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Minimizing Power Draw in Small, Portable Devices

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In battery-powered wearable systems, such as sports watches and fitness monitors, every µA counts. The lower leakage currents of the latest microprocessors coupled with the use of load switches reduce the load current on the output of the power supply to below 10-µA levels.

This reality drives the innovation of more and more advanced power-save modes with lower and lower operating currents to increase the efficiency at extremely light loads. This article shows the importance of quiescent current (IQ) and power-save mode efficiency to the power draw of such systems where standby currents remain at very low levels for extended periods of time.

Wearable sports watches and fitness monitors have numerous difficult design goals. On the one hand, this end equipment must be very small and extremely portable if it is to be worn. On the other hand, they must support an immense and diverse array of functionality required by the user, such as: WiFi or Bluetooth connectivity; temperature, humidity, or velocity sensing; operating a display and/or LED driving; and so forth. Finally, these wearables must have a very low power consumption to maximize the battery run time and allow the use of a smaller and lighter battery. This is especially true in idle or standby mode, in which these devices operate most of the time.

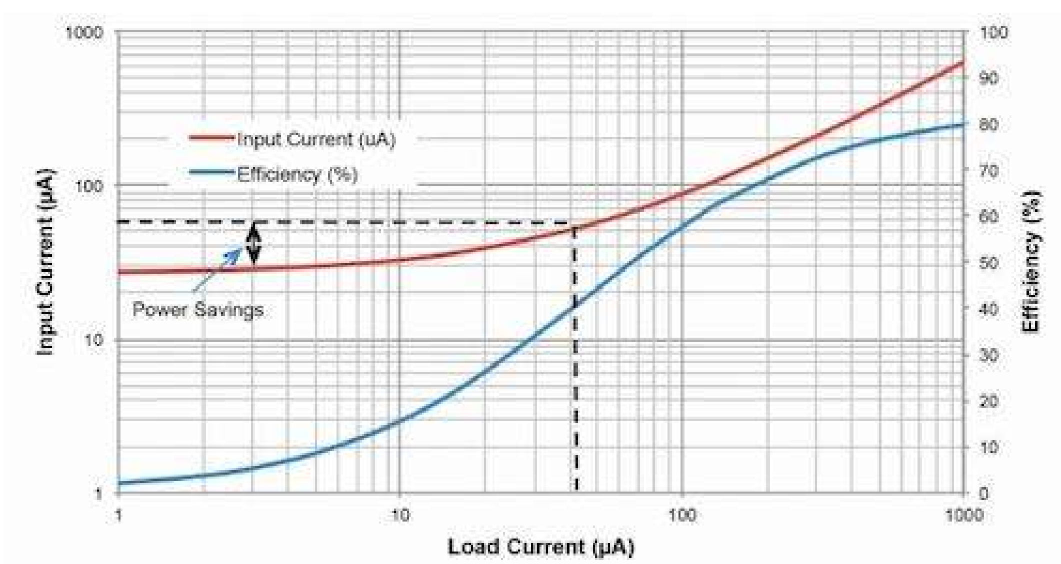


Figure 1. Efficiency and battery current (input current) of the TPS62231 step-down converter at a 3.6V input. Moving from a 50-µA to a 5-µA load current operating point provides less than two times the reduction of battery current.

Each of these design goals has power management implications. First and foremost, the current consumption of all the different subsystems in the wearable device is minimized. Just as important is the current consumption of each power supply in the system. With the lower sub-system current drawn, the power supply operates at a lower output power, especially in idle or standby mode. At this operating point, the power supply's quiescent current is the dominant parameter, which defines the battery current drawn.

Therefore, in order to significantly reduce the battery current, it is no longer effective to simply reduce the sub-system's current. The power supply's quiescent current must be reduced to achieve meaningful reductions in battery current draw and therefore longer run times. As well, the power supply's power-save mode operation should be optimized for efficiency at these very low output powers.

Small steps

Figure 1 shows the efficiency graph and corresponding input current of a low-power wearable device power supply, which is very small in size: 1 mm x 1.5 mm x 0.6 mm. It has low-noise and a high power supply rejection ratio (PSRR) to power the RF sub-systems and operates with a low 22-µA quiescent current. The graphs show a typical 3.6V input battery with a 1.8V output voltage. Even if the sub-system designer reduces the leakage current from 50 µA to 5 µA (an amazing 10 times reduction), the battery current only reduces from 56 µA to 30 µA -- a disheartening 1.9 times decrease.

Because these very low current operating points occur in the portion of the efficiency graph where the efficiency is rapidly decreasing (from 45% to 8%), the input current reduction due to a reduction in output power is somewhat insignificant. At this point, the input current is slowly trending down to slightly above the IC's quiescent current. A lower quiescent current device, as well as a more efficient power-save mode, is needed to achieve a greater input current reduction.

Giant leaps

Figure 2 shows the input current and efficiency of an ultra-low-power device particularly suited for wearable applications. While keeping the high PSRR and good noise performance required to power many of the rails in a wearable device, it reduces its quiescent current to an ultra-low 360 nA -- or just 1.6% of the previous device. As well, it optimizes its power-save mode for ultra-low load currents. When the load current is reduced from 50 µA to 5 µA, this reduces the battery current from 29 µA to just 3.3 µA -- almost a nine times reduction. Though a larger area is required (the device is 3 mm x 2 mm x 0.8 mm), it incorporates a load switch to enable easier system implementation.

