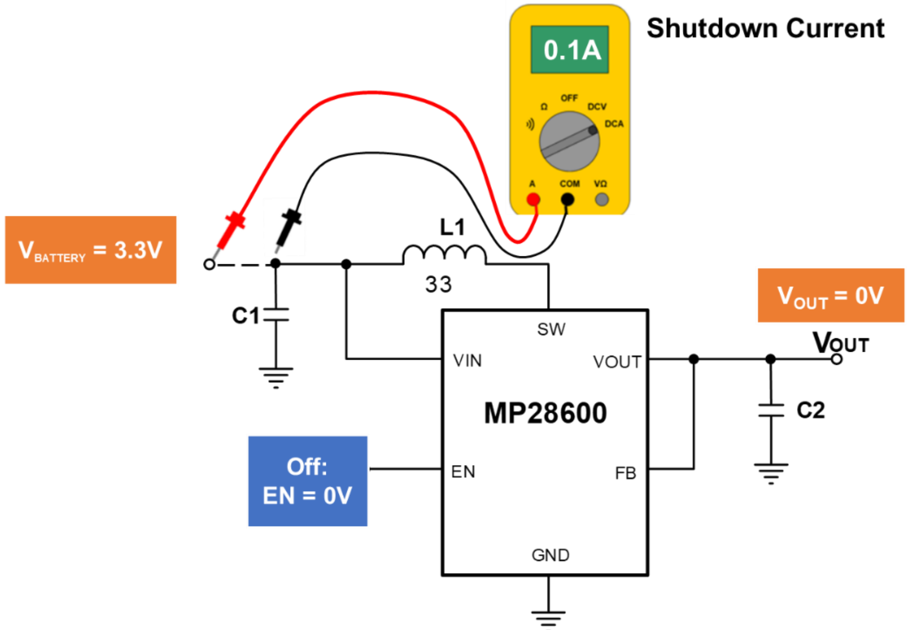

Figure 2: Measuring I_{SD}

It may be difficult to understand why the IC consumes current even though it has shut down. This is because some of the internal circuitry, such as the start-up loop, still leak small amounts of power to the ground (GND); this leakage consumes battery current (see Figure 3).

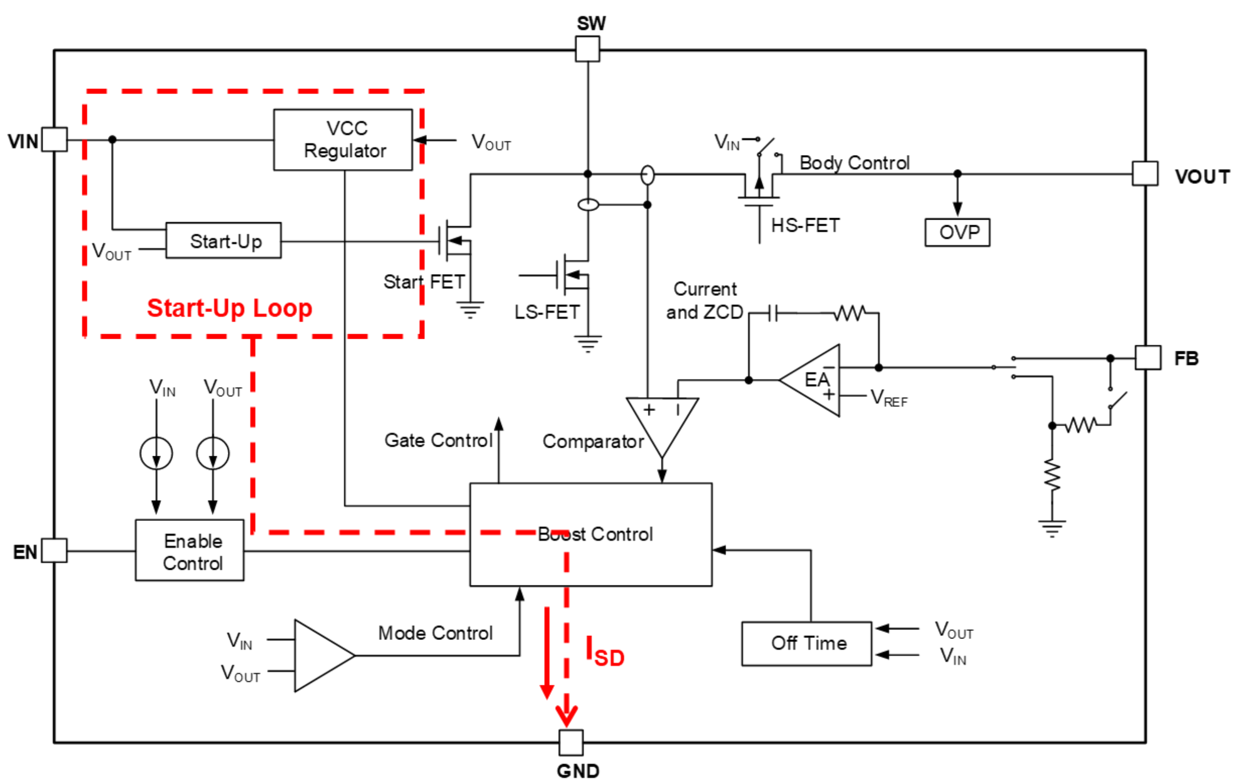

Figure 3: I_{SD} in an IC Circuit

Consider the following real-world example. If you buy a battery-charged electrical device from the store, and that device has been on the shelf for a significantly long time, then you may not be able to turn it on until it has been sufficiently charged. This is because the IC continuously consumes a certain ampere of current from the battery. In addition, when the battery is over-discharged, it can be damaged and have a reduced full-charge capacity if there is no protection.

