DESIGN SOLUTIONS
POWER

Prolong Your Smart Watch Lifetime with SIMO

The market growth of smart watches continues unabated, fueled by a plethora of new features and applications. Personal health and fitness products include new features like tracking, alerts, and connectivity. The rise in smart watch-controlled automotive is fueled by features like emergency assistance and car status updates. Waterproof and shockproof features as well as brighter displays are driving the growth of this market globally. High-definition cameras, GPS receivers, tiny powerful speakers, ample storage, and other new features are on the horizon. However, the requirement for smaller form factors escalates the challenge of miniaturization in electronics and presents additional ones for longer battery life. This design solution presents an innovative power management system that delivers power with higher efficiency in a very small space, while enabling longer battery life for miniaturized wearable devices (Figure 1).

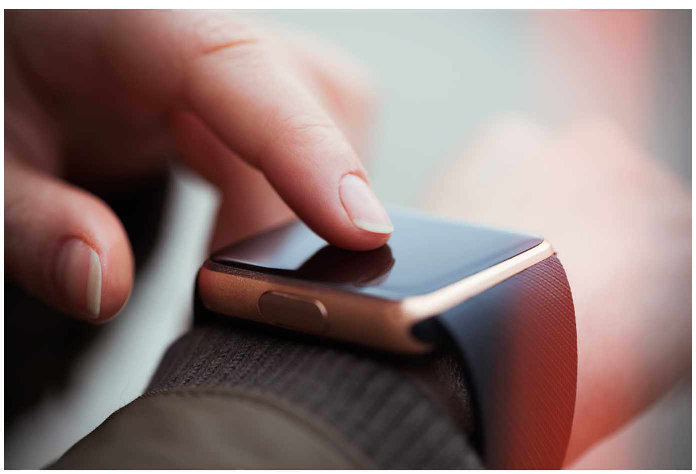

Figure 1. Smart Watch in Action

Programmable SIMO to the Rescue

Ideally, an efficient solution occupies minimal space and integrates the battery charger and required regulation to power the smart watch blocks all in one chip. A single-inductor multiple-output (SIMO) buck-boost converter that implements three switching regulators with a single inductor further reduces the occupied space. Each regulator's topology is programmable, supporting buck-boost operation for voltages within and above the battery voltage range as well as providing buck operation—inherently more efficient than buck-boost—for voltages below the battery voltage. Finally, high-frequency operation allows the use of a small inductor, further minimizing the space required. Two on-chip LDOs are used for noise-sensitive loads or as load switches. Figure 2 illustrates a highly integrated SIMO PMIC. For simplicity, the external passives are not shown here.

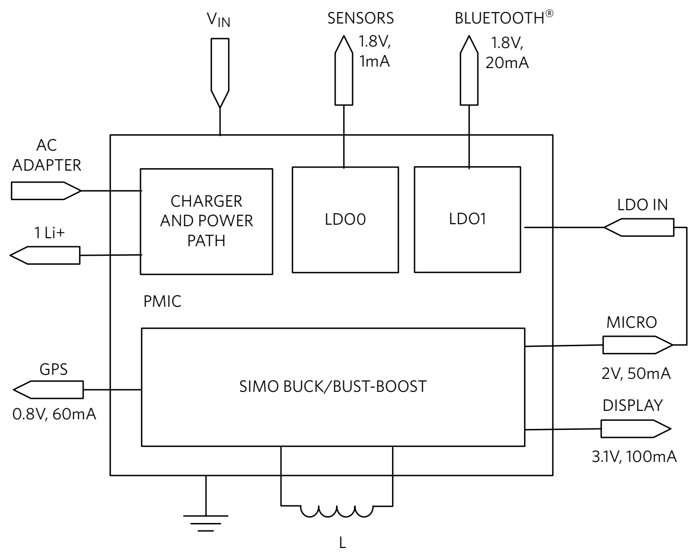

Figure 2. Highly Integrated SIMO PMIC Block Diagram

The SIMO Power Tree

Figure 3 is a system power tree, reporting each regulator's output voltage, load current, efficiency, and power dissipation (PD). Three out of five loads are supplied directly by the high-efficiency SIMO switching regulator. The LDOs for the fourth and fifth loads are also supplied by the SIMO, achieving 90% efficiency because of the low dropout (2V to 1.8V). The overall system efficiency is an outstanding 86.2%.

