Technical Article
3 Quiescent-current (Iq) Specifications to Understand

![Texas Instruments logo]

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A common definition of quiescent current (I_Q) is the current drawn by an integrated circuit (IC) in a no-load and nonswitching but enabled condition. A broader and more useful way to think about it is that quiescent current is the input current consumed by an IC in any number of its ultra-low-power states.

For battery-powered applications, this input current comes from the battery, so it determines how long the battery operates before it either needs recharging (for rechargeable batteries, such as lithium-ion (Li-Ion) or nickel metal hydride (Ni-MH)) or replacing (for primary batteries, such as alkaline or lithium manganese dioxide (Li-MnO$_2$)). For battery-powered applications that spend a large amount of their time in standby or sleep mode, I_Q can impact the battery's run time by years. For example, using an ultra-low-I_Q buck converter like the 60-nA TPS62840 to power an always-on application, such as the smart meters shown in Figure 1, enables 10 years of battery run time.

Figure 1. Smart Meters

I_Q also impacts the battery run time of applications that we interact with on a daily basis. Perhaps you've purchased a smart watch, only to find that it needed to be charged for an hour before you could use it. Or maybe you always carry a physical key for your house in case the battery in your smart lock, like the one shown in Figure 2, dies. Both of these scenarios also relate to I_Q.
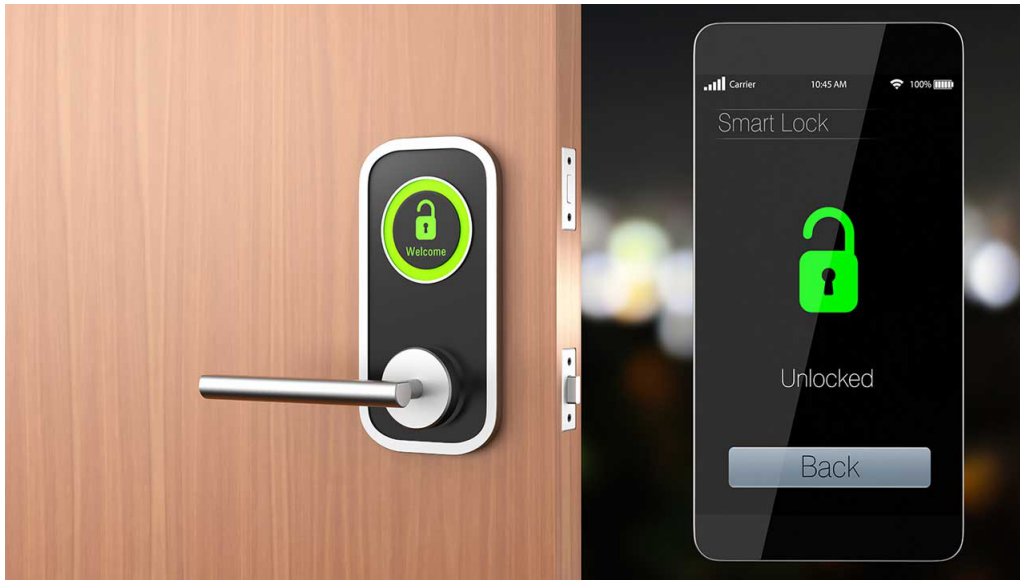
Figure 2. Smart Lock Application

In this article, I'll explain three of the most commonly used DC/DC converter data sheet specifications related to I_Q – shutdown current, nonswitching I_Q and switching I_Q – and how these specifications impact system power consumption.

Overcome low-I_Q challenges in low-power applications

Read our white paper, "Overcoming Low-I_Q Challenges in Low-Power Applications," for tips on how to extend battery life while also providing higher performance.

Shutdown Current

Shutdown current is measured when the IC is turned off or disabled. Given this, you might think nonswitching I_Q should always be zero. In reality, some ICs exhibit leakage currents in this state, while others actually have internal circuitry that consumes a small amount of current to maintain housekeeping functions even while the IC is disabled.

Think about consumer electronics sitting on a store shelf. The reason why your smart watch might not work out of the box has to do with each of its IC's shutdown current specifications, like those shown in Figure 3. When an end product is sitting on a store shelf or on a higher shelf in a warehouse (where the temperature is likely elevated, leading to a faster battery drain), most DC/DC converters, for example, are in a shutdown state. So, even though the DC/DC converters are disabled, the battery is slowly discharging.

6.4 Thermal Information

THERMAL METRIC[1]		BQ21061 YFP (DSBGA) 20-PIN	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance [2]	36.1	°C/W
$R_{\theta JA}$	Junction-to-ambient thermal resistance	74.4	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	0.5	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	17.6	°C/W
Ψ_{JT}	Junction-to-top characterization parameter	0.3	°C/W
Ψ_{JB}	Junction-to-board characterization parameter	17.7	°C/W
$R_{\theta JC(bot)}$	Junction-to-case (bottom) thermal resistance	N/A	°C/W

(1) For more information about traditional and new thermal metrics, see the Semiconductor and IC Package Thermal Metrics application report.
(2) Measured in BQ21061EVM board.

