Extend Battery Life Using Load Switches and Ideal Diodes

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Extending the life of a battery-operated system enhances the experience people have with the product and can potentially cut replacement costs. The battery life of products can be extended by considering current consumption, battery stress, and battery deterioration. This document will address two different scenarios that are often found in battery-operated systems. The first scenario consists of a system composed of several subsystems that can be temporarily shut down in order to preserve battery life. For instance, a wearable fitness tracker may not need Bluetooth® powered throughout the majority of the day. The solution used to turn power on or off such a subsystem must also be optimized for current consumption in order to maximize battery life.

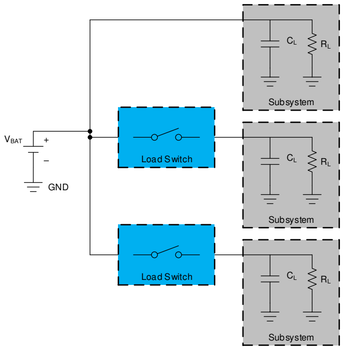

Figure 1. Turning off Subsystem Loads

The second scenario is a system with a backup power supply circuitry. Such systems, like an electricity meter, use an ORing configuration traditionally implemented with diodes. This configuration switches to the backup power supply when the main power supply is no longer present. The ORing configuration must power the load with minimal power dissipation to extend the operating time of the battery. The diodes can be replaced by ideal diodes, as seen in Figure 2, to reduce the power dissipation by minimizing the forward voltage drop typically seen in diodes.

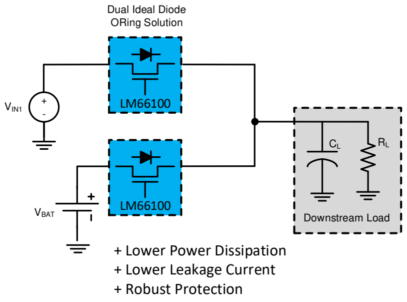

Figure 2. Backup Power Configuration

Saving Power by Turning off Subsystems

Switching solutions must minimize current consumption during both on and off states. Ideally, when a particular subsystem is disabled using a switch, there is no current consumption. However, switch solutions have some current consumption, typically denoted as shutdown current (I_{SD}), in the off-state. The shutdown current is comprised of the FET leakage and controller circuitry that remains on to protect the FET. The TPS22916 load switch has a shutdown current of 10 nA, which reduces the current consumption in the off-state. There are also current consumption considerations while in the on-state. In load switches, this current is called quiescent current (I_Q). Quiescent current travels internally from the V_{IN} pin to the GND pin of the load switch in the on-state.

Table 1. Case Study

	TPS22916/TPS22917	PFET Discrete Solution	Other Load Switch
I_{SD}	10 nA	2 nA	100 nA
I_Q	0.51 µA	9.25 µA	1.11 µA
Capacity Usage	**1.44 µAh**	**22.24 µAh**	**4.82 µAh**
Solution Size	0.55 mm^2	17.08 mm^2	0.94 mm^2

Another on-state current consumption factor comes from a pulldown resistor on the enable pin of the switch to keep it from floating. The pulldown resistor draws current when the switch is enabled, adding to the total on-state current consumption. The TPS22916 and TPS22917 can lower the total on-state current consumption to 0.51 µA by incorporating a smart ON pin pulldown resistor feature. This feature reduces the current consumption by disconnecting the pulldown resistor when the switch is enabled. To maximize the battery life, the shutdown, quiescent, and pulldown resistance currents must be as low as possible in a system. Table 1 shows the capacity of a battery that different switch solutions consume in a day running at a 10% duty cycle. The solutions include the TPS22916 and TPS22917, load switches in the market, and a discrete configuration similar to the one in the *When to Make the Switch to an Integrated Load Switch Application Note*. The TPS22916 and TPS22917 decrease the capacity usage of the battery by 70% when compared to other load switches. In addition to power consumption benefits, the TPS22916 reduces the solution size by 40% due to the small package.

Two other considerations to keep in mind are R_{ON} and inrush currents. These switching solutions inherently have an on-state resistance, typically denoted as R_{ON}. This resistance does not significantly contribute to the power consumption from the battery in low power applications. The TPS22916 load switch features an R_{ON} of 70 mΩ at 3.6 V input voltage. When powering a 55 mA load, this switch reduces the output voltage by only 0.1%. This amount of drop has an insignificant impact on battery life.

