

## Cut Your Losses—With an Ideal Diode

### Introduction

The always-on power source has become a common requirement for electronic devices to ensure uninterrupted operation of critical loads. The popular use of an ORing function (Figure 1)—the electrical connection of two or more power sources, which ensures that when one fails, the other intervenes—has made the Schottky diode the component of choice for most implementations.

In low-voltage applications, such as portable equipment, it quickly becomes apparent that the supposedly low dropout voltage of the Schottky diode is not so low after all, causing disproportionately high-power losses compared to the rest of the electronics. The Schottky diode's reverse leakage current is also a concern, as it becomes a drain on the device's main power source while also attempting to charge a primary, nonrechargeable battery. One solution has been to simulate the diode with a properly controlled, low  $R_{DS(ON)}$  MOSFET. This solution is bulky and costly, requiring one discrete MOSFET (active diode) or two back-to-back MOSFETs (active switch) and a controller IC. This article reviews four popular applications utilizing ORing techniques, highlighting their shortcomings while introducing a new monolithic solution to overcome them.

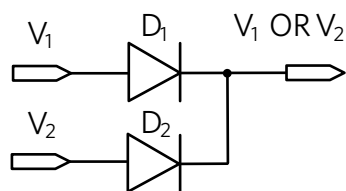


Figure 1. Diode OR Configuration

### Battery Backup

Figure 2 shows a typical backup system where the main power is provided by the wall adapter or a solar cell. In case of a main power outage, three alkaline, nonrechargeable batteries (2Ah) will keep the system alive while consuming 1A for 2 hours. Under a 1A load, the Schottky diode,  $D_3$ , will typically create a 300mV to 600mV drop, while the three battery cells deliver an average

total voltage of 3V during their two-hour lifespan. A diode drop as low as 330mV, over a 3V voltage rail, corresponds to an 11% efficiency loss! This inefficient utilization of the energy stored in the alkaline battery results in a shorter overall system runtime.

Reverse leakage is another concern when using the ORing technique. When the device is connected to the wall adapter or solar cell, the reverse-biased Schottky diode,  $D_3$ , dumps tens to hundreds of microamps of leakage current into the alkaline battery. This effectively performs unwanted and unsafe trickle charging of the nonrechargeable battery.

Finally, there is a concern with voltage headroom. With the battery delivering an average voltage of 3V, the always-on buck converter input will be at 2.4V, worst case. In this situation, the buck converter is unable to deliver the required 2.5V to its output.

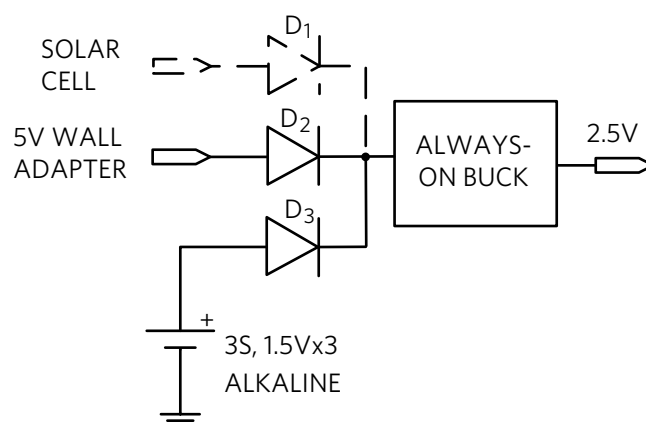


Figure 2. Battery Backup ORing Circuit

The use of a discrete MOSFET-based solution (active switch) will solve these problems, However, it comes at the cost of greater PCB space and the use of additional components since the MOSFET needs a dedicated controller to switch it "on" or "off."

### Auxiliary Power

Figure 3 shows a typical auxiliary system, where both the main and auxiliary power sources operate at 3.3V. With the

main power present, the auxiliary power is disabled; if the main power fails, the auxiliary path is enabled.  $D_1$  and  $D_2$  are active switches, activated by their respective enable (EN) pins. When the main supply is present, the resistor,  $R_2$ , pulls EN high, activating  $D_2$ , and allowing the main power to flow to the load. The inverter (INV) keeps  $D_1$  "off", disabling the auxiliary power path. When the main power is absent, the series resistors,  $R_2$  and  $R_3$ , pull the inverter input low, enabling  $D_1$  via  $R_1$  and apply the auxiliary power to the load. Here, the two active switches,  $D_1$  and  $D_2$ , solve the previously mentioned problems. However, it again comes at the cost of space and added BOM, as each active switch requires a back-to-back MOSFET and a controller IC.