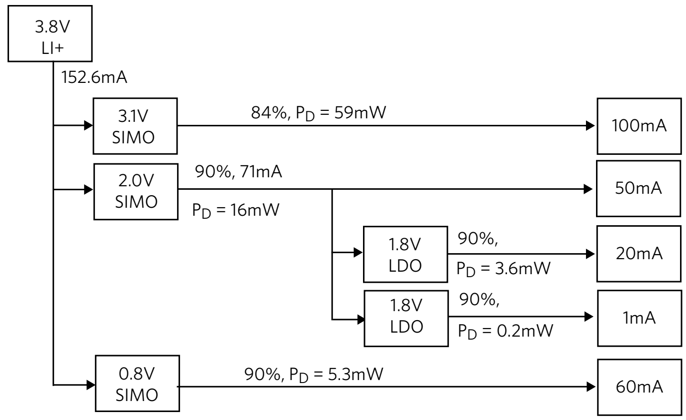

Figure 3. Power Tree of a High-Efficiency SIMO

The SIMO Converter

Figure 4 shows the block diagram of the SIMO converter (all the components, except the inductor, are integrated). The switching regulators deliver power with minimum losses, and the clever architecture eliminates the need to have one inductor for each switching regulator.

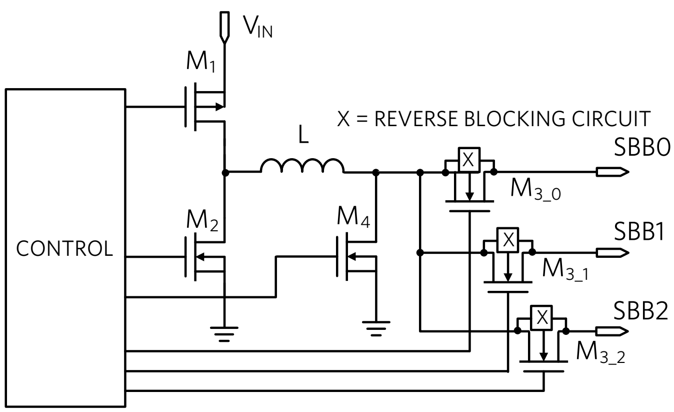

Figure 4. SIMO PMIC Power Block Diagram

Inductor Current Sharing

In this hysteretic discontinuous current mode (DCM) regulator, the inductor is shareable since the inductor current always goes to 0.

In buck-boost mode, the inductor builds up current with M_1 and M_4 'on' at the rate of V_{IN}/L. When it reaches a programmed limit, the current is delivered to the selected SBBx output, via the M_2 and M_{3_x} transistors, as shown in Figure 5.

In buck mode, M1 and M3_x turn on, delivering current to the output while building current in the inductor at the rate of $(V_{IN} - V_{SBBx})/L$. When the inductor current reaches the programmed limit, energy from the inductor is delivered to the output by turning on M_2 and turning off M_1.

Notice how in buck mode the current is directed to the output during the entire cycle, while in buck-boost the current is delivered to the output only during the phase in which M_2 and M_{3_x} transistors are on. The higher delivery of current to the output, per cycle, makes the buck converter the most efficient architecture.

Outputs are serviced in the order in which they are requested by their output error comparators, also known as first-in-first-out (FIFO).

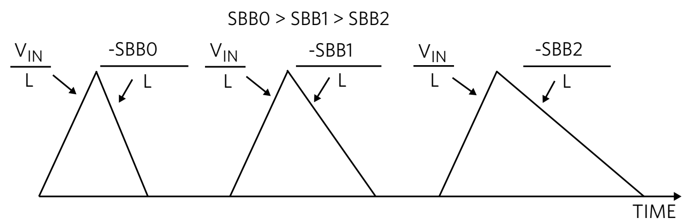

Figure 5. SIMO Current Waveforms Illustration

As shown in Figure 5, the three switching regulators are serviced one at a time and the inductor current goes to 0A, avoiding cross-regulation issues.