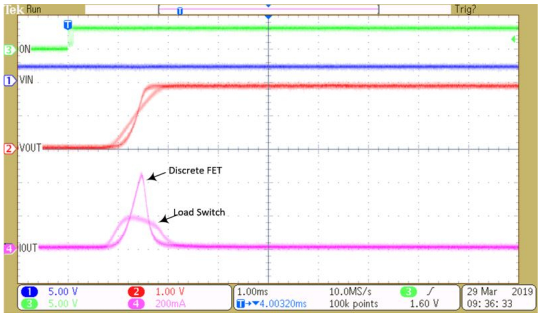

Figure 3. Inrush Current Control

Powering up of a system also affects the life of the battery. During start-up, inrush current can occur due to the load capacitance. This spike of inrush current applies stress to the battery, decreasing its capacity. To minimize the inrush current, load switches implement a soft-start to control the rate at which the switch turns on. Controlling the rate at which the output rises minimizes the spike of current being drawn from the battery, as seen in Figure 3. This reduces stress on the battery and minimizes current consumption during power-up sequences.

Battery Back-up Applications

Traditionally, the switching of power supplies is done with an ORing configuration using two diodes. A major drawback of this configuration is the high forward voltage drop of a diode. The high forward voltage drop causes a high dissipation of power which reduces the operating time of the battery. Two LM66100 ideal diodes can be implemented in backup power supply applications to reduce the forward voltage drop in this ORing configuration. The LM66100 has a much lower voltage drop in comparison to a discrete diode solution resulting in lower power dissipation as seen in Table 2. Another key element to keep in mind is the undervoltage lockout threshold of the load. With the voltage of a battery decreasing during its lifetime, the forward voltage drop of the discrete diode disables the system faster than the LM66100 solution since it reaches its minimum voltage threshold first. This undervoltage lockout condition causes the battery to operate for a shorter amount of time as illustrated in Figure 4. The difference in time depends on the battery being used and the load.

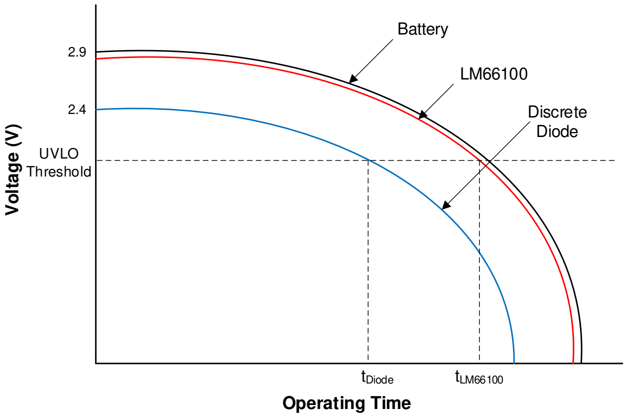

Figure 4. Voltage vs Operating Time

Another benefit of using the LM66100 ideal diode device is having a lower reverse leakage current as compared to a discrete diode. As seen in Table 2, the LM66100 has a 75% lower reverse leakage current specification. There are two cases in which reverse leakage current can affect the battery life. In the first case, when the main power supply is active, reverse leakage current flowing into the backup battery can reduce its lifetime by deteriorating its capacity. In the second case, when the backup battery is powering the system, reverse leakage current flowing into the main power supply path results in undesired current consumption. Minimizing reverse leakage current helps extend the life of the battery.

Table 2. LM66100 vs Diode

	LM66100	Discrete Diode
Power Dissipation at 5 V, 200 mA	3.16 mW	140 mW
Max Reverse Leakage Current	0.5 µA	2 µA

Conclusion

Lowering current consumption and considering the stress and deterioration of the battery is imperative to extend the life of the battery. Reducing power consumption with a switch, like the TPS22916 and TPS22917 that has low shutdown and quiescent current, keeps the battery from rapidly draining its capacity. In ORing configurations, the LM66100 lowers the forward voltage drop and reverse current leakage to extend the operating time of the battery.

Table 3. Related Documents

Document Type	Title
TI Tech Note	When to Make the Switch to an Integrated Load Switch (SLVAEC5)
TI Tech Note	Eliminate the Voltage Drop and Save Power: An Ideal Diode (SLVAEA8)

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