Quiescent Current (I_Q)

I_Q is the current consumed by the IC when it is enabled (but not switching), or when there is no load applied. This current can also be called operating quiescent current, standby current, and sleep mode current.

For example, set the MP28600's enable signal to 5V. The IC is connected to the battery, which has a V_{IN} of 3.3V. I_Q is the measured current from the MP28600's input voltage pin (see Figure 4).

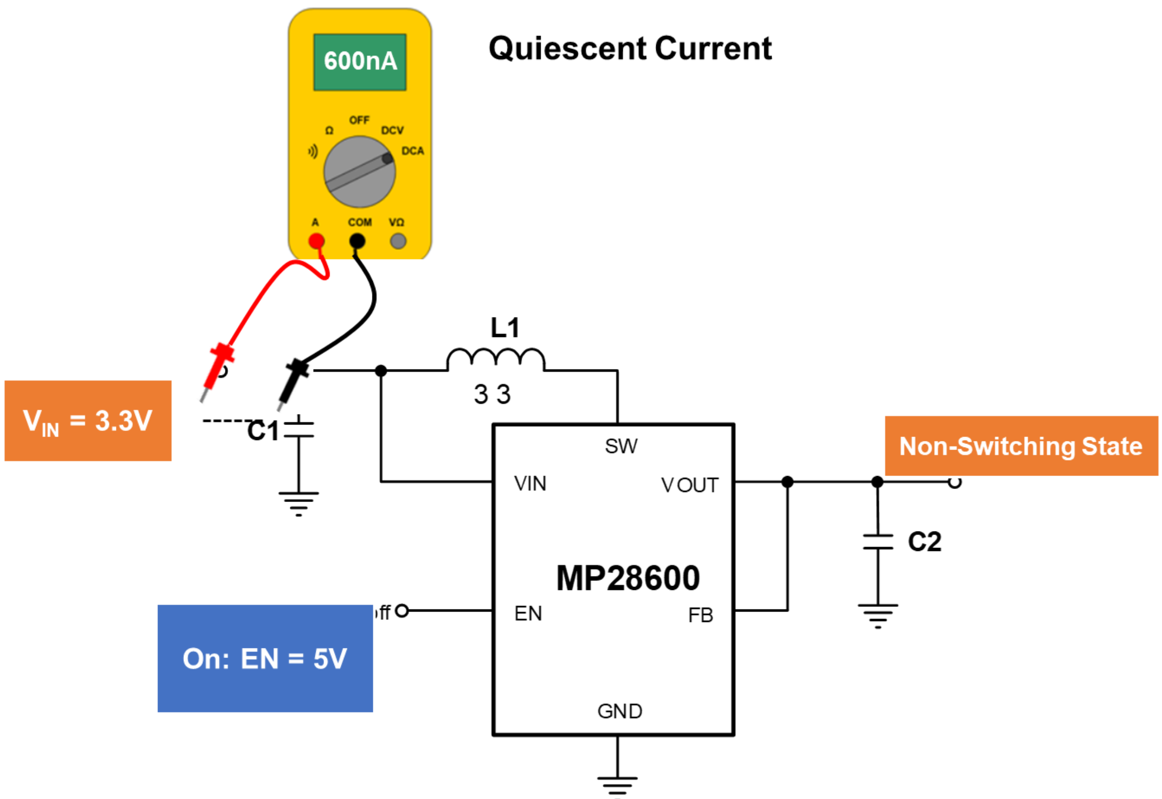

Figure 4: Measuring I_Q

Similar to I_{SD}, it may be difficult to understand why there is an I_Q. Even if there is no load and the IC is not switching most of the time, some of the internal circuitry continues operating to maintain the device's basic functions, which requires a small amount of current. Figure 5 shows a control loop that consumes current.