More Battery Life in a Smaller Space

Thanks to its SIMO switching regulators and its integrated LDOs, the small MAX77654 PMIC (WLP, 2.79mm x 2.34mm x 0.5mm), delivers power with minimum losses in a PCB space that is 41% less than the typical implementation (see next section). In Figure 6, all the PCB active and passive components are accounted for. The total board space occupied is merely 19.2mm^2.

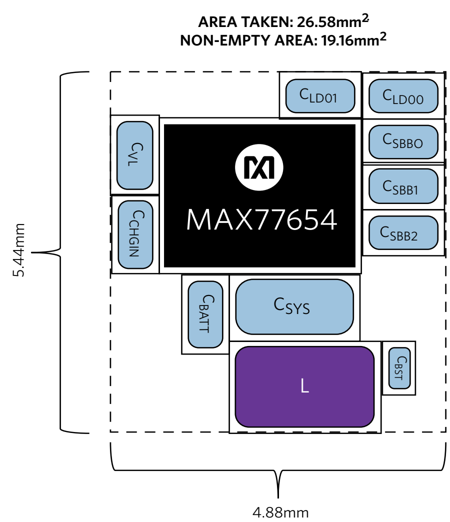

Figure 6. SIMO PMIC Solution with Minimal Board Space (19.2mm^2)

Efficiency

The ability to program buck mode whenever needed brings a greater efficiency advantage. In Figure 7, the SIMO buck operation shows a 6% efficiency advantage vs. the buck-boost operation. The programmable inductor peak current limit, I_{P_SBBX}, is set to 0.5A.

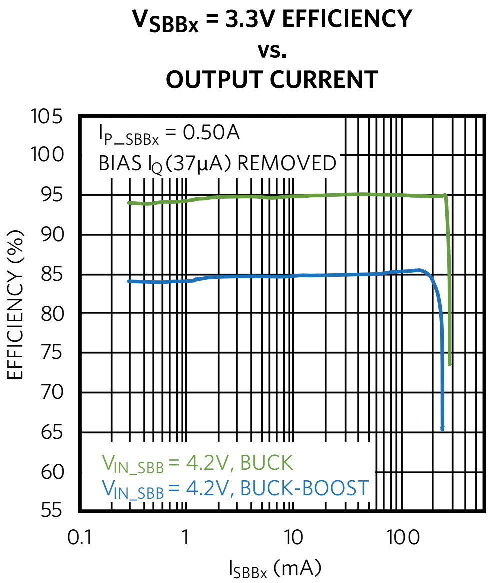

Figure 7. Buck vs. Buck-Boost Efficiency

Typical Power Management Implementation

A typical smart watch power management system is shown in Figure 8. A PMIC implements the battery charger, a buck converter which powers the micro, and an LDO which powers the display. A second IC, a dual LDO, powers the sensors and Bluetooth®. For simplicity, the external passives are not shown here.

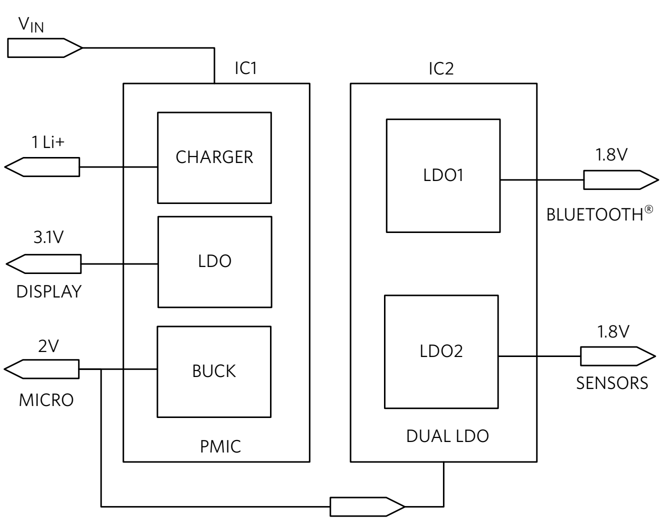

Figure 8. Typical Wearable Power Flow Diagram

The SIMO Power Advantage

The complete power tree for a typical implementation is shown in Figure 9. In this typical space-constrained solution, a heavy use of LDOs results in an overall efficiency of only 73.8%.