Since the load currents occur well above the quiescent current of the power supply and because of the efficiently tuned power-save mode, power savings are still significant. A reduction in load current achieves a corresponding reduction in the input current, prolonging battery run time.

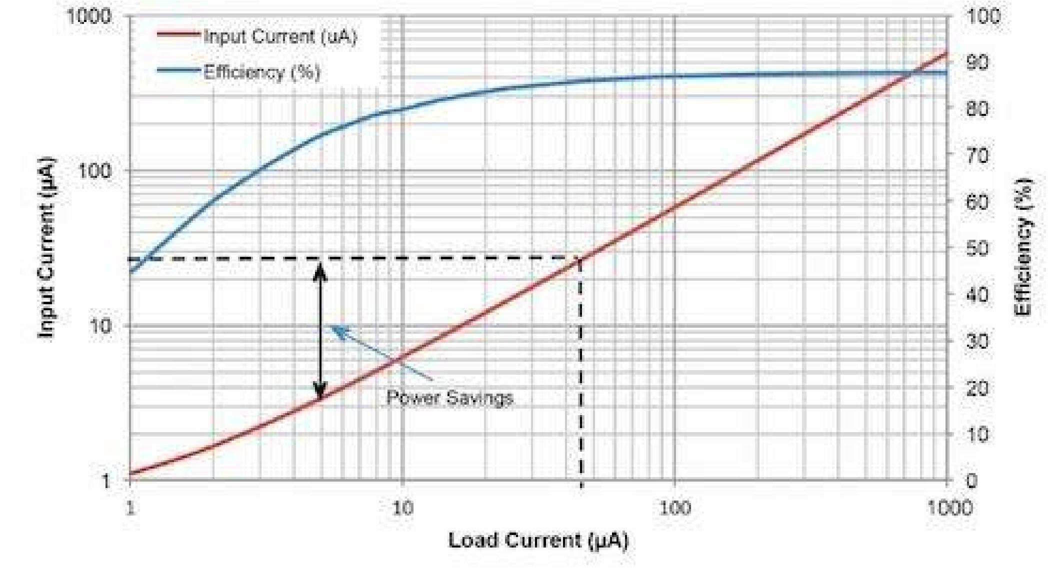
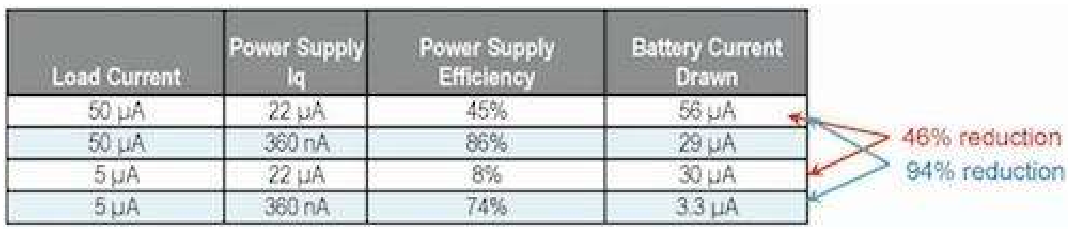


Figure 2. Efficiency and battery current (input current) of the TPS62740 at a 3.6V input. Moving from a 50-µA to a 5-µA load current operating point now reduces the battery current by 8.8 times. An integrated load switch allows simple system power savings by disconnecting disabled circuitry and its leakage.



Load Current	Power Supply Iq	Power Supply Efficiency	Battery Current Drawn
50 µA	22 µA	45%	56 µA
50 µA	360 nA	86%	29 µA
5 µA	22 µA	8%	30 µA
5 µA	360 nA	74%	3.3 µA

Figure 3. Battery current drawn from a high or low quiescent current power supply powering either a high or low current load. Combining the lower quiescent current power supply with the load current decrease provides a 94% reduction in battery current consumed.

System impact

Figure 3 summarizes the battery current drawn for the four operating scenarios shown: a high and low IQ power supply, as well as a high and low load current. With the higher IQ power supply, a reasonable 46% reduction in input current is achieved just by reducing the load current. But when the load current is reduced along with the power supply's IQ, a 94% reduction of battery current is seen. Even at this very low power operating point, the ultra-low-power switching power supply is still more efficient than a linear regulator.

Conclusion

Reducing the output power consumed does not always significantly reduce the amount of input power drawn, especially at the very low load current levels found in modern wearables. Instead, a reduction of the power supply's quiescent current coupled with an improvement in power-save mode operating efficiency provides the most benefit. It makes the most of load current decreases achieved through good system design practices, such as lowering leakage currents and implementing load switches. Just reducing the power supply's quiescent current reduces the battery current drawn by 48% in this example; while reducing the quiescent current and the load's leakage current provides current savings of 94%. These advances compel wearable device designers to take another look at the quiescent current and efficiency of their power supplies with the goal of extending their run times.

— Chris Glaser *is an applications engineer for Texas Instruments.*

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