6.5 Electrical Characteristics

$V_{IN} = 5V$, $V_{BAT} = 3.6V$. $T_J = 25°C$ unless otherwise noted.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CURRENTS						
I_{IN}	Input supply current	PMID_MODE = 01, V_{IN} = 5V, V_{BAT} = 3.6V			500	µA
		V_{IN} = 5V, V_{BAT} = 3.6V Charge Disabled			1.6	mA
I_{BAT_SHIP}	Battery Discharge Current in Ship Mode	V_{IN} = 0V , V_{BAT} = 3.6V		10		nA
I_{BAT_LP}	Battery Quiescent Current in Low-power Mode	V_{IN} = 0V , V_{BAT} = 3.6V, LDO Disabled		0.46	0.9	µA
		V_{IN} = 0V , V_{BAT} = 3.6V, LDO Enabled		1.7	1.9	µA
I_{BAT_ACTIVE}	Battery Quiescent Current in Active Mode	V_{IN} = 0V , V_{BAT} = 3.6V, LDO Disabled		18	23	µA
		V_{IN} = 0V , V_{BAT} = 3.6V, LDO Enabled		21	25	µA
POWER PATH MANAGEMENT AND INPUT CURRENT LIMIT						
V_{PMID_REG}	Default System (PMID) Regulation Voltage			4.5		V

Figure 3. Battery Discharge Current in Ship Mode for the BQ21061

Some ICs have multiple shutdown states, such as the 2-nA ship mode of TI's BQ25120A battery charger or the 4-nA bypass mode of the TPS61094 boost converter. In these advanced shutdown states, usually a very limited subset of the device's functionality remains active in order to draw the minimum amount of I_Q. Compared to the 700-nA I_Q in the BQ25120A's high-impedance (shutdown) mode and the 200-nA I_Q in the TPS61094's shutdown mode, ship mode and bypass mode extend the battery's shelf life or run time by 350 and 50 times, respectively.

Nonswitching I_Q

Nonswitching I_Q is when the IC is enabled, in between switching pulses, and without a load. This parameter is found in most switching DC/DC converter data sheets because it can be easily tested on production automated test equipment.

While non-switching I_Q provides an apples-to-apples comparison between different ICs, two shortcomings prevent it from being the best estimate for battery run time: the non-switching I_Q is not the same as the battery current drawn, and many ICs draw their I_Q from both the input voltage and the output voltage. However, since the output voltage and its I_Q ultimately come from the battery at the input, additional conversions or measurements are necessary in order to get an equivalent I_Q from the input source – you can't just add the two I_Q currents to get the total battery current drawn. For example, the TPS61099 boost converter consumes a 400-nA I_Q from V_{IN} and a 600-nA I_Q from V_{OUT}, but the no-load input current consumption is about 1.3 µA and not 1 µA.

Switching I_Q

Switching I_Q, which goes by many different names: operating I_Q, standby current, sleep-mode current, no-load input current, ground current for low dropout linear regulators (LDOs) and so forth, is the real, measured input current that occurs when the IC is operating without delivering any load current. Since it is measured under real-life conditions and not on the production line, the IC occasionally switches to overcome losses and replenish leakage at the output.

It is the best estimate of the battery current drawn under no load and appears in many data sheets, such as the 60-nA switching I_Q of the TPS62840, as shown in Figure 4.

TEXAS INSTRUMENTS

TPS62840
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TPS62840 1.8-V to 6.5-V, 750-mA, 60-nA I_Q Step-Down Converter

1 Features
- 60-nA operating quiescent current
- 100% duty-cycle mode with 120-nA I_Q
- Input voltage range V_{IN} from 1.8 V to 6.5 V
- Output current up to 750 mA

3 Description
The TPS62840 is a high-efficiency step-down converter with ultra-low operating quiescent current of typically 60 nA. The device contains special circuitry to achieve just 120 nA I_Q in 100% mode to further extend battery life near the end of discharge.

Figure 4. A 60-Na I_Q DC/DC Converter

Using low-I_Q DC/DC converters is critically important to achieving the desired battery run time for applications that spend most of their time in a very-low-power state. For example, smart locks spend most of their time in a very-low-power state waiting for a phone to send the code to open the lock. If the switching I_Q is too high, most of the battery's energy is used while waiting instead of being used to open or close the lock.

Conclusion

This article provided a brief look into how I_Q is commonly specified in data sheets and how it impacts battery run time. For more detailed technical information about I_Q, see the white paper, "Overcoming Low-I_Q Challenges in Low-Power Applications" read my Analog Design Journal article, "I_Q: What it is, what it isn't, and how to use it," or take an even deeper dive into the topic by watching our low-I_Q training series.

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