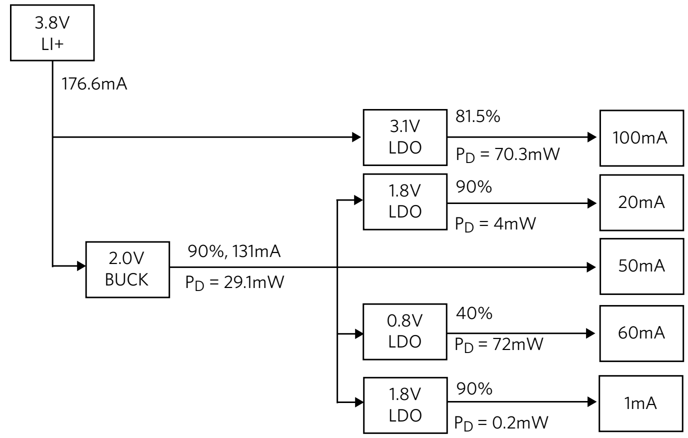

Figure 9. Power Tree of a Typical Solution with Lower Efficiency

A comparison between the two solutions' power performance is shown in Table 1.

Table 1. SIMO Advantage vs. Traditional Solution

Parameter	Traditional Solution	SIMO	SIMO Advantage
Li+ Battery Current	176.6mA	152.6mA	SIMO saves 24mA
System Efficiency	73.8%	86.2%	SIMO is 12.4% more efficient
Mimimun Li+ Battery Voltage	32.V due to 3.1V LDO	2.7V	SIMO allows more discharge

The SIMO solution's superior efficiency results in smaller battery drain, while its wider operating range, down to 2.7V, prolongs the smart watch's untethered operation.

The SIMO Size Advantage

All active and passive components for the typical power flow diagram shown in Figure 9 are accounted for in the solution drawing of Figure 10.

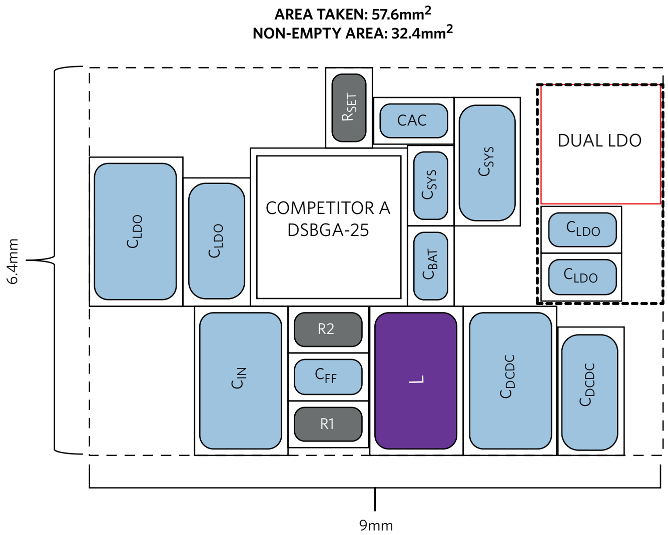

Figure 10. Board Space of a Typical Wearable Solution (32.4mm^2)

This typical wearable solution occupies a board area of about 32.4mm^2, or 69% more than that of the SIMO-based solution (19.2mm^2). Here, the relatively low level of integration, the use of multiple LDOs, and bigger passives results in a solution that is inefficient in both space and power.

Conclusion

We discussed the advantages of powering a smart watch with a highly integrated PMIC based on the SIMO architecture. We compared it to a typical solution with a low level of integration that suffers from inefficiencies in terms of both PCB space and power consumption. Thanks to a unique SIMO architecture, the MAX77654 PMIC efficiently delivers more power in a smaller space, enabling longer battery life and smaller form factor for smart watches and other miniature portable applications.

Glossary

Boost: Step-up switching regulator

Buck: Step-down switching regulator

LDO: Low dropout regulator

Li+: Lithium-ion battery

PCB: Printed circuit board

PMIC: Power management integrated circuit

SBBx: SIMO buck-boost voltage regulator output x.

SIMO: Single-inductor multiple-output voltage regulator.

Learn more:

MAX77654 Ultra-Low Power PMIC Featuring Single-Inductor, 3-Output Buck-Boost, 2-LDOs, Power-Path Charger for Small Li+, and Ship Mode

Hearables Get Longer Life with SIMO

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