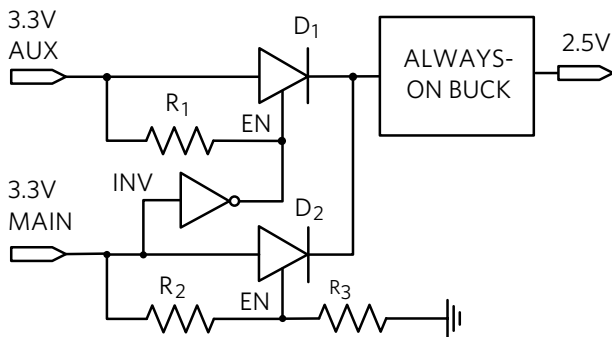


Figure 3. Auxiliary/Main Power ORing Circuit

### Wireless Power

The system in Figure 4, typical of a portable device, takes power from a wireless AC source or a USB port. The ORing function (via  $D_1$  and  $D_2$ ) is necessary to isolate the relatively large capacitor at the receiver's rectifier output from the USB port. If the gadget is a small device, like a smartwatch, the use of regular diodes will compound the efficiency problem, since the device needs to maximize runtime. The use of discrete MOSFETs and the associated controllers is not permitted due to the extremely limited space available.

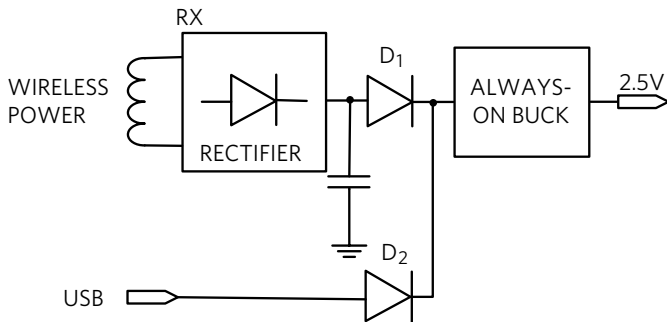


Figure 4. Wireless/USB Power ORing Circuit

### Charger/Wall Adapter

In the portable system of Figure 5, the wall adapter charges the lithium-ion (Li+) battery via the charger and supplies power via  $D_1$  with  $D_2$  reverse-biased. If the wall adapter is not connected, power is supplied via  $D_2$  by the Li+ battery. In this case, during untethered operation, the current path through  $D_2$  would greatly benefit from the use of a true low-drop diode. The small voltage drop would enable space and efficiency savings, and provide prolonged untethered operation.

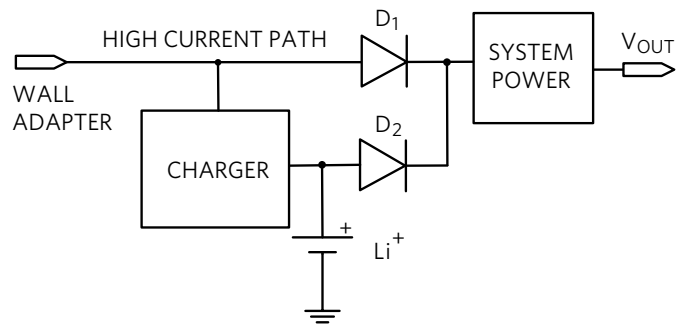


Figure 5. Charger/Wall Adapter ORing Circuit

### An Ideal Solution

Each of the applications discussed would greatly benefit from the use of a single component as simple and elegant as the Schottky diode but free from its voltage dropout and reverse leakage shortcomings.

The MAX40200 is an ideal diode that drops three times lower voltage (at high current) to ten times lower voltage (at low current) than a Schottky diode. When forward-biased and enabled, the MAX40200 conducts with less than 100mV of voltage drop while carrying currents as high as 1A. Figure 6 shows the comparison between the MAX40200 and a typical Schottky diode, both rated at 1A.

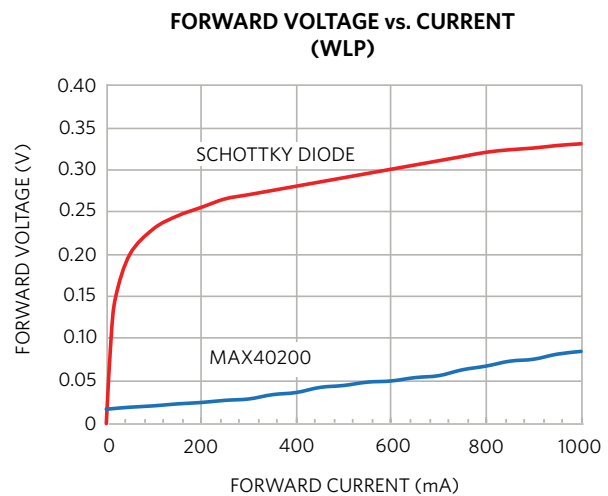


Figure 6. MAX40200 Ideal Diode vs. Schottky Diode Comparison

The voltage drop at 1A goes from 330mV when using a Schottky diode down to 85mV when using the ideal diode. The corresponding efficiency loss goes from 11% down to 2.8%!

When reverse-biased, the MAX40200 exhibits a reverse cathode current 10 to 100 times better than a typical low dropout Schottky diode (Figure 7).