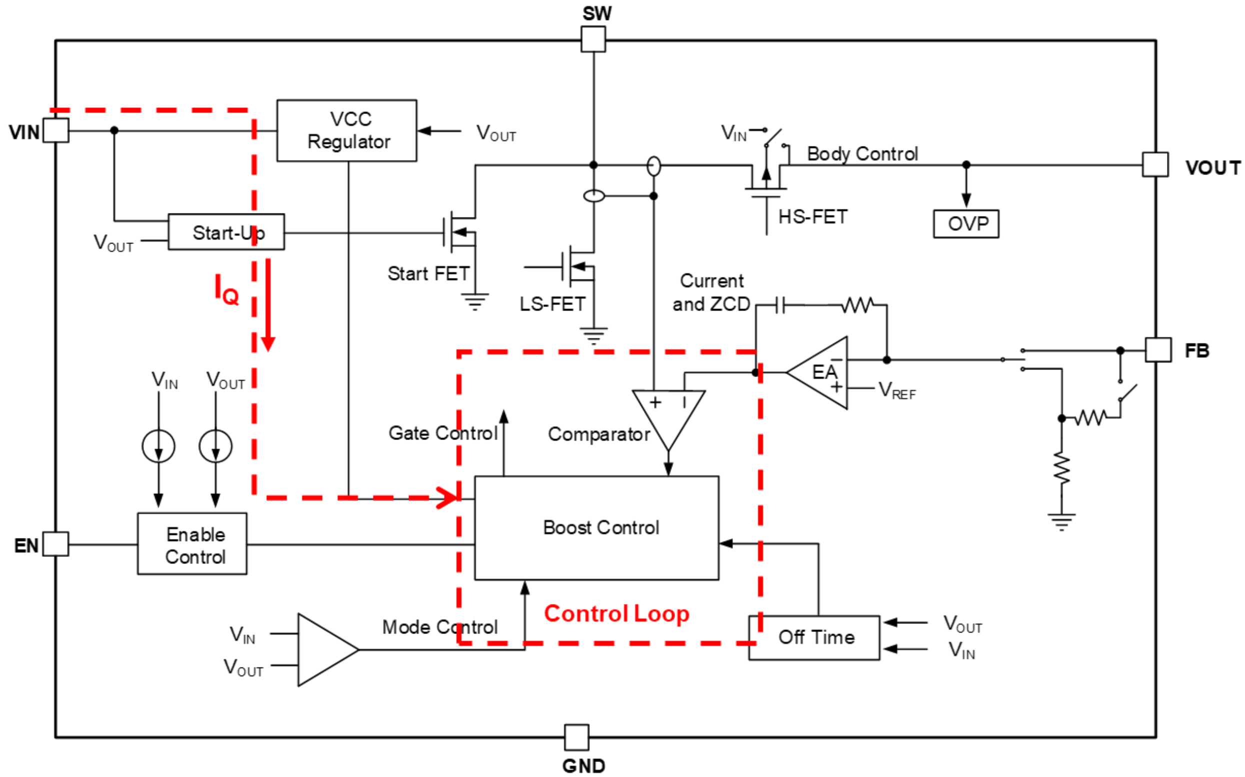

Figure 5: I_Q in an IC Circuit

Consider the following real-world example using a security sensor (see Figure 6). I_Q is essential for applications that run in a sleep state. 99% of the time, a security sensor does not detect an object or hazardous condition that triggers the alarm; however, it cannot shut down. In this scenario, the sensor can operate in sleep mode and wake up only when necessary. While in sleep mode, the IC consumes a small amount of power from the battery — this current is the operating I_Q. The smaller the I_Q, the longer the battery life.

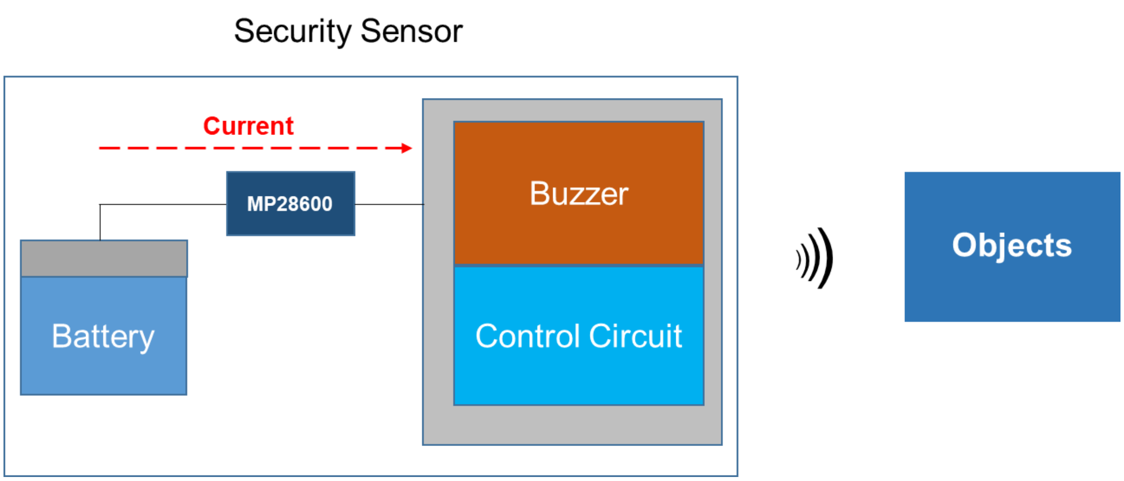

Figure 6: Security Sensor Functionality

Conclusion

This article used the MP28600, a step-up (boost) converter, to describe the differences between quiescent current and shutdown current, which can be optimized in battery-powered applications. As electrical devices become more intelligent and diverse with evolution of Internet-of-Things (IoT) devices, portable applications, medical instruments, and industrial sensors, low power consumption and a small size are paramount.

MPS provides a robust portfolio of converters to meet any application's needs.