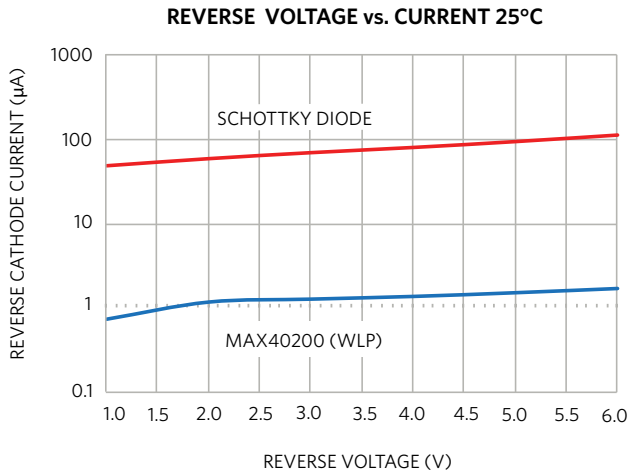


Figure 7. MAX40200 Ideal Diode vs. Schottky Diode Reverse Cathode Current Comparison

The MAX40200's minimal reverse leakage current effectively eliminates the unwanted trickle of the alkaline battery in a battery backup application.

### Ideal Diode Functionality

Looking at the functional diagram in Figure 8, the ideal diode is based on a low  $R_{DS(ON)}$  p-channel DMOSFET. The internal circuitry senses the MOSFET drain-to-source voltage and, in addition to driving the gate, keeps the body diode reverse-biased. This additional step allows the device to behave like a true open switch when EN is pulled low, or when the thermal limit is reached. A positive drain-to-source voltage turns the MOSFET "on", with current flowing in normal mode while the body diode is reverse-biased. A negative drain-to-source voltage turns the MOSFET "off", with the intrinsic diode again reverse-biased. If EN is low then the device is "off" independent of the  $V_{DD}$ -OUT polarity.

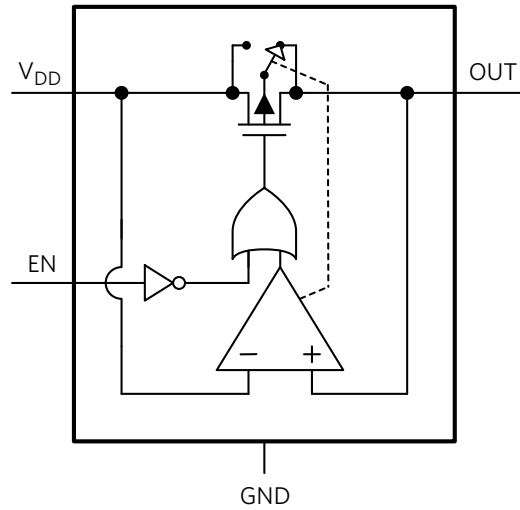


Figure 8. Ideal Diode Functional Diagram

### Ideal Diode Forward Characteristics

To properly sense the drain-to-source voltage at low current, when the intrinsic voltage ( $R_{DS(ON)} \times I_{LOAD}$ ) would be too small to detect, a minimum dropout of approximately 25mV is maintained across the device. When the drop exceeds this threshold, the voltage rises linearly according to Ohm's law ( $R_{DS(ON)} \times I_{LOAD}$ ). The logarithmic scale in Figure 9 highlights the nearly constant voltage across the ideal diode up to around 200mA.

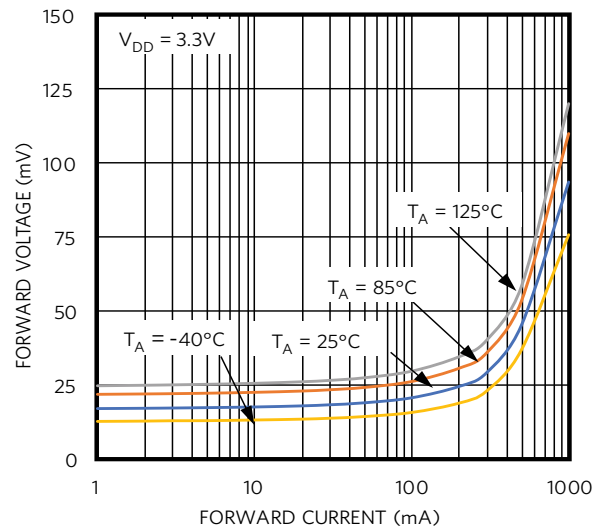


Figure 9. MAX40200 Forward Voltage vs. Forward Current

## Conclusion

Mobile systems with multiple power sources, such as backup alkaline batteries, auxiliary power supplies, wireless power, or Li+ batteries, require a diode ORing function to act as the power switch. However, the ORing function can rob precious power, energy, or space from a mobile system, and in some cases, could compromise its safety or operation. The use of the MAX40200 1A ideal diode provides a simple solution. Housed in a small WLP package, with dropout voltages an order of magnitude lower than Schottky diodes in forward mode, it also has dramatically lower leakage current in reverse mode. The MAX40200 minimizes or eliminates the limitations of the traditional ORing implementation for 5V and sub-5V systems, providing an elegant and efficient substitution for the typical Schottky diode.

Learn more:

[MAX40200 Ultra-Tiny Micropower, 1A Ideal Diode with Ultra-Low Voltage Drop](#)

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